Nominal GDP Targeting as an Alternative Framework for Monetary Policy

A New Keynesian Approach

by

Gergő Motyovszki

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Supervisor: Prof Alessia Campolmi

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Abstract

Nominal GDP level targeting has recently been proposed as a way of getting out of liquidity trap situations since the history dependent nature of level targeting regimes is argued to influence inflation expectations in the desired way. However, it is not clear whether nGDP level targeting can provide a well-functioning alternative to monetary policy even outside the extreme conditions of the zero lower bound. In this paper I investigate the above question within the context of a standard New Keynesian DSGE model with three different shocks and no ZLB. I find that nGDP level targeting results in more stable real economic activity than strict inflation targeting, although at the expense of increased inflation volatility. However, when compared to a Taylor rule with a more flexible approach, where inflation targets can temporarily be missed, nGDP level targeting performs better both in terms of inflation and output (gap) volatility. It is also in this relation that the history dependent nature of nGDP level targeting can make a difference by improving inflation/output trade-offs. These results indicate that nominal GDP level targeting might be worth considering as an alternative framework for monetary policy.

Journal of Economic Literature (JEL) codes: E52, E58, E31, C61

Keywords: monetary policy, nominal GDP targeting, history dependence, liquidity trap, inflation volatility

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1 Introduction

The global financial crisis of 2008-09 resulted in the most severe economic downturn in the advanced economies since the Great Depression of the 1930s. Even though recession has ended in most of the affected developed countries, almost 5 years on growth is still sluggish and recovery is fragile while unemployment is stuck at painfully high levels. All this is in spite of a massive monetary and fiscal stimulus. Budget deficits have soared and central banks have cut nominal interest rates to rock bottom levels in a desperate attempt to revive demand, avoid deflation and get the economy moving again. By now expansionary economic policy is nearing its limits. Continuing fiscal spending risks making public debt levels unsustainable and conventional monetary policy is constrained by the zero lower bound on short term nominal interest rates. Central bankers tried to experiment also with unconventional tools like quantitative easing. This, too, seems to have had only a modest effect, at best: inflation is still subdued and output gaps are estimated to be deep in negative territory. As Fig 1.1 illustrates, US nominal GDP is still substantially below its pre-crisis trend, and there is no sign of making up for the lost ground. Despite all the aggressive monetary stimulus of interest rate cuts and balance sheet expansion, central banks are helpless in stimulating demand and the question naturally arises why this might be the case.

Several economists have suggested that the economy might be in the dreaded liquidity trap first formulated by Keynes during the Great Depression. A liquidity trap is a situation where monetary policy looses traction and becomes ineffective in influencing the economy, as it is constrained by the zero lower bound. In addition to fiscal expansion, modern theories of the liquidity trap have suggested that the way out of the it can be by raising the inflation expectations of the public (Krugman, 1998). Following a very deep slump, the equilibrium real interest rate needed to get the economy back to full employment might very well be negative, more negative in fact, than what is possible to achieve under moderate inflation expectations. According to the Fisher identity, higher inflation expectations, however, can deliver sufficiently low real interest rates even if nominal rates are constrained by the zero lower bound, and thereby they can be successful in getting the economy out of the liquidity trap.

There are several proposals on how to engineer these higher inflation expectations. By dusting off an old idea, some economists from the non-mainstream "market monetarist" school have brought nominal GDP level back into the policy debate as an alternative nominal
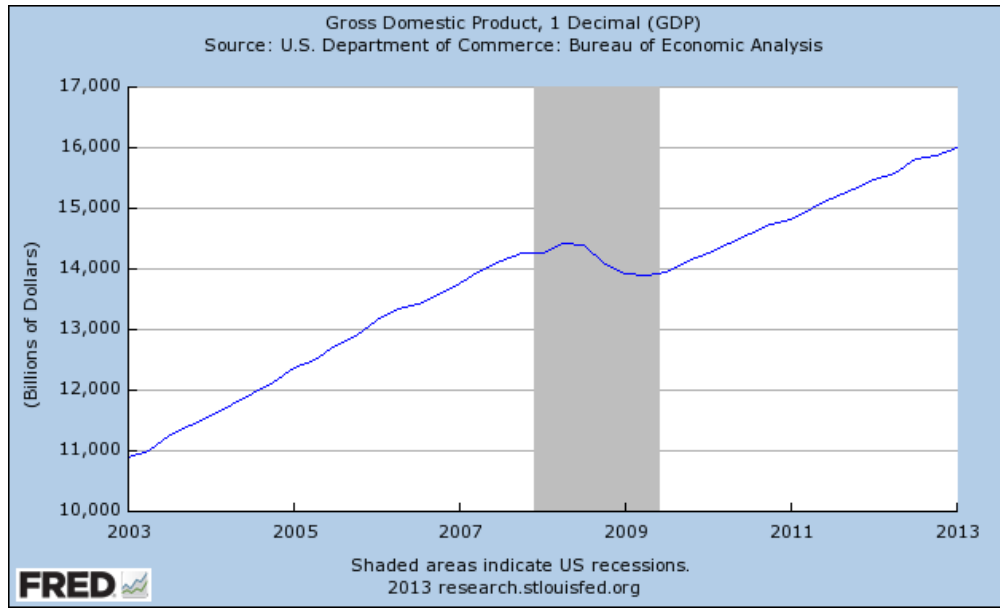
Figure 1.1: US nominal GDP. [source: Federal Reserve Bank of St. Louis (2013)]

anchor for monetary policy (Sumner, 2011; Christiansen, 2011). By targeting a path for the *level* of a nominal variable rather than its *rate of change*, policy becomes history dependent since any past deviations from the target path must be undone in the future. Compared to a purely forward looking policy, where achieving the targeted growth rate suffices, this strategy can influence expectations in a better way. Falling short of the targeted nominal GDP level makes it clear for the public that the central bank will need to create above average inflation and real growth in order to get back to the target path, and the resulting higher inflation expectations could get the economy out of the liquidity trap. This idea is gaining popularity among several mainstream economists, too, who argue that a shift to nGDP targeting could be analogous to Roosevelt's abandoning the Gold Standard in the 1930s which created room for US monetary expansion to fight the Great Depression (Romer, 2011; Krugman, 2011; Carney, 2012; Woodford, 2012).

Though useful it might be under zero-lower-bound (ZLB) conditions, nGDP level targeting is argued to be a desirable framework for monetary policy even outside the liquidity trap, during normal times (Avent, 2011*a*). However, this question is more ambiguous than the previous one. And changing the whole framework in which monetary policy is conducted just for the sake of a relatively rare event might not be worth it, and could damage central banks hard won credibility as guardians of price stability. Therefore it is of crucial importance to know how nGDP level targeting performs compared to other monetary policy rules during normal state of business.

My aim in this paper is to investigate this question in the context of a basic New Keynesian

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DSGE model which has no zero lower bound. I introduce different kinds of supply shocks and a demand shock to examine how the economy reacts under nGDP level targeting and alternative policy rules. By running a shock simulation I compare the performance of the different rules in terms of inflation and output volatility which are the considered the main determinants of social welfare.

The results show that nGDP level targeting causes higher inflation variance and lower output gap variance than a strict version of inflation targeting where inflation is perfectly stabilized. This is the same with respect to price level targeting. However, when compared to a Taylor rule with more flexible approach, where inflation targets can be temporarily missed, nGDP level targeting performs better both in terms of inflation and output gap volatility. It is also in this case, i.e. when temporary target misses are possible, that the history dependent nature of level targeting regimes can play a role. Otherwise, nGDP level targeting and price level targeting are the same as nGDP growth targeting and inflation targeting, respectively.

The remainder of the paper is organized as follows. Section 2 reviews the recent motivation for nGDP targeting more in detail; that is, how a liquidity trap can occur and how level targeting monetary regimes can help getting out of there when policy is constrained by the ZLB. In Section 3 I investigate the question of how nGDP level targeting might behave under normal economic conditions and review the literature on this matter. In Section 4 the model is described, while in Section 5 I show the results and interpret them in the context of the policy debate. Finally a brief summary concludes.

2 The liquidity trap and level targeting regimes

2.1 What is a liquidity trap?

The notion of the liquidity trap was first raised by John Maynard Keynes during the Great Depression of the 1930s and was formulated within the context of the IS-LM framework by Hicks (1937). According to this theory the real interest rate is determined by the requirement that desired savings must equal desired investments. Savings and investments also depend on the particular level of real income the economy is producing. There can be a case, however, when the real interest rate required to make savings and investments equal is negative at full employment. If the real interest rate cannot decline sufficiently (maybe because of zero-lower-bound constraint on nominal rates and low inflation expectations), then real income must adjust in order to restore equilibrium between savings and investment, and the economy will operate below its capacity. It is in this situation when the economy is in the liquidity trap.

In the presence of an asset which always earns at least zero nominal return, i.e. money, nominal interest rates cannot be reduced below zero. When monetary policy is up against the ZLB, money and interest-bearing, less risky assets (bonds) become almost perfect substitutes and any increase in the money supply would only be hoarded and substituted for bonds, leaving the interest rate unchanged. This also means that monetary policy loses traction and becomes ineffective in influencing the real economy: no matter how aggressively it expands the money supply, it cannot stimulate spending.[1] The only way to get out of this liquidity trap is by fiscal expansion directly increasing demand.[2]

The possibility of liquidity traps arises also in more modern macroeconomic models.

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[1]Illustrated within the context of the IS-LM framework this means that the IS curve passes through a horizontal section of the LM curve, so rightward shifts in the LM curve (meaning expansions) fail to affect output.

[2]Fiscal expansion means shifting the IS curve to the right, up to the point where it crosses the LM curve at its non-horiontal section.

Paul Krugman (1998) presents an intertemporal model with micro foundations and short term price rigidities where aggregate demand can fall short of productive capacity despite zero nominal interest rates. That is, the interest rate needed to restore full employment is negative.[3] This might be due to poor growth prospects in the future or a strong deleveraging process which induces households to save more today — so much more, that even at zero interest rate it cannot be absorbed by the economy. The result is the same: short term, temporary monetary expansion at the ZLB, no matter how large, cannot get the economy back to full employment, which is the same situation as in the classic Keynesian liquidity trap.

The difference lies in the fact that in Krugman's model not just fiscal, but also monetary policy can revive the economy. To achieve the required negative real interest rate, the economy *needs* expected inflation under zero nominal interest rates. Prices are fixed only in the short run, so by raising the long run price level the central bank can deliver the needed expected inflation. Within a dynamic framework this can be done by a *permanent* increase in the money supply as opposed to a *temporary* one. Hence, it is not the direct effect of increasing the money supply now which will affect the real economy but rather the indirect effect through inflation expectations of promising higher money supply also in the future. Therefore, by managing the inflation expectations of the public, monetary policy can regain traction even in a liquidity trap.

Krugman argued in 1998 that Japan was in a liquidity trap: plagued by deflation, it faced sluggish growth despite practically zero nominal interest rates. According to the above analysis, the Bank of Japan could have got the economy out of trouble, had it not focused so strongly on price stability. Krugman's conclusion was that at the ZLB quantitative easing has no direct effect, therefore inflation expectations must be increased which can only be achieved by credibly promising to be irresponsible, that is, by loosening focus on the price stability objective and promising that monetary policy will remain loose even after prices begin to rise. An ever increasing number of economists are applying the same prescription for advanced economies in the current crisis, as well. This has given rise to various ideas on how best to increase the inflation expectations of the public.

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[3]This possibility of negative equilibrium real interest rates can arise even when we allow for investment in home or abroad. Although both of these are supposed to have positive real return, once we consider changes in asset prices or in the real exchange rate, real return can be negative (Krugman, 1998).

2.2 Bygones should not be bygones

Since the recent crisis, the Federal Reserve has experimented with different kinds of forward guidance in which it aims to signal market participants for how long it intends to keep short term nominal interest rates close to zero. This strategy, however, is unlikely to be effective in raising inflation expectations unless the targets of monetary policy are also changed. In order to convince people of higher future inflation, the central bank must *credibly* commit to maintain loose policy even *after the recovery begins.* The Federal Reserve tried to make this kind of promise as well (Board of Governors of the Federal Reserve System, 2012); however, without changing also the long run goals of monetary policy, this promise is likely to be time inconsistent and therefore not credible: once the crisis is over and the economy is out of the liquidity trap, with its current mandate the Fed will be tempted to act upon stabilizing inflation and the output gap (Csermely and Tóth, 2013). In order to be credible, monetary policy must tie its own hands within a well specified target framework.[4]

As argued by Woodford (2012), the recent threshold rule of Charles Evans, President of the Chicago Fed, according to which the target for the federal funds rate will remain low as long as inflation is below 3% and unemployment is above 7%, is subject to the same lack of ability to engineer temporarily higher inflation expectations. It is still suboptimal in the sense that it is a purely *forward looking* criterion, as opposed to *history dependent*: this rule does not imply any reason why inflation should not be stabilized once the economy is out of the liquidity trap, and therefore fails to signal the willingness of monetary policy to remain loose even after the recovery begins. A credible commitment to such a rule would not generate the higher inflation expectations needed to mitigate the problems caused by the ZLB.

Woodford (2012) refers to an earlier model by Eggertson and Woodford (2003) which has similar implications to that of Krugman (1998), but is more sophisticated and detailed. In this New Keynesian DSGE model the zero lower bound can bind and liquidity trap situations can occur. Current aggregate demand is determined by the entire expected path of future real interest rates, that is, long term real interest rates matter. However, open market operations in long term asset markets (quantitative easing) are argued to have little direct effects unless

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[4]In a sense, this problem is analogous to the one arising during the Great Inflation of the 1970s. In order to avoid time inconsistency and credibly convince the public about the central banks commitment to price stability, monetary policy had to give up discretion and throw away unemployment stabilization from its goal function. By tying their own hands with rules, central banks could break the inflation expectations of the public (Kydland and Prescott, 1977). Now something similar needs to be achieved but in the opposite direction. Somewhat ironically, within a liquidity trap, some of that credibility for price stability needs to be reversed and changed into credibility for temporarily higher inflation.

expectations about future policy are changed, too. This is because long term markets are difficult to decouple from the rest of the term structure, so monetary policy must signal its commitment to keep also short term interest rates low for an extended period, which is the same result as in Krugman (1998): monetary expansion is only effective in a liquidity trap if it is permanent as opposed to temporary. The main difference in Eggertson and Woodford (2003) lies in the solution by which the central bank signals its willingness to maintain loose monetary policy for longer.

Eggertson and Woodford (2003) derive the optimal path for the policy interest rate following a large shock which pushes the economy into the liquidity trap, and then construct a policy rule which reproduces this optimal outcome. According to their results an optimal policy rule targets the "output gap adjusted price level", which is defined as the sum of the (log of the) general price level and some multiple of the output gap. The essence of this rule lies in the fact that it is *history dependent*, rather than purely forward looking, which enables it to influence expectations in the desired way. History dependence is achieved by specifying the target in terms of the *level* of a nominal variable, as opposed to its *rate of change*, since any past (cumulative) departure from the target path must be undone in the future. In other words, it is not enough to deliver the previous average growth rate following a downward deviation from the target (like in the case of a purely prospective rule), but policy has to compensate for past target misses in a backward-looking manner by *temporarily* generating above average growth in order to get back to the pre-specified target path. This automatically creates anticipation of a more expansionary policy and therefore higher inflation expectations, which exactly complies with the above mentioned steps needed to get out of a liquidity trap: a commitment to maintain loose policy even after recovery has begun.

This property of level targeting monetary policy regimes is not unique to the optimal Eggertson and Woodford type output gap adjusted price level. Other nominal quantities can also be chosen as the nominal anchor of monetary policy, provided that the target is specified in level terms, which guarantees history dependence. The important criterion is that bygones are not bygones, that is previous cumulative departures from the trend have to be made up for in the future.

One alternative proposal, researched quite intensively by the Bank of Canada in the 2000s, is price level targeting (PLT), which specifies a target path for a chosen measure of price level (e.g. CPI) consistent with the desired steady state inflation rate (Ambler, 2007; Cote, 2007).

Another is the long ignored nominal GDP, which has recently been put forward by Scott Sumner (2011) and is gaining increasing popularity in the policy debate as several economists are joining the advocates camp (Carney, 2011; Romer, 2011; Krugman, 2011 and Woodford, 2012). Nominal GDP is basically the money value of what a country produces, that is, output

unadjusted for inflation. It can be calculated as the product of real output and GDP deflator, the latter being a measure of inflation. By estimating the steady state growth rate of real GDP (e.g. 2.5%) and deciding on the desired rate of steady state inflation (e.g. 2%) one can construct a target path for nominal GDP which grows in accordance with the above values (here by 4.5%).

nGDP targeting is almost the same as targeting the output gap adjusted price level, the difference being that nGDP targeting involves the *steady state* level of real output in the target path, while the other operates with *potential* output which is the level of output in the absence of nominal rigidities. Although nGDP targeting is not the optimal policy rule in the Eggertson-Woodford model, it is a much simpler concept and easier to understand by the public, which is a key feature in reality when the very essence of a policy strategy depends on its ability to influence the expectations of the public. And the fact that bygones are not bygones under nGDP targeting guarantees most of the desired properties even if in theory one could construct a better rule.

So far we have seen, why switching to level targeting regimes in general, and nGDP targeting in particular might be a useful strategy for monetary policy under liquidity trap conditions. However, a switch should not be temporary since monetary policy needs a stable framework in order to be able to anchor expectations. That is why any new regime must perform equally well also during normal times and not just at the zero lower bound. Therefore the costs and benefits of nGDP targeting must be carefully weighed against current monetary policy strategies, like inflation targeting by examining their performance outside the liquidity trap, over a normal business cycle. That is what I turn to in the rest of the paper.

3 nGDP targeting outside the liquidity trap

3.1 How would nGDP targeting work?

Nominal GDP is likely to provide a good nominal anchor in the long run. Under nGDP level targeting long run price stability is guaranteed, since the target path is specified in such a way that under steady state growth it is consistent with low inflation. Even if temporarily higher nGDP growth is required after a downward deviation from the target path (which will be divided between higher output growth and higher inflation), once the target path is reached and shocks die out, inflation should come down in order to comply with the target. In any case, monetary policy cannot influence real output on the long run, so compliance with the nominal GDP target must come through the adjustment of price level. If the target path is specified correctly, an nGDP targeting monetary policy results in the desired, low inflation over the long run. Compared to inflation targeting (IT), nGDP level targeting does not mean systematically looser monetary policy, either: upward deviations from the target path must also be compensated for, by generating temporarily below average nGDP growth (and inflation).

Another reason why nGDP targeting might be considered a looser policy framework is the fact that it implicitly involves a reaction to real output. When the divine coincidence a la Blanchard and Galí (2007) does not hold, i.e. there is a trade-off between inflation and output gap stabilization, a central bank with such an objective will place more weight on real output at the expense of less stable inflation. However, in this case it is not necessarily a problem. As long as monetary policy is not trying to systematically push the economy above its potential, inflation will not spiral out of control and output gap stabilization can be a desirable thing even if it means temporarily missed inflation targets. This is also reflected in the so called "flexible" approach to inflation targeting, whereby the central bank does not focus strictly on inflation, and may chooose to ignore the temporary inflationary effects of a shock so that it does not depress the economy further.

So nGDP targeting also ensures long run price stability, but reactions to various shocks are certainly different under this and alternative policy regimes, which makes the short run outcomes different. That is what I will explain more in detail when examining the impulse

response functions in Section 5.2. As noted before, due to the history dependent nature of level targeting regimes, nGDP targeting will involve temporarily above average nGDP growth (also above average inflation) after a downward deviation from the target path, while IT will stop easing once the targeted inflation rate is achieved and nominal GDP is back on a trend parallel to, but under the previous one (see Fig3.1).
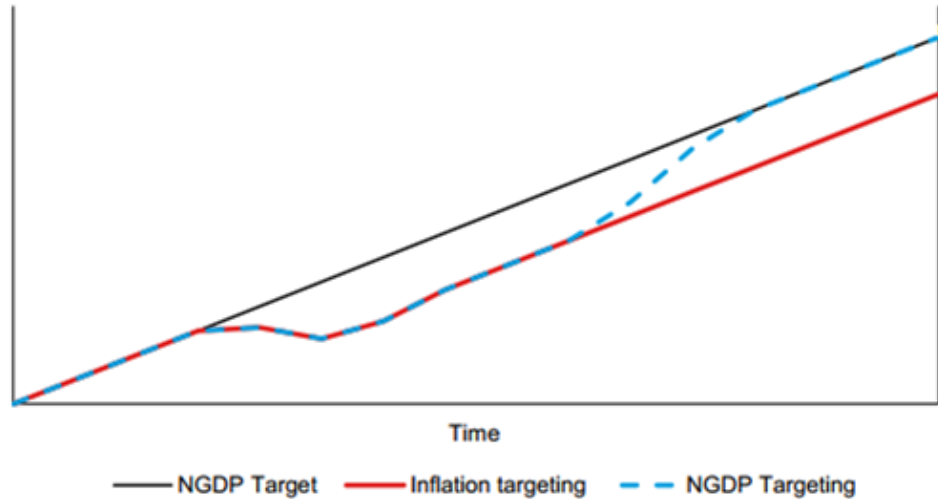

Figure 3.1: Carney's (2012) Bygones are not bygones under nGDP targeting

Based on this it might seem that, nGDP targeting may result in more volatile inflation in the short term. However, it is of crucial importance to distinguish two different sources of this increased volatility. One comes from the fact that real output is explicitly included in the target variable and stabilizing it happens at the expense of inflation stabilization when certain supply shocks introduce trade-off between the two. The other is a result of the level targeting nature of nGDP targeting which means that past departures from the target path have to be compensated with temporarily above/below average growth. The latter is also a feature of price level targeting (PLT) which completely disregards real output. In the context of PLT the argument takes the form that long run price *level* stability is traded off for higher short run inflation volatility.

However, the researchers of the Bank of Canada argue that the above result is not necessarily true in the presence of forward looking expectations. They reason that level targeting regimes exhibit the kind of history dependence which enables them to influence expectations in a better way, such that trade-offs between inflation and output gap can improve. For example, following an inflationary shock, the public would know that the central bank will undo any past upward deviation from the target path by generating below average inflation for some time in the future. This will lower their inflation expectations today, which also

lowers current inflation, in essence causing a downward shift in the forward-looking Phillips curve (Cote, 2007). Lower inflation expectations also exert their effect through the demand channel by raising ex ante real interest rates and pulling back demand, and in turn, current inflation (Ambler, 2007). The result of this is that the inflationary effect of the shock will be smaller under the level targeting regime and the central bank will not have to engineer that much contraction in aggregate demand to offset the upward deviation of the price level from the target path. In other words, the improved trade-off between inflation and the output gap makes it possible that inflation volatility does not increase even under a level targeting measure. This feature should also apply to nominal GDP targeting.

Based on the above, therefore, it is ambigous whether nGDP level targeting should be preferred to alternative regimes in terms of inflation and output volatility. Some aspects of it point to the direction of higher inflation variance while others towards smaller volatility, so deciding on this question requires a more formal, quantitative analysis.

Before reviewing the literature on what it finds about the above matter, it should be noted that several practical concerns were declared related to nGDP targeting. That is, even if theoretically it was superior to other monetary strategies, implementing it in real life might prove to be difficult. Csermely and Toth (2013) summarize some of the key points, the most important of which is the measurement uncertainty in potential growth. When specifying the target path for nominal GDP, it is crucial to have an idea about steady state potential growth, since the difference between the target path consistent nGDP growth and trend real growth will determine steady state inflation in the future. Potential output and potential growth, however, cannot be observed directly and can only be estimated with substantial uncertainty, therefore it is hard to judge what the long run growth rate in real output is.[1] The task is all the more complex as structural changes in the supply side of the economy may alter the long run growth potential, so various averaging and trend calculating methods may be misleading. A central bank, which overestimates potential growth and specifies its nGDP target path accordingly, will face higher inflation than originally intended. With slower long run growth, which monetary policy cannot influence, the economy can only remain on the

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[1]Long run steady state output is determined by the supply side of the economy which central banks cannot influence. Potential output also represents the supply side of the economy, but it incorporates the effect of temporary shocks in the short run. Once all shocks die out, potential output is equal to the long run steady state. Actual, observed output is determined by the demand side of the economy, and due to nominal rigidities it can deviate from potential. Central banks can temporarily affect demand, but they have no influence over the steady state potential where real output will eventually converge (Motyovszki and Gabriel, 2013).

target path for nGDP if the central bank generates higher inflation.[2]

Other criticisms include the fact the nominal GDP is also more difficult to measure than inflation as it is subject to major revisions and is usually only available with quarterly frequency and with substantial delay. Revisions in GDP numbers can therefore alter the past path for nGDP again and again, which also change the desired policy *retrospectively.* It is also argued that in some cases nGDP targeting is more rigid than flexible IT, since it does not make it possible to ignore temporary cost shocks, but has to compensate them in order to get back to the target path, which may result in unnecessarily tight policy or even the need for deflation (Csermely and Toth, 2013). Although this may apply more to price level targeting, an nGDP targeting regime is unlikely to react that aggressively, since there is no such thing as a pure price shock which leaves real output unchanged. We will see that, in response to an adverse cost push shock, nominal GDP remains fairly stable (real output falls), therefore an nGDP targeting central bank can remain as idle as under flexible IT.

3.2   Models about nGDP targeting

In order to be able to decide whether nominal GDP targeting can deliver superior outcomes in terms of inflation and output (gap) volatility compared to other monetary policy strategies, one cannot rely only on the rather intuitive above analysis, but a formal model has to be built. This is my aim in this paper, but before specifying the particular model, I review what has been done in the literature and place my own model in this context.

Hall and Mankiw (1994) summarize the early literature on nominal income targeting which dates back as early as the late 1980s. The idea was raised as an alternative nominal anchor to the by-then discredited money supply targets. Bean (1983) uses a general equilibrium macro model with aggregate demand shocks and inelastic labor supply to show that nominal income targeting minimizes the variance of real output. The optimal policy differs only in the respect that it targets the combination of real output and the price level with different weights on the two variables. Taylor (1985), in the context of a small dynamic model, shows that targeting the growth of nominal income is quite unfavorable because it allows for level shifts and overshooting in real activity. In his model a rule, which targets nominal income growth equal to a constant plus the deviation real output from equilibrium, performs better in terms of output and inflation volatility. By this, Taylor was among the

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[2]The implicit target for the price level and the actual price level will diverge to an ever increasing extent as real output falls short of the originally estimated path by more and more. The upward deviation in the inflation rate, however, will remain constant.

first to call attention to the importance of stabilizing the level of real output instead of its rate of change.

Hall and Mankiw (1994) use a small model without micro foundations, where aggregate supply is characterized by a backward-looking Phillips curve and aggregate demand is summarized by the evolution of nominal income, which is assumed to be determined by monetary policy up to random error term. They compare nominal income *growth* targeting, nominal income *level* targeting and the Taylor-type hybrid rule and find that the volatility of inflation and output gap is better under the level targeting rule than in the growth targeting case, whereas the hybrid policy seems to generate the best results. Performance in inflation volatility is better than the historical average in the cases of level and hybrid targeting.

Frankel and Chinn (1995) set up a loss function and a very simple static model of the economy without micro foundations to analyze alternative nominal anchors under commitment of monetary policy and they find that for a wide range of reasonable parameter values a nominal GNP rule dominates the others in terms of social loss.

Another branch of the literature is focused on describing the benefits coming from the level targeting nature of policy rules. This research concentrated mainly on price level targeting (PLT), rather than nGDP level targeting, but the essence of the arguments apply also to the latter. The seminal paper of Svensson (1999b) argued that there is a free lunch of lower inflation volatility and same output volatility from switching to PLT instead of IT, which was echoed by a research program launched by the Bank of Canada in the 2000s (Cote, 2007 and Ambler, 2007). As argued above, this comes mainly from an improved trade-off between inflation and output caused by history dependence. It is demonstrated by this literature that under discretionary policy, reaction to supply shocks are closer to optimal if the central bank is given an objective function which reacts to price level rather than inflation volatility. In other words, PLT under discretion might be a substitute for commitment. Barnett and Engineer (2001) show that under policy commitment PLT is better only if expectations are forward-looking. Galí (2002) also illustrates the result that in the presence of cost push shocks, which introduce an inflation/output-gap trade-off, the optimal policy with commitment implies a stationary process for the price level.

Svensson (1997) and Ball (1999), however, debated whether these benefits of PLT also apply to nGDP level targeting. In particular, they argued that targeting the level or the growth of nominal income will result in an instable system. On the other hand, McCallum (1997) and Dennis (2001) showed that the Ball-Svensson instability result is only a consequence of specifying the Phillips curve in a backward-looking manner. By introducing forward-looking expectations to the economys supply side, both nGDP level and growth targeting generates a stable equilibrium. Mitra (2003) also illustrates in the context of a basic New Keynesian

model that the equilibrium under nominal GDP growth targeting is stable not only under rational expectations but also under recursive learning.

In the above spirit Jensen (2002) uses a New Keynesian model with forward-looking expectations to compare nominal income growth targeting and inflation targeting in the absence of central bank commitment. He finds that it is better to assign nominal income growth targets to central banks in response to cost-push shocks that include monetary policy trade-offs, since the inertial behavior induced by such a policy may improve this trade-off. In the face of shocks that do not involve such trade-off, inflation targeting is preferable. Kim and Henderson (2005) work with a full-fledged New Keynesian DSGE model with detailed micro foundations, monopolistically competitive goods and labor markets and one period nominal contracts. They also find nominal income growth targeting to dominate inflation targeting for plausible values of the parameters, but they underline the relatively high importance of productivity shocks in coming to this result.

Other papers use an approach, where instead of minimizing a loss function central banks follow an interest rate rule, a kind of reaction function, which can approximate the optimal solution quite well. E.g. McCallum and Nelson (1999) examine both growth and level targeting regimes within a small open economy New Keynesian model with explicit micro foundations (monopolistic competition, one period fixed prices, time varying markup), however without cost-push shocks. They include the target variables in the interest rate rule which also reacts to the output gap and past interest rates. The conclusion is mixed, with PLT usually generating the lowest inflation volatility, but for certain reaction coefficients nGDP level targeting also ensures lower inflation volatility than IT. For other coefficient values IT is better than nGDP level targeting in terms of inflation variance but worse in output gap volatility.

To sum up, the literature seems to point in the direction that nominal GDP level targeting might be a viable framework for monetary policy in certain circumstances. These include the presence of cost-push shocks which introduce a genuine trade-off between inflation and the output gap, and the presence of forward-looking inflation expectations which help improve this trade-off. However, most of the papers that calculate welfare losses or variances, do not include all of these features at once. They involve either nominal income *growth* targeting or *price* level targeting. nGDP level targeting is examined either in the context of very simple models or ones that lack some elements (like cost push shocks) which seem to be key to its effects. Also, in most cases the central bank is not able to commit to future policy but operates under discretion. In fact, history dependent policies are used to be a substitute for commitment, whereas it is also important to know whether they maintain their advantage also under commitment.

That is why in this paper I aim for a slightly different setup. The model I use is one from the New Keynesian DSGE family with strong micro foundations, forward-looking expectations and cost-push shocks. The model economy is closed and is not subject to the zero lower bound on nominal interest rates. I use an interest policy rule approach rather than a loss function minimization, which strategy also ensures the ability of monetary policy to commitment. The deviation of nGDP level from its target is included in the policy rule. This model is most similar to that of Eggertson and Woodford (2003), where the preferred policy reacts to deviations of the output gap adjusted price level. This measure, however, differs from nominal GDP in that it includes the ever-fluctuating potential output rather than a deterministic path for steady state output. Therefore, it is a harder concept for the public to understand, even though it is preferable in terms of welfare. It also allows for different weights on the output gap and the price level deviation, unlike nGDP level targeting which treats the two sources of deviation (real output and price level from their implied steady state targets) exactly the same way. Another difference is that Eggertson and Woodford (2003) examine the effects of a shock to the natural rate of interest at the ZLB which may die out with certain probability at any period, whereas I include several different shocks (TFP, cost-push, demand) which follow AR1 processes.

Now I turn to the description of the model.

4 The model

The model I use in this paper is a basic New Keynesian DSGE model based on Clarida, Galí and Gertler (1999) and Galí (2002). The models in this family integrate Keynesian elements like imperfect competition and nominal rigidities into a dynamic general equilibrium framework with solid microeconomic foundations. Here nominal rigidities are modeled by the Calvo-type staggered price setting (Calvo, 1983) in the goods market, while an exogenous time variation in the wage markup creates a shorthand for wage stickiness. The model economy is a closed one and abstracts from investment and capital accumulation. Monopolistically competitive firms produce differentiated products by using labor supplied by the households. Households supply differentiated labor also in a monopolistically competitive way.

In the first stage I abstract from nominal rigidities to calculate the flexible price equilibrium, then I introduce Calvo pricing for firms and exogenous variation in wage markups to derive the equations characterizing the sticky price equilibrium.

4.1 Flexible price solution

4.1.1 Households

Each household h maximizes lifetime expected utility by choosing overall consumption, saving and the wage rate at which it supplies labor, subject to a standard budget constraint and labor demand from firms (Eq. A.2), which is derived as a solution to the firm's expenditure minimization problem (see Appendix A). The instrument for saving is a one period discount bond B_t with price Q_t. In addition to earning wages from labor and spending it on consumption, the households also receive any profits from the firms, wage subsidy, τ_w from the government and pay lump-sum taxes T_t.[1]

$$\max_{W_t(h),B_t,C_t} \sum_{t=0}^{\infty} \beta^t \left[\frac{C_t^{1-\sigma}}{1-\sigma} - \frac{N_t(h)^{1+\varphi}}{1+\varphi} \right]$$

---

[1]Assuming symmetry across households, the subscript h is left out. Labor and wage are exceptions since here h will be needed for further derivations.

$$s.t. \ P_tC_t + Q_tB_t \ \leq \ B_{t-1} + (1 + \tau_w) \, W_t(h)N_t(h) + profits_t - T_t$$

$$N_t(h) = \left[\frac{W_t(h)}{W_t} \right]^{-\theta_{w,t}} N_t$$

Taking first order conditions, combining them and assuming symmetry across households yields the equations describing the behavior of households; the standard Euler-equation (intertemporal consumption-saving decision) and the labor supply relation (intratemporal consumption-labor decision):

$$Q_t = \beta E_t \left(\frac{C_{t+1}}{C_t} \right)^{-\sigma} \frac{P_t}{P_{t+1}} \tag{4.1}$$

$$N_t^\varphi C_t^\sigma \frac{\theta_{w,t}}{\theta_{w,t} - 1} \frac{1}{1 + \tau_w} = \frac{W_t}{P_t} \tag{4.2}$$

From the last equation it is clear that there is a wedge between the real wage $\frac{W_t}{P_t}$ and the marginal rate of substitution between consumption and labor $N_t^\varphi C_t^\sigma$ which is introduced by a time varying wage markup, $\mu_{w,t} \equiv \frac{\theta_{w,t}}{\theta_{w,t}-1} > 1$ as $\theta_{w,t} > 1$. In other words, the labor market is not efficient due to monopolistic competition which gives workers market power. However, this distortion can be eliminated in steady state (where $\bar{\theta_w}$ is constant) by the appropriate setting of the wage subsidy, $\tau_w = \frac{1}{\theta_w - 1}$.

4.1.2 Firms

Each firm i maximizes profits in each period by choosing the price for its differentiated product and labor demand subject to the production technology and to demand for its good i (derived from Eq.A.1). [2] Labor costs are subsidized by the government at rate of τ. A_t denotes total factor productivity.

$$\max_{P_t(i),N_t(i)} P_t(i)Y_t(i) - (1 - \tau) \, W_t N_t(i)$$

$$s.t. \ Y_t(i) = A_t N_t(i)^{1-\alpha} \tag{4.3}$$

---

[2]The demand function can be derived from the market clearing condition of $Y_t(i) = C_t(i) + G_t(i)$, where $C_t(i)$ is defined by Eq.A.1 and $G_t(i)$ denotes government purchases from good i. Along the lines in Gali (2002) the government is assumed to consume a fraction f_t of the output of each good, hence it will have the same consumption pattern as households, therefore having the same demand function for $G_t(i)$ as in Eq.A.1.

Overall output is defined as $Y_t = C_t + G_t$ which is also a CES aggregator $Y_t = \left[\int_0^1 Y_t(i)^{\frac{\theta-1}{\theta}} \, di \right]^{\frac{\theta}{\theta-1}}$

$$Y_t(i) = \left[\frac{P_t(i)}{P_t}\right]^{-\theta} Y_t$$

Solving the problem (and using the symmetry assumption) yields the FOC for the firm:

$$P_t(i) = (1 - \tau)\frac{\theta}{\theta - 1}MC_t(i) \tag{4.4}$$

where the marginal cost is:

$$MC_t(i) = \frac{\partial W_t N_t(i)}{\partial Y_t(i)} = \frac{1}{1 - \alpha}W_t\left(\frac{1}{A_t}\right)^{\frac{1}{1-\alpha}} Y_t(i)^{\frac{\alpha}{1-\alpha}} \tag{4.5}$$

Due to monopolistic competition in the goods market firms are able to charge a price markup $\mu \equiv \frac{\theta}{\theta-1} > 1$ over their marginal cost, which also distorts the labor market, driving a wedge between the real wage and the marginal product of labor $(1 - \alpha)A_t N_t^{-\alpha}$. This can be seen from the labor demand equation, which we get by combining Eq.4.3, Eq.4.4 and Eq.4.5, and assuming symmetry across firms:

$$\frac{W_t}{P_t} = \frac{1}{1 - \tau}\frac{\theta - 1}{\theta}(1 - \alpha)A_t N_t^{-\alpha} \tag{4.6}$$

The static distortion arising from this inefficiency can be eliminated by setting the wage-cost subsidy $\tau = \frac{1}{\theta}$.

4.1.3 Flexible price equilibrium

Market clearing in the bonds market imply $Q_t B_t = B_{t-1}$. Assuming the government must run a balanced budget, the government budget constraint is then $P_t G_t + (\tau_w + \tau)W_t N_t = T_t$. At the firms level the following relation must hold: $P_t Y_t - (1 - \tau)W_t N_t = profit_t$. Combining all these with the households budget constraint we get the goods market clearing condition $Y_t = C_t + G_t$.

To make further derivations easier recall that the government consumes a fraction f_t of current output, that is $G_t = f_t Y_t$. Substituting this in, rearranging and defining $\frac{1}{1-f_t} \equiv \Gamma_t$ yields:

$$Y_t = C_t \Gamma_t \tag{4.7}$$

In order to close the model, exogenous AR1 processes for TFP, the wage markup and government expenditures are specified below:

$$\log A_t \equiv a_t = \rho_a \log A_{t-1} + \varepsilon_t^a \tag{4.8}$$

$$u_t = \rho_u u_{t-1} + \varepsilon_t^u \tag{4.9}$$

$$\log \Gamma_t \equiv g_t = \rho_g g_{t-1} + \varepsilon_t^g \tag{4.10}$$

where $u_t \equiv \frac{\lambda(1-\alpha)}{1-\alpha+\alpha\theta} [\log \mu_{w,t} - \log \bar{\mu}_w]$ is interpreted as a cost-push shock, which comes from the deviation of wage markup from its steady state. All ε_t are white noise processes.

The flexible price equilibrium is characterized by Eqs. 4.1, 4.2, 4.3, 4.6, 4.7, 4.8, 4.9 and 4.10, which describe the evolution of 8 variables: C_t, N_t, Y_t, $\frac{W_t}{P_t}$, $Q_t \frac{P_{t+1}}{P_t}$, A_t, u_t, g_t. It can be seen that in the flexible price equilibrium nominal variables are not pinned down and monetary policy is neutral. Log linearizing these equations (and omitting the exogenous processes) we get the following system:

$$c_t = E_t c_{t+1} - \frac{1}{\sigma} [i_t - E_t \pi_{t+1} - \rho] \tag{4.11}$$

$$\sigma c_t + \varphi n_t + \log \left(\frac{\bar{\mu}_w}{1 + \tau_w} \right) = w_t - p_t \tag{4.12}$$

$$a_t - \alpha\, n_t + \log (1 - \alpha) - \log [\mu (1 - \tau)] = w_t - p_t \tag{4.13}$$

$$y_t = a_t + (1 - \alpha) n_t \tag{4.14}$$

$$y_t = c_t + g_t \tag{4.15}$$

where lower case letters denote the log of the original variable and where the following relations were also used: $-\log Q_t = log(1+i_t) \approx i_t$ is the net nominal interest rate; $-log(\beta) = log(1 + \rho) \approx \rho$ is the net personal discount rate; and $log(\frac{P_{t+1}}{P_t}) = log(1 + \pi_{t+1}) \approx \pi_{t+1}$ is the net inflation rate.

Solving this system expressions can be derived for the flexible price equilibrium value of certain endogenous variables, which in the New Keynesian literature are called the natural rate of output (or potential output) and the natural rate of real interest. When computing the latter, the Fisher relation $r_t \approx i_t - E_t \pi_{t+1}$ is used.

$$
\begin{aligned}
\bar{y}_t &= \left[\log (1 - \alpha) - \log [\mu (1 - \tau)] - \log \left(\frac{\bar{\mu}_w}{1 + \tau_w} \right) \right] \frac{1 - \alpha}{\sigma (1 - \alpha) + \varphi + \alpha} \\
&+ \frac{1 + \varphi}{\sigma (1 - \alpha) + \varphi + \alpha} a_t + \frac{(1 - \alpha) \sigma}{\sigma (1 - \alpha) + \varphi + \alpha} g_t
\end{aligned} \tag{4.16}
$$

$$\bar{r}_t = \rho - \frac{\sigma(1+\varphi)}{\sigma (1 - \alpha) + \varphi + \alpha}(1 - \rho_a)a_t + \frac{\sigma(\varphi + \alpha)}{\sigma (1 - \alpha) + \varphi + \alpha}(1 - \rho_g)g_t \tag{4.17}$$

An expression for the log real marginal cost $mc_t \equiv \log \left(\frac{MC_t}{P_t} \right)$ can be derived by using the

logarithmized version of Eq.4.5, Eq.4.12 and Eq.4.14.

$$mc_t = \frac{\sigma(1-\alpha) + \varphi + \alpha}{1-\alpha} y_t - \frac{1+\varphi}{1-\alpha} a_t - \sigma g_t - \log(1-\alpha) + \log\left(\frac{\mu_{w,t}}{1+\tau_w}\right) \tag{4.18}$$

Note that by Eq.4.4 the real marginal cost under flexible prices is constant and is equal to the inverse effective price markup: $\overline{mc_t} = -\log\left[\mu\left(1-\tau\right)\right] = \overline{mc}$. As the time varying wage markup $\mu_{w,t}$ is introduced only as a shortcut for explicitly sticky wages, it makes sense to work with the steady state constant wage markup $\overline{\mu_w}$ in the flexible price equilibrium.

4.2 Sticky price solution

4.2.1 The New Keynesian Phillips Curve

In this model, dynamic distortions are created by nominal rigidities in the goods market which is modeled by firms being subject to the Calvo type staggered price setting (Calvo 1983), which means that each firm can reset its price with a given probability, $1 - \xi$ each period. The inability of certain firms to set their prices optimally in every period will result in price dispersion and hence in inefficient allocation. This also introduces monetary non-neutrality, whereby the relation between nominal and real variables is restored. This relation is captured by the New Keynesian Phillips Curve (Clarida, Galí and Gertler, 1999).

Now the firms which have the chance to reset prices at the current period face the following problem:

$$\max_{P_t^*} E_t \sum_{T=0}^{\infty} \xi^T Q_{t,t+T} \left[P_t^*(i)Y_{t+T}(i) - (1-\tau)TC_{t+T}(i)\right]$$

$$s.t. \ Y_{t+T}(i) = \left[\frac{P_t^*}{P_{t+T}}\right]^{-\theta} Y_{t+T}$$

$$TC_{t+T}(i) = W_{t+T}\left(\frac{Y_{t+T}(i)}{A_{t+T}}\right)^{\frac{1}{1-\alpha}}$$

$$Q_{t,t+T} = \beta^T \left(\frac{Y_{t+T}}{Y_t}\right)^{-\sigma} \frac{P_t}{P_{t+T}}$$

where $Q_{t,t+T}$ is the stochastic discount factor, which takes into account that with some probability P_t^* cannot be changed in future periods. The FOC of this problem is:

$$E_t \sum_{T=0}^{\infty} \xi^T Q_{t,t+T} Y_{t+T}(i) \left[P_t^* - (1-\tau) \mu \, MC_{t+T}(i)\right] = 0$$

Following the steps shown by Clarida, Galí and Gertler (1999) a first order approximation

of this FOC can be derived to yield:

$$\pi_t = \frac{(1-\xi)(1-\xi\beta)}{\xi}\frac{(1-\alpha)}{1-\alpha+\alpha\theta}\widehat{mc}_t + \beta E_t \pi_{t+1}$$

where $\widehat{mc}_t = mc_t - \overline{mc}$ is the deviation of the log real marginal cost from its steady state. An expression for this can be derived by using Eq4.18 with the sticky price, flexible price and steady state levels of the variables, and using the fact that mc is the same in the latter two cases:

$$\widehat{mc}_t = (mc_t - \overline{mc}) - (\overline{mc_t} - \overline{mc}) = \frac{\sigma(1-\alpha)+\varphi+\alpha}{1-\alpha}(y_t - \bar{y}_t) + \log\left(\frac{\mu_{w,t}}{\bar{\mu}_w}\right)$$

where $y_t - \bar{y}_t \equiv x_t$ is defined as the output gap, that is the deviation of real output from its flexible price level. Plugging this into the FOC and using the definition for cost-push shock we arrive at:

$$\pi_t = \beta\, E_t \pi_{t+1} + \kappa x_t + u_t \tag{4.19}$$

where $\kappa = \lambda\frac{\sigma(1-\alpha)+\varphi+\alpha}{1-\alpha+\alpha\theta}$ and $\lambda = \frac{(1-\xi)(1-\xi\beta)}{\xi}$. This is a standard New Keynesian Phillips Curve (NKPC), with forward-looking expectations and cost push shocks introducing a genuine trade-off between inflation and output gap stabilization. Hence, the divine coincidence does not hold. This relation describes the behavior of the supply side of the economy.

4.2.2 Sticky price equilibrium

The demand side of the economy is not subject to nominal rigidities, so it can be described by using the flexible price equations with interpreting the variables as their sticky price self. Combining Eqs. 4.11, 4.15, 4.17 and manipulating it, yields the dynamic IS equation (DIS), which describes how the deviation of the ex ante real interest rate from its flexible price level affects the output gap:

$$x_t = E_t x_{t+1} - \frac{1}{\sigma}\left[i_t - E_t \pi_{t+1} - \overline{r_t}\right] \tag{4.20}$$

In other words, this equation captures how the presence of nominal rigidities may cause aggregate demand to deviate from potential output, thereby opening up an output gap.

The NKPC and the DIS, together with the natural rate of interest (Eq4.17) and with the exogenous processes for TFP, the cost-push shock and government expenditures (Eqs4.8, 4.9, 4.10), almost completely describe the system. Observe that cost push shocks affect the economy through the NKPC, while TFP and demand shocks enter into the DIS through their effect on the natural rate of interest.

In order to close the model, a path for the nominal interest rate has to be specified, which

essentially means that monetary policy is no longer neutral. Observe that by controlling nominal interest rates, monetary policy can affect inflation only indirectly, through the aggregate demand channel (DIS). However, if the central bank is able to commit itself to future policy, it can also influence inflation expectations, thereby having a direct effect on current inflation through the forward-looking NKPC.

It can be seen from the above model that shocks to the natural real interest rate (TFP, demand) push the output gap and inflation in the same direction, i.e. there is no trade-off between inflation and the output gap. In this case zero inflation and zero output gap constitutes an equilibrium, and from the DIS it is also visible that this can be achieved with setting nominal interest rates to the natural real interest rate (Galí, 2002). Even if such a policy could not be implemented, a policy that sufficiently stabilizes the inflation rate, will also stabilize the output gap, i.e. the divine coincidence holds (Blanchard and Galí, 2007).

In contrast, cost-push shocks introduce a trade-off between inflation and the output gap, which makes it impossible to simultaneously stabilize both. As stressed by Clarida, Galí and Gertler (1999), it is in this respect that the central bank's ability to credibly commit to a systematic pattern of responses to shocks, and thereby its ability to influence future inflation expectations, is desirable, since by this the inevitable trade-off within the Phillips curve can be improved.

4.2.3 Alternative policy rules

Up until here, the model is quite standard, but it is within this framework that I want to analyze the newly proposed monetary policy strategy of nominal GDP targeting and to compare it to more conventional policy rules considered in the literature. The rule-based nature of policy also ensures the ability of commitment. The alternative interest rate rules to close the model are the following:

- Taylor rule (inflation targeting - IT)

$$i_t = \rho + \phi_x x_t + \phi_\pi \pi_t \tag{4.21}$$

- Taylor rule with steady state output

$$i_t = \rho + \phi_x (y_t - \bar{y}) + \phi_\pi \pi_t \tag{4.22}$$

- nGDP level targeting

$$i_t = \rho + \phi_z (z_t - \tilde{z}) =$$

$$= \rho + \phi_z(p_t + y_t - \bar{p} - \bar{y}) =$$
$$= \rho + \phi_z \pi_t + \phi_z p_{t-1} + \phi_z(y_t - \bar{y}) \tag{4.23}$$

- output gap adjusted price level targeting

$$i_t = \rho + \phi_z \pi_t + \phi_z p_{t-1} + \phi_z(y_t - \overline{y_t}) \tag{4.24}$$

- nGDP growth targeting

$$i_t = \rho + \phi_z(z_t - z_{t-1}) =$$
$$= \rho + \phi_z \pi_t + \phi_z(y_t - y_{t-1}) \tag{4.25}$$

- price level targeting (PLT)

$$i_t = \rho + \phi_p(p_t - \widetilde{p}) =$$
$$= \rho + \phi_p \pi_t + \phi_p p_{t-1} \tag{4.26}$$

where $p_t = \pi_t + p_{t-1}$ is the log of the current price level, $z_t = y_t + p_t$ is log nominal GDP, and $\tilde{z} = \bar{y} + \bar{p}$ is the target level for nGDP. As the model equations are derived under a zero inflation steady state, the steady state price level is constant and is chosen arbitrarily so that $\bar{p} = 0$. Without trend growth in real output, $\bar{y}$ is also constant in steady state; therefore the target path for nominal GDP level is constant, too, rather than growing at a constant rate, as discussed in earlier sections. However, along the lines of Woodford (2012), the results from such a rule can be generalized to a growing nGDP target path as well. The dynamics of the model do not fundamentally change by removing a deterministic trend from the price level or real output.

Eq4.21 describes a Taylor rule where the central bank reacts to deviations of inflation and the output gap from their target levels. Eq4.22 works with the deviation of real output from its steady state rather than from its potential, should the latter be difficult to observe. Strict inflation targeting can be described by both of these rules when ϕ_x is zero and ϕ_π is set very high, thereby ensuring high reaction of the nominal interest rate in response to deviations of inflation from its target, even at the expense of widening output gap. Flexible inflation targeting places higher weight on output stabilization and operates with a relatively smaller ϕ_π.

Eq4.26 describes price level targeting, where interest policy reacts to the deviation of price level from its steady state. History dependence in this rule can be seen from the fact

that the previous period price level, a state variable enters the equation.

Eq4.23 is the policy rule of primary interest, nominal GDP level targeting. It reacts to deviations of nGDP from its target level. Apart from its parameters, it is different from Eq4.22 only in also including the previous period price level, which introduces history dependence into this rule as well. Eq4.24 considers an alternative with potential output rather than steady state output being in the target. Apart from the weights, this is the Eggertson and Woodford (2003) type of "output gap adjusted price level target" within a reaction function. Compared to a Taylor rule, it differs also in history dependence. Finally, Eq4.25 is the policy rule for nGDP growth targeting.

This completes the description of the model.

5 Results

5.1 Calibration

The calibration of the model follows standard parameters found in the literature. Using values from Galí (2008) and Galí and Monacelli (2005) the baseline calibration can be seen in Table B.1 (see Appendix). The value for the steady state discount factor implies an average annual real return of about 4 percent. The relative risk aversion parameter implies log utility for consumption which makes the model consistent with a balanced growth path, in case we would introduce trend real growth. The inverse (Frisch) elasticity of labor supply is set to a standard value. The elasticity of substitution between different goods implies a steady state markup of 20 percent, and the steady state elasticity of substitution between different labor types is assumed to be the same as in the goods market. Wage subsidies, both to firms and workers, are set exactly to offset the static distortions resulting from monopolistic competition both in the goods and the labor market. This eliminates inefficiency in both markets at the steady state and under flexible prices. The share of capital in income is set to one third. The Calvo parameter of price stickiness implies an average price duration of three quarters.

As far as the policy reaction parameters are concerned, I followed Galí (2008) for the flexible IT case, and for strict targeting rules I set the reaction parameters so high that the target is practically stabilized in response to all shocks. For nominal income and price level targeting, policy reactions are very similar to a wide range of parameters (from 1.5 to 100). I chose 100 in the baseline calibration to ensure almost perfect attainment of targets but I examine also the case with $\phi_p = \phi_z = \phi_{\pi,s} = 1.5$ when I want to look at situations in which targets are not perfectly met.

5.2 Impulse responses

5.2.1 TFP shock

Impulse responses to a 1 percent positive TFP shock are depicted in Fig B.1 (see Appendix). The increase in productivity raises the natural rate of output, the one that would prevail in the absence of nominal rigidities. As the TFP shock is dying out, future potential output is

expected to decline gradually, which makes the marginal rate of substitution between current and future consumption smaller, which in turn causes the natural rate of interest to fall on impact. Higher productivity lowers marginal costs for firms by Eq 4.18, therefore it puts downward pressure on prices. In the presence of nominal rigidities, however, only a fraction of the firms will be able to adjust their prices downwards in the short run, so prices will fall by less than they would in the flexible price case, which makes aggregate demand (real output) increase by less than the increase in production capacities (natural output). This results in a negative output gap and falling employment, in spite of higher real output. Hence, a TFP shock moves inflation and the output gap in the same direction and creates no trade-off between the two. This is the divinie coincidence a la Blanchard and Galí (2007).

The lack of trade-off between inflation and the output gap allows a strict inflation targeting central bank to stabilize both by following a sufficiently accommodating policy, i.e. by lowering nominal interest rates, which is what we see in Fig B.1. Under flexible IT, the central bank does not stabilize inflation fully, therefore we observe falling inflation and negative output gap. Note that this is in spite of a more aggressive cut in nominal interest rates than under strict IT. The reason for this lies in the fact that with its smaller reaction parameter $\phi_\pi = 1.5$ flexible IT does not threaten economic agents enough that it will react strongly to any deviation in inflation, i.e. inflation expectations of the public are not managed that well in the desired direction, which makes policy less effective and results in lower inflation and more negative output gap even in the presence of looser policy.

Price level targeting (PLT) stabilizes the inflation rate and the price level, just as strict IT does, and the impulse responses of the two regimes are almost identical. Both strategies represent a very strong commitment to price stability. When almost perfect achievement of the target is possible, the level and the growth rate targeting regimes do not differ, hence history dependence cannot make a difference between PLT and strict IT. However, if the reaction parameter of strict IT and PLT is loosened to $\phi_{\pi,s} = 1.5$ and $\phi_p = 1.5$ instead of 100, inflation stabilization becomes imperfect. In this case impulse responses of strict IT move closer to flexible IT, while those of PLT remain almost unchanged as it can be seen from Fig B.2. This suggests that the history dependent nature of PLT can substitute for strong reaction parameters and manage inflation expectations in the desired direction, although it only plays a role when the target variable cannot be perfectly stabilized - which is mostly the case in real life.

Under nominal GDP level targeting, nominal output is perfectly stabilized. As the productivity shock moves the price level and real output in exactly the opposite directions, nominal output can remain stable even without any change in the policy interest rates. Hence we see that nGDP level targeting indeed means a stricter monetary policy in response

to positive TFP shocks than IT: real output increases by much less. This results in falling inflation and a wide negative output gap on impact which is clearly visible in Fig B.1. [1]

However, both inflation and the output gap converge back towards their steady state substantially faster than under flexible IT, even in spite of higher interest rates. The reason for this is the more effective expectations channel: (i) the public knows that in order to remain on the target path for nominal GDP even after output returns to steady state, monetary policy will have to undo any past decline in prices by generating positive inflation in the future; or (ii) alternatively, as real output starts to fall back towards steady state, prices have to start increasing in order to keep nominal GDP (growth) stable. Increasing inflation expectations lead to rapidly falling ex ante real interest rates which pushes inflation and the output gap upwards very fast. That is why a period of above target inflation (sustained by a positive output gap) follows falling prices, as prices converge back to their level consistent with the nominal GDP target path. Observe that the expectation channel is so strong in this case that with credible commitment the central bank does not actually need to do anything: the transition takes place without the smallest change in the policy interest rate.

Based on the first argumentation (i) we might think that the history dependent nature of nGDP level targeting plays a role here in managing expectations, but the impulse responses for nGDP growth targeting, which is a forward-looking strategy, are identical, as shown in Fig B.1. When the nominal GDP target path is perfectly attained, both growth and level targets are met by definition, thus there can be no difference between the two strategies. History dependence only matters when there are *past* deviations from targets which have to be undone later. This is not the case here, as nominal GDP is perfectly stabilized both with $\phi_z = 100$ and with $\phi_z = 1.5$.

Real wages are pushed into opposite directions by the falling price level and higher productivity on the one hand (upward), and falling employment on the other (downward), as is clear from Eq 4.13. The net effect of these forces is positive in the case of IT and PLT regimes as they do not allow for that much decline in the output gap, and hence in employment, as does nGDP level targeting, where the net effect is negative in spite of the larger decline in prices.

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[1]Avent (2011*b*) and Beckworth (2011) argue that this feature of nGDP targeting is desirable compared to the procyclical approach of IT, i.e. easing monetary policy in response to increasing real output growth. They refer to Christiano, Motto and Rostagno (2007) who argues that this kind of procyclical response to supply shocks might result in boom-bust cycles and asset price bubbles.

5.2.2 Cost push shock

Cost-push shocks introduce a genuine trade-off between inflation and the output gap, thus divine coincidence no longer holds. As is clear from Fig B.3, in response to an adverse cost-push shock strict IT and PLT can only stabilize inflation at the cost of wide negative output gap by tightening policy and raising interest rates. Flexible IT is more concerned about output stabilization and a 1 percentage point smaller output gap is indeed achieved, but only at the cost of substantially higher inflation. And all this is done with a stricter policy stance than under strict IT, which is again due to the suboptimal management of inflation expectations, resulting in worse inflation-output trade-offs and larger sacrifice ratio.

This trade-off is better under nGDP level targeting, which is why it can achieve a substantially smaller output gap on impact than flexible IT, while not allowing for bigger increase in inflation. Also, inflation falls much faster. In the meantime the negative output gap is sustained for only a little longer. Basically, in response to an adverse cost push shock, nGDP level targeting allows prices to increase and lets output fall so that nominal income evolves in a stable way along its target path. The initial increase in the price level must eventually be undone by below average inflation when real output starts converging back to its steady state. This fact helps anchor inflation expectations much more effectively than under flexible IT, even though nGDP targeting places a higher weight on output stabilization. As in the case of TFP shock, all this takes place without any change in the policy interest rate. Thus, in response to an adverse cost-push shock, monetary policy is looser under nGDP targeting than under IT.

Again, nGDP *growth* targeting produces identical impulse responses to its level targeting counterpart since the target path for nominal income is perfectly attained also under this regime. This suggests that history dependence does not make a difference in improving inflation/output gap trade-offs for nGDP level targeting in this particular case. However, if accidental deviations from the target path are possible, the level targeting regime should perform better in this respect.

In short, when comparing its performance to strict IT and PLT, the looser stance of nGDP targeting results in higher inflation on impact but smaller output gap, which is the same as if we compared flexible IT to the two stricter regimes. However, in comparison with flexible IT, nGDP targeting performs better both in inflation and output gap stabilization, the reason being the improved inflation/output gap trade-off due to its management of inflation expectations in a more desirable way.

The cost-push shock is introduced here via exogenous variation in wage markups. As this enables workers to charge real wages higher above the marginal product of their labor, there is an upward pressure on real wages from the supply side, to which labor demand adjusts by

lowering employment. A more accommodative monetary policy, however, can partly offset this effect by giving a boost to aggregate demand, and that is why under nGDP targeting employment falls by less and real wages can increase by more than under strict IT and PLT, even though inflation is also higher.

5.2.3   Demand shock

A negative demand shock moves inflation and the output gap in the same direction, so divine coincidence is restored and the trade-off between inflation and output gap stabilization vanishes. Fig B.5 shows that strict IT and PLT, by sufficiently lowering nominal interest rates, stabilize both inflation and the output gap. This, however, is achieved with falling real output because of the type of demand shock, which also affects the flexible price equilibrium: due to a fall in government purchases the natural rate of output decreases, too. In other words, a "trade-off" still exists between inflation and real output stabilization. Therefore, within this framework, recession is not avoided under strict IT. It is even more so under flexible IT where in spite of the more aggressive reaction in policy rates, the central bank fails to close the output gap and bring inflation back to target. The reason is again the less effective expectations channel which makes real interest rates actually higher even with lower nominal interest rates. As the public knows that monetary policy will not eliminate deflation (or below target inflation) immediately, inflation expectations will remain low.

nGDP level targeting, on the other hand, is implicitly (i.e. by its components) concerned not about the output gap but about the deviation of real output from its steady state, where this kind of shock still poses trade-offs against inflation stabilization. Along this trade-off nGDP targeting gives higher weight to output; hence the central bank cannot allow as big recession as in the case of strict IT, which it achieves with a more aggressive monetary easing. This, however, will keep real output above its natural rate resulting in a *positive* output gap and above target inflation. The central bank will allow the price level to increase only to such an extent so that it exactly offsets the fall in real output, thereby contributing to a perfectly stable nominal GDP path. The eventual need to bring the price level back to its implicit target path makes a period of below target inflation necessary when real output starts growing again. Observe that although nGDP targeting has a larger reaction coefficient both on inflation and output, the central bank does not engage in as aggressive monetary easing as in the case of flexible IT, and yet it is able to achieve outcomes associated with looser policy. Again, the power of the more efficient expectations channel does much of the work, rather than the brute force of actually lowering interest rates.

As far as the labor market is concerned, employment moves exactly together with real output. As changes in the demand side of the economy dominate in this story, movements

in real wages are influenced by the evolution of aggregate demand. That is why real wages increase the most under nGDP targeting while they fall under flexible IT.

With the baseline parameterization, the history dependent nature of level targeting regimes does not make a difference: very high reaction parameters can achive the same outcome of perfect target attainment, in which case the two types of regimes produce identical outcomes. Fig B.5 demonstrates that the impulse responses of PLT and strict IT coincide as well as those of nGDP level and growth targeting. However, with loosening the strict reaction parameters from 100 to $\phi_p = \phi_{\pi,s} = \phi_z = 1.5$ targets are not achieved perfectly, which is when history dependence can play a role. Fig B.6 shows that history dependence seems to be a substitute for strict reaction parameters in managing inflation expectations and thereby in improving inflation/output trade-offs: "strict" IT moves closer to flexible IT and nGDP growth targeting moves far away from its original position, while the history dependent policies, PLT and nGDP level targeting stay close to where they were.

5.3 Shock simulation

Now I turn to the analysis of inflation and output (gap) variance when all the above described shocks are considered. The exogenous processes for TFP, the cost push shock and the demand shock (specified by Eqs 4.8, 4.9, 4.10) include a random normally distributed error term with zero expected value and standard deviations shown in Fig B.1. I generated a random realization of these error terms for a 1000 periods and fed them into the system of dynamic equations describing the model economy, so that the evolution of endogenous variables were pinned down for 1000 periods. Thereafter variances of these variables were calculated and shown in Table B.2.

It can be seen that inflation variance is smallest for strict IT and PLT, where it is practically zero. As we have observed at the impulse responses, these two regimes are able to stabilize inflation, and therefore, also the price level perfectly. Nominal GDP targeting (both level and growth) performs worse in this matter, as it allows for price level deviations in order to keep nGDP stable when real output is pushed into the opposite direction by a shock. In fact, all of the shocks considered here are of such type, i.e. there is trade-off between price level and real output stabilization. The rule described by Eq 4.24, similar to the output gap adjusted price level target of Eggertson and Woodford (2003), performs little better as it is concerned with output gap, with respect to which inflation stabilization does not involve trade-offs in the case of TFP and demand shocks. The worst performers are flexible IT regimes which fail to take aggressive policy action in response to missed inflation targets.

As for output gap variance, it is nGDP targeting that beats strict IT and PLT, which is

not surprising given the larger weight for output stabilization in this rule. However, it also outperforms flexible IT, which makes nGDP targeting the best policy rule from this point of view. The pattern is similar for real output variance.

In the case of price level the ranking of the rules is similar to that for inflation variance. It is only for the two flexible IT regimes where the variance is larger by several order of magnitude, as these policies allow for a drift in the price level in the baseline scenario. Should some target misses occur, strict IT and nominal GDP growth targeting would also experience drifts in the price level, and hence higher price level variance which is exactly what we see in the alternative scenario with looser reaction coefficients (Table B.3).

Analysing the loose scenario in Table B.3 we can see that strict IT and nominal GDP growth targeting became worse also in terms of inflation variance. In fact, nGDP level targeting outperforms both of them in this respect while maintaining its position as the policy regime with the smallest output gap variance. Again, the improved inflation/output trade-off and better guidance of inflation expectations are behind this. To achieve this, the strong threat by high reaction parameters can be substituted by the history dependent nature of policy.

5.4   Discussion

Within the above framework all shocks are such that they generate a trade-off between stabilizing inflation and *real output*, even in those cases when divine coincidence holds with respect to inflation and the *output gap*. As we have seen, nominal GDP targeting is a monetary policy strategy which balances along this trade-off by allowing for some deviation both in inflation and in real output. In the presence of these particular types of shocks it will never be able to fully stabilize both; however, it is the very reason why it attains its target for nGDP.

In comparison to strict IT, the poorer inflation performance is therefore the result of output being given higher weight at the expense of inflation stabilization. This means, on the other hand, that in output stabilization nGDP targeting is better than strict IT. Based on this, it seems to be a matter of choice between inflation and output (gap) stabilization, where nGDP targeting cannot be ruled out as a reasonable alternative for monetary policy, especially as it outperforms flexible IT in both respect.

The choice depends on society's preferences. It is possible to derive a second order approximation of the household's utility function to get a social welfare loss function expressed in terms of inflation and output gap variance. Based on Rotemberg and Woodford (1999),

this function is of the following form for a similar model as I used above:

$$L = \frac{1}{2}\left[\left(\sigma + \frac{\varphi + \alpha}{1 - \alpha}\right) var(x_t) + \frac{\theta(1 - \alpha + \alpha\theta)}{\lambda(1 - \alpha)} var(\pi_t)\right]$$

Substituting in the variances for the baseline scenario we get the results shown in the last column of Table B.2, based on which inflation targeting wins against nominal GDP targeting at this parameterization of the model. As expected, flexible IT is definitely worse, while "potential" nGDP targeting (Eq 4.24) is slightly better than "normal" nGDP targeting. However, as argued before, it must also be considered that potential nGDP targeting is more complex, and might be a harder concept to understand for the public which makes its usefulness as an anchor of expectations doubtful.

In contrast, when we work with the variances obtained from the alternative scenario with looser reaction coefficients, we get a different picture as shown by Fig B.3. Due to the increased inflation variance, strict IT loses its leading position and becomes a worse policy regime than nGDP level targeting as does nGDP growth targeting. Althogh, in this case PLT is the best framework, the fact that nGDP level targeting follows closely behind must be underlined. This emphasizes the potential in nGDP level targeting to provide an alternative monetary policy framework to inflation targeting under certain circumstances, i.e. when IT is not as strict that inflation targets can be perfectly attained at all times. This is even more so if we compare nGDP level targeting to flexible IT, which is captured here by a Taylor rule thought to approximate the historical monetary policy of the Federal Reserve quite well. Based on this model framework, the Fed could have done better had it targeted a path for nominal GDP.

The role of history dependence in achieving the above results is an important thing to analyse. Under the baseline scenario, level targeting policy regimes do not differ at all from their growth rate targeting counterparts. Impulse responses and implied variances are the same for strict IT and PLT, as they are also the same for nGDP growth and level targeting. This suggests that history dependence has no added value with such high reaction parameters. Any difference between alternative regimes should come from the fact that they target different variables with different weight attached to them, and not from the fact that they target the level or the growth of a particular variable. This might be due to the perfect attainment of each of the targets, which has interesting results: if growth targets are achieved perfectly, it must follow that levels cannot deviate at all, either, but stability in level terms comes only as a byproduct of perfect growth targeting. Similarly, if a variable is perfectly kept at its target path, this essentially means that the implied growth target must also be attained. Hence, the two strategies are identical with strict attainement of the targets and

history dependence cannot add anything more to this.[2]

The history dependent nature of level targeting can exert its effect only when there are past deviations from the target path, that is, when *history* is different than it should have been under the target. It is only in this situation, when the need to make up also for past target misses can influence expectations in such an effective way that it improves inflation output trade-offs and results in a "free lunch" a la Svensson. Under the alternative scenario, with smaller reaction coefficients, such target misses become possible, and indeed we see that history dependent level targetig regimes perform better.[3] Note that in the case of nominal GDP targeting it is demand shocks that make the difference: for the other two types of shocks both nGDP growth and level targeting are able to perfectly achieve their targets even with looser reaction parameters.

In another framework it might be possible to achieve target misses by other ways than smaller reaction coefficients in the policy rule, e.g. by making the information set of monetary policy different, or by introducing lags in the monetary transmission mechanism. Possible extensions to the above model also include the introduction of the zero lower bound, which is definitely a constraint causing potential target misses, and which recently motivated the consideration of nGDP level targeting. An open economy context could also be different.

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[2]Although there are deviations from the implied price level target in the case of nGDP level targeting also under high reaction parameters, it still does not make any difference compared to nGDP growth targeting as long as the nGDP targets are perfectly met. This is because in this case the deviation in inflation needed to offset deviation in output growth exactly coincides with the requirement of price level returning to its implied target. That is, history dependence achieves the same result as strict reaction parameters.

[3]It can be argued, however, that with smaller reaction coefficients the particular policy rules could no longer be called "targeting" regimes in the sense that they do whatever they can to achieve their primary objective. The type of Taylor rule, dubbed flexible IT, considered above is not a targeting regime in this sense, either.

6 Conclusion

Fears that some of the advanced economies might be in a liquidity trap have called for alternative ways of further monetary easing. One proposal is to target the level of a nominal variable, rather than its growth rate, thereby introducing history dependence and achieving higher inflation expectations even when the zero lower bound binds. One currently popular suggestion is nominal GDP level targeting. Reasonable as this may sound, critics argue that apart from these extreme conditions nGDP targeting would perform worst than the currently widely applied inflation targeting strategy.

In this paper I reviewed the different arguments for nGDP targeting outside the liquidity trap. According to these, the history dependent nature of nGDP level targeting results in more efficient management of inflation expectations as the public knows that any past deviations from the nominal GDP target path must eventually be undone. This entails an improved trade-off between inflation and output, if there is any, and it can also dampen the effect of a shock on impact.

Within the context of the simple New Keynesian model which I used above, nGDP targeting results in more stable real economic activity than strict inflation targeting, although at the expense of increased inflation volatility. Its better way of influencing expectations, however, makes it outperform a traditional Taylor rule, which is thought to approximate historical Fed policy quite well, in both respect. Therefore, nGDP targeting might be considered as an alternative monetary policy framework even outside the liquidity trap, although it is certainly not a panacea. It depends on society's preferences if it is willing to trade-off a bit higher inflation volatility for more stable real output and employment. Based on a standard welfare criterion, society is still better off with strict IT than with nGDP targeting.

When "targeting" is used in the strict sense, i.e. that policy targets are perfectly achieved, nGDP level targeting does not differ from its purely forward looking counterpart, nGDP growth targeting, which suggests that history dependence plays no role here. However, when considering a more realistic scenario of possible target misses, it is shown that the history dependent nature of nGDP level targeting can make a difference, as it can be a substitute for the threat posed by strong reaction function coefficients in policy rules. In this case, nGDP level targeting achieves better performance in inflation volatility than nGDP growth targeting and than inflation targeting itself. At the same time it maintains low output gap variance which makes it a superior policy framework compared to most of the alternatives.

Although the above model is highly stylized and simple, and there are other practical concerns regarding nominal income targeting, the results indicate that this policy rule might be worth considering as an alternative framework for monteray policy.

A Expenditure minimization problems

A.1 Households

A continuum of monopolistically competitive firms $i \in [0, 1]$ produce a continuum of differentiated goods at different prices $P_t(i)$. Households must choose a level of consumption from each goods $C_t(i)$ which minimizes their expenditure, *given* their overall level of consumption C_t. Overall consumption is a CES aggregator of the quantity of the different goods consumed. Formally the problem is the following:

$$\min_{C_t(i)} \int_0^1 C_t(i) P_t(i) \; di$$

$$s.t. \; C_t = \left[\int_0^1 C_t(i)^{\frac{\theta-1}{\theta}} \; di \right]^{\frac{\theta}{\theta-1}}$$

θ is the elasticity of substitution between different goods. After some manipulation of first order condition we arrive to the demand function for good i:

$$C_t(i) = \left[\frac{P_t(i)}{P_t} \right]^{-\theta} C_t \tag{A.1}$$

where $P_t \equiv \left[\int_0^1 P_t(i)^{1-\theta} \right]^{\frac{1}{1-\theta}}$ is defined as the overall price level.

A.2 Firms

A continuum of $h \in [0, 1]$ monopolistically competitive workers supply differentiated labor at wage rate $W_t(h)$. Each firm i must determine demand $N_{t,i}(h)$ for labor type h so that it minimizes its total wage costs, *given* its overall demand for labor $N_{t,i}$. Overall labor demand is a CES aggregator of the different types of labor, with the elasticity of substitution between them, $\theta_{w,t}$ exhibiting exogenous variation in time.

$$\min_{N_{t,i}(h)} \int_0^1 N_{t,i}(h) W_t(h) \; dh$$

$$s.t. \ N_{t,i} = \left[\int_0^1 N_{t,i}(h)^{\frac{\theta_{w,t}-1}{\theta_{w,t}}} \ dh \right]^{\frac{\theta_{w,t}}{\theta_{w,t}-1}}$$

After some manipulation of the FOC we arrive to the labor demand function for type h labor by *all* of the firms:

$$N_t(h) = \left[\frac{W_t(h)}{W_t} \right]^{-\theta_{w,t}} N_t \tag{A.2}$$

where $W_t \equiv \left[\int_0^1 W_t(h)^{1-\theta_{w,t}} \right]^{\frac{1}{1-\theta_{w,t}}}$ is the overall wage rate. We also assumed symmetry across firms so that we can integrate over i to get the overall demand for labor type h. $N_t = \int_0^1 N_{t,i} \ di$ is the overall demand for all types of labor.

B Figures and tables of the results

β	0.99	personal discount factor
σ	1	relative risk aversion
φ	3	Frisch elasticity of labor supply
θ	6	elasticity of substitution between goods
$\bar{\theta}_w$	6	elasticity of substitution between labor types
τ	$1/\theta$	wage cost subsidy to firms
τ_w	$1/(\bar{\theta}_w - 1)$	wage subsidy to workers
α	1/3	capital share of income
ξ	2/3	Calvo price stickiness parameter
ρ_a	0.95	persistence for TFP shock
ρ_u	0.85	persistence for cost push shock
ρ_g	0.80	persistence for demand shock
σ_a	0.007	standard deviation of TFP shock
σ_u	0.007	standard deviation of cost push shock
σ_g	0.007	standard deviation of demand shock
ϕ_x	0.5/4	output gap reaction parameter under flexible IT
$\phi_{x,s}$	0	output gap reaction parameter under strict IT
ϕ_π	1.5	inflation reaction parameter under flexible IT
$\phi_{\pi,s}$	100	inflation reaction parameter under strict IT
ϕ_p	100	price level reaction parameter under PLT
ϕ_z	100	nGDP reaction parameter under nGDP targeting

Table B.1: Model parameters for the baseline scenario

VARIANCES (baseline)	inflation (0.001 *)	output gap (0.01 *)	price level (0.01 *)	real output (0.01 *)	WELFARE LOSS (0.1 *)
strict IT	**0.0000**	0.33	**0.00**	0.38	**0.100**
PLT	**0.0000**	0.33	**0.00**	0.38	**0.100**
flexible IT	0.3833	0.21	58.08	0.25	0.331
IT with "trend gap"	0.4127	0.21	67.19	0.25	0.351
nGDP level targeting	0.1348	**0.17**	0.20	**0.20**	0.146
nGDP growth targeting	0.1348	**0.17**	0.20	**0.20**	0.146
potential GDP targ	0.1235	0.17	0.17	0.21	0.138

Table B.2: Variances and welfare losses from the shock simulation – **baseline** scenario $\phi_z = \phi_{\pi,s} = \phi_p = 100$ (bold underlined values indicate the best performers in each column)

VARIANCES (alternative)	inflation (0.001 *)	output gap (0.01 *)	price level (0.01 *)	real output (0.01 *)	WELFARE LOSS (0.1 *)
strict IT	0.1458	0.26	20.84	0.30	0.179
PLT	**0.0025**	0.30	**0.00**	0.35	**0.092**
flexible IT	0.3833	0.21	58.08	0.25	0.331
IT with "trend gap"	0.4127	0.21	67.19	0.25	0.351
nGDP level targeting	0.1348	**0.17**	0.20	**0.20**	0.146
nGDP growth targeting	0.1417	0.18	1.21	**0.20**	0.152
potential GDP targ	0.1235	**0.17**	0.17	0.21	0.138

Table B.3: Variances and welfare losses from the shock simulation – **alternative** scenario $\phi_z = \phi_{\pi,s} = \phi_p = 1.5$ (bold underlined values indicate the best performers in each column)
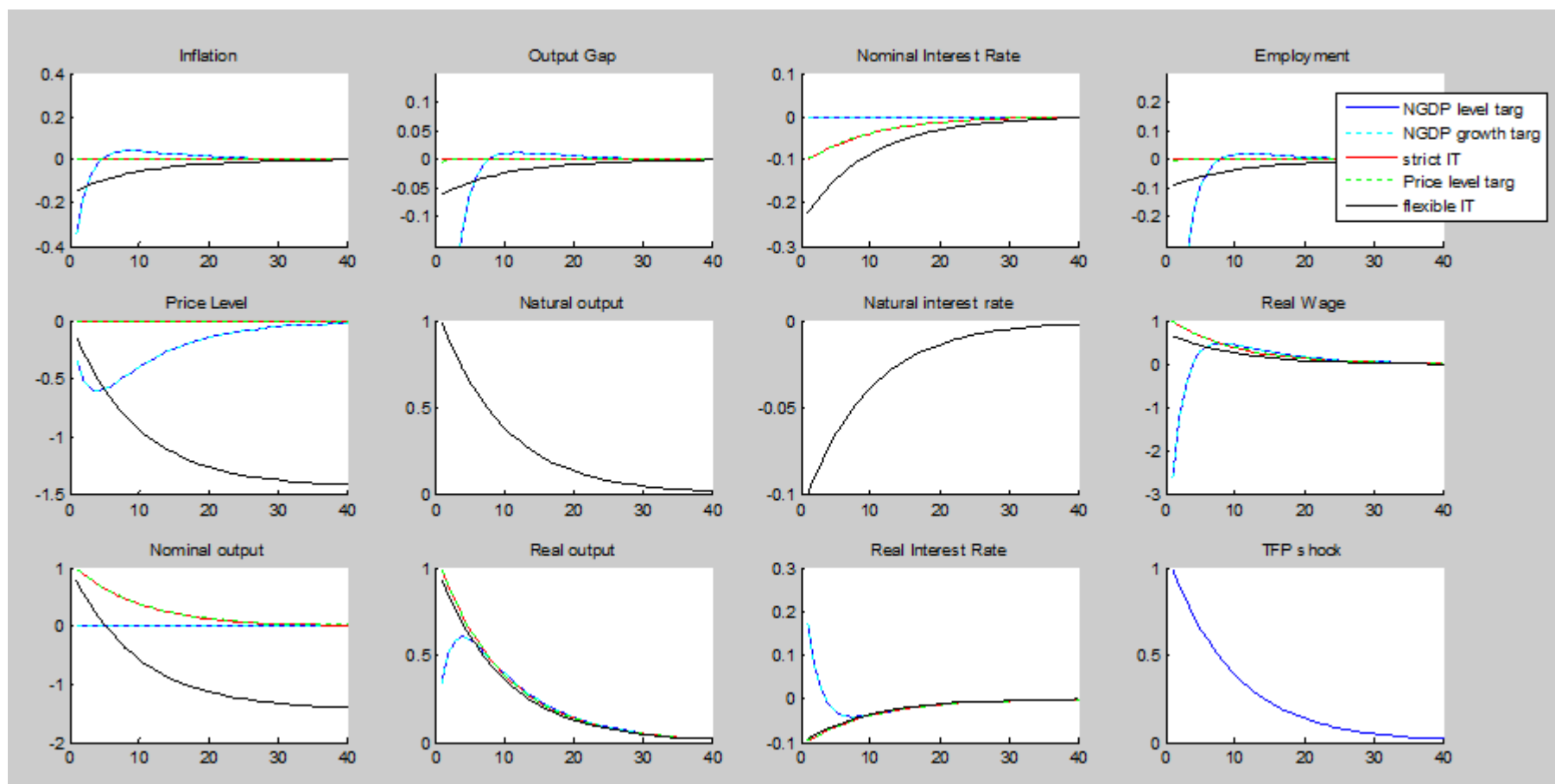
Figure B.1: Impulse responses to a 1% positive TFP shock – **baseline** scenario $\phi_z = \phi_{\pi,s} = \phi_p = 100$ – (percentage deviations from steady state)
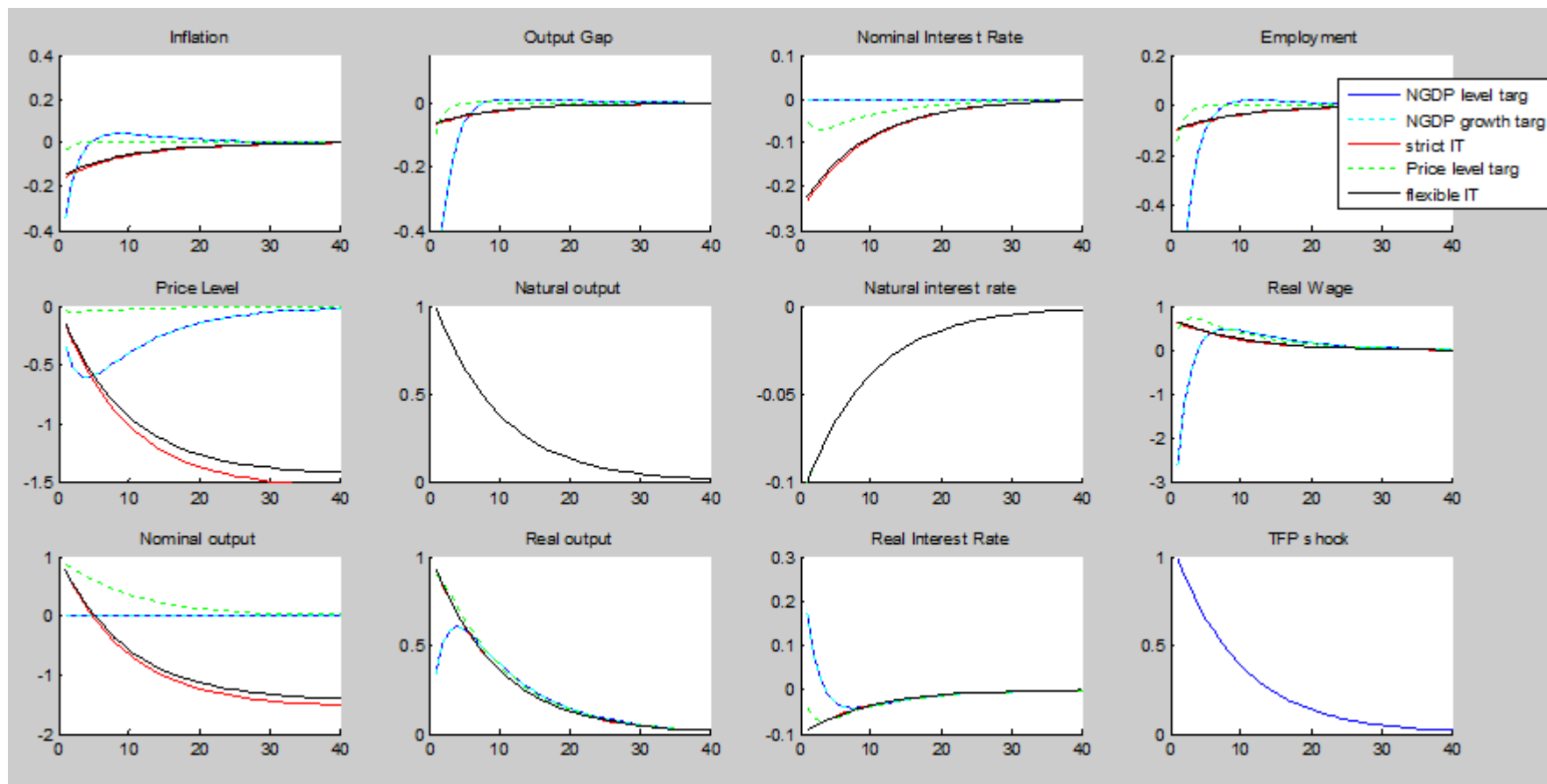
Figure B.2: Impulse responses to a 1% positive TFP shock – **alternative** scenario $\phi_z = \phi_{\pi,s} = \phi_p = 1.5$ – (percentage deviations from steady state)
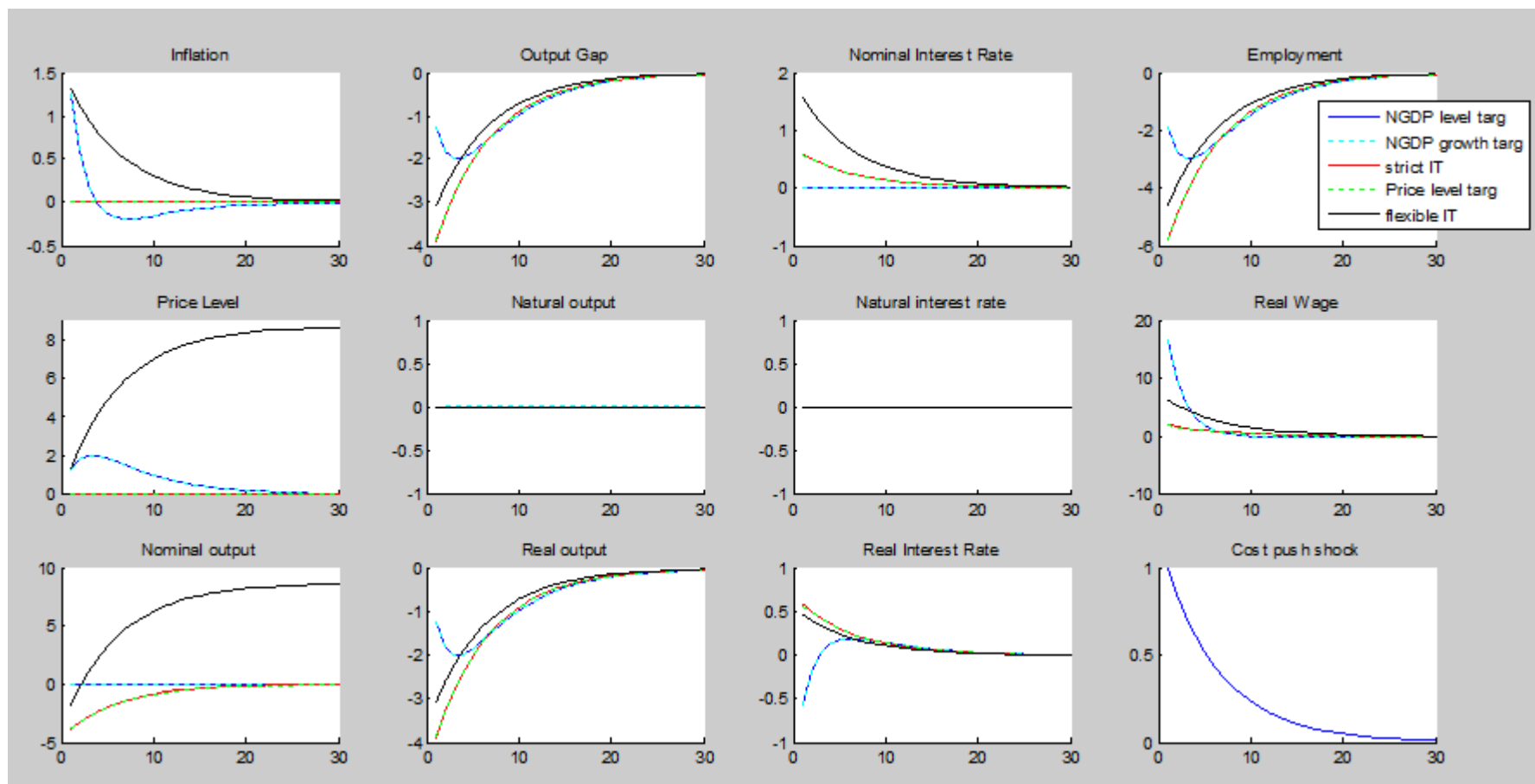
Figure B.3: Impulse responses to a 1% adverse cost push shock – **baseline** scenario $\phi_z = \phi_{\pi,s} = \phi_p = 100$ – (percentage deviations from steady state)
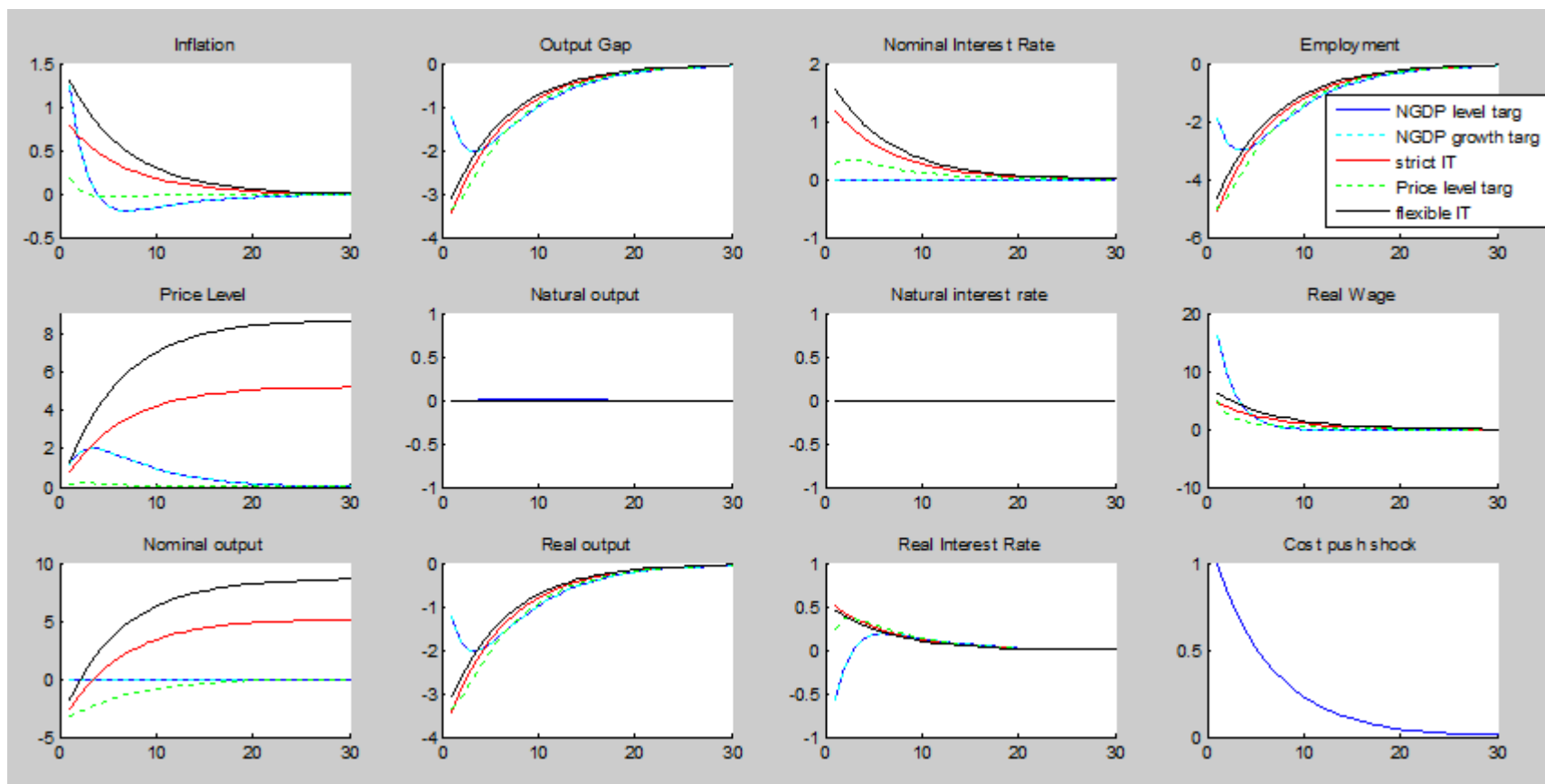
Figure B.4: Impulse responses to a 1% adverse cost push shock – **alternative** scenario $\phi_z = \phi_{\pi,s} = \phi_p = 1.5$ – (percentage deviations from steady state)
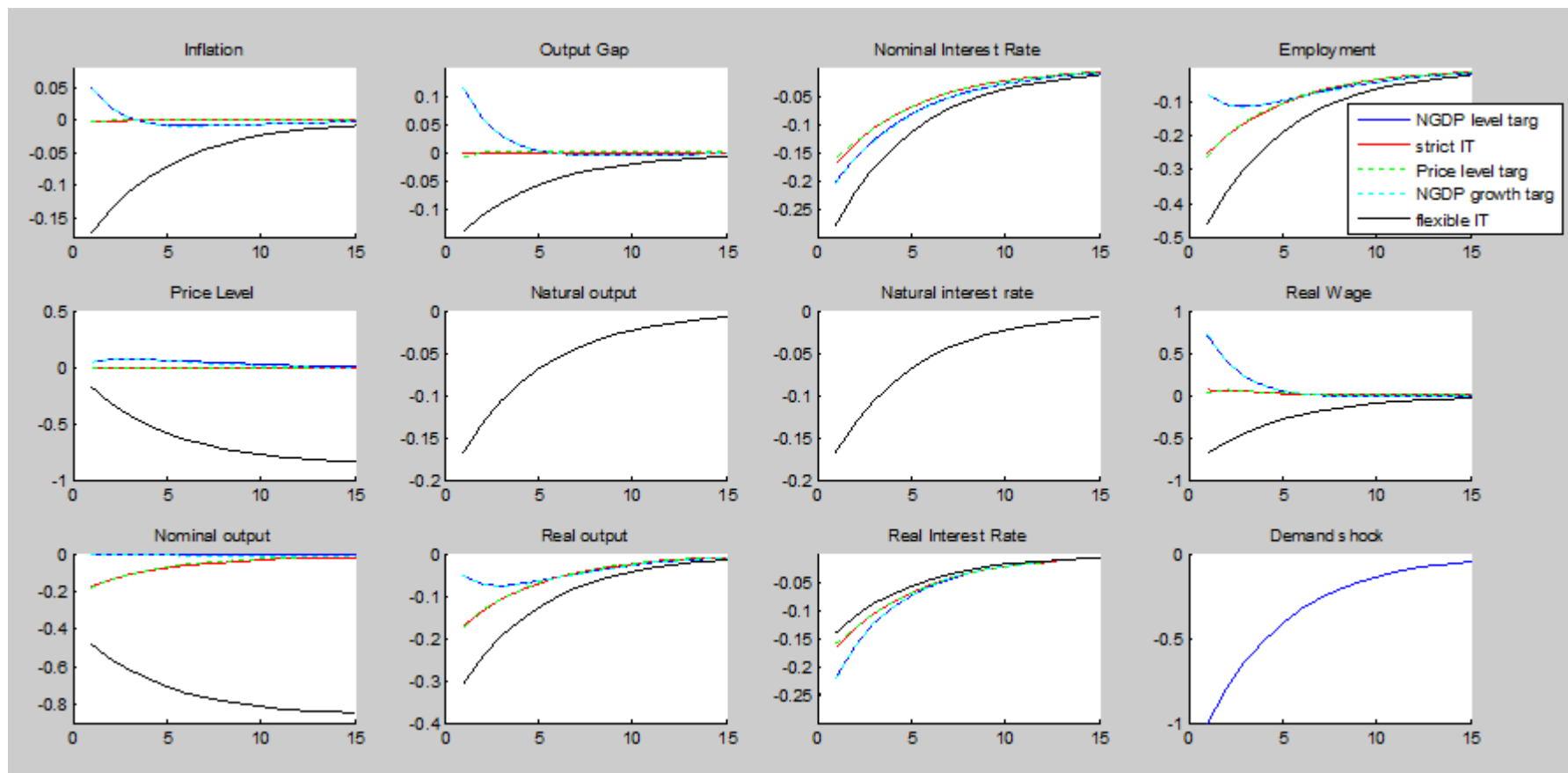
Figure B.5: Impulse responses to a 1% negative demand shock – **baseline** scenario $\phi_z = \phi_{\pi,s} = \phi_p = 100$ – (percentage deviations from steady state)
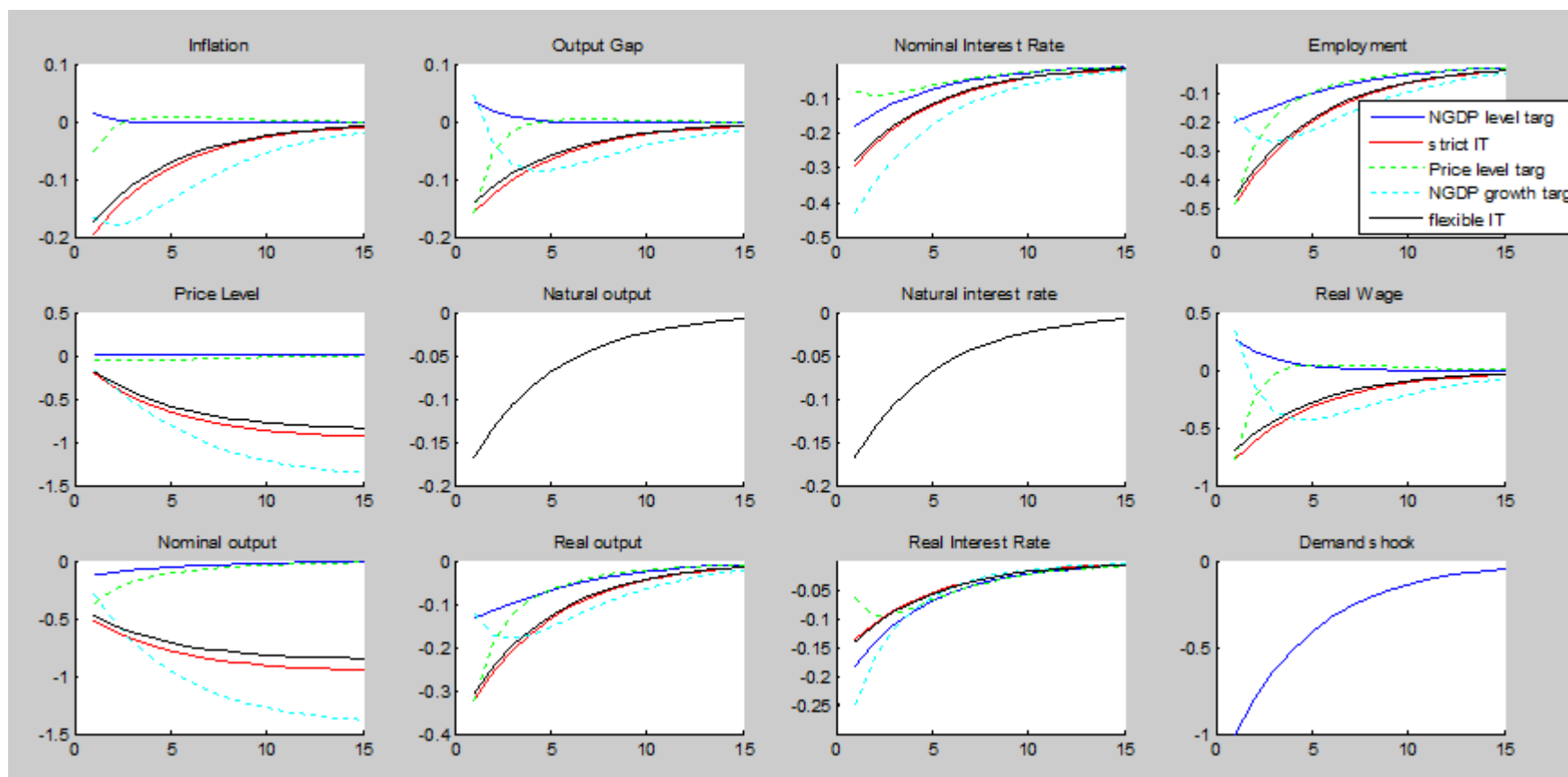
Figure B.6: Impulse responses to a 1% negative demand shock – **alternative** scenario $\phi_z = \phi_{\pi,s} = \phi_p = 1.5$ – (percentage deviations from steady state)

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