ANALYSIS

Post-crisis monetary policy modelling

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In the aftermath of the global financial crisis many central banks cut their policy rates close to zero or even below and introduced non-standard monetary policy measures. The financial crisis and the European debt crisis that followed demonstrated the importance of the linkages between financial markets and the real economy. In this article we survey the open issues in economic research posed by limits on how low central banks are able to cut policy rates, and the unconventional measures, especially forward guidance and large scale asset purchase programmes.

New policies call for new models

Before the global financial crisis in 2008–2009, central banks in advanced countries implemented monetary policy mainly by steering the short-term nominal interest rate.[1] With inflation hovering around central bank targets, around 2% in most countries, and real interest rates above 2 %, monetary policy had ample space within which to operate.

The crisis that originated on the financial markets took professional economists by surprise. Although some economists understood the possibly disruptive implications of finance for the real economy, the financial markets were insufficiently integrated in macroeconomic models before the crisis. In addition, the likelihood of nominal interest rates falling to zero was considered negligible, and analytical tools for such an environment[2] were lacking.[3] But as inflation and output plummeted during the crisis, policy rates were quickly reduced to the ZLB, making it difficult to provide further stimulus with the conventional policy tool.

With the ZLB binding, central banks had to look for new measures to stimulate demand and bring inflation back to the target. For instance, many central banks adopted quantitative easing and forward guidance.[4] Yet, formal frameworks for analysing these measures were largely missing at the time. The view after the crisis is that *"the problem with quantitative easing is it works in practice, but it doesn't work in theory"* (Bernanke (2014)). Actually, one could claim that the problem with forward guidance is that it works perhaps too well in theory, compared with the effects found in empirical studies. These puzzles have spurred substantial effort for developing more realistic models about the new policy environment.

This paper surveys the recent monetary policy models that have been developed since the crisis. For instance, several models now deal with financial constraints and frictions. Similarly, models that take into account non-linearities stemming from an asymmetry in that there is a limit to interest rate cuts, thus an inability to cut rates further, are readily available and increasingly used by policymakers. The development has also partly been driven by the experience with unconventional policy measures. Forward guidance, for example, has turned out to be somewhat less potent as a policy tool than pre-crisis models predicted. This, in turn, has highlighted the importance of incorporating deviations from rational expectations to generate more realistic predictions.[5] In contrast, quantitative easing turned out to be more effective than expected, which suggests that heterogeneity among market participants may be important for aggregate outcomes.

In this article we review the key recent developments in monetary policy frameworks following the crisis. In the next section we look more closely at the challenges that the ZLB presents to the monetary policy transmission mechanism. "Monetary policy and financial frictions" section concerns how financial frictions will change the monetary policy transmission channel outside the liquidity trap. In sections "Forward guidance" and "Quantitative easing" we analyse unconventional monetary policy measures, forward guidance and quantitative easing. In section "Conclusions" we draw some conclusions.

Modelling monetary policy at the zero lower bound

The crisis uncovered an important asymmetry in the transmission of monetary policy stemming from the fact that a central bank has limits below which it cannot cut its policy rates.

Before the crisis the probability of hitting the ZLB was considered small. According to Orphanides and Wieland (1998) and Reifschneider and Williams (1999) the probability could be reduced further by setting a positive inflation target. As a result, the workings of pre-crisis monetary policy could be described relatively well by an interest rate rule, such as the Taylor rule.[6]

The crisis changed this view. Firstly, it would seem that the probability of hitting the ZLB is much higher than previously thought (Kiley and Roberts, 2017). This may stem from the fall in the level of the natural rate, implying a rising incidence of the effective ZLB in the future. Further, the earlier estimates on the likelihood of the ZLB were based on data from the Great Moderation, from the mid-1980s until the crisis. Finally, it takes longer than previously expected to recover from ZLB episodes.

The existence of the ZLB limits the degree of monetary stimulus from the negative real interest rate, a monetary stimulus that might be required to avert an economic downturn. Under such

circumstances the real interest rate is not low enough: people want to save more than firms are willing to invest. Then to equate savings and investments, output and aggregate income have to fall. With the lower level of income, the amount of savings (the aggregate amount of euros or dollars saved in the economy) is also lower, and investments can absorb savings. However, while the economy reaches an equilibrium, the outcome is rather unpleasant: output is lower and unemployment is higher.

Expectations of reaching the ZLB in the future may affect the current behaviour of households, firms and the central bank. In particular, if households and firms expect a binding ZLB and a recession, they may reduce their spending, and the resulting fall in aggregate demand may render the recession a self-fulfilling expectation. Crucially, the actions of households and firms depend on their expectations about the central bank's policies. The optimal policy requires the central bank to lower policy rates aggressively in response to adverse shocks, in order to reduce the probability of a binding ZLB in the future (Nakov 2008).

Because of the monetary policy constraints induced by the ZLB, non-linearities should be incorporated explicitly in the solutions, simulations and estimations of macroeconomic models. In the past, dynamic stochastic general equilibrium (DSGE) models have been typically solved by using a first or second order local approximation. More recently, researchers have started to use solution algorithms that maintain the nonlinearity in the interest rate rule, but log-linearize the remaining equilibrium conditions (Eggertsson and Woodford (2003); Bodenstein, Guerrieri and Gust (2013); Guerrieri and Iacoviello (2015)). Alternative solution methods include non-linear projection techniques, as in Gust, López-Salido and Smith (2012) and Gust, Herbst, López-Salido and Smith (2017).

Finally, we should note that at the ZLB the interest rate does not guarantee a unique equilibrium of the model. The Taylor principle, i.e. a sufficiently strong reaction of nominal interest rate to inflation, is needed to provide a unique equilibrium. At the liquidity trap, the nominal interest rate is fixed to the ZLB for a possibly unknown time period and hence the interest rate cannot provide equilibrium selection. In other words, there may exist a multitude of different equilibria where self-fulfilling expectations give rise to different economic outcomes – i.e. different time paths of output, unemployment, inflation etc.

Monetary policy and financial frictions

The recent crisis has demonstrated that financial markets can greatly amplify shocks originating in other economic segments. This has led to renewed interest in investigating the interaction between macroeconomic and financial variables.

From a central bank perspective it is important to understand the channels through which monetary policy transmits to financial variables, in particular to credit costs. Pre-crisis macroeconomic models typically predicted that the response of lending rates to monetary policy interventions is determined exclusively by the expected path of the target policy rate – the interest rate channel. A change in the policy rate is then expected to be extended to the longer rates via the expectations hypothesis of the yield curve.

Recent empirical papers find evidence of alternative transmission channels. Gertler and Karadi (2015) show that movements in US medium and long-term rates after an unexpected tightening of monetary policy reflect an increase in the term premium. Caldara and Herbst (2018) find that unexpected monetary policy changes in the federal funds rate are key drivers of credit spreads. Miranda-Agrippino and Ricco (2017) document a significant and persistent rise in corporate bond spreads and premia after a contractionary monetary policy shock, consistent with an increase in the external finance premium, i.e. the wedge between external (e.g. bonds, loans equity) and internal (e.g. earnings) financing costs.

These empirical findings point to a credit channel of monetary policy embedded in many post-crisis macro models. This channel posits that the effects of monetary policy interventions on lending rates are amplified by endogenous changes in the external finance premium. In turn, the existence of an external, positive finance premium is generally attributed to some financial market imperfections or frictions such as imperfect information or costly contract enforcement on financial markets (Bernanke et al. 1999, Kiyotaki and Moore 1997). Recent papers (Linde et al. 2016; Del Negro and Schorfheide 2013) show that including financial frictions in macro models is essential to describe the evolution of macroeconomic variables since the Great Recession. Moreover, these papers point to time variation in the relevance of financial frictions, which can occasionally become more severe, as demonstrated by the latest crisis.

The existence of a credit channel is even more relevant at the ZLB when the interest rate cannot be moved and the expectations hypothesis channel cannot be used to affect long-term rates. This will be discussed in more details in the following sections.

Forward guidance

As the conventional policies turned out to be redundant at the liquidity trap, central banks have started to employ, among other unconventional measures, forward guidance, thus providing information about, or commitment to, their future monetary policy actions. The key idea in forward guidance is that the central bank can alleviate the recession (today) by promising to keep nominal interest rates low (at zero) in the future.

Empirical evidence on forward guidance

Several empirical studies have attempted to quantify the effects of forward guidance on measures of real activity or expectations thereof. Forward guidance itself is typically measured from data on futures contracts, as a revision in the expected path of the policy rate following a monetary policy announcement. The majority of studies find that forward guidance has substantial impact on the yields on long-dated securities, in line with conventional monetary policy transmission.

The real effects of forward guidance are, however, less clear cut. Campbell et al. (2012), for instance, find that an expansionary forward guidance shock leads to negative effects on the real economy. To explain this puzzle, they conjecture that forward guidance has two opposing informational effects. To the extent that it signals a commitment to a pre-specified expansionary monetary policy path (Odyssean forward guidance), for example, the effects should resemble the conventional ones. However, if market participants interpret the guidance as a signal that the central bank sees a deterioration in the future outlook (Delphic forward guidance), and subsequently revise their own expectations downward, it can have the opposite effect.

Recent empirical studies attempt to distinguish between Odyssean and Delphic forward guidance. They find that the latter can almost fully explain the puzzling effects (e.g. Campbell et al. (2018)). Focusing on Odyssean forward guidance, a number of studies find real responses that are well in line with those reported for conventional monetary policy (e.g. Gertler and Karadi (2015); Bundick and Smith (2017); Hubert and Labondance (2017)). Nevertheless, unexpected Odyssean forward guidance shocks are typically rather small in magnitude. Moreover, its estimates may be exaggerated as it is difficult to separate them from the effects of quantitative easing programmes that are announced at the same dates. Hence, while most studies find that forward guidance can occasionally serve as a useful tool, if implemented with care, its overall effects are difficult to estimate.

Forward guidance puzzle and proposed remedies

While forward guidance seems to work in practice, it works much better in theory. Indeed, in standard New Keynesian macro models, Odyssean forward guidance is an implausibly strong policy tool. Moreover, in these models forward guidance is the more effective the further in the future the promised policy action will take place (McKay et al (2016); Del Negro et al (2015)).[7]

Why is forward guidance so powerful in standard New Keynesian macro models? If the central bank can engineer a boom in the future, the expected good times will create a boom – or at least alleviate a recession – already today.[8] Moreover, in the standard New Keynesian model (current) inflation depends on expected cumulative future output. An interest rate drop today will then

create a transitory boom, lasting for one period – the current quarter – and raises current inflation only modestly. However, a promise to lower interest rates in 10 years' time creates a boom lasting for 40 quarters and gives rise to hyperinflation today (see e.g. McKay et al (2016)).

The main reason behind the forward guidance puzzle is that the standard New Keynesian macro models are highly forward-looking. How can we weaken the grip of the future over the present? Recently proposed remedies, or modifications to the standard New Keynesian framework include i) heterogeneous agent New Keynesian models (HANK) and ii) deviations from rational expectations: behavioural New Keynesian models, k-level rationality, lack of common knowledge/ higher-order beliefs. These proposed remedies are discussed in more detail in sections "Heterogeneous agent New Keynesian models and forward guidance" and "Departures from the assumptions of rational expectations and forward guidance".

The proposed remedies to the forward guidance puzzle are closely linked to the monetary policy transmission mechanism in New Keynesian macro models. Roughly speaking, the transmission mechanism can be decomposed into two parts: a) direct/partial equilibrium effects: intertemporal substitution; b) indirect/general equilibrium effects: income effects, Keynesian multipliers.

The *direct effect* of monetary policy is the portion of monetary policy transmission that would take place if consumers only took into consideration the announced change in monetary policy, while assuming that the rest of the economic environment, for example aggregate economic activity, would remain unchanged. The direct effect essentially boils down to intertemporal substitution. For example, after a (promised) drop in the (current or future) interest rate, households frontload their consumption, i.e. they move it from the future towards the present.

The *indirect effects* of monetary policy result from consumers, or economic agents, reacting to changes in the macro economy. Due to the direct effect, discussed above, more accommodative monetary policy boosts aggregate demand and aggregate output. But higher aggregate output results in higher income, which boosts aggregate demand, which boosts aggregate output, and so on. These *general equilibrium* effects essentially resemble a Keynesian multiplier.[9]

To summarize the proposed remedies, in heterogeneous agent New Keynesian models, the direct/ partial equilibrium effect of monetary policy is weakened, while the indirect/general equilibrium effects are typically reinforced. When the assumption of rational expectations – or more generally the assumption of perfect rationality – is relaxed, the general equilibrium effects of monetary policy are typically muted. Therefore, the effectiveness of forward guidance is diminished to perhaps more plausible and realistic levels.

Heterogeneous agent New Keynesian models and forward guidance

The key starting point in heterogeneous agent New Keynesian (HANK) models is that people are different, and they face different idiosyncratic (or individual specific) shocks: for example, a person may find or lose a job, fall ill, or be more or less fortunate in their personal investments. Furthermore, these idiosyncratic shocks are uninsurable (whereas in the standard New Keynesian model all consumers belong to a large representative household, which provides insurance against all idiosyncratic shocks). In particular, after a sequence of adverse shocks, the household may become borrowing constrained (Kaplan and Violante (2018); Kaplan et al. (2017); Ravn and Sterk (2017)).

In the HANK models, the *direct, partial equilibrium, effect* of forward guidance is weakened. An individual consumer is less inclined to increase his consumption today in response to promised laxer monetary policy in the future. In order to take advantage of the announced future interest rate drop, the consumer should run down his assets, or incur debt, and then pay back in the future when interest rates are lower. But in the meantime, before the drop in interest rates takes place, the consumer may become unemployed or face other adverse (idiosyncratic) shocks, so that the asset cushion would be needed (McKay et al. (2016)).

Indirect effect of monetary policy (income effects, Keynesian multipliers) in HANK models. When people (may) face borrowing constraints, current income becomes a more important determinant of current consumption, as opposed to some measure of permanent income, or life cycle income. In other words, the marginal propensity to consume from current income increases, at the individual level, as well as at the aggregate level. This then strengthens the Keynesian multiplier, and the indirect income effects of forward guidance are more powerful in heterogeneous agent New Keynesian models than in the standard representative household model (Werning (2015)).[10]

To sum up, HANK models change our view of the monetary policy transmission mechanism, compared with the pre-crisis New Keynesian paradigm, which relied on the representative household assumption. However, it is still unclear whether heterogeneous agents, by themselves, can resolve the forward guidance puzzle. The key issue seems to be whether the weakening of the partial equilibrium effect of monetary policy announcements outweighs the stronger general equilibrium effect: McKay et al. (2016) and Kaplan et al. (2016) obtain this result, implying that HANK models help to resolve the forward guidance puzzle. On the other hand, Werning (2015) and Fahri and Werning (2017) show the opposite case is also possible.

Departures from the assumptions of rational expectations and forward guidance

Many of the departures from the rational expectations assumption aim to weaken the indirect

general equilibrium effects of promised future monetary policy: boundedly rational economic agents do not take all the general equilibrium effects into account. Since the importance of general equilibrium effects, vis-à-vis partial equilibrium effects, is significant for promised future policies, the power of forward guidance is weakened.

Garcia-Schmidt and Woodford (2015) and Fahri and Werning (2017) drop the assumption of rational expectations and replace it with k-level rationality. The implications of k-level rationality, or k-level thinking, can be understood by considering the Keynesian multiplier process imbedded in the indirect effects of monetary policy: laxer monetary policy boosts aggregate demand, which boosts aggregate output, which boosts aggregate demand, which boosts aggregate output, and so on. In the rational expectations equilibrium, it is implicitly assumed that consumers follow this train of thought for an infinite number of rounds. Under k-level rationality, it is instead assumed that people stop this thought process after k rounds. Under k-level rationality, the multiplier is weaker than under rational expectations, and the indirect effects of monetary policy, in particular forward guidance, are muted.

Broadly similar themes are explored by Angeletos and Liam (2017), who relax the assumption of common knowledge: people do not know for sure what others think about the future. This is important, since the indirect, general equilibrium effects of monetary policy depend on these higher order beliefs. Essentially, one should feel optimistic about the future only if other people are optimistic: if others are pessimistic, aggregate demand will be weak, and output and income will be lower. Then, if a person does not know for sure what others think, he will react less strongly to a monetary policy announcement.

Gabaix (2017) proposes a behavioural model where the power of forward guidance is weakened by economic agents' limited attention, or myopia. The agents do not pay attention to all the myriad aspects of the economy, instead building a simplified model of the world they live in, and use this as a basis for action. The more distant the events in the future, the less clearly the behavioural agents see them. While in the k-level rationality approach (Garcia-Schmidt and Woodford (2015); Fahri and Werning (2017)) and the higher order beliefs approach (Angeletos and Liam (2017)) the general equilibrium effects of forward guidance are muted, in Gabaix (2017) not only the general equilibrium effects, but also the partial equilibrium effects of forward guidance are weakened by agents' limited attention and myopia.

Quantitative easing

Since the onset of the financial crisis, several central banks have resorted to QE measures by purchasing a variety of assets, ranging from safe and liquid government debt to risky and less-liquid private or government debt. While QE programs differ in their implementation with respect

to timing and assets purchased, they share a common objective: to stimulate the economy when conventional monetary policy cannot be used, i.e. when the policy rate reaches its nominal lower bound.

Empirical evidence on quantitative easing

QE operates primarily by affecting the yield curve, in particular by reducing longer-term interest rates. Indeed, it has been documented that central bank asset purchases led to economically meaningful declines in interest rates on a range of securities, including government bonds, agency mortgage-backed securities and corporate bonds (D'Amico and King (2013) and Gagnon, Raskin, Remach and Sack (2011) provide evidence for the US; Joyce et al. (2011) for the UK; Andrade et al. (2016) for the euro area). These declines in yields have translated into a reduction of key housing interest rates (Gabriel and Lutz (2014); Hancock and Passmore (2011)) and an increase in stock prices (Krishnamurthy, Nagel and Vissing-Jørgensen (2014)).

Quantifying the wider macroeconomic effects of QE is particularly challenging for two reasons: firstly, there is little historical precedent for these programmes; secondly, a number of other measures were adopted at the same time in response to the crisis: e.g. fiscal policy, forward guidance. Nevertheless, a number of studies seek to isolate the contribution of QE to the economic developments of the past few years by conducting a counterfactual analysis, i.e. estimating the evolution of output, unemployment and inflation in the absence of QE. The general finding is that QE policies have significantly affected the broader economy by averting significant risks both of deflation and of further decline in output or employment. The effects are generally stronger on real activity than on inflation. Increases of up to 3% are reported for US output, and up to 1% for inflation (Liu et al. (2017)). Results for the euro area point to a positive effect of QE: inflation would have been lower and output losses higher without the ECB purchase programme (Andrade et al. (2016)). Peak effects on the level of real GDP and annual inflation in the UK amount to 1.5% and 1.25%, respectively (Kapetanios et al. (2012)). In Japan, the gains from QE policies are estimated to be more modest, with a rise in industrial production by 0.4% in response to a 7% rise in the bank reserves held by the Bank of Japan (Schenkelberg and Watzka 2013).

Quantitative easing in macro models

Perhaps somewhat surprisingly, the standard view emerging from pre-crisis macro models was that quantitative easing measures are irrelevant. This property dates back to the seminal work by Wallace (1981). Wallace's irrelevance result states that alternative sizes and compositions of the central bank balance sheet have no real or nominal effect on the economy: in particular output, unemployment and inflation should not be affected by quantitative easing.[11] More recently,

Eggertsson and Woodford (2003) have shown that the irrelevance holds in standard New Keynesian models, when monetary policy is constrained by the zero lower bound.

The gist of the irrelevance result is that any changes in the central bank's (or more generally the public sector's) balance sheet are crowded out by the reactions of the private sector. Essentially, any losses or gains incurred by the public sector are eventually covered by the consumers, or households, populating the economy. Thus, moving assets to the public sector balance sheet is just as irrelevant as moving them from the right pocket of a consumer to the left pocket. (The basic logic is similar to the Ricardian equivalence property that holds in many simple macro models.)

The view after the crisis is that *"the problem with QE is it works in practice, but it doesn't work in theory"* (Bernanke (2014)). Breaking the irrelevance property involves the introduction of various forms of frictions and market incompleteness into the pre-crisis macro models. In particular, financial frictions have played a key role in recent modelling. The theoretical efforts of explaining the effectiveness of QE have fallen under the *credit/liquidity channel* by Araújo et al. (2015), Del Negro et al. (2017), Driffill and Miller (2013), Gertler and Karadi (2011), Williamson (2014) etc., the *portfolio rebalancing channel* by Chen et al. (2012), Ellison and Tischbirek (2014) and the *signalling channel* by Eggertsson and Woodford (2003).

The *signalling channel* is tightly linked with forward guidance, discussed in Section "Forward guidance" above. When buying securities, whose (future) value depends on future monetary policy, the central bank puts its money where its mouth is. Hence the central bank signals that it is serious about the announcements concerning future policies. (If the central bank reneges on its promises, it will suffer losses when asset prices fall.)

In models that incorporate the *credit/liquidity channel*, financial frictions break the Wallace irrelevance result. Del Negro et al. (2017) look at the swapping of illiquid assets for liquid assets. In particular, they include some liquidity frictions in an otherwise standard DSGE model featuring nominal and real rigidities. These frictions include a standard financing constraint that allows firms to borrow only up to a fraction of the value of their current investment. The second important friction is that a firm with an investment opportunity can sell only up to a certain fraction of its illiquid (equity of other firms, commercial papers, bank loans, mortgages etc.) assets in each period. In their model, the central bank can do open market operations whereby it swaps liquid (money and government bonds) assets for these less liquid assets. This reduces the liquidity premium[12] and therefore lowers interest rates.

The financial frictions in the Del Negro et al. model could be interpreted as a proxy for the collapse of certain asset markets and collateral values of assets. The central bank can, however, at least partially help to circumvent these frictions by providing much-needed liquidity. Hence QE matters,

and the irrelevance result does not hold.

In models that address the *portfolio balance channel*, market segmentation breaks the irrelevance property. Chen et al. (2012) assume that there are two types of households. The unrestricted households can save via both short and long-term bonds, but they have to pay a premium for the extra possibility that they can transform along the maturity. The restricted households can save only through long-term bonds. This heterogeneity creates separated short and long-term bond markets i.e. market segmentation. The central bank can change the maturity on the bond markets by, for example, buying at the long end and selling at the short end (Operation Twist). Swanson (2011) found that, in practice, Operation Twist yielded significant negative effects on long-term rates.

Conclusions

The financial crisis challenged the prevailing paradigm of New Keynesian macro modelling. Firstly, pre-crisis models were ill suited to handle nonlinearities imposed by the ZLB. Secondly, standard pre-crisis macro models did not include interaction between financial markets and the real economy. Thirdly, pre-crisis models were ill-equipped to analyse the effects of unconventional monetary policies like quantitative easing and forward guidance.

The new unconventional monetary policies are challenging to model. Quantitative easing seems to work in practice but not necessarily in theory. The commitment type of forward guidance seems to have huge effects in theory, whereas the softer forms of guidance applied in practice come with significantly smaller effects. Including heterogeneity, financial frictions and other forms of market incompleteness, as well as possibly non-rational behaviour, in our models appears to help to solve these puzzles. Nevertheless, these are still highly uncharted waters for research. When implementing changes in the macro models, we may also have to reconsider the transmission mechanism of conventional monetary policy.

There remain many unanswered policy and modelling questions which we did not cover in this short article, such as the policy space and cooperation between different policies. As a result of the prevailing ZLB, monetary policy space has turned out to be highly persistent. This is challenging, since the current business cycle might turn down at some point, and under such circumstances the monetary policy space is relatively limited. A related question is whether central banks should alter their inflation target or accept a more flexible price level or nominal GDP target to increase the policy space. The other interesting policy issue, not covered in this survey, is how policy coordination between monetary, fiscal and financial (macro prudential and regulatory) policies should be arranged.

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Footnotes

1. The central bank sets nominal interest rates by managing the supply of liquidity to private banks. If firms adjust their prices sluggishly, this also allows the central bank to

exert temporary influence over the real interest rate. The goal is to maintain price stability and possibly to reduce output fluctuations as well. ↑

2. Henceforth, we shall use the term 'ZLB' (zero lower bound) to denote the lowest level central banks are willing to adjust their rates to, even if in some instances (including the Eurosystem) rates have been reduced into negative territory. The terms 'ZLB', 'effective zero lower bound' and the 'liquidity trap' are used as synonyms. ↑
3. Long-term secular trends, such as societal aging, may have increased savings and lowered real interest rates more generally, and thereby also increased the likelihood of reaching the ZLB. For a review of the relevant literature, and critical evidence on this hypothesis, see Borio et al. (2017). ↑
4. Quantitative easing refers to a policy whereby the central bank buys financial assets, such as government bonds, from private banks with the intent of easing longer term financing conditions. In forward guidance, the central bank seeks to influence private expectations by communicating its commitment to a future policy path. ↑
5. Rational expectations imply that agents form mathematical expectations based on the full model structure. This requires very strong informational assumptions that are unlikely to be met in practice. ↑
6. The Taylor rule ties the nominal interest rate to the deviations of inflation from target inflation and the output gap. ↑
7. Early papers addressing the forward guidance puzzle include Laséen and Svensson (2011) and Verona et al. (2013). ↑
8. Assume that (in period t, or today) the central bank promises to lower interest rates at some future date T. This triggers consumers to increase their consumption in period T, and since output is demand driven (in the short run), also period T output goes up. But higher period T consumption and output encourages people to consume more in period T-1, and also period T-1 output goes up. Following the same logic backwards in time, one can conclude that output rises in every period between today (when the interest rate drop is promised) and period T (when the promised interest rate drop is implemented). ↑
9. In standard representative household New Keynesian models the direct effect of monetary policy tends to be much stronger than the indirect effects. This is basically because in these frameworks consumption depends on (some version of) permanent income, and while monetary policy affects current income streams, it tends to have very limited impact on permanent income. However, the indirect/general equilibrium effects become relatively more important at longer horizons of forward guidance. ↑
10. More generally, in HANK models monetary policy can affect aggregate output and inflation through income and wealth redistribution. For example, lower interest rates redistribute income from lenders to borrowers. On the other hand, monetary policy may

affect equilibrium wages – possibly differently for low and high earners – and the rate of return on capital. Since the marginal propensity to consume varies between different groups (for example borrowers and low income earners typically consume a larger share of their current income than lenders and high income earners), these distributional changes translate into changes in aggregate demand and aggregate output. See Auclert (2017) and Kaplan and al. (2017) for a more comprehensive account of different income-redistribution-related transmission mechanisms of monetary policy. ↑

11. This is close to the Modigliani-Miller and Ricardian Equivalence theorems. The Modigliani-Miller theorem states that it does not make any difference if the firm finances its new investment with equity or debt. ↑
12. A liquidity premium is a premium demanded by investors when any given security cannot be easily converted into cash for its fair market value. ↑

Key words

financial frictions, forward guidance, macro models, quantitative easing, zero lower bond