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Interest Rate Policy and Supply-side Adjustment Dynamics

by

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Abstract

In contrast to the present consensus view of stabilization policy, theoretical and empirical research strongly support the consideration of supply-side adjustment to pronounced variations of factor-utilization in order to trace a more realistic pattern of macroeconomic adjustment dynamics within simulation studies. Against this background, our paper seeks to illuminate the relevance of endogenous supply-side adjustment for monetary policy research. We modify a basic New Keynesian model by explicitly considering demand-side stimulus on the evolution of productive capacity and analyze stability, impulse response, and welfare issues if the central bank follows a simple monetary policy rule. Thereby, we control for the robustness of our policy implications by various states of output gap mismeasurement the central bank might be confronted with. We find that, in contrast to a basic New Keynesian Model, output gap stabilization plays a more prominent role when potential output is endogenous.

Keywords: Monetary policy, factor-utilization, endogenous potential output, output gap mismeasurement.

JEL code: E32, E50, E52.

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1 Introduction

Implications of standard consensus models of stabilization policy are typically derived from simulations that rely on specific assumptions with regard to the equilibrium level of production. Thereby, the evolution of equilibrium output rests on an asymmetric separation of supply-side and demand-side adjustment to macroeconomic shocks. In particular, this consensus perspective does not account for demand-side stimulus on an economy's productive capacity.

The record of the Phillips-curve extensively documents the fact that output gap dynamics have constituted the explanation of the evolution of inflation for the most part and, therefore, have been used as a central building block within models designed for monetary policy research. Against the background of such popularity of output gaps for stabilization purposes, one can easily identify equilibrium output as a central concept within the framework of stabilization analysis.

Macroeconomic literature has introduced several terms and concepts of the equilibrium level of production (see McCallum, 2001, p. 261). The most common and intuitive understanding of potential output in the context of macroeconomic stabilization research has been connected to the contribution of Okun (1962). Okun (1970, pp. 132-133) defines the equilibrium level of output as *"the maximum production without inflationary pressure, [. . .] or more precisely [. . .] the point of balance between more output and greater stability."* Hence, the concept matches the maximum amount of production from a technical point of view with the degree of factor-utilization that may provide a stable development of goods prices (e.g., Macroeconomic Policy Institute, 2007, p. 30 and Kuttner, 1994, p. 361). According to this, rather than solely on the technical dimension, stabilization policy primarily focuses on the level of production that may be in line with a stable development of goods and factor prices (see European Central Bank, 2000, pp. 37-38 and European Central Bank, 2005, p. 46). This perspective is also highlighted by Hall and Taylor (1991, p. 16) as they define the equilibrium level of production as *"the amount of output that* *would have been produced had the economy been in neither boom nor recession [. . .] from the existing capital stock and labor force."*

As the efficiency and availability of productive factors determine the amount of goods and services that can be produced at a certain point in time, it is the (quantitative) accumulation as well as the qualitative development of productive capacity that constitute an economy's level of potential output (see European Central Bank, 2000, pp. 39-40; European Central Bank, 2005, p. 46; and German Council of Economic Experts, 2007, p. 440). In contrast to the rather static view within the context of stabilization policy that, traditionally, has been focusing on a production capacity which may be given in the short-run, the analysis of changes in potential output meets fundamental aspects of growth theory. As economic growth is identified with changes in the efficiency and the accumulation of the factors of production, variations of potential output are to be explained by changes of the capital stock, shifts of the supply of labor as well as technical innovation (e.g., European Central Bank, 2000, pp. 37-39; European Central Bank, 2005, p. 46; German Council of Economic Experts, 2007, p. 440).

Although the latter may seem intuitively clear, most popular models of stabilization theory have been reflecting the view of a highly asymmetric quality of macroeconomic shocks affecting an economy's supply-side performance, thereby replicating a variation of the well-known dichotomy of trend and cycle. However, such consequent separation of short-run and long-run macrodynamics suppresses important aspects that are essential for the analysis of cyclical dynamics as well as for the conduct and the effects of stabilization policy (e.g., Blanchard, 1997, pp. 89-90; Hicks, 1965, p. 4). As variations of factor-utilization stimulate procyclical adjustment of production factors, one can hardly understand (long-term) supply-side economic development without short-term macroeconomic outcomes that are clearly driven by demand-side impulses.[1]

[1] This has also been addressed by Blanchard (1997) and Solow (2000a). Furthermore, questioning the separation of short-run and long-run macroeconomic analysis may blur the popular categorization of factor-utilization and factor accumulation - consequently the parting line between cycle and growth cannot be clearly identified (see, e.g., Blanchard, 1997, p. 89; Hagemann, 2008, pp. 151-152; Solow, 1991, p. 16; Steindl and Tichy, 2009, p. 159).

In line with this, the implications of variations in potential output due to changes in factor-utilization are poorly considered in standard consensus models of stabilization policy. The story that New Keynesian macroeconomics tells about equilibrium output appears as a special case of the asymmetric mechanism that has been sustained for several decades by neoclassical theory.[2] Thereby, the evolution of productive capacity is basically explained through the spectacles of Real Business Cycle Theory that ascribes the expansion of potential output first and foremost to technological impulses without any clear connection to the evolution of aggregate demand.[3]

2 Channels of Procyclical Supply-side Adjustment

In contrast to frequently used consensus models, there are clear insights that there is more than technology shocks and permanent income to the explanation of macroeconomic fluctuations. More generally, Kaldor (1972, p. 1246) emphasizes that *"[. . .] the process of economic development can be looked upon as the resultant of a continued process of interaction - one could almost say, of a chain-reaction - between demand increases which have been induced by increases in supply, and increases in supply which have been evoked by increases in demand."* In particular, besides varying net capital formation, procyclical adjustment of potential output is suggested by labor market hysteresis and investment-induced technological progress through the impact of changes in factor-utilization on production factors' efficiency and accumulation (e.g., Kriesler and Lavoie, 2007, pp. 390-395 and Palacio-Vera, 2005, p. 755).

Due to its effects on both income and capacity, investment dynamics play a central role for the analysis of the business cycle and the deduction of stabilization strategies. Although capital investment is at the core with regard to the explanation of macrodynamics, basic

2 Moreover, this view seems to have become not only a basic feature within New Keynesian research, but also rather pragmatic models within the inflation targeting context have stuck to this convention (see, e.g., Svensson, 2000, p. 161).

3 See Galí and Gertler (2007, p. 28), Goodfriend (2004, pp. 22-27), Mankiw (1989, p. 81), and Plosser (1989, pp. 53-54). At the same time, according to New Keynesian research, technological impulses may stimulate aggregate demand through the mechanism of permanent income (e.g., Amato, 2005; Clarida et al., 1999, pp. 1665-1666; Galí and Gertler, 2007, p. 40; Goodfriend, 2004).

consensus models neither explicitly account for the demand for capital goods, nor for its capacity effects, but rather focus exclusively on the development of consumer spending. Against this background, it is remarkable that many authors do not judge this as a serious shortcoming of New Keynesian analysis. For example, Clarida et al. (1999, p. 1665) state: *"For convenience, we abstract from investment and capital accumulation. This abstraction, however, does not affect any qualitative conclusions, as we discuss."* In contrast to this, one might argue that models which do not consider investment dynamics seem rather limited for the purpose of stabilization research (Blanchard, 2008, p. 9; Boianovsky and Trautwein, 2006, p. 182; Spahn, 2008, pp. 126-127).[4] Such (over-)simplification of an evolution of productive capacity that is independent of demand-side stimulus on the one hand and the mechanisms of procyclical adjustment of production factors on the other hand reveal a strong macrotheoretical tension which is partly reflected in the asymmetric treatment of changes in equilibrium output in the context of basic New Keynesian models.

In addition, literature provides a variety of theoretical and empirical research on labor market hysteresis. A clear connection of cyclical unemployment's impact upon the supply side of the economy has already been given by Phelps (1972, p. 23) who identifies hysteresis with path dependency of the natural rate of unemployment. *"[The] natural unemployment rate at any future date will depend upon the course of history in the interim. Such a property is sometimes called hysteresis."* According to Ball and Mankiw (2002, p. 119) a demand-side stimulus may cause persistent procyclical adjustment of the labor force. *"A recession that raises unemployment leaves a permanent scar on the economy, as [the natural rate of unemployment] is higher even after the initial shock that caused the recession has disappeared."*[5] Research on labor market hysteresis suggests that cyclical changes of

[4] It is worth mentioning that Woodford (2003, pp. 242-243 and pp. 352-359) motivates an extension of the basic model-setup by explicitly highlighting the effects of changing investment dynamics on the capital stock and concludes that production capacity as well as the equilibrium real rate of interest are affected by monetary policy. As a result, neither the evolution of equilibrium output can be understood independently from movements of aggregate demand nor may disequilibrium adjustment paths end up in unique (predetermined) equilibria (see also Amato, 2005, pp. 3-4 and Boianovsky and Trautwein, 2006, p. 180).

[5] This has also been addressed by Ball (2009), Blanchard and Summers (1988, p. 187), Franz (1990, p. 117), Hargreaves Heap (1980, pp. 612-613), Solow (2000b, pp. 5-9), and Spahn (2000, pp. 219-220).

factor-utilization that stimulate the demand for factor inputs (on labor markets through a falling demand for employees) may lead to a decrease of effective factor supply (rising long-term unemployment). The most prominent channels are insider-outsider mechanisms (e.g., Blanchard and Summers, 1987, pp. 289-292; Lindbeck and Snower, 1988, p. 40) and de-qualification (Hargreaves Heap, 1980, pp. 613-614; Pissarides, 1992, p. 1372). Empirical findings widely support the respective theoretical considerations. For example, Coe (1990) as well as Layard and Nickell (1986) report a decreasing impact of long-term unemployed on wage formation. Blanchard and Summers (1988) as well as Layard and Bean (1989) state empirical evidence for de-qualification and decreasing re-employment options of long-term unemployed. Hargreaves Heap (1980) and McGregor (1978) observe a positive relationship of averaged unemployment duration and the level of unemployment.

On a more aggregate level, the impact of total demand upon an economy's supply-side development has also been discussed in the context of its effects on labor productivity. According to Léon-Ledesma and Thirlwall (2002, p. 445) *"[. . .] there is a host of ways in which labor productivity growth may be enhanced as output growth increases: micro (static) economies of scale, macroeconomies of scale [in the Allyn Young (1928)-sense] and dynamic economies of scale associated with induced capital accumulation; embodied technical progress; and learning-by-doing."* I.e., market expansion stimulates efficiency gains through the division of labor and industrial specialization (see Blitch, 1983, pp. 365-366; Kaldor, 1972, pp. 1240-1241; and Young, 1928, pp. 529-534). Thereby, intersectoral spillovers may raise productivity on a macroeconomic level (e.g., Blitch, 1983, p. 360; Kaldor, 1966, p. 10; Setterfield, 2003, p. 26). Further, rising efficiency can be explained by the application of innovative production techniques (Jones, 1975, pp. 186-191; Setterfield, 2002, p. 5; Solow, 1960, p. 91) or simply by the use of new machinery (vintages) that itself is stimulated by capacity adjustment due to the expansion of sales markets (see Blitch, 1983, p. 365; Cornwall, 1970, p. 61; Jones, 1975, p. 196; Kaldor, 1957, 1961; Kaldor, 1972, pp. 1242-1245). In particular, the development and implementation of new capital equipment exhibits two effects: First, it stimulates the generation and accumulation of know-how (depending on the level of production that has been experienced so far) as new capital goods embody contemporary production techniques. Second, it initiates intersectoral knowledge spillovers.[6] Empirical studies highlight the concept of the Verdoorn relationship which suggests a positive impact of aggregate demand upon labor productivity.[7] Besides this, there is research on the procyclical stimulus of innovation due to market expansion on the efficiency of production (e.g., Brouwer and Kleinknecht, 1999; Geroski and Walters, 1995; Judd, 1985). An overview of 80 studies largely confirming the Verdoorn relationship is given by McCombie et al. (2002). Furthermore, in an investigation on 15 OECD countries from 1961 to 1995 Léon-Ledesma and Thirlwall (2002) point out the procyclical influence of aggregate demand on the development of labor productivity. Moreover, based on a study of 16 OECD countries from 1960 to 1989 Cornwall and Cornwall (2002) report evidence of export demand and investment dynamics stimulating labor productivity.

3 Motivation and Specification

Building upon these insights, there have been several authors such as Ball (1999), Lavoie (2004), and Solow (2000b) that address the relevance of changing factor-utilization for the development of potential output, thereby calling for a more reflected understanding of output gap dynamics in the context of monetary policy research (see also DeGrauwe and Costa Storti, 2007; Galí, 2009; Léon-Ledesma and Thirlwall, 2002). Against this background, our paper seeks to illuminate the relevance of endogenous supply-side adjustment for monetary policy research. We modify a basic New Keynesian model by explicitly considering demand-side stimulus on the evolution of productive capacity. With such an augmented model we adress the policy implications of modified output gap dynamics. In particular, our comparison to the performance of a standard New Keynesian model re-evaluates the widespread view of strict inflation targeting as the policy maker's dominant

[6] This has been addressed by Arrow (1962, pp. 155-158 and p. 168), Jones (1975, pp. 204-205), Léon-Ledesma and Thirlwall (2002, p. 445), Romer (1990, p. 77), and Setterfield (2003, p. 27).

[7] See, e.g., Kaldor (1966, p. 10), Léon-Ledesma and Thirlwall (2002, p. 445), McCombie et al. (2002, p. 2), and Palacio-Vera (2005, p. 757) refering to Verdoorn (1949).

strategy. Therefore, we analyze stability, impulse response, and welfare issues if the central bank follows a simple monetary policy rule. We also control for the robustness of our welfare implications when the central bank faces output gap mismeasurement.

As proposed by basic New Keynesian research, our investigation abstracts from explicit distinction between specific demand categories such as consumption and investment. However, in contrast to standard models, the qualitative and quantitative evolution of productive capacity stimulated by changing investment dynamics and hysteresis in labor markets is to be captured. Due to the aggregated setup, variations of the capital stock as well as shifts in the equilibrium rate of unemployment are completely absorbed in the evolution of aggregate productive capacity. The core equations of our model build upon Galí (2008, pp. 41-49). The latter is supposed to serve as a benchmark setup for our stability analysis, impulse response dynamics, and welfare considerations.[8]

With regard to the implications of output gap dynamics for the evolution of potential output the analysis closest to ours is Kapadia (2005)'s model which explicitly includes procyclical effects of changing factor-utilization to productive capacity.[9] Since we highlight the consequences of endogenous supply-side adjustment to changes in factor-utilization for monetary policy, the starting point of our investigation is similar to Kapadia (2005). However, there are several aspects within our approach that constitute a clear distinction: First, in line with Giordani (2004) we assume an exogenous AR(1) process as the basic pattern for the time path of potential output. Second, Kapadia (2005) explores optimal monetary policy, whereas our analysis focuses on monetary policy conducted with a simple rule. This leads us to investigate stability issues which are not part of Kapadia (2005). Third, to guarantee a preferably direct comparison to standard New Keynesian implications our basic non-policy equations as well as the central bank's reaction function are identical

8 Against the background of our extended model setup, Galí's reference framework can be interpreted as a special case as we argue below.

9 See Kapadia (2005, pp. 6-7) refering to Hargreaves Heap (1980) and Mankiw (2001). Note that with regard to the examination of the relevance of endogenous supply-side adjustment for monetary policy, the distinction between the natural and the efficient level of production is not relevant in the first place. For a discussion see, e.g., Woodford (2001).

to Galí (2008, pp. 49-50). This also holds for the baseline calibration as well as for the quality and the extent of the shocks that are used within the impulse response simulations.

The remainder of the paper is structured as follows. Section 4 introduces our model setup. Section 5 discusses stability issues. Corresponding impulse response dynamics are presented in section 6. Section 7 provides insights with regard to welfare aspects. Section 8 examines the robustness of our policy implications given misspecification of the output gap. Finally, section 9 summarizes our findings and evaluates basic results with regard to related research.

4 Model

As in Galí (2008, pp. 41-49) the dynamic IS-equation of our model reads

$$y_t = E_t\{y_{t+1}\} - \frac{1}{\sigma}(i_t - E_t\{\pi_{t+1}\} - \rho), \tag{1}$$

where y_t is (log) output, i_t is the central bank's (nominal) interest rate, π_t is the inflation rate in period t, and ρ is the discount rate. This IS-equation is a log-linearized version of the household's Euler equation combined with the market clearing condition that consumption equals output.

Nominal supply-side dynamics are captured by a forward-looking Phillips curve given by

$$\pi_t = \beta E_t\{\pi_{t+1}\} + \kappa(y_t - y_t^*) \tag{2}$$

where y_t^* is (log) potential output in period t. This modeling can be derived by aggregating the log-linearized optimal price-setting rules of firms facing a constant probability of resetting prices, in a neighborhood of the zero inflation steady state. In the context of this model, potential output is the equilibrium level of output if prices were completely flexible. We assume that a suitable subsidy is in place which offsets the inefficiency that comes along with the assumption of monopolistic competition in the goods market. In this case, the flexible price equilibrium corresponds to the efficient allocation.

The central bank follows a Taylor-type rule according to

$$i_t = \rho + \gamma\pi_t + \psi(y_t - y_t^*) + \nu_t \tag{3}$$

where ν_t is a monetary policy shock, and γ and ψ are parameters determining the strength of the central bank's reaction to inflation and the output gap.

According to our motivation outlined in the previous sections, we augment this standard model by an equation which expresses potential output as a function of actual output to take into account procyclical supply-side adjustment in response to demand-side stimulus. Similar specifications can be found in Lavoie (2004, p. 26), Hargreaves Heap (1980, p. 612) or Mankiw (2001, p. C56). We express potential output as

$$y_t^* = \delta y_{t-1}^* + \eta(y_{t-1} - y_{t-1}^*) + a_t. \tag{4}$$

Here, potential output is a function of lagged potential output[10], (log) technology a_t, and lagged actual output. The parameter η represents the degree of endogeneity of potential output. We can see that the baseline model in Galí (2008) is basically nested in our specification: Setting $\delta = \eta = 0$ results in the setup of our benchmark model up to a constant.

In order to analyze the model and its dynamics, we write this system of difference equations in matrix form. Plugging (3) into (1) and rearranging yields

$$E_t\{y_{t+1}\} = \frac{\sigma + \psi}{\sigma} y_t - \frac{1}{\sigma} E_t\{\pi_{t+1}\} + \frac{\gamma}{\sigma}\pi_t - \frac{\psi}{\sigma} y_t^* + \frac{1}{\sigma}\nu_t. \tag{5}$$

[10] This has also been implemented by Giordani (2004, p. 1274) refering to Svensson (2000, p. 161).

Rearranging (2), we get

$$E_t\{\pi_{t+1}\} = \frac{1}{\beta}\pi_t - \frac{\kappa}{\beta}(y_t - y_t^*). \tag{6}$$

Plugging this in (5) and collecting terms gives

$$E_t\{y_{t+1}\} = \frac{\beta(\sigma+\psi)+\kappa}{\sigma\beta}y_t + \frac{\beta\gamma-1}{\sigma\beta}\pi_t - \frac{\beta\psi+\kappa}{\sigma\beta}y_t^* + \frac{1}{\sigma}\nu_t. \tag{7}$$

Additionally, we can iterate (4) one period forward to obtain

$$E_t\{y_{t+1}^*\} = (\delta-\eta)y_t^* + \eta y_t + E_t\{a_{t+1}\}.$$

Assuming an autoregressive process for technology according to $a_t = \rho_a a_{t-1} + \epsilon_t^a$, this becomes

$$E_t\{y_{t+1}^*\} = (\delta-\eta)y_t^* + \eta y_t + \rho_a a_t. \tag{8}$$

We can now summarize equations (7), (6) and (8) compactly by the system

$$E_t\begin{pmatrix} y_{t+1} \\ \pi_{t+1} \\ y_{t+1}^* \end{pmatrix} = A\begin{pmatrix} y_t \\ \pi_t \\ y_t^* \end{pmatrix} + B\begin{pmatrix} \nu_t \\ a_t \end{pmatrix}, \tag{9}$$

where

$$A = \begin{pmatrix} \frac{\beta(\sigma+\psi)+\kappa}{\sigma\beta} & \frac{\beta\gamma-1}{\sigma\beta} & \frac{-\beta\psi-\kappa}{\sigma\beta} \\ -\frac{\kappa}{\beta} & \frac{1}{\beta} & \frac{\kappa}{\beta} \\ \eta & 0 & \delta-\eta \end{pmatrix}; \quad B = \begin{pmatrix} \frac{1}{\sigma} & 0 \\ 0 & 0 \\ 0 & \rho_a \end{pmatrix}.$$

5 Stability

This above derived system has one predetermined variable (y_t^*) and two non-predetermined variables (y_t and π_t). Hence, a stationary unique solution will exist if and only if A has one eigenvalue inside and two eigenvalues outside the unit circle (see, e.g., Blanchard and Kahn, 1980). It turns out that this condition is analytically not tractable. However, it is possible to show numerically that the determinacy of the equilibrium depends on the reaction parameters of the central bank as well as on the endogeneity parameter η under a baseline calibration for the other parameters.

Following Galí (2008), we choose $\beta = 0.99$, $\kappa = 0.13$ and $\sigma = 1$.[11] Additionally, δ is set to 0.9.[12] Assuming that the central bank can adjust its reaction parameters γ and ψ in 0.1-steps, figure 1 illustrates the determinacy and indeterminacy regions in the (γ, ψ)-space for different degrees of potential output endogeneity, namely $\eta = 0.2$, $\eta = 0.5$, $\eta = 0.8$, and $\eta = 1$. We look at positive values for γ up to five and for ψ up to two.

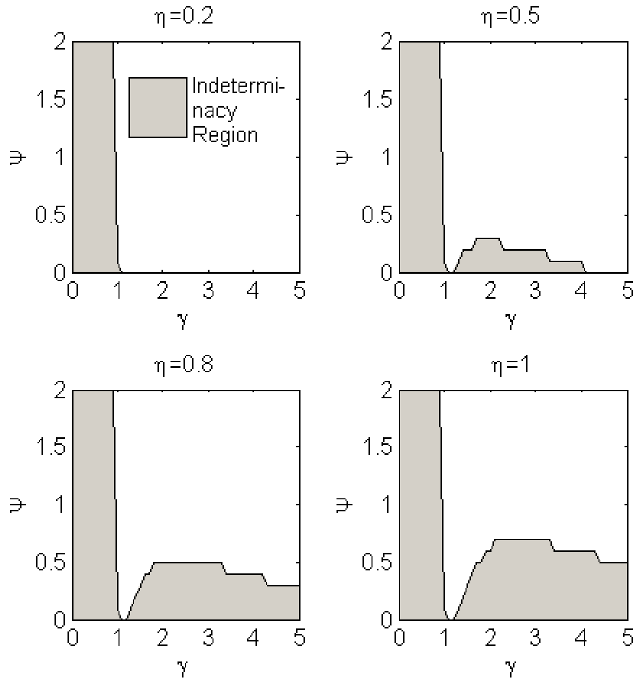
Comparing the resulting indeterminacy regions with the one of our baseline model - see Galí (2008, p. 78), figure 4.1 - several results stand out: First, with a low degree of potential output endogeneity (upper left panel), the indeterminacy region is similar to the one in the baseline model; specifically, a reaction parameter for inflation bigger than one suffices in order to guarantee determinacy of the system. For $\gamma < 1$ a very large reaction to the output gap is required to achieve determinacy.

Second, for higher η (upper right and bottom panels) the indeterminacy region expands. In particular, setting $\gamma > 1$ does not ensure determinacy any more. This is only the case for values of γ up to 1.2. For higher γ the reaction parameter for the output gap ψ has to rise approximately proportionally to γ up to a certain point in order to guarantee determinacy. Thereafter, the level of ψ may remain constant for rising γ before it can even be decreased

[11] For an explanation of the realization and motivation of these parameter values see Galí (2008, p. 52).

[12] Throughout our examination we stick to the calibration of $\delta = 0.9$. Note that variations within a range of $0.6 < \delta < 0.99$ do not alter our findings qualitatively, for $\delta = 1$ the system is mathematically instable due a unit root problem and remaining values outside this interval are not plausible from an economic point of view.

Figure 1: Determinacy for Different Values of η.



slightly as γ increases (for $\eta = 0.5$, the required level of ψ even falls to zero when $\gamma > 4$). This pattern is more distinct for higher values of η.

Put differently, the presence of a certain degree of procyclical supply-side adjustment obviously necessitates a reaction of the central bank to the output gap if it wants to achieve a unique stable equilibrium, given that it chooses to react to inflation sufficiently strongly (but not too strongly for $\eta = 0.5$).

We interpret these findings as follows: Suppose the central bank raises the interest rate in order to bring down inflation. This will cause output and (with an initially constant potential output) the output gap to fall. Due to endogenous supply-side adjustment potential output will fall subsequently, thus dampening underutilization. However, this reduces the originally intended downward pressure on inflation, as the negative output gap closes from the supply side. Hence, the monetary authority needs to react to the output gap variation (which requires an interest rate movement in the opposite direction) in order to cushion the initial interest rate increase and being able to bring inflation to its equilibrium level. But why then does the required reaction to the output gap (i.e., ψ) decrease with a larger reaction to inflation (i.e., γ)? The reason is that a very large γ implies a larger output gap and, consequently, brings down inflation to its equilibrium value quicker. Therefore, the balancing effect of the reaction to the output gap does not have to be that strong any more.[13]

6 Impulse Responses

Next, we examine the economy's equilibrium responses to exogenous shocks for different values of the endogeneity parameter η and compare them among themselves as well as with the respective impulse responses of the benchmark model. In order to present a meaningful comparison, the central bank reaction parameters will be the same for each impulse response function. We set $\gamma = 1.5$ and $\psi = 0.3$ for two reasons: These parameter values ensure determinacy of the system for all considered values of η (see section 5) and they are close to what is deemed to be consistent with observed interest rate movements of the Fed.[14] In addition, we set $\rho_\nu = 0.5$ and $\rho_a = 0.9$.[15] The remaining parameters are calibrated as above.

Figures 2 and 3 show the impulse response functions for a monetary policy shock and a technology shock, respectively, for the benchmark model as well as for the augmented model with different degrees of potential output endogeneity.[16] For ν_t, we assume the following process: $\nu_t = \rho_\nu \nu_{t-1} + \epsilon_t^\nu$. The monetary policy shock corresponds to a 25 basis point increase in ϵ_t^ν, which implies an annualized impact of 100 basis points. The technology shock corresponds to a 100 basis point increase in ϵ_t^a.[17]

In general we find that the higher the value of the parameter η the more pronounced is the difference to the benchmark framework. Moreover, we observe rising persistence of inflation and output irrespectively of the type of shock that leads to the adjustment

[13] A supplemental illustration of this pattern will be given in the context of the following impulse response analysis, see section 6.

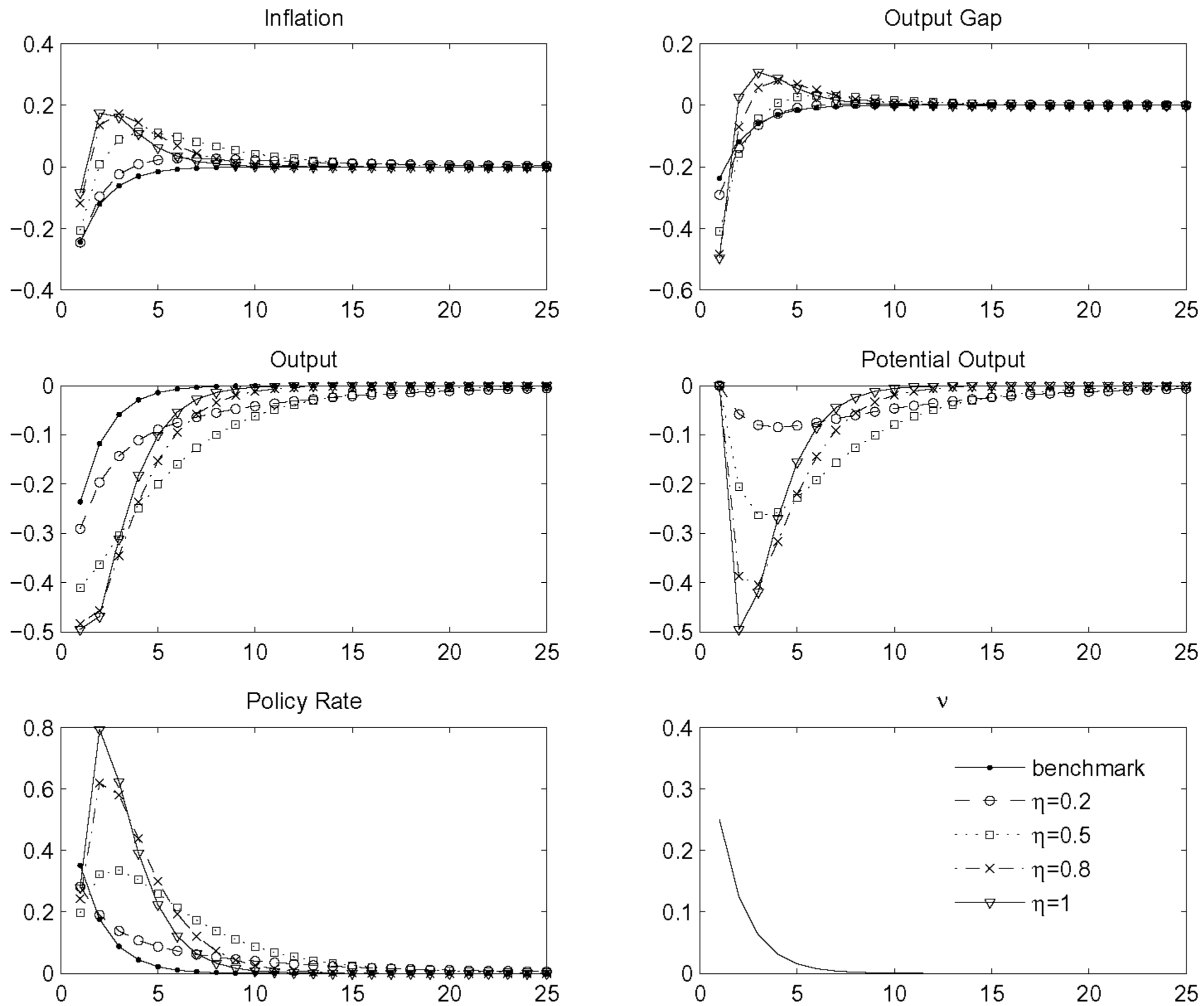
[14] See, e.g., Taylor (1999). If we were to chose $\gamma = 1.5$ and $\psi = 0.5/4$ as in the original Taylor rule, the system would be indeterminate for $\eta = 0.5$, $\eta = 0.8$ and $\eta = 1$.

[15] Galí (2008, pp. 52-55) also chooses these values for the autoregressive parameters.

[16] As is standard with impulse response functions, the abscissa depicts time periods.

[17] Note that inflation and the policy rate are reported in annual terms.

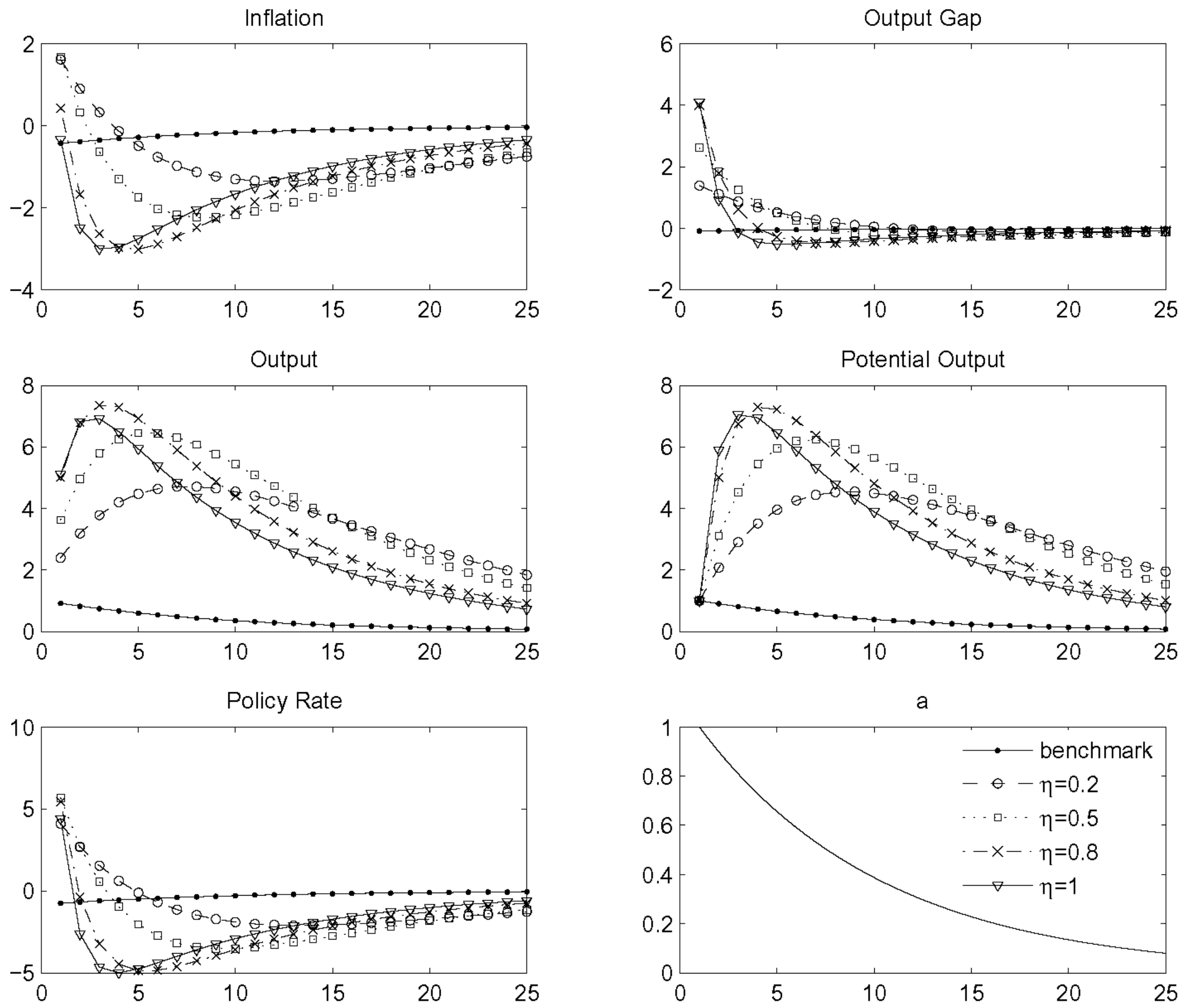
Figure 2: Responses to Monetary Policy Shock



dynamics. This is in line with empirical studies of responses of output and inflation to monetary and productivity shocks and hence a very desirable feature of the model (see Christiano et al., 2005 or Smets and Wouters, 2003). Further, the increased persistence requires a more sustained stabilization response in terms of interest rate stimulation by the central bank.

The respective responses to an *interest rate shock* are presented in figure 2. In the modified model the stimulus to the interest rate (lower right panel) contracts output (centered left panel) and exhibits a negative impact to potential output (centered right panel) whereas in the benchmark framework productive capacity is not affected at all by the interest rate impulse. According to the strength of supply-side adjustment in the modified

Figure 3: Responses to Technology Shock



model falling output leads to a graded decline in productive capacity. As a consequence, within the modified model the fall in the output gap firstly is more pronounced than in the benchmark setup (upper right panel) but catches up rather fast and finally tends to overshoot the reference adjustment path. This characteristic becomes stronger the higher the value of η.

Initially, inflation declines due to a negative output gap (upper left panel). However, in contrast to standard dynamics, the evolution of the inflation rate within the modified model is characterized by a hump-shaped course - which also is in line with empirical evidence - as well as by remarkable persistence, as noted above. In the modified model output gap dynamics and its consequences for inflation oblige the central bank to ease the monetary contraction more slowly, whereas in the benchmark model the restrictive impulse may be followed by a steady reduction of the policy rate (lower left panel).[18]

Figure 3 displays impulse responses to a *technology shock*. In the modified model an impulse to productivity (lower right panel) causes an expansion of potential output (centered right panel). Due to the straight forward-looking specification of the IS-curve output outperforms the rise of productive capacity (centered left panel) resulting in a positive output gap (upper right panel). In contrast to this, the reaction of output in the benchmark setup is remarkably weaker. In particular, the benchmark model exhibits comparably poor dynamics from a real supply-side stimulus.

According to the positive output gap inflation increases. Note again the hump-shaped response of this variable. As both inflation and the output gap rise, the policy rate has to be adjusted upwards in the first place.[19] A steadily declining output gap and the corresponding fall of the inflation rate lead to an easing of the initial monetary contraction and may even signal a strong interest rate cut, whereas in the reference framework the policy rate varies little. Within the latter output and potential output rise slightly, leaving the output gap nearly unchanged. As a consequence inflation dynamics are quite smooth so there is no need to adjust the policy rate strongly.

Moreover, the observed adjustment and interaction dynamics complement the interpretation of the model's stability characteristics addressed in the context of the determinacy investigation given in section 5. As described above, the coincidence of the forward-looking specification (provided by the New Keynesian benchmark framework) and procyclical supply-side adjustment evokes a specific overshooting characteristic of the output gap (and consequently of inflation) that forces the central bank to balance inflation and

[18] Although it may be a rather technical aspect we note that high parameter values of $\eta = 0.8$ and $\eta = 1$ even indicate a further rise of the policy rate due to an overshooting pattern of the output gap after the initial contraction. This is because of the induced fall of potential output which is documented in the overshooting behavior of the output gap.

[19] Note that output gap dynamics and inflation (as well as the corresponding reaction of the interest rate) to a technological shock crucially depend on assumptions with regard to the dynamic IS-specification. In the context of New Keynesian research that builds upon rational expectations and a stable permanent income mechanism that connects expected output gains to real supply-side impulses technological shocks cause an increase in output suggesting rising interest rates.

output gap dynamics instead of solely focusing on inflation. Take, for example, a deviation of inflation and the output gap from the steady state path of the same sign (e.g., caused by a monetary policy shock). In the benchmark framework, inflation and the output gap pick up to their steady state values steadily and in a smooth one-sided fashion. Within the modified model (e.g. for the adjustment corresponding to $\eta = 0.5$), as illustrated by the hump-shaped pattern (which corresponds to a change of sign with regard to adjustment dynamics) inflation crosses the zero-line (steady state value) at $t = 2$ and approaches the steady state value steadily until $t = 25$. The output gap crosses its steady state at $t = 4$ and fades out until $t = 20$. Consequently, between $t = 2$ and $t = 4$ the central bank observes diverging signals and may not be able to handle the dynamics by an interest rate adjustment that exclusively focuses on inflation.[20]

7 Welfare Analysis

Our investigation on stability issues suggests that the central bank's reaction parameter to variations of the output gap gets to play a prominent role concerning the determinacy of the model when potential output is endogenous to actual output. Further exploration whether this might also be the case from a welfare perspective, requires a criterion to evaluate the performance of monetary policy. In the literature, it has become common to use a second order approximation of the consumer's utility function in order to derive a welfare loss approximation, as for example in Rotemberg and Woodford (1999). However, within our analysis such a derivation would yield different loss functions for the benchmark framework and our augmented setup which in turn will rule out a clear comparison between both models.[21] Therefore, we focus on an ad-hoc welfare loss function which is widely used in the literature by authors such as Taylor (1979, p. 1276), Bean (1983, p. 807) or

[20] On the other hand, a very strong interest rate reaction to inflation will bring down inflation faster and, therefore, does not exhibit pronounced overshooting characteristics that have to be balanced by active output gap stabilization, see section 5.

[21] The reason for the different results for the welfare loss function is that its derivation involves the usage of the specification for potential output. However, this feature just constitutes the basic difference between the benchmark setup and the modified model.

Orphanides et al. (2000, p. 127). It expresses the welfare loss in terms of a weighted average of the variance of inflation and the variance of the output gap:

$$L = \left[\phi var(y_t - y_t^*) + var(\pi_t)\right]. \tag{10}$$

Here, ϕ is the relative weight of the variance of the output gap. Note that this welfare loss function has the same form as the welfare loss function obtained by a second-order approximation of the consumer's utility function in Galí (2008, p. 82)'s benchmark New Keynesian model. There, ϕ takes on the value 0.02, and we adopt this calibration for the simulations to follow.

Regarding the basic New Keynesian model, it is a well known result that the welfare loss is minimized by reacting aggressively to inflation but not at all to the output gap (so called strict inflation targeting). However, as can be observed in Galí (2008, p. 82), this result is obtained by looking at ν_t not as a monetary policy shock but as "driving force" proportional to the deviations of potential output from steady state output. This reinterpretation is necessary in order to start the analysis from an interest rate rule that only contains variables which are observable in real time (i.e., the output gap and therewith potential output is not a component of the rule) but then rewrite it in a way that reintroduces the output gap so as to harmonize the analysis with previously found model interrelations.

In order to retain the monetary policy shock in the model we stick to the originally proposed interest rate rule with the original interpretation of ν_t and tackle the issue of unobservability of potential output in a different way described in section 8.

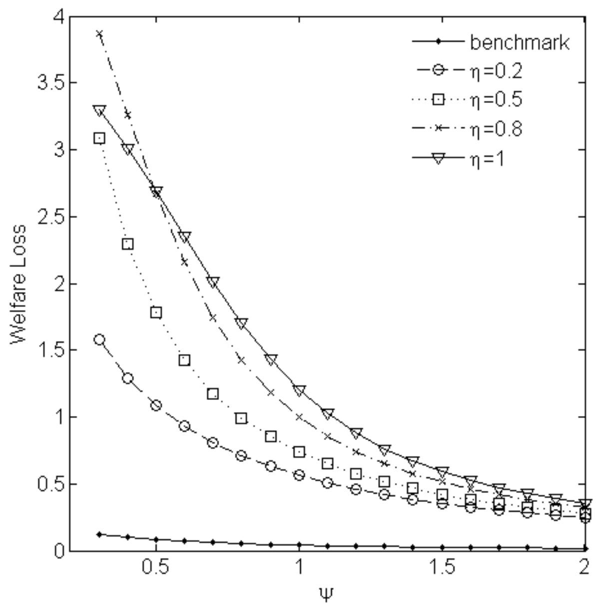
Hence, we have to evaluate the question whether the role for output gap stabilization differs in the original benchmark model and the modified model featuring endogenous potential output, as proposed in section 4, from a welfare point of view. To shed light on this aspect, we apply the following procedure: For all parameter constellations of γ and ψ which yield a determinate system (the ranges for the parameter values correspond to the investigation presented above), we calculate the welfare loss based on the implied variances of the output gap and inflation according to equation (10). Again, we alter the parameter values in 0.1-steps. The remainder of the parameters is calibrated as described above. Further, we check which reaction parameter constellation yields the minimum welfare loss. The resulting central bank reaction function is a so called optimized simple rule. As before, we perform the calculations for four different degrees of potential output endogeneity. As for the impulse response functions, we approximate the benchmark model by $\eta = \delta = 0$.

The results show that for the original benchmark model as well as for the augmented model the welfare loss is smallest if the central bank reacts aggressively to inflation *and* the output gap. In other words, the minimized welfare loss occurs for the highest possible parameter values of ψ and γ, irrespectively of the considered degree of potential output endogeneity.[22] What is more, for every γ the welfare loss declines for higher values of ψ. However, there is a considerable difference between the augmented and the benchmark model: The achieved reductions of the welfare loss by increasing ψ are much larger in the model with endogenous potential output than for the benchmark setup, and the relevance of this pattern more and more increases with the degree of supply-side adjustment to variations of the output gap. A graphical illustration is given in figure 4 that plots the welfare loss against the central bank's reaction parameter ψ for different values of η and for the benchmark model.[23]

The convex courses of the graphs indicate a positive but decreasing marginal benefit from the rise of ψ. Therefore, we reach the preliminary conclusion that output gap stabilization becomes relatively more important when potential output is endogenous to actual output. This finding may be explained as follows: In the extended model an aggressive reaction to inflation renders potential output to fall considerably in the next period and hence brings about a relatively quick supply-side adjustment of the output gap which by itself intensifies the inflationary pressure relative to a situation without procyclical supply-side effects. Therefore, a reaction to the output gap - which signals an interest rate change of opposite sign compared to the response to inflation - balances the reaction to inflation in

[22] The outcomes do not change if wider ranges of the parameter values are considered.
[23] The value of γ is fixed to 1.5 in the figure, but the picture looks similar for other values of γ.

Figure 4: Welfare Loss Against ψ



the sense that the output gap is stabilized in order to bring down inflation, hence reducing the variability of both variables.

8 Output Gap Uncertainty

Our analysis so far clearly favors active stabilization of the output gap rather than solely focusing on inflation dynamics. However, a popular critique of this policy implication is that in reality the output gap is measured with error and thus may not be a suitable variable to base policy decisions upon. Due to incomplete information about the current state of the economy and the unobservability of potential output the central bank faces data uncertainty with regard to output gap dynamics. As, in general, output gap data is only available with a considerable time lag monetary policy has to rely on estimated values. Diverging estimation results provided by different measuring techniques as well as the frequent and considerable data revisions extensively illustrate the disputable reliability of output gap measures and therefore raise concerns with regard to its usefulness for monetary policy (see European Central Bank, 2000, p. 39; Onatski, 2000, p. 31; Orphanides, 1999).

In particular, overestimation of potential output in times of weak factor-utilization and its underestimation during macroeconomic expansion evokes the risk of procyclical overreaction. Therefore, the central bank may have to fear an unanticipated course of productive capacity that ultimately classifies the original interest rate reaction as inadequate. Hence, a smoother conduct of interest rate policy, in the sense that it attributes less weight to such poorly measured output gap targets, is often suggested (e.g., Onatski, 2000, p. 32 or Willems, 2009, p. 23). With regard to the associated welfare implications of an explicit consideration of the output gap, McCallum (2001, p. 262) concludes that given the weak guide provided by real-time estimates of potential output *"[...] it is undesirable to respond strongly to the output gap."* Further, Orphanides et al. (2000, p. 139) argue that *"[...] such [measurement] error makes the output gap a less useful guide to setting the funds rate, and leads to an increase in the variability of output and inflation"*.

To evaluate the effective risk of suboptimal policy reactions to a poorly observable output gap in the context of endogenous supply-side adjustment we analyze the robustness of our model's welfare performance when the output gap is measured with error.[24] As proposed by Orphanides et al. (2000, pp. 124-127) we capture output gap mismeasurement by an additive observation distortion within the central bank's reaction function (see equation 11). Therefore, we augment equation (3) by an error term and specify its persistence by the following representation: $\xi_t = \rho_\xi \xi_{t-1} + \epsilon_t^\xi$. Here, ξ_t denotes the process describing the expost data revisions with regard to the exante estimate of the output gap and ϵ_t^ξ is white noise.

$$i_t = \rho + \gamma\pi_t + \psi[(y_t - y_t^*) + \xi_t] + \nu_t \tag{11}$$

Based on this specification we find that the relevance of output gap stabilization for the central bank's welfare performance depends on two aspects: First, the policy maker's

[24] The concept of robustness examines the ability of a central bank's strategy to guarantee desirable results for different macroeconomic specifications. Given the uncertainty regarding the exact state of macroeconomic aggregates robust policy rules are preferable. See, for example, McCallum (1988) and McCallum (1997).

success in identifying the current degree of capitacity-utilization - which is approximated by the assumed measurement error ξ_t - and second, the strength of macroeconomic distortions. More precisely, the optimal value of ψ proves to be sensitive to the relative strength of the measurement error (characterized by the values of σ_ξ and ρ_ξ) compared to the amplitude of technological and monetary shocks (characterized by σ_a and σ_ν).

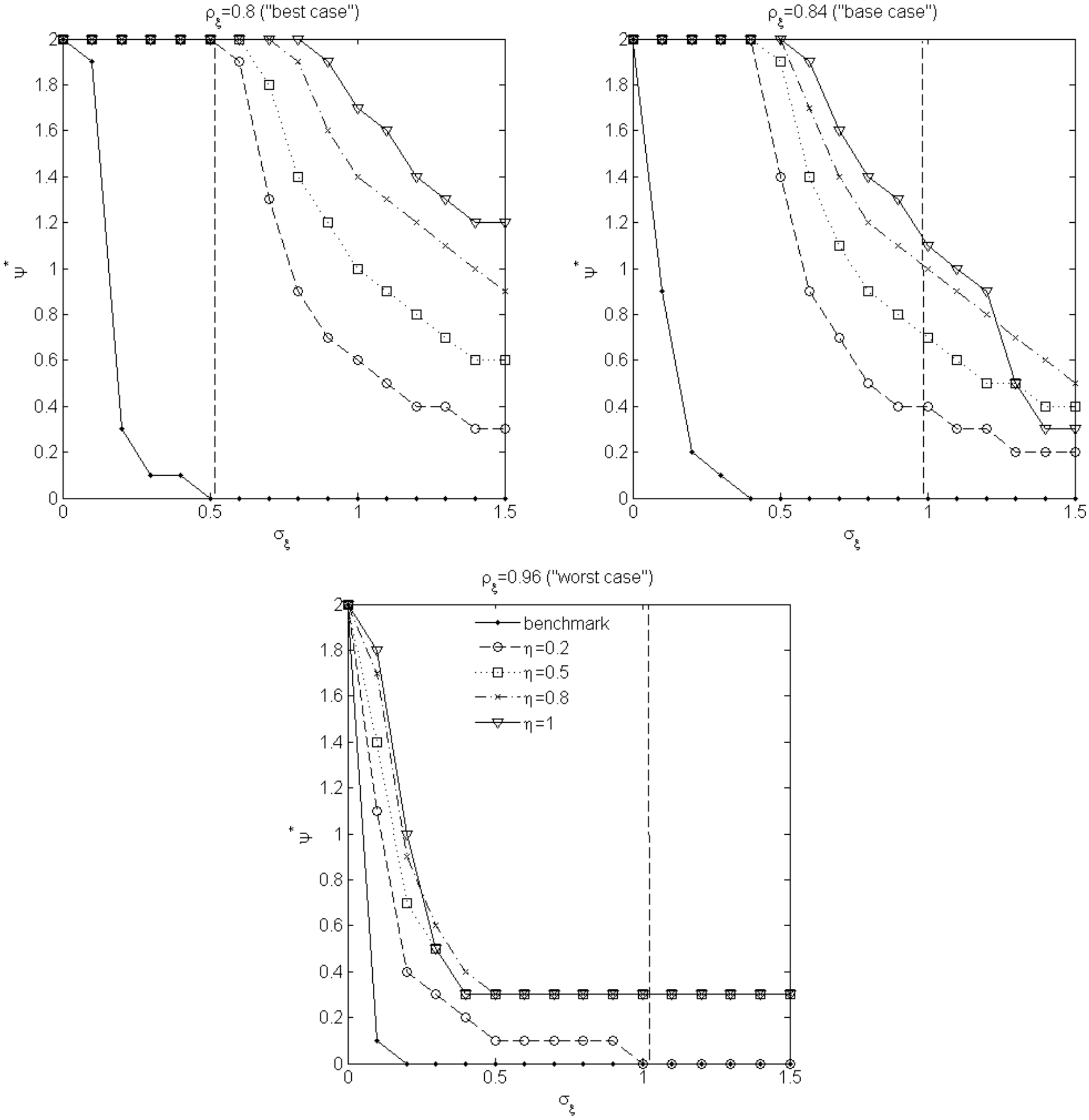
Following Orphanides et al. (2000, p. 125) with regard to the persistence of the measurement error we contrast three specifications: Within the *"best case"*-scenario ρ_ξ equals 0.80, the *"base case"* sets $\rho_\xi = 0.84$, for the *"worst case"*-specification ρ_ξ equals 0.96. Figure 5 illustrates the loss-minimizing reaction to the output gap ψ^* for these values of ρ_ξ and a respective range of σ_ξ (abscissa).[25] Again, varying intensities of procyclical supply-side adjustment will be accomodated by different values of η. Note that, for $\eta = \delta = 0$ we may approximate the respective implications for the benchmark model.

As mentioned above, in general, we observe that increasing mismeasurement (either approximated by a rising value of ρ_ξ or by an increase of σ_ξ) suggests a decrease of ψ and, therefore, classifies active output gap stabilization less attractive from a welfare point of view.

However, we observe that ψ^* increases with the strength of endogenous supply-side adjustment (given a sufficiently high value of σ_ξ). This is stated more precisely by the vertical dotted lines that designate different values of σ_ξ corresponding to the respective degree of mismeasurement as proposed by Orphanides et al. (2000, p. 125) in each panel. Thereby, the relevant values of ψ^* clearly support an improvement of the welfare performance if the output gap is actively stabilized by the central bank. For the *"best case"*-specification (upper left panel) a value of $\sigma_\xi = 0.51$ suggests $\psi \geq 2$ for each η. The *"base case"* (upper right panel, $\sigma_\xi = 0.97$) documents optimal values for ψ in the range of $0.4 \leq \psi \leq 1.2$, respectively depending on the size of the endogeneity-parameter η. Actually, within the *"worst case"*-scenario (lower panel, $\sigma_\xi = 1.09$) which is supposed to represent a compara-

[25] As implemented in section 6, again, we assume a constant value of $\gamma = 1.5$. The results do not change qualitatively for higher values of γ. Note that Orphanides et al. (2000) and our examination in sections 7 and 8 are based on the same welfare loss function which is illustrated in equation 10.

Figure 5: Optimal ψ given Output Gap Misspecification



bly strong measurement error we also observe that a positive ψ is suggested (even though this only holds for $\eta > 0.2$).[26]

Our findings are further strengthened by the underlying calibration that may even underestimate the relevance of ψ compared to the scale and persistence of the shocks suggested by Galí (2008, pp. 52-55) and introduced in the context of impulse response dynamics in section 6. For the simulation in figure 5 we stick to an empirically motivated calibration of

[26] Within this panel the constant value of $\psi^* = 0.3$ for $\eta = 0.5 = 0.8 = 1$ that results for $\sigma_\xi \geq 0.5$ reflects the fact that (given $\gamma = 1.5$) the system is still stable.

the macroeconomic distortions as proposed by Smets and Wouters (2003, p. 1142). This is supposed to provide an appropriate counterpart to the dimensioning of the policy maker's mismeasurement error estimated by Orphanides et al. (2000). Compared to the calibration of Galí (2008) our setup promotes a comparably small ψ^* as the macroeconomic shocks are weaker.[27] Therefore, the influence of output gap mismeasurement which itself reduces the attractiveness of output gap stabilization from a welfare point of view may by trend be overestimated in our simulation. Consequently, we interpret these insights as comparably strong results in favor of active output gap stabilization.

9 Conclusion

Policy implications of the present consensus view of stabilization policy depend on specific assumptions with regard to the equilibrium level of production. Thereby, the interpretation of equilibrium output rests on a separation of supply-side and demand-side adjustment to macroeconomic shocks promoting a dichotomy of short-term and long-term macrodynamics. In contrast to this, there are several channels that constitute procyclical stimulus of aggregate demand and changing factor-utilization to the accumulation and efficiency of an economy's productive capacity. Theoretical and empirical research strongly support the explicit consideration of supply-side adjustment to pronounced variations of aggregate demand within the context of simulation studies as the latter is supposed to trace a realistic pattern of macroeconomic adjustment dynamics.

Our augmentation of a common New Keynesian model framework by endogenous supply-side adjustment to changes in factor-utilization reveals remarkable differences compared to standard impulse response dynamics. In line with empirical evidence, we find rising persistence of inflation and output irrespectively of the type of shock that leads to the adjustment dynamics, requiring a more sustained stabilization response in terms of interest rate stimulation by the central bank. Moreover, we observe hump-shaped responses

[27] Calibration of the macroeconomic shocks suggested by Smets and Wouters (2003, p. 1142) is $\rho_a = 0.85$, $\sigma_a = 0.45$ and $\sigma_\nu = 0.09$, whereas Galí (2008, pp. 52-55) proposes $\rho_a = 0.9$, $\sigma_a = 1$, $\rho_\nu = 0.5$ and $\sigma_\nu = 0.25$.

of output and inflation for a productivity shock and a hump-shaped response of inflation for a monetary shock which is also an empirically desirable feature of the model.

Furthermore, both stability and welfare implications suggest that demand-side induced adjustment of potential output and its effects with regard to inflation dynamics should be incorporated within the central bank's reaction pattern. In particular, in contrast to standard New Keynesian implications, within the modified framework stability of the system requires a reaction to the output gap for a wide range of parameter values of the central bank's inflation coefficient. Besides this, welfare analysis proposes a more important role to the active stabilization of output gaps in order to minimize welfare losses than is suggested in the context of standard New Keynesian analysis.

The robustness of our policy implications can further be confirmed by incorporating various degrees of data uncertainty the policy maker might be confronted with when estimating the output gap in real time. In general, active stabilization of the output gap loses attractiveness when misspecification increases. On the other hand output gap stabilization systematically gains relevance the stronger the endogenous supply-side adjustment. For a set of empirically plausible calibration parameters active output gap stabilization clearly improves the welfare performance when potential output is endogenous to factor-utilization even when the central bank can only poorly asses the true value of the output gap.

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