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Yield Curve Control

Mika Kortelainen, Adviser

Abstract

We study the yield curve control in Eurozone. We apply Chen, Cúrdia and Ferrero (2012) model that uses a financial friction to break Wallace's neutrality. We calibrate a bond supply shock that corresponds to the observed change in the time premium in euro area when the APP program was introduced. With some model simulations, we show that the effectiveness of both unconventional monetary policy and fiscal policy are enhanced, when the yield curve control is applied. Thus, we find that the yield curve control can be an effective tool, if applied in a credible manner for a long enough time period during an effective lower bound episode.

Keywords: Yield curve control, monetary policy, fiscal policy, efficient lower bound, liquidity trap

JEL codes: E52, E58

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1. Introduction

Covid-19 pandemic has wreaked havoc not only in public health but also in economies. Growth and inflation expectations have stumbled at least momentarily. Monetary and fiscal authorities have ridden into the rescue by loosening policies considerably.

The Great Recession of 2008 has however left many developed countries with narrow monetary policy space ten years after. Indeed many countries are currently close to their effective lower bound, which restricts the use of conventional interest rate cuts. Furthermore, the unconventional monetary policy tools like quantitative easing, forward guidance and funding for lending schemes are still widely in effect in the developed economies. Under these circumstances monetary authorities try to find novel ways to implement monetary policy easing to counteract the economic consequences of the pandemic shock.

One such new(ish) monetary tool is yield curve control. Under the yield curve control the central bank buys unlimited number of long-term debt securities (like government bonds) to fix the interest rate at certain maturity. This strategy, if trusted and perceived as credible could be highly beneficial when combined with other easing measures. The reason is that the central bank effectually commits to unlimited buying of long-term bonds (Bernanke, 2016). In addition, if viewed credible by investors the actual buying of the central bank might turn out to be small in practice.

We find with the help of some model simulations that the yield curve control can be an effective tool, if applied (in a credible manner) for a long enough time period during an effective lower bound episode. Hence, it is a potential tool to jolt the economy towards the price stability objective of close but below two percent inflation in the medium run in the euro area.

In what follows, we first discuss some pre-existing experiences of yield curve control. Second, we do some simulations utilizing economic model which endogenizes long-term rates and is therefore a suitable for yield curve control analysis. Third, we discuss about the results and especially how these relate to other proposed monetary measures as well as about the possible caveats in this study. Finally, we draw some policy conclusions.

2. Pre-Existing Experiences of Yield Curve Control

Yield curve control is not a new proposal. It has been applied by U.S. Federal Reserve Bank during and after the Second World War and by the Bank of Japan since 2016. Recently the Reserve Bank of Australia has also adopted yield curve control measures.

After entering the Second World War U.S. FED started applying yield curve control that was fixed for the duration of the war, see Garbade (2020). The short term interest rate (T-bill) was

fixed to a ⅜ percent rate while the long-bond rate was fixed to a 2½ percent rate. This positively sloped yield curve was quickly adopted by investors in the capital markets. As the bond returns were perceived to be higher without any risk add-ons, investors shifted their portfolios by selling T-bills and buying longer term bonds.

Yield curve control was gradually dismantled after the war. This gradual process started by unwinding first the short-term T-bill rate on 1947. Finally the Treasury-Federal Reserve accord ended ten years of inflexible interest rates in 1951.

FED draws two key lessons from its yield curve control experience. First, the shape of the yield curve cannot be fixed independently of the volatility of interest rates and debt management policies, and second, large-scale open market operations may be required in the course of refixing, from time to time, the shape of the yield curve. Regarding the first lesson, the positive slope of the yield curve created an incentive for investors to load of the short-end buy long-end while the Treasury was issuing in all maturities. Together, these required massive operations of FED to buy in the short-term to absorb T-bills. This could have been avoided or diminished by aiming at flatter yield curve target. Second lesson stems from the gradual relaxation of yield curve control which generated massive portfolio shifts as investors moved to shorter maturity when it was freed from yield curve control.

Japan adopted yield curve control in 2016. Their short term policy rate is at -10 bps while the targeted ten year yield is at zero percent with the target band of +/- 20 bps. Japanese yield curve control is thus based on only slightly increasing yield curve. Therefore it is difficult to see any major portfolio shifts that could occur if they will in some day abandon their yield curve control in a similar gradual way as the FED did.

Entirely another question is whether Japanese yield curve control helped economy and reduced the deflationary pressures. So far the results do not indicate that the Japanese economy has been disconnected from the low inflation/deflation. This on the other hand is difficult to judge since we do not know the counterfactual. Some have nevertheless judged that the Japanese yield curve control may be less effective since it was applied only after the deflationary pressures were more deeply rooted in the economy.

Reserve bank of Australia cut the short-term policy rate to 25 bps and announced yield curve control on three year government bond rate at the 25 bps on March 19, 2020. At the moment of this announcement, the yield on the three-year government bond was ½ percent. Therefore, RBA will need to buy government bonds without limits to push up the price of the bond and lower the yield to target. RBA announced also that they may start raising interest rates and abandon yield curve control only after they are confident inflation will be sustainably within the 2–3% target band. They expect to be at this level of yield curve control for an extended period.

3. Yield Curve Control Simulations

We do two sets of simulations to highlight the possibilities of yield curve control. First we examine how yield curve control can amplify unconventional monetary policy in the form of quantitative easing. Second, we do the same with fiscal policy.

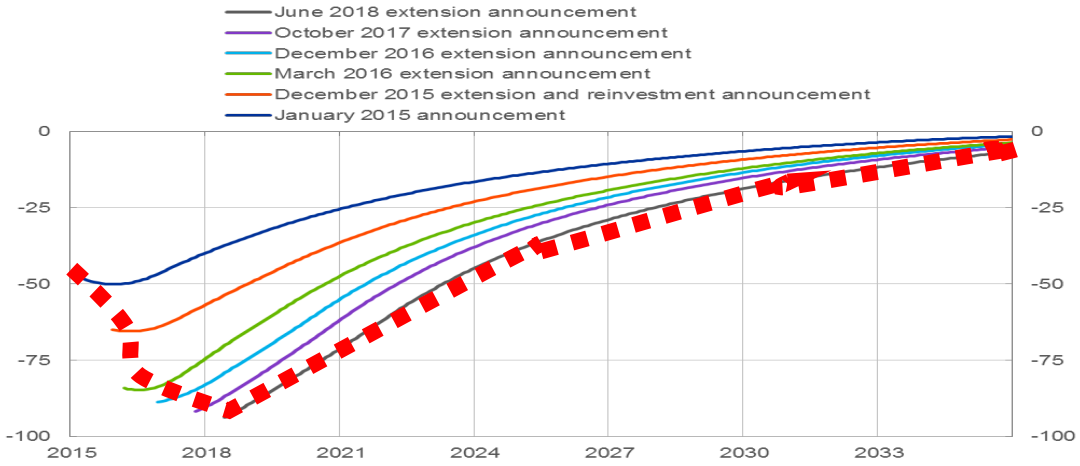
3.1 Quantitative Easing and Yield Curve Control

We demonstrate the impact of the yield curve control by using an economic model by Chen et al. (2012) that considers the term structure of interest rate[1]. This model relies on market segmentation where not all investors can hold both short-term and long-term government securities. Limited participation is not the only possible way to introduce short- and long-term securities and to endogenize the term premium in the model, but this suffices for our purposes to show the effects of yield curve control.

In calibrating the quantitative easing shock we use the market observations in the euro area in Figure 1. The observed term premium (dashed line is added) is taken from the study of Eser et al. (2019). The announcement effect of the APP program in January 2015 decreased the ten year term premium by some 50 basis points and also appeared to show great persistency. The further refinements of the APP program indicate that the term premium fell by whopping 100 bps in three years. The cumulative effect of this QE is shown in the dashed red line in Figure 1.

[1] We use the original model except stationarized fiscal policy rule, AR(1) formulation for all shock processes and appending the data set with the public consumption, see Appendix 1 for brief description of the model. We calibrate the model to data by using estimated US parameters for priors apart few parameters defined by the euro area data. Prior for the elasticity of term premium to debt is calibrated to match the observed fall in term premium and the decrease in the supply of long-term bonds. Latter is obtained by the ratio of announced 1.1 trillion € APP program and the estimated potential purchase space of 5.3 trillion €, see Couere (2015). These give us a rough estimate of 21.5% fall in the supply of long-term bonds. In order to capture the immediate fall in the term premium we frontload this fall in the supply of long-term bonds. If we use actual APP bond increments then the fall in the term premium is more gradual and growth and inflation increase somewhat due to larger and more persistent fall in the bond supply. The difference is however small. Bayesian estimation results of posterior mean are applied in this study.

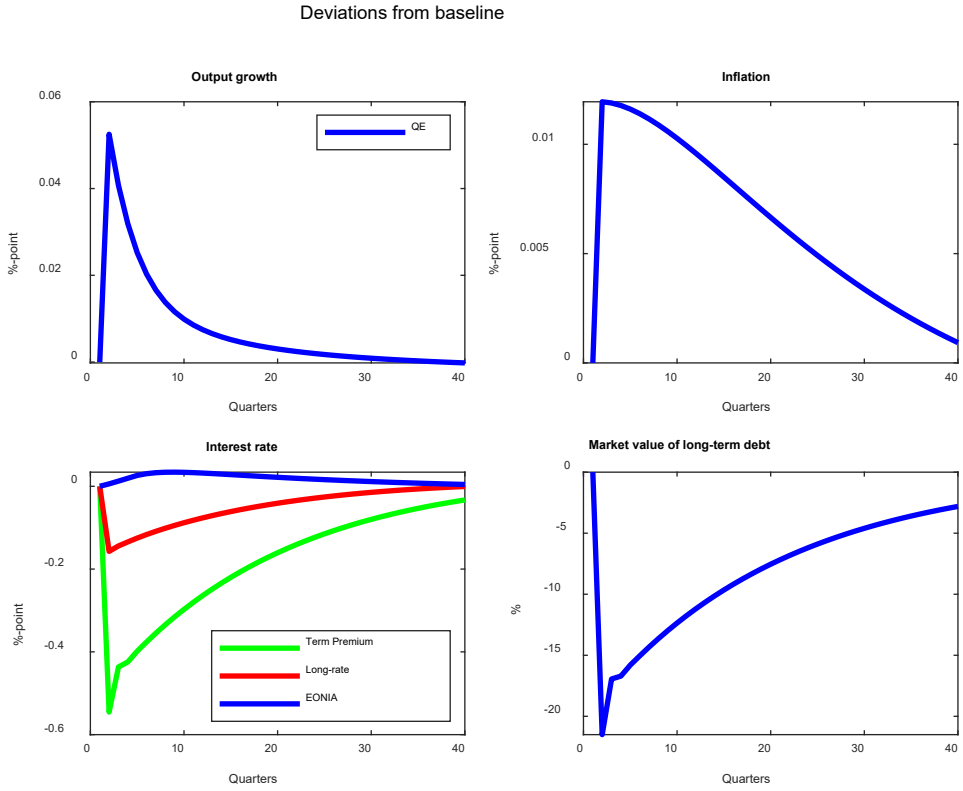
Figure 1 The observed fall in the term premium



Using above results we first introduce a shock which generates a similar fall in ten year term premium. The results of this simulation is shown in Figure 2[2]. As can be seen this unconventional monetary policy easing increases output growth and inflation. However, when conventional monetary policy is allowed to react normally to pick up in inflation, short term interest rate increases. This dampens notably the effect of quantitative easing (QE). Indeed the overall easing effect is really small in the Figure below.

[2] *All simulation results in this note are deterministic. This gives us a quick ballpark estimates which are likely robust to different stochastic shocks. Nevertheless, it would be interesting to do proper stochastic analysis for comparison.*

Figure 2 QE shock with endogenous monetary policy

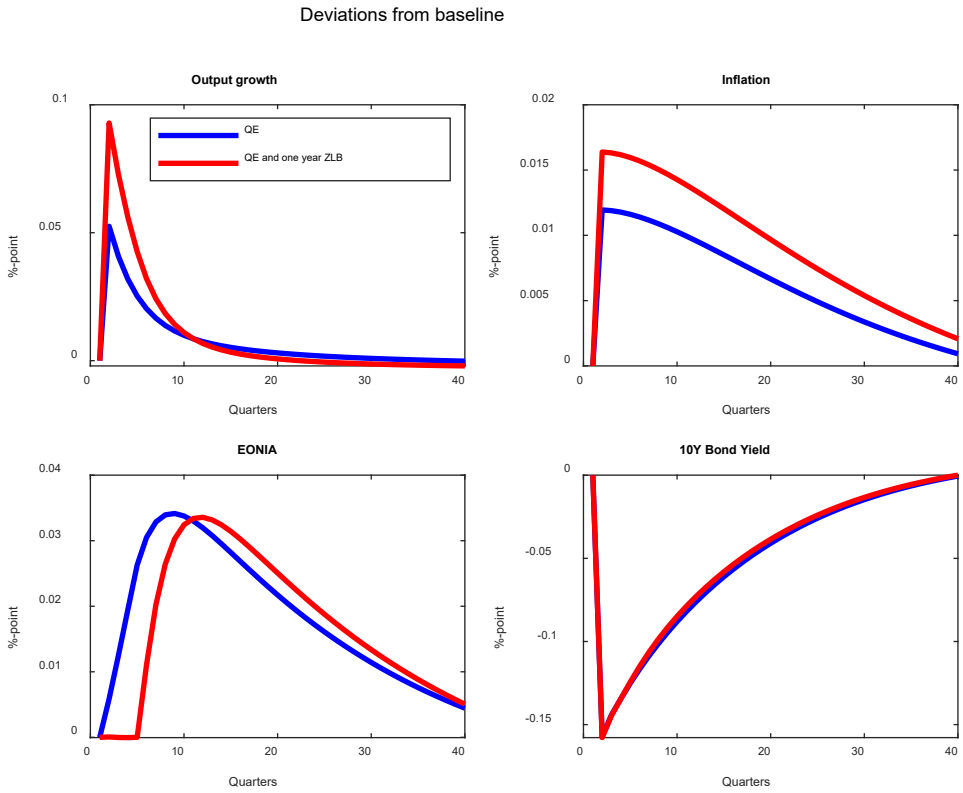


As can be seen the term premium falls by more than the long-term interest rate. Sovereign 10 year long-term yield is a combination of the expected average of short-term interest rates up to ten years and the 10 year term premium. Hence, as the short-term policy rate is allowed to react to inflation the expected average of short-term interest rates increases, and therefore the long-term yield does not fall as much as the term premium.

Next we refine this unconventional policy shock by assuming that the central holds policy rate unchanged in the short run. This monetary policy accommodations (we call it ZLB in Figure below) is assumed to be one year long and is shown in Figure 3. As can be seen monetary policy accommodation greatly amplifies the monetary easing. The effect on output growth is almost doubled in comparison with the case where the short term rate is allowed to change immediately. The amplifying effect is also present in inflation while much lower than in the output growth. All in all the growth and inflation effects are amplified but still small.

The monetary policy accommodation beyond the current quarter is forward guidance. Here, it is assumed that this forward guidance commitment of the central bank is fully credible. The model we use has a forward guidance puzzle with respect to conventional monetary policy which at least partly explain the amplification of conventional monetary policy i.e. monetary accommodation, see Appendix 2.

Figure 3 QE with and without one year monetary accommodation (ZLB)



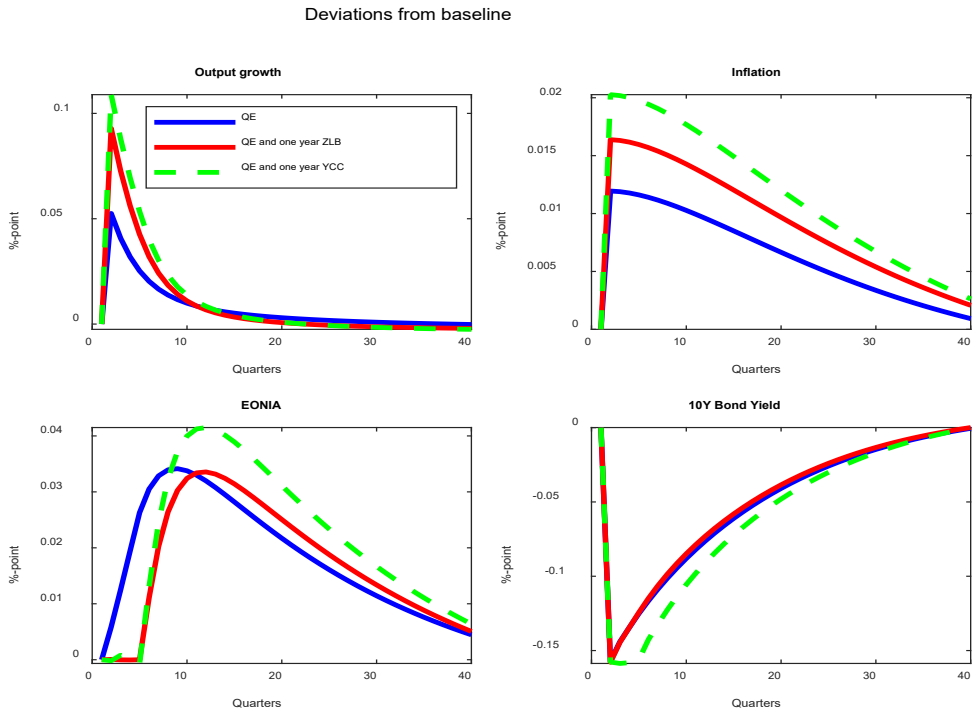
Next, we assume that the central bank uses yield curve control (YCC) to complement quantitative easing. This yield curve control is assumed to consist of one year monetary accommodation in the short term policy rate and fixing the 10 year bond yield rate for one year. The results are shown in Figure 4. As can be seen yield curve control amplifies the unconventional monetary easing in comparison to one year monetary accommodation.

Next, we consider what happens if the monetary accommodation is extended to second year but without yield curve control. The results of this simulation are presented in Figure 4. As can be seen the amplification of quantitative easing is increased. The output growth is almost 5x larger than in the case where policy rates is allowed to rise. Furthermore, it is about 2.5x larger than in the case where the monetary accommodation is only done for one years. Latter amplification effect is at least partly due to the forward guidance puzzle of conventional monetary policy also existing in the current model, see Appendix 2.

Inflation rate is also increased but not as much as the output growth. In addition, the original effect of the quantitative easing shock on the ten year yield is somewhat smaller. Latter is in part a result of lower policy rate in the short-run but higher in the medium run to contain inflation rate.

Next we consider the case where the central bank fixes long term rates for two years. Notice that this fixes the long-rate at the level of quantitative easing and does not allow it to increase as in the case of monetary accommodation of two years.

Figure 4 QE, monetary accommodation (ZLB) and yield curve control for one year



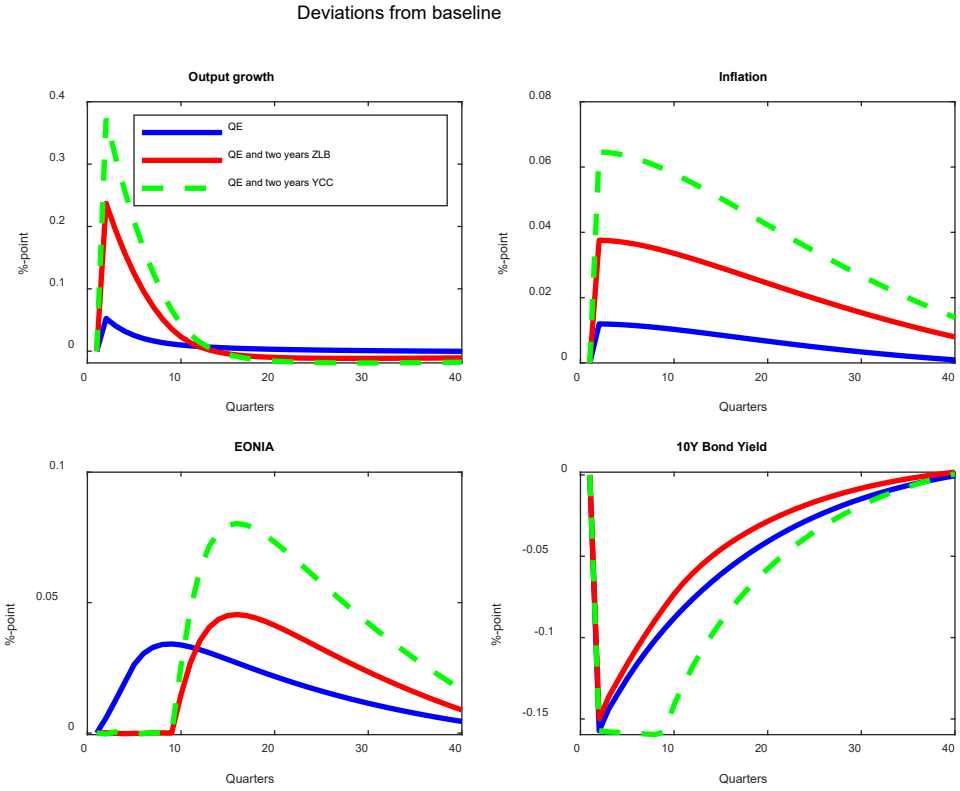
The results of this simulation is presented in Figure 5 below. This yields an important message: the yield curve control can be very effective in right settings. If done only for one year it gives only modest amplification above the monetary accommodation but extending it to second year allows one to reap the true benefits.

Indeed this simulation magnifies the original quantitative easing, by creating about 7x bigger impact on the growth rate than without any monetary accommodation or yield curve control. Furthermore this policy is far more efficient than simply fixing the short-term policy rate alone at the efficient lower bound.

Side effect is that the policy rates needs to increase considerably after the yield curve control period to contain the rapidly rising inflation rate. Despite this medium to longer term inflation stability control inflation still increases considerably.

Why is yield curve control so effective? This is so first because of an imbedded assumption that policy is fully credible. Bernanke (2016) noticed that a lot would depend on the credibility of the central bank's announcement. Here this announcement of two year yield curve control (forward guidance) is interpreted to be fully credible commitment. Second, the model has a forward guidance puzzle which at least partly explain the amplification of conventional monetary policy i.e. monetary accommodation part in this model, see Appendix 2. Third, this forward guidance puzzle is at least partly transmitted to fixing of the long rate which is a function of expected future short terms interest rates.

Figure 5 QE, monetary accommodation (ZLB) and yield curve control for two years



Is Yield Curve Control policy practical in the euro area?

In the euro area the long-rates are already quite low so there may not be anything or at least very little to gain. Notice however that yield curve control policy could be combined with the fiscal policy easing. Japanese case does not point to a breakthrough but that may be because the deflationary mindset was too deeply rooted in Japan. Perhaps low inflation and deflation expectations are not as pinched in the euro area.

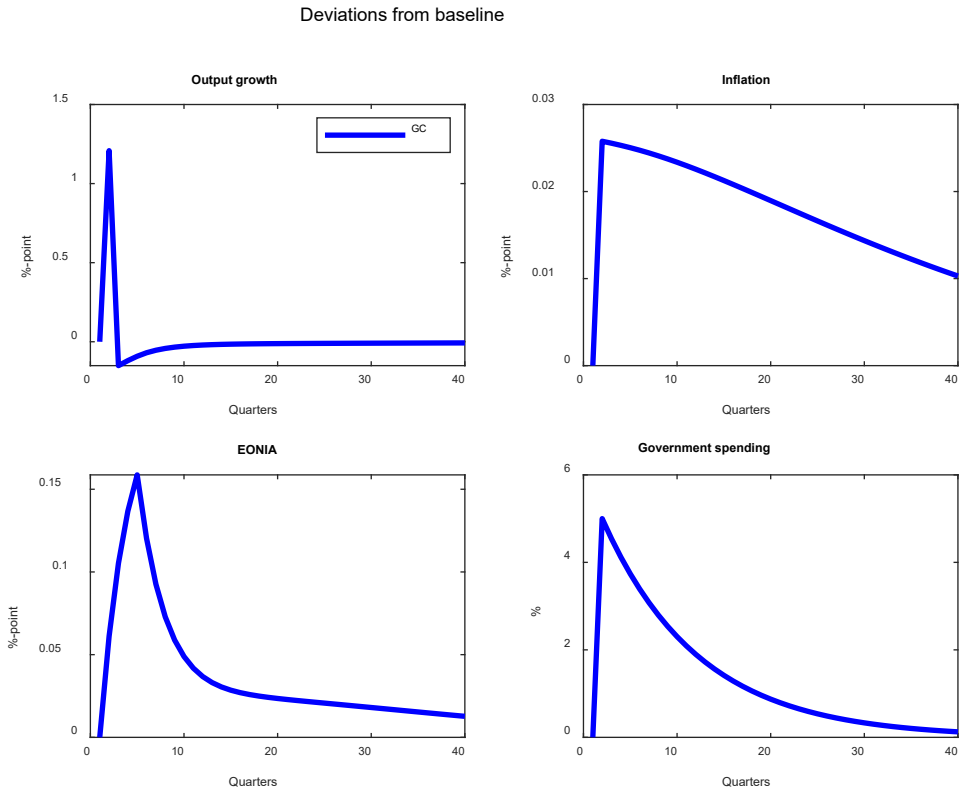
If applied in the euro area we have to remember that the short term policy rate is in fact negative in the euro area. If we fixed the short term rate to current -50 bps and the long-term say ten-year rate to zero percent, this would imply rising yield curve, potentially sparking heavy portfolio shifts now and also if unwinded gradually later on as the Fed's yield curve control experiment showed. Furthermore, the short-term policy rate has already been low for very long time. Can we really lock it down still for many years to come? Or does it speak for permanently low inflation expectations like in Japan? Additionally, the heavy debt burdens of many euro area states means that long end of the yield curve is already stretched. In below, we make some simulations about the fiscal stimulus and combine that with monetary accommodation and yield curve control.

3.2 Fiscal Spending and Yield Curve Control

Above experiments showed that yield curve control can be effective when combined with quantitative easing shock over extended periods. However, as we also noted the room for extra spark via quantitative easing in the euro area is rather limited in the current conjecture because the yields are already very low. Therefore, a natural question is that could the initial growth spark come from fiscal stimulus which then could further be stoked by the yield curve control over extended periods.

We start with a standard fiscal stimulus shock that is calibrated to be of five percent temporary increase in the government consumption (GC). Assuming that government consumption is about 20% of GDP this shock corresponds approximately to 1% of baseline GDP. The results of this simulation is shown in Figure 6. As can be seen this demand shock increases growth temporarily and also inflation a bit while latter effect is really small. Notice however that this demand shock is partially insulated by higher policy rates to fend off higher inflation.

Figure 6 Temporary but persistent government consumption (GC) shock



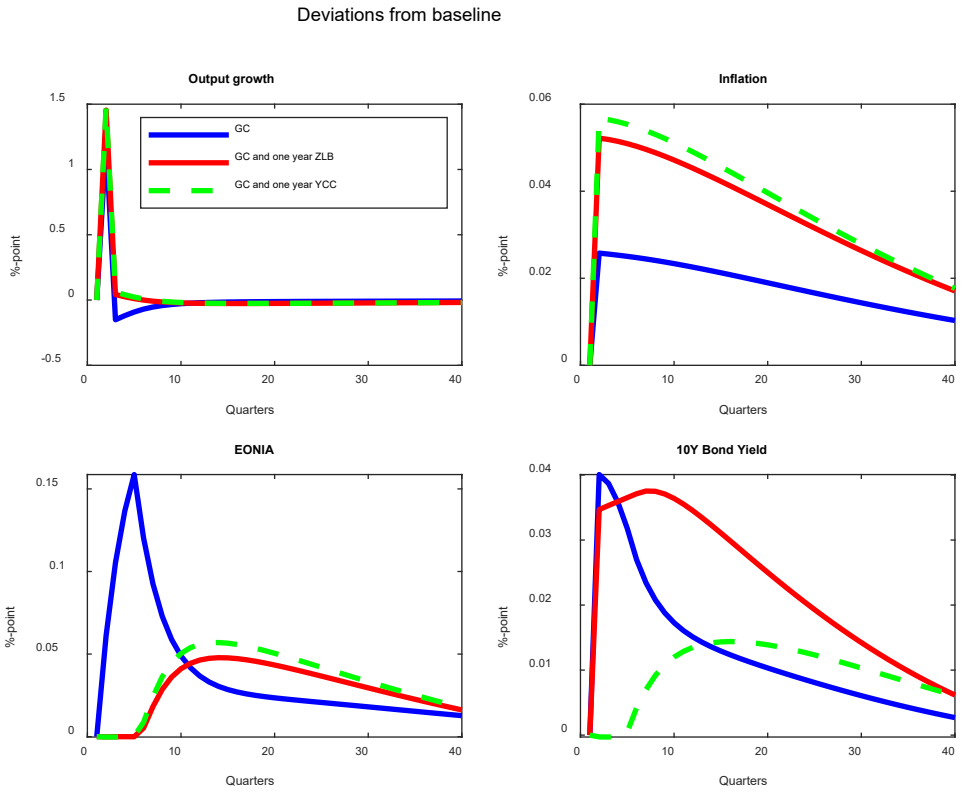
Next, we ask how much fiscal stimulus is amplified if there is one year monetary policy accommodation (ZLB). The results of this simulation are shown in Figure 7 below. Here again we see that there is some amplification but this is less pronounced than in quantitative easing shock.

Next, we ask what if the fiscal stimulus is added with not only one year monetary accommodation but also one year yield curve control. Notice that the increase in the long yield is only about 3 to 4 basis points in the previous cases. Therefore, we are not expecting a big swing in results by enforcing the long-yield close to baseline.

The result of the fiscal stimulus and one year yield curve control is presented in Figure 7. The effect of yield curve control above that of monetary accommodation in output growth is negligible. There is nevertheless a bit more inflation but also the overall effect is small.

In this simulation the fixing of the short-term interest rate carries the most positive effects on this fiscal shock. This is partly plagued by the forward guidance puzzle. Furthermore, fixing the long-term interest rate does not bring too much on the table. In fact if this yield curve control is done only for one year we see only a modest increase in output growth but the inflation increases although the overall push in inflation is small.

Figure 7 GC, monetary accommodation (ZLB) and yield curve control for one year

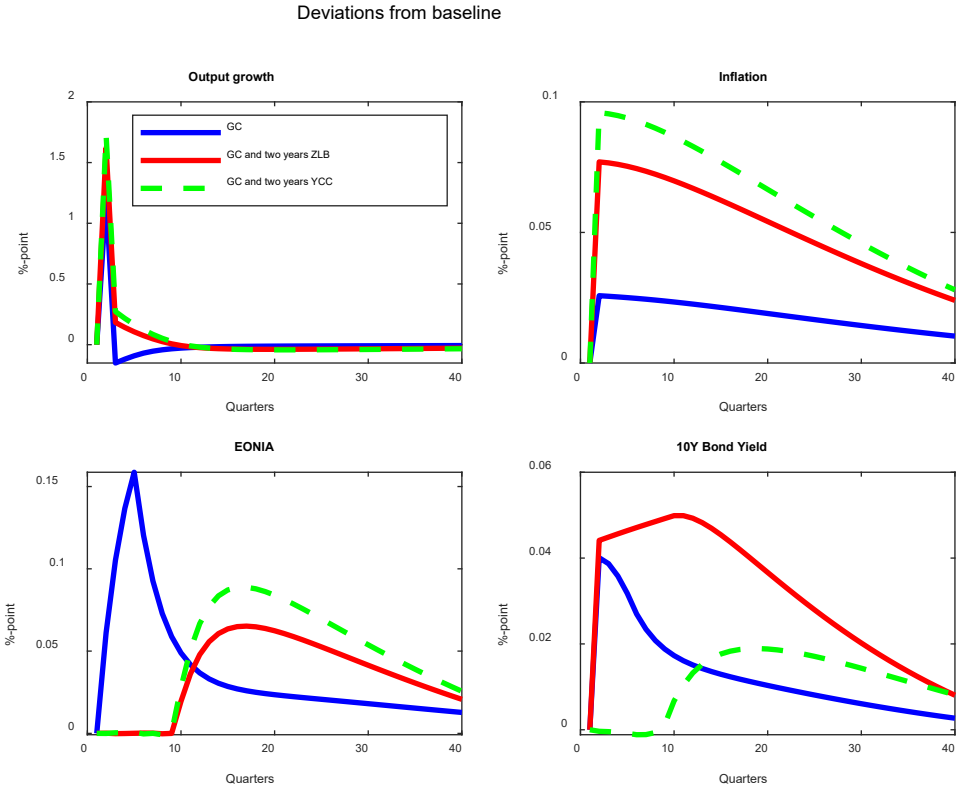


We have kept the fiscal shock as a standard 1% of GDP fiscal impulse. The actual fiscal response to Covid-19 will likely be much bigger possibly leading to discussion about the fiscal sustainability and rise in risk premium (not taken into account in these simulations). However, the ECB has accommodated long-term rates and rise in credit risk premium via different accelerated bond purchase programs. Next we move on and consider the case where monetary accommodation is extend for the second year. The results of this simulation is shown in below.

Once again we see that if monetary accommodation can be extended then the results are amplified.

Finally, we consider the case that in above previous case the central bank is also doing yield curve control for two years. The results of this simulation are shown in Figure 8. Here again the two years yield curve control amplifies both growth and inflation.

Figure 8 GC with and without two years yield curve control



4. Discussion

We collect some proposed policy measures in Table 1. We group these in three different categories: existing tools, mutualized debt and alternative proposals. In the first category we have some existing tools which have already been agreed on[3]. Nevertheless, Outright Monetary Transactions (OMT) program has so far not been utilized. European Stability Mechanism (ESM) is able to give loans to euro area nations on strict conditionality but its funding is limited, which may prove important if the current pandemic crisis takes turn on worse and vulnerable large euro area economies run into problems. Public Sector Purchase Program (PSPP) has been used in the Asset Purchase Program (APP) already extensively. ESCB has, however, utilized so far self-imposed limits in the use of PSPP. The most recent tool, Pandemic Emergency Purchase Program (PEPP) however allows temporary deviations from the capital key.

Table 1 Possible policy tools

	Existing tools				Mutualized debt	Alternative proposals		
	PSPP	PEPP	ESM	OMT	Eurobonds/corona bonds /Recovery fund	Helicopter money	Debt relief	Yield curve control
Limited	Y	Y	Y	N	N	N?	Y	N
Moral Hazard	N	N	N	Y	Y	Y	Y	Y?
Temporary	Y	Y	Y	Y	Y?	Y	N	Y

Y=yes, N=no, ?=perhaps

In the second category, we find mutualized debt proposals consisting of Eurobonds or recent proposal of Corona bonds. These proposals have met a stiff resistance from the more frugal Northern states in euro area. This resistance is partly based on fears that the euro area is transformed to a transfer union. EU Commission has recently proposed a 750bn € recovery fund of which 2/3 are grants to countries hit hardest by the pandemic and the rest is made available as loans. According to this proposal EU Commission would finance this fund by issuing bonds with different maturities in capital markets.

In the third category, there are some alternatives which have been proposed in the literature. Helicopter money is typically assumed to consist of central bank creating money and giving it to the Government to spend. This policy has several shortcomings including not least being outlawed by the Maastricht treaty. Debt relief proposals entertain the possibility that the substantial sovereign bond holdings of the ESCB could be nullified and recorded as loss of the central bank. While technically possible this has its shortcoming also such as the moral hazard problem. Furthermore, one could argue that from the consolidated government accounts nothing substantial really changes and therefore this will not create any assumed benefits.

[3] PEPP program has recently been challenged by the German constitutional court in Karlsruhe on the basis of not fulfilling principle of proportionality. The litigation concerns are beyond our study. We focus on economic issues like how these possible policy measures could help the central bank to fulfill the price stability objective.

Last in the third category we have the yield curve control. We have already shown via some model simulations that under certain conditions the yield curve control could boost the economy. The yield curve control has many features common to other policy measures such as PSPP but it is nevertheless potentially limitless. The yield curve control may contain moral hazard problem as if applied first and foremost to those countries that find sovereign financing difficult. Nevertheless, the yield curve control could also be applied in the euro area level according to the capital keys. If anything the yield curve control resembles OMT program in the sense that it pledges to do whatever it takes to help the countries to maintain reasonable level of yields. A further potential caveat of the yield curve control is that leads to further regulation of the long-term capital markets and thereby creates inefficiencies as the long-term interest rates would no more be determined in the financial markets.

5. Policy Conclusions

We find that yield curve control can be an effective easing tool if done for sufficiently long periods and if perceived as a credible commitment as shown in above simulations. Practical problem is that to be effective central banks must provide policy guidance beyond one year, one year being insufficient for the yield control to be effective according to our simulations.

One possible way to enhance the commitment to low-for-longer yield curve control is to provide an exit map of monetary easing directly linked to quantitative easing measures and forward guidance. But in practice it seems that central banks are not willing to provide well defined exit strategies for their purchase programs.

The central bank could also signal that it temporarily abandons the inflation target and that it remains passive even if inflation increased above its target. This policy can be interpreted simply as a temporary price level targeting suggested by Ben Bernanke (2017).

Another challenge, especially in the euro area, is that the central bank must effectually commit to unlimited buying of long-term bonds. In principle, this can lead to considerable expansion of the central bank's balance sheet. However, if such policy is viewed credible by investors then the actual buying of the central bank will likely turn out to be small.

A further practical point is that there may arise a need to deviate substantially from the capital key in the euro area. Current PSPP and PEPP programs allow only moderate deviations from the capital key. The current self-imposed issuer limits by ECB are guidelines that help to prevent unlimited buying of long-term sovereign debt.

Nevertheless, the yield curve control may be a more flexible tool in the medium run than some other policy tools floating in the current policy debate in the euro area. These include helicopter money and public debt relief. The former is clearly forbidden by the Maastricht treaty.

The latter while certainly having a benefit of transiting a temporary monetary easing to a permanent one would mean sailing into uncharted waters.

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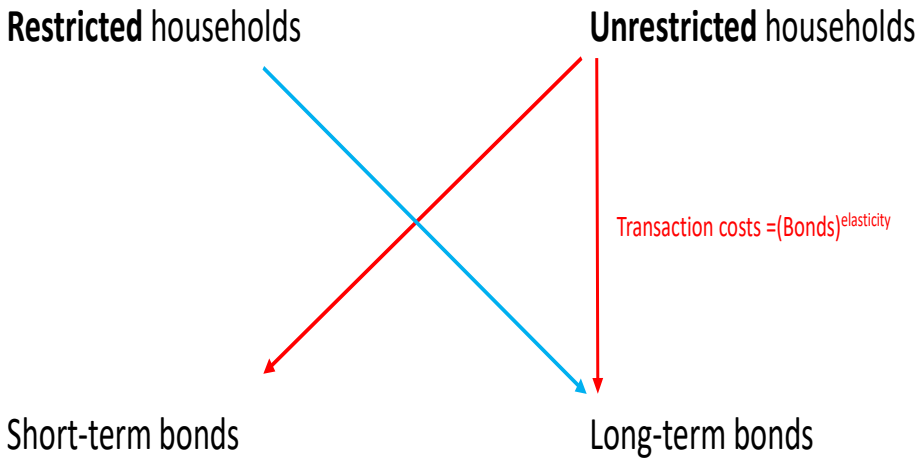
Appendix 1 A Brief Description of the Key Features of the Model

The defining feature of the Chen, Curdia and Ferrero (2012) model is that the households are divided to two groups according to their investment patterns, see Figure 9.

Figure 9 Household's investment pattern



Households in the first group, the so called restricted households, can only invest in long-term bonds if they want to smooth their consumption intertemporally. Households in the second group, the so called unrestricted households, can however invest in both short-term and long-term bonds. Latter group, nevertheless, has to pay transaction costs (a premium) if they invest in the long-term markets.

The budget constraint for an unrestricted household becomes

$$\underbrace{P_t C_t^u}_{consumption} + \underbrace{B_t^u}_{\substack{investment\ on \\ short-term\ bonds}} + \underbrace{(1+\zeta_t) P_{L,t} B_t^{L,u}}_{\substack{investment\ on \\ long-term\ bonds}} \leq \underbrace{R_{t-1} B_{t-1}^u}_{\substack{return\ on \\ short-term\ bonds}} + \underbrace{R_{L,t} P_{L,t} B_{t-1}^{L,u}}_{\substack{return\ on \\ long-term\ bonds}} + \underbrace{W_t^u(i) L_t^u(i)}_{wage\ income} + \underbrace{\mathrm{P}_t}_{\substack{profits\ from \\ intermediate\ goods\ producers}} + \underbrace{\mathrm{P}_t^{cp}}_{\substack{profits\ from \\ capital\ producers}} + \underbrace{\mathrm{P}_t^{fi}}_{\substack{profits\ from \\ financial\ institutions}} - \underbrace{T_t^u}_{\substack{lump-sum \\ taxes}}$$

For a restricted household the budget constraint is

$$\underbrace{P_t C_t^r}_{consumption} + \underbrace{P_{L,t} B_t^{L,r}}_{\substack{investment\ on \\ long-term\ bonds}} \leq \underbrace{R_{L,t} P_{L,t} B_{t-1}^{L,r}}_{\substack{return\ on \\ long-term\ bonds}} + \underbrace{W_t^r(i) L_t^r(i)}_{wage\ income} + \underbrace{\mathrm{P}_t}_{\substack{profits\ from \\ intermediate\ goods\ producers}} + \underbrace{\mathrm{P}_t^{cp}}_{\substack{profits\ from \\ capital\ producers}} + \underbrace{\mathrm{P}_t^{fi}}_{\substack{profits\ from \\ financial\ institutions}} - \underbrace{T_t^r}_{\substack{lump-sum \\ taxes}}$$

As the restricted households cannot buy short-term bonds this construct could be described as a limited participation or market segmentation model. The obvious benefit of this construct is that this brings in a financial friction that breaks Wallace neutrality and hence allows possibly nontrivial effects of QE.

Household enjoy consumption and dislike working according to following utility function:

$$E \sum_{s=0}^{\infty} \beta_j^s b_{j,t+s} \left[\frac{\left(\frac{C_{t+s}^j}{Z_{t+s}} - h \frac{C_{t+s-1}^j}{Z_{t+s-1}} \right)^{1-\sigma_j}}{1-\sigma_j} - \frac{\varphi_{t+s}^j L_{t+s}^j(i)^{1+\nu}}{1+\nu} \right],$$

where $j = \{u, r\}$. β_j is individual discount factor. σ_j is the individual coefficient of relative risk aversion. ν is the inverse elasticity of supply. h is habit coefficient. $b_{j,t}$ is a preference shock to individual j, and φ_t^j is a labor supply shock.

Above model also endogenizes the term premium:

$$\zeta_t = \left(\frac{P_{L,t} B_t^L}{P_t Z_t} \right)^{\rho_\zeta} e^{\epsilon_{\zeta,t}},$$

where P_t and Z_t are price and technology levels at period t. $P_{L,t} B_t^L$ is the outstanding nominal debt at time t. ρ_ζ is the estimated elasticity. Shocks $\epsilon_{\zeta,t}$ are assumed to follow an AR process. Endogenized term premium is due to the assumed premium that the unrestricted households have to pay to invest in long term markets. This premium or transaction costs is related to the quantity of debt with some (estimated) elasticity.

The government controls the supply of long-term bonds via following rule:

$$\frac{P_{L,t}B_t^L}{P_tZ_t} = S\left(\frac{P_{L,t-1}B_{t-1}^L}{P_{t-1}Z_{t-1}}\right)^{\rho_B} e^{\epsilon_{B,t}},$$

where P_t and Z_t are price and technology levels at period t. $P_{L,t}B_t^L$ is the outstanding nominal debt at time t. S is constant that sets this equation an identity at the steady-state. ρ_B is the estimated AR(1) coefficient. We interpret APP program as shocks $\epsilon_{B,t}$ to the outstanding government long-term liabilities.

Government adjust (through lump-sum taxation) the real primary fiscal surplus in response to the lagged real value of long-term debt:

$$\underbrace{\frac{T_t}{P_tZ_t} - \frac{G_t}{Z_t}}_{\substack{real \\ primary\ surplus}} = \underbrace{\left(\frac{\frac{P_{L,t-1}B_{t-1}^L}{P_{t-1}Z_{t-1}}}{Y_{Z,t-1}}\right)^{\phi_T}}_{\substack{long-term \\ debt\ to\ GDP}} e^{\epsilon_{T,t}},$$

where ϕ_T is the estimated elasticity and $\epsilon_{T,t}$ are assumed to follow an AR(1) process.

The rest of the CCF -model is rather standard closed economy general equilibrium model:

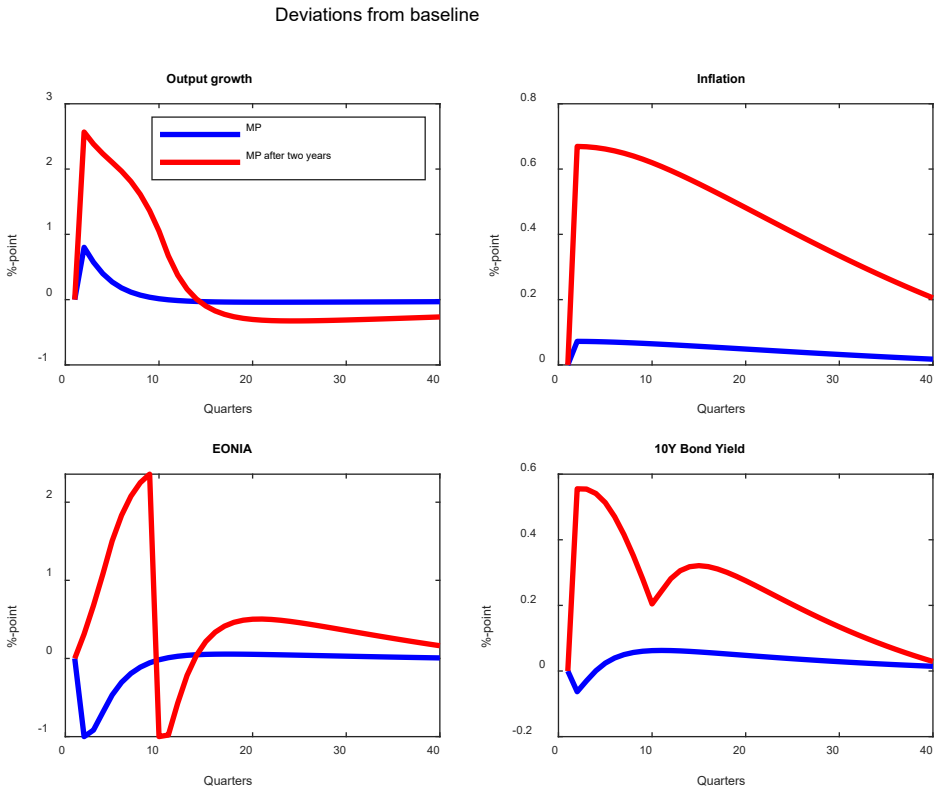
- final goods are CES-composites of intermediate goods and firm maximize profits with perfect competition
- intermediate goods are produced by Cobb-Douglas production technology while the prices are assumed to be sticky a la Calvo
- capital producers face some real adjustment costs a la Christiano et al.
- households set wages on a staggered basis (Calvo)
- conventional monetary policy is defined by Taylor-rule.

Appendix 2 Forward Guidance Puzzle

In quite many forward looking models it turns out that if policy changes are done in a distant future the current impact is much bigger than if those policy changes are done immediately. We test this phenomena in the model by Chen et al. (2012) by conducting three different policy changes: 1. conventional policy change, 2. unconventional policy change, and 3. fiscal policy change both as unanticipated and anticipated shocks. We find clear evidence that the model is plagued by the forward guidance puzzle with respect to conventional monetary policy. However, regarding unconventional monetary policy or fiscal policy we do not find clear evidence the presence of forward guidance puzzle.

In the first exercise we do a conventional monetary policy (MP) shock whereby the policy rate is cut immediately by one percentage point in the first quarter. In addition, we repeat the shock as an anticipated cut in the policy rate expected to happen two year from now. We do rescale the shock to get exactly one percentage fall in the quarter 9. The results of these simulations are shown in Figure 10 below. As one can see regarding conventional monetary policy there is definitely a forward guidance puzzle.

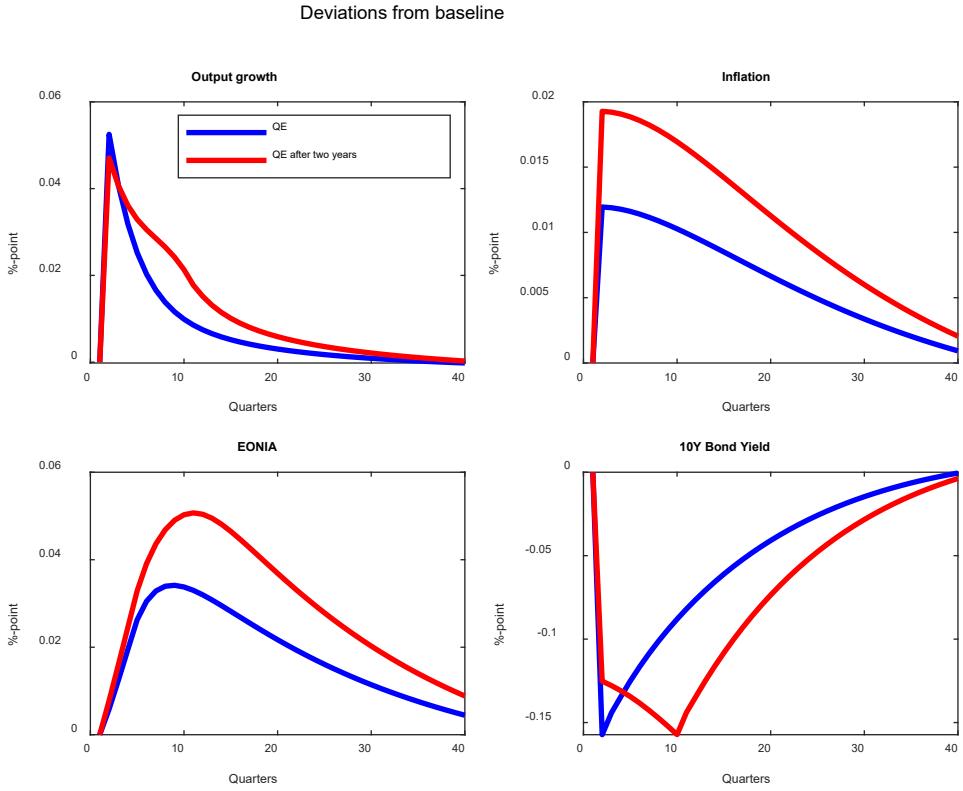
Figure 10 Forward guidance puzzle in conventional monetary policy



In the second exercise we do the same QE shock as above assumed to happen unanticipated in the first period. Furthermore, we repeat the shock as an anticipated shock expected to happen two years from now. We rescale the shock so that the fall in the long rate in quarter 9 is as big as if the shock happens in unanticipated fashion in the first quarter. The results are

shown in Figure 11. The results do not indicate any amplification with respect to the output growth. There is nevertheless slight increase in inflation to which the current policy rate reacts by increasing somewhat. This slight increase in the real interest rate dampens the output growth. Thus we find scant evidence of forward guidance puzzle with respect to the quantitative easing shock.

Figure 11 Unanticipated current and anticipated future QE



Finally we repeat the above exercise to the fiscal spending shock. First we repeat the unanticipated one percent temporary but persistent increase in government consumption. Second we rerun this shock as an unanticipated shock happening two years from now. We do rescale the shock so that the increase in government consumption is one percent in quarter 9. The results are shown in Figure 12 below. We see a slight amplification in the output growth in quarter 9. This is however small and it is not shifted to current output growth. Hence we conclude that the fiscal spending shock is neither plagued by the forward guidance puzzle.

Figure 12 Unanticipated current and anticipated future GC