The Great Recession and its effects on monetary policy: From policy transmission to target dynamics

Dissertation

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Contents

List of Figures

List of Tables

1 The Great Recession and its effects on monetary policy: an introduction

The Great Recession and monetary policy: three challenges

The global financial crisis caused new challenges for monetary policy on a worldwide scale. Policymakers failed to reach their inflation targets in its wake and exhausted conventional monetary policy instruments. At times of sluggish economic growth and subdued inflation dynamics, policy rates have been at historically low levels. New instruments were discussed and implemented after the lower bound on interest rates had been reached. Macroeconomic academia was severely criticized for relying on benchmark versions of the New Keynesian Dynamic Stochastic General Equilibrium (NK DSGE) model. The criticism originated when NK DSGE models failed to predict and explain the effects of the global financial crisis on macroeconomic dynamics and their implications for monetary policy (Stiglitz, 2011). This in turn provoked academics of macro- and monetary economics to theoretically and empirically reassess some core assumptions and components of these models.

To motivate the subsequent chapters this introduction emphasizes three major challenges to macro- and monetary economic research.[1] As a guideline for the remaining part of the chapter, it is useful to embed the discussion in a highly simplified New Keynesian macroeconomic framework. Let $\hat{r}_t^n$ be the nominal short-term interest rate, $\hat{\pi}_t$ be goods' price inflation and $\hat{y}_t$ be the real output, whereby all variables are measured in deviation of their respective steady state values. Assume that Equation (1.1) below describes aggregate

[1] Other 'challenges' and respective fields of research not discussed here include lender of last resort, fiscal policy at the effective lower bound, secular stagnation, risk shocks, macroprudential policies, government bailout of financial intermediaries and subsequent risk-spill overs, hysteresis and others.

demand, Equation (1.2) determines inflation developments by some form of a Phillips curve and Equation (1.3) closes the model with a Taylor-rule-style central bank reaction function.[2]

$$\hat{y}_t = f(\hat{r}_t^n - E_t\hat{\pi}_{t+1}, E_t\hat{y}_{t+1}) + \epsilon_{\tilde{y}_t,t} \tag{1.1}$$

$$\hat{\pi}_t = f(E_t\hat{\pi}_{t+1}, \hat{y}_t) + \epsilon_{\pi_t,t} \tag{1.2}$$

$$\hat{r}_t^n = f(\hat{\pi}_t, \hat{y}_t) + \epsilon_{i_t,t} \tag{1.3}$$

The underlying assumption of the sketched model is that the central bank mandates the control of inflation alongside the stabilisation of the business cycle. A profound understanding of the determinants of inflation is a prerequisite for optimal monetary policy and thus depends on the correct specification of Equation (1.2). The first challenge discussed concerns the reassessment of the conventional inflation model that could not fully explain consumer price dynamics since the global financial crisis.

The failure of NK DSGE models to capture the dynamics during that period hinges on the models' underlying assumption of perfect financial markets. In the absence of imperfections, financial markets can be omitted in the baseline NK DSGE model, as in the simplified macroeconomic framework here. The second challenge refers to the empirical and theoretical reconsideration of the link between financial markets and real economic activities as well as their consequences for monetary policy.

[2] ϵ reflect innovations to the respective model equation.

The severe and long-lasting macroeconomic repercussions of the global financial crisis demanded a strong response from central banks that could no longer exert their conventional measures. This implies a modification of Equation (1.3) to introduce a lower bound on the short-term interest rate setting and to extend the central bank reaction function by additional instruments. Therefore, the third challenge comprises the necessity to develop alternative monetary policy tools under a binding effective lower bound. I discuss the three challenges in consideration of the macro- and monetary economic literature in the following sections.

1.1 Monetary policy target dynamics

The success of monetary policy under an inflation-targeting framework critically hinges on the understanding of the target dynamics. A variety of recent empirical studies (Ball and Mazumder, 2011; Coibion and Gorodnichenko, 2015; Friedrich, 2016) have documented puzzling dynamics of headline inflation for advanced economies since the start of the financial crisis. These studies concern two observations on the evolution of headline inflation. Firstly, the case for ‘missing disinflation’ points to the fact that inflation rates remained surprisingly stable between 2009 and 2011 compared to accelerationist Phillips curve (PC) estimates. Secondly, the case of ‘missing inflation’ indicates that, despite improving employment conditions, inflation dropped substantially from 2012 to the end of 2015.

These results do not necessarily question the general validity of the PC framework, but might rather provoke a careful analysis of the exact macroeconomic mechanisms and underlying assumptions of the PC that prompted over-/under-forecasts of inflation in recent times. Can alternative inflation models resolve this empirical puzzle? And if so, what do these alternative models tell us about inflation dynamics and what are the consequences for monetary policy? Broadly speaking, the recent academic debate on the puzzling inflation dynamics in the post-crisis episode surrounds three potential explanations that I subsequently outline for the case of 'missing disinflation'. Firstly, anchored inflation expectations combined with a strictly forward-looking inflation process might have overshadowed downward price pressure from real economic activity on inflation dynamics. Secondly, a relatively flat PC relation muted the effect of real economic activity. Thirdly, the increasing importance of global factors drove headline inflation over the course of the crisis. To embed these proposals in the context of different macroeconomic frameworks and to specify the implications for current as well as future research, I discuss each potential explanation in the following paragraphs.

Puzzling inflation dynamics and inflation expectations

The Phillips curve specification used in the studies[3], that analyse the puzzling inflation dynamics, takes the form:

$$\pi_t = \pi_t^e + \kappa(u_t - u_t^*) + \epsilon_{\pi_t,t} \tag{1.4}$$

[3] Ball and Mazumder (2011), Coibion and Gorodnichenko (2015), Friedrich (2016)

With inflation expectations defined as

$$\pi_t^e = \tfrac{1}{4}(\pi_{t-1} + \pi_{t-2} + \pi_{t-3} + \pi_{t-4}) \tag{1.5}$$

This type of PC was originally proposed by Milton Friedman in his presidential address to the American Economic Association (Friedman, 1968), leading the natural rate revolution. Friedman's study introduced two major points of discussion to the academic discourse on inflation. Firstly, that there is no long-run trade-off between inflation and unemployment, and, secondly, that the formation of expectations and the expectations themselves are crucial in the determination of inflation dynamics. The first point comprises the concept of the non-accelerating inflation rate of unemployment (NAIRU).[4] Regarding the second point, Friedman assumes that firms have accurate inflation expectations, but inflation expectations of workers react with a lag. As a co-discoverer of the natural rate hypothesis, Phelps (1968) proposed a model of adaptive expectations, whereby not only workers but all agents' inflation expectations react with lag. The Friedman/Phelps PC implies that inflation expectations are formed in a backward-looking manner and can be approximated by past inflation as depict in Equation (1.4).[5]

One possible solution to the finding of missing dis/inflation using the Friedman/Phelps PC might be related to a misspecification of inflation expecta-

[4] This concept postulates that the long-run unemployment rate is purely determined by the microeconomic structure of labour as well as product markets and is consistent with accurate inflation expectations, u_t^* in Equation (1.4).

[5] The PC specification in Equation (1.4), however, deviates from the original Friedman/Phelps models by allowing the NAIRU to change over time. The notion that an evolving structure of the economy affects the long-run level of unemployment had initially been proposed by Gordon (1997) and has become an established feature of research studies that include PC specifications.

tions. As suggested by Williams et al. (2010), inflation expectations might be forward-looking and closely tied to the central banks' inflation targets, which in turn stabilised headline inflation during the global financial crisis. The perception that inflation expectations are formed in a forward-looking manner contrasts with the Friedman/Phelps framework and belongs to a different class of models that align with the New Keynesian thought. I subsequently outline the implications of New Keynesian models for the inflation formation.

New Keynesian models adopted the assumption of rational expectations and include explicit mechanisms for nominal wage and price rigidities. The most widely incorporated price rigidity mechanism in modern New Keynesian models is the partially micro-founded concept of Calvo (1983).[6] According to his approach, firms adjust prices when they receive price-change signals. A geometric distribution determines the probability of receiving a signal and the probability of the price contract length, whereby a shorter duration of contracts is more likely than longer durations. From an aggregate macroeconomic perspective, Calvo-pricing implies the canonical version of the New Keynesian Phillips curve (NKPC) that takes the form:

$$\pi_t = \beta E_t \pi_{t+1} + \kappa \tilde{x}_t + \epsilon_{\pi_t,t} \tag{1.6}$$

By iterating Equation (1.6) forward ($\pi_t = \kappa E_t \tilde{x}_{t+1} + \epsilon_{\pi_t,t}$), the inflation process is revealed as forward-looking in the NKPC framework since firms set their prices over the expected average marginal costs, $E_t \tilde{x}_{t+1}$, in each

[6] Other approaches have been presented by Fischer (1977), Taylor (1980) and Rotemberg (1982, 1983).

period, maximizing profits. Hence, inflation persistence is solely inherited by the persistence of marginal costs. The poor empirical performance of the purely forward-looking NKPC (Fuhrer and Moore, 1995; Fuhrer, 2006) led to a synthesis of backward-looking and forward-looking concepts entering the aggregate inflation process.[7] In this vein, Galí and Gertler (1999) developed a hybrid version of the NKPC by assuming that some firms follow the concept of Calvo pricing and other firms follow a backward-looking rule of thumb. This hybrid version of the NKPC takes the form:

$$\pi_t = \gamma^f E_t \pi_{t+1} + \gamma^b \pi_{t-1} + \kappa \tilde{x}_t + \epsilon_{\pi_t,t} \tag{1.7}$$

From Equation (1.7) it can be seen that the hybrid NKPC nests both: a fully backward-looking framework and a completely forward-looking framework. The empirical analysis of Galí and Gertler (1999) suggests that the backward-looking element is relatively small ($\gamma^b = 0.25$), yet statistically significant, for the US inflation process. Generally, their results emphasize the importance of the forward-looking expectations for the inflation process.

Hybrid NKPC versions comprise the conventional inflation modelling approach in the forefront NK DSGE models. In particular, NK DSGE models proposed by Christiano et al. (2005) as well as Smets and Wouters (2007) incorporate a price as well as a wage Phillips curve, whereby the latter partially determines real marginal costs. Moreover, these models introduce

[7] It should be noted that the poor empirical performance of the Calvo-price-setting mechanism also stands at odds with empirical microeconomic evidence on price setting as documented by, for example, Klenow and Kryvtsov (2008).

a backward-looking component into price- and wage-setting by assuming that the fraction of price/wage setters that are unable to reset their index prices/wages to former levels. Christiano et al. (2005) and Smets and Wouters (2007) set up relatively similar NK DSGE models, but differ in their estimation strategies. Both papers point towards the importance of real rigidities and nominal wage stickiness rather than price stickiness for generating sufficiently persistent inflation dynamics that match actual inflation dynamics.

Although hybrid NKPC specifications nest forward-looking inflation expectations, they cannot explain the puzzling inflation dynamics during the global financial crisis. As documented by King and Watson (2012), the model of Smets and Wouters (2007) fails to explain recent inflation dynamics to the extent that large and persistent and exogenous mark-up shocks are required to match the evolution of headline inflation over the course of the global financial crisis. This is a problematic result as mark-up shocks are hardly interpretable and only have a limited impact on macroeconomic variables other than inflation (Del Negro et al., 2015). Different proposals have been made by Del Negro et al. (2015), Gilchrist et al. (2017) and Bianchi and Melosi (2016) to account for the missing disinflation in forefront NK DSGE models. Most of these studies alter the benchmark NK DSGE model by relaxing assumptions that concern perfect markets or perfect information, but they do not directly reconsider the determination of the inflation process.[8]

[8] Alternative approaches to Calvo pricing exist that incorporate less ad hoc assumptions such as rule-of-thumb or indexation. These alternatives focus on rigidities of the information processing of agents. For example, Mankiw and Reis (2002) propose a sticky-information model, Orphanides and Williams

One reason why allowing inflation expectations to be forward-looking does not resolve the case of missing dis/inflation might be that the relation between monetary policy and inflation expectations has changed over time. This directly relates to the argument of Williams et al. (2010) that the enhanced conduct of monetary policy together with successful central bank communication helped to anchor long-run inflation expectations, implying the possibility of structural breaks and/or non-linearities in the inflation process. These features have not been taken into account in the aforementioned studies but are well supported by a range of empirical papers.[9] One line of literature relating to this topic intends to establish empirical links between changes of inflation persistence under distinct monetary policy regimes. Benati (2008) estimates a hybrid NKPC for seven advanced economies under different monetary policy regimes, and finds that the backward-looking component is zero or nearly zero for inflation targeting regimes. However, Lin and Ye (2007) as well as Johnson (2003) have raised concerns regarding the exact classification of inflation targeting economies and possible endogeneity problems. These papers find no significant effect of the adoption of inflation targeting on actual inflation and inflation volatility.

More extensive studies, which consider the link between changing inflation dynamics and the conduct of monetary policy, belong to the line of literature that analyses the sources of the Great Moderation and takes into account time

(2005) present a model where agents have to learn about parameters and Maćkowiak and Wiederholt (2009) suggest a model of rational inattention as first suggested by Sims (2003, 2006).

[9] For univariate evidence see Levin and Piger (2002) and Stock and Watson (2007).

variations of the long-run levels of inflation.[10] Among the first multivariate empirical contributions in this direction is the work of Kozicki and Tinsley (2005). They specify an ad hoc formulation of the PC in terms of an inflation-gap, based on the Beveridge-Nelson decomposition, that takes on the form:

$$(\pi_t - \pi_t^e) = \beta E_t(\pi_{t+1} - \pi_{t+1}^e) + \kappa \tilde{y}_t + \epsilon_{\pi_t,t} \tag{1.8}$$

Thereby, the inflation-gap, $(\pi_t - \pi_t^e)$, is the difference between actual inflation, π_t, and the long-run inflation expectations, π_t^e, which they interpret as the perceived nominal anchor of monetary policy. Using a two-step estimation procedure to obtain time-varying long-run inflation and PC estimates, Kozicki and Tinsley (2005) results indicate that shifts in the perceived nominal anchor led to declines of inflation persistence. Cogley et al. (2010) support this finding. Using a time-varying parameter vector autoregressive (TVP-VAR) model with stochastic volatility, they provide evidence that US inflation persistence alongside the perceived long-run inflation target increased until the period of the Volcker disinflation, and decreased thereafter. Furthermore, they assess the sources of the decline of inflation persistence in a NK DSGE framework estimated for two subsamples, and conclude that an increasingly proactive monetary policy practice, together with the stabilisation of the central bank's long-run inflation target, are the dominant reasons

[10] The literature examining the underlying reasons for the Great Moderation consists of three camps that associate the decline of macroeconomic volatilities with 'good luck', 'good policy' and 'good practice', respectively. The 'good luck' hypothesis (Stock and Watson, 2005; Leduc and Sill, 2007) relates the decline of output volatility to a reduction of exogenous shocks or to changes of the underlying shock propagation mechanism. In contrast, the 'good policy' view advocates that more active and attenuated monetary policy led to a decline of output volatility (Clarida et al., 2000; Primiceri, 2005; Lubik and Schorfheide, 2007). The 'good practice' hypothesis considers changes in the inventory management induced by information technology (McConnell and Perez-Quiros, 2000), increased flexibility of the labour market (Galí and Gambetti, 2009) and increased access to external financing to be the dominant drivers of the Great Moderation.

for the decline of inflation persistence and - to a lesser extent - the reduction of exogenous shocks to the economy.

Allowing for non-zero, long-run inflation expectations is essentially deviating from log-linearisation around the zero-inflation steady state, as done in forefront NK DSGE models associated with Smets and Wouters (2007) or Christiano et al. (2005). Cogley and Sbordone (2008) explicitly derive a hybrid Calvo-price-based Phillips curve allowing for time-varying steady-state inflation, which results in a PC specification in gap-notation with time-varying long-run inflation expectations, as well as time-varying parameters of the Phillips curve.[11] Similar to Kozicki and Tinsley (2005), Cogley and Sbordone (2008) estimate the perceived long-run inflation target and a time-varying hybrid Phillips curve specification in a two-step procedure. They find no statistically significant role for the backward-looking component of inflation and provide evidence that structural parameters of the implied NKPC vary with the levels of steady-state inflation.

In summary, whether forward-looking and anchored inflation expectations resolve the puzzling inflation dynamics in the course of the Great Recession remains an open debate. The current state of the literature, however, suggests that inflation explications are not purely backward-looking, as assumed in the studies that document the case of missing dis/inflation. Moreover, the aforementioned studies indicate that it is important to allow for a time-

[11] A complete derivation of a NK DSGE model with non-zero steady state inflation and its implications for the determinacy region of monetary policy can be found in Ascari and Ropele (2009).

varying interrelation between the degree of forward-lookingness and the level long-run inflation explications when modelling the inflation process.

Puzzling inflation dynamics and the decline of the Phillips curve slope

The second potential resolution of the missing dis/inflation puzzle is the flattening of the Phillips curve. Regarding the strength of the PC relation, the first point to emphasise is that New Keynesian models imply a trade-off between inflation and real marginal costs instead of an inflation-unemployment relation as proposed by the Friedman/Phelps PC. Generally, disputes exist over the exact underlying variable of real economic activity that determines inflation. From an NKPC perspective, this discussion centres on the question of which macroeconomic variable forms the best approximation of marginal costs.[12] The debate over the best proxy for real economic activity in PC relations is indirectly related to a series of studies concentrated in the forecasting literature that raise doubts on the general existence of a Phillips curve relation.

Among others[13], Stock and Watson (1999) performed a pseudo out-of-sample forecast using 85 indicators of economic activity separately and found that, since the mid-1980s, autoregressive univariate inflation forecasts have performed equally well as the multivariate economic activity-based inflation

[12] In addition to the suggestion of a hybrid NKPC, Galí and Gertler (1999) find average unit labour costs to be a better proxy for marginal cost than the output-gap.

[13] See, for example, Cecchetti et al. (2001).

forecasts. The relatively poor forecast performances of PC models started a horse-race between alternative uni- and multivariate ad hoc inflation models. Most prominent univariate contributions comprise the unobserved component stochastic volatility (UCSV) model of Stock and Watson (2007)[14] and the proposal of a four-quarter random walk model suggested by Atkeson and Ohanian (2001). Multivariate alternatives focus on term structure models (Tideman and Watson, 2003), the inclusion of cross-sectional price categories (Hubrich, 2005) and dynamic factor models (Marcellino, 2008).[15]

The studies by Stock and Watson (2009) and Faust et al. (2013) comprehensively compare the forecasting performances of a large variety of the uni- and multivariate models using US inflation data. Thereby, Stock and Watson (2009) focus on producing forecasts from a diversity of AR and MA univariate models using several other economic activity indicators as single predictors. They also assess survey-based forecasts, distributed lags PC models, a plain PC model and a PC model with time-varying NAIRU in their forecast comparisons.

By contrast, the study of Faust et al. (2013) adds extra focus on empirical model alternatives and includes, for example, plain vector autoregressive models (VAR), dynamic factor augmented VARs, TVP-VARs, DSGE models, and plain as well as inflation-gap PC models. Overall, the conclusions

[14] In the UCSV model inflation is decomposed into a trend component, modelled as a random walk, and a cyclical component with underlying stochastic volatility.

[15] Alongside the mentioned alternatives, some studies also consider a forecast combination as suggested by Timmermann (2006).

of these two studies differ substantially with respect to the best performing model.[16] However, both papers document that the Phillips curve forecasting success is episodic.[17]

The episodic relevance of the PC models might result from the fact that the intensity of the relation between inflation and real economic activity has changed over time. This notion has been supported by Blanchard et al. (2015), who provide empirical evidence of a flattening of PC slopes for 20 economies. Thus, the missing dis/inflation forecasts could be a result of over/under-estimating the Phillips curve slope due to the omission of non-linearities. Aside from the documentation of the over-prediction of the accelerationist Phillips curve, Ball and Mazumder (2011) illustrate that making allowance for the time-variation of the PC slope partially resolves the puzzle of missing dis/ inflation for the US.

Ball et al. (1988) were the first to provide a theoretical reasoning for the non-linearity of the Phillips curve; they illustrate that when nominal price adjustments are costly, firms optimally adjust more frequently with high levels and variance of inflation. This results in a more flexible price level and a steepening of the Phillips curve. When the level and volatility of inflation is low the PC flattens as prices change less frequently. As mentioned earlier,

[16] Stock and Watson (2009) find that the UCSV model performed best; however, Faust et al. (2013) find that survey forecasts performed best. It should be noted that the two studies use different samples. Also, Faust et al. (2013) include the UCSV model in their analysis and Stock and Watson (2009) consider survey forecasts.

[17] Stock and Watson (2009) find that PC models perform best during the early 1970s until mid-1980s, whereas Faust et al. (2013) illustrate that the predictive powers of these models are at their highest levels during the early 1990s and around the 2000s.

generalized versions of NK DSGE model, that allow for non-zero steady-state inflation, also point towards a time-varying relationship between inflation and real economic activity.

Puzzling inflation dynamics and global factors

The argument that global factors have dominantly driven inflation following the start of the global financial crisis seems likely, considering the large swings of oil and import price inflation during this episode. Regarding the importance of a global factor for the inflation formation process, Razin and Binyamini (2007) as well as Borio and Filardo (2007) suggest that domestic demand becomes more import-intensive when market openness increases. Therefore, domestic activity is less important for domestic marginal costs, which implies a flattening of the Phillips curve with respect to the domestic real economic activity. Mumtaz and Surico (2012) as well as Friedrich (2016) find some empirical support for the inclusion of a global instead of a domestic output-gap in PC specifications. Ihrig et al. (2010) directly include the domestic and rest-of-the-world measures for economic activity as well as import price inflation in a hybrid NKPC for evenly developed economies. They find that the most important determinants of inflation rates are domestic conditions. Moreover, their subsample analysis reveals no increasing sensitivity of import price inflation to domestic inflation rates. Hence, empirical evidence of a globally formulated PC relation or the inclusion of a measure of global economic slack, as an additional determinant, is rather mixed. Instead, a popularised way of accounting for global factors in many empirical studies on inflation processes is to control the cost-push shocks in terms of import and/or oil price inflation.[18]

According to the current state of the literature, it remains an open question whether the omission of global cost-push shocks, or the decline of the PC relation, or anchored inflation expectations are primarily accountable for the missing dis/inflation puzzle. Previous macroeconomic research points towards structural changes underlying the inflation process along several dimensions. These explanations include the time-variation of long-run inflation expectations together with the degree of inflation persistence that could be driven by monetary policy practices. Additionally, changes in the intensity of the relation between inflation and real economic activity need to be taken into account in the effort to understand recent inflation dynamics. For consistent and successful future monetary policy, it is essential to reach an academic consensus about what has driven inflation dynamics since the start of the global financial crisis and how this affects the general understanding of the inflation process.

[18] This essentially goes back to the formulation of the Gordon's 'triangle model'. Gordon (1977, 1982) suggests that inflation is determined by lagged inflation (built-in inflation), the unemployment-gap based on the NAIRU (demand-pull inflation) and cost-push factors such as oil price inflation (cost-push inflation).

1.2 Relevance of financial markets for macroeconomic dynamics and monetary policy

Although theoretical and empirical research point towards the influence of financial markets on business cycles, financial frictions have been buried in oblivion in forefront NK DGSE models used for policy analysis. In these frictionless models, liquidity consideration and wealth distributional effects of funds are irrelevant. An essential assumption in this framework is the Modigliani-Miller theorem of the independence of firms' value from its funding structure in the presence of perfect information, efficient markets, zero bankruptcy costs and no tax distortions. This leads to the omission of a financial intermediary sector in NK DSGE models.

Research on financial frictions in general equilibrium models formed a sideline in mainstream macroeconomic literature. The global financial crisis, however, returned it to the list of key business cycle drivers. Recent studies build on two types of financial frictions that originated in early advancements in this field of research: firstly, financial frictions based on complete loan contracts under asymmetric information, and secondly, financial frictions based on incomplete contracts under imperfect information. To embed the discussion of current theoretical and empirical advancements concerning the link between financial markets and macroeconomic dynamics, I firstly outline the theoretical concept of the two types of financial frictions and their implications for the monetary policy transmission mechanism. Secondly, I discuss advancements of financial frictions modelling approach in light of the global financial crisis. I lastly outline recent studies that take into account the occasional nature of the financial and macroeconomic linkages.

Benchmark financial accelerators and implications for monetary policy

The seminal papers of Bernanke and Gertler (1989) and Bernanke et al. (1999) introduce financial frictions, based on complete loan contracts under asymmetric information, to general equilibrium models and suggest the presence of the 'financial acceleration mechanism'. To provide an impression of how financial frictions may alter NK macroeconomic models, I subsequently augment the framework illustrated in Equation (1.1) to (1.3) with Bernanke et al. (1999) (BGG hereafter) model components. BGG assume that the economy is popularised by households that provide labour (l_t), consume goods (c_t) and supply savings, entrepreneurs that produce wholesale goods using capital (k_t) and labour and retailers that buy wholesale goods from the entrepreneurs, costlessly differentiate them and sell the final goods to the households. Entrepreneurs are assumed to be risk-neutral and to have a finite lifetime, capturing the evolution of firms' start-ups and failures. These entrepreneurs acquire physical capital for production purposes and finance these with their net worth and with external funding. BGG introduces loan contracts based on the costly state verification problem micro-founded by Townsend (1979). In this framework, lenders face auditing costs to assess the individual borrower's realized returns, which is a proportion of the gross pay-off of the respective lender. The borrower, in turn, observes their realized return costless. As the entrepreneur is risk-neutral, he is willing to bear all the aggregate uncertainty and accepts to pay the lender an interest rate that reflects the state-contingent expected value of the riskless rate. Therefore, the lender only bears the idiosyncratic risk of default, which the lender can diversify. Costly state verification contracts then drive a wedge between the costs of external and internal uncollateralized funding. This wedge is called the external financing premium (EFP hereafter), which reflects the ratio of the expected return to capital and the risk-free interest rate ($E_t\hat{r}^k_{t+1} - \hat{r}_{t+1}$). Extending the demand-side of the benchmark model (Equation (1.1)) then yields:

$$\hat{y}_t = f(\hat{c}_t(\hat{r}_t - E\hat{\pi}_{t+1}, E\hat{c}_{t+1}, \phi^c), \hat{c}^e_t(\hat{n}_t, \phi^{c^e}), \hat{i}_t, \phi^i) + \epsilon_{y,t} \tag{1.9}$$

$$\hat{r}^k_{t+1} = f(\hat{y}_{t+1} - \hat{k}_{t+1} - \hat{x}_{t+1}), \Delta\hat{q}_{t+1}, \phi^{r^k}) + \epsilon_{r^k,t} \tag{1.10}$$

$$\hat{q}_t = f(\hat{i}_t/\hat{k}_t) + \epsilon_{q,t} \tag{1.11}$$

$$E_t\hat{r}^k_{t+1} - \hat{r}_{t+1} = f(\hat{n}_{t+1}/\hat{q}_t\hat{k}_{t+1}, \phi^{efp}) + \epsilon_{efp,t} \tag{1.12}$$

Here, $\hat{r}^k_t$ reflects riskless real interest rate. Additional terms of secondary importance are generally represented by ϕ (see BGG for details). As shown by Equation (1.9), aggregate output is determined by households' consumption, investment (i_t) and entrepreneurs' consumption (c^e_t).[19] Equations (1.10) to (1.12) jointly determine the demand for investment. Thereby, Equation

[19] Entrepreneurs' consumption is a share of entrepreneurs' net worth and only constitutes a very small share of aggregate output. Determinants of households' consumption are aligned with conventional Euler-equation results. The evolution of investment is determined by conventional capital accumulation formulas.

(1.10) reflects the conventional inverse relation between the return on capital and the level of investment[20] and the inverse link between the price of capital, $\hat{q}_t$, and investment to capital ratio is shown by Equation (1.11). Equation (1.12) represents the core of the financial accelerate mechanism and determines the EFP, which depends inversely on the ratio between entrepreneurs' net worth and gross capital holdings. In the absence of financial frictions, the level of investment changes until the expected return on capital equals the real interest rate, $E_t\hat{r}^k_{t+1} = \hat{r}_{t+1}$. Moreover, the net worth of entrepreneurs evolves as $\hat{n}_{t+1} = f((\hat{r}^k_t - \hat{r}_t)RK/N, \hat{n}_t, \phi^n)$. Thus, the net worth depends on the current evolution of net worth and the impact of $(\hat{r}^k_t - \hat{r}_t)$ weighted by the gross capital holdings relative to the net worth RK/N. Thereby, changes of this ratio over-proportionally affect the net worth.[21] Imagine a positive technology shock that increases investment and raises asset prices; the accelerator then implies that increases in asset prices alter entrepreneurs' net worth and push down the EFP, which in turn stimulates investment and increases asset prices further. Therefore, the EFP moves countercyclically to macroeconomic conditions.

In studies that focus on the second type of financial frictions, the information asymmetry arises before the contracting occurs, as payments cannot be specified in certain states of the world. Ex-ante funding is limited because borrowers and lenders anticipate that indeterminable payments incentivise

[20] Whereby $\hat{x}_t$ is the gross mark-up of the wholesale goods.

[21] The remaining parts of the model comprise aggregate supply as depicted by Equation (1.2), monetary policy reaction function as depicted by Equation (1.3), a conventional formulation of a production function and a labour market equilibrium. The labour market equilibrium refers to the households' labour market as entrepreneurs' labour is assumed to be fixed.

contract partners to renegotiate their contracts in their respective favours, with some realisation becoming non-pledgeable. Collateralising the initial contract overcomes the limited pledgeability and alters funding possibilities. The work of Kiyotaki and Moore (1997) (KM hereafter) first popularised this type of financial friction in general equilibrium models. KM assumes two types of agents that differ in their degrees of productivity when aggregate capital is fixed. Agents that are more productive borrow from less productive agents but cannot commit their human capital ex-ante, as their technology is idiosyncratic. Therefore, productive agents' repayment is limited to their asset value. This implies that the external financing cost is constant up to the collateral constraint and then becomes infinite. Their margin requirement is, thereby, increasing in capital holdings. Unproductive agents, in turn, do not face an idiosyncratic technology nor a borrowing constraint. Instead, higher capital holdings of productive agents imply that unproductive agents use less capital for their production with a higher marginal product of capital that, in turn, is balanced by higher opportunity costs of holding assets. When the economy is hit by an unexpected shock that results in a decline of prices of the collateral, the net worth of productive agents declines. The presence of binding collateral constraint induces the productive agents to decrease their demand for capital. The unproductive agents' demand for capital increases and the opportunity costs of holding this capital reduces, triggering a further fall in the price of assets.

Under both types of financial frictions, the financial accelerator mechanism implies an additional magnification of the transmission of monetary policy alongside the conventional interest rate channel. This amplification is known as the credit channel. Bernanke and Gertler (1995) propose two underlying mechanisms of the amplification of the monetary policy transmission via the credit channel. The first mechanism, the balance sheet channel, emphasises the direct and indirect effects of monetary policy on borrowers' balance sheet positions. In particular, an expansionary monetary policy can lower the external financing premium as it increases the net worth and collateral of creditors, magnifying the increase of investment.

The second channel, the bank-lending channel, reflects the impact of the monetary policy on the credit supply via balance sheet effects of financial intermediaries. As originally proposed by Bernanke and Blinder (1988), changes in monetary policy induce changes in reservable deposits and, consequently, banks have to adjust the supply of lending as reserve requirements represent a binding constraint. The supply of credit is only affected when reservable deposits and external types of funding are imperfect substitutes. In that regard, Kashyap and Stein (1995) illustrate that it is costly for banks to raise uninsured deposits after a tightening of monetary policy and the subsequent reduction of reservable deposits. Moreover, they suggest that a good proxy for the bank's access to external funding is the size as well as the liquidity position of the bank (Kashyap and Stein, 2000). Not only the imperfect substitutability of funding types but also the state of the intermediary's balance sheet has important implications for credit supply. Decreases in asset price due to a tightening of monetary policy may lead to a deterioration of the banks' balance sheets and leverage ratios. This, in turn, reduces banks' capital when external financing for the banks' is costly. As a result, banks need to deleverage by reducing lending activities. Hence, with the presence of a financial accelerator mechanism the credit channel should have altered the effect of monetary policy over the course of the global financial crisis.

Financial accelerator mechanisms in the light of the global financial crisis

The inclusion of either type of the aforementioned financial friction mechanisms in NK DSGE models alters the understanding of the macroeconomic dynamics at play during the global financial crisis, but to a surprisingly small extent. Brzoza-Brzezina and Kolasa (2013) empirically compare frictionless NK DSGE models with versions that include the financial accelerators of BGG and KM. Marginal likelihoods of the models indicate that models enriched by the BGG and KM frictions improve upon the frictionless model version. Thereby, the BGG framework outperforms the KM model version.[22] Furthermore, the results of a historical decomposition in Brzoza-Brzezina and Kolasa (2013) reveal, not surprisingly, that the baseline NK DSGE model attributes almost all movements of GDP growth to negative exogenous preferences shocks. In contrast, models including BGG and KM frictions show

[22] Kocherlakota (2000) and Cordoba and Ripoll (2004) point out that the amplification is of a limited strength and depends on a relatively high share of capital, a low elasticity of intertemporal substitution and a relatively high share of constraint agents.

that adverse financial shocks to net worth as well as increasing risk explain, but not dominantly, the decline of US GDP growth between 2007 and 2009. Lindé et al. (2016) support the perception of the relatively limited empirical effect of the financial accelerator mechanism, as proposed by BGG, during the global financial crisis.

One explanation for this result is that the frameworks of BGG and KM do not account for frictions that originate within the financial intermediation sector, but rather focus on frictions between borrowers and lenders represented by entrepreneurs and/or households. Recent advancements in the literature on financial frictions in NK DSGE models propose different but explicit models of financial sectors and distinct forms of information asymmetries. The research in this field generally serves to shed light on the effects of shocks stemming from the financial intermediation sector to the economy alongside the implied propagation mechanism. These studies categorise distinct focal points including the detailed modelling of the financial intermediaries' sector and its interaction with remaining markets (Goodfriend and McCallum, 2007; Gerali et al., 2010) and the effectiveness of macroprudential policy (Christiano et al., 2014; Quinta and Rabanalb, 2014).[23]

[23] An additional line of studies analyses the influence of housing market on macroeconomic dynamics, for example Iacoviello (2005).

The large adverse effects of recent financial turmoil induced to assess whether the presence of financial frictions has consequences for optimal monetary policy. Among others[24], Curdia and Woodford (2010) investigate the extent to which a central bank can be misled by basing the decisions on NK DSGE models without financial intermediaries and frictions. The bottom line in Curdia and Woodford (2010) is the fact that the inclusion of this type of financial accelerator mechanism does not fundamentally change the characterization of optimal monetary policy, which is well approximated by a basic NK DSGE framework. Supporting this argument, they illustrate that a Taylor rule, that is augmented by a credit spread, is inferior to the original targeting rule. In the presence of a binding effective lower bound on nominal interest rates, reconsideration of optimal monetary policy under financial frictions also concern unconventional monetary policy measures.

The studies of Gertler and Karadi (2011), Gertler et al. (2010) that focus on a problem of moral hazard in the banking sector, provide prominent examples. An agency problem between private banks and household depositors is induced by the fact that bankers can side-line a fraction of deposits and 'run away' with it. This leads to an endogenous leverage ratio constraint for the financial intermediaries. The monetary authority, in contrast, is not constrained. In the event of a large negative shock to the banks net worth, government equity injection into the banking system as well as the government taking over of a part of the financial intermediation in the economy is

[24] See, for example, Fiore and Tristani (2013).

welfare increasing. This is a striking implication and contrasts the 'irrelevance result' of balance sheet policy in baseline NK DSGE models (see the next section for a detailed explanation).

Acknowledging the occasional nature of financial and macroeconomic linkages

Although recent models containing financial frictions improve an empirical and theoretical understanding of the global financial crisis, these studies do not account for the episodic empirical presence of financial turmoil. One explanation for this phenomena is that financial innovation and deregulation enable the efficient distribution of credit risk across institutions and investors, which renders financial markets somehow negligible as a source of business cycle fluctuations, yet serve as an amplifier of the monetary policy transmission mechanism. Notably, innovations in the funding markets for financial intermediaries may have resulted in improved access to low-priced external funding for banks that are in turn less dependent on reservable deposits. As illuminated in the credit channel critique of Romer et al. (1990), the importance of the credit channel was undermined by the possibility of bank funding via covered bonds and asset-backed securities as well as certificate deposits. Indeed, in the decade prior to the financial crisis, the market volumes for securitizations increased enormously and banks adopted a new business model: 'Originate, repackage and sell'. This model assisted the banks to hedge risk underlying granted credits.

Additionally, international financial integration abated the effects of monetary policy on credit supply. Ashcraft (2006) illustrates that banks that are affiliated with international bank holding companies face lower costs of raising external funding, and can absorb changes in policy rates better than unaffiliated banks. In this vein, Loutskina and Strahan (2009) as well as Altunbas et al. (2009) provide empirical evidence for a weakening of the bank-lending channel as growing activity of banks on the security markets improved banks' balance sheets and liquidity positions. Cetorelli and Goldberg (2012) provide evidence that the increasing globalisation of banks diminished the lending channel through cross-border banking of internal capital markets.

Claessens et al. (2012) and Borio (2014) adopt a macro perspective of the episodic presence of financial frictions and advocate the idea of a financial cycle in coexistence with a business cycle. They promote this notion empirically by factorising a combination of distinct credit and equity prices into trend and cycle components. These credit-gaps illustrate that the 'financial cycle' spans approximately 20 years, and reveal a substantially lower frequency in comparison with the business cycle. Now, financial cycles are an empirical stylised fact that lacks an extensive theoretical foundation, although they have been intensively discussed, especially by policymakers.

Studies that focus on theoretical explanations of the infrequent relevance of the financial and macroeconomic link flag the presence of non-linearities and incorporate a maturity mismatch of financial intermediaries' assets and liability side. Gertler and Kiyotaki (2015) and Gertler et al. (2016) distinguish between wholesale and retail banks, whereby the former hold short-term deposits from the latter as a means of financing their long-term assets. Then, either short-term liabilities can be rolled over or the wholesale bank has to sell assets. Moreover, creditors take into account the possibility of a situation where the wholesale banks are unable to renew their short-term funding but have to sell their long-term assets to less experienced agents. In this event, agency problems come into effect as agents only accept relatively low prices of long-term assets. This implies that the realisation of a roll-over crisis depends on the creditors' perception of the wholesale banks' net worth. Moreover, the probability of such a crisis is assumed as proportional to the share of creditors that lose in the crisis event. Gertler et al. (2016) suggest that financial innovation in the wholesale banking sector leads to a slow but continuing build-up of higher leverage as monitoring costs decline. This in turn alters the probability of a roll-over crisis when moderate contractions hit the economy.[25] Hubrich and Tetlow (2015) provide first empirical evidence on the episodic relevance of financial markets for macroeconomic dynamics. They use a Markov-switching VAR and allow not only coefficients but also variances to change across regimes. They find that financial shocks have negligible effects in non-stress regimes yet substantially influence macroeconomic dynamics in stress-events, whereby the financial 'stress events' are characterised by altered volatilities and coefficients.

[25] See Brunnermeier and Sannikov (2014) for an alternative theoretical framework that yields similar results.

In summary, recent literature advances the depiction of financial intermediaries and emphasizes particular frictions and informational asymmetries in NK DSGE models respectively. The occasional empirical relevance of financial frictions points towards the presence of non-linearities of the link between financial markets and real economic activity. It remains an open question exactly how frictions in the financial sector interact with the transmission of monetary policy. Also, it is still unclear which types of friction dominantly drive the link between financial and real economic activity to the extent that one can generalise the inclusion of some forms of financial frictions in benchmark NK DSGE models.

1.3 Binding effective lower bound and monetary policy alternatives

According to Keynesian economics, money supply affects real economic activity and inflation via the nominal interest rate, which is constrained to be not less than zero; otherwise, 'money demand' becomes indeterminate and agents become indifferent to holding riskless assets or money. Explicitly introducing this zero lower bound in the simplified macroeconomic framework, depicted in Equation (1.1) to (1.3), implies an adjustment in the monetary policy response function in the following way:

$$\hat{r}_t^n = \begin{cases} \hat{r}_t^n & \text{if } \hat{r}_t^n = f(\hat{\pi}_t, \hat{y}_t) > 0 \\ 0 & \text{if } \hat{r}_t^n = f(\hat{\pi}_t, \hat{y}_t) \leq 0 \end{cases} \tag{1.13}$$

The reaching of a lower bound of the level of overnight interest rates has been no more than a theoretical curiosity for some time, yet it became a reality for many central banks during the previous decade. To stimulate inflation and a real economic activity, two main alternative instruments have been intensively deployed by central banks, namely central bank balance sheet policies - including 'quantitative easing' - and/or other targeted asset purchases and 'forward guidance'.[26]

Central bank balance sheet policies

Beginning the discussion with the first alternative, the Bank of Japan introduced the term 'quantitative easing' in March 2001, which implies quantity targets of the central bank reserves. It is intended to replace the operating target - the call interest rate - that had been at its effective lower bound for a few years. During the repercussions of the global financial crisis, a variety of central bank balance sheet policies emerged across economies, whereby central banks increased the money supply and intended to reduce yields of specific assets from the financial sector or government by purchasing a pre-committed amount of these assets. Owed to the differences of balance sheet policies with respect to the underlying assets and exact design as well as the timing, the subsequent discussion highlights the main theoretical points and empirical findings.

[26] Many other unconventional monetary policy measures have been used by central banks, such as reciprocal currency arrangements and long-term refinancing operations. For a comprehensive discussion about these other measures the reader is referred to Taylor and Williams (2009), Christensen et al. (2014) and Fleming et al. (2010).

A key result of basic New Keynesian models is that under a binding effective lower bound the effectiveness of an expansion of the monetary policy supply critically hinges on whether monetary policy is able to commit to an expansionary future policy path. Krugman et al. (1998) but also Eggertsson et al. (2003) have highlighted the related 'irrelevance result'. Eggertsson et al. (2003) suggests that, in an economy where central banks follow a Taylor rule, economic agents anticipate that as soon as inflation overshoots the inflation target, any expansion of the monetary base will be reversed by the central bank. Furthermore, they argue that, in the presence of the binding lower bound, an expansion of the monetary base is only effective if the central bank credibly commits to holding the policy rate at its effective bound for a considerable period beyond the point where deflationary pressures vanish. Then, expectations of an upcoming economic boom stimulate current demand. The suggestion of Eggertsson et al. (2003) intensely affects monetary policy practices, and is related to the use of 'forward guidance' by central banks facing a binding effective lower bound.

However, a popular argument utilised by central banks is as follows: that increases in the central bank balance sheet used to purchase long-term assets may circumvent the irrelevancy results via the portfolio-balance effect.[27] This mechanism, primarily supported by monetarists, suggests that central banks' purchases of long-term assets - such as government bonds - alter the overall liquidity, which lowers the yields on these assets. In turn, agents

[27] See, for example, Bernanke et al. (2012).

will rebalance their portfolios towards other riskier assets, stimulating the aggregate output. This effect assumes that private agents are not uniformly indifferent across assets, such as the distinct underlying degrees of risk.[28] Eggertsson et al. (2003) argue that, even allowing for different risks across asset maturities does not overcome the 'irrelevance result' of balance sheet policies, since the agent interprets assets held by the central bank or the government and their own assets as indistinguishable. Hence, when the central bank purchases risky assets and sells less-risky assets the representative household proportionally sells risky assets and buys less-risky assets. This is because they hedge against risks of future tax and transfers that result from changes to central bank portfolio earnings passed on to the Treasury. The implied Ricardian equivalence can be resolved by introducing some forms of financial frictions.[29]

Empirical evidence of the effectiveness of balance sheet policies can be categorised by studies that emphasise the effect on financial market assets (associated with the portfolio-balance channel), and by studies that assess the effect on macroeconomic outcomes. The former body of empirical papers relies on high-frequency financial market data and generally suggests that balance sheet policies have influenced the targeted asset yields. Among others[30], Krishnamurthy et al. (2011) present empirical evidence that the purchases of long-term bonds and Treasuries by the Federal Reserve (Fed hereafter) be-

[28] This argument is underlined by the preferred-habitat term structure model proposed by Vayanos and Vila (2009).

[29] See, for example, Gertler and Karadi (2011).

[30] See Stroebel and Taylor (2012), Hancock and Passmore (2011) and Swanson (2011).

tween 2008 and 2011 effectively lowered mortgage-backed security and corporate yields. They suggest that the first wave of balance sheet policy was relatively more effective in reducing the mortgage-backed security and corporate yields than the second wave. The empirical literature that focuses on macroeconomic effects indicates a positive impact of balance sheet policy on real economic activity and, to some extent, inflation dynamics (Baumeister and Benati, 2013).[31]

Central bank communications

According to the term structure of interest rates, long-term interest rates should, in principle, be the expected sequence of future overnight interest rates. This idea is depicted in Equation (1.14), whereby R_t^n reflects the D-day nominal interest rate on a long-term instrument that is determined by the term premium, a, the current short-term nominal interest rate, r_t^n, and its expected future values, r_{t+d}^e. The conventional rationale underlying the effectiveness of monetary policy today is that the central bank is able to affect the future path of overnight interest rates. As pointed out by Woodford (2005), given a stationary economic environment with a central bank that is credibly committed to a static policy rule, and agents who behave completely rational, then any incoming economic data would be perfectly processed by agents in the light of monetary policy. Central bank communication would, therefore, have no effect. For central bank communication to matter requires the relaxation of at least one of the aforementioned assumptions. The broadly

[31] See Lenza et al. (2010) and Del Negro et al. (2017).

accepted view is that an information asymmetry between agents and the central bank exists.[32]

$$R_t^n = a + 1/d(r_t^n + \sum_{d=1}^{D} r_{t+d}^e) + e_t^R \tag{1.14}$$

$$r_{t+d}^e = f(s_t, y_t, R_t^n, \dots) + e_t^{r^e} \tag{1.15}$$

This then allows an augmentation of the basic macroeconomic framework depicted in Equation (1.1) to (1.3) by a function determining the expected future path of short-term interest rate, Equation (1.15). Thereby, s_t comprises various signals from central bank communication that affect r_{t+d}^e, which in turn affects aggregate demand, Equation (1.4). The crucial empirical question is whether central bank communication successfully navigates public expectations on the future path of monetary policy. Prior to the global financial crisis, a variety of empirical studies (Ehrmann and Fratzscher, 2007; Gürkaynak et al., 2005; Kohn and Sack, 2003; Rozkrut et al., 2007) suggested that it does. The majority of these studies assess the effect of central bank communication on financial markets using high-frequency data around regular but also irregular announcements of the central bank.

To counter the repercussion of the global financial crisis, many central banks relied on forward guidance as an alternative monetary policy measure. Comparing the effects of FOMC statements before and after the start of the global financial crisis, Campbell et al. (2012) confirm the findings of earlier studies such as Gürkaynak et al. (2005) that Treasury yields and private forecasts

[32] An example is the adaptive learning framework of Orphanides and Williams (2005).

always react to FOMC communications - also before the global financial crisis. Hence, Treasury yields react in the intended direction in that yields increase in response of a tightening communication shock. By contrast, private inflation and unemployment forecasts move in the opposite direction of the expectation; for instance, inflation expectations rise, and unemployment expectations fall after a tightening shock. Furthermore, they introduce the differentiation between Odyssean and Delphic forms of forward guidance. Odyssean forward guidance is binding to future policy decisions. Delphic forward guidance, contrastingly, represents communications about the expected economic outlook and possible policy actions of the central bank. Campbell et al. (2012) interpret that Delphic forward guidance results in the contradicting behaviour of private sector expectations, as the central bank reveals private information that, in turn, reverses private sector expectations. Forward guidance had been used by the Bank of Japan, the European Central Bank and the Bank of Canada. The international empirical evidence on the effectiveness of forward guidance remains very limited and mixed at the present time.[33]

Facing a binding effective lower bound, central banks began using Odyssean forward guidance more frequently as an accommodative monetary policy measure. Laséen and Svensson (2011) as well as Carlstrom et al. (2015) incorporate Odyssean forward guidance in a DSGE framework, wherein forward guidance is modelled as anticipated deviations of the short-term policy

[33] See Okina and Shiratsuka (2004) and Chehal et al. (2009).

rate from the underlying policy rule. Del Negro et al. (2015) argue that reactions of macroeconomic variables to those central bank announcements appear to be unrealistically large compared to empirical estimations. Campbell et al. (2017) modify a medium-scale DSGE model by introducing additively separable stochastic preferences for holding government bonds, in order to overcome the 'forward guidance puzzle'. From a broader perspective, the preferred modification of Campbell et al. (2017) introduces differences across assets as prerequisite by the portfolio-balance channel of targeted asset purchases. Campbell et al. (2017) estimate the model and perform a counterfactual analysis to extract the effect of Odyssean forward guidance of the FOMC. They find that this forward guidance has helped to align inflation rates with targets, and has enhanced real economic activity from 2011 onwards.[34]

The presence of a binding effective bound on policy rates generally draws attention to the explicit inclusion of this non-linearity in benchmark NK DSGE models. With respect to alternative measures of monetary policy, recent empirical evidence indicates that not only central bank communications, but also balance sheet policy combined with forward guidance, affected asset prices as well as real macroeconomic activities. Heated but open discussions continue on how to rationalise the general usage - as well as the

[34] Kiley (2016) as well as McKay et al. (2016) present examples of alternative approaches to resolving the 'forward guidance puzzle'. Kiley (2016) suggests that the so-called 'forward guidance puzzle' hinges on large fiscal and monetary policy multipliers, as implied by NK DSGE models, under a binding effective lower bound. He proposes a sticky information model, where an altered frequency of information updating (together with greater price flexibility) reduces the multipliers and moves the model's responses towards the neoclassical benchmark. McKay et al. (2016) illustrate that the introduction of incomplete markets, in the form of uninsurable income risk and borrowing, constrains the impact of forward guidance through precautionary savings effects.

empirically evident effects - of these alternative policy measures in current forefront models.

1.4 Focus and outlook of the dissertation

Monetary policy has recently faced major challenges that were induced by the global financial crisis. These challenges comprise three elements. Firstly, they require an understanding of monetary policy target dynamics, including the evaluation of headline inflation and a reconsideration of its conventional modelling approach. Secondly, they require a thorough consideration of the link between financial markets and real economic activity, as well as subsequent incorporation into benchmark macroeconomic models. Thirdly, further theoretical as well as empirical analyses are needed to capture the full impact of a binding effective lower bound on the policy rate, and therewith, on the use and effectiveness of alternative measures. Keeping information from the previous discussion in mind, recent studies that have evolved in association with these three challenges jointly indicate that it is essential to pay heed to structural changes of macroeconomic relations. Can the incorporation of possible non-linearities alter the understanding of the actual macroeconomic dynamics that were at play throughout the global financial crisis? This dissertation contributes to the finding of clear answers to these questions by providing empirical evidence that mainly addresses the first two challenges.

The second and third chapter contribute - on an empirical basis - to the debates that centre on the presence of multiple non-linearities in inflationary processes, and on the influence of a monetary policy in driving observed changes of inflation dynamics. The second chapter investigates the drivers of Euro area inflation dynamics using a panel of regional Phillips curves and identify long-run inflation expectations by exploiting the cross-sectional dimension of the data. This approach simultaneously allows for country-specific inflation and unemployment-gaps as well as time-varying parameters. To relate the proposed Phillips curve specification to existing inflation modelling approaches, the chapter includes a comparison between the proposed panel specification and a variety of aggregate, uni- and multivariate unobserved component models.

The third chapter investigates the key drivers of consumer price inflation in ASEAN-5 countries (Indonesia, Malaysia, Philippines, Singapore and Thailand) during 1995-2016, through estimating time-varying Phillips curves. It is of particular interest to assess the evolution of the inflation processes in these economies, as their monetary policy frameworks and macroeconomic dynamics have almost simultaneously undergone substantial structural changes in the wake of the Asian Financial Crisis. This circumstance enables a careful analysis of the interrelation between changes in the inflation processes and enhancements of monetary policies and communication strategies. Additionally, the analysis contributes to the question whether a generalised conclusion can be drawn on the determinants of inflation across economies at distinct stages of their development.

The fourth chapter of this dissertation provides an empirical contribution to the non-linear link between business cycle dynamics and financial markets. Recent empirical studies point towards a time-varying intensity of the interplay between financial markets and macroeconomic dynamics. Moreover, the theoretical contributions of Brunnermeier and Sannikov (2014) and Gertler et al. (2016) suggest that firstly, financial innovation exogenously reduces the idiosyncratic risk of banks and enhances the long-run level of financial intermediaries' leverage ratios (at least throughout the mid-1980s to late 1990s in the US) and that secondly, altered long-run leverage ratios increase the financial amplification of structural shocks. The higher degree of financial acceleration implies that sudden disruptions in the banking sector reveal altered shock propagation to real economic activity. This increased financial amplification also applies to the propagation of a monetary policy shock to the extent that the credit channel becomes more relevant. The fourth chapter investigates changes in the intensity of the financial acceleration of structural shocks to the US economy and assesses whether the financial amplification has increased during the last thirty years, as suggested by the theoretical contributions of Brunnermeier and Sannikov (2014) and Gertler et al. (2016). Therefore, a TVP- VAR with stochastic volatility is estimated and a structural banks' capital quality shock, a monetary policy shock and a productivity shock are identified by using sign restrictions that rely on the monetary DSGE model of Gertler and Karadi (2011). The final chapter contains a summary of the results and a general conclusion.

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2 | Inflation dynamics during the Financial Crisis in Europe: cross-sectional identification of long-run inflation expectations

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2.1 Introduction

Headline inflation in the Euro area has been below the medium-term inflation target of the European Central Bank (ECB) for several years now. The year-on-year change in harmonized consumer prices has even been negative in early 2015 and again in early 2016. Understanding why inflation rates have been so low is important for assessing past and designing future monetary policy and for forecasting inflation. This has been stressed, among others, by central bankers, see for example the speech given by the vice president of the ECB at the Jackson Hole Economic Symposium in August 2015 (Constâncio, 2015).

The New-Keynesian Phillips curve (NKPC) delivers a framework for the analysis of inflation dynamics. According to the NKPC, inflation is driven by expectations about future inflation, marginal costs of production and cost-push shocks including oil prices. Marginal costs which are difficult to measure are often approximated by an indicator of economic slack like output gap or the difference between actual unemployment and long-run average (or structural) unemployment (unemployment-gap).

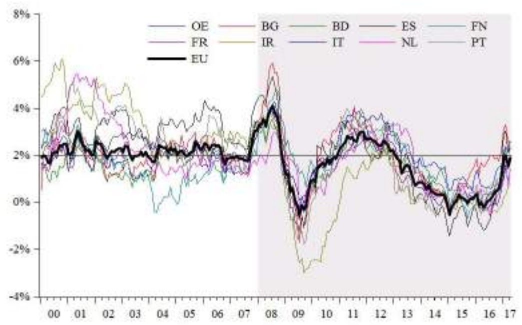
Figure 2.1 shows (a) headline inflation rates in the Euro area and in ten member countries of the European Monetary Union (EMU), (b) two indicators for inflation expectations, (c) unemployment rates, and (d) oil price changes. As the Figure reveals, the possible inflation drivers may all have contributed to the low inflation rate in recent years. However, the coefficients in estimated Phillips curves may vary over time (Blanchard et al., 2015).

In the Euro area, estimating relations with time-varying parameters is difficult because the Euro has only been introduced in 1999 which implies relatively short time-series. Furthermore, there is evidence for the U.S. that regional Phillips curves are more stable than an aggregated national Phillips curve (Fitzgerald et al., 2013). In this paper, we propose a new methodology to estimate a panel of country-specific Phillips curves exploiting the cross-sectional dimension of inflation data in the Euro area. We specify and estimate a panel non-linear unobserved component stochastic volatility (UCSV) Phillips curve model (Cogley et al., 2010; Stella and Stock, 2013) using country-specific data for Austria, Belgium, Germany, Ireland, Italy, Finland, France, the Netherlands, Portugal and Spain (hereafter we refer to this country group as EU10) and allowing for time-varying parameters. We show that this model has a very good forecasting performance compared to alternative specifications that have been proposed in the literature. From the estimated model we infer to what extent actual inflation in the Euro area has been driven by the various possible inflation drivers: long-run inflation expectations, unemployment-gaps and cost-push shocks. It turns out that economic slack in the Euro area as indicated by unemployment-gaps and decreasing oil prices can explain a large share of the inflation dynamics. However, there is also evidence that long-run inflation expectations have fallen below the ECB's medium-term inflation target, and that inflation persistence has increased in the Euro area. Since unemployment-gaps are currently closing in the Euro area due to the economic upswing and oil prices have been increasing recently our model predicts that headline inflation will also approach its long-run average value again. But because inflation persistence is higher than it used to be before the financial crisis convergence to the long-run average takes longer than before. Additionally, long-run inflation expectations have contributed about 0.5 percentage points to the decline in headline inflation and are still below the medium-term target according to our estimations. Therefore, inflation may be lower than the inflation target for a prolonged period. Long-run inflation expectations below the inflation target may be an indication of inflation de-anchoring which would be a major challenge for monetary policy (Blinder, 2000).

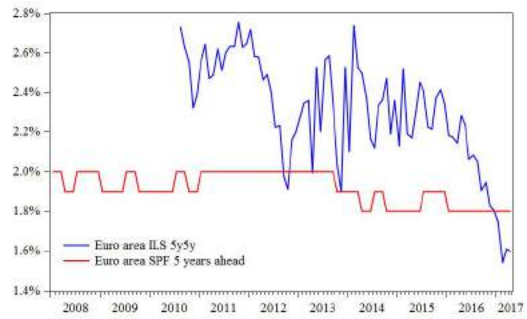
Overall, this paper adds to three strands of the literature, namely the literature on the modelling of inflation dynamics using non-linear UCSV specifications, the literature on long-run inflation expectations and inflation expectations (de-)anchoring in the Euro area, and the literature on changes in the inflation dynamics during and after the Great Recession. The paper is organized into eight sections. The second section provides a brief literature review and explains our contribution to the literature in more detail. The third section is dedicated to the empirical methodology, including the econometric model, data, and estimation details. In the fourth section, we present the empirical results of our benchmark model, including the contributions of the distinct factors to headline inflation rates. The fifth section contains a

Figure 2.1: Euro area inflation dynamics and possible drivers

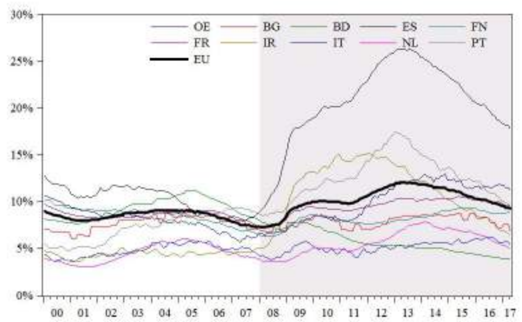
(a) Headline inflation (yoy)



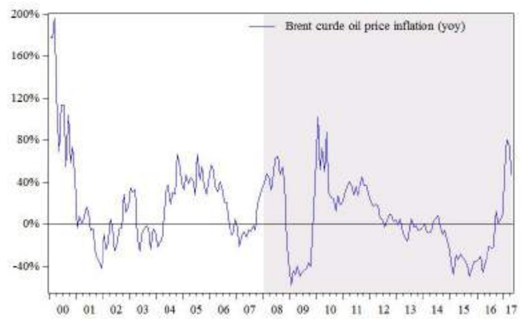
(b) Survey- and market-based inflation expectations



(c) Unemployment rates



(d) Oil price inflation



Source: We obtained the series of survey- and market-based inflation expectations from Consensus Economics, Thomson Reuters and our own calculations. For the remaining data sources, we refer to the data and estimation section.

comparison of our benchmark model to commonly used non-linear UCSV-models. In the sixth section, we undertake a forecasting exercise, comparing the forecast performance of our proposed panel structure to that of a variety of other inflation models. The seventh section includes a robustness analysis, and is followed by the last section, in which we offer a brief conclusion.

2.2 Literature Review

Unobserved component models for inflation dynamics have been used in the literature to decompose actual inflation into a long-run component - called ‘trend inflation’ - and short-run fluctuations. Chan et al. (2016) for example, estimate a non-linear Phillips curve for the U.S. and identify both trend inflation and the non-accelerating inflation rate of unemployment (NAIRU). They show that their non-linear specification outperforms various vector autoregressive models as well as linear or partially non-linear unobserved components models in terms of forecasting accuracy. Garnier et al. (2015) propose a multivariate Beveridge-Nelson decomposition using various measures of inflation as well as measures of real economic activity to identify overall trend inflation and show that a multivariate trend specification improves forecast accuracy over univariate models. We combine the unobserved components approach with exploiting multivariate data by extending the non-linear unobserved component stochastic volatility (UCSV) model to panel data. At least to our knowledge, we are the first to estimate a Euro area Phillips curve identifying unobserved unemployment-gaps and allowing for time-varying coefficients.

Our estimated panel UCSV model implies model-compatible long-run inflation expectations. These can be compared to other measures of inflation expectations which have been constructed using survey data or derived from financial market prices. In several countries, survey-based inflation expectations measures have persistently predicted inflation rates above or below the actual inflation rates for extended periods. This raises the question whether these survey-based indicators are reliable measures for long-run inflation expectations, or whether they are systematically biased. Fuhrer et al. (2012) find that Japanese survey-based inflation expectations measures are persistently above actual inflation rates. Chan et al. (2017) find systematic time-varying deviations of survey-based expectations measures from trend inflation for the U.S., UK and Japan. It has been shown that social and psychological factors might drive the outcomes of survey-based inflation expectations.[1] Market-based inflation expectations can be extracted from break-even-inflation (EBI hereafter) rates based on inflation-indexed government bonds. However, EBI are only available for a few countries in the Euro area and are traded at low volumes, which complicates the estimation of possibly time-varying risk premiums. Therefore, empirical evidence on the accuracy of inflation expectations anchoring based on EBI estimates is mixed.[2] Moreover, considering break-even inflation rates might not be a sensible way to estimate long-run inflation expectations due to their high volatility (Faust and Wright, 2013).

We also contribute to the literature on inflation dynamics during and after the Great Recession and the literature on the missing (dis-)inflation puzzle. For the U.S. case of missing disinflation Watson (2014) compared inflation predictions from traditional Phillips curve estimations with actual inflation during the global financial crisis and finds that inflation did not fall as predicted given the size of the unemployment-gap. He suggests that several

[1] Van der Klaauw et al. (2008) show that the phrasing of questions in the inflations-expectations survey of Reuters/University of Michigan Survey of Consumers led to distinct interpretations and increased dispersions in the answers given. Moreover, participants may provide what they deem to be a socially desirable answer in favour of the issuer of the questionnaire (Paulhus, 2002).

[2] Nautz et al. (2017) apply a multiple break-point test to break-even inflation and found that the inflation expectations in the Euro area were well anchored until late 2011 but have since then significantly reacted to macroeconomic news. By contrast, Autrup and Grothe (2014)) did not find any evidence of expectations de-anchoring in the Euro area following a similar approach like Nautz et al. (2017) but using a smaller time-span and different indicators to control for the liquidity risk premium.

factors could be at work including anchored inflation expectations, changes in inflation indexation and changes in the slope of the Phillips curve. Applying the non-linear Phillips curve specification of Matheson and Stavrev (2013) to 23 advanced economies, Blanchard et al. (2015) find that the slope of the Phillips curve significantly declined in the 1990s but has remained stable since then. Mertens (2016) shows that U.S. trend inflation declined in the course of the global financial crises and that at the same time uncertainty about the trend level increased. As in the U.S., the Euro area experienced inflation rates persistently above the predicted rates between 2008 to 2011. However, in the recovery phase of the sovereign debt crisis, the puzzle reversed, and headline inflation has been continuously over-predicted. Using a large-scale vector autoregression Bobeica and Jarocinski (2017) show that the headline inflation dynamics in the Euro area can be mainly explained by global factors during the global financial crisis and by domestic factors from 2011 to 2014. Other empirical work by Riggi and Venditti (2015) and Jarociński and Lenza (2016) derives an alternative measure of output gap estimates that match inflation dynamics after the sovereign debt crisis. In contrast to large-scale empirical approaches, our panel UCSV model allows a structural interpretation of events, because our specification is based on a theoretically founded New-Keynesian Phillips Curve relationship.

2.3 Empirical Methodology

2.3.1 Baseline model

We estimate a non-linear, bivariate unobserved component model of the unemployment-based Phillips curve, similar to the models used by Chan et al. (2016) and Stella and Stock (2013). What differentiates our model from the aforementioned ones is that we introduce cross-sectional information for the identification of the long-run trend inflation and common time-varying parameters. Our benchmark model takes on the following form:

$$
\begin{aligned}
\pi_{n,t} - \tau_t^{\pi,EU} &= \rho_t^{\pi}(\pi_{n,t-1} - \tau_{t-1}^{\pi,EU}) + \lambda_t(u_{n,t} - \tau_{n,t}^{u}) + \beta_t \pi_t^{oil} + \epsilon_{n,t}^{\pi} \\
u_{n,t} - \tau_{n,t}^{u} &= \rho_{n,1}^{u}(u_{n,t-1} - \tau_{n,t-1}^{u}) + \rho_{n,2}^{u}(u_{n,t-2} - \tau_{n,t-2}^{u}) + \epsilon_{n,t}^{u} \\
\tau_t^{\pi,EU} &= \tau_{t-1}^{\pi,EU} + \epsilon_t^{\tau,\pi} \\
\tau_{n,t}^{u} &= \tau_{n,t-1}^{u} + \epsilon_{n,t}^{\tau,u} \\
\rho_t^{\pi} &= \rho_{t-1}^{\pi} + \epsilon_t^{\rho,\pi} \\
\lambda_t &= \lambda_{t-1} + \epsilon_t^{\lambda} \\
\beta_t &= \beta_{t-1} + \epsilon_t^{\beta}
\end{aligned}
\tag{2.1}
$$

with $n = 1, \ldots, N$ number of countries, $t = 1, \ldots, T$ points in time. The first line reflects the Phillips curve relation, written in the inflation-gap formulation - that is the difference between $\pi_{n,t}$, the annualized quarter-on-quarter change of harmonized consumer prices (HICP), and $\tau_t^{\pi,EU}$, the unobserved trend inflation. In this Phillips curve specification, we assume that the current inflation-gap is explained by the past inflation-gap, the unemployment-gap and by a cost push factor, namely oil price inflation. The second row specifies the unemployment-gap - that is the deviation of unemployment rates from the non-accelerating inflation rate of unemployment (NAIRU) modelled as an AR(2) process. We allow all coefficients in the Phillips curve relation to be time-varying. We chose to do so because Stella and Stock (2013) have shown that allowing the persistence parameter to vary over time is empirically important. Additionally, we allow the level of the error variance to change over time and introduce a common stochastic volatility component in the inflation-gap equation. The error terms of the model can be summarised in the following way:

$$\begin{aligned}
\epsilon^{\pi}_{n,t} &\sim N(0, e^{h_t}) \\
h_t &= h_{t-1} + \epsilon^{h}_{t} \\
\epsilon^{h}_{t} &\sim N(0, \sigma^2_h) \\
\epsilon^{u}_{n,t} &\sim N(0, \sigma^2_{n,u}) \\
\epsilon^{\rho^{\pi}} &\sim TN(-\rho^{\pi}_{t-1}, 1-\rho^{\pi}_{t-1}; 0, \sigma^2_{\rho^{\pi}}) \\
\epsilon^{\lambda} &\sim TN(-1-\lambda_{t-1}, 0-\lambda_{t-1}; 0, \sigma^2_{\lambda}) \\
\epsilon^{\beta} &\sim TN(-\beta_{t-1}, 1-\beta_{t-1}; 0, \sigma^2_{\beta})
\end{aligned} \tag{2.2}$$

As the literature on time-varying coefficients suggests, we assume that the Phillips curve parameters and the stochastic volatility evolve as driftless random walks (see among others Cogley et al. (2010), Stock and Watson (2007) or Chan et al. (2013)). As Chan et al. (2016) points out, the state specification of driftless random walks introduces excess uncertainty about the location of states when economic analysis of past developments allows a reasonable parameter space to be defined ex ante. Therefore, we introduce truncated distributions for λ, ρ_{π} and ρ_u. In particular, we assume that the slope, persistence and cost-push shock parameters lie within the intervals $(-1, 0)$, $(0, 1)$ and $(0, 1)$, respectively. The unemployment-gaps evolve as stationary AR(2) processes, implying that $\rho^u_{n,1} + \rho^u_{n,2} < 1$, $\rho^u_{n,2} - \rho^u_{n,1} < 1$ and $|\rho^u_{n,2}| < 1$. Due to interrelations between the latent variables $\tau_t^{\pi,EU}$, $\tau^u_{n,t}$, λ_t, ρ^π_t, β_t and h_t the model shown in equation (2.1) is non-linear.

2.3.2 Trend inflation, inflation expectations, and monetary policy

An important feature of our model specification is the decomposition of trend inflation and country-specific cyclical movements of inflation rates. This is so because changes in the trend and country-specific cyclical inflation components have different policy implications. Thus, movements in trend inflation relate to changes in the long-run inflation and the degree of central bank credibility. By contrast, movements in country-specific inflation-gaps are driven by business cycle conditions, including the country's monetary policy stance and exogenous cost-push shocks. While there may be different long-run inflation trends in the countries of the Euro area, the ECB's monetary policy is only directed towards stabilizing Euro area average inflation. The Euro area average time-varying inflation trend $\tau_t^{\pi,EU}$ is therefore important for monetary policy purposes. Model (1) implies that, in the long-run (in the absence of unemployment and oil price shocks) Euro are average inflation converges to $\tau_t^{\pi,EU}$. Therefore, period t's model-based long-run inflation expectation for the Euro area as a whole is equal to $\tau_t^{\pi,EU}$. However, it could be that different countries in the Euro area follow different inflation trends. This is not captured by our model since country-specific unemployment-gaps

$\pi_{n,t} - \tau_t^{\pi,EU}$ have a zero unconditional mean. Recall that our main purpose is not to estimate country specific inflation dynamics but to use country-specific information to identify Euro-area average dynamics, and model (1) is intended to be useful for understanding the overall Euro area inflation trend.

2.3.3 Data and Estimation

We use seasonally adjusted data on a monthly frequency for EU10 countries (Austria, Belgium, Finland, France, Germany, Ireland, Italy, the Netherlands, Portugal and Spain) from 1999m01 until 2017m04. As a measure for inflation we use the overall change in harmonized index of consumer prices (HICP hereafter) and corresponding country weights provided by the ECB Data Warehouse and Eurostat. The unemployment rate and underlying number of unemployed persons and labour force data are taken from Eurostat. We use the latter two data sets to calculate country-specific weights to construct hypothetical EU10 unemployment series. For oil prices, we use the Brent crude oil spot price from the U.S. Energy Information Administration (EIA). We calculate annualized quarter-on-quarter percentage changes for all series except the unemployment rate. Moreover, we de-mean the oil price inflation series.

We employ Bayesian estimation techniques to estimate latent states, parameters and variances. In particular, we use the precision-based MCMC algorithm proposed by Chan and Strachan (2012). Thus, we rewrite our benchmark model, as in Chan et al. (2016), but include a panel dimension, in which we use the usual matrix notation of time-fixed effects in panel models (see for example Greene (2014)) to specify the common latent states. The full derivation of conditional densities as well as the choice of prior and a prior sensitivity analysis is outlined in the technical appendix.

2.4 Results

We discuss our results in three steps. We begin by examining and interpreting the empirical results of our benchmark model in detail, including the inflation trend estimate, country-specific inflation-gaps, the country-specific NAIRUs and unemployment-gaps, as well as the estimates of time-varying parameters. Then we compare the key results of our benchmark model to the corresponding outcomes of various other inflation models that have recently been presented in the literature. Finally, we carry out a forecasting exercise, evaluating the forecasting performance of the panel-structured Phillips curve against that of a number of uni- and multivariate inflation models.

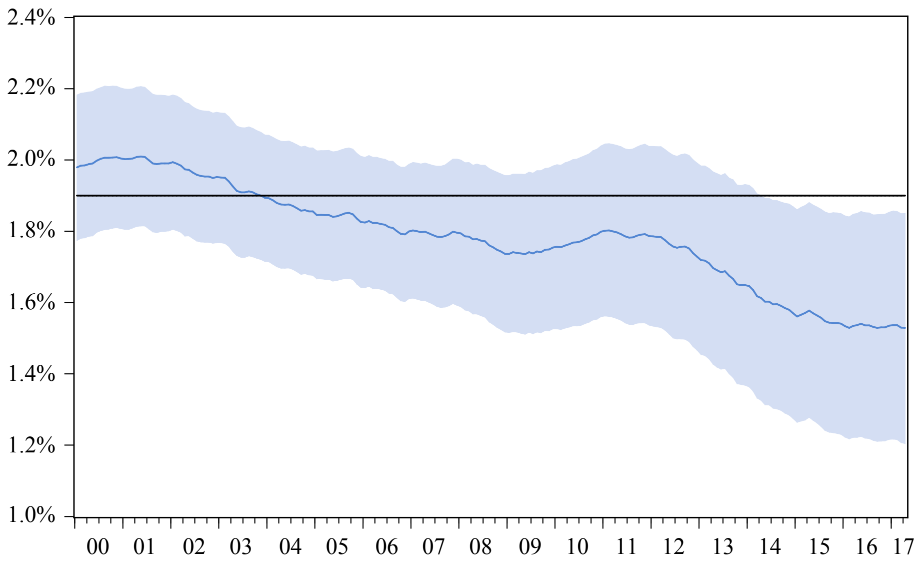
2.4.1 Empirical results of the baseline model

Trend inflation

The estimates of the trend inflation and the country-specific inflation-gaps are shown in Figures 2.2 as well as 2.3 and are discussed in turn, starting with trend inflation.

The estimates of the trend inflation are not significantly different from 1.9% between 1999 and 2013. This is in line with the ECB's inflation target of below (but close to) 2%. The posterior mean of trend inflation declined from 2% in 1999, and stabilized to 1.8% in the course of the global financial crisis. In mid-2013, the trough of the sovereign debt crisis (see CEPR Euro Area Business Cycle Dating), trend inflation started to fall significantly below 1.9%, and continued to decline to 1.5% in mid-2016. It stabilized thereafter. The upper and lower probability bands have the same quantitative magnitude of the survey-based and market-based inflation expectation measures in the last few years, amounting to 1.8% and 1.2%, respectively.

Figure 2.2: Trend inflation estimates



The solid line shows the posterior means and the shaded area indicates the 95% probability bands.

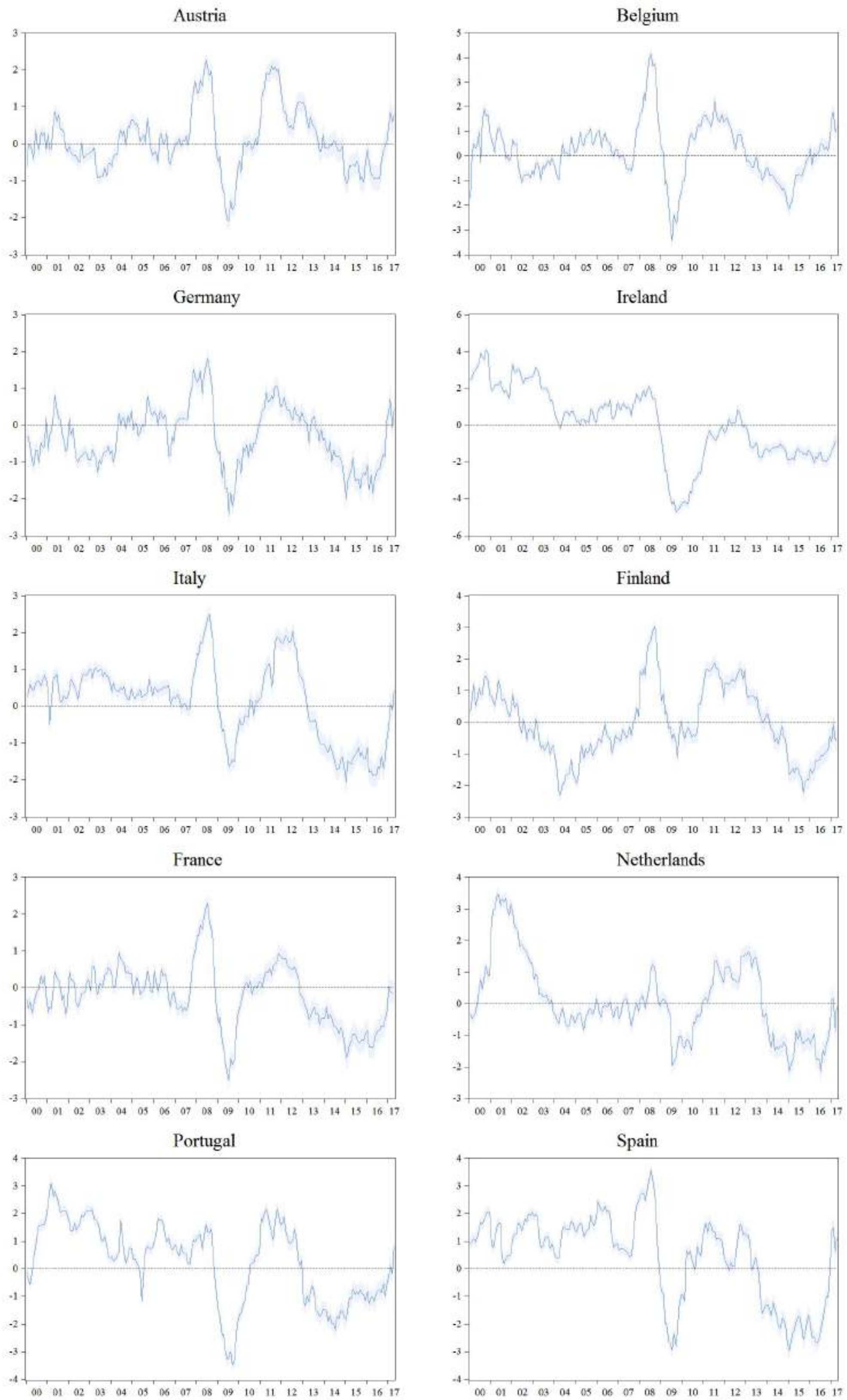
From a Phillips curve perspective, the anchoring of long-run inflation expectations is determined by two conditions. Firstly, long-run inflation expectations should equal the central bank's desired level of long-run inflation. Secondly, the inflation process should be predominantly driven by these long-run expectations (along with economic activity and cost-push shocks) rather than past inflation values. A deviation of either of these conditions is sufficient to cause a situation of de-anchored long-run inflation expectations. The former condition is approximated by our results on the trend inflation estimates in Figure 2.2. They reflect a continuous and significant deviation of long-run inflation expectations from the ECB's desired long-run inflation level from 2013 onwards. The latter condition relates to the persistence parameter and is discussed later in this section. Generally, our estimates indicate that persistently low headline inflation between 2013 to 2017 is at least partly driven by a decline in trend inflation and is not purely a cyclical and/or cost-push shock phenomenon.

Country-specific inflation-gaps

The dynamics of inflation-gap estimates shown in Figure 2.3 differed substantially across countries before the start of the global financial crisis, but appear to be homogeneous thereafter. In the pre-crisis period, Ireland, Italy, Portugal and Spain experienced persistently positive inflation-gaps - the average inflation-gap estimates for the pre-crisis period ranged from 0.64 for Italy to 1.63 for Portugal. By contrast, for Austria, Belgium, Germany, Finland and France, the inflation-gap estimates fluctuated evenly, with no persistent deviation in either direction. This heterogeneity of the inflation-gap estimates across countries, and especially the persistently positive inflation-gap estimates of the periphery countries in the pre-crisis episode, are consistent with empirical findings on causes of macroeconomic imbalances in the EMU. The literature suggests that inflation differentials can be related to an increase of unit labour costs and a rise of current account imbalances in periphery countries, due to the misallocation of capital across the EMU that led to persistent real exchange rate misalignments, rather than a catching-up effect in the tradeable sector (see Coudert et al. (2013) and references therein).

In the post-crisis period, the dynamics of inflation-gap estimates appeared much more homogeneous in quality and quantity across countries. Apart from substantial spikes in both directions around 2008 and 2009, inflation-gaps were persistently positive between 2010 to 2013, and peaked in 2012, at roughly 2% for most countries (except for Germany and France, where it was roughly 1%, and Ireland, where it was roughly 0.5%). Thereafter, the inflation-gaps turned negative and declined continuously until the end of 2016, with inflation-gaps around -2% for all countries, except for Austria (around -1%) and Spain (around -3%). Towards the end of the sample, inflation-gaps started to close again. Overall, the estimates suggest that headline inflation dynamics across EU10 countries were subject to amplified but relatively more homogeneous cyclical movements in the post-crisis period. Moreover, the sharp drop in the inflation-gaps between late 2012 to 2016 indicate that cyclical factors played an important role in explaining the period of low inflation in EU10 countries.

Figure 2.3: Inflation-gap for EU10 countries in percentage points



Solid lines show the posterior means and shaded areas indicate the 95% probability bands.

NAIRU and unemployment-gap estimates

Figure 2.4 illustrates the posterior means and 95% probability bands of the country-specific NAIRUs (blue lines and shading) together with the corresponding actual unemployment rates (black line), the NAWRU estimates of the European Commission (red line). Figure 2.5 shows the posterior means and 95% probability bands of the unemployment-gaps for each country. A striking feature of the actual, cyclical and structural unemployment rates across the EU10 countries is the continuous heterogeneity in both the levels and the dynamics.

For Ireland, Portugal, Spain and Italy, the NAIRU estimates increased significantly from the start of the financial crisis until the peak of the sovereign debt crisis, and declined thereafter. unemployment-gap estimates (see Figure 2.5) for this country group were primarily negative for the first part of the sample and turned positive in the course of the double dip recession, peaking at the height of the sovereign debt crisis and partly declining thereafter. Thus, prior to the crisis, these countries experienced reduced unemployment rates, mainly as a cyclical phenomenon, and structural unemployment was relatively stable.

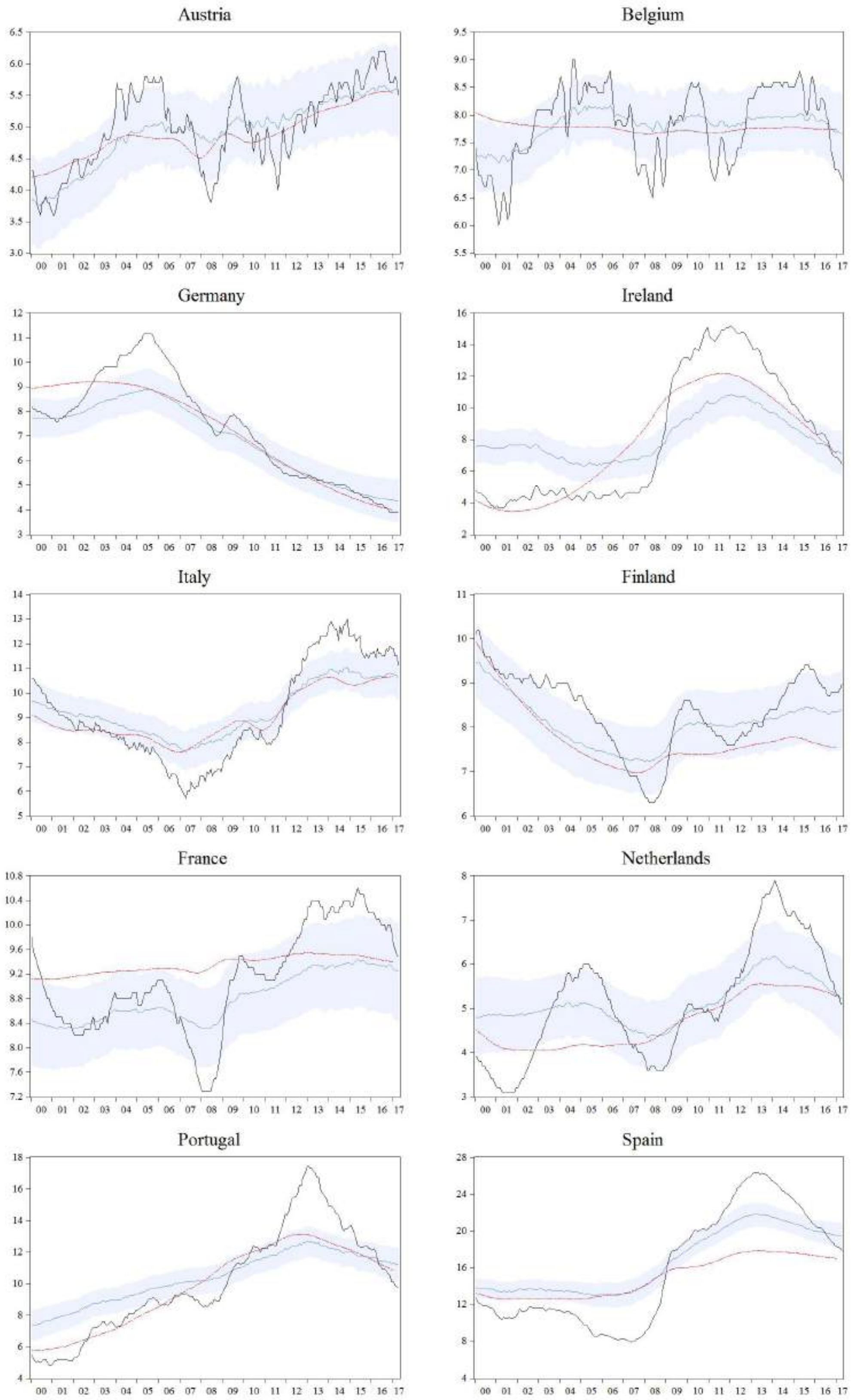
In the course of the double dip recession, however, the substantial increase in the unemployment rates for Ireland, Portugal, Spain and Italy originated from cyclical effects, as shown by positive unemployment-gaps of up to 5.7% (Spain), and from significant increases in structural unemployment rates.

For example, Portugal's NAIRU increased by 4.2 percentage points from the beginning of global financial crisis up to the end of 2012. By contrast, the NAIRU estimates of Austria, Belgium, France, Finland and the Netherlands (Figure 2.4) did not change significantly throughout the sample period. Germany was an exception, because the German NAIRU estimates declined continuously from 2005 onwards. These countries displayed positive unemployment-gaps around 2005 (except for France) and in the course of the recession (to lesser extent for Germany). While this group of countries experienced cyclical effects over the sample, estimates indicated no significant positive long-run effect on structural unemployment.

The asymmetries of the NAIRU and unemployment-gap estimates mirror the structural differences in the labour markets well, and reflect the severity of the financial and sovereign debt crisis across countries. Turning to the latter, Anderton et al. (2012) shows that elasticity estimates of GDP components to unemployment are substantially higher for domestic production than for exports. Discontinuity in the construction sector and/or accumulated competitiveness losses in Spain, Portugal, Ireland and Italy might partially explain the quantitatively higher increases of the unemployment-gaps from the beginning of the crisis in these countries, compared to the unemployment-gaps in the remaining countries.

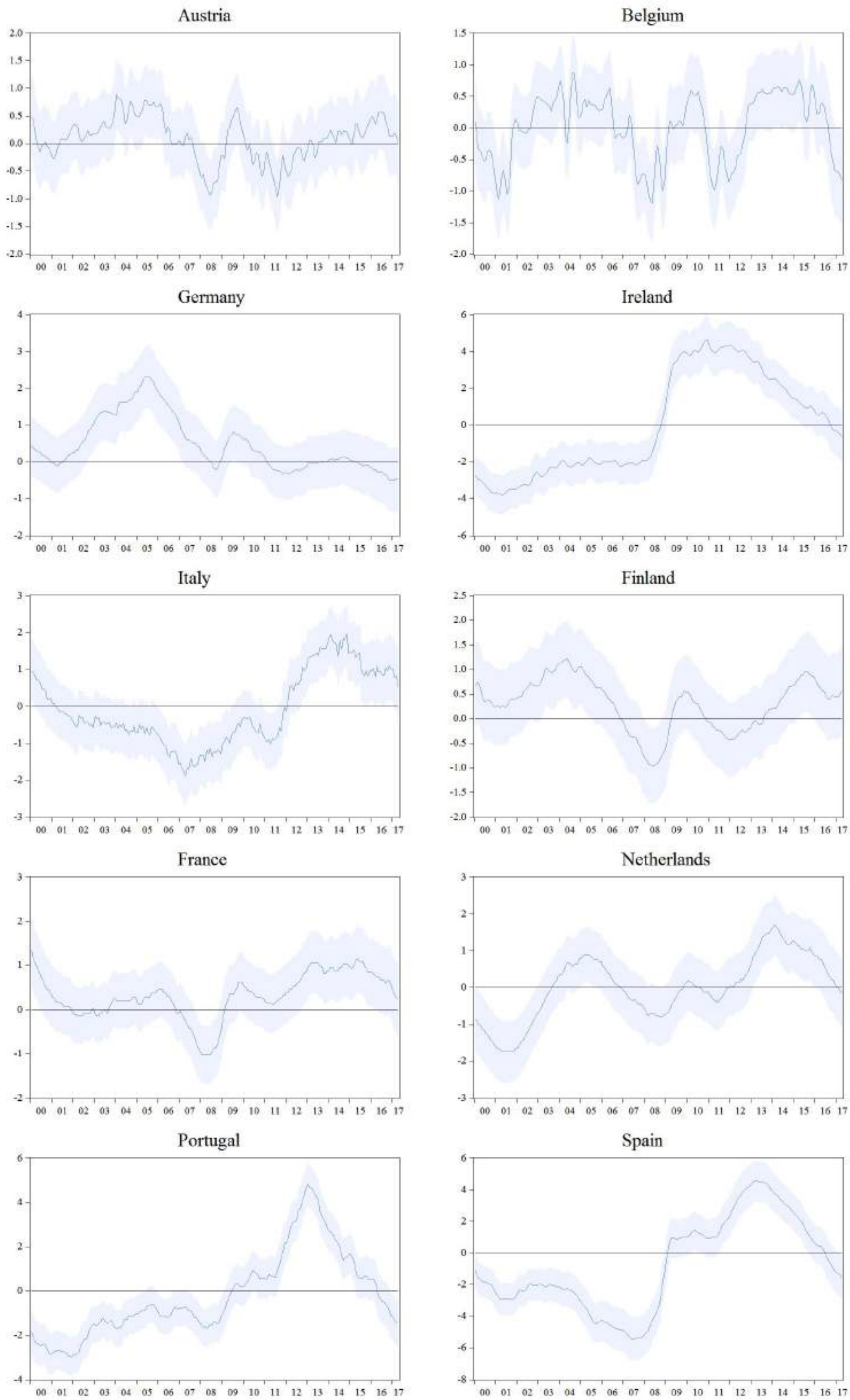
For Austria, Belgium, Germany, France, Finland and the Netherlands, where declines in exports were the main driver of the decrease in real economic

Figure 2.4: Estimated NAIRU and actual rate of unemployment for EU10 countries in percent



The solid blue lines show the posterior means, the blue shaded area indicate the 95% probability bands of NAIRU estimates, the red line indicates the NAWRU estimates of the EC and the black line depicts actual unemployment.

Figure 2.5: Estimated unemployment-gap for EU10 countries in percentage points



The solid lines show the posterior means and the shaded areas indicate the 95% probability bands.

activity, the effects of the Great Recession on the cyclical and structural unemployment dynamics are more limited.

The heterogeneous dynamics of our NAIRU estimates are also consistent with empirical findings on labour market performance, as well as differences in labour market institutions and structures across EU10 countries. Arpaia et al. (2014) report that countries that experienced a sector-specific boom prior to the crisis (such as the construction sector boom in Spain, Portugal and Ireland) faced a substantial increase in the degree of mismatch between the skills demanded by employees and those supplied by the unemployed on the labour market. The rise in the level of mismatch is to some extent permanent and therefore contributes to a rise in structural unemployment, because the existing human capital available from employees in those sectors that were hardly hit by the crisis might be of limited use for new jobs in expanding sectors.[3]

Another important determinant of structural unemployment dynamics is labour market and social benefit reforms. The most pronounced example is the labour market reform package that Germany introduced in the early 2000s. Consistent with the decline in our NAIRU estimates for Germany, Dustmann et al. (2014) found that the major reshaping of German labour market institutions, unemployment benefits and regulation lowered structural unemployment substantially and facilitated better labour market per-

[3] This effect has been called 'hysteresis' as described in Ball (2009). The scope of our paper does not allow us to engage in the recent debate around hysteresis effects on unemployment.

formance in the course of the crisis. The declining tendencies in the NAIRU estimates for Ireland, Italy, Portugal and Spain between 2013 and 2017 may be a result of ongoing labour market reforms, as part of structural policy packages supporting the recovery from the sovereign debt crisis. Overall, our NAIRU estimates are well able to capture recent economic episodes and developments on labour markets for each country, respectively, and they also compare well to the NAWRU estimates of the European Commission. Given our model specification, the altered unemployment-gaps of the periphery countries should partially translate into declining EU10 headline inflation rates.

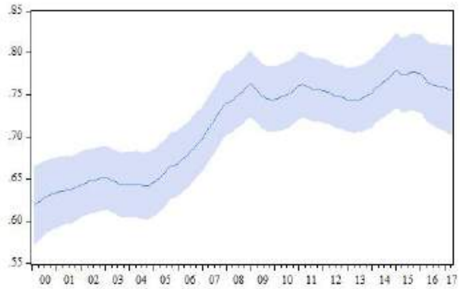
Time-varying Phillips curve parameters

Posterior means and 95% probability bands of the persistence coefficient, the Phillips curve slope and oil price coefficient are shown in Figure 2.6. Panel a of Figure 2.6 indicates that during the global financial crisis, inflation persistence increased significantly from around 0.65 between 1999 and 2006 to 0.75 from 2008 onwards. This implies that the degree of backward-lookingness of price setters has increased. This may relate to the credibility of the monetary policy regime (Erceg and Levin, 2003).

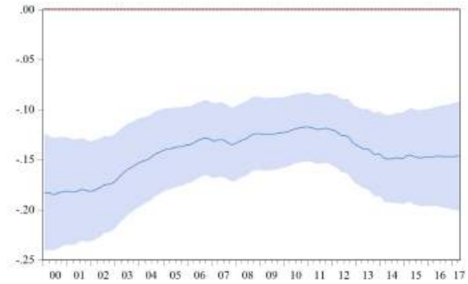
In this sense the magnitude of inflation persistence reflects the agent's uncertainty about whether the central bank can accomplish its long-run inflation target. From a monetary policy perspective, this implies that in addition to a decline in the trend inflation below the desired long-run level of 1.9% (see the

Figure 2.6: Time varying parameter estimates

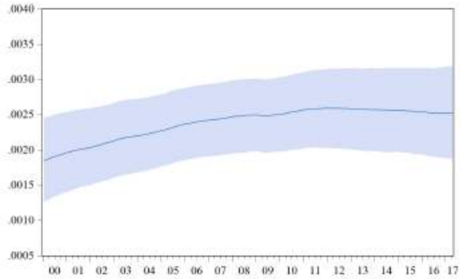
(a) coefficient on inflation persistence



(b) coefficient on unemployment-gap



(c) coefficient on oil price



The solid lines show the posterior means and the shaded areas indicate the 95% probability bands.

above discussion of trend inflation estimates), headline inflation has become less anchored to its long-run trend, indicating a rise in uncertainty from 2013 onwards about whether the ECB will be able to achieve its long-run inflation target.

The posterior mean of λ indicates that the Phillips curve for the EU10 countries is generally rather flat, averaging to -0.15 for the entire sample. Thereby, the posterior mean of the slope parameter reveals that the Phillips curve flattened throughout the period from early to mid-2000. The implied flattening of the EU10 Phillips curve is in line with the empirical evidence reported by Blanchard et al. (2015). In late 2013, however, the slope starts to increase again. Although the decline of λ is not significant, this could potentially explain missing inflation in the euro area. Riggi and Venditti (2015) also report that the elasticity of inflation with respect to real economic activity intensified in 2013 and 2014. The posterior mean of the oil price coefficient (Panel c, Figure 2.6) gradually increased from 0.0017 to 0.0023.

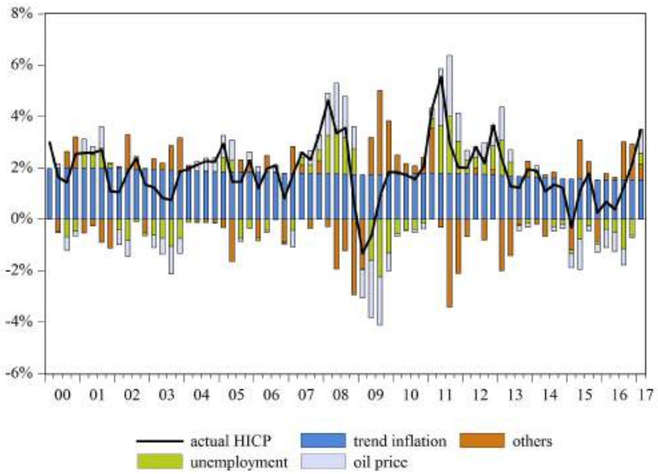
Decomposition of actual inflation

To show how different cyclical and long-run drivers affect headline inflation rates, we present the contribution of each of these factors to headline inflation rates across EU10 countries. We base the simulation of contributions on the posterior means of states and parameters. We also construct a hypothetical EU10 headline inflation rate, together with the consolidated contributions of the aforementioned inflation components. We do so by applying the official HICP weights provided by Eurostat to the country-specific headline inflation rates and corresponding contributions.

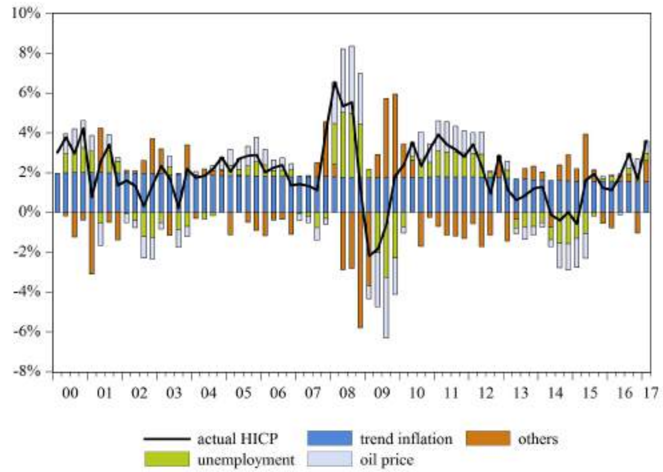
Across counties (see Figures 2.7, 2.8 and 2.9) the contribution of trend inflation explains quantitatively the largest share of headline inflation rates. Country-specific contributions assemble the dynamics of inflation and unemployment-gaps discussed in the previous section. We find that the dynamics of the contribution of unemployment and oil price inflation across countries were heterogeneous before the global financial crisis, but became more homogeneous from 2008 onwards.

Figure 2.7: Contributions to inflation I/III

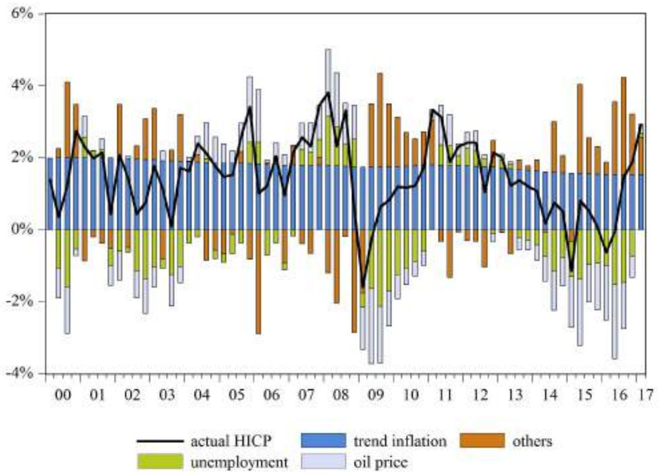
(a) Austria



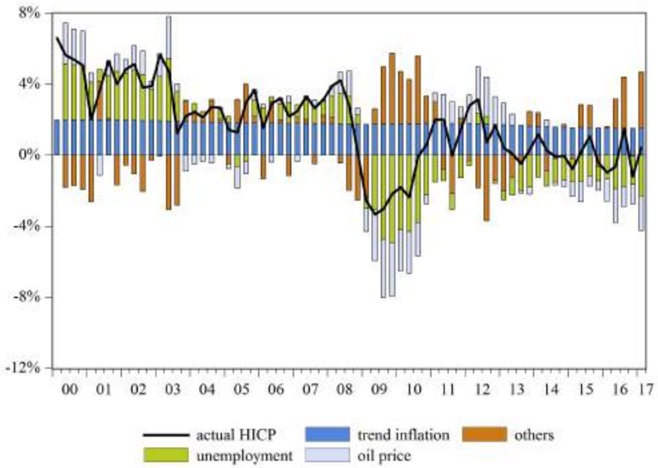
(b) Belgium



(c) Germany



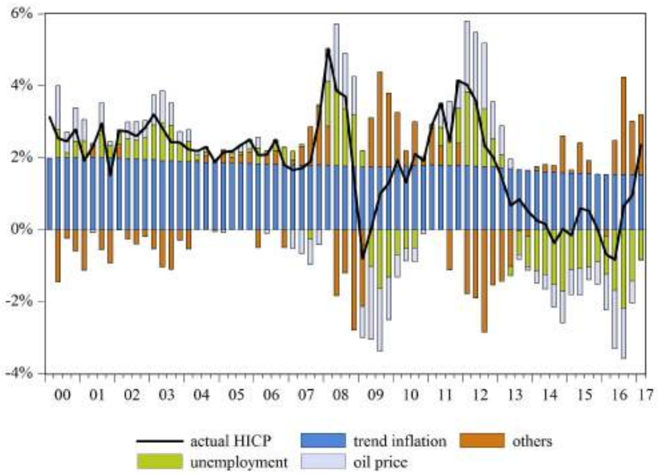
(d) Ireland



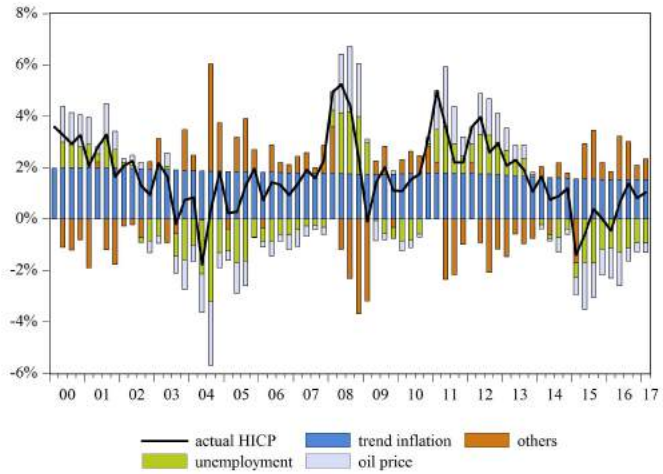
The panels present simulated contributions to headline inflation rates of the EU10 countries that result from the estimation of the benchmark model.

Figure 2.8: Contributions to inflation II/III

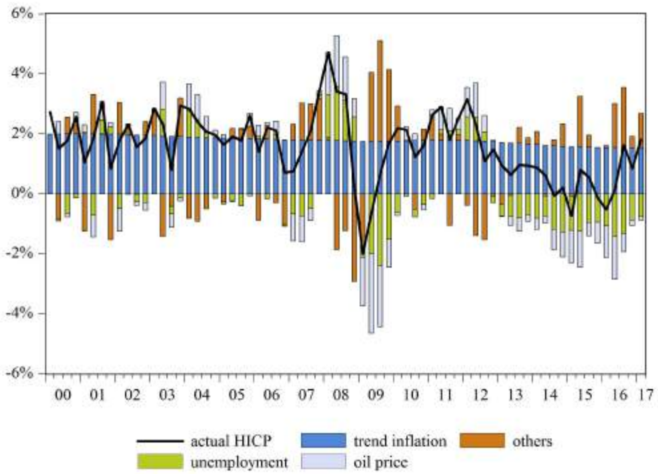
(a) Italy



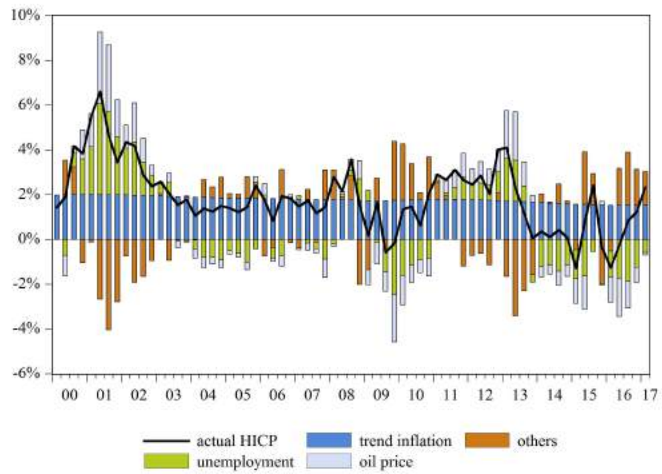
(b) Finland



(c) France



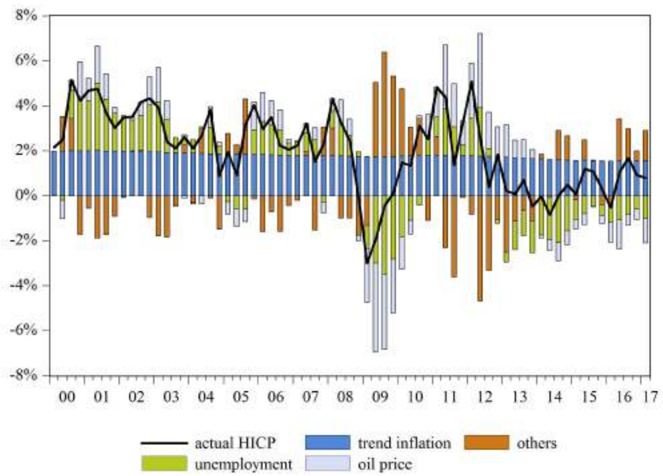
(d) Netherlands



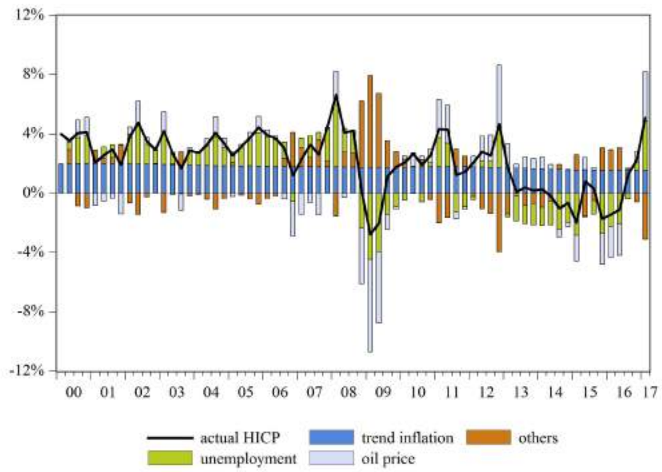
The panels present simulated contributions to headline inflation rates of the EU10 countries that result from the estimation of the benchmark model.

Figure 2.9: Contributions to inflation III/III

(a) Portugal

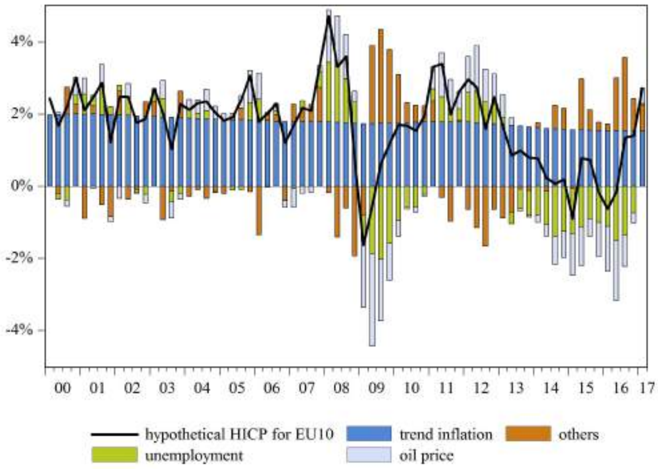


(b) Spain



The panels present simulated contributions to headline inflation rates of the EU10 countries that result from the estimation of the benchmark model.

Figure 2.10: Hypothetical EU10 contributions

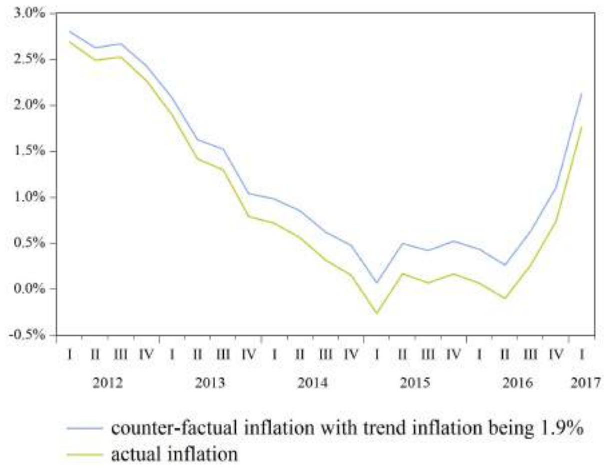


The figure presents simulated contributions to headline inflation rates of the EU10 region that are calculated as the sum of weighted country-specific contributions. The weights are the country-weights of the HICP provided by Eurostat that are converted to the country-selection used here.

Thus, the persistently higher headline inflation rates of periphery countries in the first half of the sample are partly a result of unemployment rates below the respective long-run unemployment trends. For example, the average contributions of unemployment from 1999M03 to 2007M12 amounted to 1.4% for Ireland, 0.4% for Italy, 1% for Portugal and 1.2% for Spain.

Low levels of German and Finish headline inflation in the early 2000s can, to some extent, be related to downward price pressures stemming from positive unemployment-gaps. The headline inflation rates of the remaining countries did not display persistent contributions by cyclical drivers from the early to the mid-2000s. Interestingly, the diverging country-specific contributions of unemployment balance out for the hypothetical EU10 series. This implies that fluctuations of unemployment-gaps had a limited impact on EU10 headline inflation in the early to mid-2000s (see Figure 2.10).

Figure 2.11: Actual and counter-factual inflation for the EU10 area



The figure presents the actual and the counter-factual EU10 headline inflation. The counter-factual inflation rate is obtained from simulating the benchmark model under the assumption that long-run inflation expectations have remained at 1.9% and is the weighted sum of the counter-factual, country-specific headline inflation rates. The weights are the country-weights of the HICP provided by Eurostat that are converted to the country-selection used here.

Overall, oil price inflation contributed little to headline inflation rates prior to the global financial crisis, but its influence has increased since 2008. It was especially important from 2014 to 2016. The increasing contribution of oil price inflation arose mainly from the decline of oil price inflation from 2014 onwards, rather than from changes of the underlying coefficient. Together, fluctuations in unemployment-gaps and oil price inflation contributed considerably to the reduction and the subsequent rise of country-specific and EU10 headline inflation rates after the start of the global financial crisis. Recently, the most debated episode of inflation dynamics is the continuous decline of headline inflation rates from 2012 to 2016, including periods of mild deflation around 2014. Our model suggests that persistently low inflation rates are the result, firstly, of slowly closing unemployment-gaps, together with a slight steepening of the Phillips curve, secondly, of a strong decrease in the oil price inflation, and, lastly, a drop in trend inflation.

To illustrate the implications of a decline in trend inflation on headline inflation in more detail, we calculate the counter-factual EU10 headline inflation from 2012m01 to 2017m03 that would have resulted if trend inflation had stayed at 1.9% (see Figure 2.11). The two series indicate that the decline of trend inflation accounts for up to 0.4% of the headline inflation. By comparison, the average contributions of unemployment and oil price inflation for the EU10 area between January 2014 and April 2017 were -1% and -0.7%, respectively.

2.4.2 Model comparison

To illustrate the benefit of adding a cross-sectional dimension to the UCSV inflation model, we compare our baseline model to a variety of other aggregate, uni- and multivariate UCSV models.

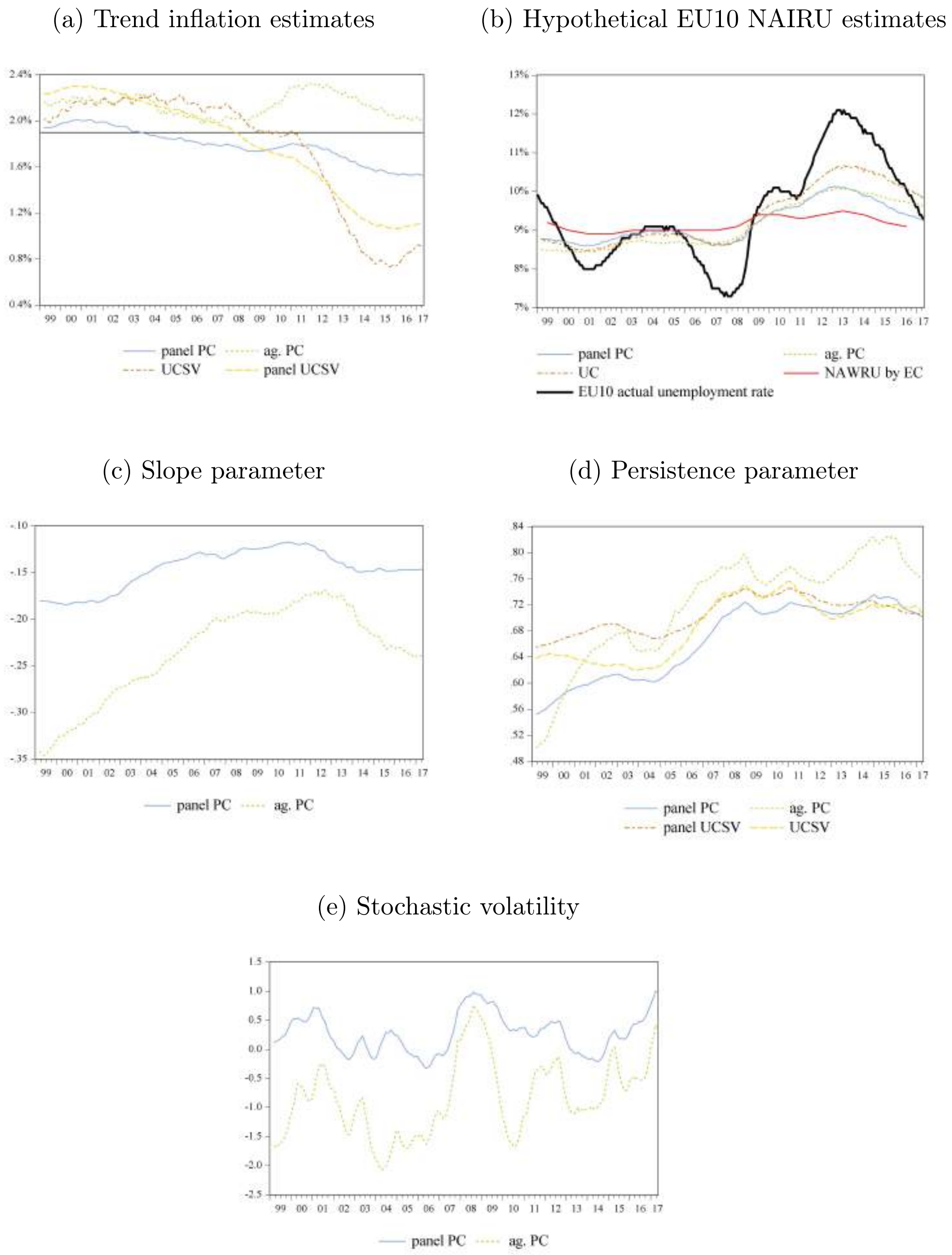
Using EU10 aggregate data from January 1999 to April 2017, we estimate the plain UCSV Stock and Watson (2007) type model in inflation-gap notation denoted **UCSV**. That is a decomposition of inflation into a trend component that follows a random walk and a cyclical component that is specified as an AR(1), and the variance of residuals and the AR(1) coefficient is time-varying. Secondly, we estimate the inflation-gap Phillips curve specification similar to Stella and Stock (2013) or Chan et al. (2013) with aggregate data and augment the former model by oil price inflation. We abbreviate this model as **ag. PC**. Next, we employ a panel structure the two aforementioned models. These models are named **panel UCSV** and **panel**

PC, whereby the latter version is our benchmark model. To simplify the comparison across the aggregate and panel models, we compute the hypothetical EU10 NAIRU using the country-specific posterior mean NAIRUs of the panel Phillips curve models, and country-specific weights resulting from the unemployment and labour force data. Estimation details of all models can be found in the technical appendix.

Figure 2.12 allows us to compare the results of our panel approach to inflation modelling along three dimensions. We can highlight the difference between panel and aggregate models, between univariate and multivariate model specification and between Phillips curve specifications. Inflation trend estimates across models (see Figure 2.12 Panel a) display a qualitatively similar dynamic until the start of the global financial crisis, but diverge thereafter. Estimates by both UCSV models (**USCV** and **panel UCSV**) reveal a stronger decline of trend inflation (0.8% in 2014) than the remaining models do (1.2% in 2014).

The strong decline of trend inflation estimates in the UCSV models results from omitted additional information, since estimates of the persistence parameter and stochastic volatility in those models are similar to those of our benchmark panel PC. In the absence of additional variables that explain the inflation-gaps, the decline of both country-specific and area-wide headline inflation rates translates mainly into a decline of trend inflation.

Figure 2.12: Key results: comparison across models



(a) Trend inflation estimates

(b) Hypothetical EU10 NAIRU estimates

(c) Slope parameter

(d) Persistence parameter

(e) Stochastic volatility

The panels present the distinct estimation results of the UCSV, ag. PC, panel UCSV and panel PC models that are included in the model comparison exercise.

Thus, for our estimation exercise, Phillips curve models imply systematically higher trend inflation estimates, especially for the end of the sample. The estimates from the aggregate version, however, are consistently higher than those of the **panel PC** model. These estimates do not fall below 1.9% throughout the sample, and increase to 2.5% around 2012.

The higher trend inflation estimates of the aggregate model are related to systematically larger magnitude and time variation of the slope and persistence parameters, compared to the panel Phillips curve models. These larger parameter values are at odds with the empirical findings reported, for example, by Blanchard et al. (2015) and Eickmeier and Pijnenburg (2013). It is important to notice that this outcome does not hinge on distinct estimation set-ups across models, because we apply the same starting values as well as priors to panel and aggregate models. The different magnitude and time variation found may instead be a result of limited information in the time dimension of the data (17 years) for estimating slowly evolving states, which is independent of the number of observations used (our sample contains 218 observations of monthly data). As pointed out earlier, we circumvent this problem by adding a cross-sectional dimension to the model. Thus applying a panel structure results in trend estimates that decline moderately from 2013 onwards, providing much more plausible outcomes compared to survey- and market-based inflation expectations measures (see Figure 2.1 Panel b). Across the univariate and multivariate models, the results of the panel specifications, especially the panel Phillips curve model including oil prices, are highly plausible in economic terms.

2.4.3 Forecasting performance

We now examine how well our panel Phillips curve can forecast inflation since the global financial crisis. We compare the forecast performance of our baseline model to aggregate models, as well as panel UCSV and various Phillips curve models. Along similar lines as a study by Faust and Wright (2013) we also include simple autoregressive and random walk models. We perform a pseudo-out-of-sample forecast exercise for the time span January 2009 to April 2017. The models included in the forecast exercise are listed below:

- **AR(p)** with $P = 1, 2, ..., 6$: autoregressive model for aggregate EU10 inflation following the specification of Faust and Wright (2013), $\pi_t = \phi_0 + \sum_{p=1}^{P} \phi_p \pi_{t-p} + \epsilon_t$
- **ARIMA(p,d,q)** with $P = 1, 2$, $D = 0$ and $Q = 1, 2$: autoregressive integrated moving average model for aggregate EU10 unemployment rate following Montgomery et al. (1998), $u_t = \sum_{p=1}^{P} \phi_p u_{t-p} + \epsilon_t + \sum_{q=1}^{Q} \theta_q \epsilon_{t-1}$
- **RW**: random walk model for aggregate EU10 inflation $\pi_t = \pi_{t-1} + \epsilon_t$
- **panel PC**: panel formulation of inflation-gap Phillips curve including oil price inflation with time-varying parameters and stochastic volatility (benchmark model)
- **panel PC excl. oil**: panel formulation of inflation-gap Phillips curve excluding oil price inflation with time-varying parameters and stochastic volatility

- **ag. PC**: aggregate inflation-gap Phillips curve including oil price inflation with time-varying parameters and stochastic volatility
- **ag. PC excl. oil**: aggregate inflation-gap Phillips curve excluding oil price inflation with time-varying parameters and stochastic volatility
- **UCSV**: unobserved component model with stochastic volatility of Stock and Watson (2007) decomposing inflation into trend and cyclical component using aggregate EU10 inflation
- **UC**: unobserved component model for EU10 aggregate unemployment with AR(2) process for unemployment-gap and a random walk process for trend unemployment.
- **panel UCSV**: panel formulation of unobserved component model with stochastic volatility
- **panel PC const.** λ: baseline model assuming that λ is constant over time
- **panel PC const.** ρ: baseline model assuming that ρ is constant over time
- **panel PC const. o** : baseline model assuming that the oil price parameter is constant over time
- **panel PC const.**: baseline model assuming that all parameters are constant over time
- **panel PC excl. sv**: baseline model assuming that the variance of the inflation-gap equation is constant over time

- **panel PC cum. oil**: baseline model including cumulated oil price inflation (one quarter)

- **panel PC cs** ρ: baseline model allowing for country-specific persistence parameters (time-varying).

The ratios of the root mean squared forecast errors (RMSFE) of each model to the RMSFE of the AR(1) forecasts for EU10 inflation is shown in Table 2.1, respectively.[4] Overall, our proposed panel structure for the Phillips curve and also for the UCSV models offers sound forecasts. For inflation forecasts from horizon 2 onwards, all our panel models outperform the aggregate uni- and multivariate models, yielding 2% to 24% smaller RMSFEs than a plain AR(1) forecast. For short-run forecasts, our benchmark model, **panel PC**, is the model that performs best. Introducing country-specific persistence in the panel Phillips curve helps to improve the short-run to mid-run (6-18 horizons) forecasts. Forecasts for 2 to 3 years ahead are predicted best by the UCSV panel model. Interestingly, the univariate AR and RW models offer better forecast performance than aggregate Phillips curves.

[4] Forecasting results for EMU unemployment rates can be found in the appendix.

Table 2.1: EU10 inflation: RMSFEs relative to RMSFE of the AR(1) model

	horizon													
model	1	2	4	6	9	12	15	18	21	24	27	30	33	36
AR(1)	1	1	1	1	1	1	1	1	1	1	1	1	1	1
AR(2)	1.04	1.04	1.08	1.08	1.03	1.01	1.00	1.00	1.00	0.99	1.00	0.99	0.99	0.99
AR(4)	0.92	0.98	0.99	0.98	1.00	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.01
AR(6)	0.91	0.98	1.06	1.05	1.06	1.02	1.01	1.00	1.00	0.99	1.00	0.99	0.99	0.99
RW	1.05	1.12	1.20	1.11	1.09	1.00	1.10	1.18	1.16	1.19	1.14	1.18	1.25	1.25
panel PC	**1.02**	**0.94**	**0.96**	**0.95**	**0.91**	**0.91**	**0.94**	**0.92**	**0.94**	**0.94**	**0.93**	**0.91**	**0.94**	**0.91**
panel PC excl. oil	1.02	0.95	0.98	0.97	0.95	0.97	1.01	1.00	1.01	1.02	1.02	1.00	1.02	1.01
ag. PC	1.30	1.61	1.81	1.89	1.87	1.65	1.31	1.60	1.39	0.99	1.20	1.08	0.91	1.01
ag. PC excl. oil	1.08	1.07	1.11	1.10	1.06	1.07	1.18	1.24	1.23	1.32	1.31	1.27	1.35	1.36
UCSV	1.02	1.00	1.01	0.97	0.96	0.96	1.01	1.01	1.02	1.02	1.04	1.04	1.05	1.06
panel UCSV	1.05	1.00	1.07	1.08	1.01	0.96	0.95	0.91	0.88	0.85	0.80	0.76	0.77	0.76
panel PC const. λ	1.01	0.95	0.98	0.97	0.92	0.93	0.96	0.95	0.96	0.95	0.95	0.93	0.96	0.94
panel PC const. ρ	1.00	0.95	0.99	0.97	0.93	0.94	0.98	0.97	0.95	0.95	0.96	0.94	0.95	0.92
panel PC const. o	1.01	0.94	0.97	0.95	0.91	0.90	0.95	0.92	0.93	0.92	0.93	0.90	0.92	0.90
panel PC const.	1.01	0.95	0.99	0.98	0.93	0.94	0.98	0.97	0.96	0.96	0.96	0.95	0.95	0.94
panel PC excl. sv	1.03	0.95	0.99	0.96	0.92	0.90	0.94	0.91	0.91	0.91	0.92	0.87	0.90	0.87
panel PC cum. oil	1.03	0.96	0.98	0.97	0.94	0.94	0.99	0.97	0.97	0.99	0.99	0.97	0.98	0.98
panel PC cs ρ	1.03	0.96	0.97	0.94	0.90	0.88	0.94	0.92	0.92	0.92	0.91	0.90	0.91	0.91

This table displays the root mean squared forecast errors (RMSFEs) of respective model relative to the RMSFEs of an AR(1) model that stem from a pseudo-out-of-sample inflation forecast for the time span January 2009 to April 2017. Values lower than 1 indicate that the RMSFEs of the respective model are lower than those of the AR(1) model. The results from the benchmark model are highlighted in bold. The shading indicates the respective forecasting performance, whereby green (light) shadings emphasize better forecasting performance.

2.5 Robustness analysis

To check the sensitivity of our baseline model, we report a series of robustness analyses in this section. The short time dimension of our sample raises the question of whether the time variation of structural parameters is a plausible assumption. Therefore, we re-estimate our benchmark model with distinct assumptions of the parameters' time variation, holding each parameter constant in turn, and then all together over time.

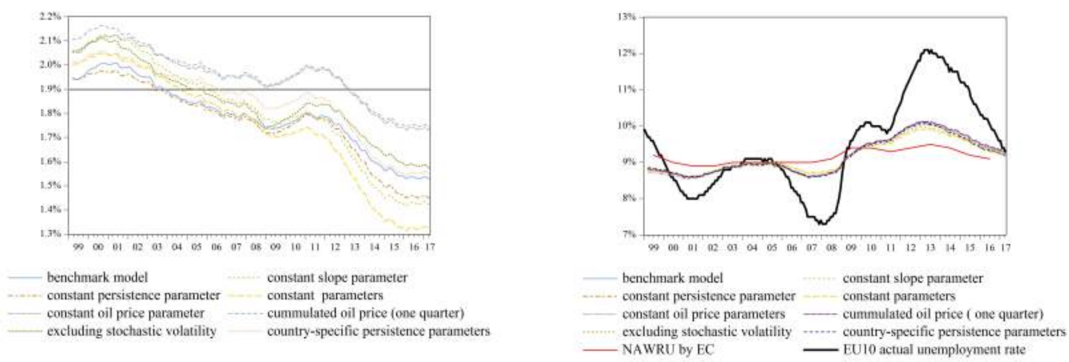
In addition, we leave aside the assumption on time-evolving variances of the inflation-gap residuals. Because cost-push factors might affect the inflation process with some delay, we also estimate a variant including cumulated oil price inflation (one quarter). Moreover, the identification of a Phillips curve for the EU10 area does not require the assumption of a common persistence parameter across countries. Hence, we include a model version with country-specific persistence.

Figures 2.13, 2.14 and 2.15 show the posterior means of the estimated states of all model variants and the benchmark specification. To summarize the country-specific NAIRU estimates, we again construct a hypothetical EU10 NAIRU for all models. All trend inflation estimates (Panel a Figure 2.13) depict qualitatively the same dynamics and differ to a minor extent quantitatively after the start of the sovereign debt crisis. This implies that the posterior means of the trend inflation are systematically higher for the model including cumulative oil prices, and for the model with no time variation of the oil price parameter. For those models, the posterior means of trend inflation amount to roughly 1.8% in 2016 compared to 1.6% for the benchmark model. For model variants where all parameters, only λ or only ρ_π assumed to be constant, trend inflation is lower at the end of the sample. The posterior means of the hypothetical EU10 NAIRUs display nearly no quantitative differences across models.

Figure 2.13: Benchmark model and robustness specifications: posterior means of trend inflation and NAIRU

(a) Trend inflation

(b) Hypothetical EU10 NAIRU

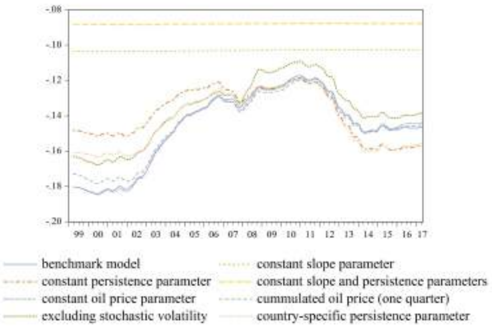


The panels present the distinct estimated trend inflation and hypothetical EU10 NAIRUs of the suite of model alternatives chosen for the robustness analysis. The hypothetical EU10 NAIRUs comprise the weighted sum of country-specific NAIRU estimates of the respective model. The weights are taken from Eurostat and are converted to the country-selection used here.

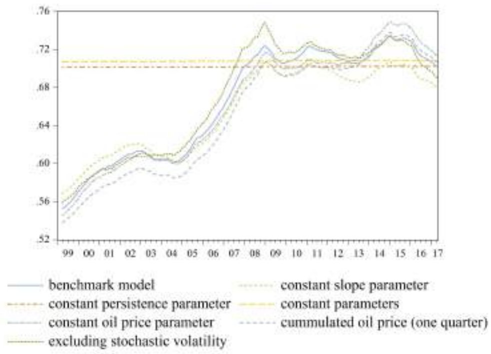
Turning to Figure 2.14, it is clear that the posterior means of the parameters display qualitatively similar dynamics. Especially the posterior means of the persistence and stochastic volatility are nearly the same across models. The slope, country-specific persistence and oil price coefficients reveal some quantitative differences. Restricting the slope to be constant over time yields lower posterior means of -0.11 and -0.086 as compared to our benchmark model. Also, the model version with constant variance of the inflation-gap inflation

Figure 2.14: Benchmark model and robustness specifications: posterior means of parameters

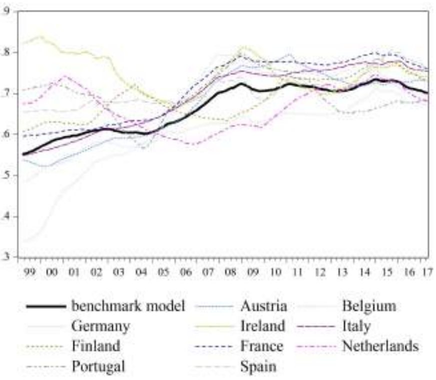
(a) Slope



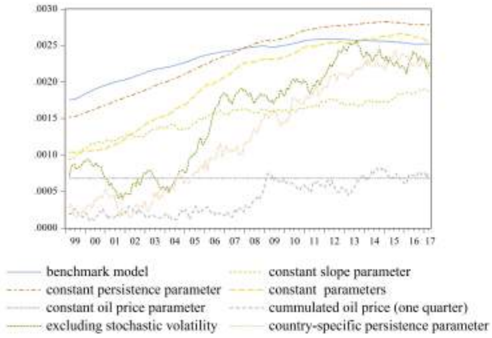
(b) Persistence



(c) Country-specific persistence



(d) Oil price parameter

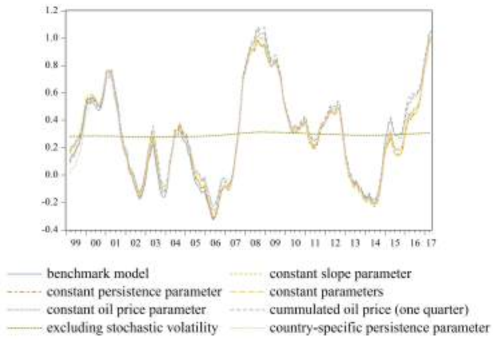


The panels present the distinct estimated time-varying or constant coefficients of the suite of model alternatives chosen for the robustness analysis.

shows systematically lower evolution of the slope. Moreover, if the persistence parameter is kept constant, that leads to lower slope parameters up to the start of the global financial crisis and amplified steepening of the slope thereafter. The posterior mean of our benchmark model is around 0.6 between 1999 and 2004. Country-specific persistence estimates, however, indicate substantial differences from 1999 until 2005, with a higher degree of persistence especially for Ireland (0.8), Finland (0.7) and the Netherlands (0.68). Over time, the persistence parameters converge and deviate by roughly ± 0.05 from the benchmark model's persistence from 2008 onwards.

Figure 2.15: Benchmark model and robustness specifications: posterior mean of stochastic volatility

(a) Stochastic volatility



The figure presents the distinct estimated of stochastic volatility of the suite of model alternatives chosen for the robustness analysis.

The most pronounced difference across oil price parameters is that between the benchmark model using oil price inflation, and the version of the model using cumulated oil prices. The latter model implies a consistently lower coefficient of around 0.0003, compared to a coefficient of 0.002 in the benchmark model, but both series show a slight increase of the oil price parameter after the start of the global financial crisis. Due to the positive autocorrelation of oil price inflation, the cumulated oil price series displays altered amplitudes. As expected, this results in a lower posterior mean of the oil price parameters.

2.6 Conclusion

Puzzling inflation dynamics in advanced economies have been studied by a growing literature on unobserved components stochastic volatility models, thus far applied mainly to US inflation. A prerequisite for using this type of model is a large sample that exhibits enough data variability on the time dimension. In this paper, we propose a panel non-linear UCSV Phillips curve model to investigate the inflation dynamics of the Euro area since the start of the Great Recession. We overcome the difficulty of having only limited information on the time dimension of the Euro area sample, by exploiting cross-sectional country-specific data. Our preferred panel structure for the non-linear UCSV Phillips curve model outperforms plain multivariate model versions in terms of the economic plausibility of results and in terms of forecast performance. Aggregate multivariate UCSV models indicate substantially higher trend inflation estimates and a steeper Phillips curve for the Euro area. Moreover, univariate UCSV models tend to overestimate the decline of trend inflation since 2013. These results are at odds with previous country-specific findings reported in the literature. The estimation results of our preferred model suggest that the reasons underlying the period of persistently low headline inflation in the EU10 area are threefold. Firstly, the EU10 inflation process has become more persistent in the course of the Great Recession and long-run trend inflation has significantly declined below 1.9% since 2013. According to our counter-factual analysis, this de-anchoring of inflation expectations accounted for 0.4% of headline inflation. Secondly, slowly closing unemployment-gaps, together with a slightly steeper Phillips curve exerted downward price pressure between 2013 and 2017. Lastly, the substantial fall of oil prices in 2014 amplified the decline of cyclical inflation.

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2.7 Appendix

In the first Section of this appendix outline the model details and the prior choice of the panel UCSV Phillips curve. In the second Section we describe the MCMC-Algorithm. In the third Section we provide details on further models presented in the paper. The last section reports a prior predictive analysis.

2.7.1 Model and priors

Our benchmark model takes on the form:

$$\begin{aligned}
\pi_{n,t} - \tau_t^{\pi,EU} &= \rho_t^{\pi}(\pi_{n,t-1} - \tau_{t-1}^{\pi,EU}) + \lambda_t(u_{n,t} - \tau_{n,t}^u) + \beta_t \pi_t^{oil} + \epsilon_{n,t}^{\pi} \\
(u_{n,t} - \tau_{n,t}^u) &= \rho_{n,1}^u(u_{n,t-1} - \tau_{n,t-1}^u) + \rho_{n,2}^u(u_{n,t-2} - \tau_{n,t-2}^u) + \epsilon_{n,t}^u \\
\tau_t^{\pi,EU} &= \tau_{t-1}^{\pi,EU} + \epsilon_t^{\tau,\pi} \\
\tau_{n,t}^u &= \tau_{n,t-1}^u + \epsilon_{n,t}^{\tau,u} \qquad (2.3) \\
\rho_t^{\pi} &= \rho_{t-1}^{\pi} + \epsilon_t^{\rho,\pi} \\
\lambda_t &= \lambda_{t-1} + \epsilon_t^{\lambda} \\
\beta_t &= \beta_{t-1} + \epsilon_t^{\beta}
\end{aligned}$$

with $n = 1, \ldots, N$ number of countries, $t = 1, \ldots, T$ points in time and

$$\begin{aligned}
\epsilon^{\pi}_{n,t} &\sim N(0, e^{h_t}) \\
h_t &= h_{t-1} + \epsilon^{h}_{t} \\
\epsilon^{h}_{t} &\sim N(0, \sigma^2_h) \\
\epsilon^{u}_{n,t} &\sim N(0, \sigma^2_{n,u}) \\
\epsilon^{\rho^{\pi}} &\sim TN(-\rho^{\pi}_{t-1}, 1 - \rho^{\pi}_{t-1}; 0, \sigma^2_{\rho^{\pi}}) \\
\epsilon^{\lambda} &\sim TN(-1 - \lambda_{t-1}, 0 - \lambda_{t-1}; 0, \sigma^2_{\lambda}) \\
\epsilon^{\beta} &\sim TN(-\beta_{t-1}, 1 - \beta_{t-1}; 0, \sigma^2_{\beta})
\end{aligned} \tag{2.4}$$

Moreover, we impose that the unemployment-gaps evolve as a stationary AR(2) process, restricting $\rho^u_{n,1} + \rho^u_{n,2} < 1, \rho^u_{n,2} - \rho^u_{n,1} < 1$ and $|\rho^u_{n,2}| < 1$. Additionally, we assume that λ_t, ρ^{π}_t and β_t lie in the intervals $(-1, 0)$, $(0, 1)$ and $(0, 1)$, respectively. The prior for initial conditions of the state equations are

$$
\begin{aligned}
\tau_1^{\pi,EU} &\sim N(\tau_0^{\pi,EU}, \omega_{\tau^\pi}^2) \\
\tau_{n,1}^u &\sim N(\tau_{n,0}^u, \omega_{\tau^u}^2) \\
\rho_1^\pi &\sim TN(0,1; \rho_0^\pi, \omega_{\rho^\pi}^2) \\
\lambda_1 &\sim TN(-1,0; \lambda_0, \omega_\lambda^2) \\
\beta_1 &\sim TN(0,1; \beta_0, \omega_\beta^2) \\
h_1 &\sim TN(h_0, \omega_h^2)
\end{aligned}
$$

whereby $\tau_0^{\pi,EU}$, $\tau_{n,0}^u$, ρ_0^π, λ_0, β_0, h_0, $\omega_{\tau^\pi}^2$, $\omega_{\tau^u}^2$, $\omega_{\rho^\pi}^2$,ω_λ^2,ω_β^2 and ω_h^2 are known constants. The specific choice of initial conditions is shown in Table 2.2. For the model parameters we choose the following priors

$$
\begin{aligned}
\sigma_{u,n}^2 &\sim IG(\underline{v}_u, \underline{S}_u) \\
\sigma_h^2 &\sim IG(\underline{v}_h, \underline{S}_h) \\
\sigma_{\tau^\pi}^2 &\sim IG(\underline{v}_{\tau^\pi}, \underline{S}_{\tau^\pi}) \\
\sigma_{\tau^u,n}^2 &\sim IG(\underline{v}_{\tau^u,n}, \underline{S}_{\tau^u,n}) \\
\sigma_{\rho^\pi}^2 &\sim IG(\underline{v}_{\rho^\pi}, \underline{S}_{\rho^\pi}) \\
\sigma_\lambda^2 &\sim IG(\underline{v}_\lambda, \underline{S}_\lambda) \\
\sigma_\beta^2 &\sim IG(\underline{v}_\beta, \underline{S}_\beta)
\end{aligned}
$$

IG denotes the inverse-Gamma distribution. The initial values and priors are shown in Table 2.2. The prior for the degrees of freedom for the parameters is small as $v = 10$, implying a large variance and therewith a relatively non-informative prior. The scale parameters are set in way as to reflect the desired smoothness desired smoothness of tvp parameters and trends in terms of expected value of the respective variances. For example, $S_{\tau^\pi} = 0.9$

with $E(\sigma_{\tau^\pi}) = 0.1$ then the prior for $E(\sigma_{\tau^\pi})$ implies a relatively smooth transition of τ^π. With a high probability τ^π changes between -0.01 and 0.01 from one period to another. Since the inflation trend is common across countries but the unemployment trend is country-specific we employ distinct scale parameters for the unemployment trends, reflecting differences across country-specific NAIRUs due to structural differences across labour markets.

Table 2.2: Initial conditions and priors

Initial conditions:											
τ_0^π	τ_0^u										h_0
	OE	BG	BD	ES	FN	FR	IR	IT	NL	PT	
1.9	4.2	8.3	5.4	9.6	10.6	9.2	5.4	9.6	4.7	5.8	1
ρ_0^π	λ_0	β_0	$\rho_{1,0}^u$	$\rho_{2,0}^u$	$\omega_{\tau^\pi}^2$	$\omega_{\tau^u}^2$	ω_h^2	$\omega_{\rho^\pi}^2$	ω_λ^2	ω_β^2	ω_u^2
0.7	-0.4	0.001	1.6	-0.7	0.01	0.1	0.2	0.005	0.005	10^{-8}	0.2
Priors											
$\underline{S}_{\tau^\pi}$	$\underline{S}_{\tau^u}$										$\underline{S}_h$
	OE	BG	BD	ES	FN	FR	IR	IT	NL	PT	
0.9	0.9	0.9	0.9	3.6	1.8	0.9	4.5	0.9	1.8	0.9	1.8
$\underline{S}_u$	$\underline{S}_{\rho^\pi}$	$\underline{S}_\lambda$	$\underline{S}_\beta$	For σ^2 of τ^π, τ^u, h, ρ^π, λ and β we set $\underline{v}$							
4.5	0.081	0.081	$4.5e^{-6}$	10							

The table indicates initial conditions and priors of the benchmark model estimation.

2.7.2 MCMC sampling

We adapt the algorithm introduced by Chan et al. (2016) and sequentially draw from

1. $p(\tau^{\pi,EU}|\pi, u, \tau^u, \rho^\pi, \lambda, \beta, h, \theta, IV)$

2. $p(\tau^u|\pi, u, \tau^{\pi,EU}, \rho^\pi, \lambda, \beta, h, \theta, IV)$

3. $p(\rho^\pi|\pi, u, \tau^{\pi,EU}, \tau^u, \lambda, \beta, h, \theta, IV)$

4. $p(\lambda|\pi, u, \tau^{\pi,EU}, \tau^u, \rho^\pi, \beta, h, \theta, IV)$

5. $p(\beta|\pi, u, \tau^{\pi,EU}, \tau^u, \rho^\pi, \lambda, h, \theta, IV)$

6. $p(h|\pi, u, \tau^{\pi,EU}, \tau^u, \rho^\pi, \lambda, \beta, \theta, IV)$

7. $p(\theta|\pi, u, \tau^{\pi,EU}, \tau^u, \rho^\pi, \lambda, \beta, h, IV)$

with $\theta = (\sigma_u, \sigma_{\tau^{\pi,EU}}, \sigma_{\tau^u}, \sigma_h, \sigma_{\rho^\pi}, \sigma_\lambda, \sigma_\beta, \rho^u)$ and IV being the initial values for the respective parameters

Conditional distribution of $\tau^{\pi,EU}$

To obtain the conditional distribution of $\tau^{\pi,EU}$ we rewrite the inflation equation in the following way:

$$K_\pi \pi = \mu_\pi + K_\pi X_0 \tau^{\pi,EU} + \epsilon^\pi,\ \epsilon^\pi \sim N(0, \Omega_\pi) \tag{2.5}$$

whereby π is $NT \times 1$, $\tau^{\pi,EU}$ is $T \times 1$, ϵ^π is $NT \times 1$, Ω_π is $diag(\sigma^2_{1,1}, \ldots, \sigma^2_{N,1}, \ldots, \sigma^2_{N,T})$ and

$$
\underset{NT \times NT}{K_\pi =} \begin{bmatrix} I_N & 0 & 0 & 0 \\ -\rho_2^\pi I_N & I_N & 0 & 0 \\ 0 & -\rho_2^\pi I_N & I_N & 0 \\ \vdots & \dots & \ddots & \vdots \\ 0 & 0 & 0 & -\rho_2^\pi I_N \end{bmatrix}
$$

I_N is an identity matrix of $N \times N$. Since $|K| = 1$, K_π is invertible for all values of ρ^π

$$
\underset{NT \times 1}{\mu_\pi =} \begin{bmatrix} \rho_1^\pi(\pi_{1,0} - \tau^{\pi,EU}) + \lambda_1(u_{1,1} - \tau_{1,1}^u) + \beta_1 \pi_1^{oil} \\ \vdots \\ \rho_1^\pi(\pi_{N,0} - \tau^{\pi,EU}) + \lambda_1(u_{N,1} - \tau_{N,1}^u) + \beta_1 \pi_1^{oil} \\ \lambda_2(u_{1,2} - \tau_{1,2}^u) + \beta_2 \pi_2^{oil} \\ \vdots \\ \lambda_2(u_{N,2} - \tau_{N,2}^u) + \beta_2 \pi_2^{oil} \\ \vdots \\ \lambda_T(u_{N,T} - \tau_{N,T}^u) + \beta_T \pi_T^{oil} \end{bmatrix}
$$

$$
\underset{NT \times T}{X_0 =} \begin{bmatrix} \iota & \dots & \dots & \dots & \dots & 0 \\ 0 & \iota & \dots & \dots & \dots & \vdots \\ 0 & 0 & \iota & \dots & \dots & \vdots \\ \vdots & \dots & \dots & \ddots & \dots & \vdots \\ 0 & \dots & \dots & \dots & \dots & \iota \end{bmatrix}
$$

ι as a column vector of $N \times 1$ ones. Note that $(X_0' X_0)$ is an invertible

$NT \times NT$ matrix.

$$(M\pi|u, \tau^u, \rho^\pi, \rho^u, \lambda, \beta, h, \theta) \sim N(MK_\pi^{-1}\mu_\pi + \tau^{\pi EU}, M'K_\pi^{'-1}\Omega_\pi K^{-1}M) \tag{2.6}$$

whereby $M = (X_0'X_0)^{-1}X_0'$. Then the prior density of $M\pi$ is given by

$$\begin{aligned} log \quad & p(M\pi|u, \tau^u, \rho^\pi, \rho^u, \lambda, \beta, h, \theta) \propto \\ & -\tfrac{1}{2}jh - \tfrac{1}{2}(M\pi - MK_\pi^{-1}\mu_\pi - \tau^{\pi,EU})'(M'K_\pi^{'-1}\Omega_\pi K^{-1}M)^{-1} \\ & (M\pi - MK_\pi^{-1}\mu_\pi - \tau^{\pi,EU}) \end{aligned} \tag{2.7}$$

with j being a $NT \times 1$ columns of ones. The state equation of $\tau^{\pi,EU}$ is defined as

$$H\tau^{\pi,EU} = \alpha_\pi + \epsilon^{\tau\pi} \tag{2.8}$$

with

$$\begin{array}{c} \alpha_\pi = \\ T \times 1 \end{array} \begin{bmatrix} \tau_0^{\pi,EU} \\ 0 \\ \vdots \\ 0 \end{bmatrix} \quad \begin{array}{c} H = \\ T \times T \end{array} \begin{bmatrix} 1 & 0 & 0 & \dots & \dots & 0 \\ -1 & 1 & 0 & \dots & \dots & \vdots \\ 0 & -1 & 1 & \dots & \dots & \vdots \\ 0 & 0 & -1 & 1 & \dots & \vdots \\ \vdots & \dots & \dots & \dots & \ddots & \vdots \\ 0 & 0 & \dots & \dots & -1 & 1 \end{bmatrix}$$

so that

$$(\tau^{\pi,EU}|\sigma^2_{\tau,\pi}) \sim N(H^{-1}\alpha_\pi, (H'\Omega_{\tau\pi}^{-1}H)^{-1}) \tag{2.9}$$

with $\Omega_{\tau\pi} = diag(\omega^2_{\tau^\pi}, \sigma^2_{\tau^\pi}, \dots, \sigma^2_{\tau^\pi})$. The prior density of $\tau^{\pi,EU}$ is given by

$$\begin{aligned} & log\ p(\tau^{\pi,EU}|\sigma^2_{\tau,\pi}) \propto \\ & \qquad -\tfrac{1}{2}(\tau^{\pi,EU} - H^{-1}\alpha_\pi)'H'\Omega_{\tau\pi}^{-1}H(\tau^{\pi,EU} - H^{-1}\alpha_\pi) \end{aligned} \tag{2.10}$$

Combining (2.7) and (2.10)

$$log\ p(\tau^{\pi,EU}|M\pi, u, \tau^u, \rho^\pi, \lambda, \beta, h, \theta) \propto$$
$$-\tfrac{1}{2}(\tau^\pi - \hat{\tau}^\pi)' D_{\tau,\pi}^{-1}(\tau^\pi - \hat{\tau}^\pi) \tag{2.11}$$

with

$$\begin{aligned}
\hat{\tau}^{\pi,EU} = &\ D_{\tau,\pi}((M' K_\pi'^{-1}\Omega_\pi K_\pi^{-1} M)^{-1}(M\pi - MK_\pi^{-1}\mu_\pi) + H'\Omega_{\tau\pi}^{-1}\alpha_\pi)\\
D_{\tau,\pi} = &\ ((M' K_\pi'^{-1}\Omega_\pi K_\pi^{-1} M)^{-1} + H'\Omega_\tau^{-1} H)^{-1}
\end{aligned}$$

We sample $N(\hat{\tau}^{\pi,EU},\ D_{\tau,\pi})$ by using the precision-based-algorithm developed by Chan and Jeliazkov (2009). This implies that we sample $\hat{\tau}^{\pi,EU}$ by applying the Cholesky factorisation to $D_{\tau,\pi}$ that is a block-banded matrix so that $C'C = D_{\tau,\pi}$. Then we solve for $\hat{\tau}^{\pi,EU}$ by backward and forward substitution, sample $u \propto N(0, I)$, solve for $Cx = u$ and get a draw of $\tau^{\pi,EU}$ by $\tau^{\pi,EU} = \hat{\tau}^{\pi,EU} + x$ with $\tau^{\pi,EU} \propto N(\hat{\tau}^{\pi,EU}, D_{\tau,\pi})$.

Conditional distribution of τ^u

Next, we derive the conditional distribution of τ^u. Therefore, we rewrite the Phillips curve equation as

$$z = \Lambda\tau^u + \epsilon^\pi,\ \epsilon^\pi \sim N(0, \Omega_\pi) \tag{2.12}$$

with

$$z = \begin{bmatrix} (\pi_{1,1} - \tau_1^{\pi,EU}) - \rho_{1,1}^{\pi}(\pi_{1,0} - \tau_0^{\pi,EU}) - \lambda_1 u_{1,1} - \beta_1 \pi_1^{oil} \\ \vdots \\ (\pi_{N,1} - \tau_1^{\pi,EU}) - \rho_{N,1}^{\pi}(\pi_{N,0} - \tau_0^{\pi,EU}) - \lambda_1 u_{N,1} - \beta_1 \pi_1^{oil} \\ \vdots \\ (\pi_{N,T} - \tau_T^{\pi,EU}) - \rho_{N,T}^{\pi}(\pi_{N,T-1} - \tau_{T-1}^{\pi,EU}) - \lambda_T u_{N,T} - \beta_T \pi_T^{oil} \end{bmatrix}$$

$$\Lambda = \quad diag(-\lambda_{1,1}, \ldots, -\lambda_{N,1}, \ldots, -\lambda_{N,T})$$

$$\tau^u = \; [\tau_{1,1}^u, \ldots, \tau_{N,1}^u, \ldots, \tau_{N,T}^u]'$$

The prior density of π is then given by

$$log\ p(\pi|u, \tau^u, \tau^\pi, \rho^\pi, \lambda, \beta, h, \theta) \propto (z - \Lambda\tau^u)'\Omega_\pi^{-1}(z - \Lambda\tau_u) \tag{2.13}$$

The second measurement equation for τ^u stems from the unemployment-gap formulation.

$$K_u u = \mu_u + K_u \tau^u + \epsilon^u, \;\; \epsilon^u \sim N(0, \Omega_u) \tag{2.14}$$

with $\Omega_u = I_T \otimes \sigma_u^2$, $\sigma_u^2 = [\omega_u^2, \sigma_{1,u}^2, \ldots, \sigma_{N,u}^2]'$ and

$$\mu_u = \begin{bmatrix} \rho^u_{1,1}(u_{1,0} - \tau^u_{1,0}) + \rho^u_{1,2}(u_{1,-1} - \tau^u_{1,-1}) \\ \vdots \\ \rho^u_{N,1}(u_{N,0} - \tau^u_{N,0}) + \rho^u_{N,2}(u_{N,-1} - \tau^u_{N,-1}) \\ \vdots \\ \rho^u_{1,2}(u_{1,0} - \tau^u_{1,0}) \\ \vdots \\ \rho^u_{N,2}(u_{N,0} - \tau^u_{N,0}) \\ \vdots \\ 0 \end{bmatrix}$$

$$K_u = \begin{bmatrix} I_N & 0 & \dots & \dots & \dots & 0 \\ -\rho^u_1 I_N & I_N & \dots & \dots & \dots & \dots \\ -\rho^u_2 I_N & -\rho^u_1 I_N & I_N & \dots & \ddots & \vdots \\ 0 & -\rho^u_2 I_N & -\rho^u_1 I_N & I_N & \dots & \vdots \\ \vdots & \dots & \dots & \dots & \ddots & \vdots \\ 0 & \dots & \dots & -\rho^u_2 I_N & -\rho^u_1 I_N & I_N \end{bmatrix}$$

whereby ρ^u_1 and ρ^u_2 are column vectors with $1 \times N$.

The prior density of u is then given by

$$log\ p(u|\tau^u, \theta) \propto -\tfrac{1}{2}(u - K_u^{-1}\mu_u - \tau^u)' K_u' \Omega_u^{-1} K_u (u - K_u^{-1}\mu_u - \tau^u) \tag{2.15}$$

The state equation τ^u takes on the form

$$\tau^u = H^{-1}\alpha_u + \epsilon_t^{\tau^u} \tag{2.16}$$

with $\alpha_u = (\tau_0^u, \ldots, 0)'$ and $\Omega_{\tau u} = \text{diag}(\omega_{\tau u}^2, \sigma_{\tau u}^2, \ldots, \sigma_{\tau u}^2)$

$$\begin{aligned} &log\ p(\tau^u|\sigma_{\tau u}^2) \propto \\ &\qquad -\tfrac{1}{2}(\tau^u - H^{-1}\alpha_u)'H'\Omega_{\tau u}^{-1}H(\tau^u - H^{-1}\alpha_u) \end{aligned} \tag{2.17}$$

Next, combining (2.13), (2.15) and (2.17) yields

$$\begin{aligned} log \quad & p(\tau^u|\pi, u, \rho^\pi, \tau^\pi, \lambda, \beta, h, \theta) \propto \\ & -\tfrac{1}{2}(z - \Lambda\tau^u)'\Omega_\pi^{-1}(z - \Lambda\tau^u) \\ & -\tfrac{1}{2}(u - K_u^{-1}\mu_u - \tau^u)'K_u'\Omega_u^{-1}K_u(u - K_u^{-1}\mu_u - \tau^u) \\ & -\tfrac{1}{2}(\tau^u - H^{-1}\alpha_u)'H'\Omega_{\tau u}^{-1}H(\tau^u - H^{-1}\alpha_u) \\ & = -\tfrac{1}{2}(\tau^u - \hat{\tau}^u)'D_{\tau^u}(\tau^u - \hat{\tau}^u) \end{aligned} \tag{2.18}$$

with

$$\begin{aligned} \hat{\tau}^u \quad &= D_{\tau^u}(\Lambda'\Omega_\pi^{-1}z + K_u'\Omega_u^{-1}K_u(u - K_u^{-1}\mu_u) + H'\Omega_{\tau u}^{-1}\alpha_u) \\ D_{\tau^u} \quad &= (\Lambda'\Omega_\pi^{-1}\Lambda + K_u'\Omega_u^{-1}K_u + H'\Omega_{\tau u}^{-1}H)^{-1} \end{aligned} \tag{2.19}$$

As before we sample the distribution by using the precision-based algorithm.

Conditional distribution of ρ^π

The measurement equation for ρ_π is

$$\pi^* + \Lambda u^* + \beta_t\pi_t^{oil} = X_\pi X_0\rho^\pi + \epsilon^\pi \tag{2.20}$$

whereby $\pi^* = \pi - X_0\tau^{\pi,EU}$, $X_\pi = diag(\pi^*_0, \ldots, \pi^*_{N,T-1})$, $\rho^\pi = [\rho^\pi_0, \rho^\pi_1, \ldots, \rho^\pi_T]'$ and $u^* = u - \tau^u$. Then it follows that

$$(MX_\pi^{-1}\pi^* + MX_\pi^{-1}\Lambda u^*) \sim N(\rho^\pi, M'X_\pi^{'-1}\Omega_\pi X_\pi^{-1}M) \tag{2.21}$$

$$\begin{aligned} log \quad & p(MX_\pi^{-1}\pi^* + MX_\pi^{-1}\Lambda u^* | \tau^\pi, \tau^u, \rho^\pi, \lambda, \beta, h, \theta) \propto \\ & -\tfrac{1}{2}j_T h - \tfrac{1}{2}(MX_\pi^{-1}\pi^* + MX_\pi^{-1}\Lambda u^* - \rho^\pi)' \\ & (MX_\pi^{-1}\Omega_\pi X_\pi^{'-1}M')^{-1} \\ & (MX_\pi^{-1}\pi^* + MX_\pi^{-1}\Lambda u^* - \rho^\pi) \end{aligned} \tag{2.22}$$

The state equation of ρ_π is given by

$$H\rho^\pi = \epsilon^{\rho^\pi} \ , \ \rho^\pi \sim N(0, H^{'-1}\Omega_{\rho\pi}H^{-1}) \tag{2.23}$$

with

$$\begin{aligned} & log \ p(\rho^\pi | \sigma^2_{\rho\pi}) \propto \\ & \qquad -\tfrac{1}{2}(\rho^{\pi'} H' \Omega^{-1}_{\rho\pi} H\rho^\pi) + g_{\rho^\pi, \sigma^2_{\rho^\pi}} \end{aligned} \tag{2.24}$$

Combining (2.22) and (2.24) yields

$$\begin{aligned} log \quad & p(\rho^\pi | \pi, u, \tau^\pi, \tau^u, \lambda, \beta, h, \theta) \propto \\ & -\tfrac{1}{2}j_T h - \tfrac{1}{2}(MX_\pi^{-1}\pi^* + MX_\pi^{-1}\Lambda u^* - \rho^\pi)'(MX_\pi^{-1}\Omega_\pi X_\pi^{'-1}M')^{-1} \\ & (MX_\pi^{-1}\pi^* + MX_\pi^{-1}\Lambda u^* - \rho^\pi) \\ & -\tfrac{1}{2}(\rho^{\pi'} H' \Omega^{-1}_{\rho\pi} H\rho^\pi) + g_{\rho^\pi, \sigma^2_{\rho^\pi}} \\ \propto \quad & -\tfrac{1}{2}(\rho^\pi - \hat{\rho}^\pi)' D^{-1}_{\rho^\pi}(\rho^\pi - \hat{\rho}^\pi) + g_{\rho^\pi, \sigma^2_{\rho^\pi}} \end{aligned} \tag{2.25}$$

with

$$\begin{aligned} g_{\rho^\pi,\sigma^2_{\rho^\pi}} &= -\textstyle\sum_{t=2}^{T}(\Phi(\frac{1-\rho^\pi_{t-1}}{\sigma^2_{\rho^\pi}} - \Phi(\frac{-\rho^\pi}{\sigma^2_{\rho^\pi}})) \\ \hat{\rho^\pi} &= D_{\rho^\pi}((M^{'}X^{'-1}_\pi\Omega_\pi X^{-1}_\pi M)^{-1}MX^{-1}_\pi(\pi^*+\Lambda u^*)) \\ D_{\rho^\pi} &= ((M^{'}X^{'-1}_\pi\Omega_\pi X^{-1}_\pi M)^{-1} + H^{'}\Omega^{-1}_{\rho\pi}H)^{-1} \end{aligned}$$

As it can be seen in EQ (2.25) the conditional density for ρ^π is truncated-normal. We follow Chan et al. (2016) and apply an independence chain Metropolis-Hastings step, whereby the candidate draws resulting from the precision-based method are accepted or rejected by an acceptance-rejection Metropolis-Hastings step.

Conditional distribution of λ

The measurement equation of λ takes on the following form

$$\pi_\lambda = X_u X_0 \lambda + \epsilon^\pi \tag{2.26}$$

with $X_u = diag(u^*_{1,0},\ldots,u^*_{N,T-1})$ and $\pi_\lambda = [\pi^*_{1,1} - \rho^\pi_1\pi^*_{1,0} - \beta_1\pi^{oil}_1, \ldots, \pi^*_{N,1} - \rho^\pi_1\pi^*_{N,0} - \beta_1\pi^{oil}_1, \ldots, \pi^*_{N,T} - \rho^\pi_T\pi^*_{N,T-1} - \beta_T\pi^{oil}_T]'$. Then it follows that

$$MX^{-1}_u w \sim N(\lambda, M'X^{'-1}_u\Omega_\pi X^{-1}_u M) \tag{2.27}$$

with

$$\begin{aligned} &log \;\; p(MX^{-1}_u\pi_\lambda|\tau^\pi,\tau^u,\rho^\pi,\lambda,\beta,h,\theta) \propto \\ &-\tfrac{1}{2}j_T h - \tfrac{1}{2}(MX^{-1}_u\pi_\lambda - \lambda)'(MX^{-1}_u\Omega_\pi X^{'-1}_u M')^{-1} \\ &(MX^{-1}_u\pi_\lambda - \lambda) \end{aligned} \tag{2.28}$$

The state equation of λ is given by

$$H\lambda = \epsilon_t^{\lambda},\ \epsilon_t^{\lambda} \sim N(0, \Omega_{\lambda}) \tag{2.29}$$

with

$$\begin{aligned} &log\ p(\lambda|\sigma_{\lambda}^2) \propto \\ &\qquad -\tfrac{1}{2}(\lambda)' H' \Omega_{\lambda}^{-1} H(\lambda) + g_{\lambda}(\lambda, \sigma_{\lambda}^2) \end{aligned} \tag{2.30}$$

Combining (2.28) and (2.30) yields

$$\begin{aligned} &log\ p(\lambda|\pi, u, \tau^{\pi}, \tau^{u}, \rho^{\pi}, \beta, h, \theta) \propto \\ &\qquad -\tfrac{1}{2}(\lambda - \hat{\lambda})' D_{\lambda}^{-1}(\lambda - \hat{\lambda}) + g_{\lambda} \end{aligned} \tag{2.31}$$

with

$$\begin{aligned} g_{\lambda}(\lambda, \sigma_{\lambda}^2) &= -\textstyle\sum_{t=2}^{T}(\Phi(\frac{-\lambda_{t-1}}{\sigma_{\lambda}} - \Phi(\frac{-1-\lambda}{\sigma_{\lambda}})) \\ \hat{\lambda} &= D_{\lambda}((MX_u^{-1}\Omega_{\pi}X_u^{'-1}M')^{-1}MX_u^{-1}\pi_{\lambda}) \\ D_{\lambda} &= ((MX_u^{-1}\Omega_{\pi}X_u^{'-1}M')^{-1} + H'\Omega_{\lambda}^{-1}H)^{-1} \end{aligned}$$

Similarly to the sampling of ρ^{π}, we include an acceptance-rejection Metropolis-Hastings (ARMH) step additional to the precision-based algorithm as the conditional density is of non-standard form.

Conditional distribution of β

We apply a similar derivation strategy as before. Then the measurement equation of β takes on the following form

$$\pi_{oil}^{*} = X_0 X_{oil}\beta + \epsilon^{\pi} \tag{2.32}$$

with $X_{oil} = diag(\pi_1^{oil}, \ldots, \pi_T^{oil})$, $\beta = [\beta_0, \beta_1, \ldots, \beta_T]'$ and $\pi_{oil}^{*} = [\pi_{1,1} - \tau_1^{\pi,EU} - \rho_1^{\pi}(\pi_{1,0} - \tau_0^{\pi,EU}) - \lambda_1 u_{1,1}^{*}, \ldots, \pi_{N,1} - \tau_1^{\pi,EU} - \rho_1^{\pi}(\pi_{N,0} - \tau_0^{\pi,EU}) -$

$\lambda_1 u^*_{N,1}, \ldots, \pi_{N,T} - \tau^{\pi,EU}_T - \rho^\pi_T(\pi_{N,T-1} - \tau^{\pi,EU}_T - 1) - \lambda_T u^*_{N,T}]'$. Then it follows that

$$\begin{aligned} log \quad & p(X^{-1}_{oil} M \pi^*_{oil} | \tau^\pi, \tau^u, \rho^\pi, \lambda, h, \theta) \propto \\ & -\tfrac{1}{2} j_T h - \tfrac{1}{2}(X^{-1}_{oil} M \pi^*_{oil} - \beta)'(X'^{-1}_{oil} M' \Omega_{oil} M X^{-1}_{oil})^{-1} \\ & (X^{-1}_{oil} M \pi^*_{oil} - \beta) \end{aligned} \tag{2.33}$$

The state equation of β is given by

$$H\beta = \epsilon^\beta_t, \ \epsilon^\beta_t \sim N(0, \Omega_\beta) \tag{2.34}$$

with

$$\begin{aligned} & log\ p(\beta | \sigma^2_\beta) \propto \\ & \qquad -\tfrac{1}{2}(\beta)' H' \Omega^{-1}_\beta H(\beta) + g_\beta(\beta, \sigma^2_\beta) \end{aligned} \tag{2.35}$$

Combining (2.33) and (2.35) yields

$$\begin{aligned} & log\ p(\beta | \pi, u, \tau^\pi, \tau^u, \rho^\pi, \beta, h, \theta) \propto \\ & \qquad -\tfrac{1}{2}(\beta - \hat{\beta})' D^{-1}_\beta (\beta - \hat{\beta}) + g_\beta \end{aligned} \tag{2.36}$$

with

$$g_{\beta,\sigma^2_\beta} = -\textstyle\sum_{t=2}^T (\Phi(\frac{1-\beta_{t-1}}{\sigma^2_\beta} - \Phi(\frac{-\beta}{\sigma^2_\beta}))$$

$$\begin{aligned} \hat{\beta} \ &= D_\beta (X'_{oil} M'^{-1} \Omega^{-1}_\beta \pi^*_{oil}) \\ D_\beta \ &= (X'_{oil} M'^{-1} \Omega^{-1}_\beta M^{-1} X_{oil} + H' \Omega^{-1}_\beta H)^{-1} \end{aligned}$$

As before, we include an acceptance-rejection Metropolis-Hastings (ARMH) step additional to the precision-based algorithm as the conditional density is of non-standard form.

Sampling h and θ

For sampling h and the remaining parameters summarized by θ, we stick to the algorithm developed by Chan and Strachan (2012) that is also used in Chan et al. (2016). Thereby, we draw ρ^u from a bivariate truncated normal distribution, employing an ARMH step. Moreover, we draw all remaining variances in separate blocks from inverse-Gamma distributions. We refer the reader to Chan and Strachan (2012) and Chan et al. (2016) for further technical details.[5]

2.7.3 Specifications of other models

We now report details on the additional unobserved component models presented in the model comparison and forecasting exercise in the paper. The algorithm underlying these models are in principle variants of the algorithm presented in the previous section and are very close to those of Chan et al. (2013) and Chan et al. (2016). For all model variants that differ with respect to the time variation of parameters, we employ the settings as presented in Table 2.2 and switch off the respective state equation(s). For the PC variants that do not include oil prices we set the same starting values and priors for the panel PC model as in Table 2.2 and for the aggregate PC model as described below. Thus, in the remainder of this section we focus on the univariate unobserved component models and the aggregate Phillips curve model. Turning first to the univariate models, the **UCSV**, **panel UCSV** and **UC** model take on the following forms:

[5] It should be noted that we do not bound $\tau^{\pi,EU}$ nor τ^u as in Chan et al. (2016).

UCSV

$$\begin{aligned}
\pi_t - \tau_t^\pi &= \rho_t^\pi(\pi_{t-1} - \tau_{t-1}^\pi) + \epsilon_t^\pi \\
\tau_t^\pi &= \tau_{t-1}^\pi + \epsilon_t^{\tau,\pi} \\
\rho_t^\pi &= \rho_{t-1}^\pi + \epsilon_t^{\rho,\pi} \\
\epsilon_t^\pi &\sim N(0, e^{h_t}) \\
h_t &= h_{t-1} + \epsilon_t^h \\
\epsilon_t^h &\sim N(0, \sigma_h^2) \\
\epsilon^{\rho^\pi} &\sim TN(-\rho_{t-1}^\pi, 1 - \rho_{t-1}^\pi; 0, \sigma_{\rho^\pi}^2)
\end{aligned}$$

panel UCSV

$$\begin{aligned}
\pi_{n,t} - \tau_t^{\pi,EU} &= \rho_t^\pi(\pi_{n,t-1} - \tau_{t-1}^{\pi,EU}) + \epsilon_{n,t}^\pi \\
\tau_t^{\pi,EU} &= \tau_{t-1}^{\pi,EU} + \epsilon_t^{\tau,\pi} \\
\rho_t^\pi &= \rho_{t-1}^\pi + \epsilon_t^{\rho,\pi} \\
\epsilon_t^\pi &\sim N(0, e^{h_t}) \\
h_t &= h_{t-1} + \epsilon_t^h \\
\epsilon_t^h &\sim N(0, \sigma_h^2) \\
\epsilon^{\rho^\pi} &\sim TN(-\rho_{t-1}^\pi, 1 - \rho_{t-1}^\pi; 0, \sigma_{\rho^\pi}^2)
\end{aligned}$$

UC

$$\begin{aligned}
u_t - \tau_t^u &= \rho_1^u(u_{t-1} - \tau_{t-1}^u) + \rho_2^u(u_{t-2} - \tau_{t-2}^u) + \epsilon_t^u \\
\tau_t^u &= \tau_{t-1}^u + \epsilon_t^{\tau^u} \\
\epsilon_t^u &\sim N(0, \sigma_u^2)
\end{aligned}$$

For comparability across models, we employ similar priors and starting values as in our benchmark specification. Thus, for panel and aggregate, UCSV models we set $\tau_0^\pi = \tau_0^{\pi,EU} = 1.9$, $\rho_0^\pi = 0.7$, $h_0 = 1$, $\omega_{\tau,\pi}^2 = 0.01$, $\omega_{\rho,\pi}^2 = 0.005$, $\omega_h^2 = 0.2$. We specify the model parameters as inverse-Gamma distributions so that for $\sigma^2_{\tau_\pi}$, $\sigma^2_{\rho,\pi}$and σ^2_h we have $\sigma^2 \sim IG(\underline{v}, \underline{S})$. We set $v_h = v_\tau = v_{\rho,\pi} = 10$, $S_h = 1.8$, $S_\tau = 0.9$ and $S_{\rho,\pi} = 0.81$. The starting values for the UC model are $\tau^u_0 = [9, 9]$, $\rho^u_{1,0} = 1.6$, $\rho^u_{2,0} = -0.7$, $\omega^2_u = 0.2$ and $\omega^2_{\tau^u} = 0.01$. We again assume that σ^2_u and $\sigma^2_{\tau^u}$ follow an inverse-Gamma distribution and set $v_{\tau^u} = v_u = 10$ and $S_{\tau^u} = 3.6$. For the aforementioned models ρ^π and ρ^u stem from truncated normal distributions as detailed in the benchmark model specification.

The multivariate, aggregate Phillips curve model is specified below. Model parameters are again specified as inverse-Gamma distributions and we apply the same starting values as well as priors as in our baseline model (see Table 2.2), except for τ^u_0 and S_{τ^u}, which we set to $[9; 9]$ and 3.6, respectively.

ag. PC

$$\begin{aligned}
\pi_t - \tau^\pi_t &= \rho^\pi_t(\pi_{t-1} - \tau^{\pi,EU}_{t-1}) && +\lambda_t(u_t - \tau^u_t) + \beta_t \pi^{oil} + \epsilon^\pi_t \\
(u_t - \tau^u_t) &= \rho^u_1(u_{t-1} - \tau^u_{t-1}) && +\rho^u_{n,2}(u_{t-2} - \tau^u_{t-2}) + \epsilon^u_t \\
\tau^{\pi,EU}_t &= \tau^{\pi,EU}_{t-1} + \epsilon^{\tau,\pi}_t && \\
\tau^u_t &= \tau^u_{t-1} + \epsilon^{\tau,u}_t && \epsilon^h_t \sim N(0, \sigma^2_h) \\
\rho^\pi_t &= \rho^\pi_{t-1} + \epsilon^{\rho,\pi}_t && \epsilon^u_t \sim N(0, \sigma^2_u) \\
\lambda_t &= \lambda_{t-1} + \epsilon^\lambda_t && \epsilon^{\rho^\pi} \sim TN(-\rho^\pi_{t-1}, 1 - \rho^\pi_{t-1}; 0, \sigma^2_{\rho^\pi}) \\
\epsilon^\pi_{n,t} &\sim N(0, e^{h_t}) && \epsilon^\lambda \sim TN(-1 - \lambda_{t-1}, 0 - \lambda_{t-1}; 0, \sigma^2_\lambda) \\
h_t &= h_{t-1} + \epsilon^h_t && \epsilon^\beta \sim TN(-\beta_{t-1}, 1 - \beta_{t-1}; 0, \sigma^2_\beta)
\end{aligned}$$

2.7.4 Prior predictive analysis

To emphasize the sensibility of our prior settings, we perform a prior predictive analysis. Therefore, we draw from the prior distribution using the starting values and priors shown in Table 2.2 and simulate with the state equations as to generate artificial data series for inflation and unemployment. We repeat this exercise 10^4 times. We compute the mean, the median, the 16%- and 84%-percentile as well as the variance of each draw of the artificial series. Then we evaluate the observed data with the cumulative density functions from the artificial data series. Table 2.3 presents the prior cdfs evaluate at the observed data for the distinct features. It can be seen that the baseline model explains well the observed data.

Table 2.3: Prior cdfs for observed data of inflation and unemployment

	inflation	unemployment
mean	0.50	0.68
median	0.49	0.40
16%	0.50	0.31
84%	0.50	0.94
variance	0.50	0.89

The table presents the results of the prior predictive analysis of the benchmark model.

2.7.5 Forecasting results on EMU unemployment rates

Turning to the evaluation of unemployment forecasts, aggregate Phillips curves and the UC models offer a substantial improvement in forecasting, compared to the AR and RW models. Panel model variants, however, again perform best from horizon 12 onwards. This implies that variations of the panel PC model only change the forecasting performance marginally across models (ratios show some variations from the third decimal point onwards). Using cumulated oil price inflation improves the unemployment forecast for the medium term. Thus, our proposed panel Phillips curve specification reveals a better forecast accuracy of EU10 inflation and unemployment (from the medium term onwards) than a variety of other UCSV and univariate time-series models.

Table 2.4: EU10 unemployment: RMSFEs relative to RMSFE of the ARIMA(1,0,1) model

	horizon													
model	1	2	4	6	9	12	15	18	21	24	27	30	33	36
ARIMA(1,0,1)	1	1	1	1	1	1	1	1	1	1	1	1	1	1
ARIMA(2,0,1)	1.04	0.96	0.70	0.73	0.87	0.98	1.08	1.14	1.18	1.18	1.16	1.12	1.09	1.07
ARIMA(2,0,2)	0.98	0.87	0.76	0.77	0.87	0.95	1.01	1.07	1.09	1.10	1.10	1.07	1.05	1.03
ARIMA(1,0,2)	1.00	0.89	0.91	0.91	0.94	0.96	0.97	0.98	0.99	0.99	0.99	0.99	0.99	0.99
RW	1.01	1.01	1.03	1.02	1.02	1.01	1.01	1.00	1.00	1.00	1.00	1.00	1.00	1.00
panel PC	**0.31**	**0.49**	**0.74**	**0.84**	**0.90**	**0.92**	**0.94**	**0.95**	**0.94**	**0.94**	**0.95**	**0.95**	**0.94**	**0.95**
panel PC excl. oil	0.31	0.49	0.74	0.83	0.90	0.92	0.93	0.94	0.93	0.94	0.94	0.94	0.94	0.94
ag. PC	0.65	0.88	1.16	1.31	1.38	1.37	1.34	1.28	1.24	1.21	1.19	1.17	1.15	1.15
ag. PC excl. oil	0.41	0.73	1.19	1.41	1.52	1.51	1.47	1.41	1.35	1.30	1.27	1.24	1.21	1.20
UC	0.52	0.66	1.00	1.28	1.51	1.59	1.61	1.56	1.51	1.47	1.43	1.40	1.37	1.36
panel PC const. λ	0.31	0.49	0.73	0.83	0.90	0.92	0.94	0.95	0.94	0.95	0.95	0.95	0.94	0.95
panel PC const. ρ	0.31	0.50	0.75	0.85	0.92	0.94	0.95	0.96	0.95	0.96	0.96	0.96	0.95	0.96
panel PC const. o	0.31	0.49	0.74	0.83	0.90	0.92	0.93	0.94	0.94	0.94	0.95	0.95	0.94	0.95
panel PC const.	0.31	0.50	0.75	0.85	0.92	0.95	0.96	0.96	0.95	0.95	0.96	0.95	0.95	0.95
panel PC excl. sv	0.30	0.49	0.73	0.83	0.90	0.93	0.94	0.95	0.95	0.96	0.96	0.96	0.96	0.96
panel PC cum. oil	0.30	0.49	0.73	0.83	0.89	0.91	0.93	0.94	0.93	0.94	0.94	0.94	0.94	0.94
panel PC cs ρ	0.31	0.50	0.74	0.84	0.91	0.93	0.94	0.95	0.95	0.95	0.96	0.96	0.96	0.96

This table displays the root mean squared forecast errors (RMSFEs) of respective model relative to the RMSFEs of an ARIMA(1,0,1) model that stem from a pseudo-out-of-sample unemployment rate forecast for the time span January 2009 to April 2017. Values lower than 1 indicate that the RMSFEs of the respective model are lower than those of the ARIMA(1,0,1) model. The results from the benchmark model are highlighted in bold. The shading indicates the respective forecasting performance, whereby green (light) shadings emphasize better forecasting performance.

3 Monetary policy and inflation dynamics in ASEAN-5 economies since the Asian Financial Crisis

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3.1 Introduction

Inflation dynamics of the founding members[1] of the Association of Southeast Asian Nations (ASEAN) have experienced substantial changes since the 1997 Asian Financial Crisis (AFC). Headline inflation levels and volatilities of ASEAN-5 economies declined in the early 2000s. These changes in inflation dynamics coincide with substantial changes in the monetary policy framework, such as the adoption of exchange rate flexibility, introduction of a price stability objective, and enhancement of central bank measures - especially in terms of central bank reporting and other communication strategies following the AFC. From a policy perspective, it is essential to determine the extent of changes to the inflation processes of ASEAN-5 economies, and how many of these changes can be related to the evolution of monetary policy frameworks. Similar to the inflation dynamics in advanced economies, headline inflation in ASEAN-5 economies experienced disinflationary pressures and even deflationary episodes over the course of the Global Financial Crisis (GFC), as well as the recent period of persistently declining oil prices. For example, Thailand's headline inflation steadily declined from 2.6% in 2012 to -1.1% in 2015. The disinflation - whether it stems from the high sensitivity of inflation to oil price changes or whether a generally low degree of expectation anchoring boosts the impact of supply-shocks - yields distinct implications for monetary policy.

[1] Indonesia, Malaysia, the Philippines, Singapore and Thailand.

Deep structural changes during the two decades suggests that the relative importance of these drivers might have changed. This imposes possible non-linearities of the Phillips curve relation. Exchange rate liberalisation and economic development possibly reduced the effect of non-oil-import inflation on headline inflation in the ASEAN-5 region. Industrialisation might have altered the sensitivity of headline inflation to oil price movements for oil-importing economies in the region. Moreover, the adoption of price stability as a major monetary policy objective served to facilitate central bank and communicative transparencies. This objective should have helped to align long-run inflation expectations to the explicit or implicit inflation targets, and should have altered the importance of inflation expectations as a driver of inflation dynamics. However, strong disinflation and/or deflation in ASEAN-5 economies indicate that supply-side shocks have not been completely offset by the forward-looking component of the inflation process.

In this study, we investigate the main drivers of consumer price headline inflation of ASEAN-5 economies, with a particular focus on the forward-looking component. For this purpose, we estimate country-specific Phillips curves allowing for time-varying parameters for each of the ASEAN-5 countries respectively, to be able to account for the evolving monetary policy regimes and changes in business cycle dynamics in the region. Firstly, we aim to determine the evolution of inflation components for the ASEAN-5 region from 1995 to 2016, as well as the distribution of the contributions across the five countries. Secondly, we investigate the quantitative contribution of structural changes of the inflation process on each component of inflation. Thirdly, we compare the forecasting performance of our benchmark model to a variety of common alternative models, including plain time-series models. Fourthly, we evaluate whether changes in the inflation drivers relate to the evolution of monetary policy transparency and communication. Finally, we examine the country-specific developments of inflation dynamics.

The contribution of this paper is threefold: Firstly, existing literature[2] on inflation dynamics for ASEAN-5 countries is generally limited and composed of only a few country-specific analyses using different model specifications, data samples and estimation techniques. Thus, to our knowledge, no empirical research on cross-country comparisons of inflation dynamics, consistent for all ASEAN-5 countries, exists. Secondly, we contribute to the literature on inflation persistence and central bank communication. As shown by Benati (2008) for cross-country analysis of advanced economies, and by Gerlach and Tillmann (2012) for Asian countries, the backward-looking component of the inflation process declines when inflation targeting is adopted as a monetary policy framework. Moreover, Van der Cruijsen and Demertzis (2007) provide early evidence of correlations between central bank transparency, inflation and inflation expectations.

Thirdly, to enhance our analysis of central bank communication and changes in the inflation process, we use trend inflation estimates of Garcia and Poon

[2] See Direkudomsak (2016), Guinigundo (2016), Hendar (2016), Khemangkorn et al. (2008), Meng (2016), Holtemöller and Mallick (2016) and Singh (2016).

(2018) to overcome shortcomings of the survey and financial indicators of long-run inflation expectations. Fourthly, we add to existing literature (Balcilar et al., 2015) on inflation forecasting in emerging economies. In the process we provide evidence related to inflation forecasting in ASEAN-5 economies, comparing the forecasting performance with a variety of plain time-series models and Phillips curve specifications.

This paper is organised as follows: The second section contains model specifications and data. In the third section, we discuss results pertaining to inflation drivers related to the evolution of monetary policy transparency and communication in the entire ASEAN-5 region. In addition, we present and interpret country-specific results. Robustness checks are discussed in the fourth section, followed by a brief conclusion in the fifth section.

3.2 Empirical methodology and data

3.2.1 Modelling inflation dynamics

A key goal of this paper is to reveal the main drivers of inflation dynamics in ASEAN-5 economies. Our empirical approach relies on the estimation of a standard Phillips curve at the country level. Our specification builds on the hybrid New Keynesian Phillips curve (NKPC) specification of Fuhrer and Moore (1995) and Galí and Gertler (1999) among others. We are particularly interested in potential changes in inflation dynamics over time. To accommodate potential structural breaks in the coefficients - resulting from the evolution of monetary policy regimes or reflecting changes in the global economic environment since the onset of the GFC - we allow for time-varying coefficients in the estimation, as exemplified by the IMF (2016) and Blanchard et al. (2015). Thus, we estimate the following Phillips curve as a benchmark specification:

$$\pi_t = \beta_t^1 \bar{\pi}_t + (1 - \beta_t^1)\pi_{t-1}^{MA4} + \beta_t^2 \tilde{y}_{t-1} + \beta_t^3 \pi_{t-1}^{imp} + \epsilon_t \qquad (3.1)$$

where π_t is the headline consumer price inflation, $\bar{\pi}_t$ denotes long-run inflation expectations, π_{t-1}^{MA4} is the moving average of inflation over the previous four quarters, $\tilde{y}_{t-1}$ is the economic slack measured as the output-gap, π_{t-1}^{imp} is inflation of imported goods and services, and ϵ_t is the measurement error and assumed to be a Gaussian white noise process. In terms of economic interpretation, the coefficient β_t^1 determines the amount of inflation driven by long-term expectations, which is the forward-looking component of inflation contrasting with the influence of lagged inflation as determined by $(1-\beta_t^1)$. β_t^2 determines the impact of cyclical economic activity on inflation, represented by the slope of the Phillips curve. The effect of import price inflation is captured by β_t^3.

3.2.2 Data

We use quarterly data from 1995Q1 until 2016Q4 for ASEAN-5 countries. Due to data limitations, the samples of Indonesia and Malaysia start at 2001Q1 and 2002Q1 respectively. Our benchmark specification incorporates the headline consumer price index (CPI) and real GDP from the World Economic Outlook (WEO) database, and import price indices from the HAVER database. Import price and headline CPI are included in the estimation of year-on-year inflation rates. Measures of the output-gap are obtained by applying a HP-filter to extract the cyclical components from the real GDP series. For our benchmark specification, we employ trend estimates of Garcia and Poon (2018) as our measures of long-term inflation expectations (explained in Section 3.3.1). As we lack long-run trend estimates for Singapore, Consensus expectations are utilised instead. For the computation of contributions (detailed in Section 3.3.1) and further robustness checks (detailed in Section 3.4), we use Brent crude oil prices and nominal exchange rates taken from the HAVER database, as well as Consensus long-run inflation expectations

3.2.3 Estimation

We estimate the model by applying a standard Kalman filter with Gauss-Newton optimisation along with the Marquardt step method. Starting values for parameters and variances are taken from ten-year rolling window OLS regressions. We also introduce country-specific variance ratios across all state equations, based on each country-specific variance of year-on-year inflation rates to the respective parameter variances from rolling window estimations. Using the estimated model, we calculate the corresponding contributions of the key inflation drivers. To enhance the focus of the discussion, particularly in relation to the disinflationary episode of 2014-16, we deconstruct the contribution of import price inflation into non-oil-import price inflation and oil price inflation. For this purpose, we regress import price inflation on oil price inflation in a rolling window OLS estimation. We apply the resulting fitted values as a hypothetical non-oil-import inflation series, and the residuals as a hypothetical oil price inflation series to the common import price parameter in our benchmark model. We later relax the assumptions and introduce distinct parameters for non-oil-imports and oil price inflation for robustness checks (Section 3.4).

3.3 Drivers of inflation dynamics in ASEAN-5 countries

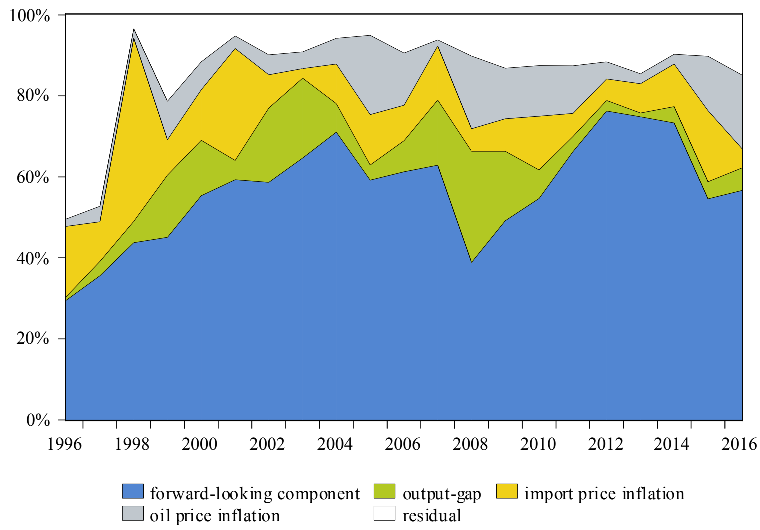
3.3.1 Key Findings

We discuss our results in two steps. We first provide an overview of our key findings from a multi-country perspective, highlighting the main characteristics of inflation dynamics in the ASEAN-5 region. Next, we elaborate on the country-specific findings, with particular emphasis on the disinflation period as experienced by those countries, from 2014 to 2016.

Overview

To illustrate the contributions of the different inflation drivers across ASEAN-5 countries, we use the country-specific estimations and compute the relative median contribution of long-term expectations (forward-looking dynamics), economic slack, oil price inflation and non-oil-import price inflation across the countries over time. The main insights, as derived from Figure 3.1, are as follows:

Figure 3.1: Relative median contribution of inflation drivers across ASEAN-5 countries



The figure presents the relative median contributions that are the ratios of the median contributions, which the benchmark models, across countries and the median headline inflation rates across counties at each point in time.

Inflation expectations are clearly the most important driver of inflation dynamics across ASEAN-5 countries and, on average, explain 59.47% of the region's median inflation. Compared to the importance of expectations the contributions of economic slack, non-oil-import and oil price inflation are modest and explain, on average, only 9.01%, 11.68% and 7.62% respectively. These percentages are not substantially different from the contribution of the residual (9.01%). ASEAN-5 inflation has become increasingly forward-looking since the AFC, although the contributions of inflation expectations to inflation declined episodically during the GFC and in the recent deflationary period. According to the variations of median contributions over time, forward-looking dynamics average at 42.98% from 1996 until 2001, then increase to an average of 66.01% thereafter. However, two episodes of reduced forward-lookingness are noticeable, which are the GFC and the recent disinflation period, with average median contributions of 59.09% and 58.56% respectively.

The quantitative contributions of economic slack are generally limited, but depict altered importance during the few years preceding the GFC. From 1995 until 2007 economic slack explains approximately 6.57% of headline inflation. Median contributions rise to 15.80% during the run-up to the GFC (from 2002 to 2007) but decline thereafter to an average of 4.89%. Increased contributions between crises indicate non-linearities in the transmission of supply shocks, and might be the result of a transitional structural phase induced by more advanced economic policy of ASEAN-5 countries after the AFC. The subsequent decline of economic slack matches empirical findings of a muted impact of economic activity on inflation dynamics in advanced economies over the course of the GFC (Watson, 2014).

Non-oil-import and oil price inflation are the major drivers of inflation rates during the AFC, but their importance declines substantially afterwards, and have since been the second most important drivers. Across the entire sample period, non-oil-import and oil price inflation offer a combined average contribution of 18.3%. As Figure 3.1 reveals, the quantitative importance of import price inflation changed notably during the sample period. Before and during the AFC (from 1996 to 2001) non-oil-import and oil price inflation accounted for 26.53% of median inflation rates, with changes in non-oil-import inflation accounting for 21.41% on its own. This means that oil price inflation, during the same period, represented a relative contribution of 5.12% only. This situation changes dramatically from 2002 onwards, when the contribution of non-oil-import inflation declines to 7.79% (from 2002 to 2016). Between 2002 and 2013 and the recent episode of disinflation (from 2014 to 2016), non-oil-import and oil price inflation together account first for 15.19% and then 18.36% of the median headline inflation. The decline in the relative median contribution of non-oil-import and oil price inflation, and particularly in the case of non-oil-import, might be related to the liberalisation of exchange rates over the course of the AFC.

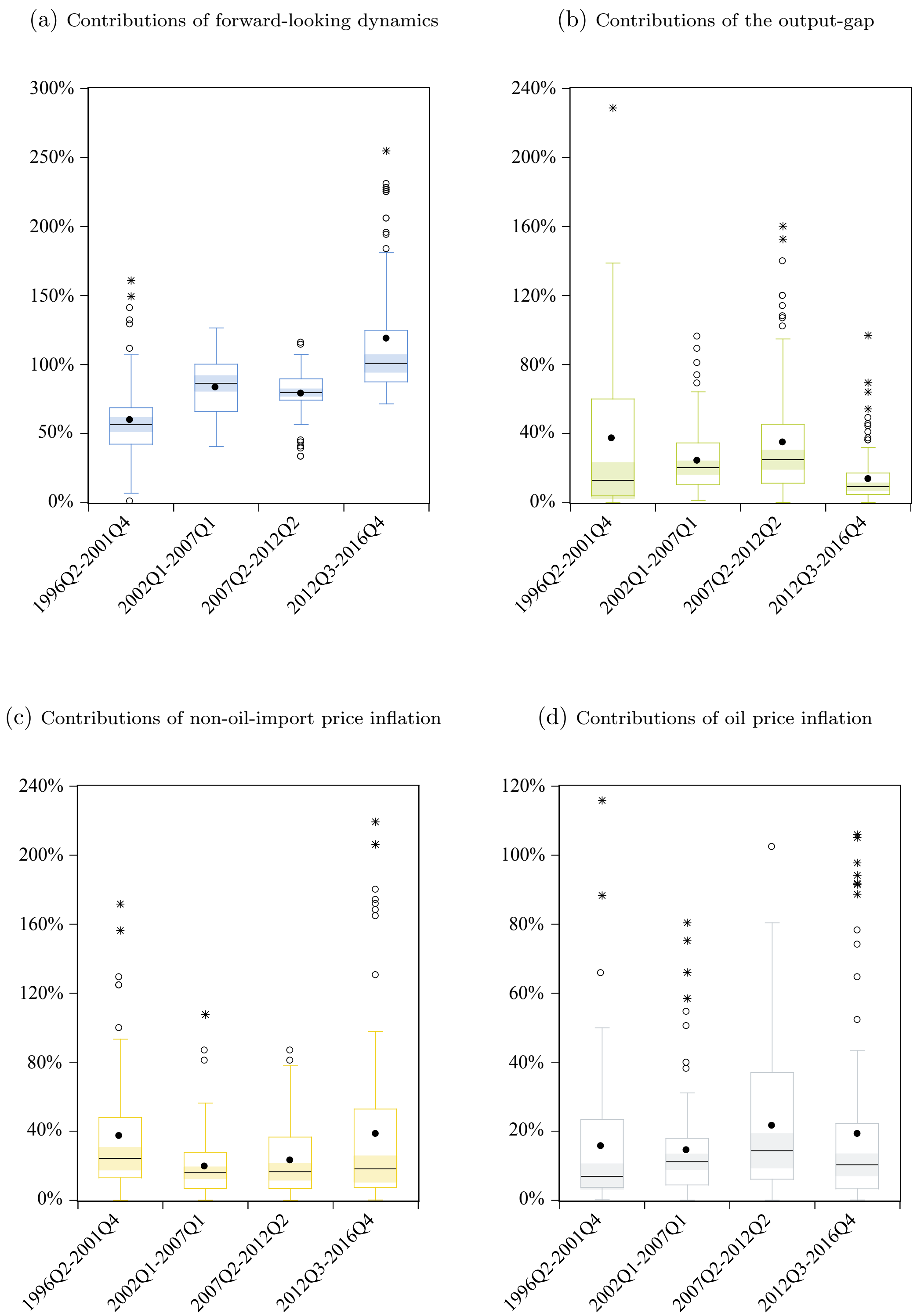
Distribution of contributions across ASEAN-5 countries

To properly assess the driving forces of inflation in the ASEAN-5 region, we put the regional relative median contributions into the context of other distributional properties of these contributions across countries. For this purpose, we split our estimation sample into four parts, 1996Q2-2001Q4, 2002Q1-2007Q1, 2007Q2-2012Q2 and 2012Q3-2016Q4; then calculate the ratio of absolute contributions over the mean of absolute headline inflation of each sub-sample, country and inflation driver, respectively. The distributions of the absolute relative-to-mean contributions are presented in the boxplot form in Figure 3.2. Note that the relative-to-mean contributions in absolute terms do not have to add up to 100%.

Two main features of ASEAN-5 inflation dynamics become immediately prominent. Firstly, in comparison to all other inflation drivers, absolute contributions of the forward-looking dynamics relative to the absolute mean of headline inflation have increased since the AFC in terms of mean, median, lower interquantiles and lower interquartiles. Secondly, the high number of outliers - especially for the distributions of output-gap, import and oil price inflation - indicates a substantial degree of heterogeneity in relative-to-mean contributions, signalling differences in the levels and corresponding parameters of these drivers.

A detailed investigation of the boxplots of the forward-looking components reveals that the median contribution of the forward-looking component accounts for around 50% of the mean headline inflation between 1996 and 2001, afterwards accounting for approximately 85% of mean headline inflation. The rising importance of forward-looking dynamics corresponds well with continual changes in the monetary policy frameworks and communication strategy of ASEAN-5 countries in the first half of the 2000s. These changes might have helped to stabilise headline inflation rates and align long-run inflation expectations, which in turn might have mitigated the effects of the GFC on headline inflation dynamics. Moreover, the boxplot of the last subsample indicates a right-tailed distribution of contributions. This reflects the fact that, in the last few years, inflation rates in the ASEAN-5 countries have declined to very low or even negative rates due to falling import and oil prices (detailed in Section 3.4). Counteracting this effect, contributions of expected long-run trend inflation, however, have remained positive and roughly constant compared to the mid-2000s.

Figure 3.2: Distribution of country-specific ratios of absolute contributions and average headline inflation



(a) Contributions of forward-looking dynamics

(b) Contributions of the output-gap

(c) Contributions of non-oil-import price inflation

(d) Contributions of oil price inflation

The underlying data for each boxplot comprises the country-specific ratios of contributions over the mean of headline inflation, both in absolute values, for each subsample and inflation driver.

Interquartile and -quantile ranges of boxplots related to the contributions of the output-gap (Figure 3.2 Panel b) indicate that economic activity had a larger effect on headline inflation during periods of crisis (here AFC and GFC) compared to 'normal time'. In our sample, this episodic increase in contributions is related to altered output-gap fluctuations in times of crisis, such as increased movements of the underlying variable, and non-linearities in the Phillips curve relationship (as explained in the following section). The boxplots of the relative-to-mean import price inflation contributions (Panel c) reveal that, although the median has declined since the AFC, the interquartile and -quantile ranges widened from 2007 onwards, reaching levels comparable to those of the first subsample.

There are underlying but distinct reasons for the increased contributions of import prices in the late 1990s and in the last few years of the sample period. Large exchange rate appreciations following the exchange rate liberalisation over the course of the AFC, with consequent large increases of import prices inflation, constitute the altered dispersion of relative contributions for import price inflation in the first subsample. However, the increased dispersion of contributions during the last few years visually represent the impact of globally declining trade volumes and decreasing levels of import price inflation in the aftermath of the GFC. The effect of the decrease of import prices has been especially prominent in Singapore, establishing nearly all the outliers in the last boxplot. Panel d in Figure 3.2 indicates that the median of relative-to-mean oil price inflation contributions increased slightly over the four subsamples, but the overall contributions are quantitatively smaller compared to those of import price and the output-gap. Here, most of the outliers are determined by relative-to-mean contributions of Thailand, with its industry being largely dependent on imported crude oil, and Singapore, being an oil exporting country with crude oil exports accounting for 5% of its GDP (on average).

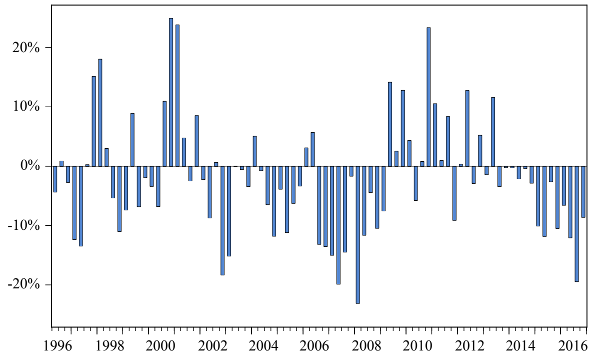
Impact of time-varying parameters

To shed light on the sources of changes of inflation drivers' relative contributions, we present the difference between median contributions simulated with the estimated benchmark model without time variation in parameters and median contributions simulated with the estimation results of the model with time-varying parameters. Figure 3.3 displays the percentage changes of relative contributions that would have resulted using a model with no time-variation.

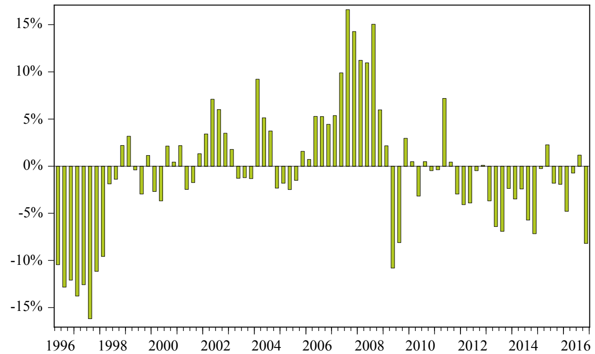
For the contribution of forward-looking dynamics (Figure 3.3 Panel a), the constant parameter model implies persistently lower relative median contributions from 2001 to 2010 and from 2014 onwards. This again emphasises the increasing importance of expected long-run trend inflation and its stabilising effect on inflation dynamics during the GFC and recent years. Panel b in Figure 3.3, indicates that the time variation of the slope parameter often becomes present during periods of crisis.

Figure 3.3: Contributions resulting from time-varying parameters

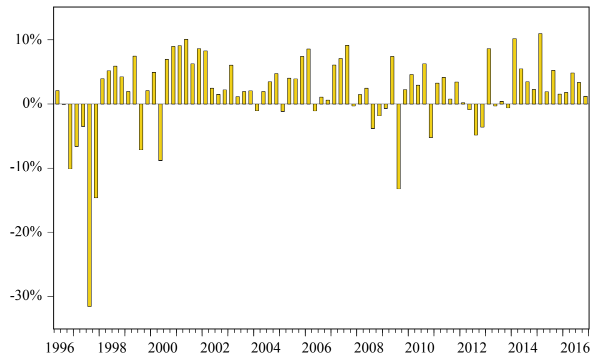
(a) Forward-looking dynamics



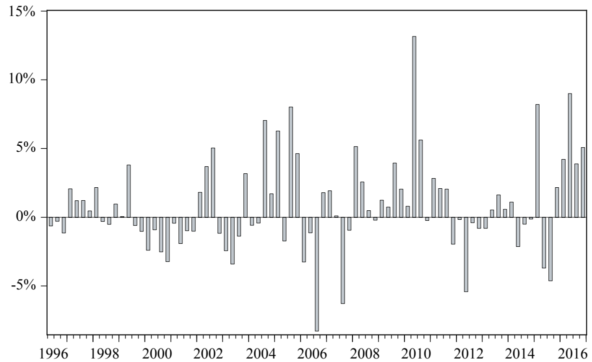
(b) Output-gap



(c) Non-oil-import price inflation



(d) Oil price inflation



The contributions of the time variation in parameters are calculated as the difference between median contributions, simulated with the estimated benchmark model, with time-invariante parameters and median contributions simulated with the estimation results of the model with time-varying parameters.

The benchmark model with constant parameters suggests approximately 10% less relative median contribution of economic slack occurring during the AFC, and 12% more relative contribution during the run-up to the financial crisis. Furthermore, under constant parameters, non-oil-import inflation relative median contributions are shown to be persistently higher after the AFC (Figure 3.3 Panel c). Similarly, relative median contributions of oil price inflation are higher under constant parameters by tendency after the mid-2000s (Figure 3.3 Panel d).

Comparison of forecasting performance

To examine the validity of our benchmark PC specification and the assumption of non-linearities in the PC relation, we perform pseudo-out-of-sample forecasts of our benchmark model, and then compared the forecast performance to a variety of other models. The models comprise further PC variants under constant and time-varying parameters, as well as plain time-series models commonly used for forecasting headline inflation.

To be specific, we consider the following models: the benchmark model (bm) as depicted in Equation (3.1); a version of our benchmark model utilising Consensus survey expectations (bm cons) instead of survey-augmented trend inflation; a PC version altogether omitting import and oil price inflation; a simple autoregressive model of lag order two (ar2) and four (ar4); and the random walk model proposed by Atkeson and Ohanian (2001), referred to here as RW-AO. The pseudo-out-of-sample forecasts start in 2005Q3, end in 2016Q4, and are obtained for forecast horizons 1, 2, 4, 8 and 12.

Table 3.1 presents the population root mean square forecast errors (PRMSFE) of the distinct models for each forecast horizon in relation to the PRMSFE of the RW-AO. Table 3.2 presents the relative root mean square forecast errors (RMSFEs) (relative to the RW-AO model) for each country respectively. The relative PRMSFEs and RMSFEs, that are larger than one, indicate that the forecast performance is worse than the forecast performance of the RW-AO model. As seen in Tables 3.1 and 3.2, the relative PRMSFEs and RMSFEs indicate that all model specifications outperform the RW-AO model across the forecasting horizons. Moreover, the autoregressive models reveal smaller relative PRMSFEs and RMSFEs than the PC specifications with constant parameters for all horizons.

However, when time variation of parameters is introduced in the PC models, the situation changes. Then, our benchmark model and the model using Consensus survey expectations reveal better forecasting performances than the ar(2) and ar(4) models across countries and horizons (as seen in Table 3.2). Additionally, the benchmark model incorporating survey augmented trend inflation (bm) beats the benchmark model utilising only Consensus survey expectations (bm cons).

In summary, the forecasting exercise implies that ASEAN-5 inflation is effectively captured by a PC specification that firstly, includes a forward-looking component and accounts for structural changes of the underlying parameter, and secondly, contains import price inflation as an additional driver

Table 3.1: PRMSFEs (relative to rw-ao model) of ASEAN-5 inflation forecasts

		horizon					
		1	**2**	**4**	**6**	**8**	**12**
ar2	mean	0.448	0.444	0.479	0.519	0.518	0.448
	median	0.463	0.463	0.497	0.533	0.548	0.456
	<0.5	4	5	3	1	2	4
ar4	mean	0.491	0.539	0.568	0.654	0.629	0.540
	median	0.533	0.530	0.558	0.726	0.671	0.558
	<0.5	2	1	1	1	1	1
bm cp	mean	0.624	0.638	0.690	0.773	0.767	0.649
	median	0.659	0.660	0.734	0.844	0.796	0.655
	<0.5	1	1	1	1	1	1
cons cp	mean	0.666	0.656	0.701	0.787	0.777	0.673
	median	0.712	0.696	0.759	0.859	0.788	0.677
	<0.5	1	1	1	1	1	1
plain cp	mean	0.691	0.676	0.720	0.802	0.790	0.671
	median	0.712	0.695	0.758	0.834	0.789	0.697
	<0.5	0	0	1	0	0	0
oil im cp	mean	0.666	0.656	0.701	0.787	0.777	0.673
	median	0.666	0.656	0.701	0.787	0.777	0.673
		1	1	1	1	1	1
oil ex cp	mean	0.645	0.639	0.687	0.769	0.760	0.655
	median	0.645	0.639	0.687	0.769	0.760	0.655
		1	1	1	1	1	1
bm	mean	0.359	0.350	0.372	0.409	0.408	0.341
	median	0.369	0.356	0.386	0.413	0.391	0.351
	<0.5	5	5	5	4	4	5
cons	mean	0.364	0.354	0.378	0.415	0.414	0.346
	median	0.374	0.361	0.403	0.418	0.396	0.353
	<0.5	5	5	5	4	4	5
plain	mean	0.483	0.469	0.499	0.546	0.545	0.457
	median	0.524	0.506	0.534	0.586	0.543	0.454
	<0.5	0	0	1	0	0	0
oil im	mean	0.364	0.354	0.378	0.415	0.414	0.346
	median	0.364	0.354	0.378	0.415	0.414	0.346
	<0.5	5	5	5	4	4	5
oil ex	mean	0.368	0.358	0.381	0.418	0.417	0.349
	median	0.368	0.358	0.381	0.418	0.417	0.349
	<0.5	5	5	5	4	4	5

bm:	benchmark model (EQ1) with constant parameters
cons:	benchmark model (EQ1) using consensus expectations
plain:	benchmark model without import prices
cp:	model estimated with constant parameters
tvp:	model estimated with time-varying parameters
ar2:	autoregressive model with lag order of 2
ar4:	autoregressive model with lag order of 4
ao rw	random walk model of AO
oil im:	benchmark model with separate coefficients for oil and import price inflation
oil ex:	benchmark model with separate coefficients for oil price inflation and exchange rate

The table presents the ratios of the PRMSFEs for the respective model relative to the PRMSFEs of the rw-ao model. Thereby, PRMSFEs refers to the population root mean squared forecast error that is the mean or median of the root mean squared forecast errors (RMSFEs) across countries. Moreover, the table presents a count of countries that depict relative RMSFEs (relative to the RMSFEs of the rw-ao model) less than 0.5.

for domestic inflation. The results further highlight the importance of non-linearities in the PC relation and the inclusion of a forward-looking component for the ASEAN-5 inflation dynamics.

Table 3.2: Country-specific RMSFEs (relative to rw-ao model) of ASEAN-5 inflation forecasts

	horizon						**horizon**					
	1	**2**	**4**	**6**	**8**	**12**	**1**	**2**	**4**	**6**	**8**	**12**
	Thailand						**Indonesia**					
ao rw	1	1	1	1	1	1	1	1	1	1	1	1
ar2	0.463	0.463	0.497	0.502	0.467	0.437	0.514	0.495	0.524	0.577	0.548	0.464
ar4	0.533	0.678	0.725	0.726	0.671	0.626	0.538	0.530	0.535	0.627	0.595	0.514
bm cp	0.693	0.698	0.753	0.767	0.709	0.655	0.716	0.749	0.817	0.857	0.796	0.630
cons cp	0.719	0.714	0.781	0.792	0.732	0.677	0.790	0.794	0.806	0.859	0.788	0.649
plain cp	0.760	0.753	0.818	0.823	0.758	0.697	0.806	0.781	0.776	0.834	0.789	0.666
oil im cp	0.719	0.714	0.781	0.792	0.732	0.677	0.790	0.794	0.806	0.859	0.788	0.649
oil ex cp	0.698	0.698	0.772	0.787	0.732	0.685	0.819	0.838	0.849	0.922	0.848	0.711
bm	0.388	0.383	0.412	0.412	0.380	0.352	0.369	0.356	0.376	0.413	0.391	0.320
cons	0.389	0.385	0.413	0.414	0.382	0.353	0.374	0.361	0.381	0.418	0.396	0.325
plain	0.554	0.547	0.587	0.589	0.543	0.503	0.524	0.506	0.534	0.586	0.555	0.454
oil im	0.389	0.385	0.413	0.414	0.382	0.353	0.374	0.361	0.381	0.418	0.396	0.325
oil ex	0.411	0.406	0.436	0.437	0.403	0.373	0.379	0.366	0.386	0.423	0.401	0.328
	Malaysia						**the Philippines**					
ao rw	1	1	1	1	1	1	1	1	1	1	1	1
ar2	0.492	0.499	0.569	0.645	0.656	0.551	0.412	0.410	0.455	0.533	0.576	0.456
ar4	0.609	0.623	0.558	0.793	0.709	0.673	0.430	0.524	0.686	0.792	0.840	0.558
bm cp	0.598	0.639	0.734	0.951	0.951	0.786	0.659	0.660	0.716	0.844	0.902	0.703
cons cp	0.638	0.632	0.729	0.938	0.940	0.822	0.712	0.696	0.759	0.890	0.947	0.742
plain cp	0.636	0.639	0.755	0.943	0.925	0.733	0.712	0.695	0.758	0.891	0.947	0.732
oil im cp	0.638	0.632	0.729	0.938	0.940	0.822	0.712	0.696	0.759	0.890	0.947	0.742
oil ex cp	0.575	0.560	0.658	0.813	0.807	0.664	0.664	0.651	0.726	0.864	0.930	0.735
bm	0.352	0.346	0.386	0.453	0.460	0.351	0.415	0.405	0.440	0.513	0.551	0.427
cons	0.367	0.361	0.403	0.472	0.480	0.366	0.417	0.406	0.442	0.515	0.553	0.429
plain	0.377	0.371	0.414	0.485	0.493	0.376	0.594	0.579	0.630	0.734	0.788	0.611
oil im	0.367	0.361	0.403	0.472	0.480	0.366	0.417	0.406	0.442	0.515	0.553	0.429
oil ex	0.350	0.345	0.384	0.451	0.458	0.349	0.423	0.412	0.449	0.523	0.561	0.435
	Singapore											
ao rw	1	1	1	1	1	1						
ar2	0.359	0.352	0.351	0.339	0.343	0.332						
ar4	0.346	0.339	0.333	0.331	0.329	0.327						
bm cp	0.454	0.443	0.430	0.449	0.477	0.470						
cons cp	0.469	0.446	0.431	0.458	0.476	0.472						
plain cp	0.540	0.512	0.491	0.517	0.534	0.525						
oil im cp	0.469	0.446	0.431	0.458	0.476	0.472						
oil ex cp	0.467	0.447	0.432	0.460	0.484	0.479						
bm	0.273	0.257	0.248	0.253	0.258	0.254						
cons	0.275	0.258	0.249	0.254	0.259	0.256						
plain	0.364	0.343	0.331	0.337	0.344	0.339						
oil im	0.275	0.258	0.249	0.254	0.259	0.256						
oil ex	0.278	0.262	0.252	0.257	0.262	0.259						

bm:	benchmark model (EQ1) with constant parameters
cons:	benchmark model (EQ1) using consensus expectations
plain:	benchmark model without import prices
cp:	model estimated with constant parameters
tvp:	model estimated with time-varying parameters
ar2:	autoregressive model with lag order of 2
ar4:	autoregressive model with lag order of 4
ao rw	random walk model of AO
oil im:	benchmark model with separate coefficients for oil and import price inflation
oil ex:	benchmark model with separate coefficients for oil price inflation and exchange rate

The table presents the country-specific ratios of the RMSFEs for the respective model relative to the PRMSFEs of the rw-ao model. Thereby, RMSFEs refers to the root mean squared forecast error.

The role of forward-looking dynamics in determining inflation outcomes

The increase in the forward-looking component of inflation dynamics in the wake of the AFC is one of the key findings of our analysis. This finding is not surprising, keeping in mind that most ASEAN-5 countries enhanced their monetary policy regimes since the AFC, allowing for somewhat greater exchange rate flexibility, as well as improved policy frameworks and operational practices. We provide additional support for that conjuncture below. In terms of our empirical framework, the coefficient on forward-looking dynamics, β_t^1, and the level of (long-term) trend inflation, $\bar{\pi}_t$, play important roles in providing stable inflation rates and macroeconomic stability, and are therefore of particular interest.

The guiding of long-term inflation expectations is a crucial element of modern monetary policymaking. The consistency of the private sector's inflation expectations at medium-to-long horizons, aligned with the central bank's target, provides a direct assessment of the credibility of monetary policy. Besides, in an environment of very low inflation, stable long-term inflation expectations are essential to returning inflation to levels that help avoid the deflation concerns that have persisted since the onset of the GFC.

Surveys of inflation expectations and expectations extracted from financial instruments are nowadays among the standard indicators monitored by many central banks.[3] In addition, the estimation of long-term inflation trends us-

[3] Surveys are traditional sources of information in terms of long-term expectations, as they have been available several times per year for many countries over several decades. With the issuance of inflation-

ing econometric models has become increasingly common in major central banks since the GFC. The rationale behind those research efforts is twofold. Firstly, given the forward-looking orientation of modern monetary policy-making, policy decisions should be based on reliable indicators of long-term inflation expectations. While survey and financial indicators provide useful information, both have significant shortcomings that might have rendered them less reliable in an environment characterised by persistently low inflation. Secondly, discrepancies between both types of indicators require a regular assessment of their information content, and the estimation of trend inflation measures can be instrumental in that regard.

Among the ASEAN-5 countries, break-even inflation rates (BEIRs) are only available for Thailand and hence do not present an alternative variable of choice as a measure of $\bar{\pi}_t$ in our econometric exercise. To account for the aforementioned shortcomings of survey-based expectations, we employed trend inflation estimates from Garcia and Poon (2018) to measure $\bar{\pi}_t$.[4] Survey-based expectations are used in their empirical model as additional sources of informative data for estimating trend expectations, by allowing systematic deviations of survey-based expectations from actual trend expectations.

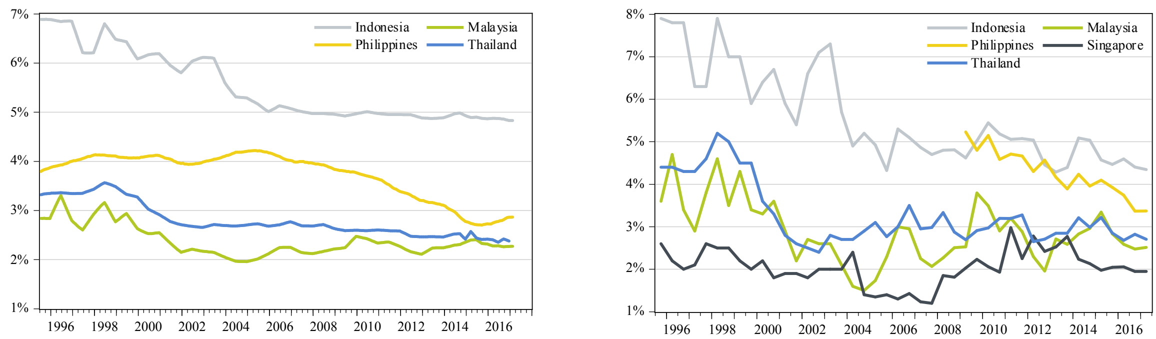
linked bonds (ILBs) in several advanced but also emerging economies, the so-called „break-even inflation rate“ (BEIR) - the yield spread between comparable conventional bonds and ILBs - has also become a crucial indicator of inflation expectations. BEIRs often provide more timely information on investors' inflation expectations than survey-based expectations. Yet, in addition to the expected inflation, BEIRs may incorporate other factors, notably inflation risk and liquidity risk premia, and should better be interpreted as the overall inflation compensation requested by investors to hold nominal assets, rather than a pure measure of expected inflation.

[4] Based on the methodology introduced by Chan et al. (2017).

Figure 3.4 illustrates the long-term trend expectations included in our benchmark estimation compared to the Consensus long-run expectations. Survey expectations are substantially more volatile compared to trend inflation estimates. Throughout the sample, trend estimates for Malaysia, Indonesia and Thailand lie below the Consensus survey expectations. Within the framework of Garcia and Poon (2018) and Chan et al. (2017), this fact points towards a systematic deviation of actual trend expectations that could be explained by informational rigidities (Coibion and Gorodnichenko, 2015; Mertens and Nason, 2015).

Figure 3.4: Long-term inflation expectations

(a) Long-run inflation trend expectations' estimates (b) Consensus long-run inflation expectations



Panel a presents long-run inflation expetctaions' estimates of Garcia and Poon (2018) for all ASEAN-5 countries, except for Singapore, and Panel b shows long-run inflation expectations obtained from the Consensus survey for all ASEAN-5 countries.

The role of monetary policy in fostering forward-looking dynamics is twofold. Aligning the private sector's inflation expectations at medium-to-long horizons with the central bank's target is necessary, but not sufficient for stabilising inflation dynamics. Additionally, long-run inflation expectations should exert a substantial influence on inflation dynamics. This means actual inflation should contain a significant degree of forward-looking dynamics, as opposed to being driven by past inflation only. Stated differently, the private sector's (long-term) inflation expectations should be aligned towards the central bank's inflation target. The public should regard the inflation target as a highly likely outcome for actual inflation in the future, and economic agents should also incorporate the inflation target into their pricing decisions.

In our hybrid PC specification shown in Equation (3.1), the sum of the degree of forward and of backwards-looking dynamics is set to be in unity. Thereby, β_t^1 determines the importance of inflation long-term trend expectations and $(1-\beta_t^1)$ represents the importance of past inflation. Galí and Gertler (1999) provide the theoretical foundation for this specification. They augmented the New Keynesian Phillips curve (NKPC) by assuming two groups of price setters; one that sets prices according to the purely forward-looking NKPC, and the other that adjusts prices according to a rule of thumb, whereby prices are set equal to the average of the most recent round of price adjustments (past inflation). The introduction of forward- and backwards-looking price setter groups extends the sources of nominal rigidities, such as Calvo pricing Calvo (1983), and overcomes the empirical implausibility of inflation leading cyclical fluctuations.

Forward-looking inflation dynamics and central bank transparency

Central bank transparency is essential for managing inflation expectations and their impact on inflation dynamics. As pointed out by Blinder et al. (2008), central bank transparency matters because firstly, not only the economy's underlying structure but also the central bank's monetary policy rules change over time. Secondly, information is distributed asymmetrically between the central bank and the public. Thirdly, expectations are not entirely rational. In this circumstance, effective communication of the central bank's objectives, strategies and decisions (along with their underlying rationale) - as well as communications regarding the economic outlook in relation to inflation and actual economic activities comprising a transparent framework of monetary policy - will improve the monetary policy environment. In our empirical model, a transparent central bank succeeds when aligning public long-run trend expectations ($\bar{\pi}_t$) with the central bank's implicit or explicit inflation target, and exercising a sufficient degree of forward-looking behaviour in terms of price setting.

Central bank transparency has increased significantly during the preceding two decades in the ASEAN-5 countries. Monetary policy frameworks have also evolved substantially in these countries in response to the AFC. Before the AFC, pegged exchange rate regimes dominated the monetary policy environment in the ASEAN-5 region. Excessive borrowing and currency mismatching by corporations and banks led to severe exchange rate pressures and depreciations when capital flow reversed. To strengthen their monetary policy independence and to gain more open capital accounts, all the ASEAN-5 countries increased their exchange rate flexibilities after the AFC. In this context, ASEAN-5 central banks significantly improved their operating frameworks, policy objectives and communicative efforts in response to challenges arriving from the global economic environment.

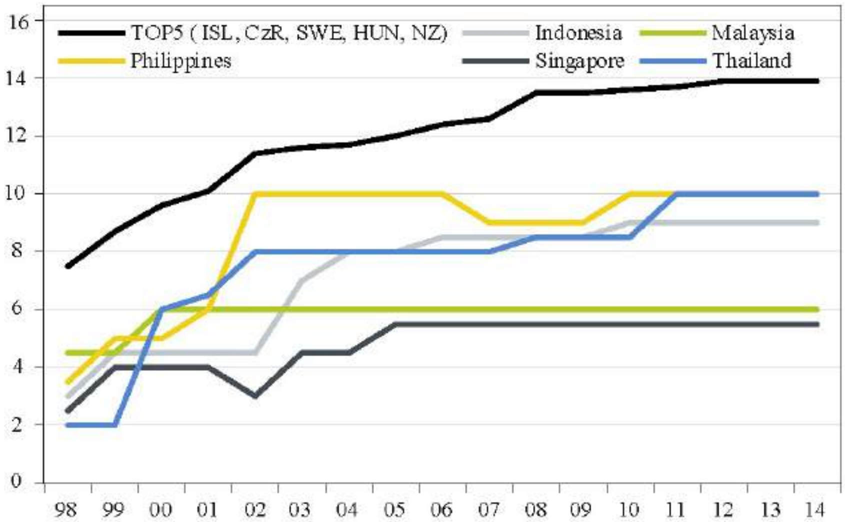
Table 3.3: Monetary policy frameworks and transparency in ASEAN-5

	Indonesia	Malaysia	the Philippines	Singapore	Thailand
Objective(s) and framework					
Central bank mandate	Achieve and maintain a stable value of rupiah	Promote monetary and financial stability conductive to sustainable growth of Malaysian economy	Promote and maintain price stability provide proactive leadership in bringing about a strong financial system, conductive to a sustainable growth of the economy	Maintain price stability foster sound and reputable financial stability ensure prudent and effective management of foreign reserves and grow Singapore's as international competitive financial center	Maintain a monetary stability and payment systems
Primary monetary policy objective	Stable price of goods and services and stable exchange rate	Price stability	Price stability	Price stability	Price stability
Stated monetary policy framework	Explicit inflation targeting (2005)	Implicit inflation targeting	Explicit inflation targeting (2002)	Implicit inflation targeting	Explicit inflation targeting (2000)
Medium term inflation target	4% ± 1% (approved target for 2013-2015)	3%	3% ± 1% (approved target for 2015-2018)	2%	2.5% ± 1% (approved target for 2015)
Report on macroeconomic outlook					
Stated inter-mediate monetary policy target	Yes	Yes	Yes	Implicit nominal effective exchange rate forecast	Yes
Inflation report	Monthly	No	Quarterly	Semi-annually	Quarterly
Decision and rational					
Monetary policy stance	Yes, on the day of decision	Yes, on the day of decision	Yes, on the day of decision	Yes, on the on the day of decision	Yes, on the day of decision
Minutes policy meetings	Yes	No	Yes, one month after the meeting	No	Yes, two weeks after the meeting
Explanation of decision making process	Yes	Yes	Yes	Yes	Yes
Explanation if missing the target	Yes, to public and parliament	Yes, to ministry of finance	Yes, to president	NA	Yes, to ministry of finance

The table presents qualitative and quantitative information about monetary policy frameworks, communication and transparency of ASEAN-5 economies based on information of the IMF APD department.

Table 3.3 provides a glance at the current status of monetary policy frameworks and communication tools in ASEAN-5 countries. Low and stable inflation is included in monetary policy objectives in each ASEAN-5 country, with Thailand, Indonesia and the Philippines adopting explicit (but in some cases flexible) inflation targeting regimes. In addition, those countries have utilised key communication tools such as statements on primary policy objectives and medium-term inflation targets, along with the publication and explanation of monetary policy decisions. Heterogeneities concerning the timing and availability of their publications of minutes and inflation rates (reported in Table 3.3) indicate further potential for the improvement of central bank transparency and communication in the ASEAN-5 region.

Figure 3.5: ASEAN-5: Dincer-Eichengreen central bank transparency index



Dincer and Eichengreen, IJCB 2014. Maximum score of 15 based on 5 dimensions of CB transparency
Political (3): about policy objectives (explicit objectives, quantification, instrument independence)
Economic (3): information used for MP decisions (data, model and CB's forecast)
Procedural (3): decision making (policy strategy, prompt account of deliberations, voting info) Policy (3): disclosure of decisions (prompt announcement, explanations, forward guidance)
Operational (3): assessing implementation (evaluation with respect to targets, shocks impairing achieving goals, explain decisions contribution to goals)
TOP5 refers to an average index of the five most transparent central banks located in Iceland, Czech Republic, Sweden, Hungary and New Zealand.

Figure 3.5 displays a quantitative measure of central bank transparency, depicting the Dincer and Eichengreen (2014) central bank transparency index (DE transparency index) for the ASEAN-5 countries, as well as a benchmark average index of the TOP 5 economic countries. Starting with low scores - between 2 and 4 index points - in 1998, the ASEAN-5 countries substantially improve their central bank transparencies. Indonesia, the Philippines and Thailand score between 9 and 10 index points in 2014, while Malaysia and Singapore respectively score 6 and 5 index points. In comparison to the TOP 5 countries, room for further improvements of central bank transparencies in ASEAN-5 countries still exists.

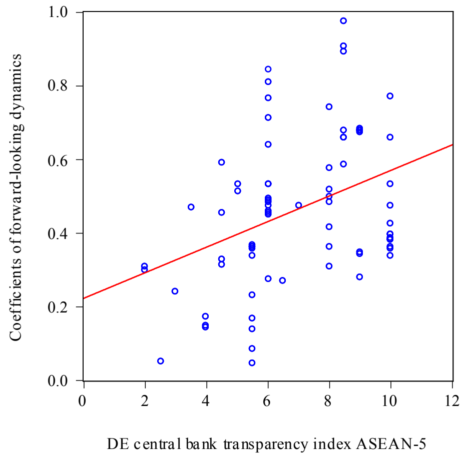
Figure 3.6 displays supporting evidence of the relation between central bank transparency and forward-looking dynamics in inflation. Both time-varying estimates of the forward-looking coefficient, β_t^1, and the overall time-varying contribution, $\beta_t^1\bar{\pi}_t$, are positively correlated to the respective DE transparency index scoring for each country. Therefore, our estimation results confirm that the improved transparency in central banks can indeed be associated with a higher degree of forward-looking dynamics in ASEAN-5 countries.

Inflation dynamics and cyclical fluctuations

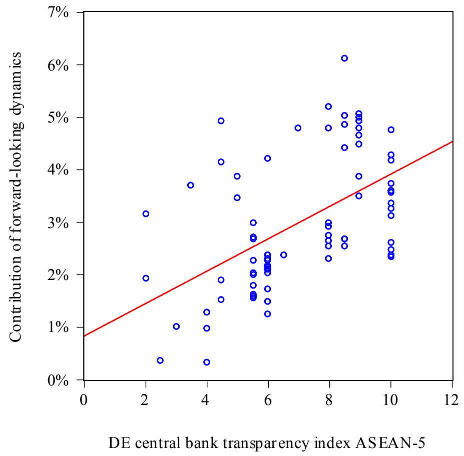
The slope of the Phillips curve is a key parameter of interest since the relationship between unemployment (economic activity) and inflation was postulated - and continues to generate substantial attention many decades later, as shown by Blanchard et al. (2015). In the case of the ASEAN-5 countries, the recovery in real economic activity since the start of the GFC has been relatively slow. It is therefore important to discuss the strength of the cyclical economic position's impact on inflation dynamics in the region.

Figure 3.6: Correlation between forward-looking dynamics and DE transparency index

(a) Coefficients of forward-looking dynamics and DE transparency index



(b) Contribution of forward-looking dynamics and DE transparency index

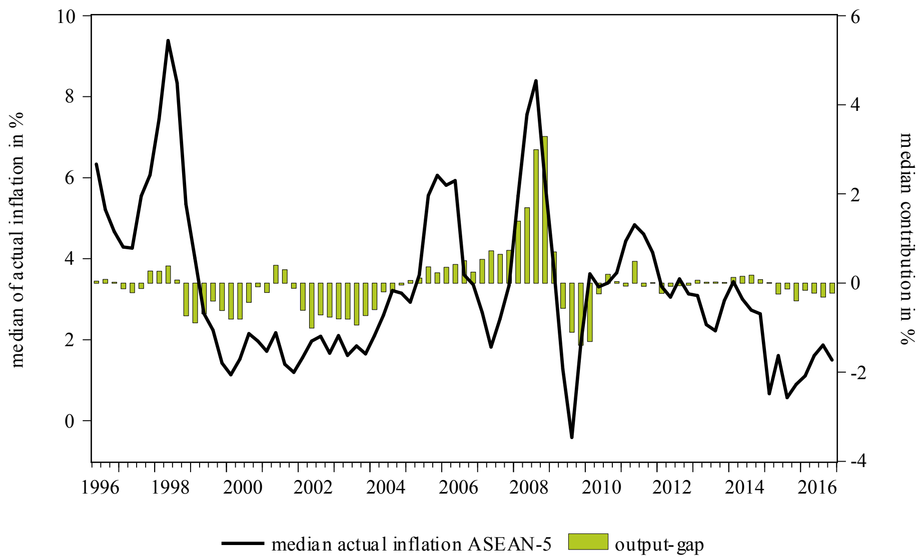


The panels contain scatter plots and the corresponding regression lines of the estimated country-specific time-varying coefficient (Panel a) as well as the simulated contribution (Panel b) of the forward-looking component, that result from the benchmark model, and the DE transparency index at each point in time.

The development of absolute ASEAN-5 median contributions of economic slack measured by the output-gap (see Figure 3.7) varies quantitatively across the sample. Preceding the AFC, movements in economic slack plays a limited role in inflation processes, with contributions varying between 0.23 and -0.53 percentage points. Between 2002 and the GFC contributions of economic slack increases (2.70 percentage points, -0.82 percentage points), but declines again (0.24 percentage points, -0.32 percentage points) afterwards.

The altered importance of economic slack in the first half of the 2000s can be ascribed to structural transitions of the ASEAN-5 economies induced by adjustment processes such as exchange rate liberalisation, enhanced economic policy and intrinsic economic transition in the wake of the AFC. The decline of economic slack contributions after the GFC matches empirical findings

Figure 3.7: Median contribution of output-gap in ASEAN-5 countries



We obtain the median contributions by estimating our benchmark model for each country, simulating the contributions of the output-gap and taking the median of the contributions across countries.

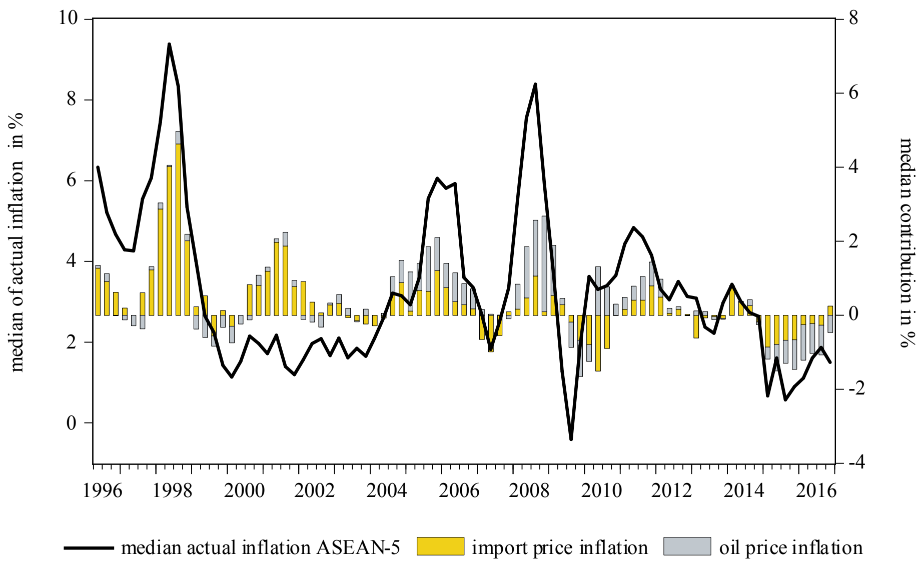
for inflation dynamics in advanced economies (Watson, 2014). The time variation in the contribution of economic slack indicates non-linearities in the PC slope parameter (see country-specific parameter estimates in the following section).

Inflation dynamics, non-oil-import and oil price inflation

The sharp decline in oil prices since 2014 serves as a recurrent explanation for recent trends of low inflation rates. This prompts the question of whether oil price inflation largely determines the headline inflation, or whether the magnitude of oil price reduction (from 2014 onwards) drives the recent inflation developments. For the ASEAN-5 region as a collective, the relation between headline inflation and oil price inflation is not clear, since Malaysia and Indonesia are oil-exporting countries, while Thailand, the Philippines and Singapore are importers of oil.

Figure 3.8 reveals that the combined contributions of non-oil-import and oil price inflation declines substantially after the AFC. Non-oil-import inflation, in particular, becomes less important after 2002. By contrast, oil price inflation gains importance after the AFC. Between 1996 and 2001 oil price contributions range between 0.30 and -0.49 percentage points, then increase to a higher range (1.41 percentage points, -0.17 percentage points) from 2002 to 2008. During the recent period of disinflation, oil price inflation deflates median inflation by -0.46 percentage points in 2015 and -0.59 percentage points in 2016.

Figure 3.8: Median contribution of import price inflation in ASEAN-5 countries



We obtain the median contributions by estimating our benchmark model for each country, simulating the contributions of the import inflation and taking the median of the contributions across countries.

During the past two decades, long-run inflation expectations become the most important driver of ASEAN-5 median inflation. This development strongly correlates with the evolution and collective upgrading of monetary policy frameworks and communicative operations among these countries. According to our results, the impact of output-gap movements on median headline inflation is generally quite small yet episodically stronger during crisis periods, indicating a non-linear Phillips curve. Contrastingly, the impact of import inflation is quite stable since the early 2000s, though import inflation plays only a limited role in the headline inflation process, whereas the contributions of non-oil-import decline substantially after the AFC.

3.3.2 Country-specific evidence

In this section, we discuss our estimation results for each individual country. We first report our estimation results in more detail, while including the evolution of time-varying parameters and the implied contributions of drivers to headline inflation for each country. We then illustrate how the particular country's economic experiences relate to the overall patterns that were identified and discussed in the previous section.

Indonesia

Inflation in Indonesia declines from an average rate of 8.5% before the GFC to approximately 5% afterwards, as revealed in Figure 3.9. Yet, particularly towards the end of the sample period, disinflationary pressures in Indonesia is limited, possibly reflecting not only a less direct effect of commodity prices compared to other non-oil producers in the region, but also the attenuating effect of forward-looking dynamics. Additionally, the marked effect of changes in administrated energy prices on inflation around 2005 encourages further coordination between fiscal and monetary policies to ensure stable inflation developments in the future.

Expectations dominantly explain Indonesia's inflation dynamics since the mid-2000s with economic slack and import inflation playing rather limited roles, which is a feature broadly in line with results for the whole ASEAN-5 region. As shown in Figure 3.9, the drivers underlying the inflation processes change towards being more expectation driven and less dependent on real economic activities and import inflation. In the early years of the 2000s, economic slack and import inflation accounts for approximately half of its total inflation development.

For example, in 2002 the Indonesian inflation rate amounts to 11.96%, of which 6.32 percentage points could be explained by economic activity and import inflation (3.45 percentage points by the output-gap, 2.11 percentage points by the non-oil-import prices, 0.76 percentage points by the oil price inflation), while forward-looking expectations account for only 3.55 percentage points. This is in stark contrast with the situation in 2015, when inflation expectations account for 4.93 percentage points of the headline inflation rate of 6.37%, while economic slack accounts for 0.05 percentage points and non-oil-import inflation and oil price inflation contribute 0.76 and -0.49 percentage points respectively.

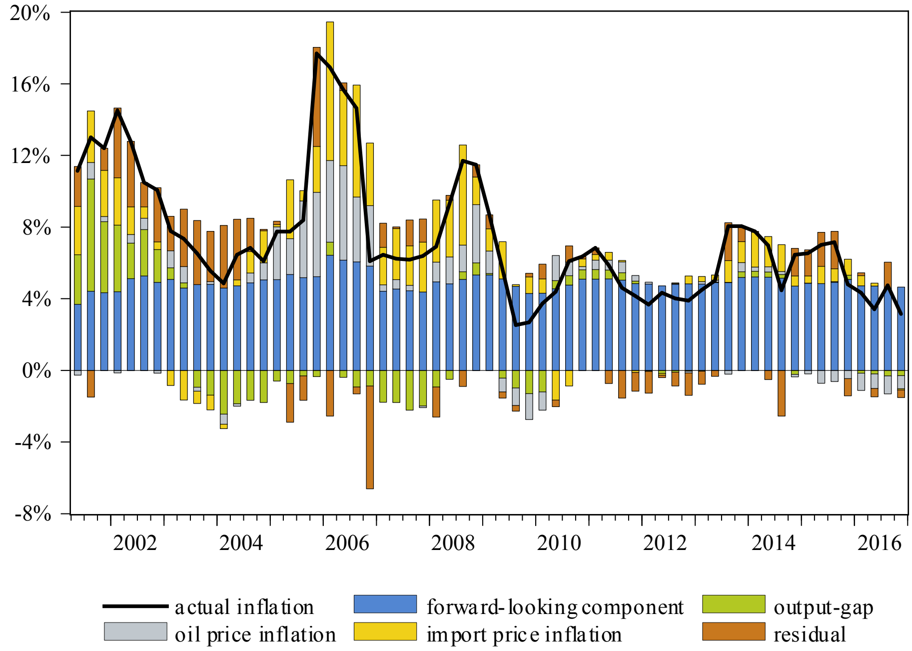
Improvements in the monetary policy framework coincided with partially strengthened forward-looking dynamics of the Indonesian headline inflation. Contributions of trend inflation expectations in Indonesia rose sharply in the first half of the 2000s, and stabilised thereafter. In particular, the contribution of forward-looking dynamics increased by 74% from 2001 (2.67 percentage points) to 2005 (4.68 percentage points), and has continued to narrowly fluctuate around 4.7 percentage points since then. The reason for the increase is twofold. Firstly, the coefficient of the forward-looking component (Figure 3.10 Panel a) rose from 0.32 in 2001 to 0.73 in 2007, stabilising near 0.7. Secondly, the Indonesian trend inflation estimates (Figure 3.4) declined from 7.9% in 2001 to only 5% in 2007 and later.

The rise in forward-looking dynamics between 2002 and 2007 appears to be related to the continual improvement of the Bank Indonesia's (BI) monetary policy framework and communications over that period[5]. In particular, the Central Bank Act of 2004 produced a clear strategy for accountability and transparency of monetary policy. These included announcements related to inflation targets, monetary policy plans to be announced annually, quarterly reports that will be submitted to parliament regarding the execution of monetary policy, Monetary Policy Reports, publications of decisions reached in Monetary Board meetings, economic forecasting models and monetary policy outlooks. Furthermore, in early 2005 the BI began to use interest rates as the main policy instrument due to difficulties involved in controlling base money.[6]

[5] In 2000 BI adopted an explicit inflation-targeting framework to achieve and maintain price stability, i.e. low and stable inflation, and stable exchange rates. Initially, base money was used as an operational target to achieve inflation targets defined in core CPI inflation rates. As core inflation proved to be a difficult target concept to clearly communicate to the public, the Central Bank Act No 3/2004 induced the government to set annual and medium-term inflation targets on headline CPI inflation rates, taking into account the recommendations of the BI.

[6] With the central bank reforms in 2004, BI was able to increase the forward-looking component of inflation dynamics up to a certain level. However, inflation volatility remained at high levels due to ad hoc adjustments of administered prices in 2005 and 2008, which led to actual CPI inflation being higher than short-term targets. This created uncertainty over inflation expectations and affected

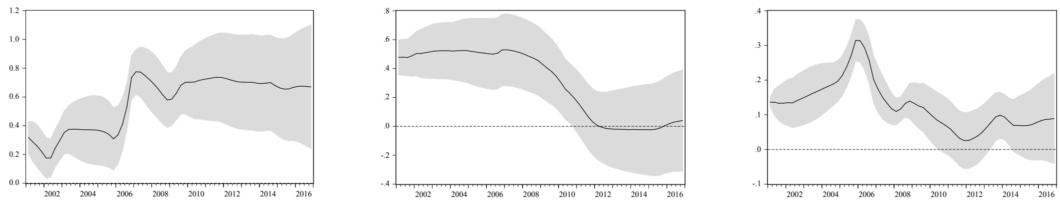
Figure 3.9: Main inflation components: Indonesia



The figure presents simulated contributions to Indonesian headline inflation, resulting from the estimation of the benchmark model for Indonesia.

Figure 3.10: Time-varying coefficients: Indonesia

(a) β_t^1 (b) β_t^2 (c) β_t^3



The panels present the estimates and 95% confidence bands of the time-varying parameters, whereby β_t^1 is the coefficient of long-run inflation expectations, β_t^2 reflects the Phillips curve slope and β_t^3 is the coefficient of import price inflation

Real economic slack plays a very limited role in determining Indonesia's headline inflation since the GFC. Contributions of economic slack decline from

the monetary policy's credibility as BI's communication mainly focused on short-term rather than medium-term inflation targets (IMF (2010), Box 3). In mid-2010 BI re-evaluated its monetary policy framework, including the adoption of mixed monetary and macroprudential policies, such as interest rate response, exchange rate policy, capital flow management and monetary policy communication and coordination (IMF, 2012). In so doing, BI's quality of communication improved, with more focus on medium-term inflation targets while avoiding explicit statements of other targets that might conflict with the inflation targets (for example, output and credit growth) (IMF, 2012).

2007 onwards, with the range declining from (4.22, -1.74) percentage points in 2001-07, to only (0.41, -0.65) percentage points in 2008-16. This can be directly related not only to a decline in the Phillips curve slope (Figure 3.10 Panel b) but also to a decreasing output-gap volatility. In terms of the PC slope, the coefficient of economic slack drops from 0.49 in 2001 to 0.03 in 2010. Simultaneously, the range of Indonesian output-gap declines from (4.22 percentage points, -1.76 percentage points) between 2001 and 2008, to (0.41 percentage points, 0.65 percentage points) afterwards.

Import price inflation becomes less relevant over recent years, especially non-oil-import price inflation. After an increase from 0.13 in 2001 to 0.31 in 2006, the coefficient of import prices stabilise at approximately 0.08 between 2008 and 2016 (Figure 3.10 Panel c). Contributions of non-oil-import and oil price inflation evolves correspondingly, declining from respective averages of 2.4 percentage points and 1.54 percentage points between 2001 and 2008, to 0.83 percentage points and 0.12 percentage points thereafter. The attenuated impact of oil price inflation between 2000 and 2007 appears to be associated with pressures from administrated prices that arose from energy subsidy reforms (Hendar, 2016). Since 2008, improved coordination between the central bank and the government's policy on administrated prices serves to attenuate the impact of oil price fluctuations on inflation.

Indonesia's headline inflation has been stable at low levels (near 5%) since the GFC. This stabilisation can be related to improvements in the monetary policy framework and communication, assisted by a decline of the importance of import prices, including oil and non-oil-import prices. Further improvements in terms of more forward-looking monetary policy communication and coordination between monetary and fiscal policies are likely to ensure a stable headline inflation in the future.

Malaysia

Malaysian inflation rates have remained remarkably stable compared to the other ASEAN-5 countries since the GFC. An increasing forward-looking coefficient (Figure 12, Panel a) and stable long-run expectations (Figure 3.12 Panel a) have decisively limited the disinflationary pressures stemming from falling oil and import prices since 2014. Over the entire sample period, Malaysian headline inflation averages 2.3%, of which 2.08 percentage points are explained by forward-looking inflation expectations, and 0.19 percentage points are related to economic slack and import inflation (0.02 percentage points to the output-gap, 0.06 percentage points to the non-oil-import price inflation , 0.11 percentage points to the oil price inflation).

The shift towards forward-looking dynamics in Malaysian inflation since 2009 is noticeable, while improvements in the monetary policy framework appear to fulfil a crucial role. The contribution of inflation expectations (Figure 3.11) increase from an average of 1.77 percentage points in 2002-07 to an average of 2.28 percentage points in 2008-16. Since trend inflation estimates remain quite stable near 2.5% throughout the sample period (Figure 3.4), the rise in forward-looking dynamics can be attributed to the increase in the forward-looking coefficient (Figure 3.12 Panel a) from 0.4 (from 2002 to 2005) to 0.8 (from 2006 to 2016). This rise might further be related to the continued improvement of the Malaysian monetary policy framework. Since the early 2000s, Bank Negara Malaysia (BNM) has steadily enhanced its monetary policy framework, transparency standard and communicative strategy regarding its two major objectives, namely low inflation and stable exchange rates. Since mid-2003, monetary policy statements have been released on a quarterly basis.

From 2006 onwards, shortly after Malaysia migrated from a U.S. Dollar peg to effective exchange rate stability, statements have been released immediately following monetary policy meetings. The Central Bank Act of 2009 redefined and expanded the BNM monetary policy framework, and in 2010 an initiative to further strengthen existing communication and transparency standards were launched. This initiative included quarterly economic and financial reports, monthly statistical publications, monetary policy committee press conferences and statements, as well as annual reports that incorporate BNM forecasts for economic growth, inflation and policy outlook.

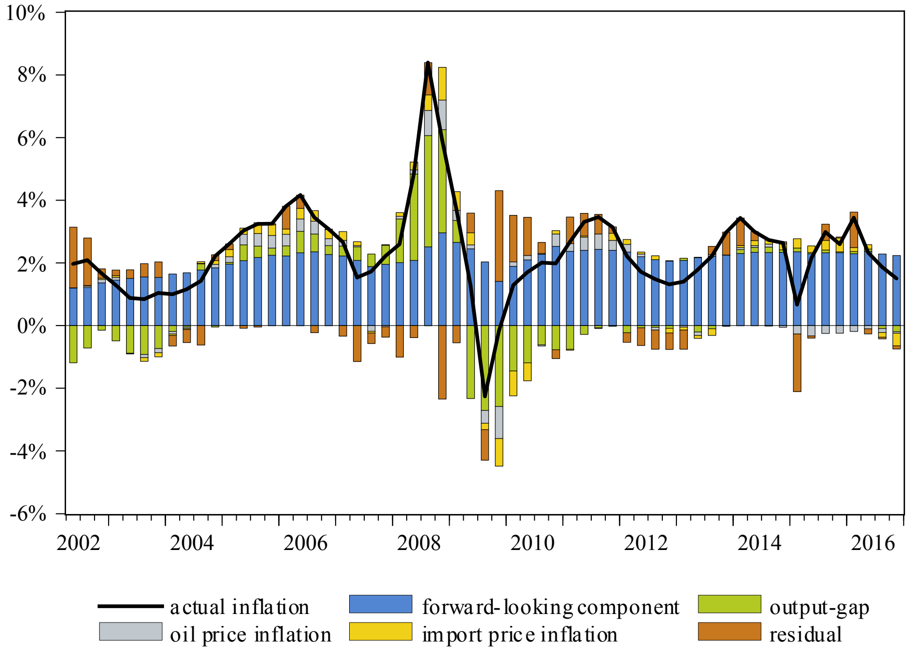
The overall quantitative importance of economic slack in the Malaysian inflation rate is limited, with the exception of the GFC time line Economic activity has a significant impact on Malaysian headline inflation during the

GFC, with its contribution ranging from 3.18 percentage points to -1.56 percentage points (from 2008 to 2010). Apart from the crisis period around 2008, economic slack has a quite limited impact on inflation, resembling the results for the ASEAN-5 region in the previous section. The altered impact of the output-gap on inflation during the GFC can partly be explained by an increase in the coefficient of economic slack (Figure 3.12 Panel b). The PC slope parameter averages approximately 0.4 across the sample period, but rises to 0.8 over the period 2008 to 2010.

Non-oil-import and oil prices have a limited impact on Malaysian headline inflation. Figure 3.11, indicates that the contributions of import inflation to Malaysian headline inflation is quite stable but small, ranging from 0.46 percentage points to -0.24 percentage points for non-oil-import inflation, and 0.37 percentage points to -0.26 percentage points for oil price inflation over the entire sample period. By contrast, the coefficient of import inflation depicts statistically significant time variations (Figure 3.12 Panel c), increasing from 0.006 between 2002 and 2008 to 0.1 in between 2009 and 2016. The stable and limited contribution of oil price movements to inflation movements might be related to the fact that Malaysia is a crude oil exporter, whereby crude oil prices are substantially administered for the majority of the sample period. However, the liberalisation of energy prices and the introduction of a goods and service tax via the fiscal act in 2010 may lead to more volatile headline inflation in the future.[7]

[7] As pointed out by Singh (2016), the fiscal act of 2010 might alter inflation volatility due to the removal of subsidies on selected food, fuel and utilities, and the introduction of a goods and service tax. After the gradual removal of subsidies, Malaysia implemented a managed-float pricing mechanism for fuel

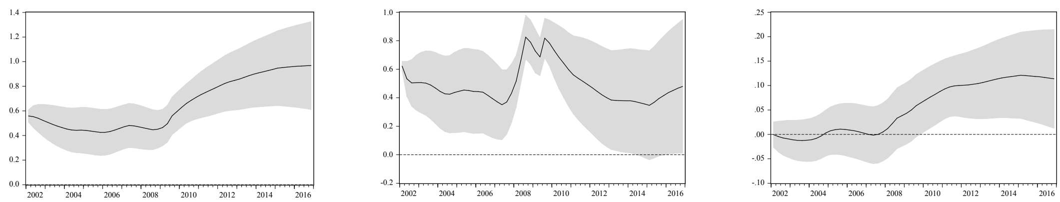
Figure 3.11: Main inflation components: Malaysia



The figure presents simulated contributions to Malaysian headline inflation, resulting from the estimation of the benchmark model for Malaysia.

Figure 3.12: Time-varying coefficients: Malaysia

(a) β_t^1 (b) β_t^2 (c) β_t^3



The panels present the estimates and 95% confidence bands of the time-varying parameters, whereby β_t^1 is the coefficient of long-run inflation expectations, β_t^2 reflects the Phillips curve slope and β_t^3 is the coefficient of import price inflation.

The Philippines

Inflation expectations gained importance for the Philippines' inflation dynamics but long-run trend inflation declines steadily towards the end of the

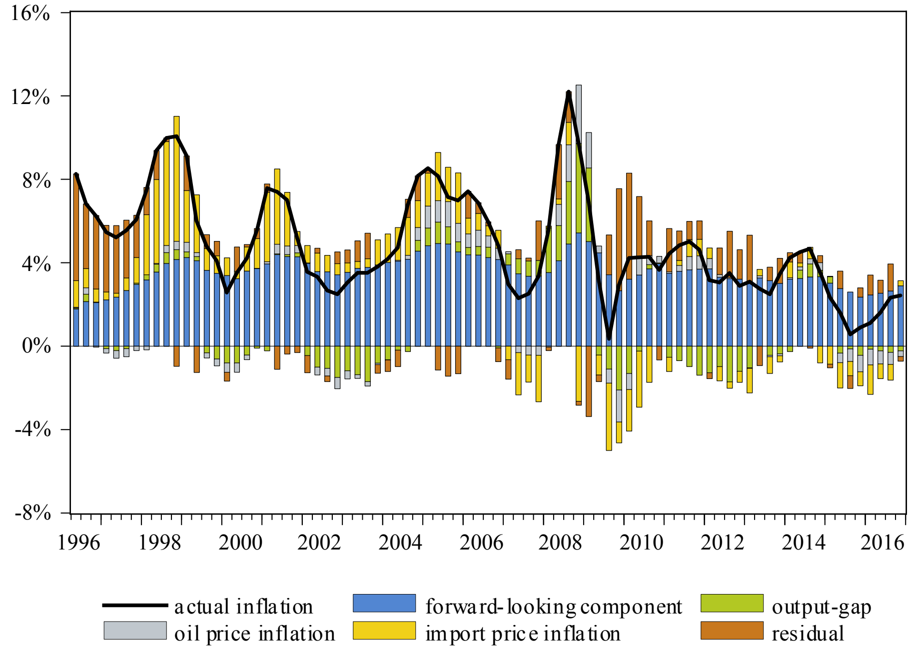
in December 2014, whereby fuel prices are adjusted monthly in response to changes in market prices. This might alter the pass-through of oil price movements to headline inflation in the future, increasing inflation volatility. Furthermore, future tax rate changes of the recently introduced goods and service tax will eventually map into consumer price developments.

sample, altering the risk of disinflationary pressures from import price inflation. Over the entire period, forward-looking dynamics account for 72% of headline inflation (on average, 3.56 percentage points of 4.91% headline inflation). In comparison, the contributions of economic slack and import inflation are limited.

The contribution of inflation expectations to the Philippines headline inflation increases mildly, being affected mainly by declining trend expectations. During 1996-2007, forward-looking dynamics account for 64% of the average headline inflation (on average, 3.64 percentage points of 5.8% headline inflation), as illustrated by Figure 3.13. Since the GFC, this share has increased to 87% (on average, 3.41 percentage points of 3.88% headline inflation between 2008 and 2016). A possible explanation is that the decline of the Philippines' headline inflation reflects the effects of decreasing trend expectations from around 4% between 1995 and 2008 to 2.85% in 2016. It must be noted that the weight with which trend inflation entered the inflation process is stable, since the coefficient of the trend expectations (Figure 3.14 Panel a) never deviates significantly from the value of 0.4 across the entire sample period, and hence cannot serve as an explanation for the increasing importance of the forward-looking component.

Non-oil-import and oil price inflation have a limited impact on headline inflation in the Philippines. The contribution of import prices to headline inflation declines substantially (Figure 3.13). Between 1996 and 2002, 28% of headline inflation (on average) can be associated with non-oil-import infla-

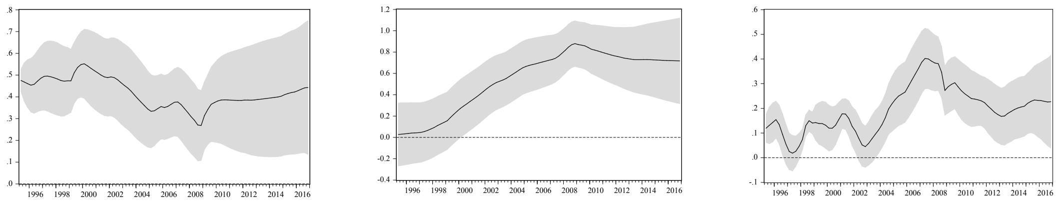
Figure 3.13: Main inflation components: the Philippines



The figure presents simulated contributions to the Philippines' headline inflation, resulting from the estimation of the benchmark model for the Philippines.

Figure 3.14: Time-varying coefficients: the Philippines

(a) β_t^1 (b) β_t^2 (c) β_t^3



The panels present the estimates and 95% confidence bands of the time-varying parameters, whereby β_t^1 is the coefficient of long-run inflation expectations, β_t^2 reflects the Phillips curve slope and β_t^3 is the coefficient of import price inflation.

tion (1.71 percentage points of 6.01% average headline inflation), whereas the relative contribution declines to 3% (0.14 percentage points of 4.37% average headline inflation) from 2003 to 2016. By contrast, oil price contributions are quite stable across the sample period, ranging from 1.04 percentage points to -0.55 percentage points. The underlying coefficient of import inflation (Figure 3.14 Panel c) increases from 0.1 in 1996 to 0.41 in 2006, and stabilises near 0.23 thereafter.

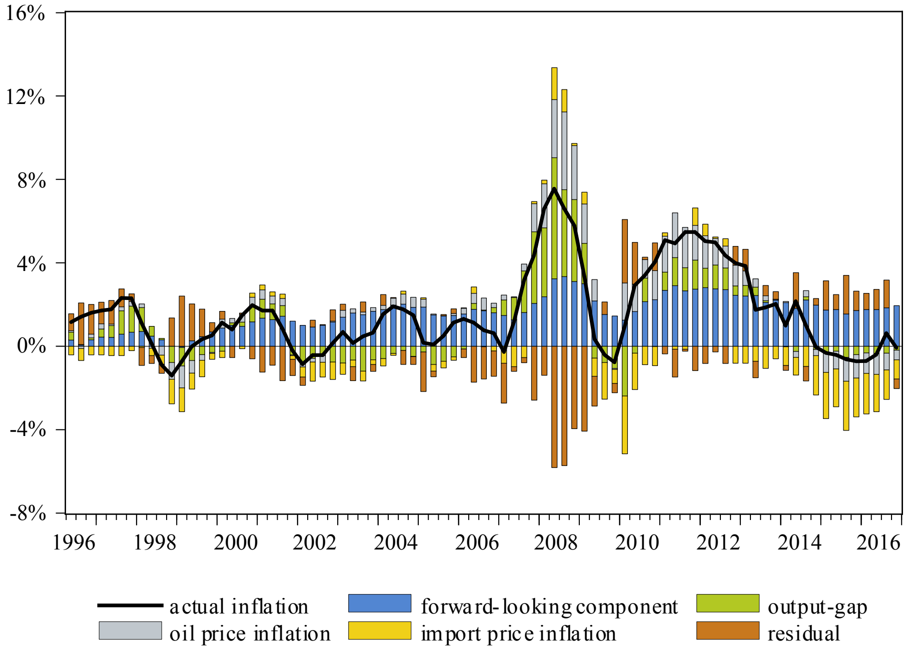
The Philippines' headline inflation stabilises and forward-looking dynamics increases after the GFC. Guinigundo (2016) also studies inflation dynamics in the Philippines, reaching the conclusion that the anchoring of inflation expectations may have strengthened recently. Our results, however, suggest that the increased contribution is not due solely to an increased sensitivity of inflation to forward-looking expectations, but can instead be explained by the fact that inflation declines following decreasing long-term inflation expectations. The long-run trend expectations have been lower than the BSP official inflation target rate of 3% since 2014, and continue to decline. From the perspective of monetary policy and central bank transparency, a continuation of inflation expectations below the official inflation target increases the risk of inflation expectations de-anchoring in the future. Against a background of persistently low oil prices, it may also increase the risk of further disinflation in the future.

Singapore

Being a small and open economy, Singapore's inflation dynamics are particularly vulnerable to cost-push shocks in times of economic turmoil. Singapore's headline inflation volatility increases after the GFC and experiences strong disinflationary pressures from 2011 up to 2016, which can be ascribed to declining non-oil-import and oil price inflation. This fall in non-oil-import and oil price inflation is dramatic enough to outweigh the increasing importance of forward-looking dynamics, causing a drop in inflation rates from 4.5% in 2012 to 1% in 2014, and into negative territory in 2016. Singapore's inflation drivers exhibit significantly higher variation over time than those of the other large ASEAN economies. Over the past two decades, headline inflation averages 2.4% (Figure 3.15), out of which forward-looking dynamics explain 1.85 percentage points. The movements of economic slack, non-oil-import and oil price inflation explain only 0.16 percentage points, 0.47 percentage points and -0.11 percentage points of the headline inflation, respectively.

The importance of forward-looking dynamics increases until the mid-2000s; thereafter inflation expectations help to mitigate large supply shock effects. The contribution of inflation expectations increases from 0.22 percentage points in 1996 to an average of 2.18 percentage points between 2007 and 2016, explaining 88% of average headline inflation during that period. The rising importance of inflation expectations stems from an increasing coefficient (Figure 3.16 Panel a) of forward-looking dynamics that rise from 0.19 in 1996 to 0.34 in 2016. These numbers are comparable to the results of Meng (2016). However, the coefficient on inflation expectation drops to 0.05 in 2008 before increasing again to 0.39 in 2010. This sudden decline and the subsequent rise of the coefficient is due to an abrupt drop of inflation expectations from 2.2% to 1.34% in 2004 (Figure 3.4). Inflation expectations remain at this low level until 2009 when expectations suddenly rise to 1.9%. Since long-run trend estimates for Singapore are not available and we thus rely on Consensus inflation expectations, it is likely that this sudden movement reflects common drawbacks (as mentioned in Section 3.1.5) of survey-based inflation expectations measures.

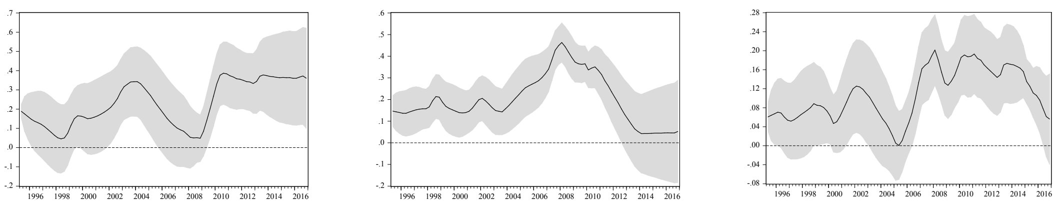
Figure 3.15: Main inflation components: Singapore



The figure presents simulated contributions to Singapore's headline inflation, resulting from the estimation of the benchmark model for the Singapore.

Figure 3.16: Time-varying coefficients: Singapore

(a) β_t^1 (b) β_t^2 (c) β_t^3



The panels present the estimates and 95% confidence bands of the time-varying parameters, whereby β_t^1 is the coefficient of long-run inflation expectations, β_t^2 reflects the Phillips curve slope and β_t^3 is the coefficient of import price inflation.

The significance of cyclical conditions as a driver of Singapore's inflation have been limited over the past two decades, with the exception of the GFC time line The average absolute contribution of economic slack is 0.51 percentage points, which is rather modest except for the GFC period. This low contribution is reflected in the dynamics of the coefficient on real economic activity (Figure 3.16 Panel b), with the value of 0.14 between 1996 and 2004, then rising to 0.46 during the GFC, and declining again to 0.05 in 2016. Non-oil-import and oil price inflation are more important as drivers of Singapore's headline inflation compared to the other ASEAN-5 countries.

Singapore has a trade intensive economy, which is reflected in a larger relative contribution of non-oil-import and oil price inflation to headline inflation, as compared to the whole ASEAN-5 region. The average absolute contribution of non-oil-import and oil price inflation increases from 0.59 percentage points between 1996 and 2006 to 1.9 percentage points from 2007 onwards, with the contributions of non-oil-import inflation being systematically higher than those of oil price inflation. Aligned with the increased contribution to headline inflation, the coefficient of import inflation increases from 0.06 in 1996 to 0.15 in 2014 but is decreasing thereafter.

Thailand

Even though the forward-looking component of Thai headline inflation is substantially strengthened after the AFC, it is not able to offset recent disinflationary pressures stemming from oil price declines. The evolution of Thailand's monetary policy framework following the AFC helped to anchor inflation expectations and strengthened the contribution of the forward-looking component of inflation dynamics, until the GFC occurred. However, Thailand experienced deflation in 2008 and 2015 due to the elevated importance of underutilisation during 2008 and the increased pass-through of oil price decline from 2014 onwards. Over the course of these episodes, the expectation-driven component of Thai headline inflation had not been able to offset supply-side shocks, indicating further improvements in monetary policy and communication.

Thailand's headline inflation has been on a gradual downward trend over the past two decades. Its headline inflation declines substantially from an average of 6.5% before the AFC, to only 2.5% thereafter. Thailand adopted an explicit inflation targeting scheme in 2001, and the implementation of a well-defined monetary policy framework had a significant impact on Thailand's inflation dynamics. Following the AFC, forward-looking dynamics explain more than half (53.25%) of headline inflation, a relative increase of two-thirds as compared to the period preceding the AFC (33.10%).

However, disinflation pressures after the GFC and finally deflation since early 2015 have raised concerns about the weakening of that expectations channel. From 2001 to 2010 the absolute contribution of forward-looking dynamics is 2.4 percentage points, but decreases to 2 percentage points thereafter. Moreover, the lower contribution of forward-looking dynamics reflects both lower coefficient estimates (Figure 3.18 Panel a) and a decline of long-run trend expectations (Figure 3.4). Contributions of economic slack to Thailand's headline inflation reveal a similar non-linear pattern compared to the other

ASEAN-5 countries: The contributions of economic slack are quite limited in 'normal times', but peak during the AFC and GFC. The time-varying contribution of economic slack to Thailand's headline inflation is comparable to the other ASEAN-5 countries. The impact of output-gap fluctuations reflects a non-linear pattern in the sense that the contribution is rather limited, yet it gains importance during the GFC.

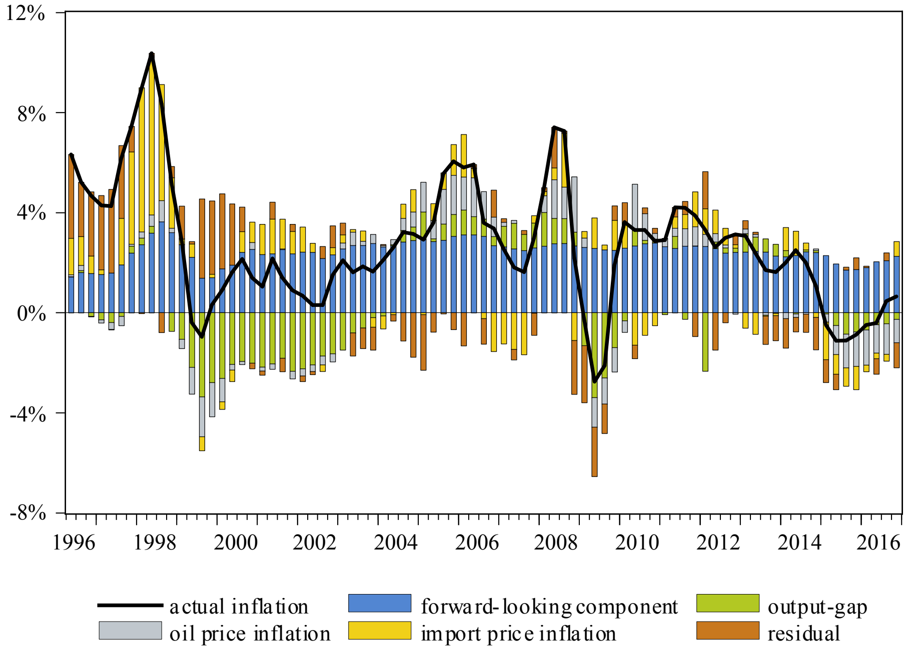
As Figure 3.17 reveals, the contribution of economic slack to inflation is on average -2.13 percentage points and -2.58 percentage points during the AFC and GFC respectively. By contrast, its average contribution is -0.08 percentage points since 2010. The increased importance of the output-gap during the GFC is not only due to a higher volatility of economic slack, but also to a temporary increase of structural relevance in the inflation process. The coefficient of economic slack increases from 0.03 percentage points in 1995 to 0.54 percentage points in 2008, then declining to 0.3 percentage points in 2015 (Figure 3.18 Panel b).

The contributions of oil price and non-oil-import price inflation are quite stable over time, and do not solely explain recent disinflation pressures. As Thailand has an oil-importing economy, it suggests that oil price movements should be relevant for Thailand's headline inflation to a certain degree. During the recent episode of disinflation and deflation, the actual level of oil price pass-through to consumer prices had been particularly relevant for policy decision-making, since oil price shocks can be regarded as an exogenous cost-push shock. However, Figure 3.17 reveals that the absolute contribution of oil price movements to headline inflation is quite constant, taking into account the lower level of headline inflation, which may reflect the Thai government's efforts to stabilise domestic oil prices by means of an oil fund levy and fuel excise (Direkudomsak, 2016).

Over the entire sample period, the absolute contributions of non-oil-import and oil price inflation were, on average, 0.54 percentage points and 0.75 percentage points. Notably, the contribution of non-oil-import inflation declines from an absolute average of 1.44 percentage points during the AFC to 0.47 percentage points for the remaining sample period. The coefficient of import inflation increases from 0.08 in 1996 to 0.2 in 2008, remaining stable thereafter. The unchanged quantitative impact of import inflation on headline inflation is hence a combined effect of lower non-oil-import price volatility and an altered sensitivity to import price inflation.

The evolution of the key drivers of Thailand's inflation dynamics over the past two decades has had important implications for monetary policy. Thailand is the only ASEAN-5 member country to have experienced deflation during the GFC. It must be noted that, while Thailand's headline inflation dynamics become increasingly forward-looking after the AFC, the weakening of the expectation component in the wake of the GFC causes Thailand's inflation to be more vulnerable to adverse price shocks.

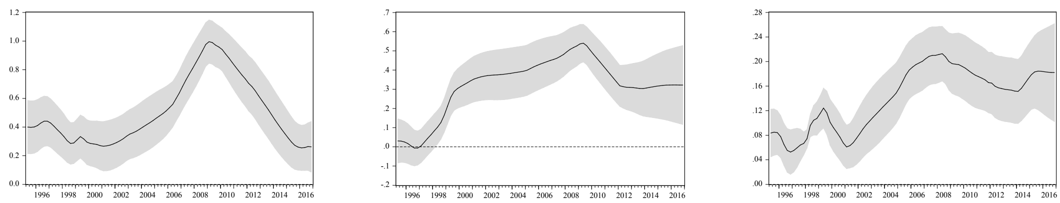
Figure 3.17: Main inflation components: Thailand



The figure presents simulated contributions to the Thai headline inflation, resulting from the estimation of the benchmark model for Thailand.

Figure 3.18: Time-varying coefficients: Thailand

(a) β_t^1 (b) β_t^2 (c) β_t^3



The panels present the estimates and 95% confidence bands of the time-varying parameters, whereby β_t^1 is the coefficient of long-run inflation expectations, β_t^2 reflects the Phillips curve slope and β_t^3 is the coefficient of import price inflation

Thailand's well-developed monetary policy framework helped to anchor inflation expectations until the GFC occurred. The Bank of Thailand (BOT) instituted an explicit inflation-targeting regime in 2000, managing to maintain low inflation rates and stabilise the exchange rate.[8] The BOT continu-

[8] The monetary policy framework of the Bank of Thailand (BOT) in the past two decades can be

ally developed its monetary policy framework as well as its transparency and communication strategies. In particular, the strategic switching from a core inflation target (targeting 0.5% to 3% for the quarterly average inflation) to a headline inflation target (annual average of 2.5%±1.5%) in early 2015 coincided with the intensification of disinflationary pressures stemming from the decline in oil prices, and represented an important challenge for the central bank's communicative strategy.

The Memorandum of Understanding with the Minister of Finance specifies that the Monetary Policy Committee (MPC) should explain why an inflation target is missed for a particular year. In addition to its regular communications and official publications concerning the state of the economy and monetary policy decisions, the BOT then has to issue a letter detailing the period within which inflation is expected to return to the target band, and how the Committee contemplates an appropriate monetary policy response. Unfortunately, BOT's assessment of headline inflation returning to its target did not materialise in 2015 and 2016.[9]

categorised into three different regimes. From 1995 until 1997 the BOT instituted a pegged exchange rate regime to the US Dollar; between 1997 and 2000 monetary targeting comprised BOT's monetary policy framework.

[9] In February 2015, the Thai MPC attributed negative inflation to the sharp decline in oil prices. While noting potential downside risks to its forecasts, the MPC expected inflation to return to positive territory in 2015 Q3, benefiting from lower oil prices raising disposable income and still high inflation expectations. No policy stimulus was envisaged at that stage, but policy rates were cut twice to 1.5% by April 2015. Throughout 2015, however, inflation rates remained negative, driven by persistent declines in energy prices, weak fresh food prices and low demand pressures. By January 2016 the return to positive territory was expected within the first half of 2016, to the target band in the second half of 2016, and to the mid-point target within two years. Monetary policy has remained on hold since April 2015, and attention to adverse consequences of excessively aggressive policy actions on financial market volatility and financial stability risks was stressed.

Our results suggest that the reduced importance of the forward-looking component did not offset the oil price shock that initiated a period of deflation for Thailand. The development of the monetary policy framework, communication strategy and expectations management strengthened the forward-looking component of Thailand's headline inflation until the GFC occurred. However, disinflationary pressures and deflation of recent years do not depend solely on falling oil prices, but also on continual communication efforts and policy actions to alter impact expectations and better align long-run inflation expectations to the inflation target. The purpose is to ensure that cost-push shocks of large magnitudes, such as the oil price fall in 2014 and 2015, can be spring-cushioned by the stable forward-looking behaviour of price setters that regard the central bank as a credible policy institution. Among others[10], Chantanahom et al. (2004) find that well-anchored inflation expectations are instrumental in preventing second-round effects from excessive swings in commodity prices in Thailand.

The recent downward trend in long-term inflation expectations in Thailand may become a future inflation risk (Figure 3.4). Communication from BOT is crucial for managing inflation expectations and dismissing perceptions of a constrained monetary policy. Further guidance, in terms of envisaged actions to achieve the target over a given time horizon, is fundamental to avoiding a de-anchoring of long-term inflation expectations after quite a protracted period of below-target inflation. A critical assessment of past performance,

[10] See Manopimoke (2015), Khemangkorn et al. (2008) and Carney (2015).

a detailed discussion of the shocks impairing the achievement of the inflation target, and a further elaboration on the internal debate underlying the policy decisions - reflecting dissenting views and arguments in the MPC minutes if applicable - can be instrumental in guiding the private sector's expectations and enhancing the effectiveness of Thailand's monetary policy. In addition, the announcement of an inflation target spanning a longer time horizon than one year could contribute to a stronger anchoring of inflation expectations.

3.4 Robustness checks

In this section we report on a series of sensitivity analyses of our benchmark model, Equation (3.1). We assess the performance of our estimation in two key dimensions; the data choices of distinct measures, and the model specifications. Our qualitative findings are robust to all these sensitivity checks. Corresponding results are here summarised, with detailed results shown in the appendix.

3.4.1 Different measures of macroeconomic indicators

While focusing on the specific model variations and re-estimations, the first set of robustness checks is concerned with different measures of the macroeconomic indicators used in the benchmark estimation.

Measures of the output-gap

The first variation is related to possible differences in the measurements of the output-gap due to different filtering techniques. We use the standard Hodrick-Prescott (HP) filter in our benchmark model. As a robustness test, we obtain output-gap measures from a two-sided band-pass filter, which also limits the sample size compared to the benchmark model. There are only marginal quantitative differences between the results from the re-estimated benchmark model with band-pass filtered output-gap and the HP-filtered output-gap (see Figures 3.19 to 3.25). Qualitatively, the results of coefficients and contributions are the same. Quantitative differences appear in the coefficients of output-gap that are slightly higher during the GFC across all countries. Furthermore, the median contribution of time variation of output-gap and import price inflation is marginally lower.

Indicators of inflation expectations

The second variation is concerned with possible differences between the estimates of the long-term inflation trend-expectations and more traditional survey-based expectations. Since survey-based expectations might be systematically biased, we use long-run trend expectations estimates, incorporating information from survey-based expectations. Our results indicate that inflation expectations are a crucial driver for inflation dynamics that can potentially outweigh exogenous cost-push shocks. Therefore, it is important to verify whether the coefficients and contributions are robust across different measures of inflation expectations. We hence substitute the trend-expectation estimates with Consensus long-term inflation expectations. Re-estimating our benchmark model using Consensus long-run inflation expectations yield qualitatively equal results of coefficients and contributions (see Figures 3.26 to 3.32). As revealed in Figure 3.4, trend expectations and consensus expectations display some quantitative differences, depending on the point in time and the respective country. Overall, Consensus survey expectations are systematically higher than the long-run inflation trend estimates. This is reflected in the median contributions of the forward-looking component using Consensus expectations compared to the benchmark results. The median contributions related to the time variation in parameters are quantitatively slightly more pronounced for the output-gap and import price inflation, and less pronounced for the forward-looking component. Estimated coefficients, however, depict almost no quantitative differences compared to the benchmark results.[11]

Import price measures

Import price inflation data might depend on whether it is retrieved from terms of trade or obtained from national accounting. Even though data quality and provision has been improving constantly, and depending on the country, there are still substantial differences across the import price series retrieved from different sources. Thus, we also re-estimate our benchmark model with import prices obtain from the WEO database as a third variation. Overall, the qualitative implications of the re-estimated coefficients and con-

[11] Results of Singapore exactly match the benchmark results, as we could not use trend inflation estimates for Singapore in the benchmark estimation.

tributions (see Figures 3.33 to 3.39) are in line with our benchmark model estimates and respective contributions. The coefficients of the forward-looking component are systematically higher, and hence the correlation between the DE transparency index and the coefficients on the forward-looking component is altered to 0.69. Although the combined contribution of oil and import price inflation is quantitatively similar to the benchmark results, the weight between the contributions of import and oil price inflations shifts towards the latter. Resultantly, the oil price inflation constitutes a much larger share of the median - and also country-specific - contribution than import price inflation.

3.4.2 Model specifications

The second set of robustness checks is concerned with the model specification.

Coefficients of non-oil-import and oil price inflation

The fourth variation is related to possible differences of coefficients of non-oil-import price inflation and oil price inflation in the Phillips curve. As mentioned in the estimation section, we only estimate three parameters for our benchmark model: a coefficient for the forward-looking dynamics, a coefficient for the economic slack that represents the slope of the PC, and one coefficient for overall import price inflation, averaging across different dynamics of non-oil-import prices and oil prices. We decompose the contributions using the import price coefficient for both series ex-post. The reasoning for our benchmark procedures is that import price inflation should in principle contain oil price inflation for oil importing countries. Since not all the ASEAN-5 countries are oil importers though, we explicitly include non-oil-import price inflation and oil price inflation in the model for the fourth variation, estimating the four parameters.

Results from the model with four parameters (see Figures 3.40 to 3.46) depict much higher contributions of the residuals to the median as well as country-specific headline inflation, whereby median contributions account for near 30%, compared to roughly 10% in the benchmark estimation. Moreover, the contribution of oil price inflation is substantially altered, whereby the contributions of forward-looking dynamics are quantitatively lower in comparison with the benchmark results.

The country-specific coefficients of non-oil-imports are systematically higher (by roughly 0.05), but they reveal the same dynamics as in the benchmark case. For the oil-exporting countries (Singapore and Malaysia), the coefficients of oil price inflation are significantly positive throughout the sample period, but reveal little time variation. The oil price inflation coefficients are small and do not change significantly over time across the countries - the significant levels of coefficients range from 0.005 to 0.028. The remaining coefficients are quantitatively negligible in difference. Overall, the fourth specification reveals qualitatively similar results to the benchmark estimation.

Model including oil price inflation and exchange rate

As most of the ASEAN-5 economies are highly open economies, exchange rate movements might have a relevant pass-through to headline inflation. In the last robustness check, we augment the model specification with the exchange rate in addition to expectations, economic slack and oil price inflation. In line with the empirical work done by Devereux and Yetman (2014), exchange rate pass-through is very limited for the ASEAN-5 countries (see Figures 3.47 to 3.53). The coefficient on exchange rates is significant across countries and time.[12] The median contributions of the forward-looking component only reveal slight quantitative differences compared to the benchmark model. The median and country-specific contributions of the exchange rate are quantitatively very small. The median and country-specific contributions of oil price inflation, however, are larger than in the benchmark model.

3.5 Conclusion

The primary purpose of our work is to investigate the main drivers of consumer price headline inflation of the ASEAN-5 economies. We aim to determine the evolution of inflation components from 1995 to 2016 for the ASEAN-5 region, and to evaluate whether changes in the inflation drivers are related to the evolution of monetary policy transparency and communication. We also investigate the country-specific developments of inflation dynamics. For this purpose, we estimate the country-specific Phillips curves

[12] Singapore is an exception with a significant coefficient of -0.8. The coefficient does not change significantly over time.

allowing for time-varying parameters for each of the ASEAN-5 countries respectively to account for the region's evolving monetary policy regimes and business cycles, using trend inflation estimates as an indicator of long-run inflation expectations.

We find that, for the inflation dynamics of the ASEAN-5 region as a whole, expectations are quantitatively more important than economic slack, non-oil-import and oil price inflation. Moreover, the relative contributions of forward-looking dynamics increase over time, especially since the AFC. The coefficient of the forward-looking component of inflation, as well as the absolute contribution of the forward-looking dynamics, depict a positive relation with central bank transparency. Thus, a higher degree of central bank transparency in the ASEAN-5 countries is associated with a higher forward-looking dynamic in these countries. In terms of the supply-side drivers of headline inflation in the ASEAN-5 region, we find that quantitative contributions of economic slack are limited, with the exception of the AFC and GFC episodes. Non-oil-import price inflation becomes less important in the early 2000s, which is possibly related to exchange-rate liberalisation during the recovery phase of the AFC. By contrast, oil price inflation becomes slightly more important over time, especially during the recent episode of low inflation. Our results indicate the existence of non-linearities in the transmission of supply shocks during times of recession. The importance of the forward-looking component for ASEAN-5 inflation, as well as non-linearities in the Phillips curve, is reinforced when we compare the forecasting performance of our Phillips curve specification to a variety of alternative models, including plain time-series models.

We can draw the following conclusions from our country-specific analysis:

In the case of Indonesia, the increased importance of forward-looking dynamics stabilised the headline inflation after the GFC. Improvements in the anchoring of inflation expectations, as well as improved coordination between the government's policies on administrated energy prices and the central bank, served to attenuate the downward pressures from oil price developments in 2015.

Malaysian headline inflation is remarkably stable compared to the other ASEAN-5 member countries. An increasing coefficient of the forward-looking component and stable long-run expectations helped to limit the disinflationary pressures that stemmed from falling oil and non-oil-import prices. However, the implementation of the fiscal act of 2010 might threaten stable inflation rates in Malaysia due to more volatile energy price developments, and adjustments of goods and service tax rates.

Inflation expectations has become ever more important for the Philippines' headline inflation. However, this is not due to an increased sensitivity of inflation to the forward-looking component, but can rather be explained by inflation following decreasing long-run trend expectations, which have been lying below the BSP official inflation target since 2014. Combined with the altered impact of supply-side shocks, this may threaten the stable headline inflation in the future, especially in the circumstance of persistently low oil prices.

The forward-looking component of Singapore's headline inflation has substantially increased since 2008. Inflation dynamics in Singapore are especially vulnerable to cost-push shocks in times of economic turmoil. The non-oil-import and oil price inflation rates are more significant elements of Singapore's inflation processes, compared to the other countries in the ASEAN-5 region. Especially in recent years, exogenous cost-push shocks in the form of import inflation movements outweighed the forward-looking component.

The evolution of Thailand's monetary policy framework in the wake of the ACF helped to anchor inflation expectations, and to strengthen the contribution of the forward-looking component of inflation dynamics up until the GFC. However, Thailand experienced deflation in 2008 and 2015, and over the course of these episodes the expectation-driven component of Thai headline inflation had been unable to offset supply-side shocks.

In the overall view, our results indicate that oil price inflation is a key driver of the recent disinflation episode, but from a historical perspective, its contribution to headline inflation dynamics is relatively limited. Similarly, while cyclical fluctuations are important in severe recessions, they play a limited role in regular economic circumstances. We also find strong empirical support for the view that monetary policy affects inflation dynamics in these countries. We illustrate that improved management of inflation expectations by the respective central banks serves to reduce the contributions of oil prices and economic slack to the overall inflation dynamics.

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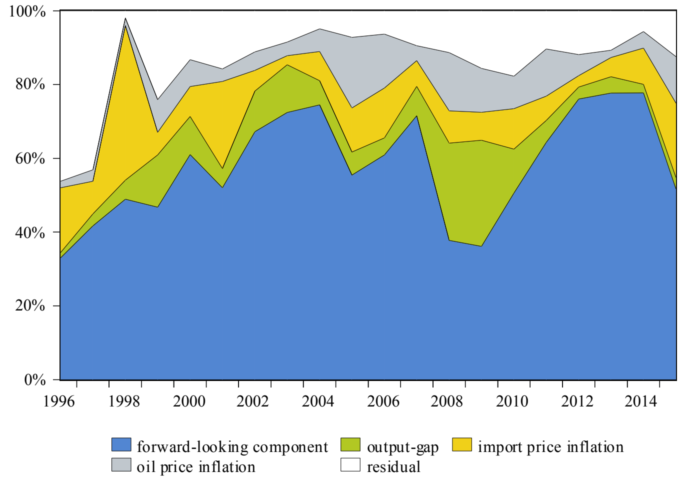
3.6 Appendix

In this appendix we present detailed results of all additional model variants that are discussed in the forecasting and in the robustness exercise. Underlying methodology and data used is described in the paper. Variations that involve modification of the benchmark specification Equation (3.1) is denoted at the beginning of each subsection.

3.6.1 Model with BP-filter

Figure 3.19: Relative median contribution of inflation drivers across ASEAN-5 countries: BP-filtered output-gap

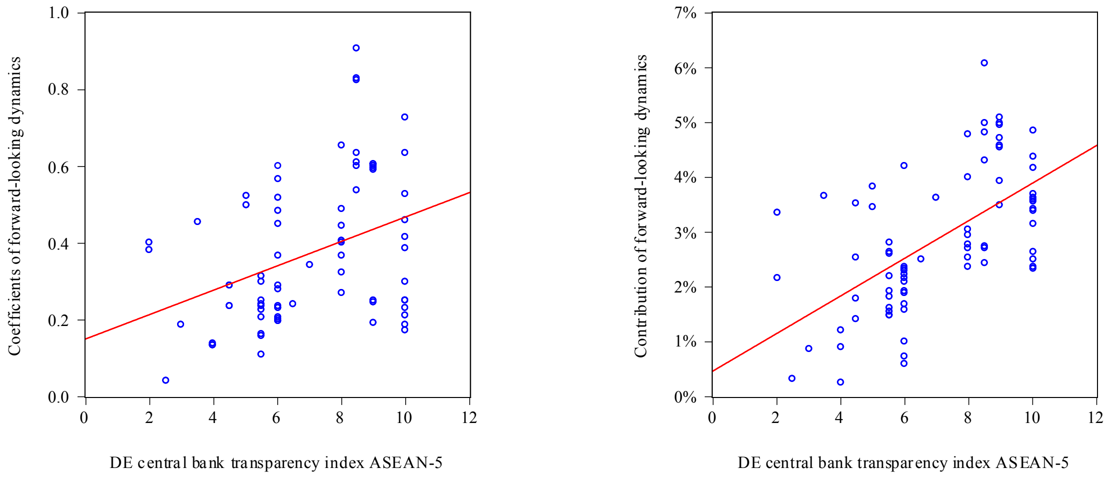


The figure presents the relative median contributions that are the ratios of the median contributions, that result from the models with the BP-filtered output-gaps, across countries and the median headline inflation rates across counties at each point in time.

Figure 3.20: Correlation between forward-looking dynamics and DE transparency index: BP-filtered output-gap

(a) Coefficients and DE transparency index

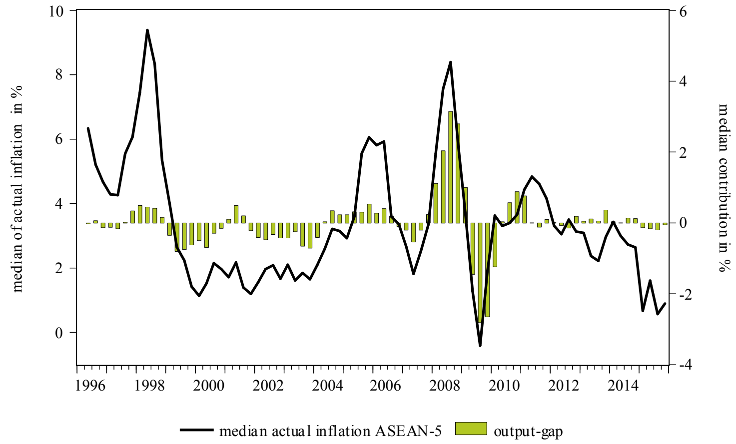
(b) Contributions and DE transparency index



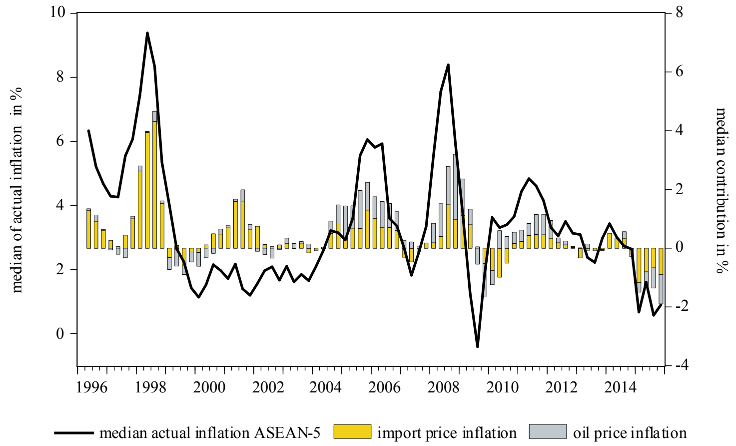
The panels contain scatter plots and the corresponding regression lines of the estimated country-specific time-varying coefficient (Panel a) as well as the simulated contributions (Panel b) of the forward-looking component,that result from the model with the BP-filtered output-gap, and the DE transparency index at each point in time.

Figure 3.21: Median contributions of ASEAN-5 countries: BP-filtered output-gap

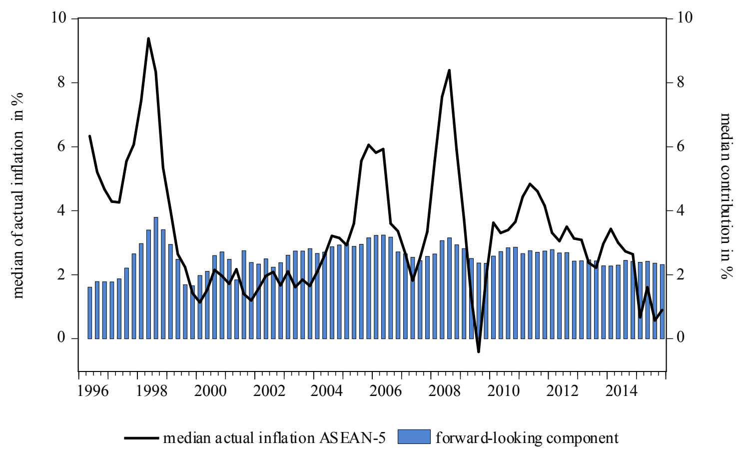
(a) Output-gap



(b) Import and oil price inflation



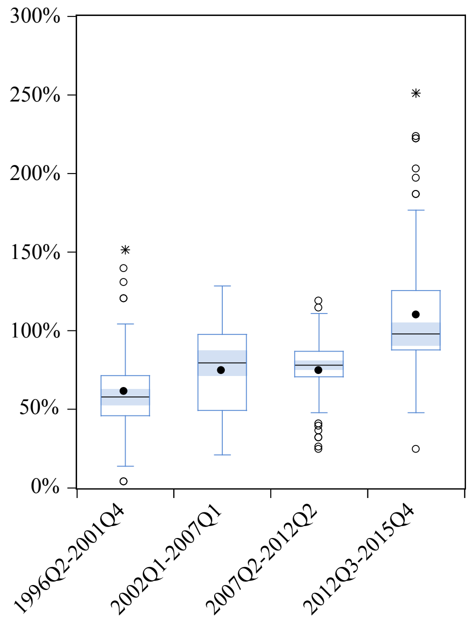
(c) Forward-looking dynamics



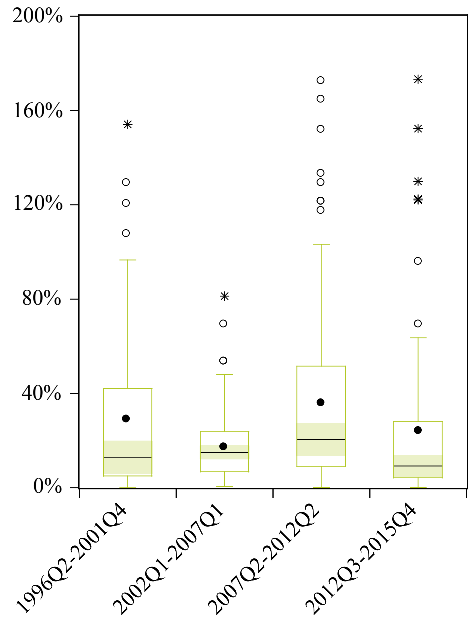
We obtain the median contributions by estimating the model, that include the BP-filtered output-gap, for each country, simulating the contributions of the inflation drivers as well as the residual and taking the median of the contributions across countries.

Figure 3.22: Distribution of country-specific ratios of absolute contributions and average headline inflation: BP-filtered output-gap

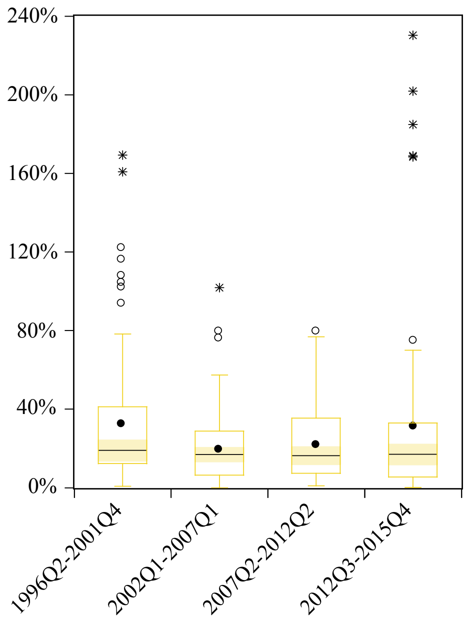
(a) Contributions of forward-looking dynamics



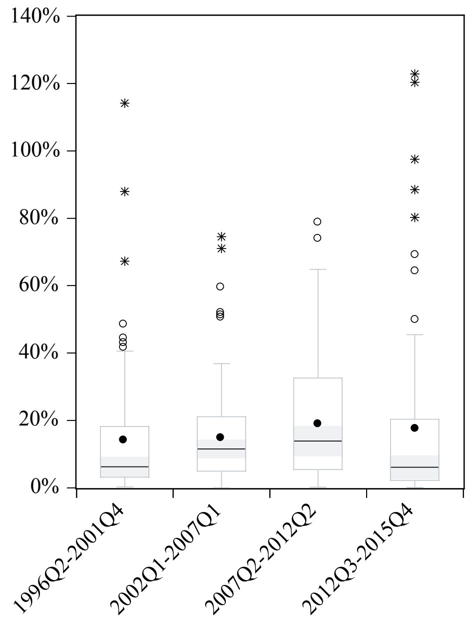
(b) Contributions of the output-gap



(c) Contributions of import price inflation



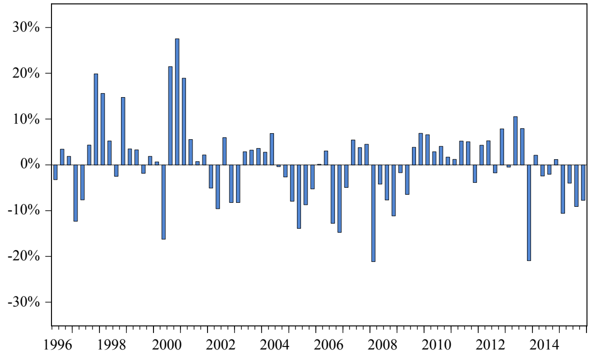
(d) Contribution of oil price inflation



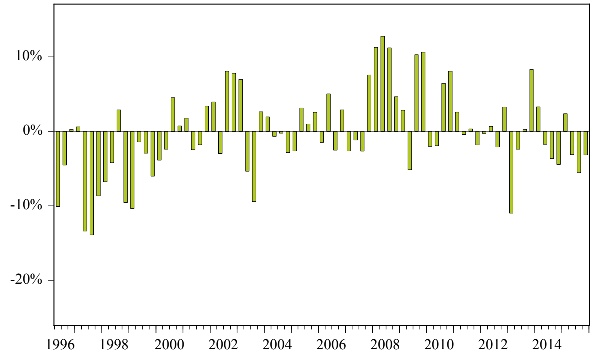
The underlying data for each boxplot comprises the country-specific ratios of contributions, which result from the model with BP-filtered output-gap, over the mean of country-specific headline inflation, both in absolute values, for each subsample and inflation driver.

Figure 3.23: Contributions resulting from time-varying parameters: BP-filtered output-gap

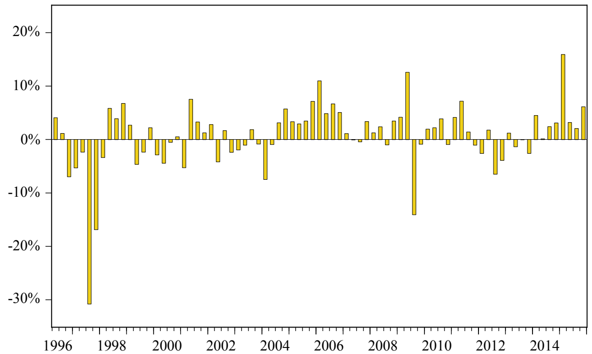
(a) Forward-looking dynamics



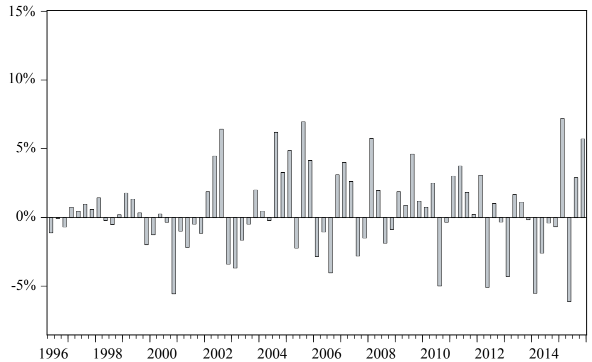
(b) Output-gap



(c) Non-oil-import price inflation



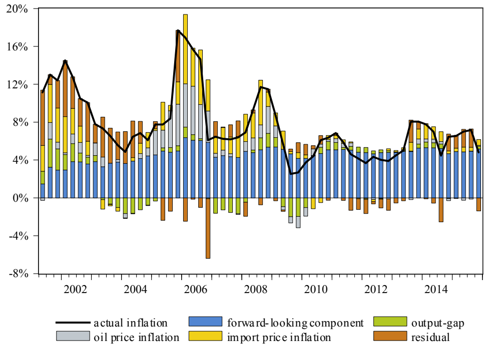
(d) Oil price inflation



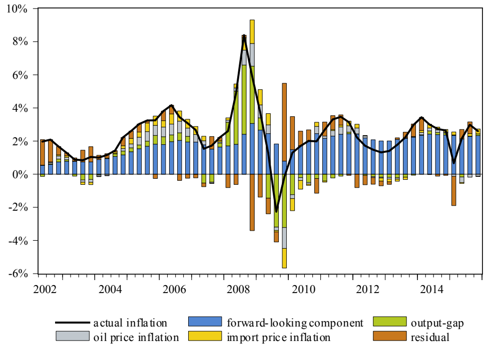
The contributions of the time variation in parameters are calculated as the difference between median contributions simulated with the estimated model, that include BP-filtered output-gap, without time variation in parameters and median contributions simulated with the estimation results of the model with time-varying parameters.

Figure 3.24: Main inflation components: BP-filtered output-gap

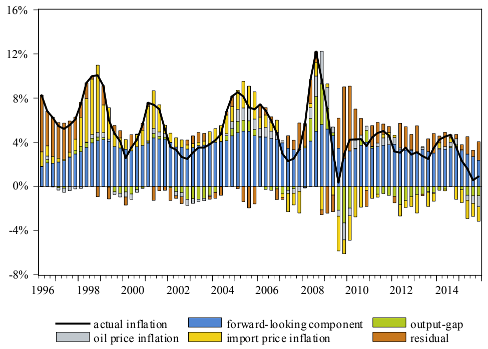
(a) Indonesia



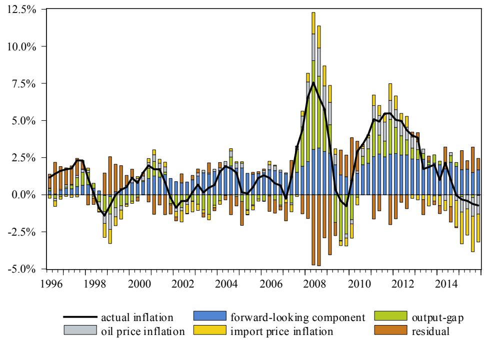
(b) Malaysia



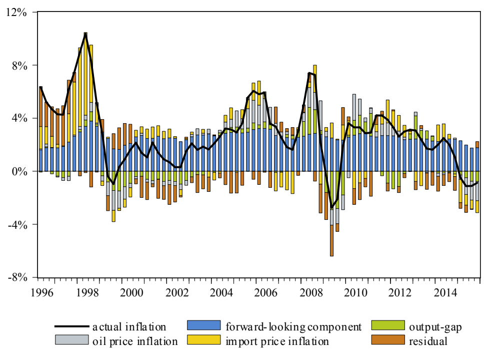
(c) The Philippines



(d) Singapore

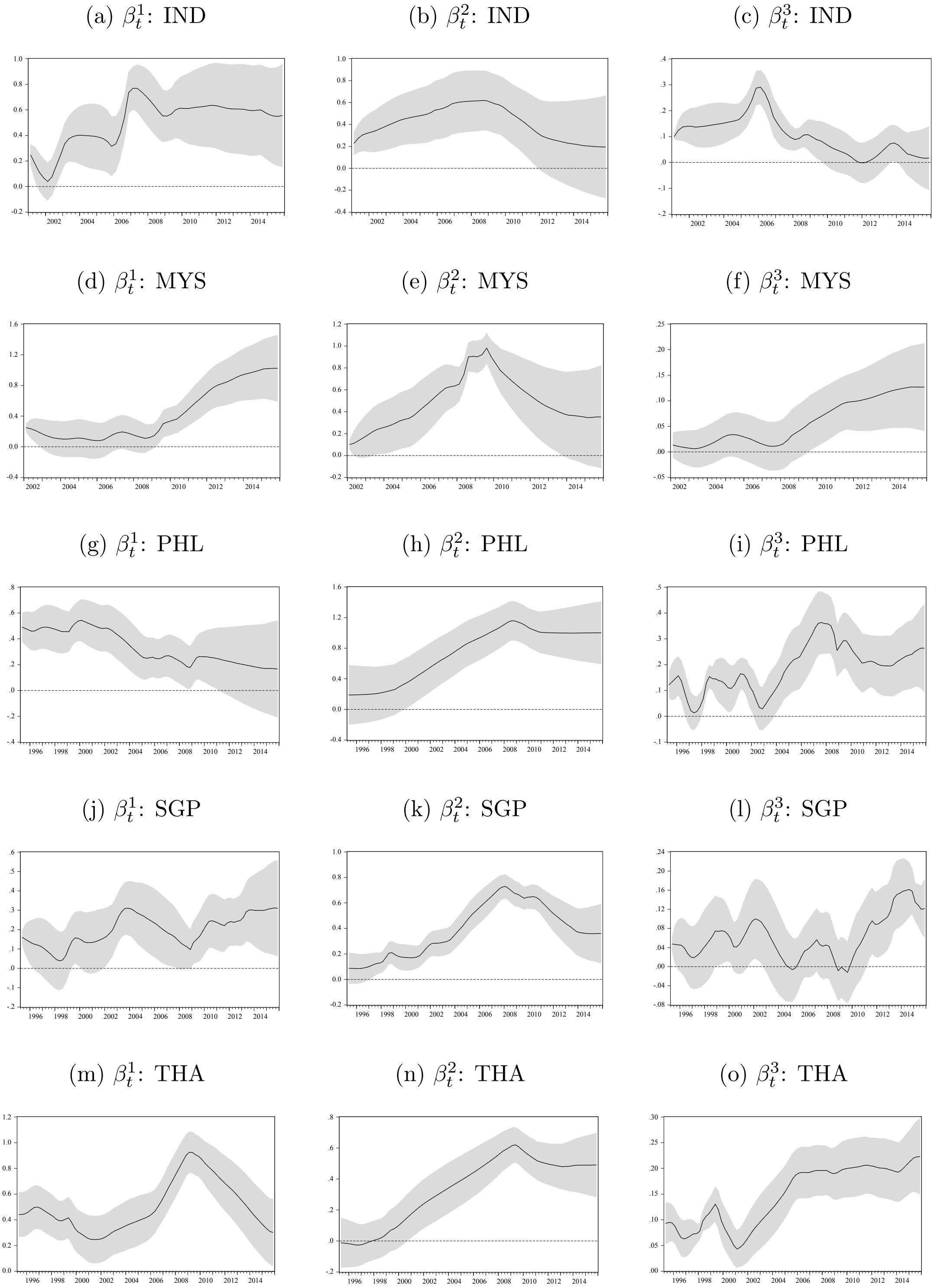


(e) Thailand



The panels presents simulated country-specific contributions to the ASEAN-5 headline inflation rates, resulting from the country-specific estimation of the model that include BP-filtered output-gap.

Figure 3.25: Time-varying coefficients: BP-filtered output-gap



(a) β_t^1: IND (b) β_t^2: IND (c) β_t^3: IND

(d) β_t^1: MYS (e) β_t^2: MYS (f) β_t^3: MYS

(g) β_t^1: PHL (h) β_t^2: PHL (i) β_t^3: PHL

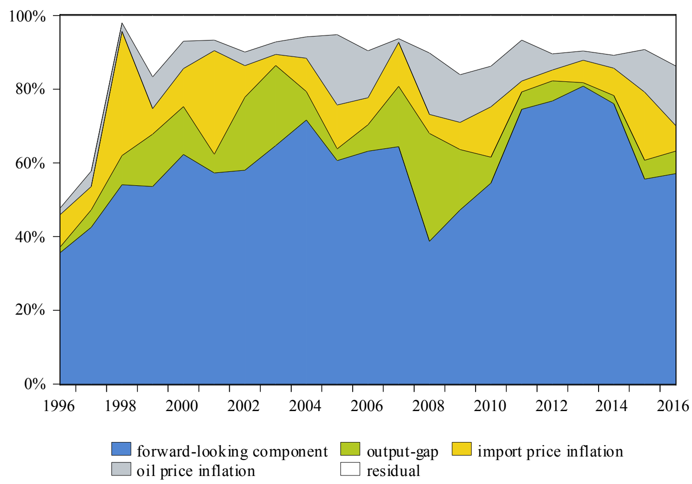
(j) β_t^1: SGP (k) β_t^2: SGP (l) β_t^3: SGP

(m) β_t^1: THA (n) β_t^2: THA (o) β_t^3: THA

The panels present the estimates and 95% confidence bands of the time-varying parameters, whereby β_t^1 is the coefficient of long-run inflation expectations, β_t^2 reflects the Phillips curve slope and β_t^3 is the coefficient of import price inflation. Country-codes are defined as IND-Indonesia, MYS-Malaysia, PHL-the Philippines, SGP-Singapore and THA-Thailand.

3.6.2 Model with Consensus expectations

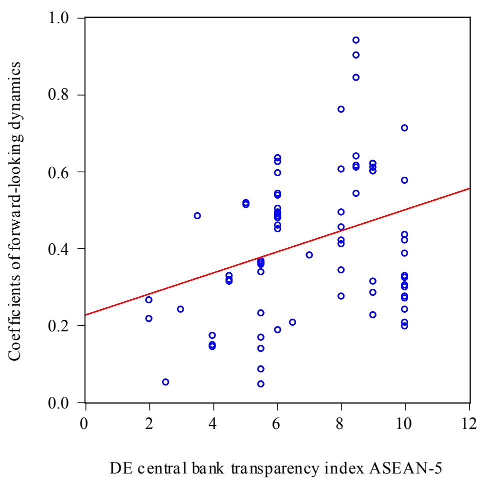
Figure 3.26: Relative median contribution of inflation drivers across ASEAN-5 countries: Consensus expectations



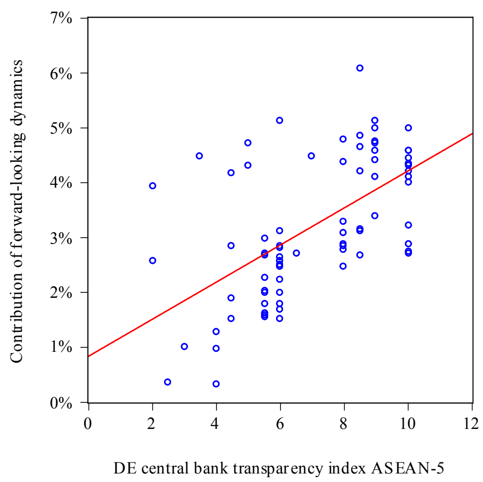
The figure presents the relative median contributions that are the ratios of the median contributions, that result from the models with Consensus expectations, across countries and the median headline inflation rates across counties at each point in time.

Figure 3.27: Correlation between forward-looking dynamics and DE transparency index: Consensus expectations

(a) Coefficients and DE transparency index



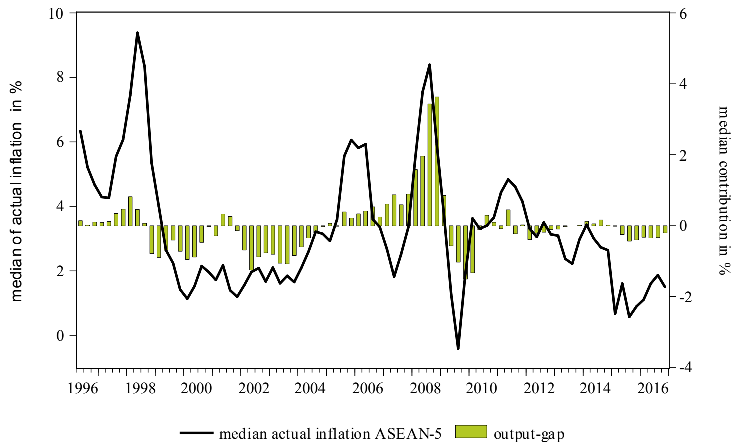
(b) Contributions and DE transparency index



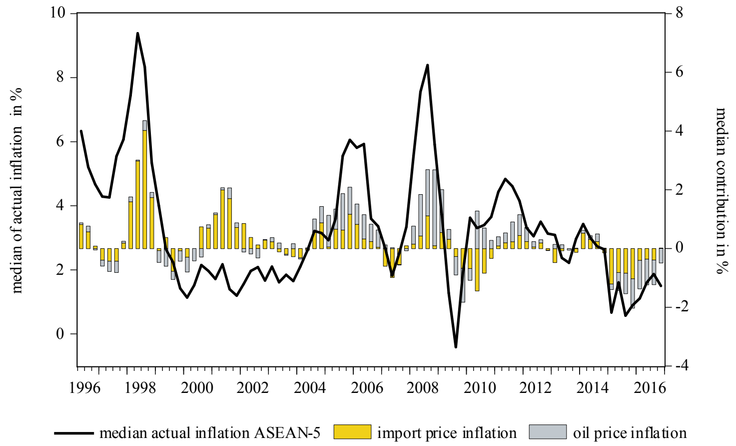
The panels contain scatter plots and the corresponding regression lines of the estimated country-specific time-varying coefficient (Panel a) as well as the simulated contribution (Panel b) of the forward-looking component, that result from the model with the Consensus expectations, and the DE transparency index at each point in time.

Figure 3.28: Median contributions of ASEAN-5 countries: Consensus expectations

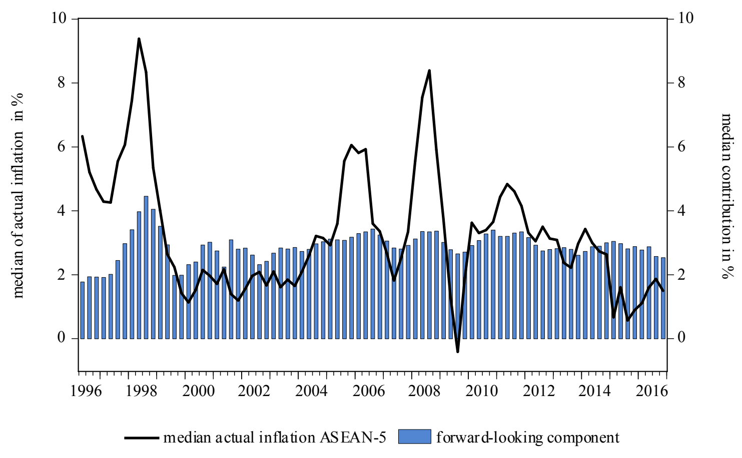
(a) Output-gap



(b) Import and oil price inflation



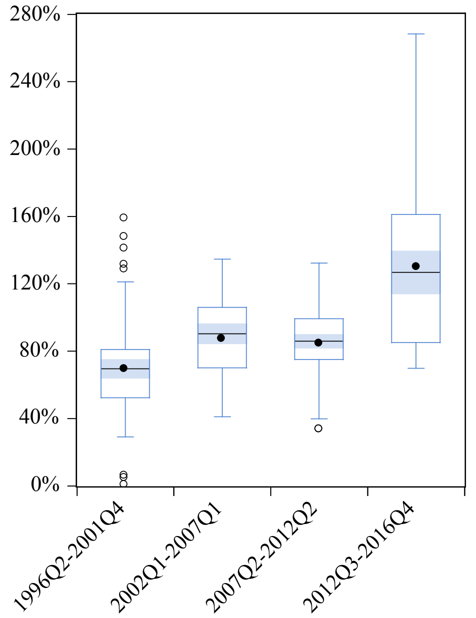
(c) Forward-looking dynamics



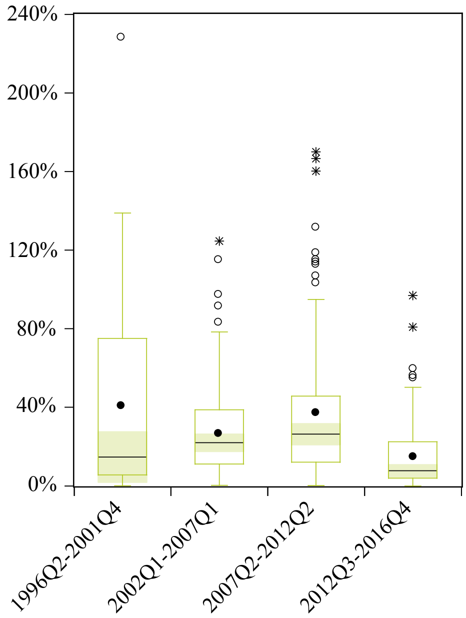
We obtain the median contributions by estimating the model, that include Consensus expectations, for each country, simulating the contributions of the inflation drivers as well as the residual and taking the median of the contributions across countries.

Figure 3.29: Distribution of country-specific ratios of absolute contributions and average headline inflation: Consensus expectations

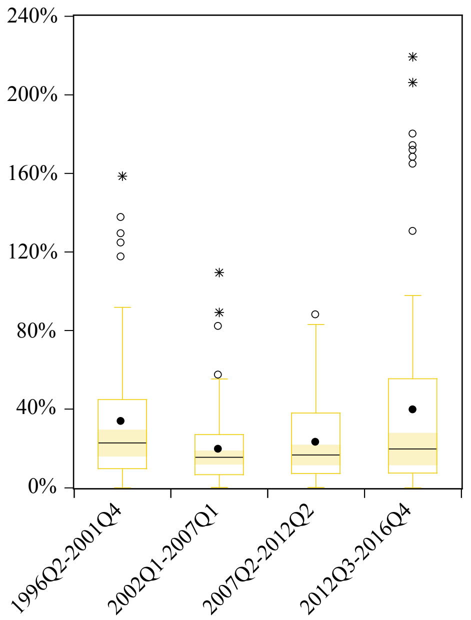
(a) Contributions of forward-looking dynamics



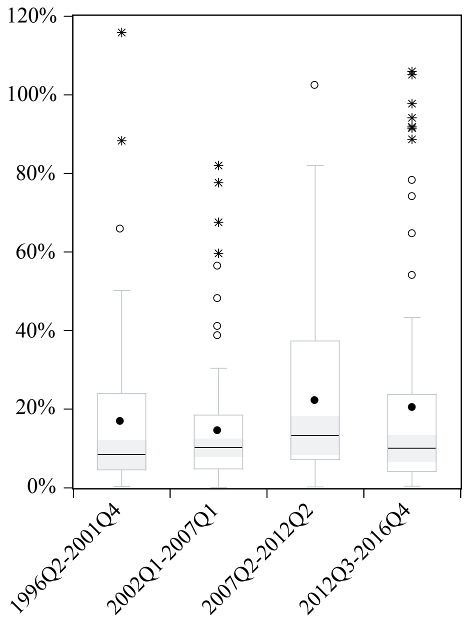
(b) Contributions of the output-gap across



(c) Contributions of import price inflation



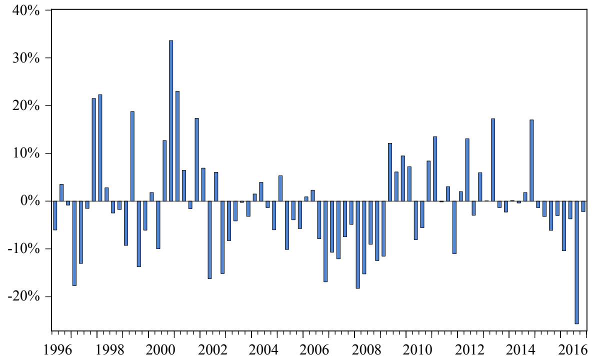
(d) Contribution of oil price inflation



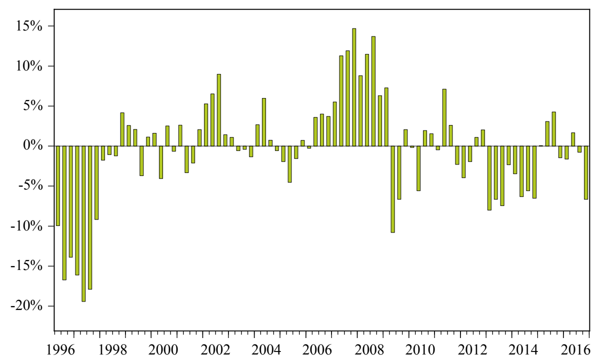
The underlying data for each boxplot comprises the country-specific ratios of contributions, that result from the model with Consensus expectations, over the mean of country-specific headline inflation, both in absolute values, for each subsample and inflation driver.

Figure 3.30: Contributions resulting from time-varying parameters: Consensus expectations

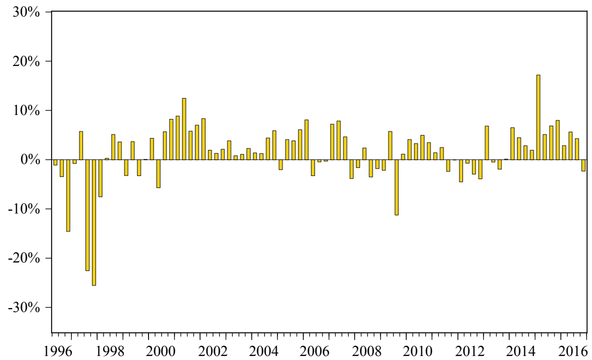
(a) Forward-looking dynamics



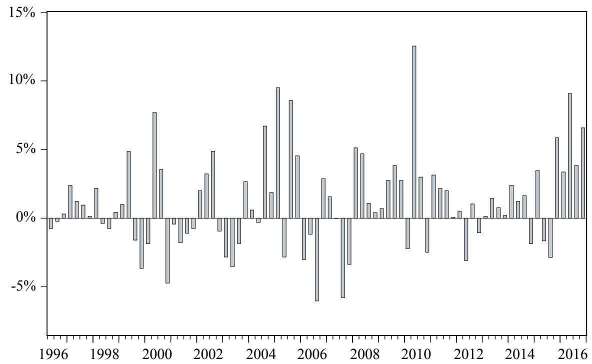
(b) Output-gap



(c) Non-oil-import price inflation



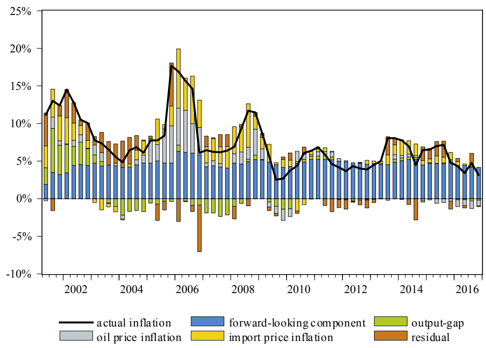
(d) Oil price inflation



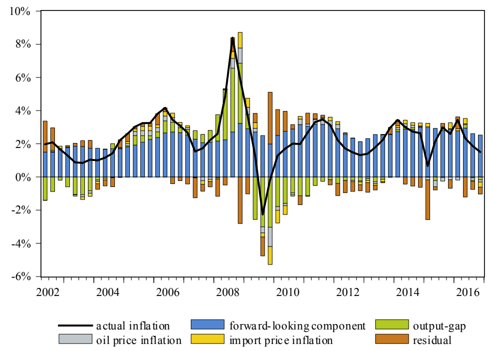
The contributions of the time variation in parameters are calculated as the difference between median contributions simulated with the estimated model, that include Consensus expectations, without time variation in parameters and median contributions simulated with the estimation results of the model with time-varying parameters.

Figure 3.31: Main inflation components: Consensus expectations

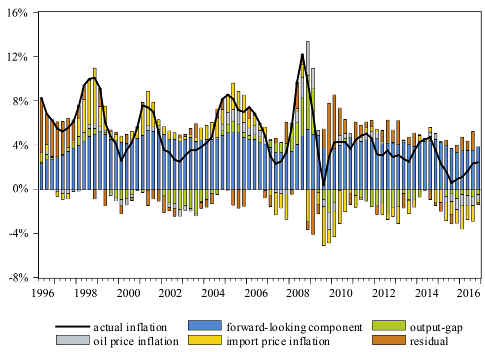
(a) Indonesia



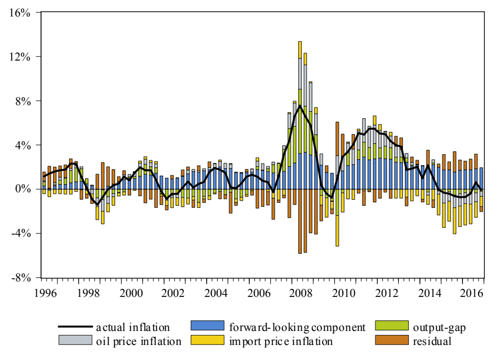
(b) Malaysia



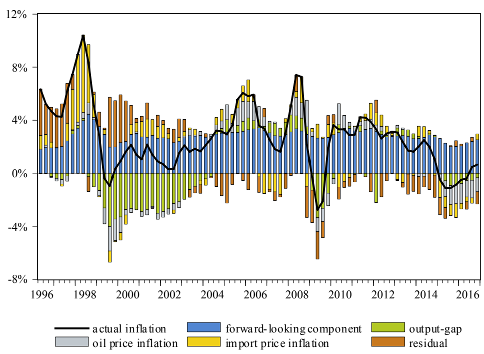
(c) The Philippines



(d) Singapore

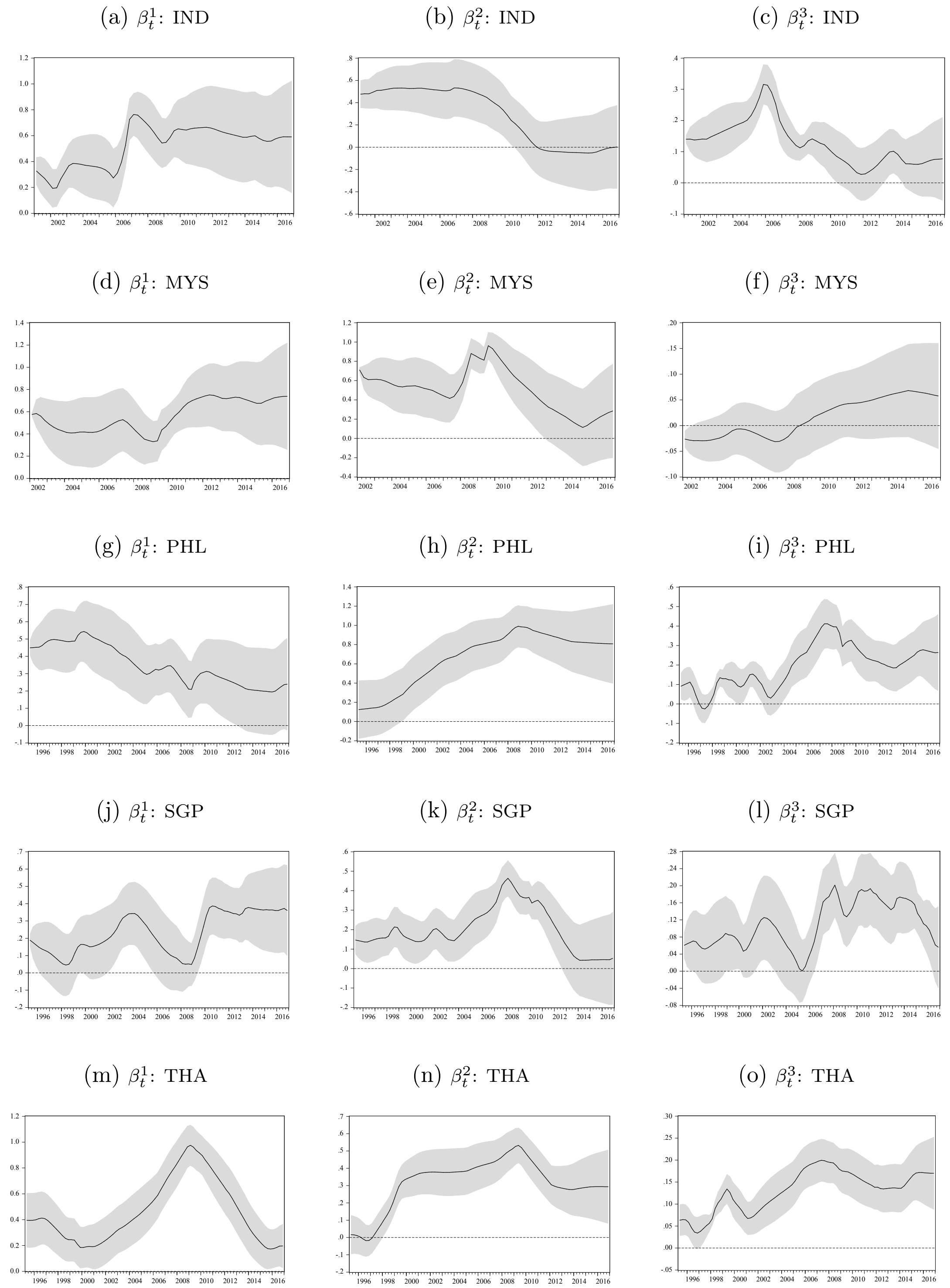


(e) Thailand



The panels presents simulated country-specific contributions to the ASEAN-5 headline inflation rates, resulting from the country-specific estimation of the model that include Consensus expectations.

Figure 3.32: Time-varying coefficients: Consensus expectations



(a) β_t^1: IND (b) β_t^2: IND (c) β_t^3: IND

(d) β_t^1: MYS (e) β_t^2: MYS (f) β_t^3: MYS

(g) β_t^1: PHL (h) β_t^2: PHL (i) β_t^3: PHL

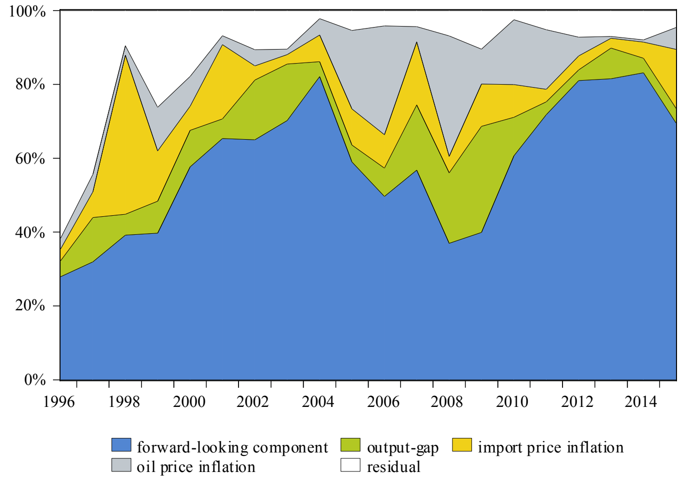
(j) β_t^1: SGP (k) β_t^2: SGP (l) β_t^3: SGP

(m) β_t^1: THA (n) β_t^2: THA (o) β_t^3: THA

The panels present the estimates and 95% confidence bands of the time-varying parameters, whereby β_t^1 is the coefficient of long-run inflation expectations, β_t^2 reflects the Phillips curve slope and β_t^3 is the coefficient of import price inflation. Country-codes are defined as IND-Indonesia, MYS-Malaysia, PHL-the Philippines, SGP-Singapore and THA-Thailand.

3.6.3 Model using WEO import price inflation

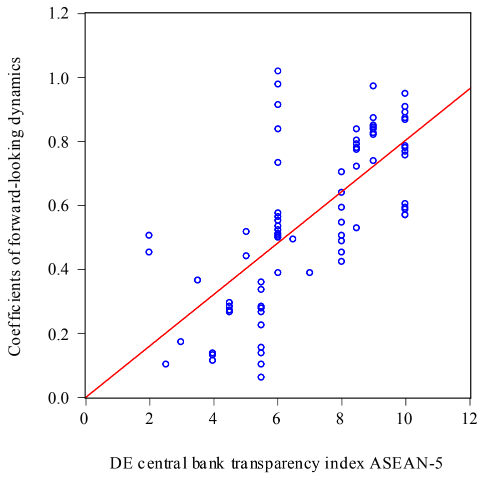
Figure 3.33: Relative median contribution of inflation drivers across ASEAN-5 countries: WEO import prices



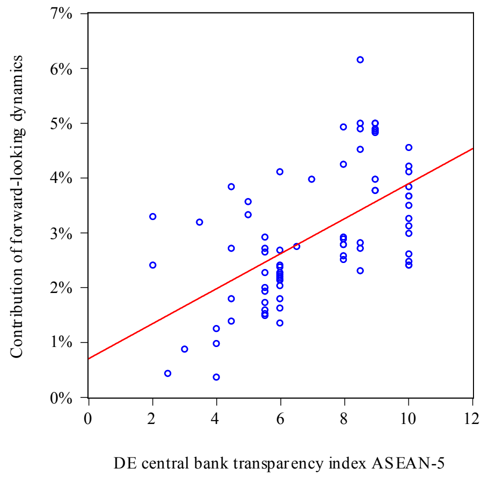
The figure presents the relative median contributions that are the ratios of the median contributions, that result from the models with WEO import prices, across countries and the median headline inflation rates across counties at each point in time.

Figure 3.34: Correlation between forward-looking dynamics and DE transparency index: WEO import prices

(a) Coefficients and DE transparency index



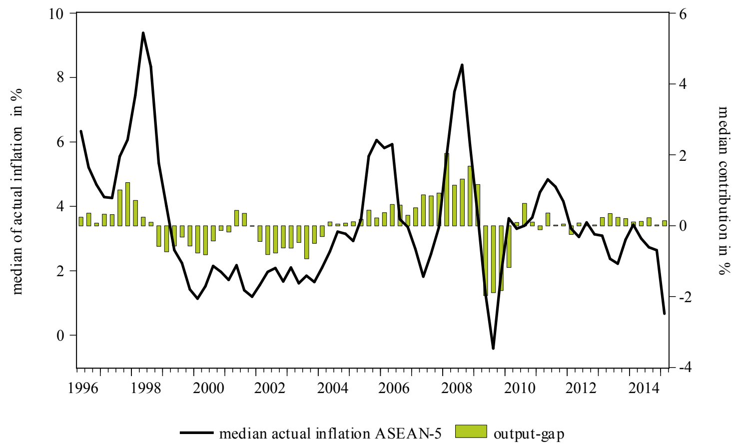
(b) Contributions and DE transparency index



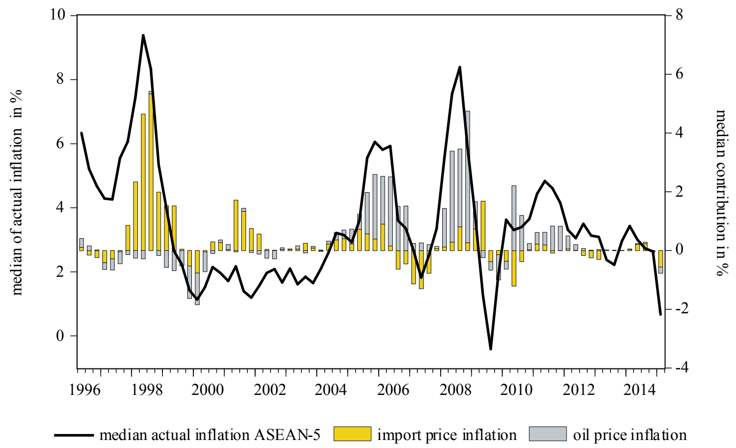
The panels contain scatter plots and the corresponding regression lines of the estimated country-specific time-varying coefficient (Panel a) as well as the simulated contribution (Panel b) of the forward-looking component, that result from the model with WEO import prices, and the DE transparency index at each point in time.

Figure 3.35: Median contributions of ASEAN-5 countries: WEO import prices

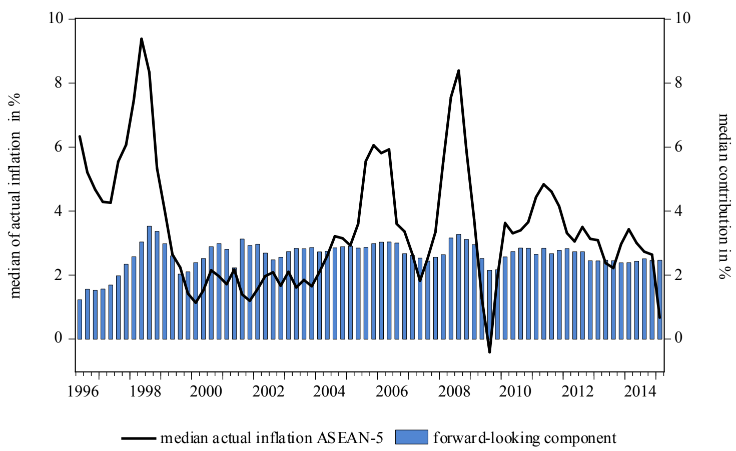
(a) Output-gap



(b) Import and oil price inflation

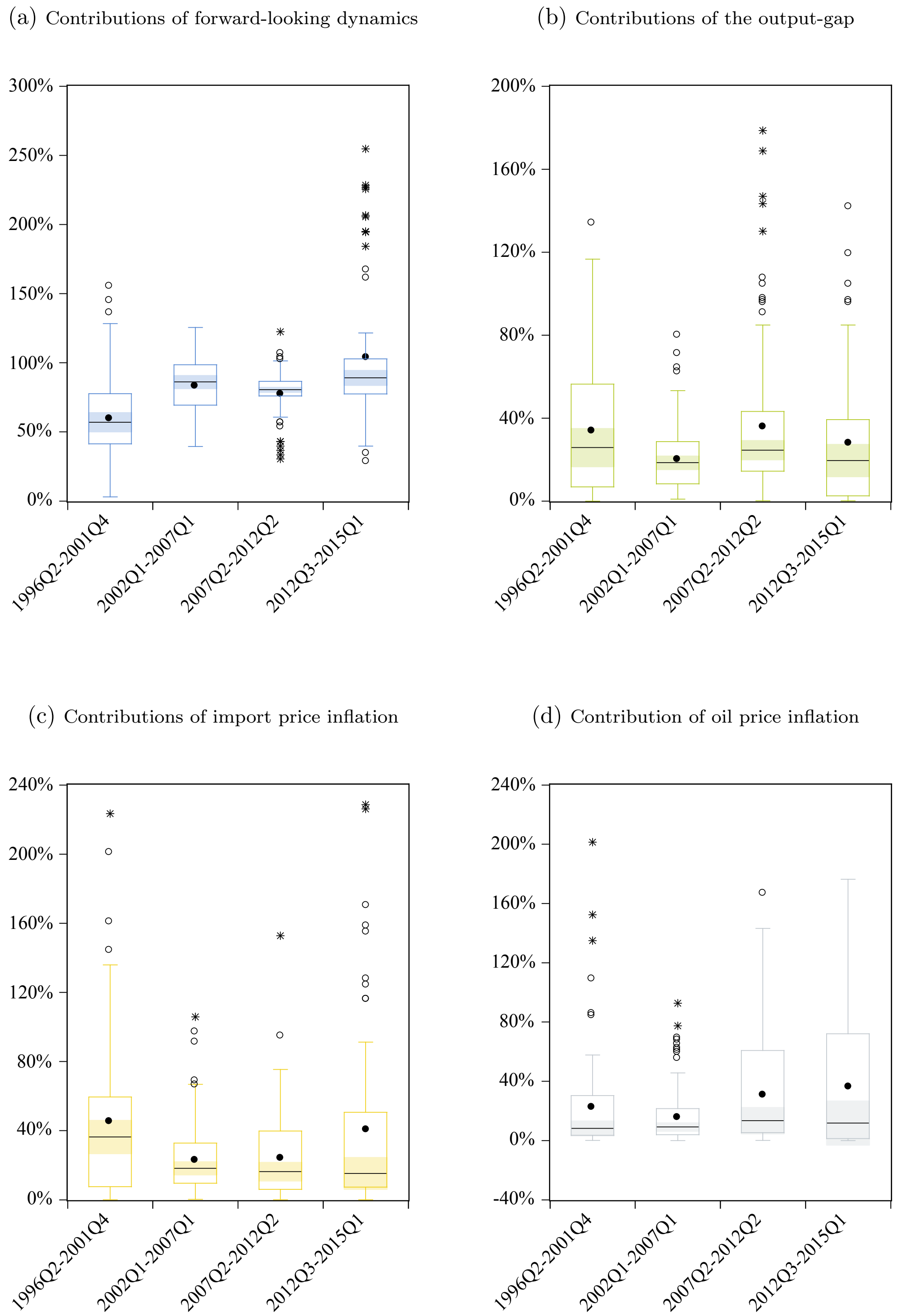


(c) Forward-looking dynamics



We obtain the median contributions by estimating the model, that include WEO import prices, for each country, simulating the contributions of the inflation drivers as well as the residual and taking the median of the contributions across countries.

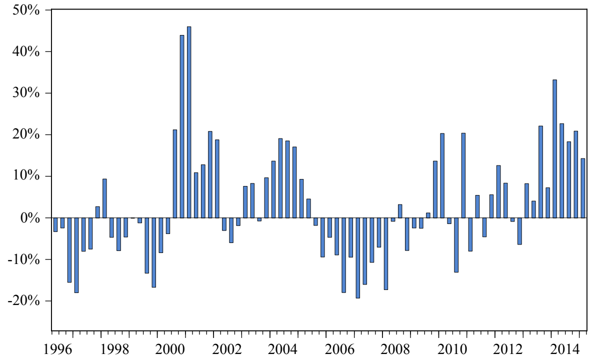
Figure 3.36: Distribution of country-specific ratios of absolute contributions and average headline inflation: Consensus expectations: WEO import prices



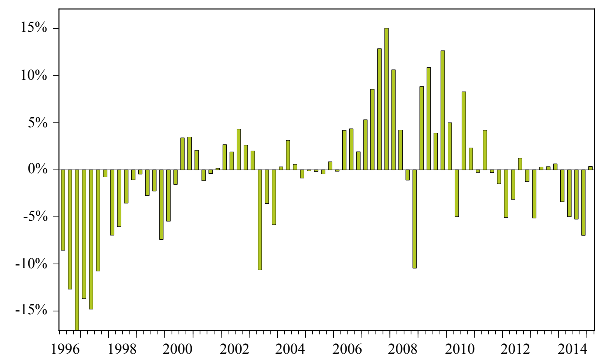
The underlying data for each boxplot comprises the country-specific ratios of contributions, which result from the model with WEO import prices, over the mean of country-specific headline inflation, both in absolute values, for each subsample and inflation driver.

Figure 3.37: Contributions resulting from time-varying parameters: WEO import prices

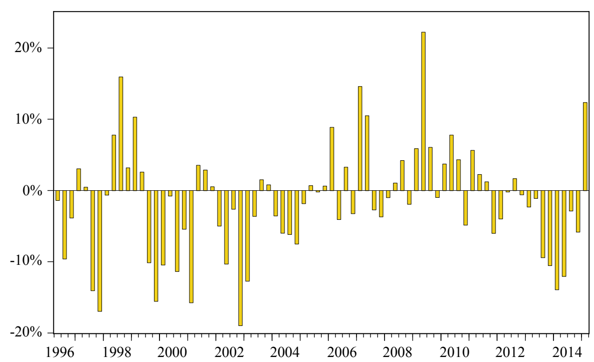
(a) Forward-looking dynamics



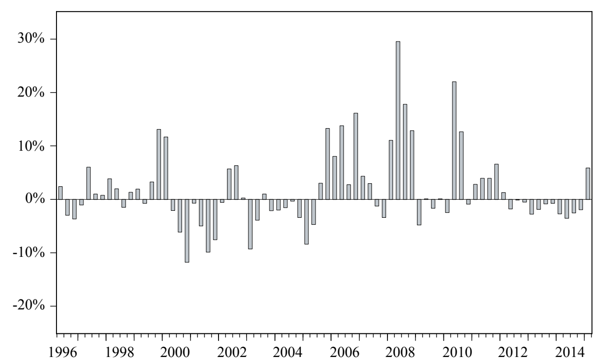
(b) Output-gap



(c) Non-oil-import price inflation



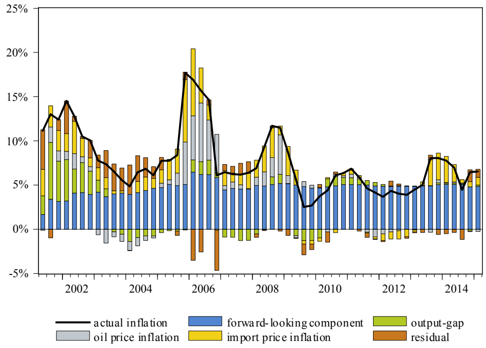
(d) Oil price inflation



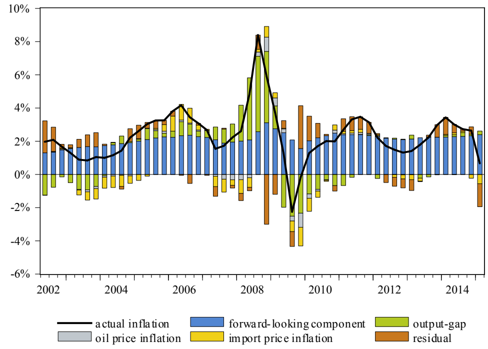
The contributions of the time variation in parameters are calculated as the difference between median contributions simulated with the estimated model, that include WEO import prices, with time-invariante parameters and median contributions simulated with the estimation results of the model with time-varying parameters.

Figure 3.38: Main inflation components: WEO import prices

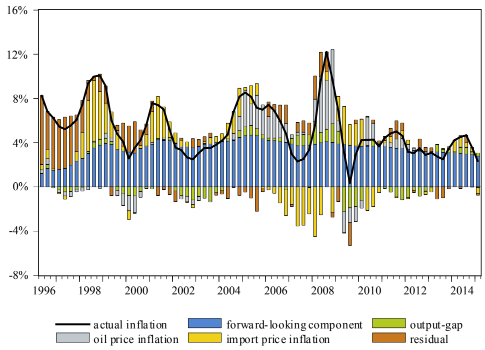
(a) Indonesia



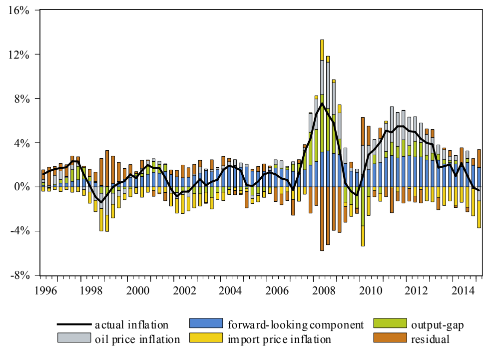
(b) Malaysia



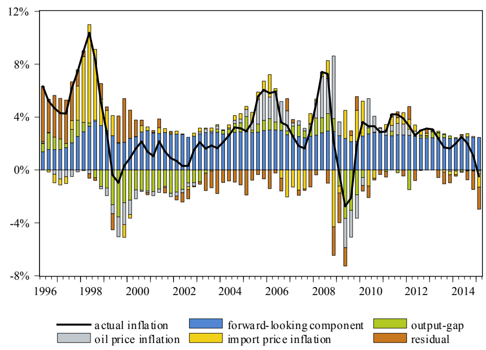
(c) The Philippines



(d) Singapore



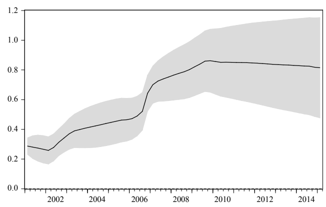
(e) Thailand



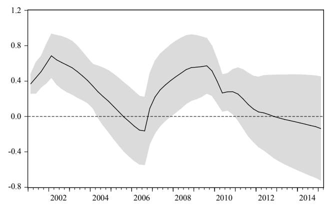
The panels presents simulated country-specific contributions to the ASEAN-5 headline inflation rates, resulting from the country-specific estimation of the model that include WEO import prices.

Figure 3.39: Time-varying coefficients: WEO import prices

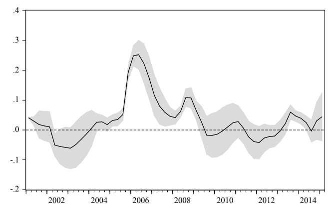
(a) β_t^1: IND



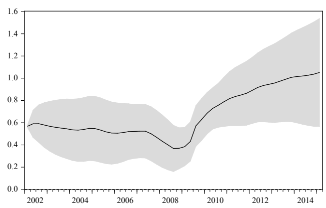
(b) β_t^2: IND



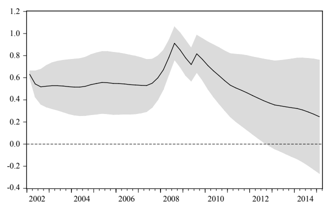
(c) β_t^3: IND



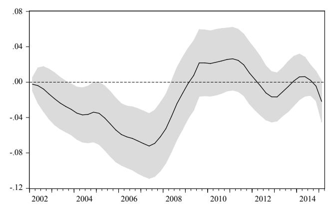
(d) β_t^1: MYS



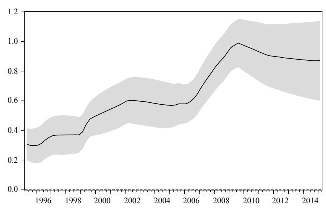
(e) β_t^2: MYS



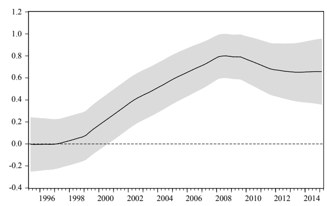
(f) β_t^3: MYS



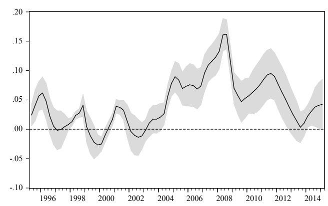
(g) β_t^1: PHL



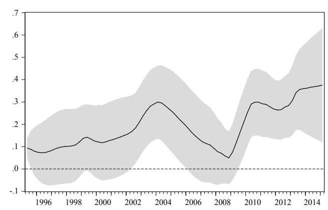
(h) β_t^2: PHL



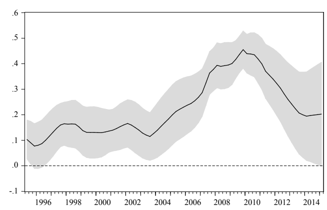
(i) β_t^3: PHL



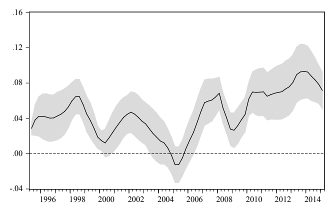
(j) β_t^1: SGP



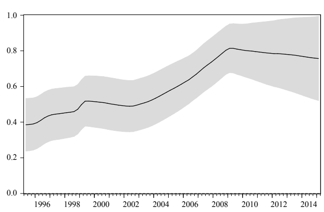
(k) β_t^2: SGP



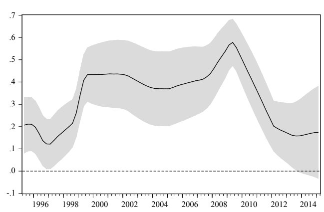
(l) β_t^3: SGP



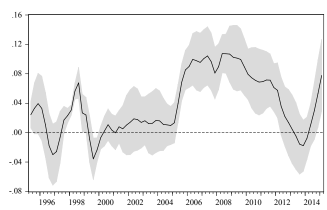
(m) β_t^1: THA



(n) β_t^2: THA



(o) β_t^3: THA

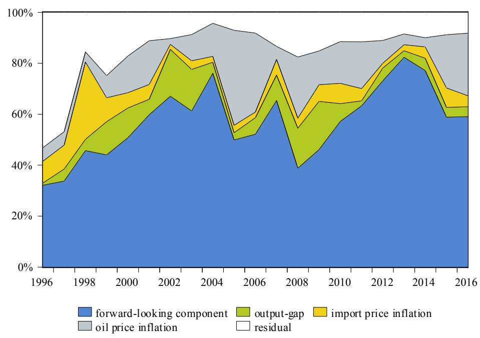


The panels present the estimates and 95% confidence bands of the time-varying parameters, whereby β_t^1 is the coefficient of long-run inflation expectations, β_t^2 reflects the Phillips curve slope and β_t^3 is the coefficient of import price inflation. Country-codes are defined as IND-Indonesia, MYS-Malaysia, PHL-the Philippines, SGP-Singapore and THA-Thailand.

3.6.4 Model with separate coefficients for oil and import price inflation

$$\pi_t = \beta_t^1 \bar{\pi}_t + (1 - \beta_t^1)\pi_{t-1}^{MA4} + \beta_t^2 \tilde{y}_{t-1} + \beta_t^3 \pi_{t-1}^{imp} + +\beta_t^4 \pi_{t-1}^{oil} + \epsilon_t \tag{3.2}$$

Figure 3.40: Relative median contribution of inflation drivers across ASEAN-5 countries: separate oil and import prices

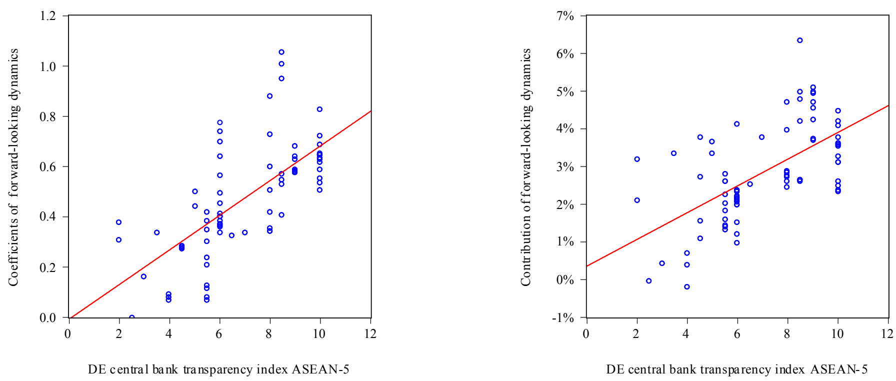


The figure presents the relative median contributions that are the ratios of the median contributions, that result from the models with WEO import prices, across countries and the median headline inflation rates across counties at each point in time.

Figure 3.41: Correlation between forward-looking dynamics and DE transparency index: separate oil and import prices

(a) Coefficients and DE transparency index

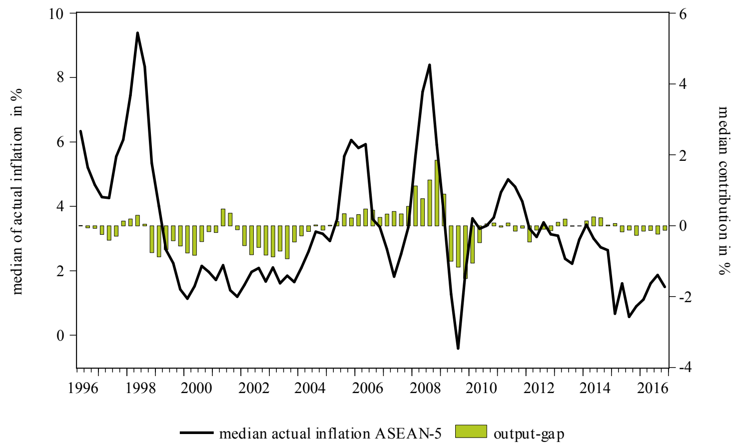
(b) Contributions and DE transparency index



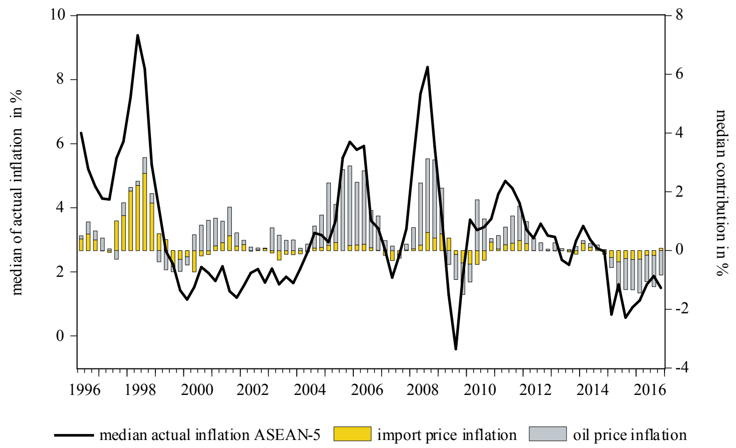
The panels contain scatter plots and the corresponding regression lines of the estimated country-specific time-varying coefficient (Panel a) as well as the simulated contribution (Panel b) of the forward-looking component, that result from the model with separate oil and import prices, and the DE transparency index at each point in time.

Figure 3.42: Median contributions of ASEAN-5 countries: separate oil and import prices

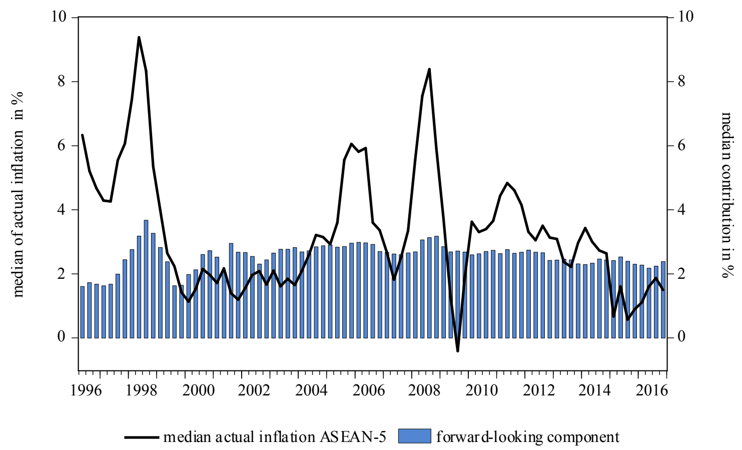
(a) Output-gap



(b) Import and oil price inflation

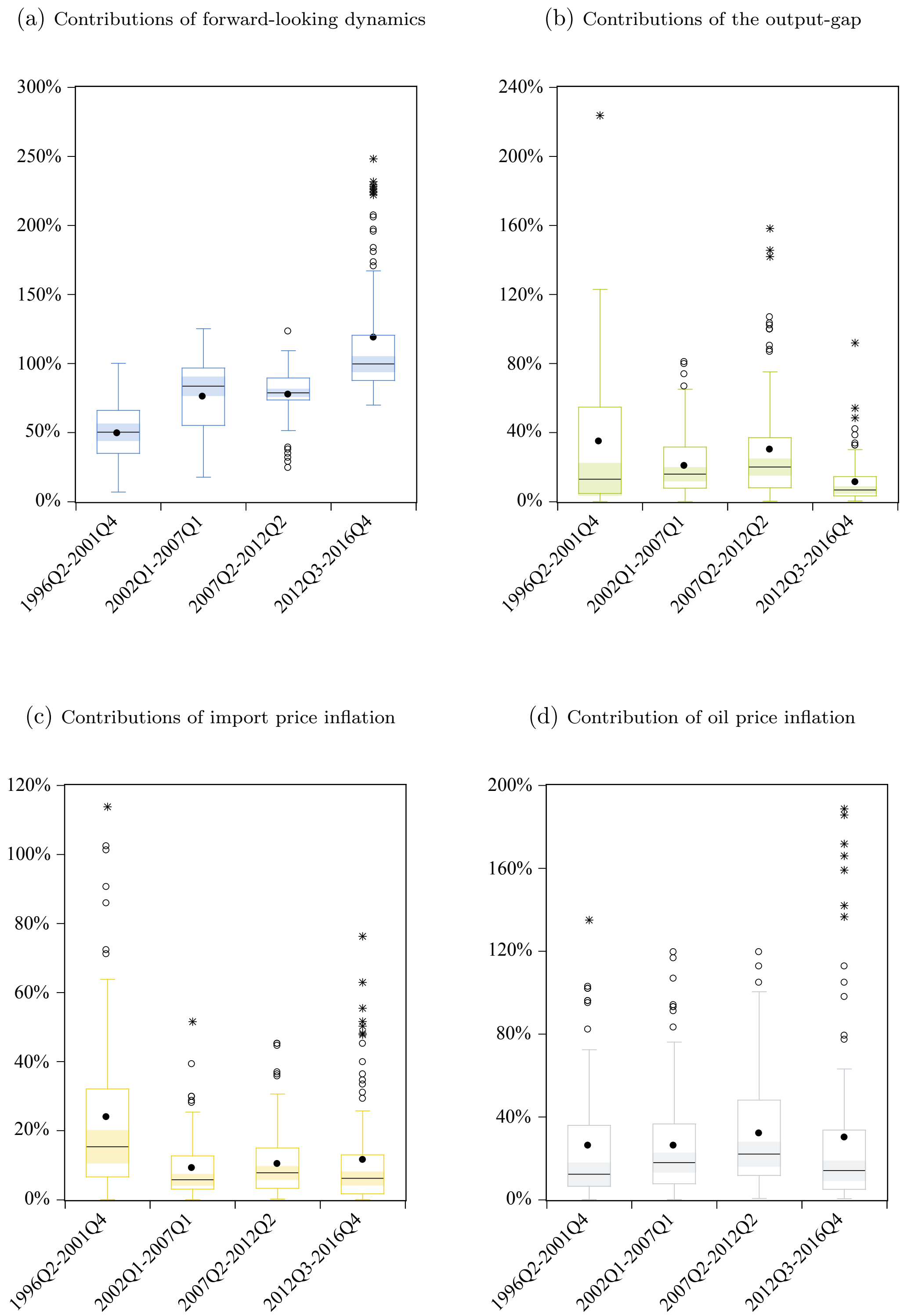


(c) Forward-looking dynamics



We obtain the median contributions by estimating the model, that include separate oil and import prices, for each country, simulating the contributions of the inflation drivers as well as the residual and taking the median of the contributions across countries.

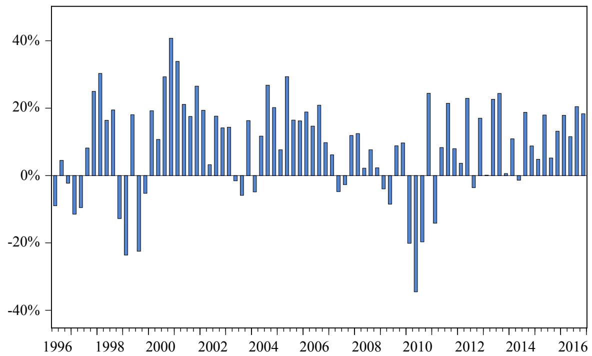
Figure 3.43: Distribution of country-specific ratios of absolute contributions and average headline inflation: Consensus expectations: separate oil and import prices



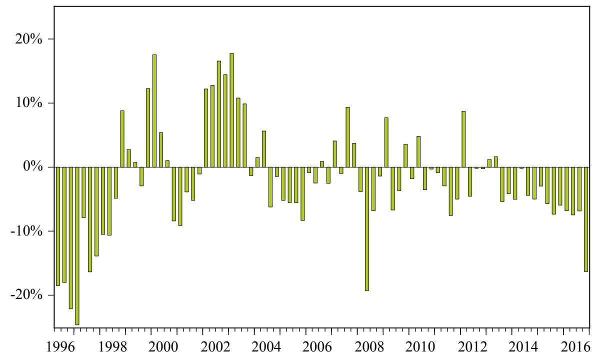
The underlying data for each boxplot comprises the country-specific ratios of contributions, which result from the model with separate oil and import prices, over the mean of country-specific headline inflation, both in absolute values, for each subsample and inflation driver.

Figure 3.44: Contributions resulting from time-varying parameters: separate oil and import prices

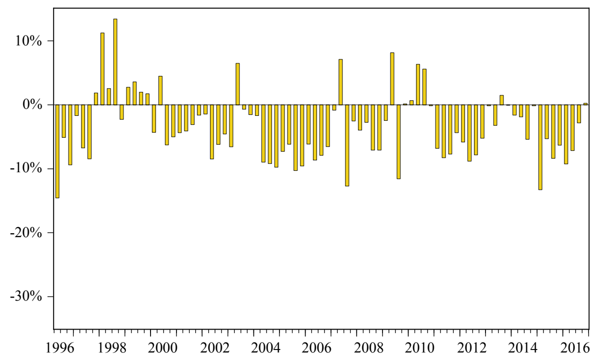
(a) Forward-looking dynamics



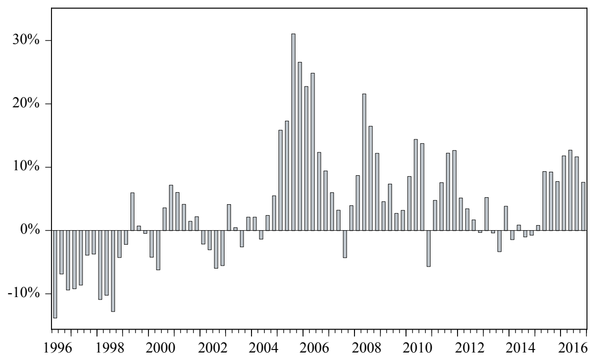
(b) Output-gap



(c) Non-oil-import price inflation



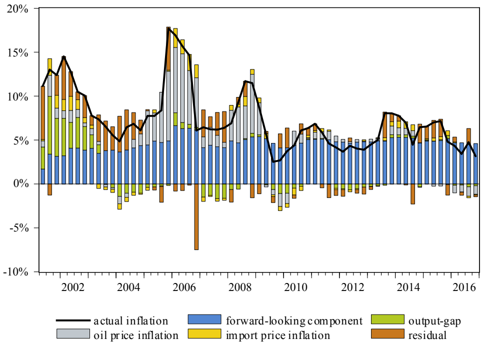
(d) Oil price inflation



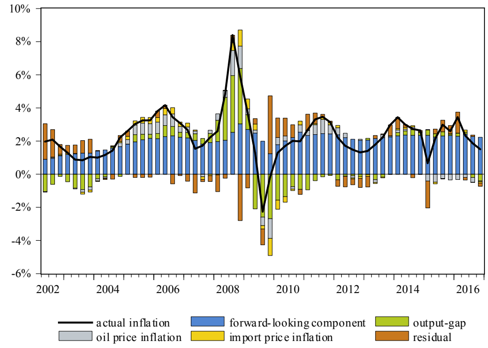
The contributions of the time variation in parameters are calculated as the difference between median contributions simulated with the estimated model, that include separate oil and import prices, with time-invariante parameters and median contributions simulated with the estimation results of the model with time-varying parameters.

Figure 3.45: Main inflation components: separate oil and import prices

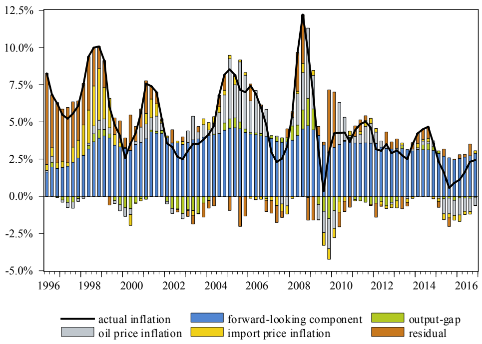
(a) Indonesia



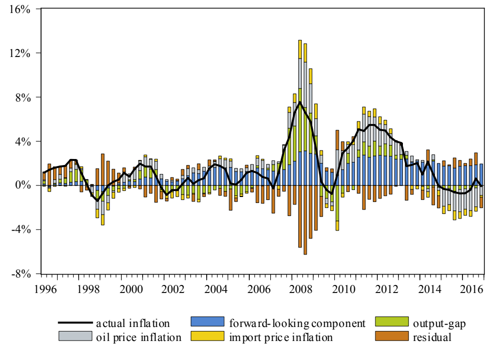
(b) Malaysia



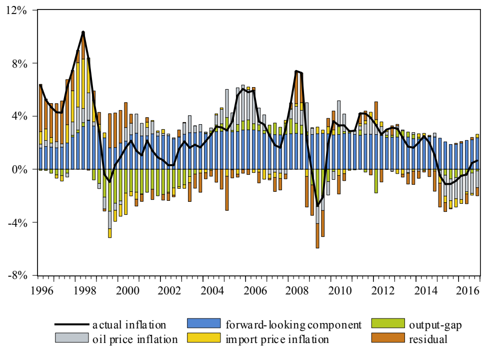
(c) The Philippines



(d) Singapore



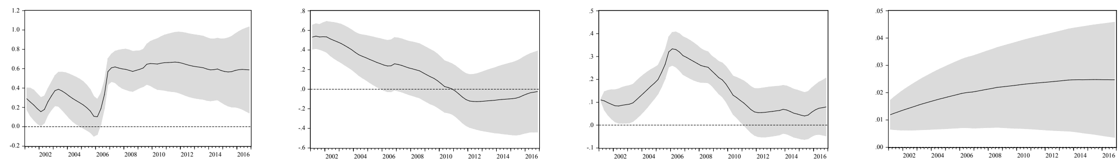
(e) Thailand



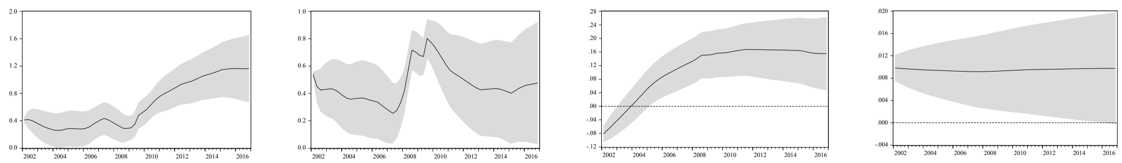
The panels presents simulated country-specific contributions to the ASEAN-5 headline inflation rates, resulting from the country-specific estimation of the model that include separate oil and import prices.

Figure 3.46: Time-varying coefficients: separate oil and import prices

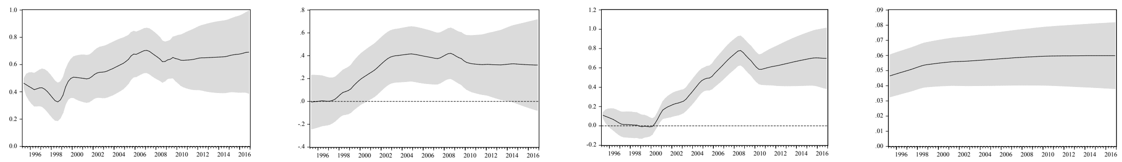
(a) Forward-looking dynamics: IND | (b) β_t^2: IND | (c) β_t^3: IND | (d) β_t^4: IND



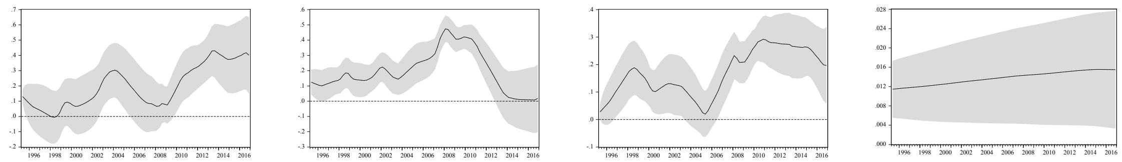
(e) β_t^1: MYS | (f) β_t^2: MYS | (g) β_t^3: MYS | (h) β_t^4: MYS



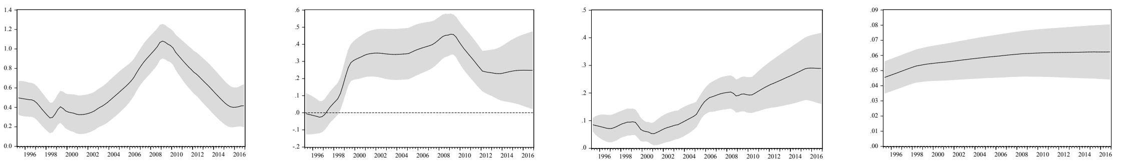
(i) β_t^1: PHL | (j) β_t^2: PHL | (k) β_t^3: PHL | (l) β_t^4: PHL



(m) β_t^1: SGP | (n) β_t^2: SGP | (o) β_t^3: SGP | (p) β_t^4: SGP



(q) β_t^1: THA | (r) β_t^2: THA | (s) β_t^3: THA | (t) β_t^4: THA

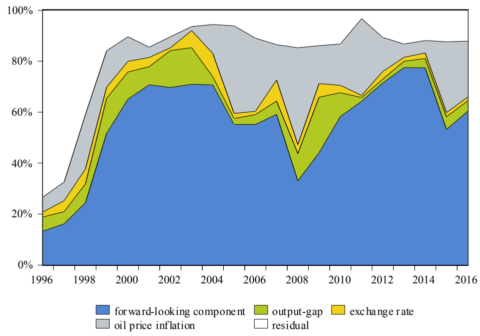


The panels present the estimates and 95% confidence bands of the time-varying parameters, whereby β_t^1 is the coefficient of long-run inflation expectations, β_t^2 reflects the Phillips curve slope, β_t^3 is the coefficient of import price inflation and β_t^4 is the coefficient of oil price inflation. Country-codes are defined as IND-Indonesia, MYS-Malaysia, PHL-the Philippines, SGP-Singapore and THA-Thailand.

3.6.5 Model with separate coefficients for oil price inflation and exchange rate

$$\pi_t = \beta_t^1 \bar{\pi}_t + (1 - \beta_t^1)\pi_{t-1}^{MA4} + \beta_t^2 \tilde{y}_{t-1} + \beta_t^3 ex_{t-1} + +\beta_t^4 \pi_{t-1}^{oil} + \epsilon_t \tag{3.3}$$

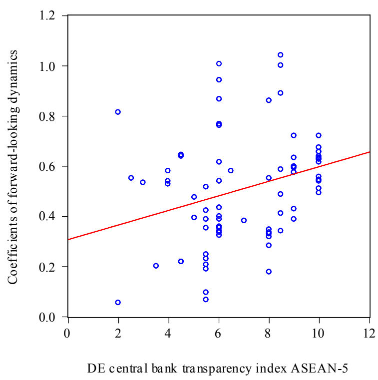
Figure 3.47: Relative median contribution of inflation drivers across ASEAN-5 countries: oil price inflation and exchange rate



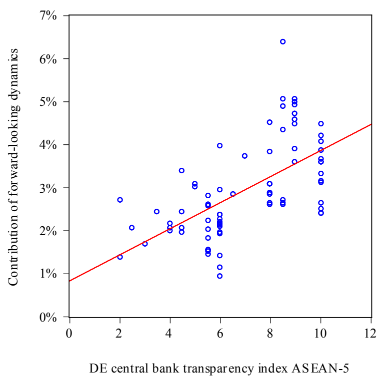
The figure presents the relative median contributions that are the ratios of the median contributions, that result from the models with oil price inflation and the exchange rates, across countries and the median headline inflation rates across counties at each point in time.

Figure 3.48: Correlation between forward-looking dynamics and DE transparency index: oil price inflation and exchange rate

(a) Coefficients and DE transparency index



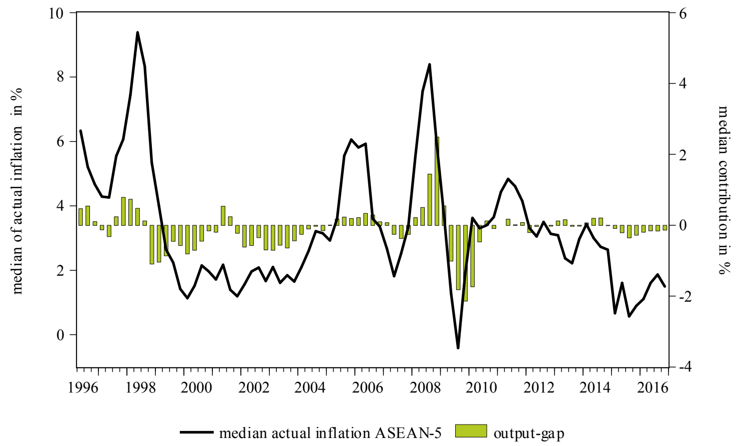
(b) Contributions and DE transparency index



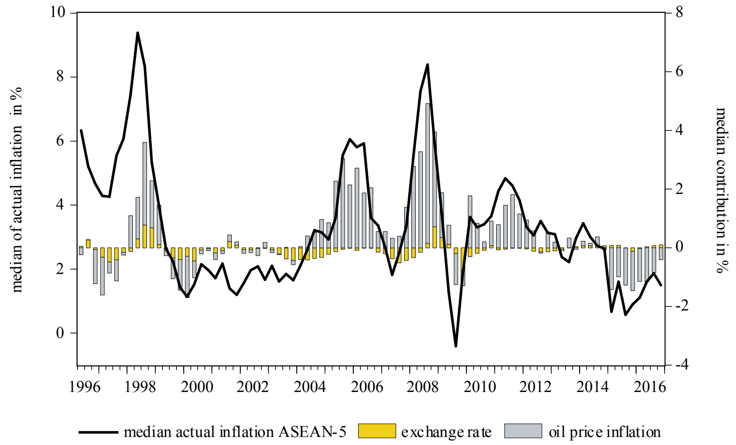
The panels contain scatter plots and the corresponding regression lines of the estimated country-specific time-varying coefficient (Panel a) as well as the simulated contribution (Panel b) of the forward-looking component, that result from the model with oil price inflation and exchange rates, and the DE transparency index at each point in time.

Figure 3.49: Median contributions of ASEAN-5 countries: oil price inflation and exchange rate

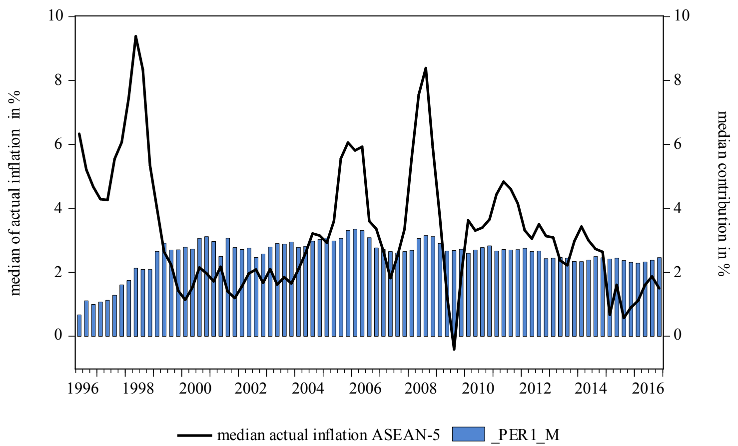
(a) Output-gap



(b) Import and oil price inflation

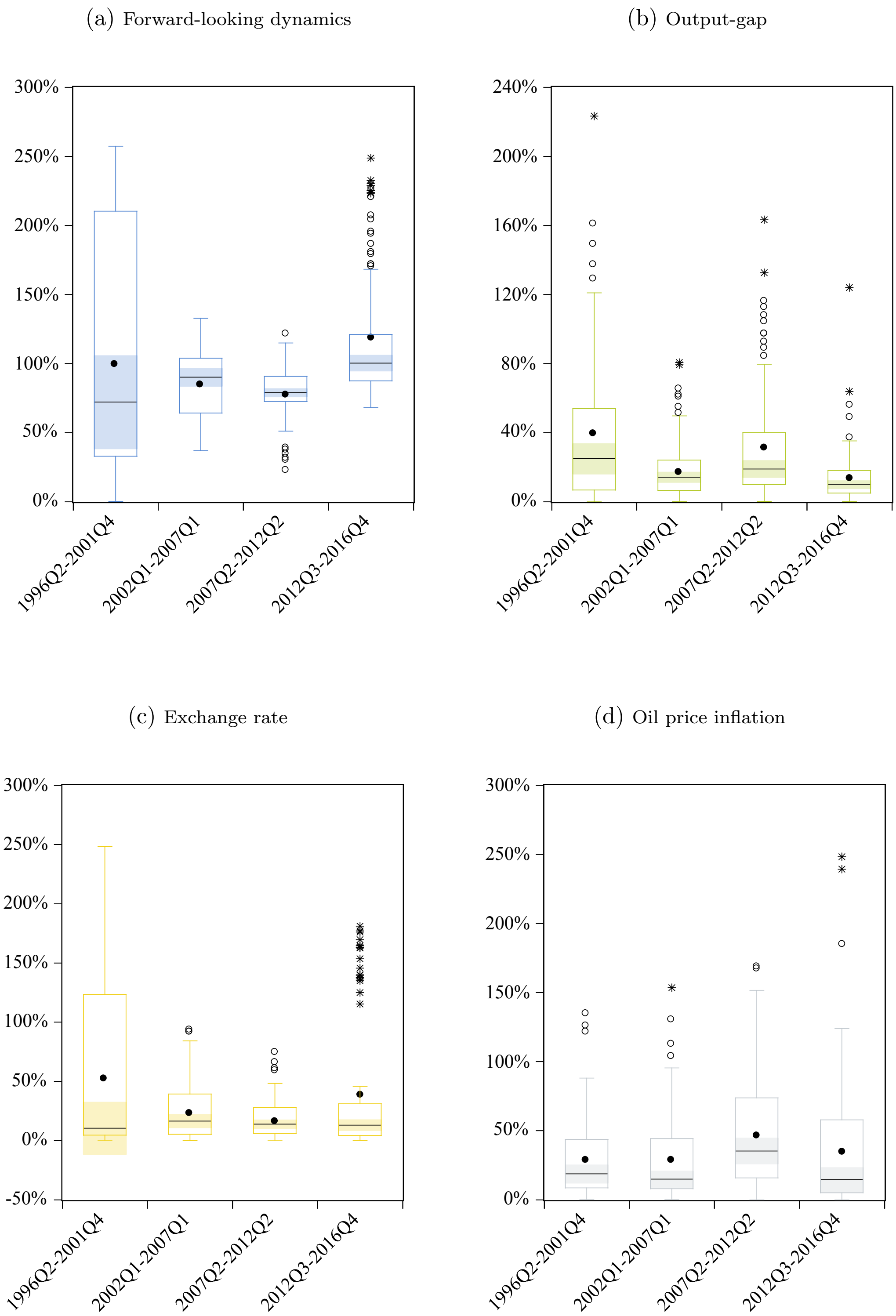


(c) Forward-looking dynamics



We obtain the median contributions by estimating the model, that include oil price inflation and the exchange rate, for each country, simulating the contributions of the inflation drivers as well as the residual and taking the median of the contributions across countries.

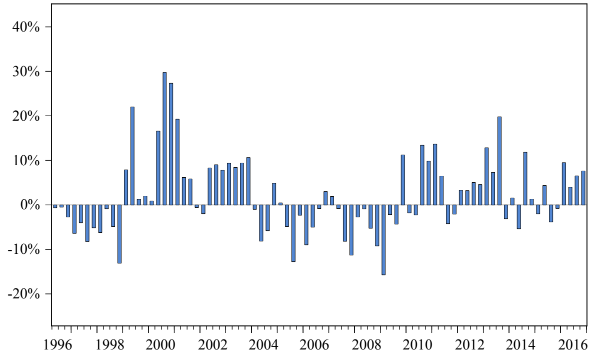
Figure 3.50: Distribution of country-specific ratios of absolute contributions and average headline inflation: Consensus expectations: oil price inflation and exchange rate



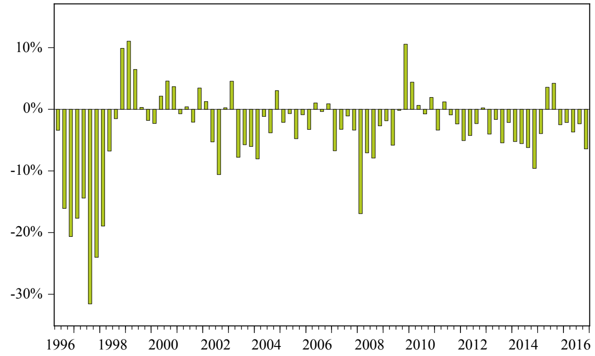
The underlying data for each boxplot comprises the country-specific ratios of contributions, which result from the model with oil price inflation and exchange rate, over the mean of country-specific headline inflation, both in absolute values, for each subsample and inflation driver.

Figure 3.51: Contributions resulting from time-varying parameters: oil price inflation and exchange rate

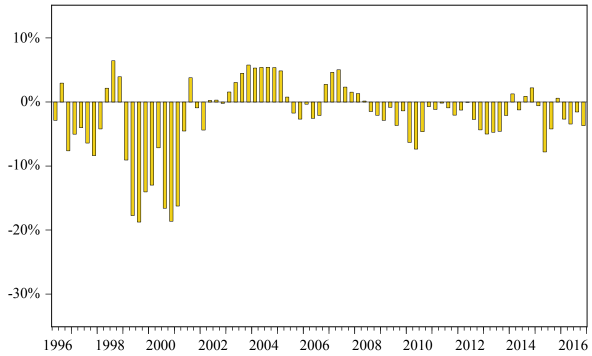
(a) Forward-looking dynamics



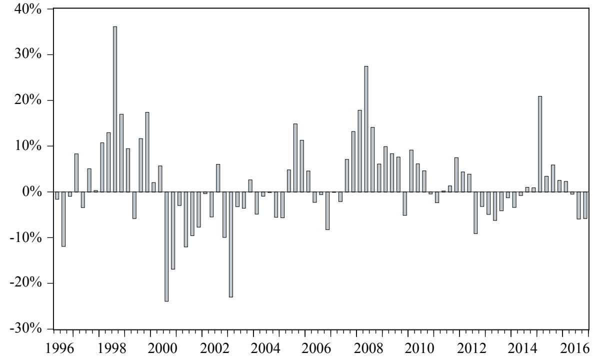
(b) Output-gap



(c) Exchange rate



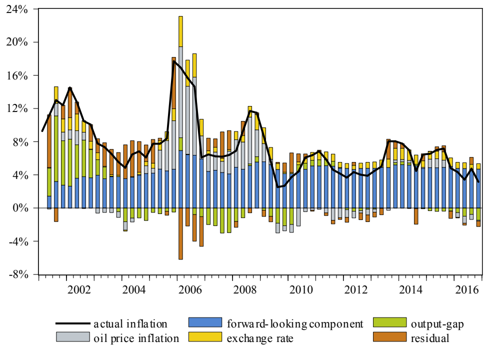
(d) Oil price inflation



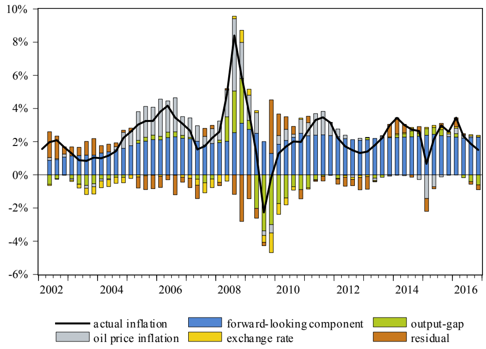
The contributions of the time variation in parameters are calculated as the difference between median contributions simulated with the estimated model, that include oil price inflation and exchange rate, with time-invariante parameters and median contributions simulated with the estimation results of the model with time-varying parameters.

Figure 3.52: Main inflation components: oil price inflation and exchange rate

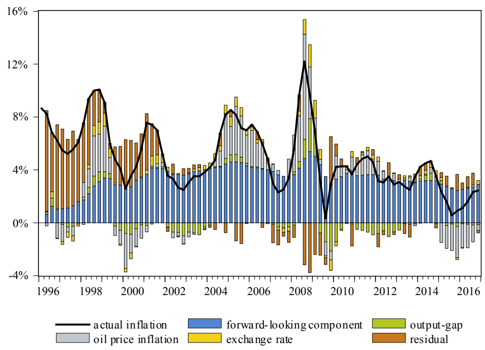
(a) Indonesia



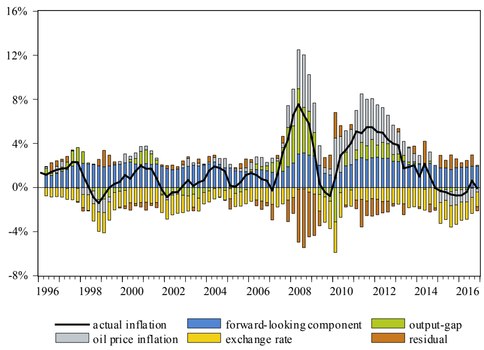
(b) Malaysia



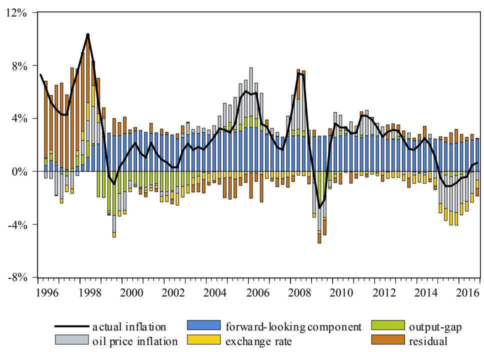
(c) The Philippines



(d) Singapore



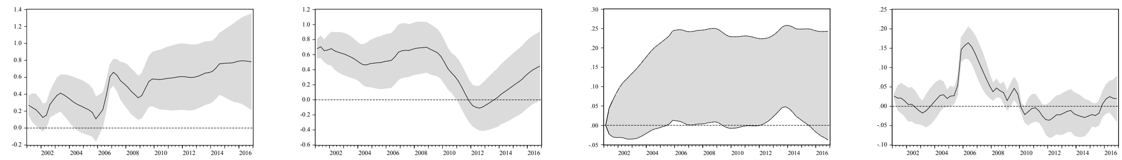
(e) Thailand



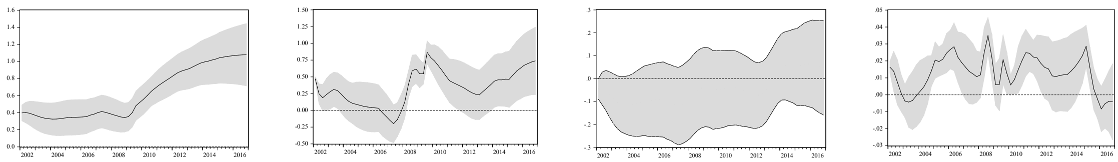
The panels presents simulated country-specific contributions to the ASEAN-5 headline inflation rates, resulting from the country-specific estimation of the model that include oil price inflation and the exchange rate.

Figure 3.53: Time-varying coefficients: oil price inflation and exchange rate

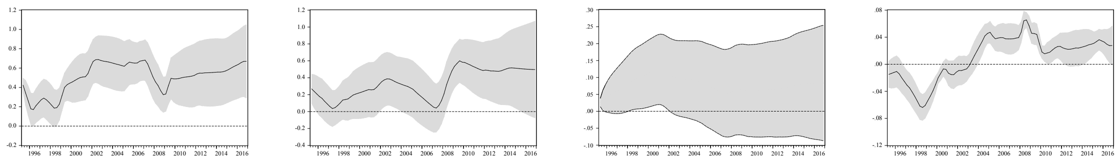
(a) β_t^1: IND (b) β_t^2: IND (c) β_t^3: IND (d) β_t^4: IND



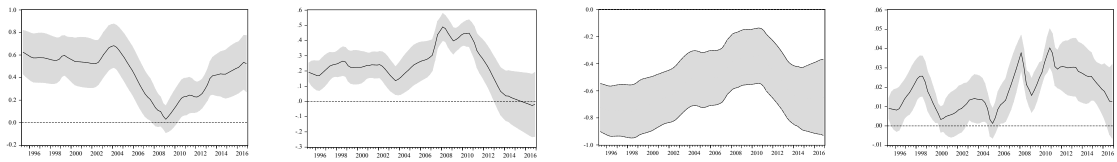
(e) β_t^1: MYS (f) β_t^2: MYS (g) β_t^3: MYS (h) β_t^4: MYS



(i) β_t^1: PHL (j) β_t^2: PHL (k) β_t^3: PHL (l) β_t^4: PHL



(m) β_t^1: SGP (n) β_t^2: SGP (o) β_t^3: SGP (p) β_t^4: SGP



(q) β_t^1: THA (r) β_t^2: THA (s) β_t^3: THA (t) β_t^4: THA

The panels present the estimates and 95% confidence bands of the time-varying parameters, whereby β_t^1 is the coefficient of long-run inflation expectations, β_t^2 reflects the Phillips curve slope, β_t^3 is the coefficient of the exchange rate and β_t^4 is the coefficient of oil price inflation. Country-codes are defined as IND-Indonesia, MYS-Malaysia, PHL-the Philippines, SGP-Singapore and THA-Thailand.

4 Time variation of the financial accelerator and the credit channel: a time-varying VAR analysis

I thank Oliver Holtemöller, Lutz Kilian, Lawrence Christiano, Jan-Christopher Scherer, Mathias Trabandt, Gregor von Schweinitz, the participants of the EEA-ESEM 2016 and of the IAAE 2016 for very valuable comments on earlier drafts.

4.1 Introduction

The severe repercussions of the global financial crisis highlighted the importance of the link between financial markets and macroeconomic activity. From an international perspective, the real economic effects of the global financial crisis have been more pronounced in economies where the overall level of financial intermediaries leverage ratios were generally high (Fink and Schüler, 2015; Berkmen et al., 2012). The theoretical contributions of Brunnermeier and Sannikov (2014) and Gertler et al. (2016) suggest that firstly, financial innovation exogenously reduces the idiosyncratic risk of banks and enhances the long-run level of financial intermediaries' leverage ratios (at least throughout the mid-1980s to late 1990s in the US) and that secondly, altered long-run leverage ratios increase the financial amplification of structural shocks. The higher degree of financial acceleration implies that sudden disruptions in the banking sector, like unexpected devaluations of banks' capital, reveal altered shock propagation to real economic activity.

This increased financial amplification also applies to the propagation of a monetary policy shock to the extent that the credit channel becomes more relevant. However, empirical evidence on the importance of the credit channel and its role for monetary policy transmission during the global financial crisis is mixed (Aysun et al., 2013; Ciccarelli et al., 2015; Gertler and Karadi, 2015; Hubrich and Tetlow, 2015). Although, recent empirical studies point towards a non-linear intensity of the interplay between financial markets and macroeconomic dynamics, these studies focus on the heterogeneous effects across economies (Bijsterbosch and Falagiarda, 2015; Ciccarelli et al., 2012) or on non-linearities of coefficients and business cycle dynamics related to regimes with high and low financial stress (Cardarelli et al., 2011; Hubrich and Tetlow, 2015).

Instead, im this paper I am interested in changes in the intensity of the financial accelerator over time. Therefore, this paper investigates the evolution of financial amplification of structural shocks to the US economy and assesses whether the financial acceleration has intensified in the last thirty years as suggested by the theoretical contributions of Brunnermeier and Sannikov (2014) and Gertler et al. (2016). The focus lies on the financial amplification of an unexpected devaluations of banks' capital and monetary policy surprises, as the contribution of these shocks to the business cycle center the macro- and monetary economic debate in the last decade.

To account for the changes in the propagation of structural shocks, the structure of financial markets and real markets but also to control for changes in variances, the analysis is based on a time-varying parameter vector autoregressive model (TVP-VAR) with stochastic volatility. Instead of relying on ad hoc imposed identification assumptions, I base the identification of structural shocks on the monetary DSGE model with financial frictions in the banking sector of Gertler and Karadi (2011), which is re-simulated for distinct long-run levels of bank sector's leverage ratio. The identification of a structural banks' capital quality shock, a monetary policy shock and a technology shock is achieved by applying sign restrictions.

The contribution of the study is twofold. Empirical studies, that document the impact of financial stress on real economic activity, so far either do not account for time-variation (Aksoy and Basso, 2014; Ciccarelli et al., 2015; Fornari and Stracca, 2012) or assume that financial stress is an exogenous regime shifting indicator of financial crisis (Balke, 2000; Hubrich and Tetlow, 2015; Mallick and Sousa, 2013). In contrast, this paper investigates in the evolution of financial market structure and the real economy as well as possible implications for the intensity of the financial accelerator by using a TVP VAR with stochastic volatility. Additionally, this paper bases the identification of structural shocks stemming from the financial sector on a monetary DSGE model with financial frictions in the banking sector.

In theory, the presence of financial frictions suggests that financial amplification also accelerates the propagation of monetary policy surprises and forms an additional channel of the monetary policy transmission mechanism. Although theoretically undistributed as long as financial frictions are present, the empirical evidence of the credit channel is rather mixed. For example, Hubrich and Tetlow (2015) find that monetary policy transmission is weaker in times of financial crisis than in 'normal' times. This is in line with the argument raised by Romer et al. (1990) , which suggests that the importance of the credit channel was undermined by the possibility of bank funding via covered bonds and asset-backed securities as well as certificate deposits. In contrast, Gertler and Karadi (2015) (for the US) and Ciccarelli et al. (2015) (for the euro area) find the credit channel to be statistically important component of the monetary policy transmission but both papers do not allow for non-linearities in their econometric frameworks. This paper adds another layer to this line of empirical literature by assessing not only the overall importance but also the evolution of the credit channel as part of the monetary policy transmission mechanism.

The findings of this study indicate that the amplification of structural shocks by financial frictions has increased during the last 30 years. In particular, sudden changes of the banks' capital quality reveal a rising impact on the risk-adjusted premium of financial intermediaries and real economic activity since the early 1990s. Moreover, the results also suggest that the responses of the risk-adjusted premium and GDP to a monetary policy shock have increased, however, to a relatively smaller extent. This suggests that the credit channel as part of the monetary policy transmission channel has gained importance, especially since the beginning of the 2000s. Overall, the analysis provides evidence of an increasing intensity of the financial accelerator as suggested by the theoretical frameworks of Brunnermeier and Sannikov (2014) and Gertler et al. (2016).

The structure of the paper is as follows: The second section details the identification approach as well as the implication of increasing long-run leverage ratios by outlining the model of Gertler and Karadi (2011). The third section presents the empirical methodology, including the econometric model, the data and the identifying assumptions. The results are presented in the fourth section followed by a robustness analysis in the fifth section. Finally, I briefly conclude the findings in the sixth section.

4.2 The financial accelerator mechanism under distinct long-run leverage ratios

The theoretical work of Brunnermeier and Sannikov (2014) and Gertler et al. (2016) suggest that financial innovation exogenously reduce the idiosyncratic risk of banks and enhance the overall level of financial intermediaries' leverage ratios, which in turn increase the financial amplification of structural shocks. Since the interest of this paper lies on changes of the shock propagation amplified by financial frictions, the identification is based on impulse response functions implied by the monetary DSGE model with financial frictions of Gertler and Karadi (2011) (GK model hereafter). This model captures well the mechanism and sources behind the deterioration of banks' balance sheets in 2008, the subsequent decline in intermediation, an increase in interest rate spreads and the following economic downturn. Although the GK model does not explicitly account for the long-run development of the banking sector, it is fairly traceable and one can still mimic the implications of Gertler et al. (2016) by exogenously varying the equilibrium values of banking sector's parameters.

In particular, Gertler and Karadi (2011) introduce a new form of financial friction in an otherwise standard monetary DSGE framework by including a banking sector with moral hazard occurring in the form of bankers *'running away'* with a part of the money they manage. To detail the underlying mechanisms of the GK model, to elaborate on the relation between equilibrium leverage ratios as well as the strength of the financial accelerator and to explain the identification strategy, I subsequently describe the main mechanisms and implications of the model. Moreover, I present simulation results of a structural banks' capital quality and a monetary policy shock under distinct equilibrium leverage ratios.

DSGE model with bankers 'running away'

Gertler and Karadi (2011) develop a quantitative monetary DSGE model similar to the ones of Christiano et al. (2005) and Smets and Wouters (2007), incorporating financial frictions through moral hazard in the banking sector. I now turn to the main outline of the model but refer the reader to Gertler and Karadi (2011) for derivation and a detailed description. The agency problem in the GK model is induced by the fact that bankers can sideline a fraction of deposits and 'run away' with it. In the model, households lend funds to competitive financial intermediaries for a gross return R_{t+1}. The financial intermediaries use the deposits to lend to capital producing firms, receiving the stochastic return $R_{k,t+1}$. In every period the financial intermediaries have the possibility to sideline a fraction λ of the available funds. The households in turn may recover the remaining share, $1-\lambda$, by forcing the intermediary into bankruptcy, but λ is lost.

As a consequence, the households will only be willing to lend to the financial intermediaries as long as the incentive constraint is fulfilled according to which the losses from cheating have to be always at least as large as the possible gains (see Equation 9 in Gertler and Karadi (2011)). This constraint „limits the intermediaries leverage ratio to the point where the banker's incentive to cheat is exactly balanced by the cost. In this respect the agency problem leads to an endogenous capital constraint on the intermediary's ability to acquire assets.“ (Gertler and Karadi (2011), p.20).

This implies that financial intermediary responds to a decline in its net worth by lowering the rate on deposits to strengthen the depositors' confidence and avoid withdrawals. This then drives up the risk-adjusted financing premium of the intermediaries; the return on deposits, and the return on their assets, $R_{k,t+1} - R_{t+1}$. With frictionless financial markets, this risk-adjusted financing premium is assumed to be zero in the model. However, a sudden decline in the quality of capital underlying banks assets deteriorates the return on banks asset and therewith the net worth of financial intermediaries and credit supply declines. Banks reduce their rate on deposits as to prevent depositors to take their money elsewhere. Due to a lack of bank funding, intermediation and credit supply declines further, amplifying the downturn in economic activity. As prices and output fall, monetary policy reacts expansionary. Financial intermediaries slowly build up their net worth to previous levels to match their equilibrium leverage ratio and therewith the economy recovers. For sudden changes of monetary policy, the underlying agency problem yields an accelerating effectiveness in form of the credit channel. Similar to the model of Bernanke et al. (1999) with costly state verification under asymmetric information, an expansionary monetary policy reduces the financing premium as it lowers refinancing costs for financial intermediaries. A striking implication of the GK model for understanding the interplay of financial markets and real economic activity is that in the situation of a negative shock to the capital quality of banks' government equity injections into the banking system as well as the government taking over a part of the financial intermediation in the economy is shown to be welfare increasing.

In the GK model the equilibrium level of the leverage ratio determines the strength of the financial accelerator. As Lerner and Tufano (2011) suggest, financial liberalization, innovation and globalization led to improvements in risk-diversification of financial intermediaries' portfolios and therewith to increasing long-run levels of leverage ratios. To illustrate the implications of different equilibrium leverage ratios, I re-simulate the model over the range ϕ =[4,10,15,20,25,30,35,40] of distinct equilibrium leverage ratio values, whereby the range is chosen to depict average and extreme values of observed banks' leverage ratios (Brei and Gambacorta, 2014). The remaining parameter values are taken over from Gertler and Karadi (2011) and are shown in Table 4.1.

Table 4.1: Calibration of the GK model

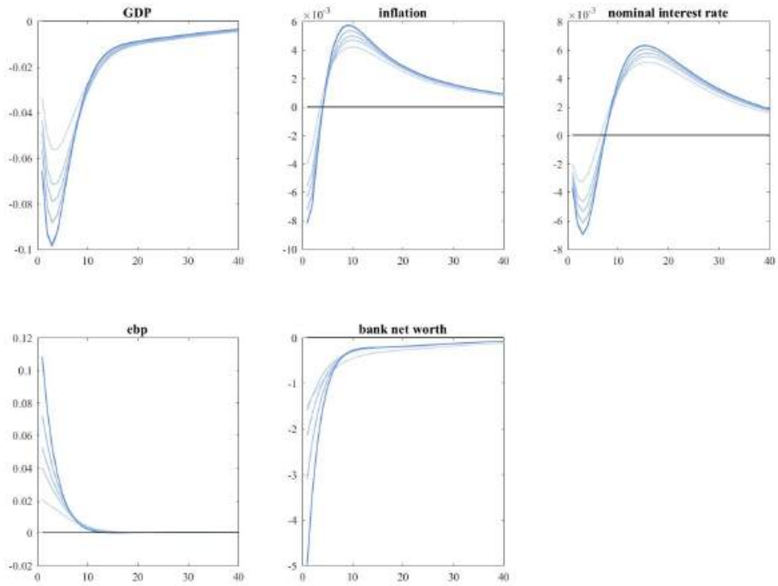
Parameter	**Value**	**Description**
Households		
β	0.99	Discount rate
h	0.815	Habit formation parameter
χ_0	3.4	Starting value for the labour utility weight
φ	0.276	Inverse Frisch elasticity of labour supply
Financial intermediaries		
λ_0	0.381	Starting value for the fraction of divertible funds
ω_0	0.002	Starting value of proportional starting up funds
θ	0.9716	Survival probability of bankers
$R_k - R$	0.1/4	Risk-adjusted financing premium
Intermediate good firms		
ζ	7.2	Elasticity of marginal depreciation wrt the utilization rate
U	1	Steady state capital utilization rate
$\alpha(U)$	0.33	Capital share
δ	0.025	Depreciation rate
η_I	1.728	Elasticity of investment adjustment cost
Retail firms		
ϵ	4.167	Elasticity of substitution between goods
γ	0.77	Calvo parameter
γ_P	0.24	Price indexation parameter
Monetary policy and government		
ρ_i	0.8	Interest smoothing parameter
κ_π	1.5	Inflation coefficient
κ_y	-0.5/4	Output-gap coefficient
$\frac{G}{Y}$	0.2	Government expenditures over GDP

The table presents parameter calibration of the Gertler and Karadi (2011) model for the re-simulation exercise.

The simulation results of a sudden devaluation of banks' capital quality and a restrictive monetary policy surprise are shown in Figures 4.1 and 4.2, whereby the line colour intensifies with an increasing level of long-run leverage ratios underlying the simulated model. Overall, the simulation results indicate that a higher equilibrium level of leverage ratio amplifies the responses of GDP, the risk-adjusted premium and banks' net worth to both shocks. In particular, with a higher long-run leverage ratio a sudden devaluation of banks capital lead to an altered response of banks net worth. In turn, the banks have to lower deposit rates relatively more as to prevent withdrawals of deposit. Therefore, the risk-adjusted premium increases further, amplifying the effect on real economic activity. Similarly, under a higher equilibrium level of leverage an adverse monetary policy shock decreases the banks' net worth and thereby, increases the risk-adjusted premium by more than in the case of lower leverage ratio level in the long-run.

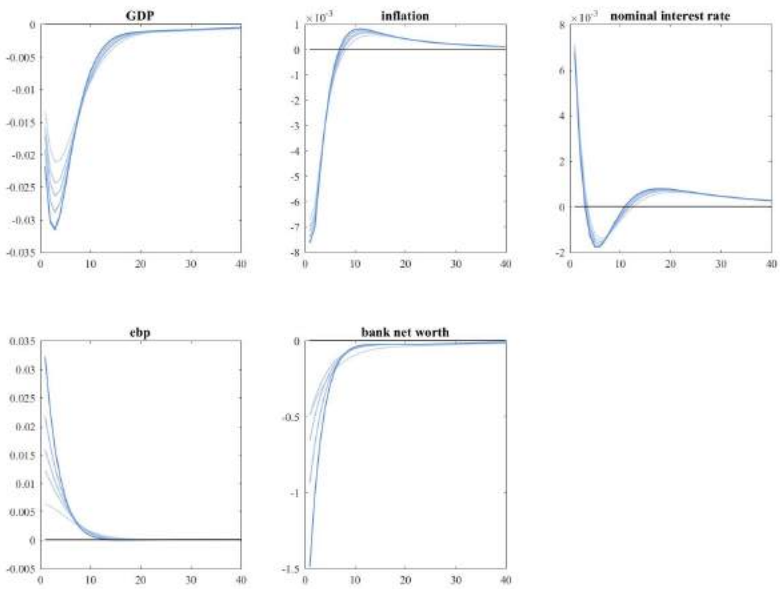
Thus, the GK model implies that the intensity of the financial accelerator depends on the long-run level of financial intermediaries' leverage. Form a historical perspective, this suggests that the propagation of shocks originating from the financial sector but also the amplification of monetary policy shock should have increased in the last 30 years alongside altered long-run leverage ratios of banks. The empirical methodology, used to assess whether the financial amplification has changed over time, is outlined in the next section.

Figure 4.1: Simulation results of the Gertler and Karadi (2011) model: capital quality shock



The panels present impulse responses to a capital quality shock from re-simulation of the Gertler and Karadi (2011) model using distinct levels of equilibrium leverage ratios, whereby the line colour intensifies with an increasing level of long-run leverage ratios.

Figure 4.2: Simulation results of the Gertler and Karadi (2011) model: monetary policy shock



The panels present impulse responses to a monetary policy shock from re-simulation of the Gertler and Karadi (2011) model using distinct levels of equilibrium leverage ratios, whereby the line colour intensifies with an increasing level of long-run leverage ratios.

4.3 Empirical Methodology

4.3.1 Econometric Model

I employ a TVP-VAR and stochastic volatility in the style of Primiceri (2005). The model is well suited for the analysis for several reasons. First, it accounts for structural changes of financial markets and the real economy by allowing coefficients to change over time. Second, this model discriminates between changes in coefficients and changes in volatility of the underlying variables. In this line, Gambetti and Musso (2017) and Bijsterbosch and Falagiarda (2015) use such a model to investigate in the evolution of loan supply shocks in the US, UK and the Euro area. Consider the reduced-form TVP-VAR model of the following form:

$$y_t = B_{0,t} + B_{1,t} y_{t-1} + ... + B_{k,t} y_{t-k} + u_t \quad t = 1, ..., T \tag{4.1}$$

where y_t is an $n \times 1$ vector of endogenous variables $y_t = [GDP_t, \pi_t, i_t, pre_t, bcq_t]'$, where GDP_t is real GDP, π_t is CPI inflation rate, i_t is a measure short term interest rate, pre_t is the risk-adjusted premium and bcq_t is the proxy for banks' capital quality. $B_{0,t}$ is a $n \times 1$ vector of time-varying intercepts, $B_{j,t}$ for $j = 1, ..., k$ are $n \times n$ matrices of time varying coefficients and $\theta_t = vec(B_t^{'})$. Also, u_t are heteroskedastic unobservable shocks with a variance covariance matrix Ω_t. Consider the triangular reduction of Ω_t of the following form:

$$A_t \Omega_t A_t^{'} = \Sigma_t \Sigma_t^{'} \tag{4.2}$$

with A_t having a lower triangular form

$$A_t = \begin{pmatrix} 1 & 0 & \cdots & 0 \\ \alpha_{21,t} & 1 & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ \alpha_{n1,t} & \cdots & \alpha nn-1,t & 1 \end{pmatrix} \tag{4.3}$$

and Ω_t being

$$\Sigma_t = \begin{pmatrix} \sigma_{1,t} & 0 & \cdots & 0 \\ 0 & \sigma_{2,t} & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ 0 & \cdots & 0 & \sigma_{n,t} \end{pmatrix} \tag{4.4}$$

Then $y_t = B_{0,t} + B_{1,t}y_{t-1} + ... + B_{k,t}y_{t-k} + A_t^{-1}\Sigma_t\epsilon_t \equiv X_t^{'}\theta_t + A_t^{-1}\Sigma_t\epsilon_t$ with $t = 1, ..., T$ and $X_t^{'} = I_n \otimes [1, y_{t-1}^{'}, y_{t-2}^{'}, ..., y_{t-k}^{'}]$. Consider a vector α_t to be the non-zero and non-one elements of A_t and let σ_t be the vector of the diagonal elements of Σ_t. As in Primiceri (2005), the time varying elements of θ_t and α_t are assumed to be random walks and the elements of σ_t are modelled as geometric random walks. Thus, the dynamics of time variations in parameters can be summarized as:

$$\begin{aligned} \theta_t &= \theta_{t-1} + \nu_t \\ \alpha_t &= \alpha_{t-1} + \zeta_t \\ \log \sigma_t &= \log \sigma_{t-1} + \eta_t \end{aligned} \tag{4.5}$$

The innovations of the model are assumed to be jointly normally distributed. And the variance covariance matrix of $\epsilon_t, \nu_t, \zeta_t$ and η_t is assumed to be

$$V = Var \begin{pmatrix} \epsilon_t \\ \nu_t \\ \zeta_t \\ \eta_t \end{pmatrix} = \begin{pmatrix} I_n & 0 & 0 & 0 \\ 0 & Q & 0 & 0 \\ 0 & 0 & S & 0 \\ 0 & 0 & 0 & W \end{pmatrix} \tag{4.6}$$

where S is block diagonal, which implies that the coefficients of the contemporaneous relations among variables are assumed to evolve independently in each equation (Primiceri, 2005). I present the main results in form of structural impulse response functions that are calculated using the moving average representation of the form:

$$\begin{aligned} \Phi_t^i &= J' B_t^i J' \text{with } J = [I_n : 0_n \times n(k-1)] \\ y_t &= \sum_{i=0}^{\infty} \phi_t^i u_{t-i} = \sum_{i=0}^{\infty} \phi_t^i A_t^{-1} A_t u_{t-i} = \sum_{i=0}^{\infty} \phi_t^i A_t^{-1} \epsilon_{t-i} \end{aligned} \tag{4.7}$$

4.3.2 Identification

I impose sign restrictions implied by the model of Gertler and Karadi (2011) and shown in Table 4.2 to identify three shocks, namely a monetary policy shock, a banks' capital quality shock and a productivity shock. Moreover, I apply as many restrictions as necessary on the first to horizons of of the impulse responses to achieve identification of the three shocks, leaving two shocks unidentified to soak up further disturbances. As pointed out in Kilian and Murphy (2012), this narrows the set of admissible responses since one can exclude the possibility that the banks' capital quality shock is just an endogenous reaction to other shocks. In particular, an unexpected decrease of banks' capital quality lowers the monetary policy rate, GDP and inflation but alters the risk-adjusted premium. Furthermore, a restrictive monetary policy shock shifts down GDP and prices and increases the risk-adjusted financing premium as shown in Figure 4.2. A positive supply shock increases GDP and reduces inflation.

Table 4.2: Imposed sign restrictions

variables	**banks' capital quality shock**	**monetary policy shock**	**technology shock**
GDP	−	−	+
inflation	−	−	−
nominal interest rate	−	+	*
risk-adjusted premium	*	*	*
banks' capital quality	−	−	*

The table indicates the sign restrictions of three structural shocks imposed on the first two horizons of impulse responses that are derived from the re-simulation exercise of the Gertler and Karadi (2011) model.

To extract the structural shocks, I apply a similar algorithm as the one suggested by Rubio-Ramirez et al. (2010), including the QR decomposition to obtain impact multiplier matrices. As pointed out by Kilian and Murphy (2012) and also Inoue and Kilian (2013) the vector of point-wise posterior median responses do not match response functions of admissible models. To overcome this problem, the response function that has minimum distance to the median response is selected as to reflect the median responses (Fry and Pagan, 2011).

4.3.3 Data and Estimation

Bayesian estimation techniques are applied to estimate the presented model. Gibbs sampling, a type of Markov Chain Monte Carlo (MCMC) methods, is used to draw from conditional posteriors of low dimension as to obtain joint and marginal distributions for the parameters of interest. The choice of the priors is consistent with Primiceri (2005), which has been also used by Gambetti and Musso (2017) and Bijsterbosch and Falagiarda (2015). Thus, I assume the priors for the time-varying coefficients, the simultaneous relation coefficients and the log volatility to be normally distributed. I use the first seven years of the data as a training sample to calibrate the priors. Hence, the mean and four times the variance of B_0 as well as A_0 are calibrated as the point estimates and four times the variance of time invariant OLS VAR estimates of the training sample. The prior for the mean of $log\sigma_0$ is the logarithmic OLS estimates of the standard errors of the training sample and the variance covariance is chosen to be the identity matrix.

$$\begin{aligned}
B_0 &\sim N(B_{OLS}, 4 * V(B_{OLS})) \\
A_0 &\sim N(A_{OLS}, 4 * V(A_{OLS})) \\
log\sigma_0 &\sim N(log\ \sigma_{OLS}, I_n))
\end{aligned} \tag{4.8}$$

The hyperparameters S, Q, and W are assumed to be distributed as independent inverse Wishart. The priors for W and S are set to have degrees of freedom such that they exceed the dimension of the matrix of W and the blocks of S, respectively, by one. For Q the degrees of freedom are set to the size of the training sample. The scale matrices for Q, S, and W are constant fractions of variances of the respective OLS estimates of the training sample times $k_W^2 = 0.01$, $k_S^2 = 0.1$ and $k_Q^2 = 0.01$ as well as the degrees of freedom, respectively. The setting of k_W^2, k_S and k_Q^2 implies diffuse and uninformative priors. Accordingly, the priors for the hyperparameters can be summarized as

$$
\begin{aligned}
Q &\sim IW(k_Q^2 * 40 * V(B_{OLS}), 28) \\
W &\sim IW(k_W^2 * N + 1 * I_n, N) \\
S_i &\sim IW(k_S^2 * M_i + 1 * V(A_{i,OLS}), M_i) \\
&\quad \text{with } i = 1, ..., I,
\end{aligned} \tag{4.9}
$$

where I is the number of blocks in S, $A_{i,OLS}$ reflect corresponding blocks of A, M_i is the number of the elements of $A_{i,OLS}$ that are neither zeros nor ones and N is the number of endogenous variables entering the model. The reader is referred to Primiceri (2005) and Del Negro and Primiceri (2015) for the details of the Gibbs sampling algorithm. A total number of 25000 Gibbs draws is obtained, whereby 10000 draws are defined as the burn-ins. From the remaining 15000 Gibbs draws every tenth draw is kept. The convergence diagnostics of the estimation can be found in the appendix.

The data used for the estimation of the TVP-VAR model comprises quarterly seasonally adjusted US data for real GDP and CPI from $1973Q1$ to $2012Q4$ that is taken from the U.S. Bureau of Economic Analysis. GDP and CPI enters the estimation in annualized quarter-to-quarter growth rates. To approximate the risk-adjusted premium, I use the excess bond premium (EBP hereafter) of Gilchrist and Zakrajšek (2012) as this captures the cyclical changes between default risk and credit spreads or in other words the unanticipated default risks of the financial sector.

A well-established measure to approximate the banking systems asset quality is the ratio of non-performing loan to total loans (Jiménez et al., 2013; Cole and White, 2012). However, data availability of non-performing loans is limited. To my knowledge the longest available time-series for the US is the non-performing loans (past-due 90+ days) to total loans for all US banks from the Federal Reserve Bank of St. Louis, starting in the mid-1980s. Using this series to approximate the banking systems capital quality is problematic because recovering slowly moving parameters with a TVP-VAR model requires relatively long-time series. Moreover, the non-performing loan measures potentially reflect devaluations of banks' capital quality with a lag. Therefore, I introduce an alternative measure that is the ratio of the banking sector specific stock market index to the overall stock market index, whereby both series are obtained from Thomson and Reuters Datastream. This stock index ratio is highly correlated to the non-performing loans ratio (NPL hereafter), especially at leads of the NPL, as it can be seen in Table 4.3.

Table 4.3: Cross-correlations between non-performing loans and the stock index ratio as well as the EBP

variables	NPL(+3)	NPL(+2)	NPL(+1)	NPL	NPL(-1)	NPL(-2)	NPL(-3)
stock index ratio	-0.72	-0.73	-0.71	-0.68	-0.60	-0.54	
EBP	0.49	0.43	0.35	0.27	0.19	0.12	0.06

This table presents the cross-correlations between the non-performing loans (NPL) and the stock index ratio as well as the EBP at a 95% significance level from 1985Q1 to 2012Q4.

As a monetary policy rate I use the federal funds target rate, provided by the Federal Reserve, and I merge the series with the shadow rate of Wu and Xia (2016) from 2004 Q4 onwards as to account for unconventional monetary policy measures and the zero lower bound.

4.4 Results

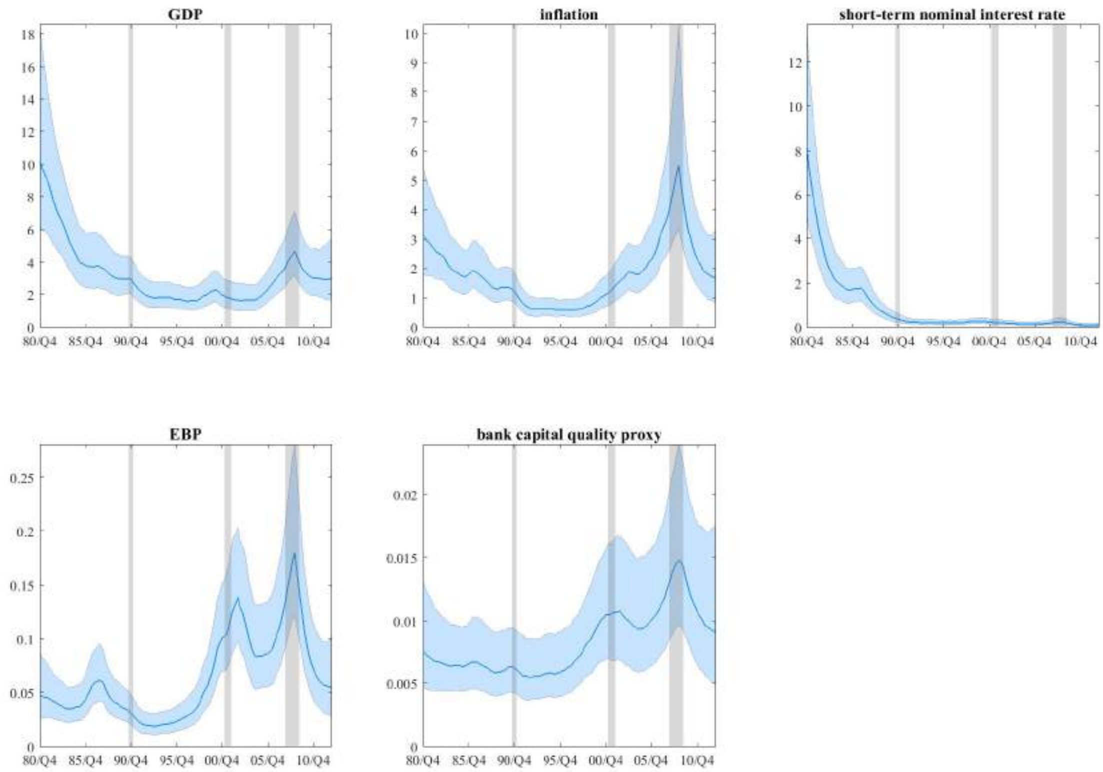
This Section presents the main results in four steps. I begin by examining the evolution of the stochastic volatilities. Then, I present the results of the structural shocks that are obtained from imposing the sign restrictions outlined in Table 4.2 on the first two horizons of impulse responses. Since the focus of this study is on the evolution of the banks' capital quality and the monetary policy shock propagation, the following discussion is limited to these two structural disturbances. The results for the technology shock are presented as supplementary material in the appendix (see Figures 4.8 and 4.9). Secondly, I present the median impulse responses of the posterior distribution across time to provide a general impression of how the impulse responses have changed over time. To shed light on the statistical significance of the impulse responses, I, thirdly, show a comparison of impulse responses at specific horizons. Fourthly, I present results of testing whether the impulse responses' posterior distributions have equal means and medians across peaks and troughs of the business cycle to detail the evidence of the changes in the shock propagation.

4.4.1 Evolution of volatilities

Figure 4.3 shows the evolution of time-varying variances of the five variables included in the estimation, whereby the thick lines depict the medians of the variance posterior distributions and the shaded areas indicate the corresponding 68% probability bands. To relate the variance series to financial and real economic turbulences, recessions are indicated by vertical, shaded areas. These areas span from economic peaks to troughs as documented by the NBER business cycle dating.

The stochastic volatilities of GDP, inflation and the nominal interest rate decline significantly from the 1980s to the mid-1990s. This decrease of variances reflects well the dynamics of the Great Moderation documented by Stock and Watson (2005) and Galí and Gambetti (2009) among others. The volatility of the excess bond premium depicts a peak in 1987 and significantly declines in the early 1990s.

Figure 4.3: Stochastic volatilities of the TVP-VAR



Each panel shows the evolution of stochastic volatilities for the five variables included in the estimation. The solid lines represent the median and the shaded areas the 68% probability bands of the variance posterior distribution. The vertical shaded areas indicate recessionary episodes documented by the NBER business cycle dating (peak to trough).

These movements can be related to the savings and loan crisis. In the early 1980s the Depository Institutions Deregulation and Monetary Control Act and Garn-St. Germain Depository Institutions Act deregulated these 'thrift' banks to the extent that these institutions gained more lending authority under less regulatory supervision. The presence of Federal Deposit Insurance Corporation together with the deregulation led the 'thrift' banks to engage in more risky activities. The reduction of nominal interest rates and decline of property prices in the first half of the 1980s induced the failure of one-third of the savings and loan associations by the mid-1990s. In contrast, the volatility of the net worth proxy reveals no significant change between the 1980s and the mid-1990s.

From the early 2000s onwards, volatilities across all variables significantly increase, except the volatility of the nominal interest rate, and peak during the global financial crisis. Especially the variances of the EBP and the banks' capital quality depict a pronounced rise around the Dot-com crisis in the late 2000s. Overall, Figure 4.3 supports the use of stochastic volatilities in the TVP-VAR model since variances show significant variation over time.

4.4.2 Banks' capital quality shock and monetary policy shock

Impulse responses across time

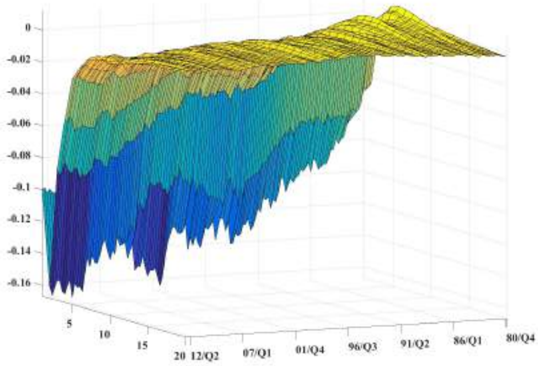
Figures 4.4 and 4.5 depict the median impulse responses of the five variables underlying the TVP-VAR estimation to a banks' capital quality shock and a monetary policy shock, respectively. The shocks are identified as outlined in Section 4.3.2, whereby the sign restrictions are applied to the first two horizons. It is important to note that the time variation of impulse responses does not stem from changes of the underlying stochastic volatility but solely present time variation of the shock propagation. This is so, because the variance-covariance posterior distribution has been standardized to the respective average shock size over time before applying the identification procedure.

Figure 4.4 presents the evolution of impulse responses to an adverse one standard deviation (average over time) banks' capital quality shock. By construction the banks' capital quality shock is on impact -0.0093 across time (see Panel e). The decline of banks' capital quality after the shock impact intensifies and extends over horizons from the early 1990s onwards. Similarly, the median impulse responses of the external bond premium depict altered dynamics. As it can be seen in Panel d, the shock response of the EBP increases on impact and extends over a number of horizons since the early 1990s. Thereby, the shock propagation is especially pronounced in the mid-1990s and during the global financial crisis.

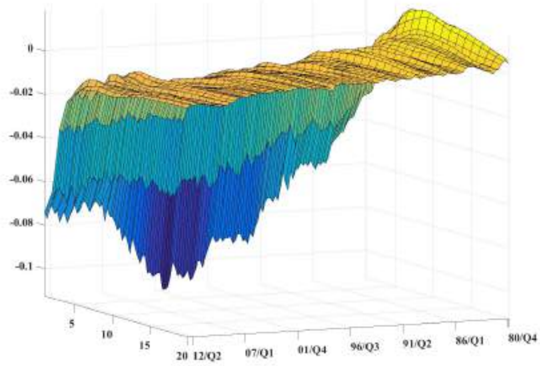
Turning to the key macroeconomic drivers, the median impulse responses of headline inflation (see Panel b) continuously declines on impact from -0.04 percentage points to -0.1 percentage points between the mid-1980s and the early 2000s. Compared to the early 2000s the shock impact is substantially smaller during the global financial crisis. This result is in line with the

Figure 4.4: Impulse responses to a banks' capital quality shock

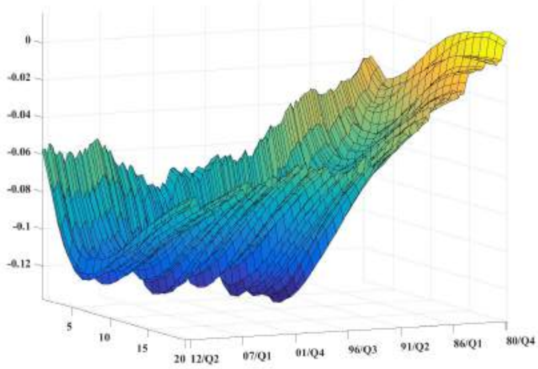
(a) GDP



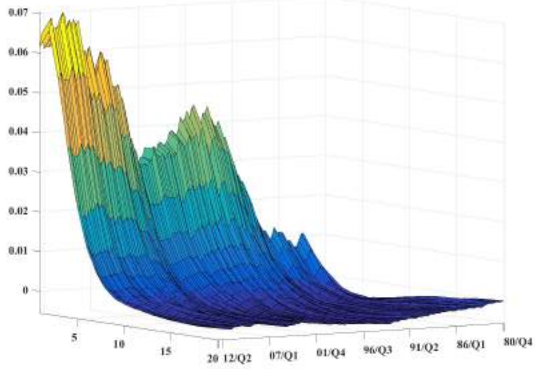
(b) Inflation



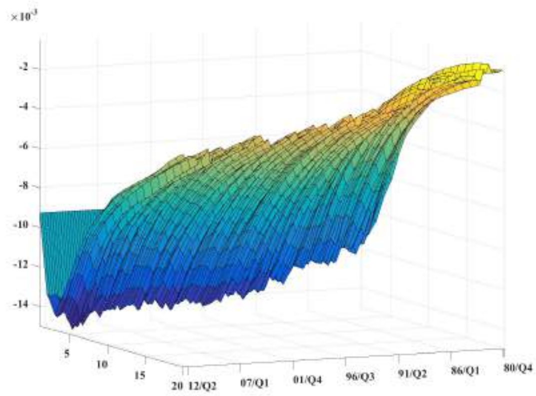
(c) Nominal interest rate



(d) EBP



(e) Banks' capital quality proxy



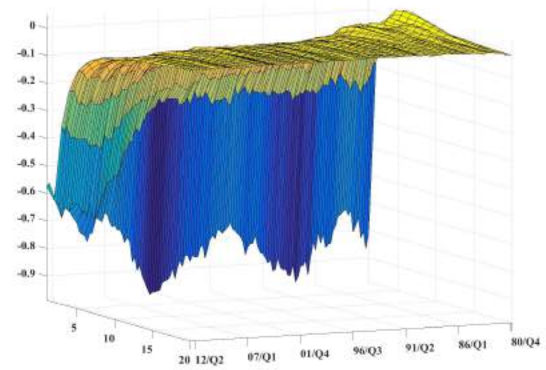
Each panel presents the median of the impulse responses' posterior distribution up to the 20th horizon for each date of the estimation sample.

phenomenon of missing dis/inflation that points towards a relatively muted evolution of headline inflation during the Great Recession in comparison to inflation dynamics in previous economic downturns. Major reasons for the puzzling inflation dynamics comprise a flattening of the Phillips curve (Ball and Mazumder, 2011), anchored inflation expectations (Williams et al., 2010) and altered cost-push shocks. Over the sample the median impulse responses of inflation are relatively short-lived and the curvature of responses reveals nearly no changes. From the early 2000s onwards, the shock propagation extends over horizons and intensifies between horizon 2 to 6, especially during the global financial crisis. The impulse responses of the nominal interest rate, as depict in Panel c, intensify on impact and depict more pronounced curvature across time. This evolution of the nominal interest rate responses consistently reflects the monetary policy reaction to banks' capital quality shock effects on GDP and inflation.

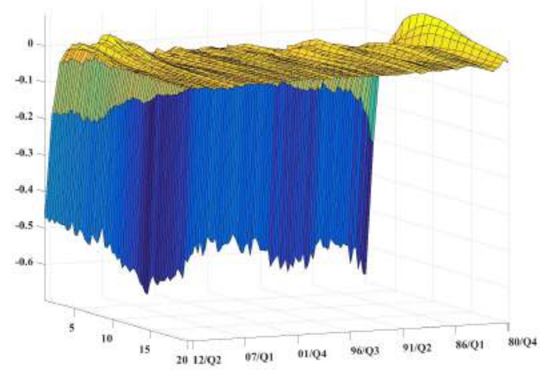
The impulse responses to the monetary policy shock are shown in Figure 4.5. The median impulse responses of the EBP (see Panel d) indicate that the shock impact increases between the early 1980s to the early 1990s, stabilizes throughout the 1990s and rises again 2000 onwards. The curvature of the EBP responses alters and responses extend over horizons 2 to 5 until the beginning of the 1990s, stabilizing thereafter. This can be interpreted as a rising importance of the credit channel, an additional channel of monetary policy transmission, and is in line with the empirical evidence of Gertler and Karadi (2015). As shown in Panel e, the median impulse responses to the banks' capital quality proxy decline on impact from the late 1980s to the mid-1990s but then increases over the remaining sample.

Figure 4.5: Impulse responses to a monetary policy shock

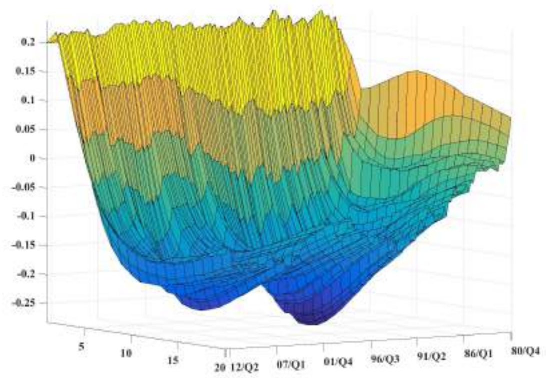
(a) GDP



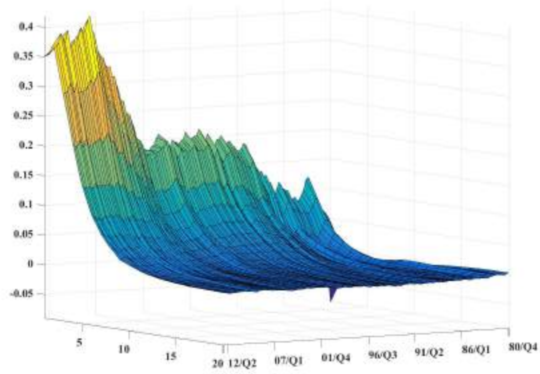
(b) Inflation



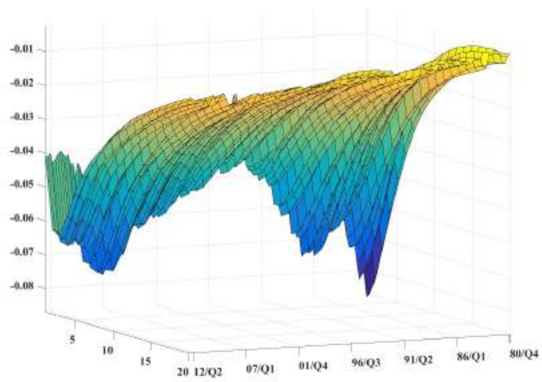
(c) Nominal interest rate



(d) EBP



(e) Banks' capital quality proxy



Each panel presents the median of the impulse responses' posterior distribution up to the 20th horizon for each date of the estimation sample.

The impulse responses of the core macroeconomic variables, GDP and inflation, generally show only limited variation over time. As depict in Panel a, the impact of a monetary policy shock on GDP only increases slightly on impact around the mid-1990s and early 2000s. The evolution of the median impulse responses of headline inflation (see Panel b) reveal nearly no change over the entire sample and are relatively short-lived. The curvature of both, GDP and inflation, evolves relatively stable, except for a mild attenuation of the GDP responses during the global financial crisis.

Overall, the evolution of median impulse responses to a banks' capital quality shock suggest an intensified shock propagation to the relative refinancing costs of financial institutions, EBP, and a rising shock impact on GDP as well as inflation. Thereby, the results on the latter confirm previously documented puzzling inflation dynamics during the global financial crisis. In contrast, median impulse responses of GDP and inflation to a monetary policy shock reveal to be rather stable over the entire sample, whereby the responses of GDP are slightly altered during the global financial crisis. Moreover, the quantitative size of structural responses that result from the TVP VAR are in line with the quantitative size of impulse responses stemming from the re-simulation of the GK model.[1] To indicate the statistical significance of the impulse responses and to deepen the discussion about the evolution of shock propagation, I subsequently present the median of the impulse responses' posterior distribution and corresponding 68% probability bands across time at specific horizons.

[1] Distinct sizes of the monetary policy shock in terms of nominal interest rates on shock impact needs to be taken into account when comparing impulses responses to a structural monetary policy shock resulting from the TVP VAR and the re-simulated GK model.

Horizon comparison

Figures 4.6 and 4.7 depict the evolution of impulse responses for horizon 2, 4, and 6 to a banks' capital quality shock and a monetary policy shock, respectively. Thereby, the solid lines present the median of the posterior distributions and the shaded areas are the corresponding 68% probability bands.

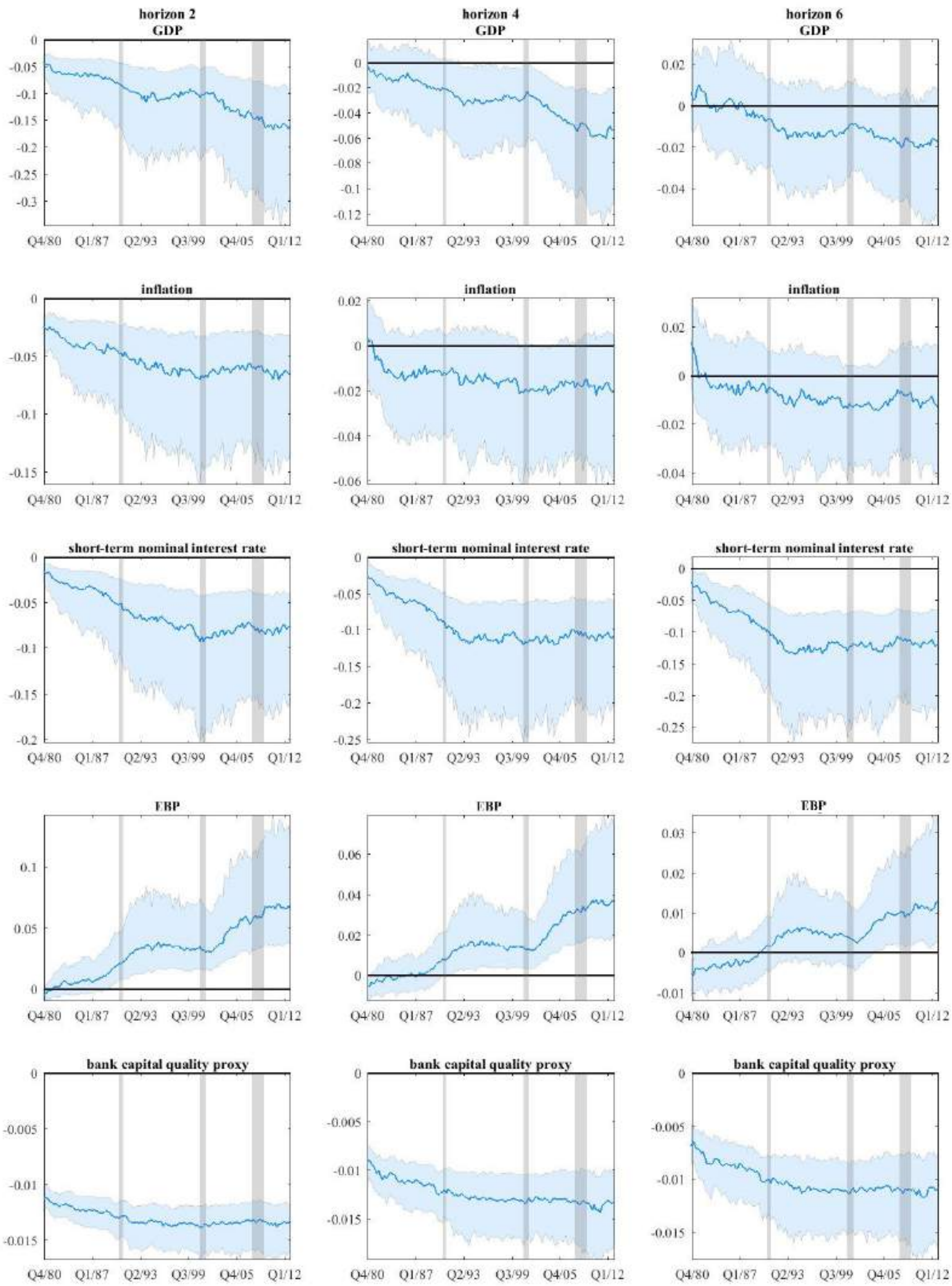
Turning firstly to the banks' capital quality shock, the panels in the fifth column of Figure 4.6 reflect the evolution of the impulse responses to the banks' capital quality proxy and support the aforementioned notion that the response dynamics are altered at horizon 4 and 6, however, not significantly. The panels in the fourth column of Figure 4.6 show that a banks' capital quality shock significantly increases the excess bond premium at horizon 2 and 4 from the early 1990 onwards and at horizon 6 from the early 2000s onwards. One should recall that no sign restrictions are applied to the EBP. Moreover, the responses of the EBP continuously increase over the sample to the extent that the responses in 1980s are significantly smaller than the responses in the 2000s at horizon 2 and 4.

The first column of Figure 4.6 depicts the evolution of the impulse responses of GDP and shows that GDP declines significantly in response to a banks' capital quality shock at horizon 4 from the mid-1990s onwards. Moreover, the responses of GDP intensify over the sample, however, not significantly. In contrast, the impulse responses of headline inflation (see second column of Figure 4.6) do not reveal any changing dynamics and are only significant for horizon 2 on which the sign restrictions still apply. As suggested by the third column of Figure 4.6, the nominal interest rate declines significantly in response to a banks' capital quality shock at horizon 2, 4, and 6. Also, the response is amplified although not significantly throughout the entire sample and across horizons. Figure 4.7 presents the evolution of impulse responses resulting from a monetary policy shock across time at horizon 2, 4, and 6.

Focusing firstly on the variables related to the financial intermediaries, the fifth column Figure 4.7 shows that banks' capital quality proxy declines significantly in response to a restrictive monetary policy shock over the entire sample and across horizons. The responses across horizons indicate that banks' capital quality only slowly reverts back to zero. Moreover, the shock propagation does not change significantly over time. It can be seen in the fourth column of Figure 4.7 that a restrictive monetary policy shock leads to a significant rise of the excess bond premium from the early 1990s onwards. Moreover, the responses of the EBP are significantly altered over time at horizons 2 and 4.

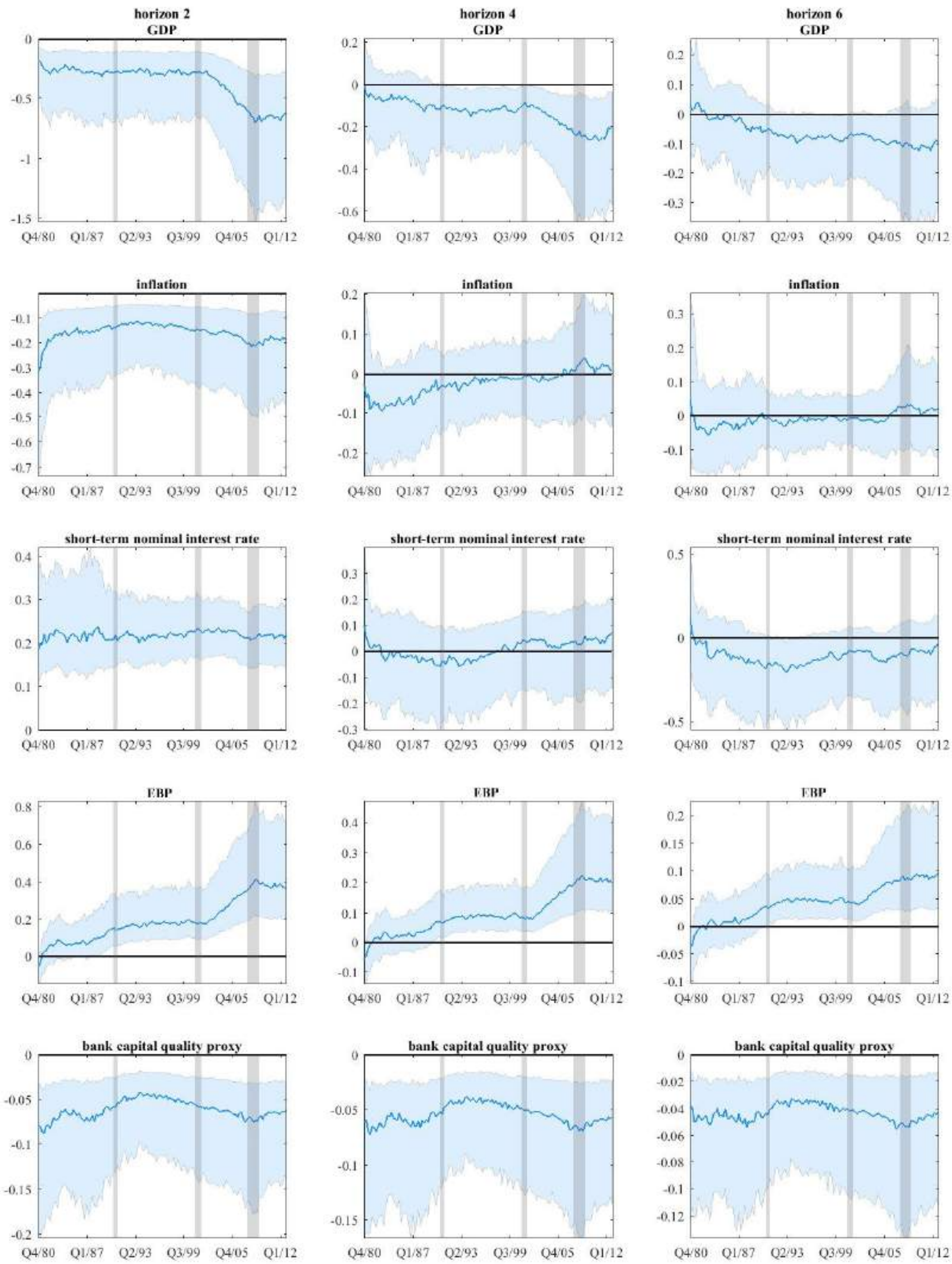
The impulse responses of GDP, as depicted in the first column of Figure 4.7, indicate that GDP significantly declines in response to a restrictive monetary policy from the early 1990s onwards at the fourth horizon. Moreover, the responses are attenuated, although not significantly, since the early 2000s. Together with the increased responses of the EBP, this points to a rising importance of the credit channel since the early 1990s. In contrast, impulse

Figure 4.6: Horizon comparison of impulse responses to a banks' capital quality shock



The panels reflect the impulse responses to a banks' capital quality shock of one standard deviation at the horizons 2, 4 and 6 (columns) across time. Thereby, the shock size has been standardized across time to reflect the average standard deviation of the sample. The solid lines represent the median of the posterior distribution and the shaded areas the 68% probability bands.

Figure 4.7: Horizon comparison of impulse responses to a monetary policy shock



The panels reflect the impulse responses to a monetary policy shock of one standard deviation at the horizons 2, 4 and 6 (columns) across time. Thereby, the shock size has been standardized across time to reflect the average standard deviation of the sample. The solid lines represent the median of the posterior distribution and the shaded areas the 68% probability bands.

responses of inflation (see the third column of Figure 4.7) do not react significantly to a monetary policy shock beyond the imposed sign restrictions and the evolution of responses do not change significantly.

In summary, the comparison of impulse response horizons indicates that a banks' capital quality shock significantly impacts the excess bond premium and GDP form the mid-1990s onwards. Moreover, the responses of the EBP and GDP point towards an attenuation of shock propagation especially throughout the 2000s. The impulse responses to a monetary policy shock are relatively stable in comparison. However, responses of GDP become significant from the early 2000s onwards and show an increasing tendency. Together with the altered responses of the EBP, this suggests that the credit channel has gained importance from the mid-1990s onwards.

4.4.3 Testing for changes in the shock propagation

To support the argument that the shock propagation of a banks' capital quality shock and to a monetary policy shock has increased over time, I test whether the posterior distribution of impulse responses of a specific variable reveal an equal mean and/or median across business cycle turning points. Therefore, I apply a two-sided t-test to test for equal means and a Wilcoxon ranksum test to test for equal medians of the impulse responses at specific horizons and time-spans. As focal points for testing the changes in the shock propagation, I choose all business cycle peaks over the sample that are documented by the NBER business cycle dating. Three peaks are listed for the estimation sample, namely Q3 1990, Q1 2001 and Q4 2007 and correspond to the early 1990s recession (abbreviated by 90s), the Dot-com crisis (abbreviated by DC) and the Great Recession (abbreviated by GR).

To ensure that the test results do not hinge on the estimation results of impulse response of a particular quarter, I merge posterior distributions of impulse responses at specific horizons across four and eight quarters after each peak and prior to each peak. I then test for equal means and medians across these distributions, comparing results across distinct business cycle points.

If the test results reject equal means or medians, I infer whether the means or medians of impulse responses at specific horizons are larger or smaller, respectively. I indicate the finding of smaller or larger mean/median by ‘<’ (green/lighter cell shades) and ‘>’ (red/darker cell shades) respectively, whereby I refer to the absolute values of impacts. Moreover, ‘=’ indicates that the Null-hypothesis could not be rejected.

Tables 4.4 and 4.5 present test results at the 95% significance level for impulse responses at the horizons 2-3, 4-5, 6-7 and 8-9 to a banks’ capital quality shock and a monetary policy shock. The results for distribution of eight quarters prior to the peaks and after the peaks are included in the appendix as they show no qualitative difference to the test results presented here. Overall, the results of the two-sided t-test and ranksum test reveal equal results. The

Table 4.4: Test of equal mean/median of impulse responses to a banks' capital quality shock across time

Time		ranksum test			two-sided t-test		
+ 4 quarters		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
2-3	y	<	<	<	<	<	<
	π	<	<	>	<	<	>
	i	<	<	>	<	<	>
	EBP	<	<	<	<	<	<
	BCQ	<	<	>	<	<	>
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
4-5	y	<	<	<	<	<	<
	π	<	<	>	<	<	>
	i	<	<	>	<	<	>
	EBP	<	<	<	<	<	<
	BCQ	<	<	>	<	<	<
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
6-7	y	<	<	<	<	<	<
	π	<	<	>	<	<	<
	i	<	<	>	<	<	>
	EBP	<	<	<	<	<	<
	BCQ	<	<	>	<	<	>
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
8-9	y	<	<	<	<	<	<
	π	<	<	>	<	<	>
	i	<	<	>	<	<	>
	EBP	<	<	<	<	<	<
	BCQ	<	<	>	<	<	<
- 4 quarters		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
2-3	y	<	<	<	<	<	<
	π	<	<	>	<	<	>
	i	<	<	>	<	<	>
	EBP	<	<	<	<	<	<
	BCQ	<	<	>	<	<	>
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
4-5	y	<	<	<	<	<	<
	π	<	<	>	<	<	>
	i	<	<	>	<	<	>
	EBP	<	<	<	<	<	<
	BCQ	<	<	>	<	<	>
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
6-7	y	<	<	<	<	<	<
	π	<	<	>	<	<	>
	i	<	<	>	<	<	>
	EBP	<	<	<	<	<	<
	BCQ	<	<	>	<	<	>
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
8-9	y	<	<	<	<	<	<
	π	<	<	>	<	<	>
	i	<	<	>	<	<	>
	EBP	<	<	<	<	<	<
	BCQ	<	<	>	<	<	>

The table presents qualitative test results of a two-sided t-test to test for equal means and a Wilcoxon ranksum test to test for equal medians to the impulse responses at specific horizons and time-spans. A finding of a smaller or a larger mean/median is indicated by ‘<’ (green/lighter cell shades) and ‘>’ (red/darker cell shades) respectively. Moreover, ‘=’ indicates that the Null-hypothesis could not be rejected at a 95% significance level.

test results from Table 4.4 indicate that across horizons the median and mean of the impulse responses of GDP and the EBP increased over time, pointing towards an intensification of the link between macroeconomic dynamics and financial markets. Moreover, Table 4.4 indicates that the responses of inflation, the banks' capital quality and the nominal interest rate is smaller

Table 4.5: Test of equal mean/median of impulse responses to a monetary policy shock across time

Time		ranksum test			two-sided t-test		
+ 4 quarters		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
2-3	y	<	<	<	<	<	<
	π	=	<	<	=	<	<
	i	<	<	>	<	<	>
	EBP	<	<	<	<	<	<
	BCQ	=	<	<	=	<	<
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
4-5	y	<	<	<	<	<	<
	π	>	>	>	>	>	>
	i	<	<	=	<	<	=
	EBP	<	<	<	<	<	<
	BCQ	>	<	<	>	<	<
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
6-7	y	<	<	<	<	<	<
	π	<	>	>	<	>	>
	i	<	<	=	<	<	=
	EBP	<	<	<	<	<	<
	BCQ	>	<	<	>	<	<
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
8-9	y	<	<	<	<	<	<
	π	<	=	>	<	=	>
	i	<	<	>	<	<	>
	EBP	<	<	<	<	<	<
	BCQ	>	<	<	>	<	<
- 4 quarters		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
2-3	y	<	<	<	<	<	<
	π	=	<	<	=	<	<
	i	<	<	>	<	<	>
	EBP	<	<	<	<	<	<
	BCQ	>	<	<	>	<	<
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
4-5	y	<	<	<	<	<	<
	π	>	>	>	>	>	>
	i	<	<	<	<	<	<
	EBP	<	<	<	<	<	<
	BCQ	>	<	<	>	<	<
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
6-7	y	<	<	>	<	<	>
	π	<	>	>	<	>	>
	i	<	<	<	<	<	<
	EBP	<	<	<	<	<	<
	BCQ	>	<	<	>	<	<
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
8-9	y	<	<	>	<	<	>
	π	<	<	>	<	<	>
	i	<	<	=	<	<	=
	EBP	<	<	<	<	<	<
	BCQ	>	<	<	>	<	<

The table presents qualitative test results of a two-sided t-test to test for equal means and a Wilcoxon ranksum test to test for equal medians to the impulse responses at specific horizons and time-spans. A finding of a smaller or a larger mean/median is indicated by '<' (green/lighter cell shades) and '>' (red/darker cell shades) respectively. Moreover, '=' indicates that the Null-hypothesis could not be rejected at a 95% significance level.

during the Great Recession compared to the Dot-com crisis but larger than in the 1990s recession.

Turning to the test results for the monetary policy shock presented in Table 4.5, the findings indicate that impulse responses of GDP and the EBP increase over the sample across horizons. This implies that the credit channel of monetary policy has gained importance since the early 1990s and is in line with the finding of an intensified propagation of the banks' capital quality shock. The test results also indicate that the response of inflation is smaller throughout the 2000s compared to the 1990s.

4.5 Robustness analysis

To check the sensitivity of the baseline model, I report a couple of robustness analyses in this section. The first robustness exercise is concerned with the number of horizons on which the sign restrictions are imposed. The second robustness analysis focuses on the omission of a demand shock in the baseline identification.

The baseline identification strategy imposes the sign restrictions that are depicted in Table 4.2 on the first two horizons of the impulse responses. As a first robustness check, I re-estimate the model and identify the structural shocks by applying the sign restrictions only to the first horizon of the impulse responses. The Figures 4.10 to 4.15 and the Tables 4.10 to 4.13 in the appendix depict the results of this specification that are qualitatively equal to the baseline results. Generally, the median impulse responses to the banks' capital quality shock are quantitatively slightly smaller compared to those of the benchmark identification but show the same dynamics. In contrast, the median impulse responses to a monetary policy shock reveal less pronounced dynamics compared to the benchmark results. Also, the responses of the

EBP to a banks' capital quality shock and to a monetary policy shock start to be significant at later points in time compared to the baseline identification.

The second robustness check is related to the omission of a structural demand shock in the benchmark specification. Leduc and Liu (2016) present empirical evidence that a structural macroeconomic uncertainty shock is in fact capturing an adverse demand structural demand shock. Therefore, I extend the baseline model by a measure of macroeconomic uncertainty of Jurado et al. (2015) and re-estimate the model. Simulated impulse response functions of a structural demand shock in the GK model imply qualitatively the same sign restrictions as a banks' capital quality shock. Therefore, I apply restrictions to the size of the impulse responses in addition to sign restrictions to distinguish a banks' capital quality shock from structural uncertainty shock, as suggested by Caldara et al. (2016). In particular, I assume that the impulse responses to macroeconomic uncertainty to a structural uncertainty shock is larger than the impulse responses to the banks' capital quality shock (and vice versa for a banks' capital quality shock). Table 4.6 present the full set of sign and size restrictions that are jointly imposed on the first horizon of impulse responses.

The impulse responses and test results of the model including macroeconomic uncertainty, which are depicted in the Figures 4.16 to 4.23 and the Tables 4.14 to 4.17, are qualitatively equal to the benchmark results. Only a few minor differences emerge. The median impulse responses to a banks' capital quality shock but also to a monetary policy shock reveal more pronounced curvatures and a slightly smaller quantitative impact across variables. Moreover, the increase of EBP's responses of both shocks, banks' capital quality and monetary policy, is smaller throughout the 1990s.

Table 4.6: Imposed sign restrictions of the model including macroeconomic uncertainty

variables	**BCQ shock**	**MP shock**	**Tech shock**	**MU shock**
GDP	−	−	+	−
inflation	−	−	−	−
nominal interest rate	−	+	*	−
risk-adjusted premium	*	*	*	*
banks' capital quality	−	−	*	−
	$>$			$<$
macroeconomic uncertainty	+	+	*	+

The table indicates the imposed sign restrictions of four structural shocks, whereby BCQ shock stands for a banks' capital quality shock, MP shock represents a monetary policy shock, Tech shock describes a technology shock and MU shock indicates a macroeconomic uncertainty shock.

Comparing impulses responses across horizons indicates that the responses of GDP to a banks' capital quality shock become significant at an earlier point in time (late 1980s) compared to the baseline model results. Also, the EBP increases significantly to a monetary policy shock from the late 1990s onwards. Overall, the mean and median test results of the model, that include macroeconomic uncertainty, confirm the baseline results, except that they do not indicate a decline of the responses of inflation to a banks' capital quality shock over time as suggested by the benchmark results.

4.6 Conclusion

Recent empirical studies point towards a time-varying intensity of the interplay between financial markets and macroeconomic dynamics. From an international perspective, the real economic effects of the global financial crisis have been more pronounced in economies where the overall level of financial intermediaries leverage ratios were generally high. The theoretical work of Brunnermeier and Sannikov (2014) and Gertler et al. (2016) suggest that financial innovation exogenously reduces the idiosyncratic risk of banks and enhances the long-run level of financial intermediaries' leverage ratios (at least throughout the mid-1980s to late 1990s in the US). In turn altered long-run leverage ratios increase the financial amplification of structural shocks. The higher degree of financial acceleration implies that sudden disruptions in the banking sector reveal altered shock propagation to real economic activity. Thes increased financial amplification also applies to the propagation of a monetary policy shock to the extent that the credit channel becomes more relevant.

This study investigates changes in the intensity of the financial acceleration of structural shocks to the US economy and assesses whether the financial amplification has increased in the last thirty years, as suggested by the theoretical contributions of Brunnermeier and Sannikov (2014) and Gertler et al. (2016). Therefore, a TVP- VAR with stochastic volatility is estimated and a structural banks' capital quality shock, a monetary policy shock and a productivity shock are identified by using sign restrictions that rely on the monetary DSGE model of Gertler and Karadi (2011). The findings suggest that the amplification of structural shocks by financial frictions has increased during the last 30 years. In particular, sudden changes of the banks' capital quality reveal a rising impact on the risk-adjusted premium of financial intermediaries and real economic activity since the early 1990s, especially within the first year following the shock impact. Thereby, results of the evolution of impulse responses of GDP and the risk-adjusted premium are qualitatively similar to those resulting from the re-simulation exercise of the model with distinct equilibrium leverage ratios. Moreover, the responses of the risk-adjusted premium and GDP to a monetary policy shock have increased, however, to a relatively smaller extent than the responses to a banks' capital quality shock. This suggests that the credit channel, as part of the monetary policy transmission, has gained importance, especially since the beginning of the 2000s. Overall, the analysis provides evidence of an increasing intensity of the financial amplifier in line with the theoretical suggestions of Brunnermeier and Sannikov (2014) and Gertler et al. (2016).

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4.7 Appendix

4.7.1 MCMC convergence statistics

This section presents results of three convergence statistics of the MCMC algorithm. The first convergence measure is the autocorrelation of the Gibbs draws kept at the lag of 30, whereby low levels of autocorrelation indicate that the draws are nearly independent. The second statistic is the relative numerical inefficiency suggested by Geweke (1992), which is the inverse of the ratio of the numerical variance and the variance of independent draws Chib (2001). A 4 % tapered window for the estimation of the spectral density at frequency zero is used as in Primiceri (2005). The third measure is the Raftery et al. (1992) diagnostic that indicates the total number of runs necessary to achieve the precision for the 0.025 and 0.0975 quantiles of marginal posteriors, the desired accuracy to 0.025 and the probability of achieving the required accuracy to 0.95. Table 4.7 displays the mean, the median, the minimum and maximum of the three convergence statistics that are calculated for each point in time of the estimation sample. The results confirm that the MCMC sample algorithm generally convergence. The median and mean autocorrelation of the 20^{th} lag are commonly low and the mean and median of relative numerical inefficiency factors are all below 30. Moreover, the median and mean number of iterations chosen, 25000, is well above the number of runs required indicated by the Raftery and Lewis statistic.

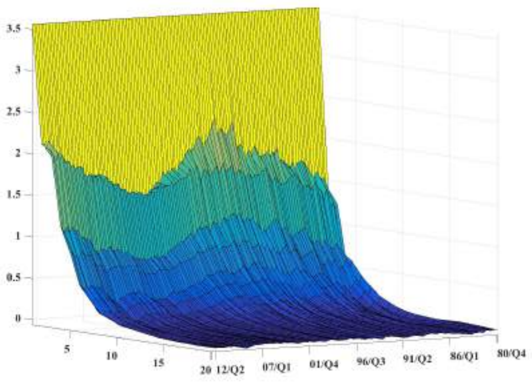
Table 4.7: MCMC convergence statistics

	20th order acf				**Inefficiency f.**				**RL runs**			
	Median	**Mean**	**Max**	**Min**	**Median**	**Mean**	**Max**	**Min**	**Median**	**Mean**	**Max**	**Min**
S	0.07	0.10	0.27	0.02	8.25	8.25	26.57	2.98	703	1075	2569	608
W	0.01	0.01	0.05	-0.02	2.02	2.02	5.46	1.13	648	680	780	596
Ω	0.30	0.30	0.50	0.12	28.34	28.34	51.41	14.62	4652	5482	10977	2463
A	0.01	0.01	0.03	-0.03	5.26	5.26	8.78	2.78	1193	1219	1742	831
B	-0.02	-0.02	0.13	-0.15	0.98	0.98	1.32	0.74	681	723	1386	675
Q	0.00	0.00	0.03	-0.02	1.02	1.02	1.68	0.66	2563	2945	5978	680
U	0.01	0.01	0.05	-0.02	2.25	2.25	6.91	1.08	633	706	1412	584

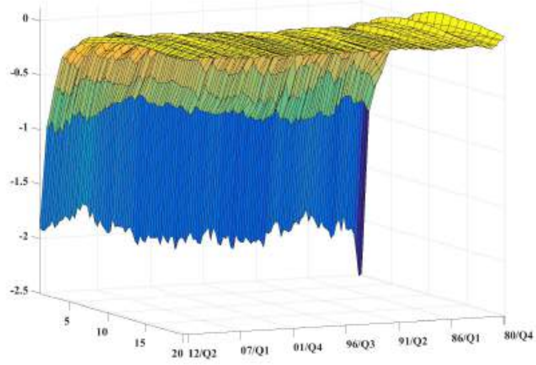
4.7.2 Benchmark TVP-VAR: additional results

Figure 4.8: Impulse responses to a technology shock

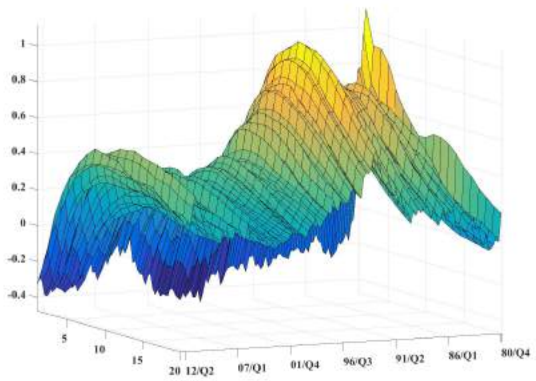
(a) GDP



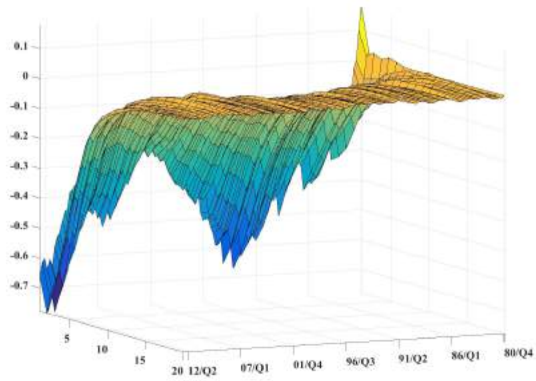
(b) Inflation



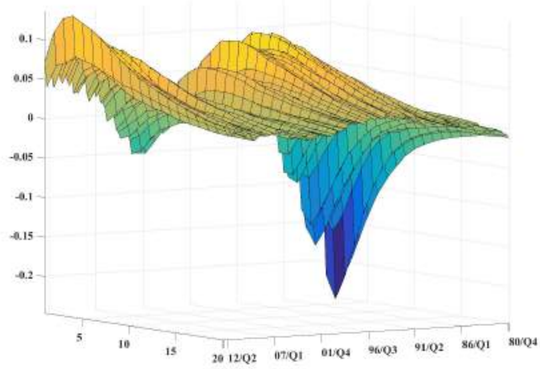
(c) Nominal interest rate



(d) EBP

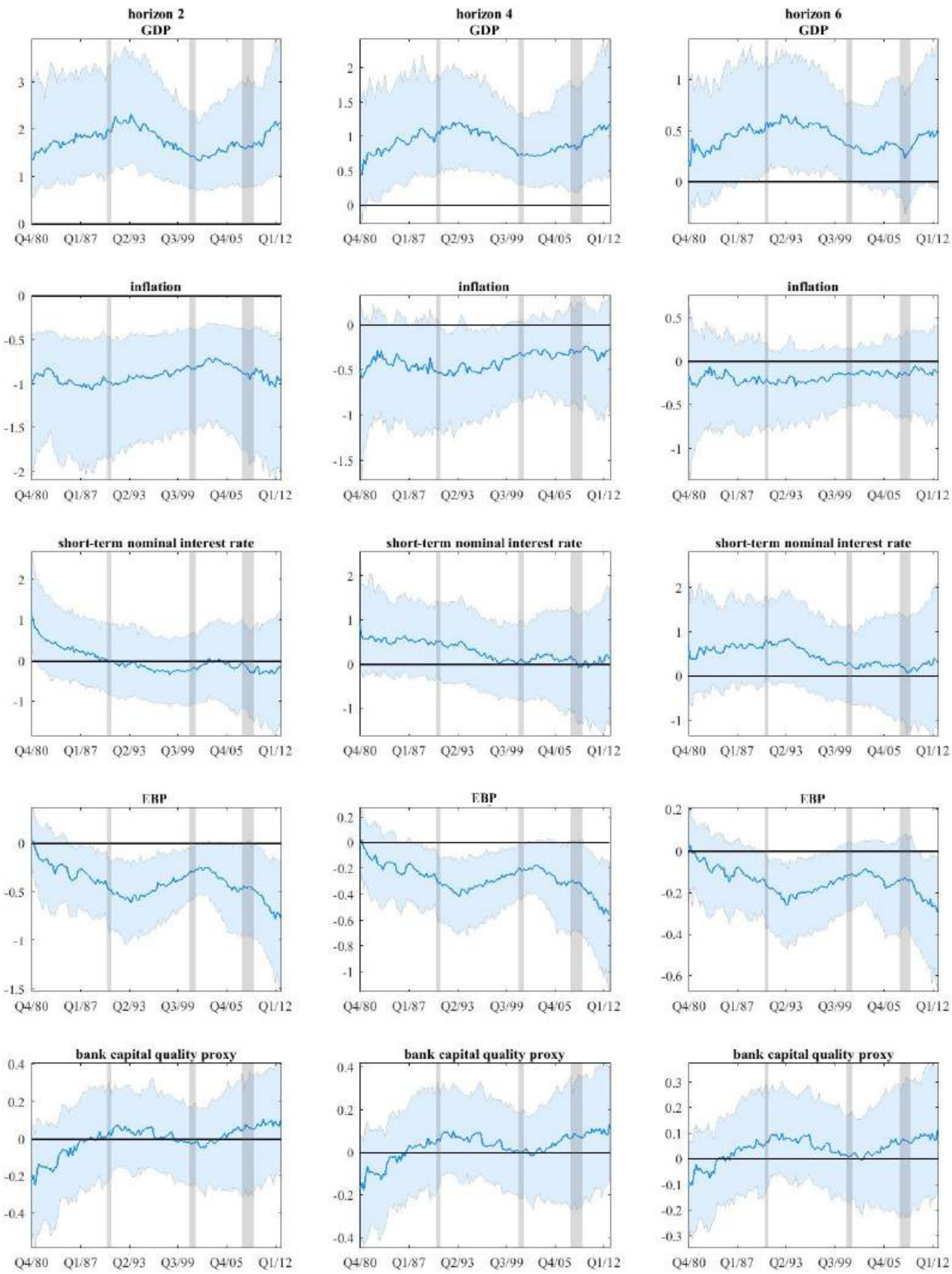


(e) Banks' capital quality proxy



Each panel presents the median of the impulse responses' posterior distribution up to the 20th horizon for each date of the estimation sample.

Figure 4.9: Horizon comparison of impulse responses to a technology shock



The panels reflect the impulse responses to a technology shock of one standard deviation at the horizons 2, 4 and 6 (columns) across time. Thereby, the shock size has been standardized across time to reflect the average standard deviation of the sample. The solid lines represent the median of the posterior distribution and the shaded areas the 68% probability bands.

Table 4.8: Test of equal mean/median of impulse responses to a banks' capital quality shock across time: eight quarters

Time		ranksum test			two-sided t-test		
+ 8 quarters		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
2-3	y	<	<	<	<	<	<
	π	<	<	>	<	<	>
	i	<	<	>	<	<	>
	EBP	<	<	<	<	<	<
	BCQ	<	<	>	<	<	<
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
4-5	y	<	<	<	<	<	<
	π	<	<	>	<	<	>
	i	<	<	>	<	<	>
	EBP	<	<	<	<	<	<
	BCQ	<	<	<	<	<	<
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
6-7	y	<	<	<	<	<	<
	π	<	<	>	<	<	>
	i	<	<	>	<	<	>
	EBP	<	<	<	<	<	<
	BCQ	<	<	>	<	<	>
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
8-9	y	<	<	<	<	<	<
	π	<	<	<	<	<	<
	i	<	<	>	<	<	>
	EBP	<	<	<	<	<	<
	BCQ	<	<	>	<	<	>
- 8 quarters		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
2-3	y	<	<	<	<	<	<
	π	<	<	>	<	<	>
	i	<	<	>	<	<	>
	EBP	<	<	<	<	<	<
	BCQ	<	<	>	<	<	<
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
4-5	y	<	<	<	<	<	<
	π	<	<	>	<	<	>
	i	<	<	>	<	<	>
	EBP	<	<	<	<	<	<
	BCQ	<	<	>	<	<	>
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
6-7	y	<	<	<	<	<	<
	π	<	<	>	<	<	>
	i	<	<	>	<	<	>
	EBP	<	<	<	<	<	<
	BCQ	<	<	>	<	<	>
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
8-9	y	<	<	<	<	<	<
	π	<	<	<	<	<	<
	i	<	<	>	<	<	>
	EBP	<	<	<	<	<	<
	BCQ	<	<	>	<	<	>

The table presents qualitative test results of a two-sided t-test to test for equal means and a Wilcoxon ranksum test to test for equal medians to the impulse responses at specific horizons and time-spans. A finding of a smaller or a larger mean/median is indicated by '<' (green/lighter cell shades) and '>' (red/darker cell shades) respectively. Moreover, '=' indicates that the Null-hypothesis could not be rejected at a 95% significance level.

Table 4.9: Test of equal mean/median of impulse responses to a monetary policy shock across time: eight quarters

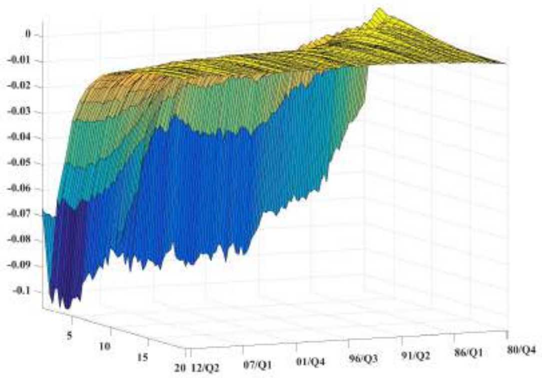
Time		ranksum test			two-sided t-test		
+ 8 quarters		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
2-3	y	<	<	<	<	<	<
	π	<	<	<	<	<	>
	i	<	<	>	<	<	<
	EBP	<	<	<	<	<	<
	BCQ	<	<	<	<	<	<
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
4-5	y	<	<	<	<	<	<
	π	>	>	>	>	>	>
	i	<	<	<	<	<	<
	EBP	<	<	<	<	<	<
	BCQ	<	<	<	<	<	<
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
6-7	y	<	<	<	<	<	<
	π	<	>	>	<	>	>
	i	<	<	<	<	<	<
	EBP	<	<	<	<	<	<
	BCQ	<	<	<	<	<	<
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
8-9	y	<	<	<	<	<	<
	π	<	>	>	<	>	>
	i	<	<	=	<	<	=
	EBP	<	<	<	<	<	<
	BCQ	<	<	<	<	<	<
- 8 quarters		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
2-3	y	<	<	<	<	<	<
	π	>	<	<	>	<	<
	i	<	<	<	<	<	<
	EBP	<	<	<	<	<	<
	BCQ	>	<	<	>	<	<
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
4-5	y	<	<	<	<	<	<
	π	>	>	>	>	>	>
	i	<	<	<	<	<	<
	EBP	<	<	<	<	<	<
	BCQ	>	<	<	>	<	<
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
6-7	y	<	<	<	<	<	<
	π	<	>	>	<	>	>
	i	<	<	>	<	<	>
	EBP	<	<	<	<	<	<
	BCQ	>	>	<	>	>	<
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
8-9	y	<	<	>	<	<	>
	π	<	<	<	<	<	<
	i	<	>	>	<	>	>
	EBP	<	<	<	<	<	<
	BCQ	>	>	<	>	>	<

The table presents qualitative test results of a two-sided t-test to test for equal means and a Wilcoxon ranksum test to test for equal medians to the impulse responses at specific horizons and time-spans. A finding of a smaller or a larger mean/median is indicated by ‘<’ (green/lighter cell shades) and ‘>’ (red/darker cell shades) respectively. Moreover, ‘=’ indicates that the Null-hypothesis could not be rejected at a 95% significance level.

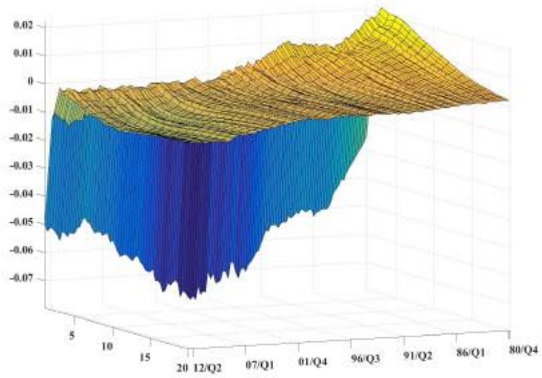
4.7.3 Impulse responses and test results with sign restrictions applied to the first horizon

Figure 4.10: Impulse responses to a banks' capital quality shock: sign restrictions on the first horizon

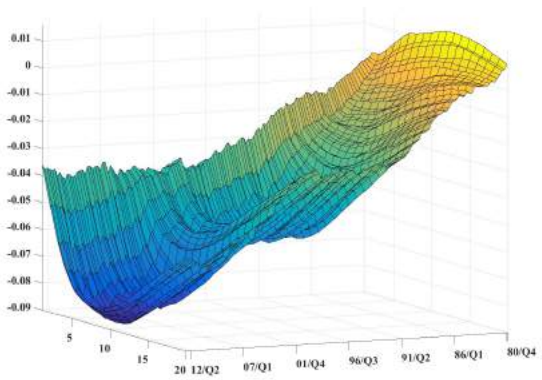
(a) GDP



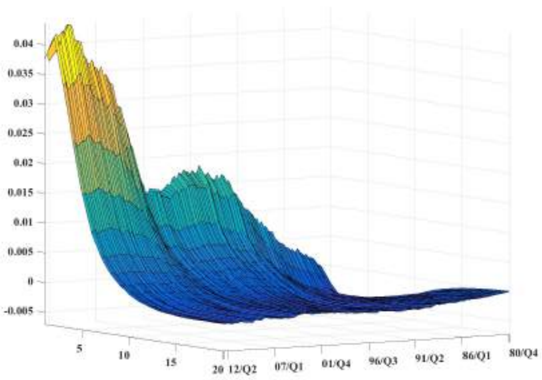
(b) Inflation



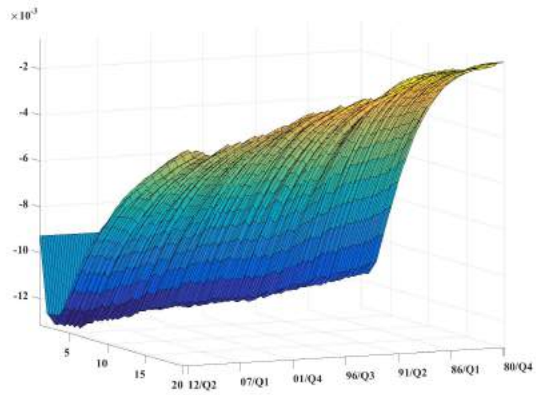
(c) Nominal interest rate



(d) EBP



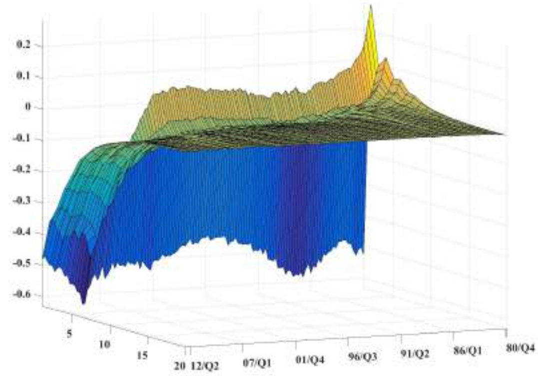
(e) Banks' capital quality proxy



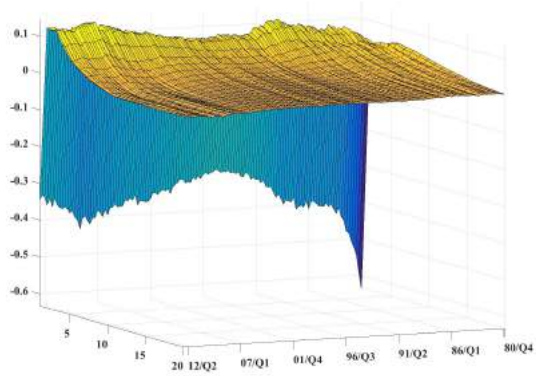
Each panel presents the median of the impulse responses' posterior distribution up to the 20th horizon for each date of the estimation sample.

Figure 4.11: Impulse responses to a monetary policy shock: sign restrictions on the first horizon

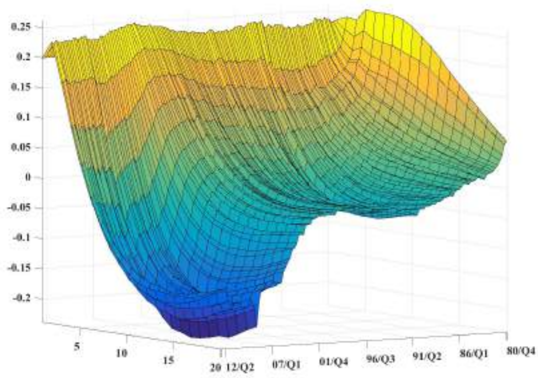
(a) GDP



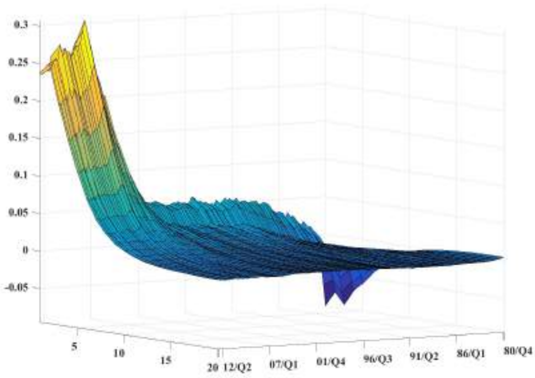
(b) Inflation



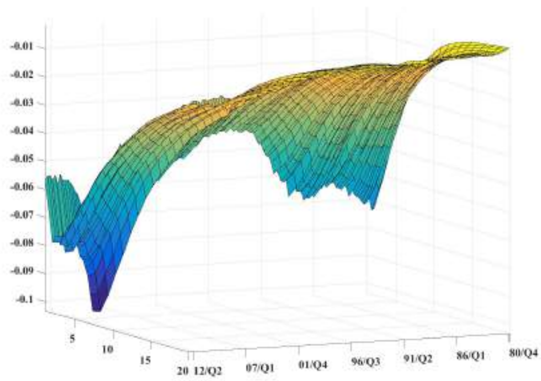
(c) Nominal interest rate



(d) EBP



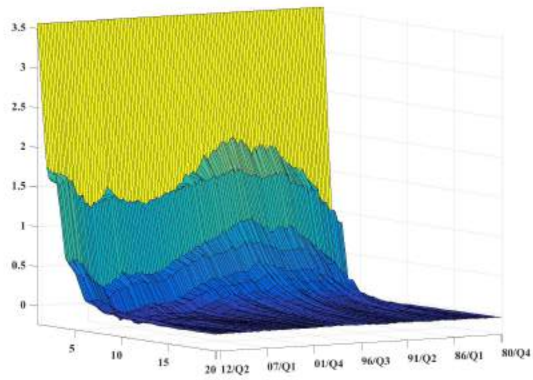
(e) Banks' capital quality proxy



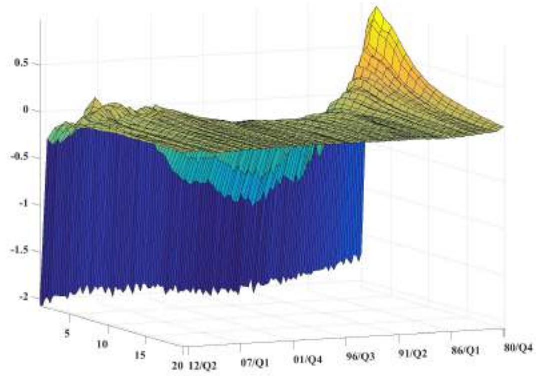
Each panel presents the median of the impulse responses' posterior distribution up to the 20th horizon for each date of the estimation sample.

Figure 4.12: Impulse responses to a technology shock: sign restrictions on the first horizon

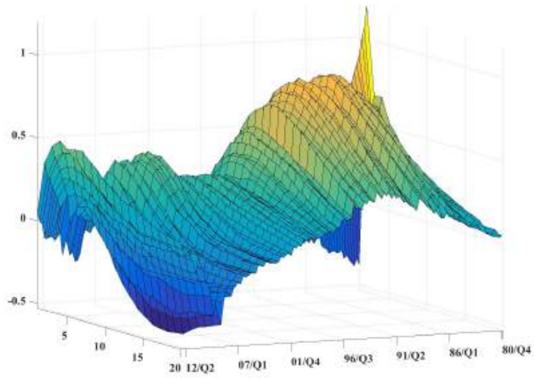
(a) GDP



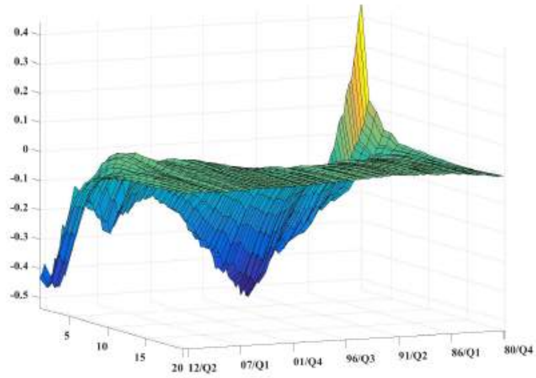
(b) Inflation



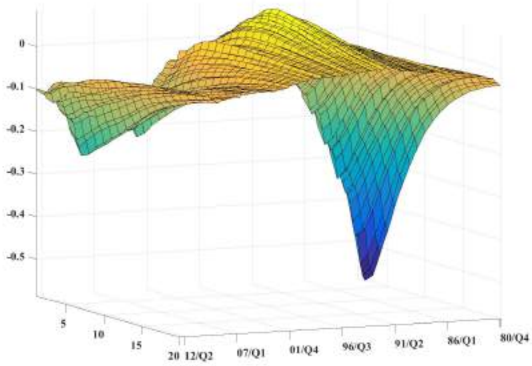
(c) Nominal interest rate



(d) EBP

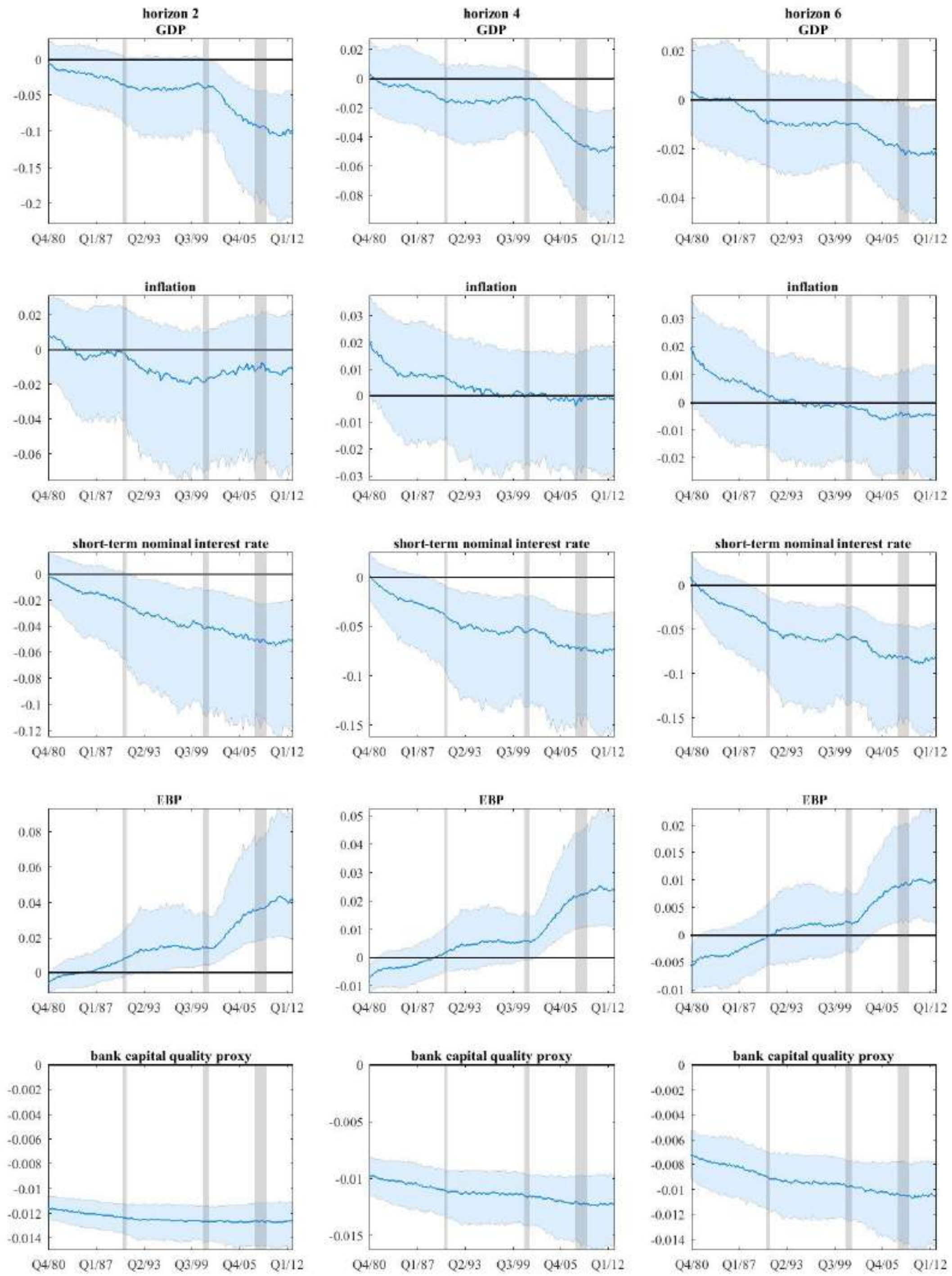


(e) Banks' capital quality proxy



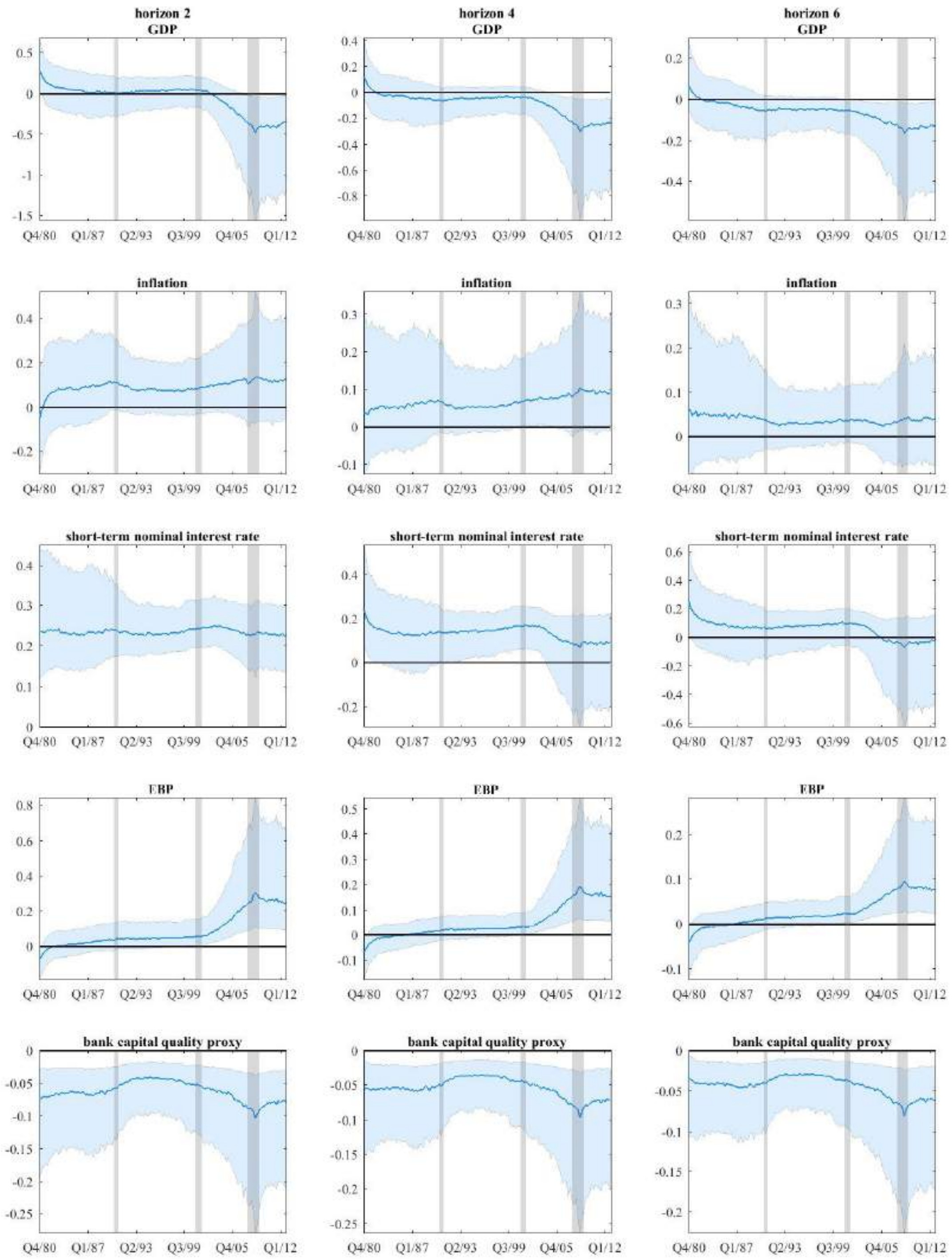
Each panel presents the median of the impulse responses' posterior distribution up to the 20th horizon for each date of the estimation sample.

Figure 4.13: Horizon comparison of impulse responses to a banks' capital quality shock: sign restrictions on the first horizon



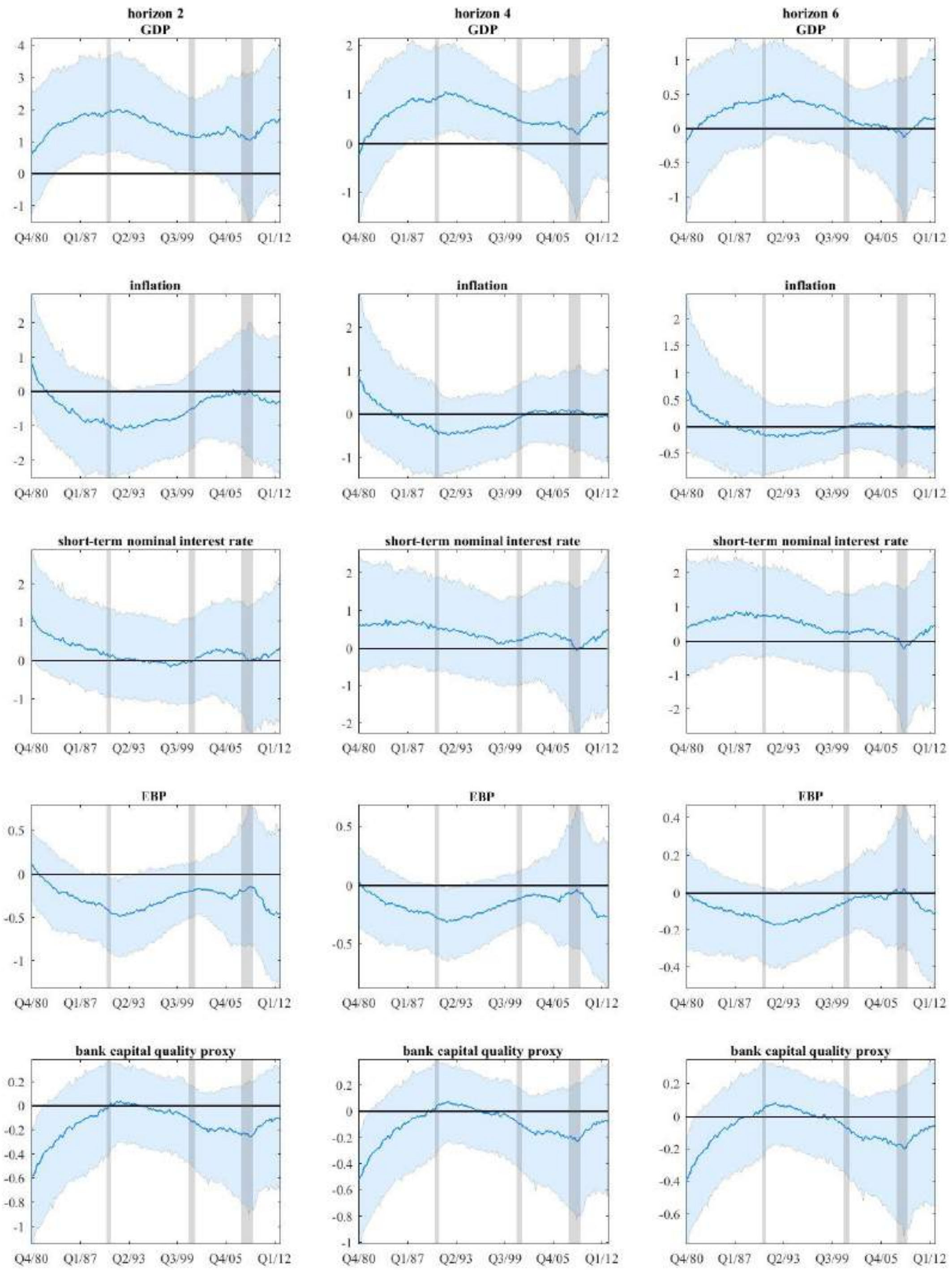
The panels reflect the impulse responses to a banks' capital quality shock of one standard deviation at the horizons 2, 4 and 6 (columns) across time. Thereby, the shock size has been standardized across time to reflect the average standard deviation of the sample. The solid lines represent the median of the posterior distribution and the shaded areas the 68% probability bands.

Figure 4.14: Horizon comparison of impulse responses to a monetary policy shock: sign restrictions on the first horizon



The panels reflect the impulse responses to a monetary policy shock of one standard deviation at the horizons 2, 4 and 6 (columns) across time. Thereby, the shock size has been standardized across time to reflect the average standard deviation of the sample. The solid lines represent the median of the posterior distribution and the shaded areas the 68% probability bands.

Figure 4.15: Horizon comparison of impulse responses to a technology shock: sign restrictions on the first horizon



The panels reflect the impulse responses to a technology shock of one standard deviation at the horizons 2, 4 and 6 (columns) across time. Thereby, the shock size has been standardized across time to reflect the average standard deviation of the sample. The solid lines represent the median of the posterior distribution and the shaded areas the 68% probability bands.

Table 4.10: Test of equal mean/median of impulse responses to a banks' capital quality shock across time: sign restrictions on the first horizon

Time		ranksum test			two-sided t-test		
+ 4 quarters		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
2-3	y	<	<	<	<	<	<
	π	<	<	>	<	<	>
	i	<	<	<	<	<	<
	EBP	<	<	<	<	<	<
	BCQ	<	<	<	<	<	<
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
4-5	y	<	<	<	<	<	<
	π	<	<	<	<	<	<
	i	<	<	<	<	<	<
	EBP	<	<	<	<	<	<
	BCQ	<	<	<	<	<	<
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
6-7	y	<	<	<	<	<	<
	π	<	<	<	<	<	<
	i	<	<	<	<	<	<
	EBP	<	<	<	<	<	<
	BCQ	<	<	<	<	<	<
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
8-9	y	<	<	<	<	<	<
	π	<	<	<	<	<	<
	i	<	<	<	<	<	<
	EBP	<	<	<	<	<	<
	BCQ	<	<	<	<	<	<
- 4 quarters		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
2-3	y	<	<	<	<	<	<
	π	<	<	>	<	<	>
	i	<	<	<	<	<	<
	EBP	<	<	<	<	<	<
	BCQ	<	<	<	<	<	<
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
4-5	y	<	<	<	<	<	<
	π	<	<	<	<	<	<
	i	<	<	<	<	<	<
	EBP	<	<	<	<	<	<
	BCQ	<	<	<	<	<	<
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
6-7	y	<	<	<	<	<	<
	π	<	<	<	<	<	<
	i	<	<	<	<	<	<
	EBP	<	<	<	<	<	<
	BCQ	<	<	<	<	<	<
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
8-9	y	<	<	<	<	<	<
	π	<	<	<	<	<	<
	i	<	<	<	<	<	<
	EBP	<	<	<	<	<	<
	BCQ	<	<	<	<	<	<

The table presents qualitative test results of a two-sided t-test to test for equal means and a Wilcoxon ranksum test to test for equal medians to the impulse responses at specific horizons and time-spans. A finding of a smaller or a larger mean/median is indicated by '<' (green/lighter cell shades) and '>' (red/darker cell shades) respectively. Moreover, '=' indicates that the Null-hypothesis could not be rejected at a 95% significance level.

Table 4.11: Test of equal mean/median of impulse responses to a monetary policy shock across time: sign restrictions on the first horizon

Time		ranksum test			two-sided t-test		
+ 4 quarters		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
2-3	y	$>$	$<$	$<$	$>$	$<$	$<$
	π	$<$	$>$	$>$	$<$	$>$	$>$
	i	$<$	$>$	$>$	$<$	$>$	$>$
	EBP	$<$	$<$	$<$	$<$	$<$	$<$
	BCQ	$>$	$<$	$<$	$>$	$<$	$<$
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
4-5	y	$>$	$<$	$<$	$>$	$<$	$<$
	π	$=$	$>$	$>$	$=$	$>$	$>$
	i	$<$	$>$	$>$	$<$	$>$	$>$
	EBP	$<$	$<$	$<$	$<$	$<$	$<$
	BCQ	$>$	$<$	$<$	$>$	$<$	$<$
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
6-7	y	$<$	$<$	$<$	$<$	$<$	$<$
	π	$=$	$<$	$<$	$<$	$<$	$<$
	i	$<$	$>$	$>$	$<$	$>$	$>$
	EBP	$<$	$<$	$<$	$<$	$<$	$<$
	BCQ	$>$	$<$	$<$	$>$	$<$	$<$
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
8-9	y	$<$	$<$	$<$	$<$	$<$	$<$
	π	$>$	$<$	$<$	$<$	$<$	$<$
	i	$<$	$>$	$>$	$<$	$>$	$>$
	EBP	$<$	$<$	$<$	$<$	$<$	$<$
	BCQ	$<$	$<$	$<$	$>$	$<$	$<$
- 4 quarters		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
2-3	y	$>$	$<$	$<$	$>$	$<$	$<$
	π	$<$	$>$	$>$	$<$	$<$	$>$
	i	$<$	$>$	$>$	$<$	$<$	$<$
	EBP	$<$	$<$	$<$	$<$	$<$	$<$
	BCQ	$>$	$<$	$<$	$>$	$<$	$<$
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
4-5	y	$=$	$<$	$<$	$=$	$<$	$<$
	π	$<$	$=$	$>$	$<$	$=$	$>$
	i	$<$	$>$	$>$	$<$	$>$	$>$
	EBP	$<$	$<$	$<$	$<$	$<$	$<$
	BCQ	$>$	$<$	$<$	$>$	$<$	$<$
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
6-7	y	$<$	$<$	$<$	$>$	$<$	$<$
	π	$<$	$<$	$<$	$<$	$<$	$<$
	i	$<$	$>$	$>$	$<$	$>$	$>$
	EBP	$<$	$<$	$<$	$<$	$<$	$<$
	BCQ	$>$	$<$	$<$	$>$	$<$	$<$
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
8-9	y	$<$	$<$	$<$	$<$	$<$	$<$
	π	$<$	$<$	$<$	$<$	$<$	$<$
	i	$<$	$>$	$>$	$<$	$>$	$>$
	EBP	$<$	$<$	$<$	$<$	$<$	$<$
	BCQ	$>$	$<$	$<$	$>$	$<$	$<$

The table presents qualitative test results of a two-sided t-test to test for equal means and a Wilcoxon ranksum test to test for equal medians to the impulse responses at specific horizons and time-spans. A finding of a smaller or a larger mean/median is indicated by '$<$' (green/lighter cell shades) and '$>$' (red/darker cell shades) respectively. Moreover, '$=$' indicates that the Null-hypothesis could not be rejected at a 95% significance level.

Table 4.12: Test of equal mean/median of impulse responses to a banks' capital quality shock across time: sign restrictions on the first horizon (eight quarters)

Time		ranksum test			two-sided t-test		
+ 8 quarters		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
2-3	y	<	<	<	<	<	<
	π	<	<	>	<	<	>
	i	<	<	<	<	<	<
	EBP	<	<	<	<	<	<
	BCQ	<	<	<	<	<	<
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
4-5	y	<	<	<	<	<	<
	π	<	<	<	<	<	<
	i	<	<	<	<	<	<
	EBP	<	<	<	<	<	<
	BCQ	<	<	<	<	<	<
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
6-7	y	<	<	<	<	<	<
	π	<	<	<	<	<	<
	i	<	<	<	<	<	<
	EBP	<	<	<	<	<	<
	BCQ	<	<	<	<	<	<
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
8-9	y	<	<	<	<	<	<
	π	<	<	<	<	<	<
	i	<	<	<	<	<	<
	EBP	<	<	<	<	<	<
	BCQ	<	<	<	<	<	<
- 8 quarters		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
2-3	y	<	<	<	<	<	<
	π	<	<	>	<	<	>
	i	<	<	<	<	<	<
	EBP	<	<	<	<	<	<
	BCQ	<	<	<	<	<	<
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
4-5	y	<	<	<	<	<	<
	π	<	<	<	<	<	<
	i	<	<	<	<	<	<
	EBP	<	<	<	<	<	<
	BCQ	<	<	<	<	<	<
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
6-7	y	<	<	<	<	<	<
	π	<	<	<	<	<	<
	i	<	<	<	<	<	<
	EBP	<	<	<	<	<	<
	BCQ	<	<	<	<	<	<
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
8-9	y	<	<	<	<	<	<
	π	<	<	<	<	<	<
	i	<	<	<	<	<	<
	EBP	<	<	<	<	<	<
	BCQ	<	<	<	<	<	<

The table presents qualitative test results of a two-sided t-test to test for equal means and a Wilcoxon ranksum test to test for equal medians to the impulse responses at specific horizons and time-spans. A finding of a smaller or a larger mean/median is indicated by '<' (green/lighter cell shades) and '>' (red/darker cell shades) respectively. Moreover, '=' indicates that the Null-hypothesis could not be rejected at a 95% significance level.

Table 4.13: Test of equal mean/median of impulse responses to a monetary policy shock across time: sign restriction on the first horizon (eight quarters)

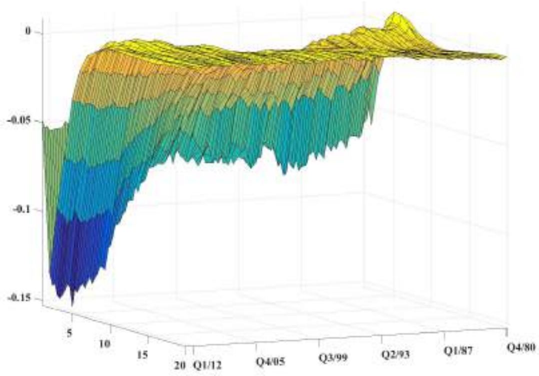
Time		ranksum test			two-sided t-test		
+ 8 quarters		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
2-3	y	$=$	$<$	$<$	$=$	$<$	$<$
	π	$<$	$>$	$>$	$<$	$>$	$>$
	i	$<$	$>$	$>$	$<$	$>$	$>$
	EBP	$<$	$<$	$<$	$<$	$<$	$<$
	BCQ	$<$	$<$	$<$	$<$	$<$	$<$
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
4-5	y	$<$	$<$	$<$	$<$	$<$	$<$
	π	$>$	$>$	$>$	$>$	$>$	$>$
	i	$<$	$>$	$>$	$<$	$>$	$>$
	EBP	$<$	$<$	$<$	$<$	$<$	$<$
	BCQ	$<$	$<$	$<$	$<$	$<$	$<$
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
6-7	y	$<$	$<$	$<$	$<$	$<$	$<$
	π	$>$	$<$	$<$	$>$	$<$	$<$
	i	$<$	$>$	$>$	$<$	$>$	$>$
	EBP	$<$	$<$	$<$	$<$	$<$	$<$
	BCQ	$<$	$<$	$<$	$<$	$<$	$<$
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
8-9	y	$<$	$<$	$<$	$<$	$<$	$<$
	π	$>$	$<$	$<$	$>$	$<$	$<$
	i	$<$	$>$	$>$	$<$	$>$	$>$
	EBP	$<$	$<$	$<$	$<$	$<$	$<$
	BCQ	$<$	$<$	$<$	$<$	$<$	$<$
- 8 quarters		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
2-3	y	$>$	$<$	$<$	$>$	$<$	$<$
	π	$<$	$>$	$>$	$<$	$>$	$>$
	i	$<$	$>$	$>$	$<$	$>$	$>$
	EBP	$<$	$<$	$<$	$<$	$<$	$<$
	BCQ	$>$	$<$	$<$	$>$	$<$	$<$
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
4-5	y	$>$	$<$	$<$	$>$	$<$	$<$
	π	$<$	$=$	$>$	$<$	$=$	$>$
	i	$<$	$>$	$>$	$<$	$>$	$>$
	EBP	$<$	$<$	$<$	$<$	$<$	$<$
	BCQ	$>$	$<$	$<$	$>$	$<$	$<$
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
6-7	y	$>$	$<$	$<$	$>$	$<$	$<$
	π	$<$	$<$	$<$	$<$	$<$	$<$
	i	$<$	$>$	$>$	$<$	$>$	$>$
	EBP	$<$	$<$	$<$	$<$	$<$	$<$
	BCQ	$>$	$<$	$<$	$>$	$<$	$<$
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
8-9	y	$<$	$<$	$<$	$<$	$<$	$<$
	π	$<$	$<$	$<$	$<$	$<$	$<$
	i	$<$	$>$	$>$	$<$	$>$	$>$
	EBP	$<$	$<$	$<$	$<$	$<$	$<$
	BCQ	$>$	$<$	$<$	$>$	$<$	$<$

The table presents qualitative test results of a two-sided t-test to test for equal means and a Wilcoxon ranksum test to test for equal medians to the impulse responses at specific horizons and time-spans. A finding of a smaller or a larger mean/median is indicated by ‘$<$’ (green/lighter cell shades) and ‘$>$’ (red/darker cell shades) respectively. Moreover, ‘$=$’ indicates that the Null-hypothesis could not be rejected at a 95% significance level.

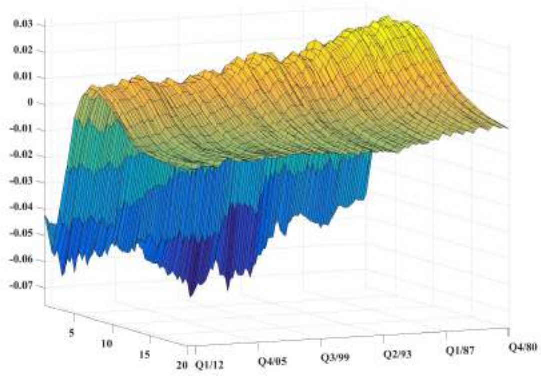
4.7.4 Estimation and test results of the TVP-VAR including macroeconomic uncertainty

Figure 4.16: Impulse responses to a banks' capital quality shock: including macroeconomic uncertainty

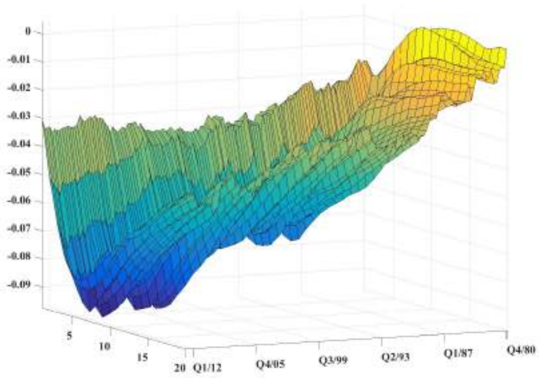
(a) GDP



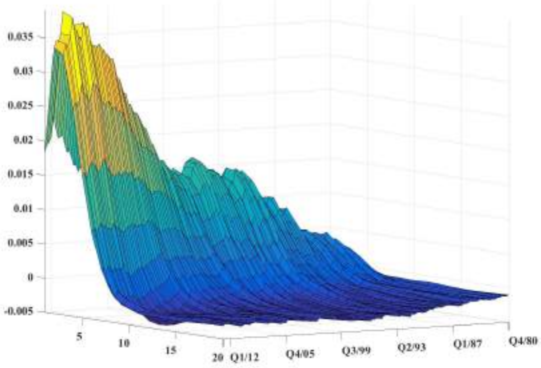
(b) Inflation



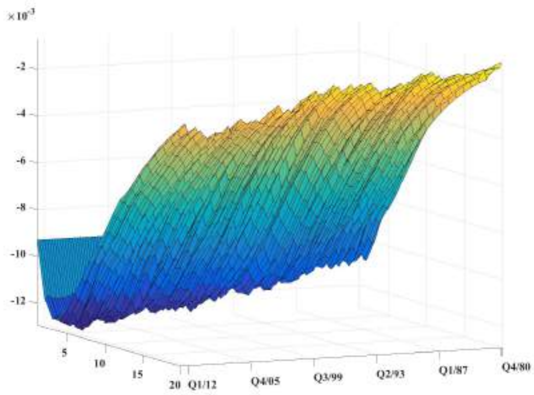
(c) Nominal interest rate



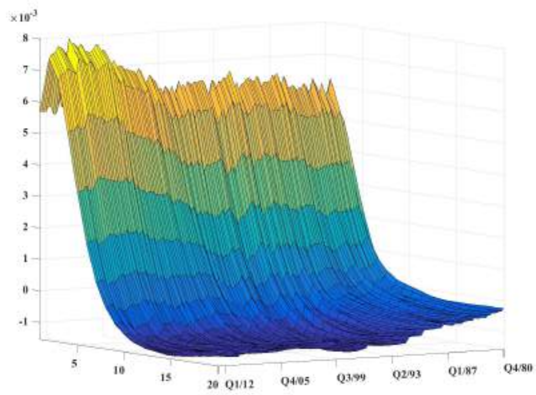
(d) EBP



(e) Banks' capital quality proxy



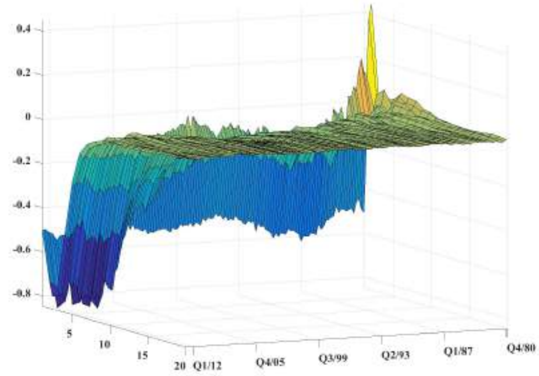
(f) Macroeconomic uncertainty



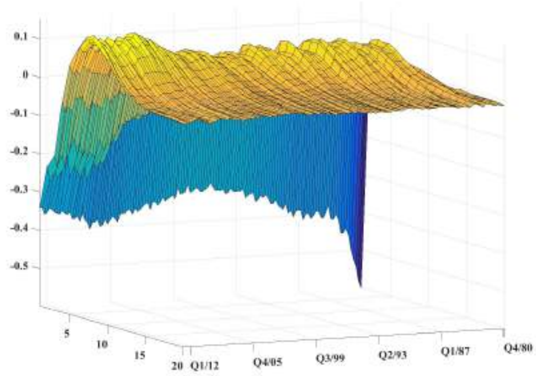
Each panel presents the median of the impulse responses' posterior distribution up to the 20th horizon for each date of the estimation sample.

Figure 4.17: Impulse responses to a monetary policy shock: including macroeconomic uncertainty

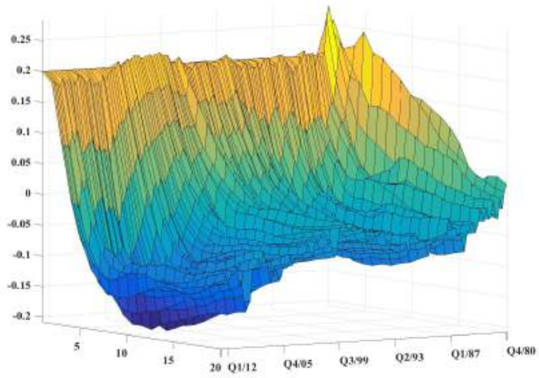
(a) GDP



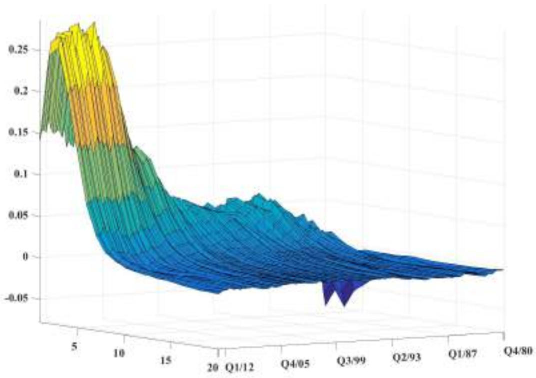
(b) Inflation



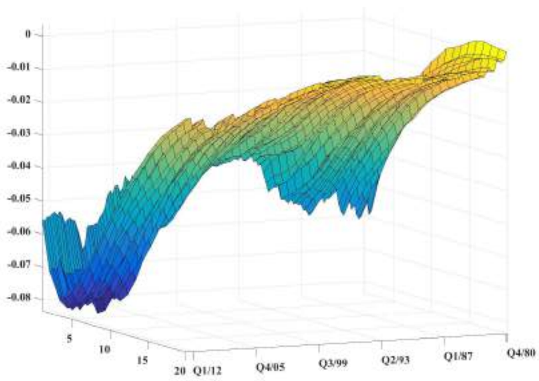
(c) Nominal interest rate



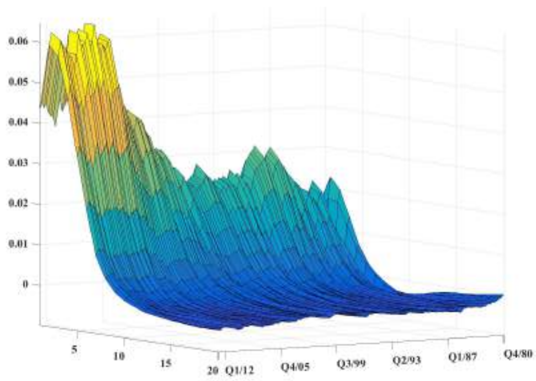
(d) EBP



(e) Banks' capital quality proxy



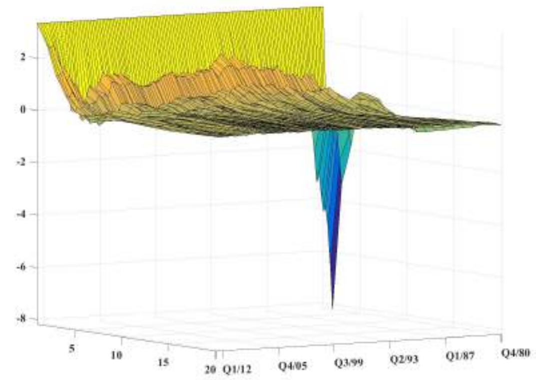
(f) Macroeconomic uncertainty



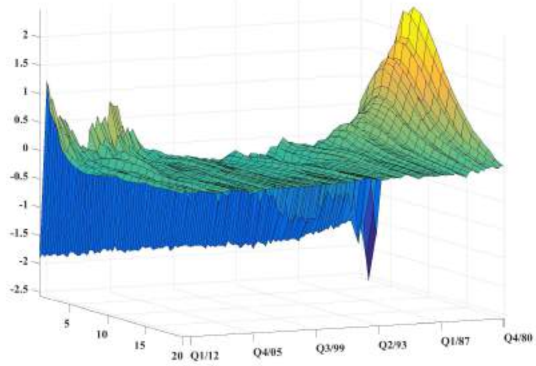
Each panel presents the median of the impulse responses' posterior distribution up to the 20th horizon for each date of the estimation sample.

Figure 4.18: Impulse responses to a technology shock: including macroeconomic uncertainty

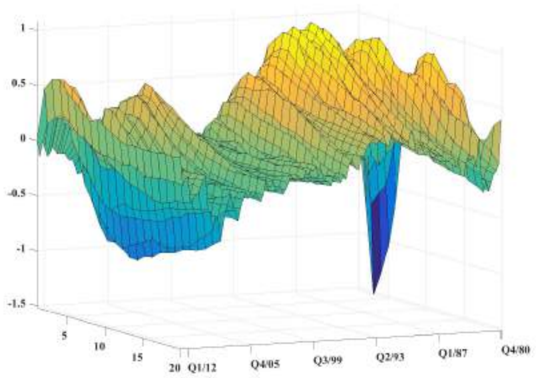
(a) GDP



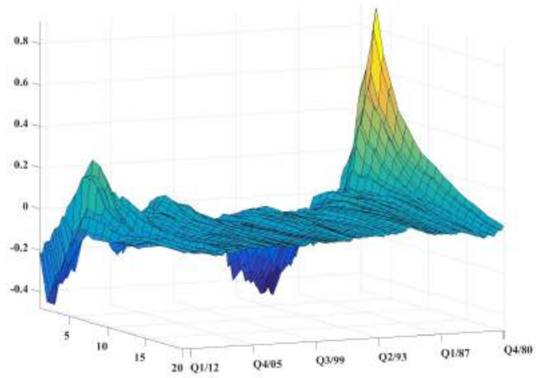
(b) Inflation



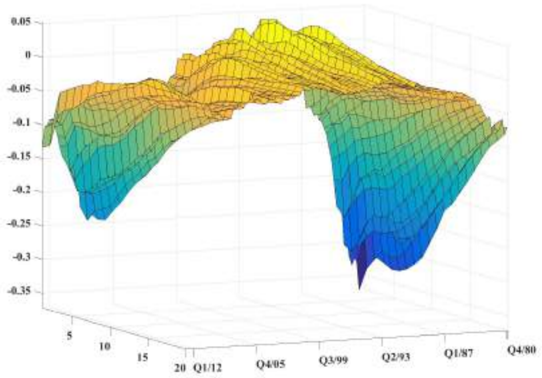
(c) Nominal interest rate



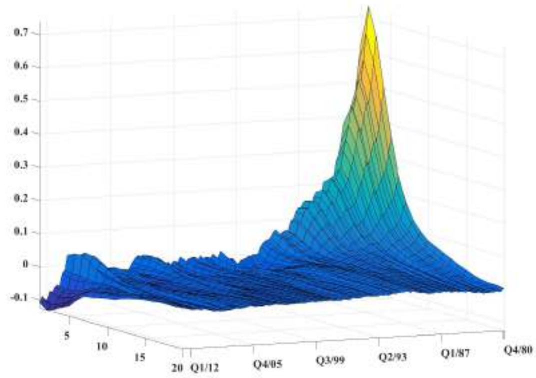
(d) EBP



(e) Banks' capital quality proxy



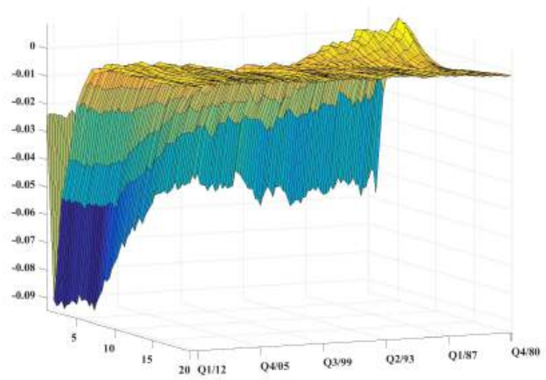
(f) Macroeconomic uncertainty



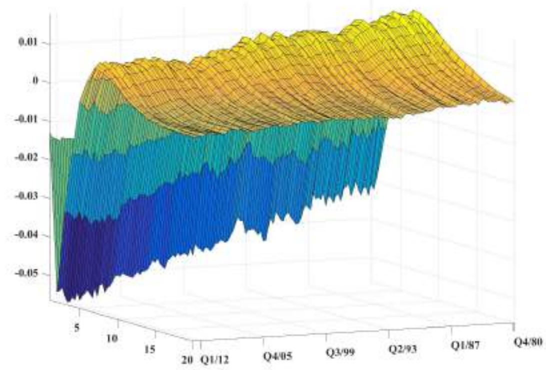
Each panel presents the median of the impulse responses' posterior distribution up to the 20th horizon for each date of the estimation sample.

Figure 4.19: Impulse responses to an uncertainty shock: including macroeconomic uncertainty

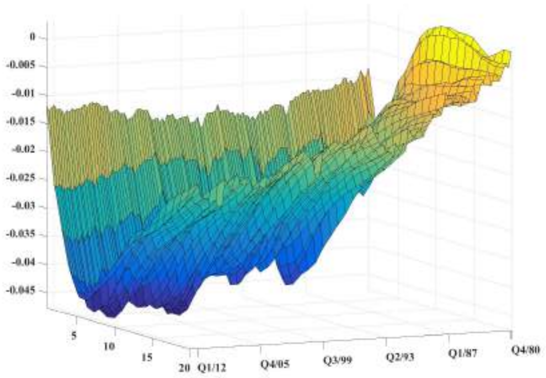
(a) GDP



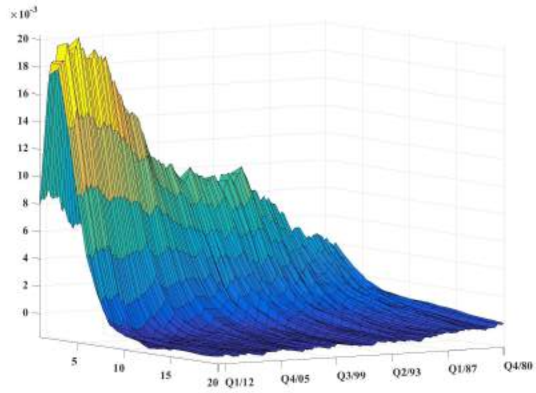
(b) Inflation



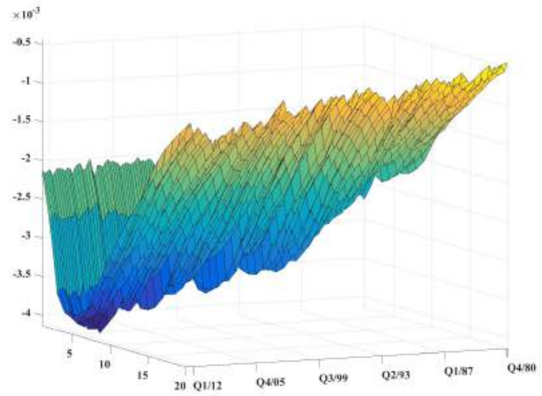
(c) Nominal interest rate



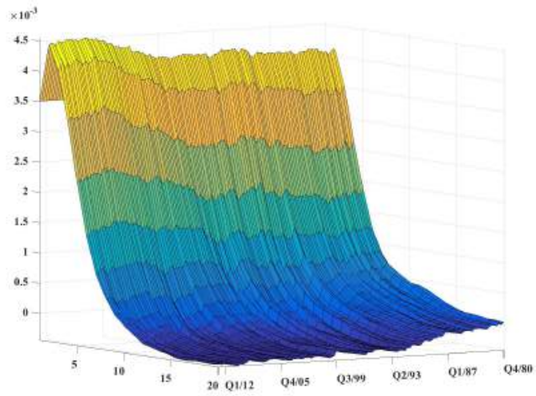
(d) EBP



(e) Banks' capital quality proxy

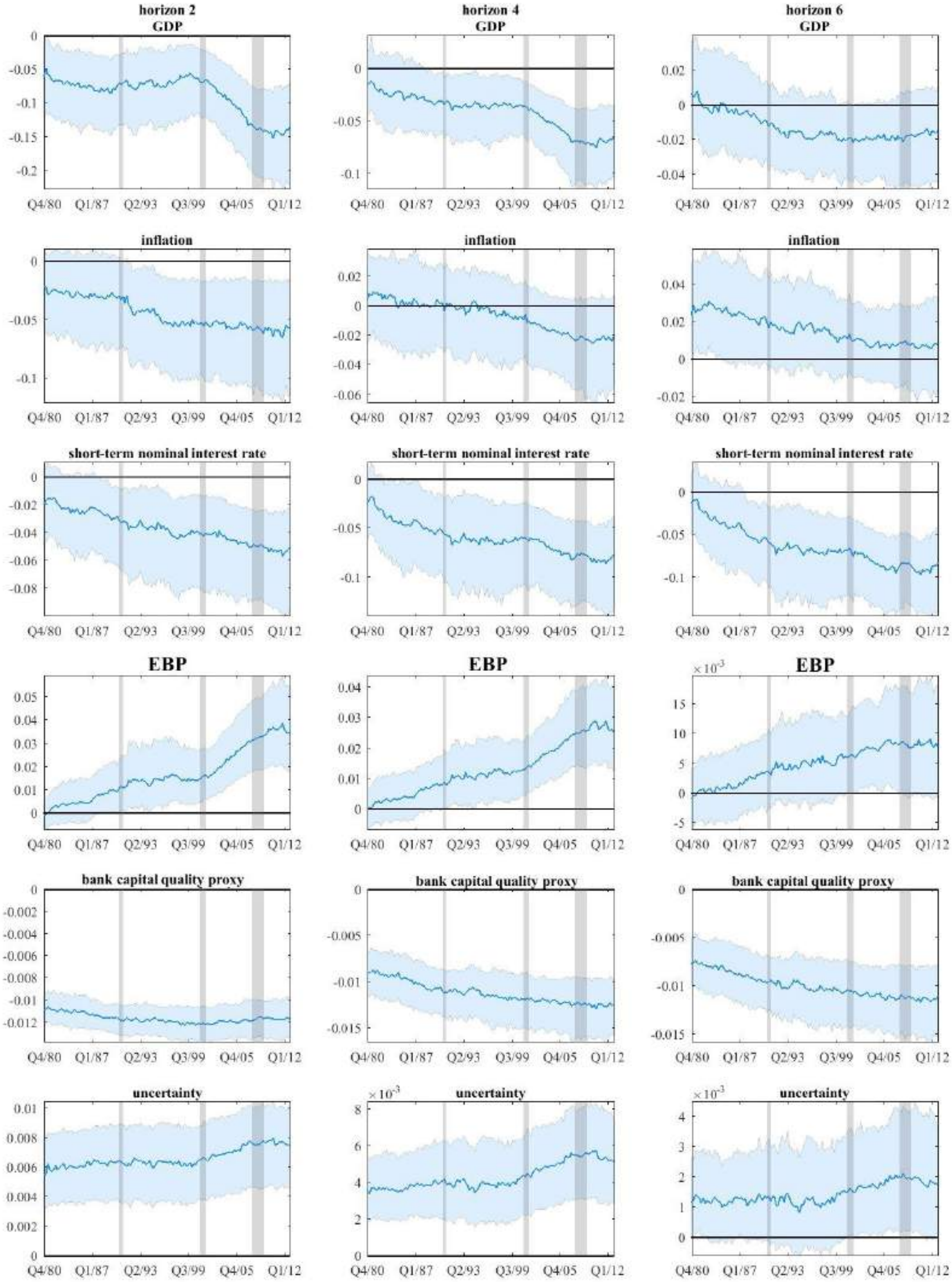


(f) Macroeconomic uncertainty



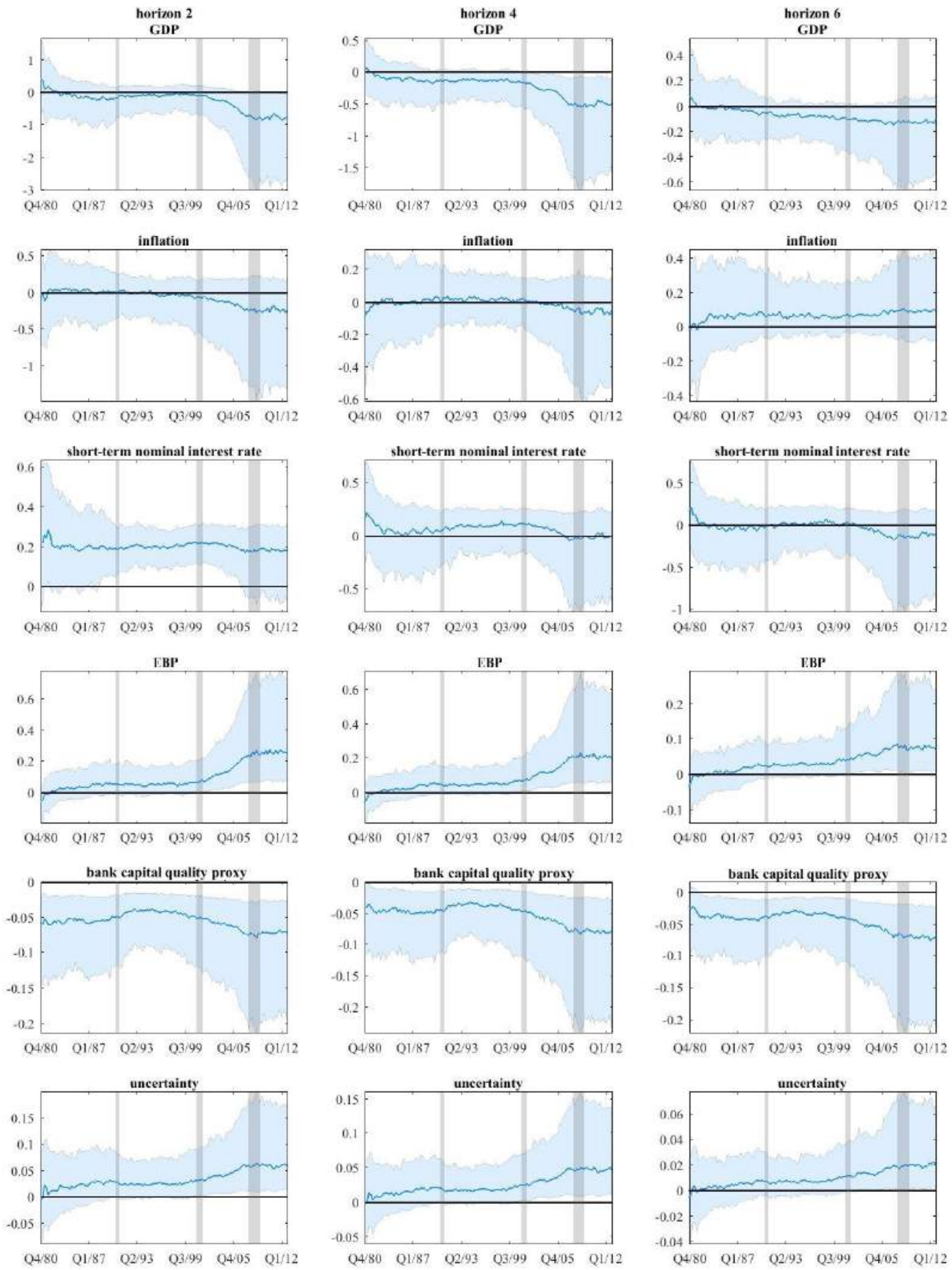
Each panel presents the median of the impulse responses' posterior distribution up to the 20th horizon for each date of the estimation sample.

Figure 4.20: Horizon comparison of impulse responses to a banks' capital quality shock: including macroeconomic uncertainty



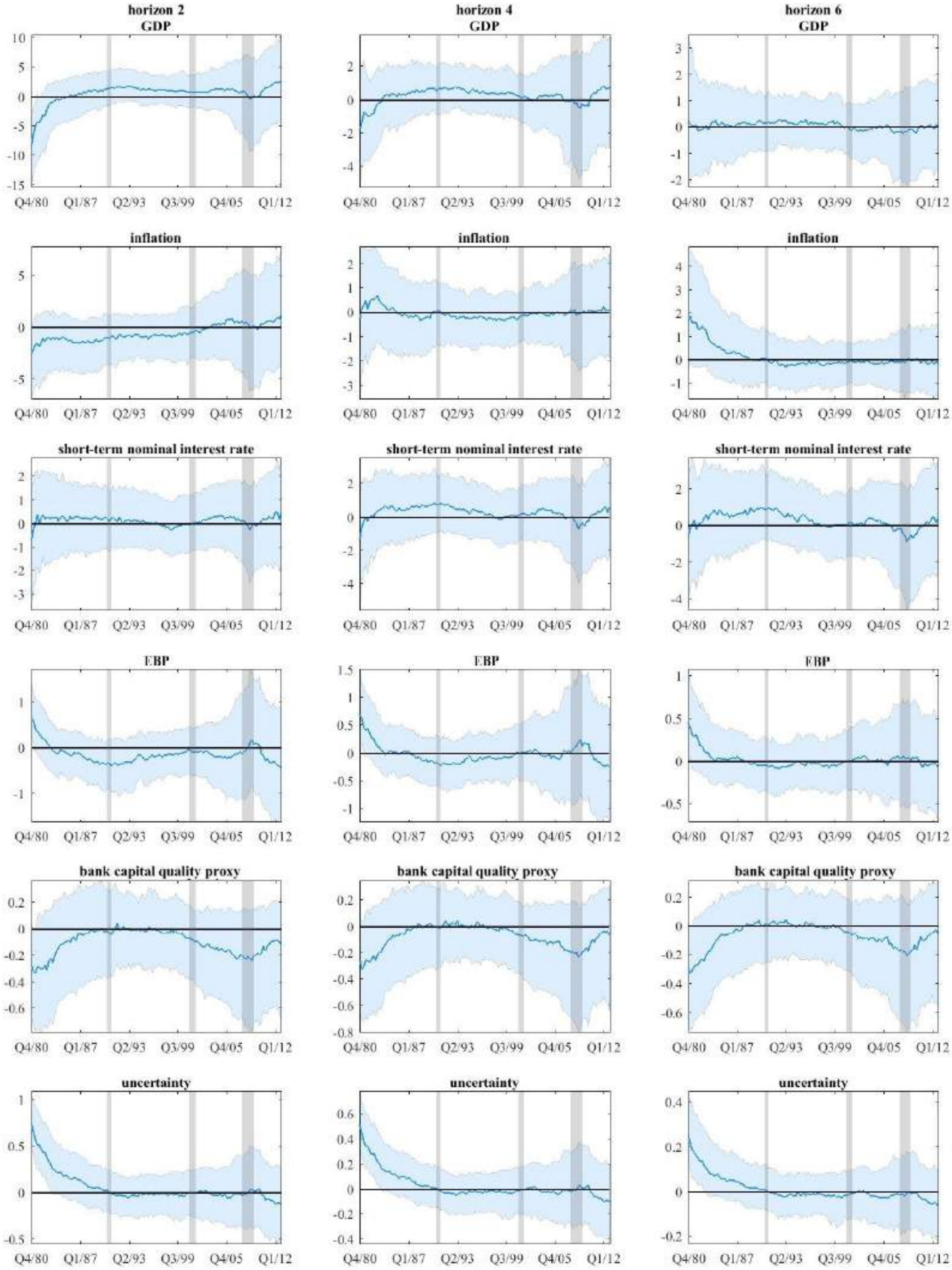
The panels reflect the impulse responses to a banks' capital quality shock of one standard deviation at the horizons 2, 4 and 6 (columns) across time. Thereby, the shock size has been standardized across time to reflect the average standard deviation of the sample. The solid lines represent the median of the posterior distribution and the shaded areas the 68% probability bands.

Figure 4.21: Horizon comparison of impulse responses to a monetary policy shock: including macroeconomic uncertainty



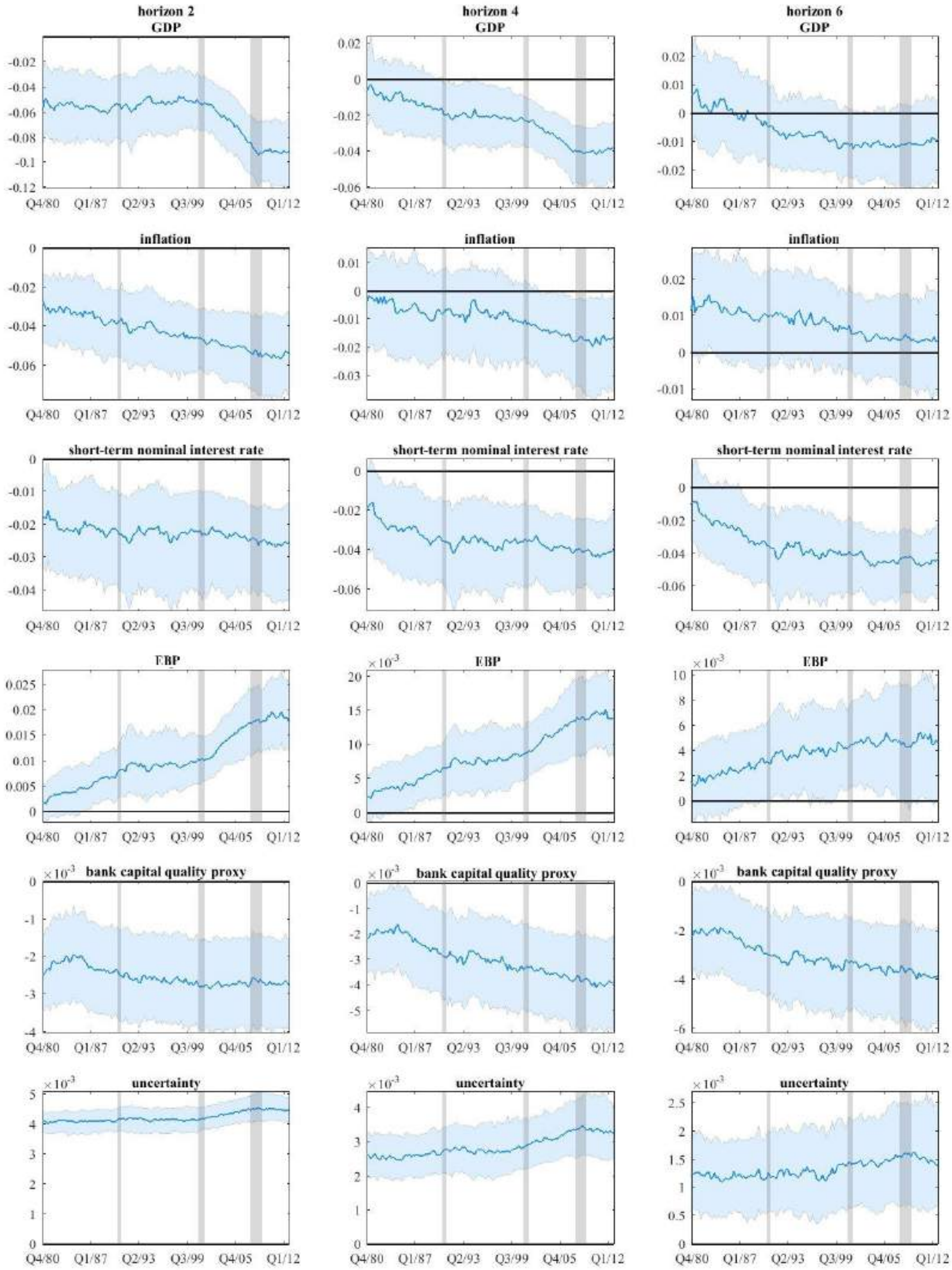
The panels reflect the impulse responses to a monetary policy shock of one standard deviation at the horizons 2, 4 and 6 (columns) across time. Thereby, the shock size has been standardized across time to reflect the average standard deviation of the sample. The solid lines represent the median of the posterior distribution and the shaded areas the 68% probability bands.

Figure 4.22: Horizon comparison of impulse responses to a technology shock: including macroeconomic uncertainty



The panels reflect the impulse responses to a monetary policy shock of one standard deviation at the horizons 2, 4 and 6 (columns) across time. Thereby, the shock size has been standardized across time to reflect the average standard deviation of the sample. The solid lines represent the median of the posterior distribution and the shaded areas the 68% probability bands.

Figure 4.23: Horizon comparison of impulse responses to an uncertainty shock: including an uncertainty shock



The panels reflect the impulse responses to a monetary policy shock of one standard deviation at the horizons 2, 4 and 6 (columns) across time. Thereby, the shock size has been standardized across time to reflect the average standard deviation of the sample. The solid lines represent the median of the posterior distribution and the shaded areas the 68% probability bands.

Table 4.14: Test of equal mean/median of impulse responses to a banks' capital quality shock across time: including macroeconomic uncertainty

Time		ranksum test			two-sided t-test		
+ 4 quarters		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
2-3	y	<	<	<	<	<	<
	π	<	<	<	<	<	<
	i	<	<	<	<	<	<
	EBP	<	<	<	<	<	<
	BCQ	<	<	>	<	<	>
	u	<	<	<	<	<	<
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
4-5	y	<	<	<	<	<	<
	π	<	<	<	<	<	<
	i	<	<	<	<	<	<
	EBP	<	<	<	<	<	<
	BCQ	<	<	<	<	<	<
	u	<	<	<	<	<	<
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
6-7	y	<	<	>	<	<	>
	π	<	<	<	<	<	<
	i	<	<	<	<	<	<
	EBP	<	<	<	<	<	<
	BCQ	<	<	<	<	<	<
	u	<	<	<	<	<	<
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
8-9	y	<	>	>	<	>	>
	π	<	<	<	<	<	<
	i	<	<	<	<	<	<
	EBP	<	>	>	<	>	>
	BCQ	<	<	<	<	<	<
	u	<	=	>	<	=	>
- 4 quarters		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
2-3	y	>	<	<	>	<	<
	π	<	<	<	<	<	<
	i	<	<	<	<	<	<
	EBP	<	<	<	<	<	<
	BCQ	<	<	>	<	<	>
	u	=	<	<	=	<	<
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
4-5	y	<	<	<	<	<	<
	π	<	<	<	<	<	<
	i	<	<	<	<	<	<
	EBP	<	<	<	<	<	<
	BCQ	<	<	<	<	<	<
	u	<	<	<	<	<	<
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
6-7	y	<	<	>	<	<	>
	π	<	<	<	<	<	<
	i	<	<	<	<	<	<
	EBP	<	<	<	<	<	<
	BCQ	<	<	<	<	<	<
	u	<	<	<	<	<	<
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
8-9	y	<	>	>	<	>	>
	π	<	<	<	<	<	<
	i	<	<	<	<	<	<
	EBP	<	>	>	<	>	>
	BCQ	<	<	<	<	<	<
	u	>	>	>	>	>	>

The table presents qualitative test results of a two-sided t-test to test for equal means and a Wilcoxon ranksum test to test for equal medians to the impulse responses at specific horizons and time-spans. A finding of a smaller or a larger mean/median is indicated by ‘$<$’ (green/lighter cell shades) and ‘$>$’ (red/darker cell shades) respectively. Moreover, ‘=’ indicates that the Null-hypothesis could not be rejected at a 95% significance level.

Table 4.15: Test of equal mean/median of impulse responses to a monetary policy shock across time: including macroeconomic uncertainty

Time		ranksum test			two-sided t-test		
+ 4 quarters		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
2-3	y	$>$	$<$	$<$	$>$	$<$	$<$
	π	$<$	$<$	$<$	$<$	$<$	$<$
	i	$<$	$>$	$>$	$<$	$>$	$>$
	EBP	$<$	$<$	$<$	$<$	$<$	$<$
	BCQ	$<$	$<$	$<$	$<$	$<$	$<$
	u	$<$	$<$	$<$	$<$	$<$	$<$
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
4-5	y	$<$	$<$	$<$	$<$	$<$	$<$
	π	$<$	$<$	$<$	$<$	$<$	$<$
	i	$<$	$>$	$>$	$<$	$>$	$>$
	EBP	$<$	$<$	$<$	$<$	$<$	$<$
	BCQ	$<$	$<$	$<$	$<$	$<$	$<$
	u	$<$	$<$	$<$	$<$	$<$	$<$
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
6-7	y	$<$	$<$	$>$	$<$	$<$	$>$
	π	$=$	$>$	$>$	$=$	$>$	$>$
	i	$<$	$>$	$>$	$<$	$>$	$>$
	EBP	$<$	$<$	$<$	$<$	$<$	$<$
	BCQ	$<$	$<$	$<$	$<$	$<$	$<$
	u	$<$	$<$	$<$	$<$	$<$	$<$
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
8-9	y	$<$	$>$	$>$	$<$	$>$	$>$
	π	$>$	$>$	$>$	$>$	$>$	$>$
	i	$>$	$>$	$>$	$>$	$>$	$>$
	EBP	$<$	$<$	$>$	$<$	$<$	$>$
	BCQ	$<$	$<$	$<$	$<$	$<$	$<$
	u	$<$	$<$	$=$	$<$	$<$	$=$
- 4 quarters		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
2-3	y	$>$	$<$	$<$	$>$	$<$	$<$
	π	$<$	$<$	$<$	$<$	$<$	$<$
	i	$<$	$>$	$>$	$<$	$>$	$>$
	EBP	$<$	$<$	$<$	$<$	$<$	$<$
	BCQ	$>$	$<$	$<$	$>$	$<$	$<$
	u	$<$	$<$	$<$	$<$	$<$	$<$
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
4-5	y	$<$	$<$	$<$	$<$	$<$	$<$
	π	$<$	$<$	$<$	$<$	$<$	$<$
	i	$<$	$>$	$>$	$<$	$>$	$>$
	EBP	$<$	$<$	$<$	$<$	$<$	$<$
	BCQ	$>$	$<$	$<$	$<$	$<$	$<$
	u	$<$	$<$	$<$	$<$	$<$	$<$
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
6-7	y	$<$	$<$	$=$	$<$	$<$	$=$
	π	$<$	$>$	$>$	$<$	$>$	$>$
	i	$<$	$>$	$>$	$<$	$>$	$>$
	EBP	$<$	$<$	$<$	$<$	$<$	$<$
	BCQ	$>$	$<$	$<$	$>$	$<$	$<$
	u	$<$	$<$	$<$	$<$	$<$	$<$
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
8-9	y	$<$	$>$	$>$	$<$	$>$	$>$
	π	$<$	$>$	$>$	$<$	$>$	$>$
	i	$=$	$>$	$>$	$=$	$>$	$>$
	EBP	$<$	$<$	$>$	$<$	$<$	$>$
	BCQ	$=$	$<$	$<$	$=$	$<$	$<$
	u	$<$	$<$	$<$	$<$	$<$	$<$

The table presents qualitative test results of a two-sided t-test to test for equal means and a Wilcoxon ranksum test to test for equal medians to the impulse responses at specific horizons and time-spans. A finding of a smaller or a larger mean/median is indicated by '$<$' (green/lighter cell shades) and '$>$' (red/darker cell shades) respectively. Moreover, '$=$' indicates that the Null-hypothesis could not be rejected at a 95% significance level.

Table 4.16: Test of equal mean/median of impulse responses to a banks' capital quality shock across time: including macroeconomic uncertainty (eight quarters)

Time		ranksum test			two-sided t-test		
+ 8 quarters		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
2-3	y	<	<	<	<	<	<
	π	<	<	<	<	<	<
	i	<	<	<	<	<	<
	EBP	<	<	<	<	<	<
	BCQ	<	<	>	<	<	>
	u	<	<	<	<	<	<
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
4-5	y	<	<	<	<	<	<
	π	<	<	<	<	<	<
	i	<	<	<	<	<	<
	EBP	<	<	<	<	<	<
	BCQ	<	<	<	<	<	<
	u	<	<	<	<	<	<
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
6-7	y	<	<	>	<	<	>
	π	<	<	<	<	<	<
	i	<	<	<	<	<	<
	EBP	<	<	<	<	<	<
	BCQ	<	<	<	<	<	<
	u	<	<	<	<	<	<
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
8-9	y	<	>	>	<	>	>
	π	<	<	<	<	<	<
	i	<	<	<	<	<	<
	EBP	<	>	>	<	>	>
	BCQ	<	<	<	<	<	<
	u	<	=	>	<	=	>
- 8 quarters		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
2-3	y	>	<	<	>	<	<
	π	<	<	<	<	<	<
	i	<	<	<	<	<	<
	EBP	<	<	<	<	<	<
	BCQ	<	<	<	<	<	<
	u	>	<	<	>	<	<
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
4-5	y	<	<	<	<	<	<
	π	<	<	<	<	<	<
	i	<	<	<	<	<	<
	EBP	<	<	<	<	<	<
	BCQ	<	<	<	<	<	<
	u	<	<	<	<	<	<
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
6-7	y	<	<	>	<	<	>
	π	<	<	<	<	<	<
	i	<	<	<	<	<	<
	EBP	<	<	<	<	<	<
	BCQ	<	<	<	<	<	<
	u	<	<	<	<	<	<
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
8-9	y	<	>	>	<	>	>
	π	<	<	<	<	<	<
	i	<	<	<	<	<	<
	EBP	<	=	>	<	=	>
	BCQ	<	<	<	<	<	<
	u	>	>	>	>	>	>

The table presents qualitative test results of a two-sided t-test to test for equal means and a Wilcoxon ranksum test to test for equal medians to the impulse responses at specific horizons and time-spans. A finding of a smaller or a larger mean/median is indicated by '<' (green/lighter cell shades) and '>' (red/darker cell shades) respectively. Moreover, '=' indicates that the Null-hypothesis could not be rejected at a 95% significance level.

Table 4.17: Test of equal mean/median of impulse responses to a monetary policy shock across time: including macroeconomic uncertainty (eight quarters)

Time		ranksum test			two-sided t-test		
+ 8 quarters		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
2-3	y	<	<	<	<	<	<
	π	<	<	<	<	<	<
	i	<	>	>	<	>	>
	EBP	<	<	<	<	<	<
	BCQ	<	<	<	<	<	<
	u	<	<	<	<	<	<
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
4-5	y	<	<	<	<	<	<
	π	<	<	<	<	<	<
	i	<	>	>	<	>	>
	EBP	<	<	<	<	<	<
	BCQ	<	<	<	<	<	<
	u	<	<	<	<	<	<
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
6-7	y	<	<	>	<	<	>
	π	>	>	>	>	>	>
	i	=	>	>	=	>	>
	EBP	<	<	<	<	<	<
	BCQ	<	<	<	<	<	<
	u	<	<	<	<	<	<
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
8-9	y	<	>	>	<	>	>
	π	>	>	>	>	>	>
	i	>	>	>	>	>	>
	EBP	<	>	>	<	>	>
	BCQ	<	<	<	<	<	<
	u	<	<	>	<	<	>
- 8 quarters	90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR	
2-3	y	>	<	<	>	<	<
	π	<	<	<	<	<	<
	i	<	>	>	<	>	>
	EBP	<	<	<	<	<	<
	BCQ	>	<	<	>	<	<
	u	<	<	<	<	<	<
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
4-5	y	<	<	<	<	<	<
	π	<	<	<	<	<	<
	i	<	>	>	<	>	>
	EBP	<	<	<	<	<	<
	BCQ	>	<	<	>	<	<
	u	<	<	<	<	<	<
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
6-7	y	<	<	<	<	<	<
	π	<	>	>	<	>	>
	i	<	>	>	<	>	>
	EBP	<	<	<	<	<	<
	BCQ	>	<	<	>	<	<
	u	<	<	<	<	<	<
		90s vs DC	90s vs GR	DC vs GR	90s vs DC	90s vs GR	DC vs GR
8-9	y	<	<	>	<	<	>
	π	<	>	>	<	>	>
	i	<	>	>	<	>	>
	EBP	<	<	<	<	<	<
	BCQ	>	<	<	>	<	<
	u	<	<	<	<	<	<

The table presents qualitative test results of a two-sided t-test to test for equal means and a Wilcoxon ranksum test to test for equal medians to the impulse responses at specific horizons and time-spans. A finding of a smaller or a larger mean/median is indicated by '<' (green/lighter cell shades) and '>' (red/darker cell shades) respectively. Moreover, '=' indicates that the Null-hypothesis could not be rejected at a 95% significance level.

5 General results and conclusion

General results and conclusion

Monetary policy has recently faced three major challenges that were induced by the global financial crisis and the Great Recession. The first challenge concerns the reassessment of the conventional inflation model that could not fully explain consumer price dynamics over the course of the global financial crisis. The second challenge relates to the omission of the link between financial markets and real economic activity in the baseline New Keynesian Dynamic Stochastic General Equilibrium (NK DSGE hereafter) model. The global financial crisis emphasized the empirical and theoretical reconsideration of the link between financial markets and macroeconomic dynamics as well as their consequences for monetary policy. The search for alternative monetary policy tools under a binding effective lower bound forms the third challenge.

Recent macroeconomic literature that has evolved in association with these three challenges collectively indicates that it is essential to pay heed to structural changes of macroeconomic relations. This dissertation provides empirical evidence of non-linearities in core macroeconomic relations alongside the first two challenges. Thereby, chapters two to four alter the understanding of the evolution of macroeconomic dynamics and policy transmission throughout the global financial crisis.

The second and third chapters contribute to the debate about underlying reasons of the puzzling inflation dynamics during the global financial crisis. Moreover, the chapters contribute to the literature concerning the interplay between changes of monetary policy and changes of inflation dynamics. The puzzling inflation dynamics concern two observations on the evolution of headline inflation. Firstly, the case for 'missing disinflation' points to the fact that inflation rates have remained surprisingly stable between 2009 and 2011 compared to accelerationist Phillips curve (PC hereafter) estimates. Secondly, the case of 'missing inflation' indicates that, despite improving employment conditions, inflation dropped substantially from 2012 to the end of 2015. Three potential explanations emerged in the recent academic debate. Firstly, anchored inflation expectations combined with a strictly forward-looking inflation process might have overshadowed downward price pressure from real economic activity on inflation dynamics. Secondly, a relatively flat PC relation muted the effect of real economic activity. Thirdly, the increasing importance of global factors drove headline inflation during the course of the crisis.

The second chapter investigates the drivers of Euro area inflation dynamics during the global financial crisis. The difficulty of having only limited information on the time dimension of the Euro area sample is circumvented by exploiting cross-sectional country-specific data. Therefore, a non-linear panel unobserved component stochastic volatility (USCV hereafter) Phillips curve model is proposed. The estimation results of the preferred model suggest that the reasons underlying the period of persistently low headline inflation in the EU10 area are threefold. Firstly, the EU10 inflation process has become more persistent in the course of the Great Recession and long-run trend inflation has significantly declined to below 1.9% since 2013. According to the counter-factual analysis, this de-anchoring of inflation expectations accounted for 0.4 percentage points of headline inflation. Secondly, slowly closing unemployment-gaps, together with a slightly steeper Phillips curve exerted downward price pressure between 2013 and 2017. Lastly, the substantial fall of oil prices in 2014 amplified the decline of cyclical inflation. Moreover, the model outperforms plain multivariate model versions in terms of the economic plausibility of results and in terms of forecast performance. Aggregate multivariate UCSV models indicate substantially higher trend inflation estimates and a steeper Phillips curve for the Euro area. Therefore, univariate UCSV models tend to overestimate the decline of trend inflation since 2013. These results are at odds with previous country-specific findings reported in the literature. Overall, the second chapter finds that all three possible explanations, namely the flattening of the Phillips curve, the de-anchoring of inflation expectation and movements of oil prices contribute to the inflation dynamics in the Euro area since 2007. However, the flattening of the Phillips curve and the de-anchoring of inflation expectations reflect the dominant drivers of changes in Euro area headline inflation.

The third chapter investigates the key drivers of consumer price inflation in ASEAN-5 countries (Indonesia, Malaysia, Philippines, Singapore and Thailand) during 1995-2016, through estimating time-varying Phillips curves. The monetary policy frameworks and macroeconomic dynamics of these economies have almost simultaneously undergone substantial structural changes in the wake of the Asian Financial Crisis (AFC hereafter). This circumstance enables a careful analysis of the interrelation between changes in the inflation processes and enhancements of monetary policies and communication strategies. Additionally, the chapter contributes to the question whether a generalised conclusion can be drawn on the determinants of inflation across economies at distinct stages of their development. The chapter presents estimation results of the country-specific Phillips curves allowing for time-varying parameters for each of the ASEAN-5 countries respectively to account for the region's evolving monetary policy regimes and business cycles, using trend inflation estimates as an indicator of long-run inflation expectations.

The findings suggest that for the inflation dynamics of the ASEAN-5 region as a whole, expectations are quantitatively more important than economic slack, non-oil-import and oil price inflation. Moreover, the relative contributions of forward-looking dynamics increased over time, especially since the AFC. The coefficient of the forward-looking component of inflation, as well as the absolute contribution of the forward-looking dynamics, depict a positive relation with central bank transparency. Thus, a higher degree of central bank transparency in the ASEAN-5 countries is associated with a higher forward-looking dynamic in these countries. In terms of the supply-side drivers of headline inflation in the ASEAN-5 region, the quantitative contributions of economic slack are limited, with the exception of the AFC and GFC episodes. Non-oil-import price inflation became less important in the early 2000s, which is possibly related to exchange-rate liberalisation during the recovery phase of the AFC. By contrast, oil price inflation became slightly more important over time, especially during the recent episode of low inflation. The results indicate the existence of non-linearities in the transmission of supply shocks during times of recession. The importance of the forward-looking component for ASEAN-5 inflation, as well as non-linearities in the Phillips curve, is reinforced when comparing the forecasting performance of the benchmark Phillips curve specification to a variety of alternative models, including plain time-series models. Overall, the third chapter indicates that inflation dynamics have substantially changed in ASEAN-5 countries since the AFC. Across the countries, the link between real economic activity and headline inflation weakened, non-oil-import inflation became less relevant. Moreover, enhanced monetary policy frameworks and communication strategies can be related to more forward-looking inflation expectations.

Regarding the research approach of the second and third chapter, the analysis of these chapters can be improved alongside a several dimensions. Firstly, the Phillips curve specifications of chapter two and three only consider a limited number of measures for economic activity and global factors. To circumvent the analysis's omission of relevant variables, a large number of domestic and global inflation drivers could be introduced as factors. To still account for possible shifts in the relevant importance of variables over time, these factors would be modelled with time-varying weights as in Mumtaz and Surico (2012). Secondly, the benchmark NK DSGE models suggest that changes of marginal costs entering the price Phillips curve are mainly determined by a wage Phillips curve (Galí, 2011; Daly and Hobijn, 2014). The direct interrelation between changes in wages and changes of consumer goods prices is neglected in the analysis of the second and third chapters but might reflect an important aspect of recent inflation dynamics. Thirdly, the use of survey-based inflation expectations or inflation-linked bonds data could alter the identification of long-run trend inflation in the Phillips curve frameworks used. For example, survey-based inflation expectations could enter the estimation model of chapter two as an additional transition equation (Chan et al., 2018).

Moreover, the results of the second and third chapters indicate that components of the Phillips curve differ in their importance over time. Thereby, further research questions naturally arise alongside two dimensions: Firstly, what explains the time variation of parameters and long-run trends within the context of the Phillips curve relation? Secondly, can we generalize the observations and underlying mechanism of non-linearities in the inflation formation process across economies? These rather broadly formulated questions contain numerous specific issues of future research. For example, the results in the second and third chapters suggest that changes in long-run inflation expectations and inflation persistence are related to monetary policy frameworks and communication practices. But whether the importance of inflation expectations is entirely driven by changes in monetary policy frameworks and communication is not directly tested and represents one possible line of further research on this topic. Given that a substantial part of change in inflation expectations and inflation persistence can be related to monetary policy, it would be essential to investigate specific measures or communication practices of monetary policy that improve inflation explications management.

The fourth chapter of this dissertation provides an empirical contribution to the non-linear and time-varying links between business cycle dynamics and financial markets. The chapter investigates the evolution of financial amplification of structural shocks to the US economy and assesses whether the financial acceleration has intensified during the last thirty years as suggested by the theoretical contributions of Brunnermeier and Sannikov (2014) and Gertler et al. (2016). Therefore, a TVP- VAR with stochastic volatility is estimated and a structural banks' capital quality shock, a monetary policy shock and a productivity shock are identified by using sign restrictions that rely on the monetary DSGE model of Gertler and Karadi (2011). The findings suggest that the amplification of structural shocks by financial frictions has increased in the last three decades. In particular, sudden changes of the banks' capital quality reveal a rising impact on the risk-adjusted premium of financial intermediaries and real economic activity since the early 1990s, especially within the first year following the shock impact. Thereby, results of the evolution of impulse responses of GDP and the risk-adjusted premium are qualitatively similar to those resulting from the re-simulation exercise of the model with distinct equilibrium leverage ratios. Moreover, the responses of the risk-adjusted premium and GDP to a monetary policy shock have increased, however, to a relatively smaller extent than the responses to a banks' capital quality shock. This suggests that the credit channel, as part of the monetary policy transmission, has gained importance, especially since the beginning of the 2000s. Overall, the analysis provides evidence of an increasing intensity of the financial amplifier in line with the theoretical suggestions of Brunnermeier and Sannikov (2014) and Gertler et al. (2016).

A critical issue of the research approach of the fourth chapter is concerned with the empirical modelling strategy and the identification of structural shocks. The empirical model of the fourth chapter assumes all coefficients to be time-varying and to be continuously evolving as a random walk. These assumptions can be problematic as firstly, not all coefficients might change over time and secondly, the coefficients might not change continuously across the time. Thus, the analysis of the fourth chapter could be improved by relaxing these assumptions and using some form of parameter shrinkage as suggest by Korobilis (2013) or directly discriminating between time-varying and constant parameters (Eisenstat et al., 2016). Moreover, the identification strategy of the analysis relies on the application of sign restrictions to obtain impulse responses of exogenous structural shocks. This identification strategy is disputable. For example, exact identification of one particular shock is dependent on the inclusion and correct identification of (all) other possible structural shocks. Also, the application of sign restrictions usually implies to draw random shocks from a normal distribution, orthogonalize those and combine them with the estimated and orthogonalized variance-covariance matrix. Baumeister and Hamilton (2015) provide analytical and empirical evidence that the assumptions on the distributional form of the random shocks can influence resulting impulse responses. Overcoming the difficulties related to the identification of a structural shock stemming from the banking sector is not a straightforward issue, as other commonly used identification approaches of structural vector autoregressive models are (also) prone to misspecifications.[1]

A new line of literature[2], assessing the impact of monetary policy surprises, has presented a novel methodology to identify structural shocks based on the inclusion of instrumental variables in structural vector autoregressive models. Although this novel approach circumvents direct assumptions about the timing of structural shocks and /or assumptions on how the structural shocks affect other variables, it necessitates the instrumental variable selection. In particular, the analysis of the fourth chapter would require an instrumental variable for the structural banks' capital quality shock. In addition to the improved identification of structural shock stemming from the financial sector, a future research topic might be to empirically assess whether structural shocks stemming from the financial sector propagate asymmetrically with respect to the direction of shock.

[1] See Kilian and Lütkepohl (2017) for a comprehensive discussion of structural shock identification methods for vector autoregressive models.

[2] See, for example, Gertler and Karadi (2015).

Relating the results of the three previous chapters to the general debate highlighted in the introductory chapter, I conclude, that the evolution of macroeconomic modelling should be viewed in light of structural changes of markets and institutions. As presented in this work, explanatory factors of monetary policy transmission and target dynamics vary in their importance over time. Thus, economic theories together with the respective models can be highly relevant over one specific episode, such as the Great Recession, but can be of altered importance in another. For that reason, economic research might rather consider and seek to understand the time variation of theoretical explanatory factors instead of aiming to just exchange an existing theory for a new one.

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