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„New Theories of the Phillips Curve"

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Danksagung

Ich möchte diese Diplomarbeit meinen Eltern widmen, die mich Zeit meines jungen Lebens immer unterstützt haben bei dem unkonventionellen Weg, den ich gehen wollte. Ohne sie würde ich heute nicht da stehen, wo ich bin.

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Zu guter Letzt möchte ich der Republik meinen Dank aussprechen: Dadurch, dass das österreichische Bildungssystem noch nicht vollständig durchökonomisiert ist, kann man noch eine ursprüngliche universitäre Bildung jenseits von Kosten- und Nutzenüberlegungen genießen, die hilft, das Wahre, Gute und Schöne zu finden. Mögen künftige Generationen dieser Möglichkeit nicht beraubt werden.

Wien, im August 2008

Bernhard Stummer

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1 Introduction

"Accordingly we find that, in every kingdom, into which money begins to flow in greater abundance than formerly, every thing takes a new face: labour and industry gain life […]. In my opinion, it is only in this interval or intermediate situation, between the acquisition of money and rise of prices, that the encreasing quantity of gold and silver is favourable to industry. When any quantity of money is imported into a nation, it is not at first dispersed into many hands; but is confined to the coffers of a few persons, who immediately seek to employ it to advantage. […] The farmer and gardener, finding, that all their commodities are taken off, apply themselves with alacrity to the raising more; […] It is easy to trace the money in its progress through the whole commonwealth; where we shall find, that it must first quicken the diligence of every individual, before it encrease the price of labour."

David Hume: Of Money (1752)

1.1 Synopsis

Ever since the beginning of classical economics more than two hundred years ago with the works of Adam Smith, many discussions have been held about and much confusion was created by the interplay between nominal and real variables. According to classical economists, nominal variables like inflation can only affect nominal variables, and real variables like output can only affect real variables. This has been challenged from the very beginning. As the quotation above shows, great minds like David Hume have noted as early as in the 18^{th} century that monetary injections obviously do have some effect in the real world. Indeed, if it were not so, why would we care at all about nominal variables like inflation or interest rates?

The Phillips curve – the negative relation between inflation and unemployment – is situated at the heart of modern macroeconomics because it is concerned with interactions between real and nominal variables. Each standard textbook of macroeconomics devotes a chapter of its own to the tradeoff between inflation and unemployment, a tradeoff that has been called "inexorable and mysterious" by Nicholas Mankiw (2001). Nowadays there is a wide consensus in economics that nominal variables can affect real variables, at least in the short run. This impact is present in the Phillips curve. The Phillips curve has been found as a statistical relationship without an ample theoretical framework, but the latter one has evolved over the last decades. New socio-economic insights have been incorporated in the underlying theory of the Phillips curve, like the importance of expectations that resulted in the expectations-augmented Phillips curve.

This is where most macroeconomics textbooks end. But theory has not stopped to evolve from there. The importance of forecasting errors and price and wage rigidities has resulted in the formulation of the so-called new Keynesian Phillips curve (NKPC). But again, the NKPC has failed to provide a fully satisfactory theory that complies with theoretical considerations and practical observations.

Since then, several promising theories have emerged, like the productivity and wage growth Phillips curve by Ball and Moffitt, the sticky information Phillips curve of Mankiw and Reis, and the real wage rigidities Phillips curve by Blanchard and Galí. This is what this thesis is about. Its aim is to analyze and compare these latest theories of the Phillips curve. While empirical results are taken into account, this thesis will mostly deal with the theoretical foundations and the mechanisms at work in the different models.

1.2 Structure

This thesis starts with an introduction to the Phillips curve. It will be described how the Phillips curve has been found, how the theoretical framework has evolved to formulate the expectations-augmented Phillips curve, and how the Phillips curve can be derived formally from the aggregate supply relation. Furthermore, stylized facts are also given, and the acceptance of the Phillips curve in macroeconomic theory is discussed.

Chapter 3 elaborates on the new Keynesian Phillips curve (NKPC). It describes how new Keynesian economic theory improves the theoretical foundations of the Phillips curve. Furthermore, the new Keynesian Phillips curve is derived formally and an early attempt to enhance it – the hybrid NKPC – is shown. Finally, the deficiencies of the NKPC are discussed.

In chapter 4, new theories of the Phillips curve as mentioned before are examined: The wage aspirations and productivity growth theory by Ball and Moffitt is based on a standard Phillips curve as described in chapter 2. The sticky information theory by Mankiw and Reis as well as the real wage rigidities theory by Blanchard and Galí is based on a new Keynesian Phillips curve as elaborated in chapter 3. For each theory, a description of the main ideas behind it is given, a formal derivation is carried out, and its properties are discussed.

Finally, chapter 5 concludes by comparing the different new theories and by summarizing the main findings.

2 The Phillips Curve

This chapter gives some historical and theoretical background to the Phillips curve, from the early incarnation until the new Keynesian Phillips curve (which will however be left to the next chapter). This chapter starts with how the Phillips curve has been found as a statistical relation and how work has evolved to develop theoretical justifications. Afterwards the Phillips curve will formally be derived from the aggregate supply relation, and the difference between the short-run and the long-run Phillips curve is pointed out. Finally, stylized facts for the behavior of macroeconomic variables that are relevant for the Phillips curve are given, and the status quo of the Phillips curve in macroeconomic theory is discussed.

2.1 The Origins of the Phillips Curve

The Phillips curve is named after Alban Phillips, who in 1958 published an econometric survey about the behavior of unemployment and money wages in the United Kingdom from 1861 to 1957. Phillips did not have a macroeconomic model as a justification in his paper, but he rather made a statistical analysis with some theoretical thoughts.

Phillips argues that *"[w]hen the demand for labour is high and there are very few unemployed we should expect employers to bid wage rates up quite rapidly"* (Phillips, 1958, p. 283). So he states that a low level of unemployment leads to increasing wages. On the other hand he also says that this relationship is *"highly non-linear"*, because when high unemployment prevails, workers will not accept wage cuts, so wages only fall slowly. Phillips also states two other factors that affect the wage rates, namely the business cycle and the rate of change of retail prices (Phillips, 1958, p. 283). Phillips explores three periods separately (1861-1913, 1913-1948 and 1948-1957) and finds evidence for all three periods that a negative relationship between unemployment and the wage rate exists. (Phillips, 1958, p. 299)

It is worth noting that this statistical relationship actually has already been found by Irving Fisher in 1926 (Fisher, 1973). Still, in 1960 when Samuelson and Solow repeated the work of Phillips for the United States, they named this relation Phillips curve[1] (Samuelson & Solow, 1960). After their article, the Phillips curve *"rapidly became central to macroeconomic thinking and policy"* (Blanchard, 2006, p. 165) and was highly important for macroeconomic discussion in the 1960s.

2.2 Expectations-Augmented Phillips Curve

After the 1960s, the Phillips curve relation in its original form broke down. A new form, usually called the expectations-augmented Phillips curve, emerged, which is the topic of this chapter. At first, in order to find out why the original relation broke down, I will analyze the economic framework for which the original Phillips curve was valid.

Today we live in a period of permanent inflation. We are used to it, every year prices increase by some percent, wages increase by some percent, the general price level increases. The price level, to speak in statistical terms, somehow follows a random walk (with a positive drift). The last year inflation was negative in the USA was 1955 (Blanchard, 2006, p. 168), in Austria it was in 1953 that inflation was negative for the last time (WIFO, 2008). This has not always been the case. Before World War I, when the gold standard was still in effect, inflation was sometimes negative and rather followed a white noise (Mankiw & Reis, 2002, p. 1314). So at the time the Phillips curve was (re-)discovered, analysis were done for periods of white noise inflation. In such periods – when households have got no expectations of inflation, or rather, expect zero inflation – the wage-price spiral, as already described in the article of Phillips, is at work:

- Low unemployment leads firms to bid up wages
- Higher wages make firms increase their prices
- Higher prices lead employees to bargain for higher wages

So we can see how in this framework a low unemployment leads to an increase in inflation. However, the economy is not that simple. The Phillips curve relation in this form broke down in the USA in the 1970s because it failed to incorporate correctly the economic behavior of human beings. Two things demonstrated this fact in the 1970s:

[1] In fact, at first they call it "Phillips schedule" (Samuelson & Solow, 1960, p. 186), later in the article they switch to "Phillips curve".

Firstly, the USA (and the world) was hit by two oil shocks. Secondly, as inflation became a permanent phenomenon, people began to expect inflation, leading them to account for inflation in wage negotiations. (Blanchard, 2006, pp. 169-170) To be able to analyze these influences, the model has been expanded to include expectations as well as price shocks. This incorporation rationalizes shifts in the Phillips curve (for an example see also chapter 2.4).

The Phillips curve in its standard textbook modern form states that inflation can be explained by three components: (Mankiw N. G., 2000, pp. 405-406)

- **Demand-pull inflation**: If unemployment is below its structural rate (u^n)[2], inflation tends to increase because of a higher aggregate demand.
- **Cost-push inflation**: This refers to supply shocks (ν). A supply shock leads firms to increase prices, which implies a higher inflation.
- **Expectations**: People form expectations (π^e) about inflation and take them into account when negotiating wages.[3]

Or, put formally:

$$\pi = \pi^e - \beta(u - u^n) + \upsilon$$

This equation is called the expectations-augmented Phillips curve. As we can see, the Phillips curve relation is existent, but in a different form: A negative relationship exists between unanticipated inflation and cyclical unemployment.

2.3 Derivation of the Phillips Curve

After having written about the origins of the Phillips curve and having explained its mutations in words, we will now formalize our observations and derive the Phillips

[2] Even if natural rate is the more commonly used term, in this thesis I will use structural rate of unemployment synonymously for natural rate of unemployment. There is nothing natural about unemployment, but it depends on a certain structure of an economy.

[3] This insight goes back to the work of Milton Friedman and Edmund Phelps in the 1960s. Friedman argued that, if nominal prices are not stable and high inflation is prevalent, then an increase in nominal wages is necessary just to keep real wages constant. High unemployment will lead to a slower rise in nominal wages compared to the anticipated rise in prices, not an absolute fall in nominal wages. Friedman summarizes: *"[T]here is always a temporary trade-off between inflation and unemployment; there is no permanent trade-off. The temporary trade-off comes not from inflation per se, but from a rising rate of inflation."* (Blanchard, 2006, p. 174)

curve mathematically. This chapter will show that the Phillips curve is an implication of the assumptions of the aggregate supply function. This derivation is based on (Romer, 2006, pp. 223-231).

I will start by defining the traditional Keynesian framework for macroeconomic policy analysis: The IS-LM model, or in this version with a more realistic money market, the IS-MP model. The IS-MP model will later be summarized as the AD (aggregate demand) function.

In the IS-LM model, there are two markets: The goods market and the money market. For now we assume that the prices are fixed. The goods market is defined the following way:

$$Demand: E = E(Y, r, G, T)$$

$$Equilibrium: Y = E(Y, r, G, T)$$

Demand E is an increasing function of output Y, a decreasing function of the real interest rate r, an increasing function of government expenditures G, and a decreasing function of taxes T. In this simple framework, supply can adjust instantly and produce all demanded output Y. Equilibrium requires demand to equal supply.

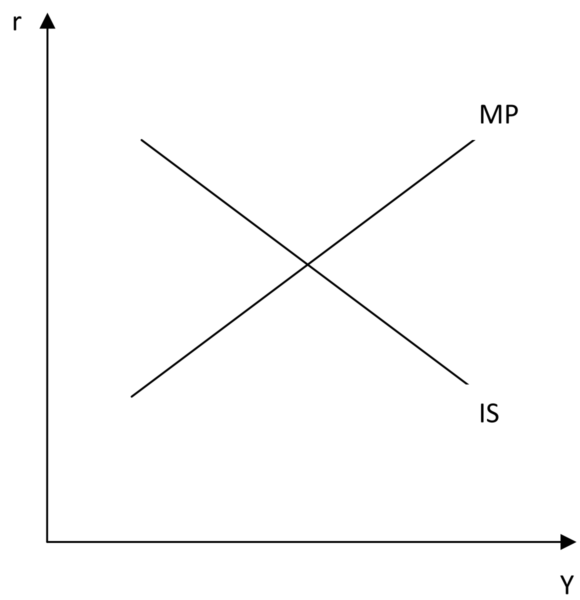
The IS curve (IS stands for investment equals savings, an implication of this model) shows all combinations where demand equals supply for given real interest rates r; it shows all equilibria in the goods market. Plotted on a (Y, r) diagram, it therefore is a downward-sloping curve, because demand decreases as the real interest rate increases.

The money market is usually defined with a demand and supply for money, the money supply given as exogenous. However, central banks target a certain interest rate and therefore endogenously adjust the money supply in order to achieve a certain interest rate. As it is more realistic and simpler, the money market can be modeled as a simple rule for the real interest rate:

$$Monetary\ policy\ rule: r = r(Y, \pi)$$

This rule expresses that the central bank adjusts the real interest rate according to output Y and inflation π: It is an increasing function in both variables, leading to an upward-sloping curve in the (Y, r) diagram in Graph 1. Note that in the short run the variable inflation plays no role, as the price level is assumed to be constant and expected inflation is zero.

Graph 1 puts together the goods market and the money market and leads to the unique equilibrium – the unique level of output and the real interest rate – that is compatible with an equilibrium in the goods market and in the money market:

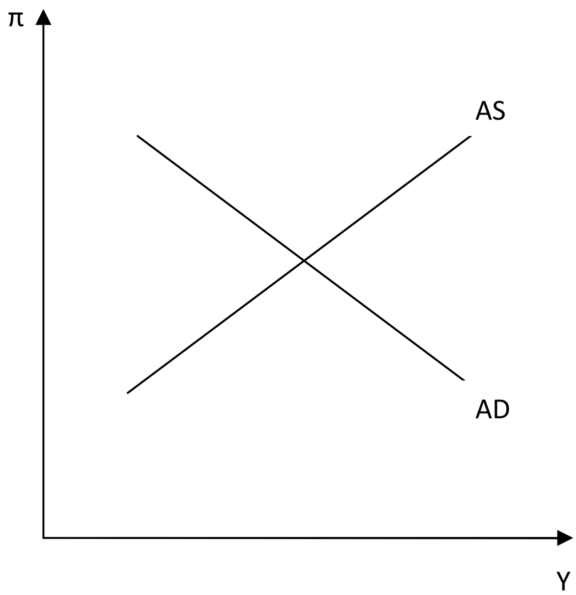


Graph 1: The IS-MP diagram

The IS-MP diagram has been derived successfully. Now we relax the assumption that prices are fixed. If prices are not fixed anymore, inflation can enter our equations. As there are no nominal variables in the goods market, it remains unchanged. However, it does enter the money market: If inflation increases, the nominal interest rate the central bank sets is increased for a given output. This means that the MP curve shifts upwards and the unique equilibrium of goods and money market changes

– output Y decreases, the real interest rate r increases. This can be plotted in a (Y, π) diagram (see Graph 2), where the AD (aggregate demand) curve is a downward-sloping curve, as I have just shown.

Graph 2 already includes the AS (aggregate supply) relation, which I have not derived yet. The AS curve represents the labor market. It can be seen in the graph that it is an upward-sloping curve that incorporates the essence of the Phillips curve: An increasing output Y (therefore decreasing unemployment) is accompanied by increasing inflation π. For this relation of course, the assumption that the price level is fixed has to be relaxed.



Graph 2: The AS-AD diagram

In the AD curve however, higher inflation is accompanied by lower output. This can be seen directly in the monetary policy rule: A higher inflation leads the central bank to set a higher real interest rate, which shifts the MP curve up in Graph 1 and leads to a lower output.

Therefore the positive relationship between inflation and output comes from the AS curve. There are different ways to model the labor market and derive the AS curve. The way presented here is based on Blanchard (2006, pp. 129-133). Different specifications of the labor market that lead to an analytically similar AS curve can be found in (Romer, 2006, pp. 242-251).

The labor market consists of employees who supply and firms who demand work. Employees demand (real) wages, firms set prices; therefore the market is modeled the following way.

$$Wage - setting: \frac{W}{P^e} = F(u, z)$$

$$Price - setting: \frac{P}{W} = 1 + \mu$$

$$Equilibrium: F(u^n, z) = \frac{1}{1 + \mu}$$

The wage-setting relation states that the expected real wage (the negotiated wage divided by the expected price level P^e) is a decreasing function of unemployment u and an increasing function of other factors z (e.g. union power, labor laws). The price-setting relation states that firms not simply set the prices as their actual wage costs, but that they can charge a markup μ. Therefore, the idea of imperfect competition is incorporated into this model. In this simple framework, the only input for the aggregate production function is labor ($Y = Y(L)$), the costs of labor are the wages W. In equilibrium (u^n denotes the structural rate of unemployment), the real wage equals $\frac{1}{1+\mu}$.

Now I can define the AS curve from the labor market and finally show that the AS curve also implies the Phillips curve (Blanchard, 2006, pp. 166-173). At first, I eliminate the wage from the labor market demand and supply formulas, which yields the AS equation:

$$P_t = P_t^e(1 + \mu)F(u_t, z)$$

The price level depends on the expected price level P^e, markup μ, unemployment u, and the catchall variable z. The price level P increases if output increases: Increasing output Y is the same as decreasing unemployment u; if unemployment decreases, the wages increase (the function $F(u, z)$ increases), therefore prices increase.

I will now use the term $1 - \alpha u_t + z$ as a functional form of $F(u, z)$. Dividing by P_{t-1} yields (as $\frac{P_t}{P_{t-1}}$ equals inflation π_t, and $\frac{P_t^e}{P_{t-1}}$ equals expected inflation π_t^e):

$$1 + \pi_t = (1 + \pi_t^e)(1 + \mu)(1 - \alpha u_t + z)$$

Dividing by $(1 + \pi_t^e)(1 + \mu)$ yields:

$$\frac{1 + \pi_t}{(1 + \pi_t^e)(1 + \mu)} = 1 - \alpha u_t + z$$

By approximating[4] $\frac{1+\pi_t}{(1+\pi_t^e)(1+\mu)}$ as $1 + \pi_t - \pi_t^e - \mu$ the final form is reached:

$$\pi_t - \pi_t^e = \mu - \alpha u_t + z$$

Now I want to incorporate the structural rate of unemployment into this equation. The structural rate of unemployment is the rate of unemployment when the actual price level equals the expected price level ($\pi_t = \pi_t^e$), which makes the left side of the equation zero, and u_t can be replaced by u^n. This yields $u_n = \frac{\mu+z}{\alpha}$.

This term can be put back into the previous equation:

$$\pi_t - \pi_t^e = -\alpha(u_t - u^n)$$

We have successfully derived the negative relationship between unanticipated inflation ($\pi_t - \pi_t^e$) and cyclical unemployment ($u_t - u^n$) from the aggregate supply function – the Phillips curve.

2.4 The Short-Run and the Long-Run Phillips Curve

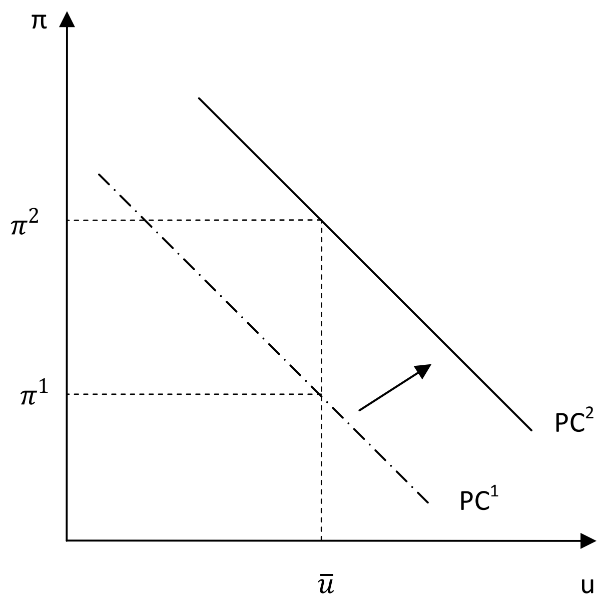
The expectations-augmented Phillips curve we have just derived in the last chapter expresses the short-run tradeoff between inflation π_t and unemployment u_t – the short-run Phillips curve. To show how parameter changes influence the Phillips curve, I first put the last formula into a different form:

[4] Mathematically this is a good approximation if inflation, expected inflation, and the markup are reasonably small (say <10%). As the Phillips curve only is empirically valid for relatively stable economies with values in this range, we can apply this approximation.

$$\pi_t = \pi_t^e - \alpha(u_t - u^n)$$

As we can see in this formula, the relationship between π_t and u_t depends on the values of expected inflation π_t^e, the structural rate of unemployment u^n, and the coefficient α that represents the influence of cyclical unemployment on unanticipated inflation.

If one of these parameters changes, the Phillips curve shifts as well. Graph 3 shows how the Phillips curve shifts to the right if expected inflation rises from π^1 to π^2. If expected inflation rises, for each value of u_t people expect a higher inflation, therefore the curve has to shift to the right. This means that the tradeoff gets worse, because for each value of unemployment, inflation is now higher than before.

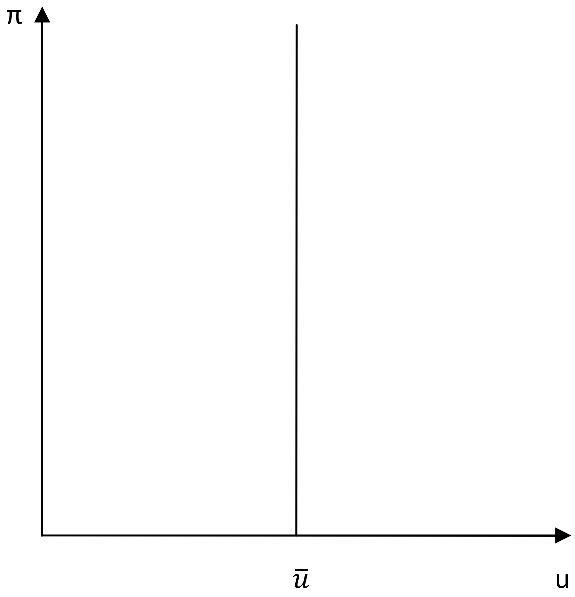


Graph 3: The short-run Phillips curve shifts if expected inflation changes

A similar concept to the structural rate of unemployment is the non-accelerating inflation rate of unemployment (NAIRU): It is the rate of unemployment for which inflation remains stable, therefore it is equivalent to the structural rate of unemployment.

As long as inflation is higher than expected inflation, unemployment is lower than the structural rate. However this cannot be sustained forever, as expectations adapt and therefore in the long run, unemployment will return to its structural level.

As unemployment will return to the structural level regardless of the inflation rate, it is compatible with every level of inflation, which is shown in Graph 4:



Graph 4: The long-run Phillips curve

In the long run, only money growth can determine the price level and the inflation rate, without having real effects: This can also be seen in Graph 4, no inflation rate has got an effect on the unemployment, a real variable.

2.5 Stylized Facts of the Aggregate Behavior of Inflation and Unemployment

After having discussed the origins of the Phillips curve and having derived it formally, it is time to have a look at the real-world economy: How do macroeconomic variables behave empirically? This information is needed in order to judge later on how well a model fits with these stylized facts[5]. I will also discuss if there is empirical evidence for nominal rigidities in prices and wages, which will be common assumptions for new models of the Phillips curve, as it will be seen in chapter 3 and 4.

The main macroeconomic actor who can influence inflation is the central bank, and the main policy instrument of the central bank is monetary policy. Therefore the

[5] Stylized facts are empirical observations that have been made so many times that they are widely perceived to be true.

question is: How do macroeconomic variables like the gross domestic product (GDP), inflation and unemployment react to monetary policy?

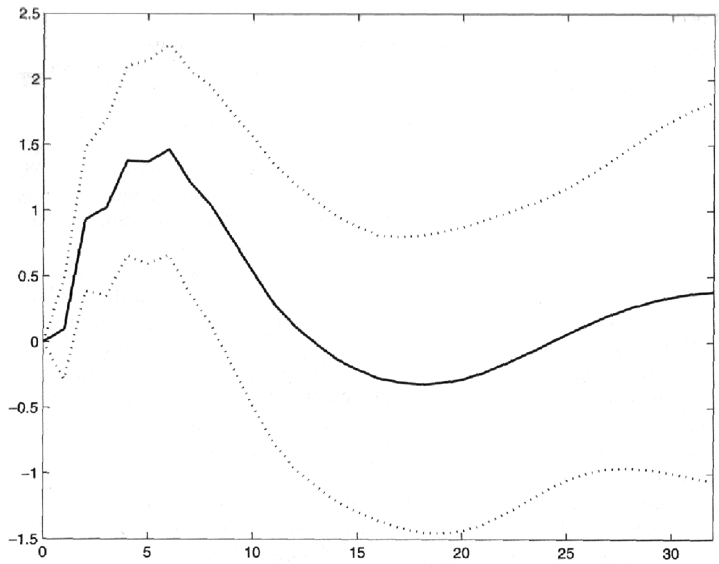
The following stylized facts are usually given on the aggregate behavior of macroeconomic variables: (Mankiw N. G., 2001, pp. C53-C58)

- Disinflations cause recessions: A disinflation by a central bank is typically followed by a recession. Even though the Lucas critique[6] states that costless disinflations should be possible, this is empirically not the case (one reason for this are contracts for a longer time period).
- Inflation is persistent: Inflation is a highly persistent variable with an autocorrelation close to 1.
- Monetary shocks have a delayed effect: The effect of shocks to monetary policy is delayed and gradual.

Now that we have seen these stylized facts, I want to verify whether this common knowledge fits with reality; therefore I will analyze empirical studies about the reaction of macroeconomic variables to monetary shocks.

The first stylized fact is that disinflations cause recessions. In a study of 28 disinflation episodes in nine countries, Ball (1993) finds that in 27 of these cases, a disinflation is accompanied by a recession. Blanchard (2006, pp. 196-200) describes similar observations: Disinflations causes an increase in unemployment, and the reaction of inflation to monetary policy has got a delay of about one to two years. A typical example of a disinflation is the Volcker disinflation (named after the then chairman of the Federal Reserve Board) of the early 1980s, which reduced inflation from 13.3% in 1979 to 3.8% in 1985, but unemployment increased from 5.8% in 1979 to 7.2% in 1985, peaking at 9.7% in 1982. Romer (2006, p. 260) also investigated six periods of disinflation in the United States and found that all of them were followed by recessions.

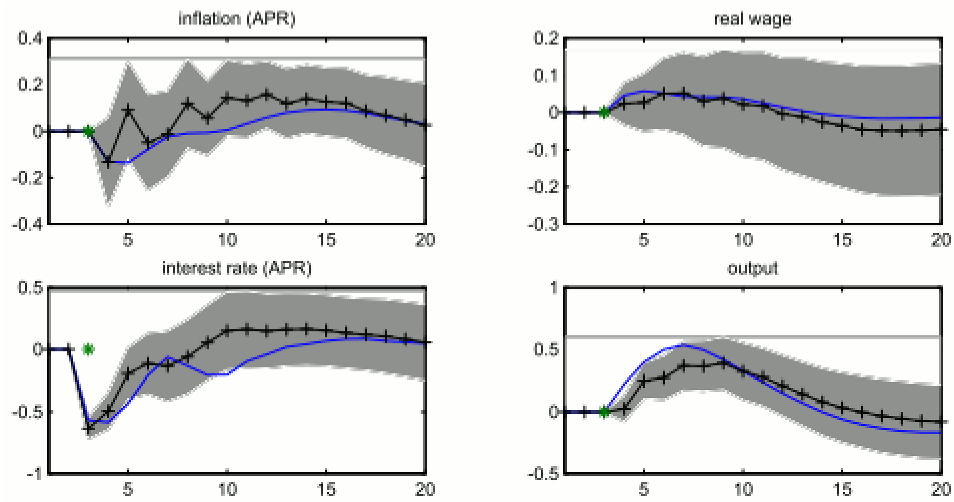
[6] The Lucas critique states that it is unreasonable to predict the effects of policy changes by past economic behavior. In the case of policy changes, it is possible that the economic behavior changes, therefore economic models might need to be adapted as well.



Graph 5: Impulse response of real GDP to an expansionary monetary shock.
Source: (Christiano, Eichenbaum, & Evans, 2001) in (Woodford, 2003, p. 175)

The next two stylized facts concern the delayed and gradual effect of monetary policy and the inertia of inflation. Graph 5 shows the estimated response of real GDP to an expansionary monetary shock according to a structural VAR (vector autoregression) model. The horizontal axis represents the time in quarters, while the vertical axis measures the effect of the unanticipated interest rate reduction on real GDP in percentage points. In the graph it can be seen that as expected, at first there is an increase in real GDP, which however returns so its initial level after some time.

Graph 6 shows us more detailed results for the behavior of different macroeconomic variables in response to an expansionary monetary shock, now including empirical data. The solid line represents the response of the model of Christiano, Eichenbaum and Evans, while the line with the points represents the observed data. The grey area is the standard confidence interval of the data. On the x-axis we have again time in quarters, on the y-axis the percentage deviation of the respective variable from its unshocked level.



Graph 6: Impulse response of macroeconomic variables to an expansionary monetary shock
Source: (Christiano, Eichenbaum, & Evans, 2001, p. 43)

The common assumptions about the behavior of these aggregate variables are confirmed: In the case of an expansionary monetary shock the interest rates falls quite sharply, and output rises quite sharply. We also see that the effect of the monetary shock is more persistent on output than on the interest rate. In fact, output reaches its peak when the interest rate has already returned to its initial level. We also see the inertia in inflation, despite the sudden change in output and interest rate, inflation remains relatively stable and rises only slowly.

Empirically we can also observe a stickiness of prices and wages. Christiano, Eichenbaum and Evans find that wage contracts last on average 3.3 quarters, while price contracts last on average 2 quarters. However, the estimate of the duration of wage contracts is significantly different from zero, while the estimate of price contracts is only slightly so. This implies that there is more stickiness in wages than in prices, a plausible result, as wage contracts are fixed for a longer period, while prices can be changed relatively flexible by the firm, even if they do not do so very often. The authors also find that their model performance relies much more on the assumption of sticky wages than on the assumption of sticky prices. (Christiano, Eichenbaum, & Evans, 2001, pp. 24-28)

2.6 Acceptance of the Phillips Curve in Macroeconomic Theory

The second chapter will be closed with a discussion on the status quo of the Phillips curve in macroeconomic theory.

For an outsider, it might have the appearance that discussions in economics are highly political, and depending on which school of thinking is more influential at the moment, certain ideas are more popular. But this is not the case. The evolution of the Phillips curve is a good example for this. If it was heavily discussed at the beginning, somehow forgotten since the 1970s and if it is now back, it is because of advances in macroeconomic theory. The first discussions were merely statistical and did not have a fundamental theoretical model. The first models constructed were too simple and did not incorporate major economic forces. This is the reason for the “disappearance” of the Phillips curve since the 1970s. The new theories described in this work all incorporate important economic insights, which is the reason why they provide a better fit with reality.

The crucial axiom of the Phillips curve is monetary non-neutrality. There is a wide consensus that money is non-neutral in the short-run. In the long run it is generally accepted that money is neutral because it is a nominal variable and therefore cannot affect output or the real interest rate. (Blanchard, 2006, p. 151) Different empirical studies are analyzed by Romer (2006, pp. 258-264) who finds that many studies show that monetary shocks are followed by output movements in the same direction.

Monetary non-neutrality in the short run as well as monetary neutrality in the long run are widely accepted in economics. However some economists even doubt that there are substantial real effects. In his macroeconomics textbook, Barro for example presents his students the following conclusion:

"Overall, the theory does allow for some relationships between nominal and real variables, but the sign of the interaction depends on the nature of the underlying disturbance. The key theoretical proposition, however, concerns monetary neutrality. Purely monetary disturbances, in the sense of changes in the monetary base, have no real effects. Although these monetary disturbances can create substantial variations in prices and other nominal variables, we still predict no response in the aggregates of output, employment, and so on."

Robert Barro (1993, p. 490)

Barro (1993, p. 494) also suggests that the Phillips curve even has got the "wrong" direction (that is, a positive correlation between unemployment and inflation) in the United Kingdom from 1947 to 1990 and also does not exist in the long run in an international comparison. Concerning short-term influences he states that it might be that it is not money that affects the economy, but the economy that affects money: The quantity of money is determined by economic forces and not set exogenously. (Barro, 1993, pp. 498-506) He concludes that *"[t]here is some suggestion that monetary nonneutrality is significant, but the evidence is not very strong"* (Barro, 1993, p. 508). Concerning persisting effects of monetary disturbances on real variables (hysteresis), he believes that households have enough information about prices and the only effect could be that investment decisions done under price confusion[7] are still followed (Barro, 1993, p. 525). He also investigates new macroeconomic theories that incorporate incomplete information into a classical framework, but again he believes that effects resulting from this cannot be a key explanation of business cycles as *"the costs of obtaining information about money and prices are not very large"* (Barro, 1993, p. 535).

This example shows that even the most fundamental facts of the relation between real and nominal variables in the short run, while accepted by a majority of economists today, are disputed by renowned economists like Barro. It is not primarily a discussion about theory – any wrong theory would not survive for a long time – but

[7] Price confusion means that the real price of something is not known certainly. This can be the case for example during periods of change in prices, or if there are complex pricing systems.

about the absolute and relative impacts of diverse effects. As often in economics, there are several economic forces at work at the same time which sometimes produce opposing effects.

Even though it has been shown in this chapter that there are some discussions about the validity of monetary non-neutrality in the short run, the vast majority of economists believes in relevant real effects of monetary policy. This is confirmed empirically, as it has been shown in chapter 2.5. The wide consensus can be summarized in two short statements: Money is non-neutral in the short run. Money is neutral in the long run.

3 The New Keynesian Phillips Curve

The previous chapter showed that the Phillips curve was found as an empirical observation and later on was enhanced by a macroeconomic theory that was derived from psychological insights about the economic actors. In this form the Phillips curve offered a wide area for attacks: Firstly, although expectations were incorporated, they were backward-looking expectations which contradicts the general economic assumption of having rational individuals. Secondly, the Phillips curve was criticized for not having microfoundations: Many building blocks of its theory were based on psychological insights about the aggregate behavior of the economic actors and on the interplay between aggregate variables. Research parried these attacks and incorporated new ideas that finally cumulated in the formulation of the new Keynesian Phillips curve (NKPC).

3.1 New Keynesian Economics

The classical economic framework with perfect competition and complete information does not allow for non-neutrality of money. According to classical economists, nominal variables can only affect nominal variables, and real variables can only affect real variables. This classical dichotomy was attacked on a large scale by John Maynard Keynes, whose book "The General Theory of Employment, Interest, and Money" is considered to be the foundation of modern macroeconomics. Keynes argued that previous classical economics were a particular case of the economy, valid only for the prevalence of perfect markets that are in equilibrium. He claimed that his economic theory had more explanatory power for the more general case, when not all resources are utilized and demand falls below its full-employment level. However, his reasoning was derived mainly from psychological insights about the behavior of economic actors. His theory allowed space for criticism, for example by monetarists or advocates of the importance of rational expectations.

Economists that stood in the Keynesian tradition like Mankiw, Woodford or Blanchard responded to these critics by incorporating some of their valid arguments and by providing microeconomic foundations for Keynesian theories, or actually reasoning derived from microeconomic theory. These works build the basis for new Keynesian economics, which includes the central ideas of Keynesian economics (like rigidities, imperfect markets, and the non-neutrality of money) and provides microfoundations for them.

The ideas of new Keynesian economics offer the basis for the new Keynesian Phillips curve. Important starting points where the works of Gordon and Taylor, who incorporated monetarist and rational expectations insights. Taylor developed a model with staggered wage setting which was consistent with rational expectations: The rigidity comes from the assumption that wages were fixed for some periods, and each period some new contracts were made (so the contracts are revised in a staggered way). Taylors work had several implications; most importantly he highlighted a new monetary policy tradeoff between output and inflation. However, critique was raised that in the USA only a small fraction of the labor contracts are made for multiple periods, and the microeconomic foundations were sketchy. (Goodfriend & King, 1997, pp. 16-19)

The next wave of research on the new Keynesian Phillips curve shifted the focus from wages to prices. Besides being easier to model, there is a theoretical explanation for this shift as well: The mere observation of wage rigidities does itself not prove any allocative consequences of this rigidity. Employment is an ongoing relationship, the effective cost of increased employment does not need to equal the wage paid, wages might be smoother than the effective costs of labor. Employees benefit because they have a preference for a smoother income stream. On the other hand, the observed rigidity in prices is more likely to have allocative consequences, as the relationship between consumers and producers more resembles a market than the one between producers and employees. (Woodford, 2003, p. 140)

In order to rationalize rigidities in the price setting, the following assumptions are needed that contradict classical assumptions about the market, but that are compatible with observations about the economy: There is imperfect competition, thus firms are modeled as monopolistic competitors. This assumption rationalizes the observation that there are not very large changes in sales in response to small changes in market conditions. E.g., in the framework of perfect competition and identical goods, in the case of a decrease in the price, the firm that fails to change its price would suddenly loose all of its sales. (Woodford, 2003, p. 144) Another important implication is that firms are price setters and can charge a markup over marginal costs. In a classical framework, all actors are price takers, the market sets the price. Furthermore, as the price equals the marginal cost of the firm, in fact a firm would not be able to adjust its production if demand rises: An increase in output means an increase in the marginal costs, as the market price equals the marginal costs, it would be a loss transaction. If however the price is already higher than the marginal cost, then a firm has got an incentive to increase output if the demand rises. In the case of an economic expansion, marginal costs increase because the firm needs to pay higher wages in order to produce the additional output. Therefore there is a procyclical movement of real wages and marginal costs. The imperfect competition framework also is an explanation why the level of employment and output is too low on average. Imperfect competition itself however does not explain the stickiness of prices. The stickiness of prices can be explained by the prevalence of menu costs[8]. Furthermore, sticky prices are a simple feature of the economic environment. (Goodfriend & King, 1997, pp. 19-21) Sticky prices can be better explained by transaction costs[9]: The main benefit of less frequent price changes is not lower menu costs, but lower information gathering and bargaining costs. (Woodford, 2003, p. 142)

The common methodology to include sticky prices comes from Guillermo Calvo (1983). Calvo enhanced the work of Taylor, who in 1980 developed a model of staggered contracts. The crucial difference of the Calvo model is that the pricing decision comes directly from the firm’s profit maximization, under the constraint of time-dependent price adjustment. (Galí & Gertler, 1999, p. 198). Optimal price setting is important because it highlights the importance of expectations. (Woodford, 2003, p. 141) Calvo pricing assumes that in any period, only a fixed random fraction of the firms

[8] Menu costs means that there are real costs when changing nominal prices. The term is derived from the scenario that restaurants have to print new menus if they change prices, which faces them with real costs.

[9] Transaction costs are all costs related to an economic exchange, besides the actual cost of the good or service. Examples are information gathering costs, bargaining costs, and settlement costs.

is able to adjust prices. This may not be a particular realistic assumption; however its purpose is to reflect the empirical fact that firms do not typically adjust prices each period.

To summarize, the following insights of new Keynesian economics combined with classical assumptions provide the synthesis for the new Keynesian Phillips curve:

- Rigidities: Because of transaction costs and imperfect information there is some kind of rigidity, whether it is in the labor market (sticky wages) or in the goods market (sticky prices).
- Imperfect competition: Firms produce a differentiated good and therefore have got some market power, which allows them to charge a markup over marginal costs.
- Rational expectations: Economic actors use all available information in order to form expectations and therefore do not have expectations that are systematically wrong.
- Microeconomic assumptions: Firms maximize their profits and individuals maximize their utilities.

3.2 Derivation of the New Keynesian Phillips Curve

The following derivation is based on (Whelan, 2007). I start with a new Keynesian economic framework with monopolistic competition and Calvo pricing (as described in the previous chapter). In any period each firm has got the fixed probability $1-\theta$ to be able to adjust prices. So the probability that the price cannot be changed is θ. When a firm is able to change the price of its differentiated product, it has to set it optimal in order to maximize expected profits. Therefore the following loss function is formulated:

(I) $L(z_t) = \sum_{k=0}^{\infty} (\theta\beta)^k E_t\{z_t - p_{t+k}^*\}^2$

The losses are the discounted sum of the difference between the chosen price z_t and the optimal price p_{t+k}^*. This difference describes the loss in profits of the firm. The quadratic function is used for modeling purposes, it is assumed to be an approximation to the unknown profit function. When a firm adjusts its price, it has to consider that this price is fixed for an unknown number of periods. Note that the losses are not only discounted by the time preference β, but also by the probability θ to not be able to reset the price. The firm wants to minimize its expected losses, the price it sets now is not set for an infinite time, therefore the losses are also discounted by θ.

Because we are looking for the optimal reset price z_t, we apply the first-order condition and differentiate (I) with respect to z_t:

(II) $L'(z_t) = 2\sum_{k=0}^{\infty}(\theta\beta)^k E_t\{z_t - p_{t+k}^*\}$

By setting (II) equal zero and taking out z_t (which we are allowed to do, as it is constant and does not depend on k, and $E_t\{z_t\} = z_t$), we have:

(III) $[\sum_{k=0}^{\infty}(\theta\beta)^k]z_t = \sum_{k=0}^{\infty}(\theta\beta)^k E_t\{p_{t+k}^*\}$

By applying the geometric sum formula to reduce $\sum_{k=0}^{\infty}(\theta\beta)^k$ to $\frac{1}{1-\theta\beta}$, we get:

(IV) $z_t = (1-\theta\beta)\sum_{k=0}^{\infty}(\theta\beta)^k E_t\{p_{t+k}^*\}$

This formula states that the firm sets the price z_t as a weighted average of the future prices it would set if there were not any price rigidities. The optimal price p_t^* can be expressed as $p_t^* = \mu + mc_t$: The optimal price is the sum of the marginal costs $mc_t$and a markup μ. The firm can impose this markup because we have a situation of monopolistic competition. The markup is assumed to be constant over time (therefore it does not have a time index). By substituting this optimal price into (IV), we have derived the optimal reset price:

(V) $z_t = (1-\theta\beta)\sum_{k=0}^{\infty}(\theta\beta)^k E_t\{\mu + mc_{t+k}\}$

In order to be able to describe the behavior of aggregate inflation, I first define the price level in this economy:

(VI) $p_t = \theta p_{t-1} + (1-\theta)z_t$

It can easily be seen that the aggregate price level is determined by the price level of the last period (because θ firms could not adjust prices) and by the optimal reset price z_t that $1-\theta$ firms were able to set.

Because (V) follows a first-order stochastic difference equation, (V) can also be written as[10]:

(VII) $z_t = \theta\beta E_t\{z_{t+1}\} + (1-\theta\beta)(\mu + mc_t)$

Now, we can rearrange (VI) as $z_t = \frac{1}{1-\theta}(p_t - \theta p_{t-1})$ and equate it with (VII), whereas $E_t\{z_{t+1}\}$ is also replaced with $\frac{1}{1-\theta}(E\{p_{t+1}\} - \theta p_t)$:

(VIII) $\frac{1}{1-\theta}(p_t - \theta p_{t-1}) = \frac{\theta\beta}{1-\theta}(E_t\{p_{t+1}\} - \theta p_t) + (1-\theta\beta)(\mu + mc_t)$

By expressing the inflation rate π_t as $p_t - p_{t-1}$ and rearranging (VIII) we get:

(IX) $\pi_t = \beta E_t\{\pi_{t+1}\} + \frac{(1-\theta)(1-\theta\beta)}{\theta}(\mu + mc_t - p_t)$

This is the standard formulation of the new Keynesian Phillips curve. We see that the inflation rate depends on next period's expected inflation rate $E_t\{\pi_{t+1}\}$ and the difference between the optimal price $\mu + mc_t$ and the current price level p_t. It is also possible to restate this and say that inflation depends on real marginal costs $mc_t - p_t$.

There are several ways to explain why real marginal costs affect inflation:

"Firms in the Calvo model would like to keep their price as a fixed markup over marginal cost. If the ratio of marginal cost to price is getting high (i.e. if $mc_t - p_t$ *is high) then this will spark inflationary pressures because those firms that are re-setting prices will, on average, be raising them."*

(Whelan, 2007, p. 7)

Another possibility to explain the mechanism behind this equation is:

"Intuitively, because [firms] (a) mark-up price over marginal costs, (b) are forwardlooking, and (c) must lock into a price for (possibly) multiple periods, they base their pricing decisions on the expected future behavior of marginal costs."

(Galí & Gertler, 1999, p. 200)

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[10] This is a bit tedious. To start, we know that a first-order stochastic difference equation of the form $y_t = ax_t + bE_t\{y_{t+1}\}$ can be solved as $y_t = a\sum_{k=0}^{\infty} b^k E_t\{x_{t+k}\}$. Now (V) follows a first-order stochastic difference equation with $y_t = z_t$, $x_t = \mu + mc_t$, $a = 1-\theta\beta$, and $b = \theta\beta$. Therefore, (V) can be expressed as $z_t = \theta\beta E_t\{z_{t+1}\} + (1-\theta\beta)(\mu + mc_t)$.

To simplify the new Keynesian Phillips curve equation (IX), I define mc_t^r as the deviation of the frictionless optimal price $\mu + mc_t$ from the current price level p_t: $mc_t^r \equiv \mu + mc_t - p_t$. Then (IX) can be written as:

(X) $\pi_t = \beta E_t\{\pi_{t+1}\} + \frac{(1-\theta)(1-\theta\beta)}{\theta} mc_t^r$

Empirically, the real marginal costs are difficult to observe, therefore the output gap y_t is often used as a proxy for real marginal costs. A relationship of $mc_t^r = \lambda y_t$ is assumed. Then (X) can be written as (where γ corresponds to $\frac{\lambda(1-\theta)(1-\theta\beta)}{\theta}$):

(XI) $\pi_t = \beta E_t\{\pi_{t+1}\} + \gamma y_t$

Such a formulation of the NKPC can be estimated empirically.

3.3 The Hybrid New Keynesian Phillips Curve

The standard new Keynesian Phillips curve, which is based on a Calvo model of sticky prices, was extended by Galí and Gertler. They included a subset of firms that use a backward-looking rule – naïve expectations – to set prices. As I will discuss in the next chapter, the NKPC has got several deficiencies, one of which is that observed inertia in inflation is unexplained. The hybrid NKPC tries to ameliorate this deficiency by including backward-looking firms.

The model starts off with a standard new Keynesian Phillips curve as described in the previous chapter: Each firm is able to adjust its prices in any period with a fixed probability $1 - \theta$. This is the first type of firm, the forward-looking type. Now a second type of firm is introduced: The second type sets the price according to the past behavior of the aggregate price level. The second type therefore does not set its price optimally according to the expected development of the aggregate price level, but on a simple backward-looking rule of adaptive expectations. (Galí & Gertler, 1999, pp. 209-211)

The following derivation is based on (Galí & Gertler, 1999) and (Galí, Gertler, & López-Salido, 2001). The price level evolves according to (this is the same as (VI) in the previous chapter):

(I) $p_t = \theta p_{t-1} + (1-\theta) p_t^{\#}$

Now, as there are two types of firms, the newly set prices $p_t^{\#}$ are set according to the following formula, where p_t^f denotes the price forward-looking firms set and p_t^b the reset price of backward-looking firms:

(II) $p_t^{\#} = (1-\omega)p_t^f + \omega p_t^b$

This means that a fraction $1-\omega$ sets prices according to the standard forward-looking formula (as (V) in the previous chapter):

(III) $p_t^f = (1-\beta\theta)\sum_{k=0}^{\infty}(\beta\theta)^k E_t\{mc_{t+k}\}$

The other fraction ω sets prices according to the backward-looking formula:

(IV) $p_t^b = p_{t-1}^{\#} + \pi_{t-1}$

(III) can also be written as:

(V) $p_t^f = (1-\beta\theta)mc_t + \beta\theta E_t\{p_{t+1}^f\}$

Inserting (II) into (I) yields:

(VI) $p_t = \theta p_{t-1} + (1-\theta)[(1-\omega)p_t^f + \omega p_t^b]$

Now p_t^f from (V) and p_t^b from (IV) can be replaced:

(VII) $p_t = \theta p_{t-1} + (1-\theta)[(1-\omega)(1-\beta\theta)mc_t + (1-\omega)\beta\theta E_t\{p_{t+1}^f\} + \omega p_{t-1}^{\#} + \omega\pi_{t-1}]$

In this formula, $(1-\omega)p_{t+1}^f$ can be replaced with $p_{t+1}^{\#} - \omega p_{t+1}^b$ (from (II)) and π_{t-1} with $p_{t-1} - p_{t-2}$, which yields the following equation:

(VIII) $p_t = \theta p_{t-1} + (1-\theta)[(1-\omega)(1-\beta\theta)mc_t + \beta\theta E_t\{p_{t+1}^{\#} - \omega p_{t+1}^b\} + \omega p_{t-1}^{\#} + \omega(p_{t-1} - p_{t-2})]$

Now p_{t+1}^b can be replaced with $p_t^{\#} + \pi_t$ (because of (IV)):

(IX) $p_t = \theta p_{t-1} + (1-\theta)[(1-\omega)(1-\beta\theta)mc_t + \beta\theta E_t\{p_{t+1}^{\#} - \omega p_t^{\#} - \omega\pi_t\} + \omega p_{t-1}^{\#} + \omega(p_{t-1} - p_{t-2})]$

We already have a formula that consists only of marginal costs, price levels and newly set prices. In order to get rid of the newly set price, we use (I) in order to replace $p^{\#}_{t+1}$ with $\frac{p_{t+1}-\theta p_t}{1-\theta}$, $p^{\#}_t$ with $\frac{p_t-\theta p_{t-1}}{1-\theta}$, and $p^{\#}_{t-1}$ with $\frac{p_{t-1}-\theta p_{t-2}}{1-\theta}$:

(X) $p_t = \theta p_{t-1} + (1-\theta)(1-\omega)(1-\beta\theta)mc_t + \beta\theta E_t\{p_{t+1}\} - \beta\theta^2 p_t - \beta\theta\omega p_t + \beta\theta^2\omega p_{t-1} - (1-\theta)\beta\theta\omega\pi_t + \omega p_{t-1} - \omega\theta p_{t-2} + (1-\theta)\omega(p_{t-1} - p_{t-2})$

Finally nominal marginal costs mc_t are replaced with real marginal costs and the price level $mc^r_t + p_t$ and π_t with $p_t - p_{t-1}$:

(XI) $p_t = \theta p_{t-1} + (1-\theta)(1-\omega)(1-\beta\theta)(mc^r_t + p_t) + \beta\theta E_t\{p_{t+1}\} - \beta\theta^2 p_t - \beta\theta\omega p_t + \beta\theta^2\omega p_{t-1} - (1-\theta)\beta\theta\omega(p_t - p_{t-1}) + \omega p_{t-1} - \omega\theta p_{t-2} + (1-\theta)\omega(p_{t-1} - p_{t-2})$

Now we have an equation that only consists of real marginal costs and price levels. We want to get an equation with inflation rates, therefore we replace p_{t+1} with $\pi_{t+1} + p_t$ and p_{t-2} with $-\pi_{t-1} + p_{t-1}$, which yields the following formula:

(XII) $p_t = \theta p_{t-1} + (1-\theta)(1-\omega)(1-\beta\theta)(mc^r_t + p_t) + \beta\theta E_t\{\pi_{t+1}\} + \beta\theta p_t - \beta\theta^2 p_t - \beta\theta\omega p_t + \beta\theta^2\omega p_{t-1} - (1-\theta)\beta\theta\omega(p_t - p_{t-1}) + \omega p_{t-1} + \omega\pi_{t-1} - \omega p_{t-1} + (1-\theta)\omega p_{t-1}$

Grouping all terms with p_t and p_{t+1} yields the following:

(XIII) $\{\theta + \omega[1-\theta(1-\beta)]\}(p_t - p_{t-1}) = (1-\theta)(1-\omega)(1-\beta\theta)mc^r_t + \beta\theta E_t\{\pi_{t+1}\} + \omega\pi_{t-1}$

Dividing through $\{\theta + \omega[1-\theta(1-\beta)]\}$ and replacing $p_t - p_{t-1}$ with π_t yields:

(XIV) $\pi_t = \lambda mc^r_t + \gamma_f E_t(\pi_{t+1}) + \gamma_b \pi_{t-1}$

In this formula the following identities hold true:

$\lambda \equiv (1-\theta)(1-\omega)(1-\beta\theta)\phi^{-1}$

$\gamma_f \equiv \beta\theta\phi^{-1}$

$\gamma_b \equiv \omega\phi^{-1}$

$\phi \equiv \theta + \omega[1-\theta(1-\beta)]$

This is the hybrid new Keynesian Phillips curve: Inflation depends on real marginal costs, expected inflation and past inflation. Recall that in the standard new Keynesian Phillips curve of the last chapter, past inflation did not play a role, as there were no backward-looking firms.

The price setting rule of the backward-looking firms has got two interesting properties: First, as long as inflation is stationary, the rule leads the firms to converge to optimal behavior over time. Secondly, this rule, although backward-looking, also incorporates information about future prices, as the past price level is also determined by the forward-looking firms. (Galí & Gertler, 1999, p. 211)

Empirical tests by Galí and Gertler suggest that a pure forward-looking specification is rejected by the data, meaning that the coefficient of the backward-looking firms is significantly different from zero. However, the importance of backward-looking firms seems to be rather small: In all of their tests, the coefficient for lagged inflation was smaller than the coefficient for expected future inflation, and it is quantitatively not important. (Galí & Gertler, 1999, pp. 213-214) The hybrid new Keynesian Phillips curve is a plausible extension of the standard new Keynesian Phillips curve; however, as the standard new Keynesian Phillips curve with purely forward-looking firms gives a reasonably good approximation of inflation dynamics, it is rather an econometric fix than a great leap forward.

3.4 Theoretical and Empirical Deficiencies

The new Keynesian Phillips curve became something like a standard model of the monetary analysis of business cycles. It had several appealing characteristics: On the theoretical side, the NKPC included rational expectations and microeconomic reasoning about the behavior of firms. On the empirical side, the NKPC seemed to provide good regressions of inflation behavior.

But it can also be attacked on both sides. The theoretical critique directly attacks the sticky price assumption: In a rational environment, why should prices be sticky? Menu costs do exists, but they are generally perceived to be quite small. Transaction costs provide a better explanation, but still we observe that firms change their prices at certain particular times of the year, which partly contradicts the assumption that they do it because of transaction costs. The hybrid NKPC can also be criticized because why should there be firms with adaptive expectations? More objectively the NKPC can be attacked on empirical grounds. Let us recapitulate the relevant stylized facts we have elaborated on in chapter 2.5:

- Disinflations usually cause recessions
- Inflation is persistent and shows inertia
- Inflation reacts slowly and gradually to monetary shocks

It soon became apparent that there were indeed several severe deficiencies compared with these empirical observations:

“Ball (1994) shows that the model yields the surprising result that announced, credible disinflations cause booms rather than recessions. Fuhrer and Moore (1995) argue that it cannot explain why inflation is so persistent. Mankiw (2001) notes that it has trouble explaining why shocks to monetary policy have a delayed and gradual effect on inflation.”

(Mankiw & Reis, 2002, p. 1295)

I will have a look at these criticisms in more detail. The counterintuitive result that a disinflation causes a boom is discussed in (Ball, 1994, pp. 285-287). Usually, examples of a disinflation are examples of a deflation – a decrease in the level of money. For such cases, Ball comes to the same result that a deflation causes a recession. However in the real world, a disinflation is usually a decrease in the growth rate of money. In his model, there is a continuum of imperfectly competitive firms i that have got profit-maximizing prices of $p_i^* = m$ – they want to keep prices in line with the money stock m. The supply is modeled as a simple quantity equation $y = m - p$, where p is the aggregate price level. According to this equation, output would be zero, which is not the case however as firms set prices at fixed intervals. Note that this is a contrast to Calvo pricing: With Calvo pricing, it is not fixed interval, but it is randomly chosen when a firm can adjust the price.

The growth rate of money is modeled as $m_t = t$, which implies that the change rate is $\dot{m}_t = 1$. At time zero, the central bank announces a disinflation of the following way: $\dot{m}_t = 1 - t$ for $0 \leq t < 1$, and $\dot{m}_t = 0$ for $t \geq 1$. If m_0 is normalized to 0, then the level of money can be expressed the following way: $m_t = t - \frac{t^2}{2}$ for $0 \leq t < 1$, and $m_t = \frac{1}{2}$ for $t \geq 1$. The price set by firms maximizes the profit for one period: $x_t = \int_{s=0}^{1} E_t\{m_{t+s}\}ds$, which in the steady inflation regime (constant money growth rate) implies that the price $x_t = t + \frac{1}{2}$ is set, which also implies that output is constant. After the disinflation is announced and as it is assumed to be fully credible, a constant output would require that $x_t = \frac{1}{2}$ for $t \geq 0$. However, the actual price set by firms (as defined before) now is below the price needed for constant output: The actual price set is an average of the money stock during the next period. Between time period 0 and 1, the money stock is below ½, while it equals ½ afterwards. Therefore, firms that set prices between time period 0 and 1, set it somewhere below ½. As mentioned before, constant output would require prices to equal exactly ½ during that period.

This means that there is a boom. As the last prices that are set too low are set before $t = 1$, the boom lasts till $t = 2$. Thus, an announced, credible, sudden but steady disinflation leads to a boom in this model. As this is against the past World War II experience of disinflations, this implies that staggered price setting is not enough to explain disinflations.

The second point of criticism of the NKPC was that the NKPC cannot reproduce the observed inertia of inflation. This critique was brought forward by Fuhrer and Moore (1995, pp. 129-131), who analyze a standard Taylor model of staggered wage setting, which is analytically similar to Calvo pricing (Mankiw N. G., 2001, p. C53). In their model, contract wages x_t are set for two periods, therefore the price level is $p_t = \frac{1}{2}(x_t + x_{t-1})$. The contract wage is modeled as an average of past and expected future wage, adjusted for excess demand y_t: $x_t = \frac{1}{2}(x_{t-1} + E_t\{x_{t+1}\}) + \gamma y_t$. By inserting the contract wages into the price level equation, we get $p_t = \frac{1}{2}(p_{t-1} + E\{p_{t+1}\}) + \frac{\gamma}{2}(y_t + y_{t-1})$. This equation shows that there is a considerable inertia in the price level. However, expressing the inflation rate from this equation yields $\pi_t = E_t\{\pi_{t+1}\} + \gamma(y_t + y_{t-1})$. This equations shows that all of the persistence in inflation comes from the excess demand terms y_t and y_{t-1}. Only if the shock itself is persistent, there is inertia in inflation. In an empirical survey, Fuhrer and Moore (1995, p. 135) find that inflation shows positive autocorrelation up to lags of about four years. In contrast to this, in the standard staggered wage setting model, the autocorrelation function dies out after about one year (Fuhrer & Moore, 1995, p. 142).

A somehow similar way to address these problems comes from Mankiw (2001, pp. C54-C58). He uses the concept of impulse response functions to address the deficiencies of the NKPC. The impulse response function describes the dynamic path of some variable (the response) to some shock (the impulse). In the case of the NKPC, we are interested in the behavior of inflation and unemployment in response to a monetary shock. The results we want to reproduce is the real world behavior that monetary shocks (temporarily) affect unemployment, and that monetary shocks have a delayed and gradual effect on inflation. Table 1 shows the theoretical behavior of unemployment in different models of the Phillips curve after a contractionary monetary shock. As it can be seen, the standard backward-looking curves produce the plausible result that unemployment increases, while in the NKPC, unemployment decreases, which is the same result that has already been discussed before – that there are disinflationary booms. This is a serious drawback for the NKPC, as this result is exactly the opposite of what we perceive to be true.

	Quarter										
	0	1	2	3	4	5	6	7	8	9	10
Inflation	0.0	0.0	−0.1	−0.3	−0.6	−1.0	−1.4	−1.7	−1.9	−2.0	−2.0
Unemployment according to:											
1. Traditional backward-looking model: $\pi_t = \pi_{t-1} - 1/8(U_t - U^*)$											
	0.0	0.0	+0.8	+1.6	+2.4	+3.2	+3.2	+2.4	+1.6	+0.8	0.0
2. Backward-looking model with hysteresis: $\pi_t = \pi_{t-1} - 1/8(U_t - U_t^*)$; $U_t^* = 0.9U_{t-1}^* + 0.1U_{t-1}$											
	0.0	0.0	+0.8	+1.7	+2.6	+3.7	+4.0	+3.5	+3.0	+2.3	+1.6
3. New Keynesian forward-looking model: $\pi_t = E_t\pi_{t+1} - 1/8(U_t - U^*)$											
	0.0	−0.8	−1.6	−2.4	−3.2	−3.2	−2.4	−1.6	−0.8	0.0	0.0
4. Fuhrer-Moore model: $\pi_t = (\pi_{t-1} + E_t\pi_{t+1})/2 - 1/8(U_t - U^*)$											
	0.0	−0.4	−0.4	−0.4	−0.4	0.0	+0.4	+0.4	+0.4	+0.4	0.0

Table 1: Theoretical impulse response functions to a contractionary monetary shock.
Source: (Mankiw N. G., 2001, p. C55)

Mankiw describes this problem in a different way than Fuhrer and Moore: When a disinflation is on the way, the firms that adjust their prices should strive to reduce their prices. However, if we enforce the observation from the impulse response function for inflation that states that inflation adjusts delayed and gradually, firms must change their expectations of future economic activity – the other variable that affects the price level. Therefore, fall of the inflation rate has to go along with an increase of economic activity, which is equivalent to a fall in the unemployment rate.

The theoretical deficiencies mentioned in the beginning of the chapter together with the empirical failures just discussed are the reasons why researchers strive to find better explanations of the behavior of inflation and unemployment and try to ameliorate the new Keynesian Phillips curve. This is what the next chapter, the main chapter of this thesis, is about.

4 New Theories of the Phillips Curve

So far we have revised the development of the original Phillips curve and showed how economists influenced by new Keynesian economic theories explained the aggregate behavior of inflation and unemployment. They incorporated rational expectations and microeconomic reasoning into their theories based on rigidities and their work cumulated in the formulation of the new Keynesian Phillips curve (NKPC). As I have shown in chapter 3.4 however, the NKPC does not fit some crucial empirical facts; therefore the underlying theories cannot capture very well the main economic forces that are at work.

In this chapter, three different approaches to improve the Phillips curve are shown: At first, the wage aspirations theory by Ball and Moffitt that assumes that there is a difference between productivity growth and wage growth. This model provides a good fit of empirical data, but it is based on the theoretically unsatisfactory standard Phillips curve. Secondly, the sticky information Phillips curve by Mankiw and Reis that relies on rigidities in the transmission of information is discussed. Their model is based on the new Keynesian Phillips curve. Thirdly, the real wage rigidities model by Blanchard and Galí states that the determining rigidities that cause the tradeoff are to be found in the real wages. It is also based on the new Keynesian Phillips curve and the crucial assumption is very similar to the one of Ball and Moffitt – that the rigidity lies in the real wages.

The latter two models have been chosen for this thesis because they are based on a new Keynesian framework, in which a lot of today's macroeconomic discussions in economics take place. Furthermore, they are among the most discussed papers.[11] The article by Ball/Moffitt is based on the "outdated" theory of the standard Phillips curve and therefore will not make its way into mainstream economics; however it makes an interesting complementary to the other two articles, as the underlying assumptions

[11] The IDEAS database (http://ideas.repec.org/) lists the article by Mankiw/Reis among the top 1‰ of articles by number of citation; the article by Blanchard/Galí is still quite new, but it has already been quoted more than 50 times. (as of June 2008)

are similar. It also shows that models based on assumptions that are not fully rational (e.g. adaptive expectations) lead to empirically valid results.

4.1 Productivity Growth and Wage Aspirations

Ball and Moffitt (2001) present a theory of the Phillips curve that incorporates the idea that workers have got wrong estimations about productivity growth. Their model is more based on a standard Phillips curve as described in chapter 2 rather than on a NKPC as described in chapter 3.

Ball and Moffitt have been inspired by the economic boom of the 1990s, sometimes called the new economy[12] boom, which in the US showed a period of low unemployment accompanied by low inflation, which is against the traditional perception of these two variables. With the inclusion of the additional variable wage aspiration in the Phillips curve, their model is able to explain in a better way the path of inflation and unemployment in the 1990s.

4.1.1 The Influence of Wage Aspirations

Neoclassical economists usually claim that the real wage paid to the workers is equal to their marginal product. This is generally assumed to be true for the long run. In the short run, however, *"a shift in productivity growth is not matched immediately by a shift in wage aspirations, because these are tied partly to past wage increases"* (Ball & Moffitt, 2001, p. 3).

What is meant by wage aspirations? The wage aspirations are the real wages that workers consider fair. The usage of the fuzzy word fair in a definition is problematic, but there are only two traceable assumptions needed about them: a) Wage aspirations affect actual wages and b) wage aspirations are tied to past wage increases. One possible explanation for this deviation from neoclassical theory is that

[12] The term new economy is used for two different issues: Firstly, as in this case, it is used for the assumed new structure of the economy in general from the 1990s onwards. The economy has changed from a post-industrial economy to a new economy, where all sectors are highly influences by the improvements of information technology. While in the post-industrial economy the tertiary sector was the most important sector of the economy, in the new economy, information technology becomes so dominant that some even claim a quaternary sector, the information sector, has arisen (which was included in the tertiary sector before). As a second utilization, the term new economy does not apply to the economy as a whole, but only to firms that operate in the fourth sector, generally IT companies.

if workers consider their wages to be unfair, they reduce work effort. This is also crucial for the efficiency wages theory: Firms pay higher wages than implied by the labor market in order to stimulate effort. The higher costs for the firm are compensated by the higher productivity. (Ball & Moffitt, 2001, pp. 3-4)

The question arises what wage is considered fair by workers. Psychological literature states that the fairness of wages is judged by comparing them to reference transactions. There are two possibilities what this reference transaction is, one is the worker's own wage in the past, and the other one is the wage of workers of the same type. On the aggregate level, however, this distinction is of no importance. (Ball & Moffitt, 2001, p. 4) There were also tests conducted whether there is micro evidence for these theories. A microeconomic version of the wage Phillips curve (which will be defined for the aggregate level in the next chapter, see formula (III)) was tested by Ball and Moffitt with Current Population Survey data. One problem on the micro level is that, while data for individual wages is available, data for individual productivity is not. So also in the tests for micro evidence, only aggregate productivity data was included, which is of course the same in one year for all education groups and all birth cohorts. Two types of wage aspirations were tested: Firstly, aspirations based on lagged wages of workers of the same birth cohort and the same skill level (e.g. all IT professionals of age 40 today). Secondly, aspirations based on lagged wages of workers of the same age (not necessarily the same birth cohort) and the same skill level (e.g. all IT professionals of age 40 in the year 2000 and all IT professionals of age 40 in the year 1990). With this distinction, differences in cohort and period effects can be seen. The aspiration variables were significantly positive in both cases, thus it can be concluded that there is microevidence for wage aspirations: Wage growth is influenced by lagged wages. (Ball & Moffitt, 2001, pp. 28-31)

4.1.2 Derivation of the Phillips Curve With Wage Aspirations

I will go on formally deriving the Phillips curve including wage aspirations, based on (Ball & Moffitt, 2001, pp. 5-9). As mentioned before, the baseline model now is a standard Phillips curve – with backward-looking expectations and no stickiness in the price setting.

I start with defining a target of wage setters for real-wage growth. Real wage growth is defined as wage inflation ω minus price inflation π. Unemployment is denoted by u, θ is labor-productivity growth, and A is the aspiration wage increase. η denotes the error term.

(I) $(\omega - \pi)^* = \alpha - \gamma u + \delta\theta + (1-\delta)A + \eta$

(I) formalizes that the real wage growth depends on several factors: Conventionally, there is a constant α as well as a negative influence of unemployment (the higher the unemployment, the lower the real wage growth). A new factor in this model is the influence of labor-productivity growth and the aspiration wage increase, which I will describe more precisely.

The aspiration wage increase A is defined as:

(II) $A = \frac{1-\beta}{\beta}\sum_{i=1}^{\infty}\beta^i(\omega - \pi)_{-i}$

The aspiration wage is modeled as a weighted average (discounted by a factor β) of past wage increases, as justified in the previous chapter 4.1.1.

As it can easily be seen, the coefficients of θ and A in (I) add up to 1. So the case where δ equals 1 can be interpreted as a neoclassical model where wage aspirations are irrelevant (the standard Phillips curve as defined in chapter 2). If this is not the case, then aspirations form a part of the real wage target of wage setters. In the other extreme case where δ equals 0, the productivity growth is irrelevant and the real wage target is only based on wage aspirations. The discount factor β in (II) defines the influence of past aspirations on current. A β close to 1 implies that the adjustment of aspirations is slow and wages are heavily influenced by past aspirations.

In order to finalize the definition of the wage setting, I must now define the nominal wage that wage setters choose one period in advance. They choose the target real wage given in (I) plus expected inflation, which equals last period's inflation π_{t-1}. So the model incorporates backward-looking naïve expectations.

(III) $\omega = \alpha + \pi_{t-1} - \gamma u + \delta\theta + (1-\delta)A + \eta$

Formula (III) yields the wage Phillips curve: Wage inflation depends on past inflation, unemployment, productivity growth, and wage aspirations.

I now define price inflation in a standard form:

$$(IV) \pi = \omega - \theta + \nu$$

Price inflation equals wage inflation ω minus productivity growth θ plus the error term ν. By substituting the wage inflation (III) into the price inflation (IV), the wage aspirations Phillips curve is derived (ε now stands for both error terms $\eta + \nu$):

$$(V)\ \pi = \alpha + \pi_{t-1} - \gamma u - (1 - \delta)(\theta - A) + \varepsilon$$

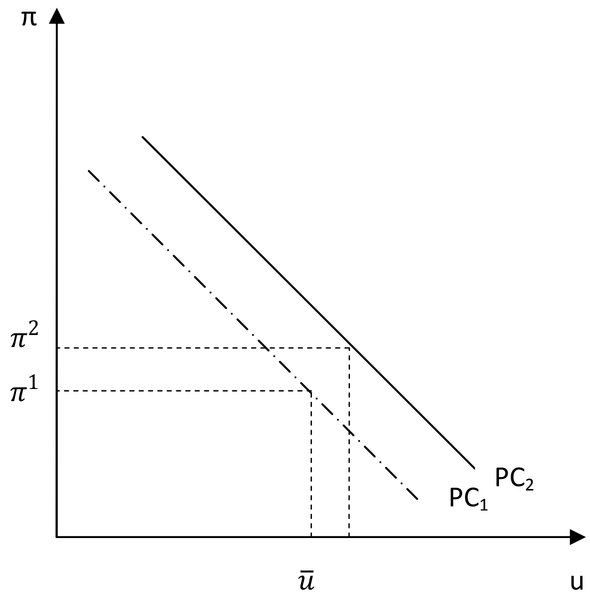
The wage aspirations Phillips curve of Ball and Moffitt states that inflation depends positively on past inflation and negatively on unemployment as well on the difference of productivity growth and wage aspirations.

4.1.3 Discussion of the Model

The model is based on a standard Phillips curve and therefore is vulnerable to the attacks that have already been mentioned in chapter 3: Expectations are not formed rationally, the assumptions about the relation between inflation and unemployment are not drawn from microeconomic theory, but from a mere observation of the behavior of aggregate variables. The model mostly is an econometric enhancement of the standard Phillips curve. Of course, there is a theoretical justification for including the difference between productivity growth and wage aspirations, which is that wage aspirations adjust slowly to productivity growth, as explained in chapter 4.1.1. So there is a theoretical reasoning why forecasting errors and rigidities occur. In this way, the model is similar to the sticky information model of the next chapter 4.2, as in that model the information about the productivity growth disseminates slowly throughout the population. However it has to be mentioned, that the wage aspirations again are based on an adaptive behavior of past real wage increases, not on a rational behavior.

I will now analyze some of the properties of this model. I start by analyzing the special case where δ equals 1, thus wage aspirations have got no impact on wage setting. In this case, formula (V) reduces to the standard Phillips curve. It cannot be seen anymore in (V), but by looking at the equations from which it results, namely the wage inflation (I) and the price inflation (IV), it can be seen that productivity growth does have an effect on price inflation, but it is fully offset by its effect on wage setting. Productivity growth is also irrelevant in the steady state where productivity growth θ equals wage aspirations A. Another important property is that while wage aspirations can be different from productivity growth, actual real wage growth cannot, as it can be seen from reformulating (IV): $\omega - \pi = \theta - \nu$. (Ball & Moffitt, 2001, pp. 7-8)

If productivity growth θ changes, it can be seen from (II) that wage aspirations do not adapt immediately because they are based on past real wage increases. This leads to a temporary shift of the Phillips curve: *"During a productivity slowdown, target wage growth rises relative to productivity growth* *<u>for given unemployment</u>*. *But higher unemployment offsets this effect or accelerating inflation reduces actual real-wage growth below the target"* (Ball & Moffitt, 2001, p. 8). This can be seen in Graph 7: The starting point is the steady state where unemployment equals the structural rate and inflation is at π_1. Now a productivity slowdown occurs (θ gets smaller). An implication of (III) is that this leads to lower nominal wages. In (IV) it can be seen that price inflation increases: Nominal wages are lower now, but they only partly capture the effect of the productivity slowdown, as wages also depend on wage aspirations. Prices however fully depend on productivity, therefore the difference between ω and θ increases, and price inflation increases. In formula (V) it can be seen that for each level of unemployment, inflation is now higher – this is also captured in Graph 7, where the Phillips curve shifts to PC_2. The Phillips curve tradeoff gets worse. Over time, wage aspirations will adjust to the new productivity growth, and the Phillips curve will slowly move down to its initial position again.



Graph 7: Temporary shift of the Phillips curve during a productivity slowdown

The NAIRU has to be defined differently in this model: Usually it is defined as the rate of unemployment that is compatible with a stable inflation. Now in this model, as temporary shifts in the Phillips curve can occur, the definition of the NAIRU has to include that the productivity growth θ equals wage aspirations A. As long as this is not the case (when there is a productivity slowdown or rise), unemployment can rise or fall while inflation remains stable. (Ball & Moffitt, 2001, pp. 8-9)

Ball and Moffitt empirically test this specification of the Phillips curve for the time period of 1962 to 1995 and come to the result that the new variable $(\theta - A)$ explains a significant part of the inflation. Furthermore, for the time period 1996 to 2000, the start of the new economy boom, the model can explain the combination of low unemployment accompanied by low inflation because of the productivity acceleration, which results in high values of $(\theta - A)$. It is important to notice however that this effect cannot be sustainable: Once aspirations adjust, $(\theta - A)$ gets slower and unemployment will return to the NAIRU. The model also provides a better fit for wage inflation: While the neoclassical equation (where wage aspirations equal productivity growth) overpredicts wage inflation after 1995 by 6,4%, the model by Ball and Moffitt underpredicts it by an insignificant amount. (Ball & Moffitt, 2001, pp. 16-20)

Ball and Moffitt do not mention any policy experiments in their paper. In order to do an analysis of macroeconomic experiments, at first an aggregate demand function has to be defined. Usually, as a simple approximation, the quantity theory of money is used for this. But in the case of a standard Phillips curve framework, the deficiencies of this framework very quickly appear: As variables like marginal costs are neglected and expectations are naïve, any expected behavior of a variable plays no role, and neither does the announcement of a change in policy. Variables will adapt in a slow way in an oscillating pattern. While the inertia of inflation for example is captured in such a framework (because it is built in into the assumption of naïve expectations), the slow and gradual effect of monetary policy cannot be reproduced. Also, while disinflations lead to a recession, due to the oscillating behavior of inflation, it also leads to a boom afterwards, which contradicts the stylized facts of disinflations.

This is a contrast to the theories that will be presented in the next two chapters: Both the model by Mankiw and Reis, and the one by Blanchard and Galí are based on a new Keynesian Phillips curve, economic actors consider costs and benefits and have got expectations about the behavior of certain variables like inflation or marginal costs. In such frameworks, a dynamic analysis can be done in a more meaningful way, and the results can be compared for example with the deficiencies of the standard new Keynesian Phillips curve, as described in chapter 3.4. For the model of Ball and Moffitt it can only be said that shocks to inflation (e.g. monetary policy) changes inflation and unemployment according to the Phillips curve, while shocks to productivity (e.g. technological progress) shifts the Phillips curve temporary. As in the original Phillips curve for example, expansionary monetary policy increases inflation and lowers unemployment; but over time, unemployment will return to its structural level, while inflation remains high: The Phillips curve shifts to a worse tradeoff in the long run.

4.2 Stickiness in the Transmission of Information

I have shown in the previous chapter that the model of Ball and Moffitt has got some interesting theoretical aspects about the prevalence of wage rigidities, which can also be interpreted as a slow dissemination of information about the status of the economy (which in that case was productivity). The main deficiency of this model was the lack of theoretical foundations, as it is based on a standard Phillips curve. I will now turn to a model that is based on the theoretically well-founded new Keynesian Phillips curve. Having been aware of the deficiencies of the new Keynesian Phillips curve, Mankiw and Reis developed a model of dynamic price adjustment that is not based on sticky prices, but on sticky information. This model is more consistent with the stylized facts of dynamic price adjustment.

4.2.1 The Concept of Sticky Information

The crucial basic assumption of the sticky information model is that *"information about macroeconomic conditions diffuses slowly through the population"* (Mankiw & Reis, 2002, p. 1296). This assumption seems to be plausible, as the population does not possess perfect information, and not all economic actors hold identical information. If facts relevant to the economic decisions of the agents change, it takes some time until a larger part of the population is aware of this. This is due to the prevalence of transaction costs, especially the costs of acquiring information. So in fact this model combines the standard Calvo pricing model with a Lucas model of imperfect information. The consequence of sticky information is that *"pricing decisions are not always based on current information"* (Mankiw & Reis, 2002, p. 1296).

In contrast to the sticky price model with Calvo pricing (as described in chapter 3.2), now all firms set new prices each period. But it is the information that is not updated each period, only a fraction of firms updates itself on the current status of the economy. This seems to be more plausible, because as I have mentioned before, the mere menu costs associated with changing prices are assumed to be relatively small; however the information gathering costs are much higher.

The implications of this are closer to the Fischer (1977) model of staggered contracts: In Fischer's model, expectations are important because they are built into the contracts. In the model of Mankiw and Reis they matter because some firms still set prices based on expectations formed in the past. (Mankiw & Reis, 2002, p. 1296)

Is there any evidence of the assumption of sticky information? The theoretical justification can come from information theory: Human beings have got a limited channel for absorbing information. A similar type to the sticky information model is Woodford's noisy information model: Price setters get a noisy signal about current monetary policy each period. So in the noisy information model people get imperfect information each period, while in the sticky information model they do get perfect information, but not in each period. Another possible theoretical explanation is that it is not so costly to find out what the monetary policy is, however it is difficult to know what it means. The cost comes from thinking and learning. There is also empirical evidence that information spreads slowly over time. Unsurprisingly, in empirical studies professional forecasters are better in forecasting inflation than the general public is, and it takes some time until the opinion of the general public adapts to that of professional forecasters. Another important insight is that this adjustment time can change, depending on how much news stories there are about inflation. (Mankiw & Reis, 2002, pp. 1314-1317)

4.2.2 Derivation of the Sticky Information Phillips Curve

In this chapter the concept of the sticky information Phillips curve will be formalized based on (Mankiw & Reis, 2002, pp. 1299-1301). Trabandt (2007), for example, has also shown that the same effects can also be reproduced in a dynamic stochastic general equilibrium model.

As mentioned before, now each firm updates the price each period, but information is gathered slowly over time. Each period, a fraction λ of the firms obtains new information and calculates new optimal prices based on this information, while other firms still calculate optimal prices based on older and therefore possibly outdated information.

A firm's optimal price p_t^* is determined by the overall price level p_t and the output gap y_t. Note that potential output is normalized to zero, so y_t does not stand for the aggregate production, but the deviation from potential output. α is a coefficient that reflects the influence of macroeconomic conditions to the price setting of a firm. The assumption that the output gap affects the optimal prize does not come from a microeconomically founded theory, but one could also do it easily: This is what I have already done in chapter 3.2 formally based on the profit maximization assumption of the firm by defining a loss function. During booms, the output gap y_t is positive – an increased demand leads to rising marginal costs, therefore the firm also wants to increase the price.

Let me now define the optimal price:

(I) $p_t^* = p_t + \alpha y_t$

The firm calculates the actual reset price x_t. A firm that last updated its plans j periods ago sets the price x_t, which equals the expectations from period t-j about the price in period t. As it can be seen this reset price is now in contrast to the new Keynesian Phillips curve not a weighted sum of future desired prices, as now the firm can adjust its price every period.

(II) $x_t^j = E_{t-j}(p_t^*)$

So (II) describes the reset price of each period, which is based on possibly outdated information updated j periods ago. The overall price level therefore evolves according to:

(III) $p_t = \lambda \sum_{j=0}^{\infty} (1-\lambda)^j \, x_t^j$

Equation (III) describes the aggregate price level. Inserting the price set of equation (II) and the optimal price (I) into (III) yields the following more detailed equation for the aggregate price level:

(IV) $p_t = \lambda \sum_{j=0}^{\infty} (1-\lambda)^j \, E_{t-j}(p_t + \alpha y_t)$

The short-run Phillips curve can easily be seen in (IV), as the output gap y_t is positively correlated with surprise movements in the price level p_t. Now recall the aggregate price level of the standard NKPC (formula (V) and (VI) in chapter 3.2):

$$p_t = \theta p_{t-1} + (1-\theta)(1-\theta\beta) \sum_{k=0}^{\infty} (\theta\beta)^k E_t\{\mu + mc_{t+k}\}$$

It can see that there is an important difference between these two equations: In the sticky information model, the aggregate price level depends on past expectations about the current economic conditions. In the sticky price model (the standard NKPC) however, the aggregate price level depends on the past price level and on current expectations about future economic conditions.

I will now formally derive the inflation rate. I start with taking out the first term of (IV) from the summation:

(V) $p_t = \lambda(p_t + \alpha y_t) + \lambda \sum_{j=0}^{\infty}(1-\lambda)^{j+1} E_{t-1-j}(p_t + \alpha y_t)$

Analogous to (IV), the price level of the period t-1 can be expressed as:

(VI) $p_{t-1} = \lambda \sum_{j=0}^{\infty}(1-\lambda)^{j} E_{t-1-j}(p_{t-1} + \alpha y_{t-1})$

Now (VI) can be subtracted from (V). I define as usually $\pi_t \equiv p_t - p_{t-1}$ and the rate of change of the output gap as $\Delta y_t \equiv y_t - y_{t-1}$, which yields the following equation:

(VII) $\pi_t = \lambda(p_t + \alpha y_t) + \lambda \sum_{j=0}^{\infty}(1-\lambda)^{j} E_{t-1-j}\{\pi_t + \alpha \Delta y_t\} - \lambda^2 \sum_{j=0}^{\infty}(1-\lambda)^{j} E_{t-1-j}\{p_t + \alpha y_t\}$

In order to eliminate the last term of this equation, the following auxiliary construction is needed. (V) is reformulated in order to get:

(VIII) $p_t - \left[\frac{\alpha\lambda}{1-\lambda}\right] y_t = \lambda \sum_{j=0}^{\infty}(1-\lambda)^{j} E_{t-1-j}\{p_t + \alpha y_t\}$

Now I use (VIII) to substitute in (VII) and finally get:

(IX) $\pi_t = \frac{\alpha\lambda}{1-\lambda} y_t + \lambda \sum_{j=0}^{\infty}(1-\lambda)^{j} E_{t-1-j}(\pi_t + \alpha \Delta y_t)$

This is the sticky information Phillips curve. As it can be seen, current inflation depends on the output gap y_t, expectations of current inflation π_t and expectations of the change of the output gap Δy_t. These expectations were formed in the past. There are now fewer constants than in the standard NKPC formulation because there is no time preference: Now there is only λ as the fraction of firms that updates information in one period, and α as the coefficient of the response of the optimal price to fluctuations in the output gap.

4.2.3 Discussion of the Model

Let me first compare generally the sticky information Phillips curve with the standard NKPC, the sticky price Phillips curve. Recall from chapter 3.2 that the standard NKPC can be expressed as:

$$\pi_t = \beta E_t\{\pi_{t+1}\} + \gamma y_t$$

The standard NKPC depends on the current output gap and current expectations on future inflation. In contrast, the sticky information Phillips curve depends on the current output gap, and past expectations on current inflation and movements in the output gap. So in the standard NKPC, current expectations of future economic conditions influence the inflation rate, while in the sticky information model past expectations of current economic conditions influence the inflation rate. This distinction between the two models leads to significant differences of the dynamics of prices and output in response to monetary policy, as it will now be examined. (Mankiw & Reis, 2002, p. 1300)

Mankiw and Reis (2002, pp. 1301-1307) compare three hypothetical policy experiments (drop in aggregate demand, unanticipated disinflation, anticipated inflation) on three models of the Phillips curve (the standard NKPC, the sticky information and a backward-looking Phillips curve). As the disinflation experiments address directly a deficiency of the standard NKPC, I will discuss them in more detail. I will start with the sudden disinflation. As it is known from chapter 2.5, a sudden disinflation usually is accompanied by a recession and a slow decline in the inflation rate.

In order to analyze the dynamic behavior of the macroeconomic variables, our model economy needs to be completed by an aggregate demand function. The simple form of the quantity theory of money approach will be taken: $m = p + y$, where m is the money supply, p the price level, and y nominal output. Two benchmarks are taken, at first, the standard NKPC:

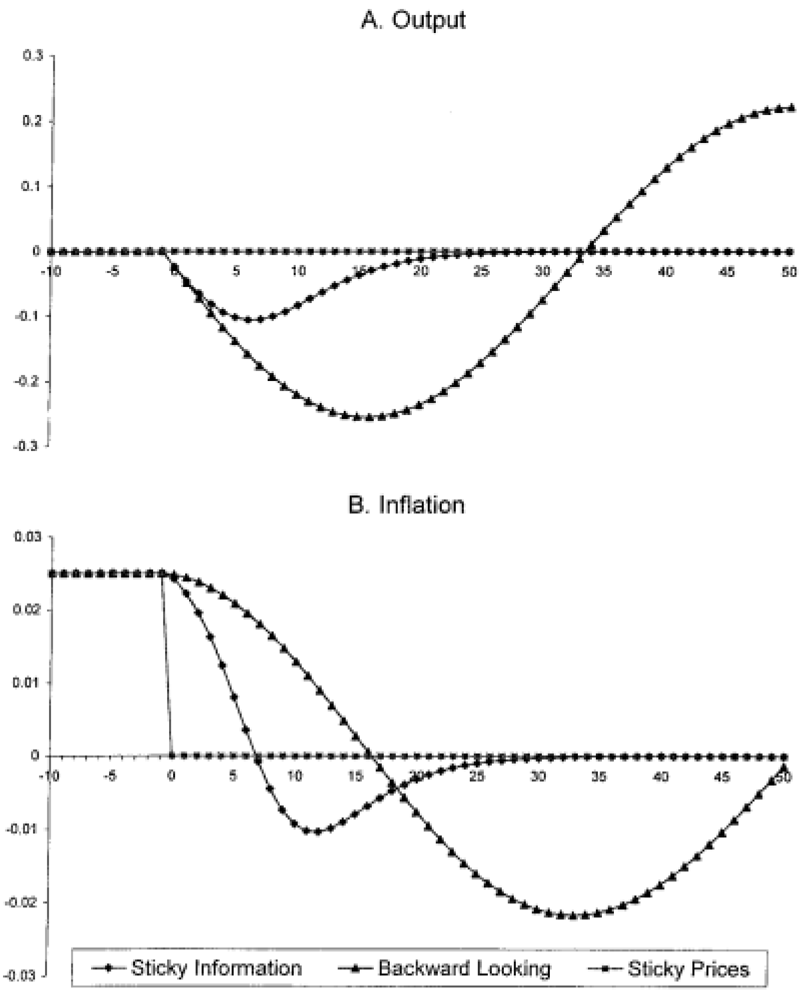
$$\pi_t = \beta E_t\{\pi_{t+1}\} + \gamma y_t$$

Secondly, a standard Phillips curve with backward-looking expectations:

$$\pi_t = \gamma y_t + \pi_{t-1}$$

By inserting the quantity equation into the firm's optimal price (I), we can rewrite this desired price as $p_t^* = (1-\alpha)p_t + \alpha m$. So the desired price consists of the price level and the money supply. In this equation it can be seen how monetary policy can directly affect our model.

The following behavior models the experiment of a sudden disinflation: Before time zero, money grows at a constant rate of 10% a year (thus, 2.5% a quarter). In period zero, the central bank sets the money supply the same as it was in the period before, and announces that it will also remain constant afterwards. Graph 8 shows the result of this experiment for the three models mentioned before.

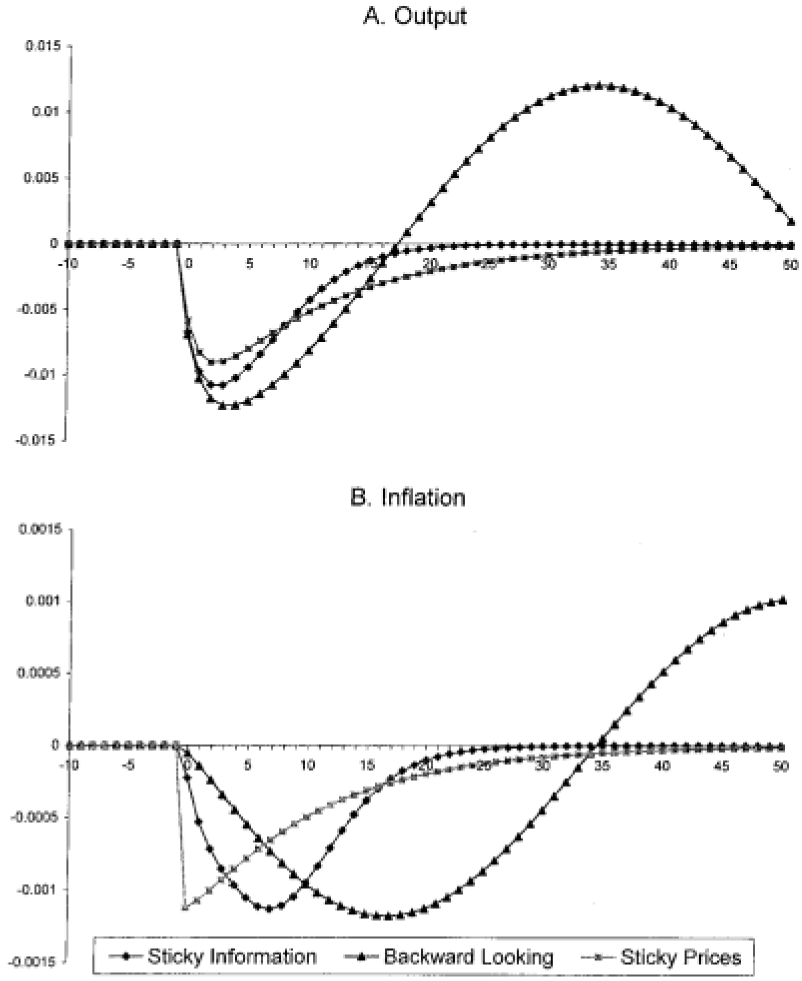


Graph 8: A sudden disinflation in three different models. Source: (Mankiw & Reis, 2002, p. 1305)

As it can be seen in the standard NKPC (or sticky price in the graph), while prices are sticky, inflation does not show any inertia, so inflation falls immediately to the new level. The proof for this behavior has already been given in chapter 3.4. Because inflation falls immediately, the output does not decrease, therefore the disinflation is costless. Both results do not conform with the stylized facts of disinflations as described in chapter 2.5. In the backwards-looking Phillips curve, as economic actors are backward-looking, they do not note that economic conditions have changed. So inflation is at first too high, then too low, and there is a recession larger than predicted (however it is followed by a small boom). The sticky information model yields the most realistic results: Prices are not sticky, but information about the disinflation slowly reaches the population. The money supply is already constant, but some economic actors expect it to rise and therefore set prices too high. Therefore the inflation adapts relatively slowly to the new economic conditions and the disinflation is accompanied by a recession, as implied by the quantity equation which describes the aggregate demand in this model.

In the experiment of an announced disinflation, the disinflation is modeled the same way as in the previous experiment, but it is credibly announced eight periods in advance. This announcement of course has no effect in the backward-looking model (as there are naïve expectations). In the standard NKPC it leads to a boom: Once the disinflation is announced, inflation falls immediately, as price setters anticipate the slowdown in money growth and therefore set lower prices. As money supply is still growing however, a boom is implied by the quantity equation. In the sticky information model, there is no change of output and inflation until the disinflations begins: Price setters also anticipate the slowdown, but as they can change prices each period, they only start changing prices once the disinflation begins. The effect of the announcement is that the output loss is smaller and inflation reacts faster to the changed economic conditions.

As a next step towards a more realistic experiment, Mankiw and Reis (2002, pp. 1308-1311) assume a more plausible stochastic process for the money supply. The process has the form of an AR(1) process: $\Delta m_t = \rho \Delta m_{t-1} + \varepsilon_t$. The change in the money supply Δm_t depends partly on the money supply of the previous period and on an error term. Based on experience of US data on GDP as well as money supply M1 and M2[13], ρ is set as 0.5, which implies that the level of money supply asymptotes to a level twice as high as the initial shock. Graph 9 shows the behavior of output and inflation after a one-time contractionary monetary shock.



Graph 9: A contractionary monetary shock in three models. Source: (Mankiw & Reis, 2002, p. 1309)

As it can be seen in the graph, in all three models, the effect on output builds over time and reaches its peak after a couple of periods. This is due to the modeling of the monetary shock as described before. Inflation behaves differently in the three models: In the standard NKPC model again, inflation adapts immediately, while it

[13] M1 and M2 are measures of money supply. M0 would be the narrowest definition of money, which only includes physical currency and central bank reserves. M1 includes M0 and checkable deposits. M2 includes M1 and saving deposits.

adapts over time in the sticky price model. This inertia also exists in the backward-looking model, where it is built in due to naïve expectations. The impulse response function for the sticky information model yields more realistic results than the other two models: There is a long lag between monetary policy actions and inflation, and the maximum impact on inflation is reached after some time. In the standard NKPC, the maximum impact of a monetary shock to inflation occurs immediately. This is the main advantage of the sticky information model: While all three models show that inflation is highly autocorrelated, only in the sticky information model the maximum impact is reached with a realistic delay.

To summarize, the sticky information Phillips curve has got several practical and theoretical advantages compared to the standard NKPC or the backwards-looking Phillips curve. On theoretical grounds, the agents behave rationally: They form rational expectations (even if there is the rigidity that they do not update their expectations each period) and they act rationally. Because of this, as stated before, credibility also plays a role. On practical grounds, the sticky information model is more able to reproduce the empirical observations than the NKPC, for example in the case of disinflations as well as plausible monetary shocks.

4.3 Real Wage Rigidities

The previous chapters showed two newer formulations of the Phillips curve, one based on a standard Phillips curve, the other one on the new Keynesian Phillips curve. There is more research being conducted in new Keynesian frameworks, as they provide better theoretical fundaments. This is why the third model discussed here – the real wage rigidities model by Blanchard and Galí (2007) – is also based on a NKPC. Blanchard and Galí have been inspired by the anomaly that the NKPC does not offer a tradeoff between stabilizing the inflation and stabilizing the output: In fact, stabilizing the output gap equals stabilizing inflation, which the authors call the “divine coincidence”. By implementing real wage rigidities in the labor market, this feature disappears and there is a trade-off between inflation and unemployment.

4.3.1 The Motivation of Introducing Real Wage Rigidities

Let me start with analyzing the standard NKPC, as it has been derived in formula (XI) in chapter 3.2:

$$\pi_t = \beta E_t\{\pi_{t+1}\} + \gamma y_t$$

It is generally accepted that it is desirable to stabilize inflation and to stabilize the output gap because neither high inflation nor high unemployment are sought-after and households have got a preference for a smooth income stream. As it can be seen in this formula, these two goals do not conflict. Stabilizing the inflation also leads to stabilizing the output gap. In the case of an oil price shock for example, the best policy according to this model would be to keep inflation constant. As we will later see, this property comes from the feature of the NKPC that the gap between the structural level of output and the efficient level of output is constant and invariant to shocks. The structural level of output is the output that prevails when there are market imperfections, while the efficient level of output is the output without such imperfections. Introducing real imperfections leads to the disappearance of this property. (Blanchard & Galí, 2007, p. 36)

The real wage rigidities are modeled the following way:

$$w_t = \gamma w_{t-1} + (1 - \gamma) mrs_t$$

The real wage partly depends on the previous period's real wage, and partly on the current marginal rate of substitution (the rate at which a household is willing to give up free time in order to earn more and therefore consume more). Blanchard and Galí do not give a lot of reasoning or microeconomic foundations why there are real wage rigidities; they simply *"assume that real wages respond sluggishly to labor market conditions, as a result of some (unmodelled [sic!]) imperfection or friction in labor markets"* (Blanchard & Galí, 2007, p. 41). So they assume that a rigidity in the adjustment of real wages is a simple feature of the economic environment.

4.3.2 First- and Second-Best-Allocation in a New Keynesian Phillips Curve

The basic model for the real wage rigidities model is an NKPC as it has been derived it in chapter 3.2; as there are some differences in the modeling, and as we need to familiarize us with the concepts of first-best and second-best equilibrium in order to understand the "divine coincidence" and why it disappears with the introduction of real wage rigidities, the model will be derived here based on (Blanchard & Galí, 2007, pp. 37-41).

I start with a baseline NKPC model with monopolistically competitive firms; as an addition, the exogenous input M is introduced in order to discuss supply shocks. Therefore, the production function of a firm is modeled the following way:

(I) $Y = M^{\alpha} N^{1-\alpha}$

This is a standard Cobb-Douglas production function with two inputs, the exogenous input M and labor N. Labor supply depends, as defined before, on the marginal rate of substitution. I go on by defining the marginal costs for the firm in natural logarithms:

(II) $mc = w - mpn = w - (y - n) - log(1 - \alpha)$

Here, mc stands for the marginal costs, w the wages, and mpn the marginal product of labor. The marginal product of labor is $\frac{\partial Y}{\partial N} = M^{\alpha}(1-\alpha)N^{-\alpha} = M^{\alpha}N^{1-\alpha}N^{-1}(1-\alpha)$, which equals in its natural logarithm form $(y - n) + log(1 - \alpha)$.

Having modeled the firms, I continue with modeling the households. Households have got a utility function defined in the following way:

(III) $U(C, N) = \log(C) - \exp\{\xi\}\frac{N^{1+\phi}}{1+\phi}$

The utility depends on consumption C, employment N, and a preference parameter ξ. In natural logarithms, the marginal rate of substitution between consumption and labor can be expressed in the convenient form:

(IV) $mrs = c + \phi n + \xi$

Having modeled firms and households, I can now go on calculating the first-best equilibrium. The first-best allocation, also called efficient allocation, is the prevailing equilibrium when there is perfect competition in the goods and the labor market. This implies that the wage equals the marginal product of labor in the goods market, and in the labor market the wage equals the marginal rate of substitution:

(V) $w = mpn = (y - n) + \log(1 - \alpha)$

(VI) $w = mrs = y + \phi n + \xi$

Formulas (V) and (VI) are simple restatements of (II) and (IV) under the assumption of perfect competition, that is also why we replaced c in (IV) by y (because the goods market clears). By equating (V) and (VI) we get the first-best level of employment n_1:

(VII) $(1 + \phi)n_1 = \log(1 - \alpha) - \xi$

The first-best level of employment does not depend on the exogenous input, but it depends negatively on the preference parameter ξ. Given the first-best level of employment, the first-best level of output is defined by (as seen in the natural logarithm version of (I)):

(VIII) $y_1 = \alpha m + (1 - \alpha)n_1$

The first-best level of output depends on shocks to both inputs m and n.

Now the assumption of having perfect competition is relaxed and a markup μ^p is introduced, which can be justified because we have a market situation of monopolistic competition. The optimal price setting of the firm now is $mc + \mu^p$. Therefore the wage paid in the goods market (formula (V)) now has to be defined in the following way:

(IX) $w = mpn - \mu^p = (y - n) + \log(1 - \alpha) - \mu^p$

Now, by combining the labor market (VI) with the goods market (IX), we get the following equation for the second-best level of employment:

(X) $(1 + \phi)n_2 = \log(1 - \alpha) - \mu^p - \xi$

The second-best level of employment is again independent of the exogenous input and now depends on the markup μ^p and the preference parameter ξ. Analogous to (VIII), the second-best level of output is defined as:

(XI) $y_2 = \alpha m + (1 - \alpha)n_2$

Now we can see an important property of the standard NKPC model: The gap between the first-best and the second-best level of output (δ) is constant, which follows from subtracting (VIII) from (XI):

(XII) $y_1 - y_2 = \frac{\mu^p(1-\alpha)}{1+\phi} \equiv \delta$

I continue with introducing Calvo pricing. As it is known from formula (X) in chapter 3.2, with Calvo pricing, inflation in a new Keynesian framework can be described as:

(XIII) $\pi_t = \beta E_t\{\pi_{t+1}\} + \frac{(1-\theta)(1-\theta\beta)}{\theta}(mc_t + \mu^p)$

The deviation of output from its second-best level follows directly from (I):

(XIV) $y - y_2 = (1-\alpha)(n - n_2)$

n can be expressed by substituting (VI) into (II):

(XV) $n = \frac{1}{1+\phi}(mc - \xi + \log(1-\alpha))$

Substituting this and n_2 from (X) into (XIV) yields:

(XVI) $mc + \mu^p = \frac{1+\phi}{1-\alpha}(y - y_2)$

Now this can be substituted into (XIII) and we get a different formulation of the NKPC where $\kappa \equiv \frac{1+\phi}{1-\alpha}\frac{(1-\theta)(1-\theta\beta)}{\theta}$:

(XVII) $\pi_t = \beta E_t\{\pi_{t+1}\} + \kappa(y - y_2)$

Inflation still depends on expected inflation and the output gap. Neither supply nor preference shocks appear directly in equation (XVII), but they are to be found in the variable y_2. It can also be seen in (XVII) that stabilizing the output gap $(y - y_2)$ is equal to stabilizing inflation. As we have found out in (XII), the distance between the first-best allocation y_1 and the second-best allocation y_2 equals a constant δ. This implies that stabilizing the output gap $(y - y_2)$ is also equivalent to stabilizing the welfare-relevant output gap $(y - y_1)$, the distance between output and the first-best output. This is what Blanchard and Galí have called the divine coincidence. Because a supply shock does not enter δ, there is no incentive for the central bank to change its policy in the event of a supply shock. This does not conform to the conventional wisdom of central bankers. In order to change this constancy of δ and therefore get more realistic results, real wage rigidities will be introduced in the next chapter.

4.3.3 First- and Second-Best-Allocation after Introducing Real Wage Rigidities

As already discussed in chapter 4.3.1, real wage rigidities are modeled the following way:

$$\text{(XVIII)} \qquad w_t = \gamma w_{t-1} + (1-\gamma) mrs_t$$

The wages of this period partly depend on the wages of the previous period, partly on the marginal rate of substitution of this period. The rigidity is that the wages depend on the last period as well, if there would be perfect market conditions, then it only would depend on the marginal rate of substitution. γ can be interpreted as the degree of real wage rigidities.

This following derivation is based on (Blanchard & Galí, 2007, pp. 41-44). As there is a distortion in the wage setting and it is not a result of preferences, the first-best equilibria (formula (VII) and (VIII)) are not affected.

Let us turn to the second-best equilibria. The wage-setting of the households is now different as compared to (VI): The introduction of real wage rigidities implies that the wage does not only depend on the marginal rate of substitution, but also on the wage of the previous period, as it was defined in (XVIII): Replacing mrs_t with $y + \phi n + \xi$ from (VI), and replacing y with $\alpha m + (1-\alpha) n$ (the log form of the technology (I)) yields:

$$\text{(XIX)} \; w_t = \gamma w_{t-1} + (1-\gamma)[\alpha(m_t - n_{2,t}) + (1+\phi) n_{2,t} + \xi_t]$$

Note that the indices now indicate the second-best level of employment as well as the time. Combing this equation with the goods market of (IX) yields:

$$\text{(XX)} \;\; \alpha(m_t - n_{2,t}) + \log(1-\alpha) - \mu^p = \gamma[\alpha(m_{t-1} - n_{2,t-1}) + \log(1 - \alpha) - \mu^p] + (1-\gamma)[\alpha(m_t - n_{2,t}) + (1+\phi) n_{2,t} + \xi_t]$$

If m_{t-1} is replaced with $m_t - \Delta m_t$, we get:

(XXI) $(1-\gamma)[\log(1-\alpha)-\mu^p] = -\alpha\gamma\Delta m_t - \alpha\gamma n_{2,t-1} + [\alpha\gamma + (1-\gamma)(1+\phi)]n_{2,t} + (1-\gamma)\xi_t$

Now θ_γ is defined as $\frac{\alpha\gamma}{\alpha\gamma+(1-\gamma)(1+\phi)}$ and the previous equation is divided by $\frac{1}{\alpha\gamma+(1-\gamma)(1+\phi)}$ to get:

(XII) $$n_{2,t} = \frac{(1-\gamma)}{\alpha\gamma+(1-\gamma)(1+\phi)}[\log(1-\alpha)-\mu^p-\xi_t] + \theta_\gamma\Delta m_t + \theta_\gamma n_{2,t-1}$$

Now $n_{1,t}$ is subtracted from both sides and we use the fact that $n_{2,t} - n_{1,t} = \frac{y_{2,t}-y_{1,t}}{1-\alpha}$ (which follows from (I)). Furthermore, $-\theta_\gamma n_{1,t-1} + \theta_\gamma n_{1,t-1}$ is added on the right side:

(XXIII) $$\frac{y_{2,t}-y_{1,t}}{1-\alpha} = \frac{(1-\gamma)}{\alpha\gamma+(1-\gamma)(1+\phi)}[\log(1-\alpha)-\mu^p-\xi_t] + \theta_\gamma\Delta m_t + \theta_\gamma\frac{y_{2,t-1}-y_{1,t-1}}{1-\alpha} - n_{1,t} + \theta_\gamma n_{1,t-1}$$

Multiplying by $(1-\alpha)$ and adding $\frac{\mu^p(1-\alpha)}{1+\phi} \equiv \delta$ (see (XII)) on both sides yields:

(XXIV) $$y_{2,t} - y_{1,t} + \delta = \theta_\gamma(y_{2,t-1} - y_{1,t-1} + \delta) + (1-\theta_\gamma)\delta + (1-\alpha)[\theta_\gamma\Delta m_t - n_{1,t} + \theta_\gamma n_{1,t-1}] + \frac{(1-\alpha)(1-\gamma)}{\alpha\gamma+(1-\gamma)(1+\phi)}[\log(1-\alpha)-\mu^p-\xi_t]$$

Now (VII) is used to replace $n_{1,t}$ with $\frac{\log(1-\alpha)-\xi_t}{(1+\phi)}$ and $n_{1,t-1}$ with $\frac{\log(1-\alpha)-\xi_{t-1}}{(1+\phi)}$:

(XXV) $$y_{2,t} - y_{1,t} + \delta = \theta_\gamma(y_{2,t-1} - y_{1,t-1} + \delta) + (1-\theta_\gamma)\frac{\mu^p(1-\alpha)}{1+\phi} + \frac{(1-\alpha)\theta_\gamma}{(1+\phi)}(\log(1-\alpha)-\xi_{t-1}) - \frac{(1-\alpha)}{(1+\phi)}(\log(1-\alpha)-\xi_t) + (1-\alpha)(\theta_\gamma\Delta m_t) + \frac{(1-\alpha)(1-\gamma)}{\alpha\gamma+(1-\gamma)(1+\phi)}[\log(1-\alpha)-\mu^p-\xi_t]$$

Because of the definition of θ_γ, this is equivalent to:

(XXVI) $$y_{2,t} - y_{1,t} + \delta = \theta_\gamma(y_{2,t-1} - y_{1,t-1} + \delta) + (1-\alpha)(\theta_\gamma\Delta m_t) + + \frac{(1-\alpha)}{(1+\phi)}(\xi_t) - \frac{(1-\alpha)\theta_\gamma}{(1+\phi)}(\xi_{t-1}) - \frac{(1-\alpha)}{(1+\phi)}(1-\theta_\gamma)\xi_t$$

This can finally be written as:

(XXVII) $y_{2,t} - y_{1,t} + \delta = \theta_\gamma\left(y_{2,t-1} - y_{1,t-1} + \delta\right) + (1-\alpha)\left(\theta_\gamma \Delta m_t\right) + + \frac{(1-\alpha)}{(1+\phi)}\left(\theta_\gamma \Delta\xi_t\right)$

As we recall from (XII), the gap δ between y_2 and y_1 was constant in a standard NKPC. This is not the case anymore after introducing real wage rigidities, as it can be seen in (XXVII): Now, it fluctuates as a function of supply shocks Δm and preference shocks $\Delta\xi$. The coefficient θ_γ is an increasing function of γ, the degree of real wage rigidities. Therefore the size and the persistence of deviations of the gap between first-best output and second-best output are increasing if the degree of real wage rigidities increases.

Now we want to find out the behavior of inflation under the assumption of Calvo pricing. The following marginal cost schedule is assumed:

(XXVIII) $mc + \mu^p = w - mpn + \mu^p$

Combining this with the wage schedule of (XVIII) yields:

(XXIX) $mc_t + mpn_t + \mu^p = \gamma(mc_{t-1} + mpn_{t-1} + \mu^p) + (1-\gamma)mrs_t$

The marginal product of labor and the marginal rate of substitution is replaced with their respective values from (V) and (VI):

(XXX) $mc_t + \mu^p + (y_t - n_t) + \log(1-\alpha) = \gamma(mc_{t-1} + \mu^p + (y_{t-1} - n_{t-1}) + \log(1-\alpha)) + (1-\gamma)(y_t + \phi n_t + \xi)$

Output can be replaced with the log formulation of (I):

(XXXI) $mc_t + \mu^p + \alpha(m_t - n_t) + \log(1-\alpha) = \gamma(mc_{t-1} + \mu^p + \alpha(m_{t-1} - n_{t-1}) + \log(1-\alpha)) + (1-\gamma)(\alpha_m + (1-\alpha+\phi)n_t + \xi)$

This can be reformulated in two steps to:

(XXXII) $mc_t + \mu^p + \log(1-\alpha) = \gamma(mc_{t-1} + \mu^p + \alpha(m_{t-1} - n_{t-1}) + \log(1-\alpha)) + (1-\gamma)[(1+\phi)n_t] - \gamma\alpha(m_t - n_t) + (1-\gamma)\xi$

(XXXIII) $mc_t + \mu^p = \gamma(mc_{t-1} + \mu^p) - \gamma\alpha(\Delta m_t - \Delta n_t) + (1-\gamma)[(1+\phi)n_t] + (1-\gamma)[\xi - \log(1-\alpha)]$

Because of the flexible price assumption we set $mc_t = mc_{t-1} = -\mu^p$:

(XXXIV) $0 = -\gamma\alpha(\Delta m_t - \Delta n_{2,t}) + (1-\gamma)[(1+\phi)n_{2,t}] + (1-\gamma)[\xi - \log(1-\alpha)]$

Subtracting (XXXIV) from (XXXIII) yields:

(XXXV) $mc_t + \mu^p = \gamma(mc_{t-1} + \mu^p) + \gamma\alpha(\Delta n_t - \Delta n_{2,t}) + (1-\gamma)(1+\phi)(n_t - n_{2,t})$

Because of (I) it follows that:

(XXXVI) $\Delta n_t - \Delta n_{2,t} = \frac{\Delta y_t - \Delta y_{2,t}}{1-\alpha}$

The analogous is valid for $n_t - n_{2,t}$. Inserting this into (XXXV) and using the lag operator L yields:

(XXXVII) $mc_t + \mu^p = \gamma L(mc_t + \mu^p) + \gamma\alpha\frac{\Delta y_t - \Delta y_{2,t}}{1-\alpha} + (1-\gamma)(1+\phi)\frac{y_t - y_{2,t}}{1-\alpha}$

This leads to the following expression:

(XXXVIII) $mc_t + \mu^p = \frac{1}{(1-\gamma L)(1-\alpha)}[\gamma\alpha(\Delta y_t - \Delta y_{2,t}) + (1-\gamma)(1+\phi)(y_t - y_{2,t})]$

Finally, I can insert this expression into the new Keynesian Phillips curve in (XIII) to get:

(XXXIX) $$\pi_t = \beta E_t\{\pi_{t+1}\} + \frac{(1-\theta)(1-\theta\beta)}{\theta(1-\gamma L)(1-\alpha)}[\gamma\alpha(\Delta y_t - \Delta y_{2,t}) + (1-\gamma)(1+\phi)(y_t - y_{2,t})]$$

Defining $\lambda \equiv \frac{(1-\theta)(1-\theta\beta)}{\theta}$ and $x_2 \equiv \gamma\alpha(\Delta y_t - \Delta y_{2,t}) + (1-\gamma)(1+\phi)(y_t - y_{2,t})$ yields the more convenient form:

(XL) $\pi_t = \beta E_t\{\pi_{t+1}\} + \frac{\lambda}{(1-\gamma L)(1-\alpha)}x_2$

This is the real wage rigidities Phillips curve.

4.3.4 Discussion of the Model

The real wage rigidities Phillips curve is based on a standard NKPC, like the sticky information Phillips curve described in chapter 4.2. However, the reason for Blanchard and Galí to provide a different framework was that they were not content with the assumptions of the sticky information framework: Recall that in the sticky information framework, prices were changed each period, while new information was only obtained every couple of periods. Blanchard and Galí argue that it is the other way round: Prices are reviewed more often than assumed; still firms decide to keep them unchanged, e.g. because of transaction costs. The rigidity in the sticky information framework is present in the prices, while in the real wage rigidities model it is to be found in the wages.

A main motivation for the model was to confront the "divine coincidence" – the property of the NKPC that stabilizing output implies stabilizing inflation, so in fact there is no trade-off between output and inflation in the baseline NKPC. In the real wage rigidities model, as we can see in (XXXIX), it is still the case that stabilizing inflation is consistent with stabilizing the output gap $y - y_2$ (the distance of actual output from its second-best level). However now, it is no longer desirable to stabilize the output gap. What matters for welfare is the distance of output to its first-best level, $y - y_1$. As we have shown (see (XXVII)), in contrast to the baseline NKPC, the distance between first-best output and second-best output is no longer constant, but affected by shocks. This result is summarized by the authors as follows:

"[T]here is no longer an exact relation, however complex, between inflation and the welfare-relevant output gap. Thus, there is no way to stabilize both in the presence of either supply or preference shocks, and monetary policy faces a clear trade-off."

(Blanchard & Galí, 2007, p. 43)

How does the real wage rigidities Phillips curve face the usual deficiencies of the NKPC as described in chapter 3.4? Let me start with an analysis of a disinflation. A sudden, unexpected, permanent disinflation from a positive level of inflation to zero is assumed to take place in period t. In the standard NKPC model, it follows from (XVII) that output has to decrease: As inflation was positive before, expected inflation equals zero after the disinflation takes place, output has to decrease by $\Delta y_t = -\frac{1-\beta}{\kappa}\pi_{t-1}$ (the second-best level of output y_2 is normalized to zero here). The model was calibrated by Blanchard and Galí by using the following parameter values for quarterly data: A time preference β of 0.99, the probability θ that the price cannot be changed of 0.5 (implying an average price duration of two quarters), an α (the exponent of the exogenous factor in the production function) of 0.025 (which roughly equals the share of oil in production), and a ϕ of 1 (the parameter of the utility function of the households, this corresponds to a unit Frisch labor supply elasticity). In the standard NKPC, this leads to disinflation costs of 5 basis points in output for a disinflation of 4 percentage points (1 percent per quarter). In the real wage rigidities Phillips curve, output has to decrease by $\Delta y_t = -\frac{1-\beta}{\kappa}(1 + \frac{\gamma(1-\alpha+\phi)}{(1-\gamma)(1+\phi)+\alpha\gamma})\pi_{t-1}$. A value of 0.9 is assumed for the parameter γ, the degree of real wage rigidities, which implies a half-life for the adjustment of real wages of about six quarters. By otherwise using the same numbers and the same disinflation policy as before, this leads to a decrease in output by 50 basis points in the period the policy is implemented. This is more consistent with the stylized facts of disinflations. (Blanchard & Galí, 2007, pp. 47-48)

Another usual deficiency of NKPCs as described in chapter 3.4 is the lack of inflation inertia. This deficiency does not hold anymore in the real wage rigidities model. If real wage rigidities are prevalent, changes in the output gap have persistent effects on inflation. The reason is that changes in the workers' reservation wage due to a change in output and employment affect the real wage and real marginal cost only gradually. Even when output has already returned to its structural level, this effect lives on because of the real wage rigidities. This can be seen by analyzing (XL): Multiplying by $(1-\gamma L)$ yields the following equation: $\pi_t = \frac{\gamma}{1+\gamma\beta}\pi_{t-1} + \frac{\beta}{1+\gamma\beta}E\{\pi_{t+1}\} + \frac{\lambda}{1+\gamma\beta}x_2$. This equation looks somehow similar to the hybrid NKPC of chapter 3.3. It can be seen in this equation that inflation inertia is present because past inflation plays a role in determining present inflation. The influence of past inflation is increasing if γ, the degree of wage rigidity, increases.

While the prevalence of real wage rigidities seems to be a realistic feature of the economic environment, it has to be mentioned that Blanchard and Galí purely assume them to be present, without giving a lot of theoretical or empirical justifications for them. It would be necessary to provide microfoundations for this crucial assumption of this model.

5 Conclusion

The goal of this thesis was to describe and compare new theories of the Phillips curve. I started with an introduction on the original Phillips curve and the new Keynesian Phillips curve, which serve as baseline models for the new theories that I discussed later on. The following three new theories were chosen: The wage aspirations theory by Ball and Moffitt, the sticky information theory by Mankiw and Reis, and the real wage rigidities theory by Blanchard and Galí. All models have been derived formally and their properties have been described, especially when it comes to facing the deficiencies of previous theories. Table 2 shows an overview of the properties of these three models.

	Wage aspirations	Sticky information	Real wage rigidities
Central idea	Wages adapt slowly to changes in productivity growth	Information disseminates slowly	Wages are influenced by past wage growth
Basic model	Standard PC	NKPC	NKPC
Rigidity in	Wages	Prices	Wages
Rigidity comes from	Adaptive expectations	Sticky information	Wage setting
Expectations	Naïve	Rational	Rational
Time horizon	Backward-looking	Forward-looking	Forward-looking
Inflation influenced by	Past inflation, unemployment, and difference between productivity growth and wage aspirations	Output gap and past expectations	Output gap and present expectations
Explains disinflations	No	Yes	Yes
Explains inertia	Yes	Yes	Yes

Table 2: Properties of the new theories of the Phillips curve

The wage aspirations theory is based on a standard PC framework as described in chapter 2; it can therefore be criticized because it does not incorporate rational expectations, and the model is not derived from microeconomic reasoning. Despite these theoretical arguments, it does offer plausible explanations for the factors explaining inflation, namely that there are wage rigidities and differences between productivity growth and wage aspirations. Nowadays it is mainstream in economics not to accept theories that incorporate irrational behavior, even if they fit the facts better; but theories should also be assessed in regard to the fit with empirical facts, not only whether it fits into the framework of a theoretical economy. In those terms, the wage aspirations theory offers a good empirical explanation of the inflation behavior, especially when it comes to the unusual behavior of inflation and unemployment during the new economy boom. Still it has to be mentioned that the wage aspirations model is merely an econometric enhancement of the Phillips curve and cannot be incorporated into a wider framework of macroeconomic theories.

The sticky information model is based on a new Keynesian framework and therefore has better theoretical foundations; the main assumption, that information disseminates slowly throughout the population, is somehow similar to the assumption of the wage aspirations theory: In the sticky information model, information about prices are not updated each period, while in the wage aspirations model, information about productivity growth takes some time to converge to the actual value. An important implication of the sticky information model was that today's inflation is partly based on past expectations formed some periods earlier. This seems plausible ad hoc, as probably everybody knows personal situations where economics decisions are based on possibly outdated information. However, in this specific context it is not very likely: In the sticky information model, firms update their prices each period, but revise their information only every couple of periods. This does not conform to the real world, where firms do not update their prices each period, but do revise their price information more often than they change prices. Still, this way of modeling captures the well-known idea of information asymmetries, and it allows reproducing the stylized facts of the behavior of inflation and unemployment.

This is also true for the real wage rigidities theory: It is based on the empirically plausible assumption that real wages are rigid. This assumption is very similar to the one of the wage aspirations theory – in both models, the wage partly depends on the wage of the previous period. The real wage rigidities model however is derived in a new Keynesian framework. In other models of the NKPC, stabilizing output was always equivalent to stabilizing inflation – thus there was no actual trade-off between these two goals. In the real wage rigidities model however, this does not hold anymore –

stabilizing output and inflation are conflicting goals and monetary policy thus faces a clear trade-off.

All theories described include some kind of rigidity and wrong expectations – both of which are essential ingredients for theories of the Phillips curve. Under perfect markets with perfect and complete information, a Phillips curve could not arise. The wage aspirations theory based on the original Phillips curve can explain the behavior of unemployment and inflation during the new economy boom, but it lacks theoretical foundations. The two other models based on the new Keynesian Phillips curve are derived from microeconomic reasoning and perform well in overcoming the deficiencies of the new Keynesian Phillips curve – namely they can explain inflation inertia and the behavior of macroeconomic variables during disinflations. The different kinds of theories show that there are many ways of deriving a PC relation. However, while progress has been made, no discussed theory seems to be fully viable so that it could make its way as the next generation Phillips curve into macroeconomic textbooks.

Appendix

Kurzfassung

Nach einer Erarbeitung der ursprünglichen und der neukeynesianischen Phillipskurve werden drei neuere Theorien beschrieben, die den negativen Zusammenhang zwischen Inflation und Arbeitslosigkeit erklären: Die Produktivitätssteigerungs- und Lohnerwartungstheorie von Ball und Moffitt, die Informationsrigiditätentheorie von Mankiw und Reis und die Reallohnrigiditätentheorie von Blanchard und Galí. Erstere basiert auf der ursprünglichen Phillipskurve, während die beiden anderen Erweiterungen des neukeynesianischen Modells sind.

Alle drei Modelle erklären den Phillipskurvenzusammenhang besser als ihre jeweiligen Vorgänger. Das Modell, welches auf der ursprünglichen Phillipskurve basiert, kann das Verhalten von Inflation und Arbeitslosigkeit während des New Economy Booms erklären, ihm mangelt es aber an einer soliden theoretischen Grundlage. Die anderen beiden Modelle, welche auf der neukeynesianischen Phillipskurve basieren, werden aufgrund mikroökonomischer Überlegungen hergeleitet und können die Unzulänglichkeiten der neukeynesianischen Phillipskurve überwinden, indem sie Inflationsträgheit und das Verhalten von makroökonomischen Variablen während Disinflationen erklären.

Abstract

After having revised the standard and the new Keynesian Phillips curve, three newer theories of the negative relation between inflation and unemployment are described: The productivity growth and wage aspirations theory by Ball and Moffitt, the sticky information theory by Mankiw and Reis, and the real wage rigidities theory by Blanchard and Galí. The first one is based on the standard Phillips curve, while the latter two are enhancements of the new Keynesian model.

It can be shown that all three models do a better job in explaining the Phillips curve relation than their respective predecessors. The model based on the original Phillips curve can explain the behavior of unemployment and inflation during the new economy boom, but it lacks theoretical foundations. The two other models based on the new Keynesian Phillips curve are derived from microeconomic reasoning and perform well in overcoming the deficiencies of the new Keynesian Phillips curve – namely they can explain inflation inertia and the behavior of macroeconomic variables during disinflations.

List of Abbreviations

AD......................... aggregate demand

AR(1)..................... first-order autoregressive process

AS.......................... aggregate supply

i.e.......................... id est (that is)

e.g.......................... exempli gratia (for example)

et al....................... et alii (and others)

GDP....................... Gross domestic product

NBER..................... National bureau of economic research

NAIRU .... Non-accelerating inflation rate of unemployment

NKPC..................... New Keynesian Phillips curve

PC.......................... Phillips curve

p............................ page

pp.......................... pages

US .... United States (of America)

VAR....................... vector autoregression

WIFO..................... Österreichisches Institut für Wirtschaftsforschung (Austrian Institute of Economic Research)

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