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Methodological Issues of Medium-Term Macroeconomic Projections – The Case of Potential Output

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Final Report

Research Report prepared for the
Federal Ministry of Economics and Technology
November 2006

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1 Introduction

Potential output measures a country's attainable aggregate living standard and is thus one of the most important categories of economics. It is also a key indicator for monetary and fiscal policy. The ECB, for example, uses the output gap – the relative difference between potential output and GDP – as a leading indicator of inflation and requires a precise growth rate of potential output to determine its reference value for M3. Potential output is also relevant for fiscal policy and medium-term fiscal planning, for example, in determining the structural budget deficit. Despite its prominence, however, potential output is a difficult concept to pinpoint both theoretically and even more so empirically.

Arthur M. Okun, who coined the term "potential output" in 1962, defined it as the level production at full employment, the latter according to Okun referring to the degree of utilization of the factors of production that does not cause inflationary pressure. In modern terms potential output is therefore the sustainable level of real GDP. In a market economy the concept of potential output necessarily implies an unemployment rate greater than zero. Therefore its analysis also requires analysis of this "equilibrium" unemployment rate, the *non-accelerating inflation rate of unemployment* (NAIRU).

As discussed in chapter 2, the theoretical difficulties of unambiguously defining potential output are due to divergent opinions about the persistency of output gaps and the possible endogeneity of potential output, both of which arise from different assumptions about the inherent stability of the economy. From a Keynesian perspective, the effectiveness of endogenous mechanisms that return the economy to equilibrium is uncertain at best. Long-lasting negative output gaps are thus a likely occurrence and entail the danger of hysteretic effects causing potential output to adjust to the GDP rather than vice versa. In contrast, monetarists and proponents of new classical theory hold the view that the rational behavior of economic agents rapidly corrects disequilibria and that potential output is unaffected by economic downswings and upswings. New Keynesians occupy a position somewhere in between. Economic policy advice differs in accordance with these divergent views. Whereas Keynesians tend to favor active macroeconomic stabilization policies and regard macroeconomic policy as a necessary adjunct to structural reform, monetarists and new classical theorists view macro policy as more or less superfluous, argue strongly for rule-based policies, and consider structural reforms to be the key to higher economic growth.

However, if output gaps close as a result of labor market hysteresis and capital stock adjustments, then macro policy is not neutral in the long run but rather affects the real economy. In addition to the NAIRU, endogenous technological progress is a second channel through which macro policy may affect the level of potential output.

From an empirical perspective, it is also the NAIRU and endogenous technological progress that make it difficult to estimate and forecast potential output with any degree of certainty. Volatile outcomes resulting from small changes in the specification or the estimation period pose a problem for policy makers because estimation errors can have dire consequences for unemployment and inflation.

In chapter 3 we therefore discuss the methods used by German and international organizations to estimate potential output and how strongly these react to movements in GDP. The estimation approaches can be categorized into three groups: first, purely statistical methods (here: Hodrick-Prescott filter and Rotemberg filter); second, methods that determine potential output primarily on statistical grounds but make use of the interaction between certain economic variables (semi-structural methods, here: multivariate Hodrick-Prescott filter and multivariate Kalman filter); and third, methods that determine potential output on the basis of economic factors (structural methods, here: production function approach and Kalman filter with exogenous variables). The analysis shows that only structural methods allow for a distinction between the theoretical approaches discussed in chapter 2. They are also better suited for forecasts, especially in the case of changes in the structural or macroeconomic environment at the end of the observation period. They supersede univariate methods by providing an economic explanation of movements in potential output.

In practice, however, estimates based on production functions are to a large extent based on univariate methods, especially the Hodrick-Prescott filter, to estimate the potential values of the individual components of the production function. It is therefore not surprising that the estimates of potential output given by different institutions are quite similar and actually more similar than are the estimates of each organization for a specific year at different points in time (chapter 4). The different take on potential output in retrospect can be seen quite clearly for the year 1999. In the spring of 2000, the International Monetary Fund estimated the German output gap for 1999 to be -2.8%; in the spring of 2006, it put the output gap of 1999 at 0.1% – not only a difference of almost 3 percentage points but also a change from minus to plus. An equally stark picture emerges when looking at the figures provided by the EU Commission and the OECD.

Like most international organizations, we use a production function approach to estimate Germany's potential output (chapter 5). The NAIRU is estimated using a Kalman filter. For various reasons we stick relatively close to the modeling strategy of the EU Commission, one being its relevance for the national governments in the Euro Area when, for instance, formulating their stabilization programs. A particularly important difference is the way in which we calculate the potential level of the components of the production function, namely the NAIRU and total factor productivity. The NAIRU estimation differs in the specification of the Phillips curve and in that we quantify the effect of exogenous variables on the NAIRU. In the case of total factor productivity, we also attempt to identify explanatory variables.

The Kalman-filter technique is well-suited for estimating the NAIRU because it was specifically developed to estimate unobservable variables. The NAIRU is estimated here as a nonstationary trend and it is assumed that deviations of actual unemployment from the NAIRU (i.e. unemployment gaps) affect inflation. To make use of the information contained in this economic relationship – the Phillips curve – the NAIRU and the Phillips curve are estimated simultaneously. The unemployment gap is modeled as an AR(2) process. Chapter 5 presents three groups of estimates: The first makes use of the Kalman filter without exogenous variables. The second group examines factors that influence the NAIRU, specifically institutional variables and a monetary policy indicator. Thirdly, we test for hysteresis.

The AR-coefficients of the unemployment gap imply an average cycle length of nine years. The unemployment gap is estimated with a small positive constant implying deflationary pressure. This is compatible with the three disinflationary periods during the estimation period. According to our estimate the NAIRU was at 8.1% in 2005.

With the exception of the tax wedge,[1] the outcomes of the estimations including institutional variables (employment protection, union density, benefit replacement ratio, tax wedge) were not robust. The limited explanatory power of these variables is in line with part of the literature. Furthermore, and again with the exception of the tax wedge, these variables should, if anything, have lowered the German NAIRU since the late 1970s.

As a result of econometric tests, the choice of monetary policy indicator fell on the difference between the real short-term interest rate and the rate of economic growth. The effect of the monetary policy stance – thus measured – is robust at 0.1%, but relatively small. This may be partly due to the relative smoothness of our Kalman filter estimate of the NAIRU. An OLS regression estimating the long-term effect of monetary policy on unemployment supports and amplifies the result above.

The results of our hysteresis estimates are also robust. Hysteresis can have different causes but the key factor seems to be that the number of long-term unemployed increases and that these influence labor market developments and wages, in particular, less than do the temporarily unemployed. According to our estimate, an increase in the rate of long-term unemployment by one percentage point raises the NAIRU by 0.9 percentage points. Translated into the effect of lagged unemployment, which is often used to measure hysteresis effects, the coefficient is 0.4. The existence of hysteresis implies that variables will affect the NAIRU if they cause unemployment to stay high or low for a prolonged period. Our analysis shows that the unemployment gap and the NAIRU are not independent of each other: to a certain degree the structure of unemployment hardens or loosens, thus causing the unemployment gap to close partly through an increase or decrease in the NAIRU.

Potential total factor productivity (TFP^*) is the second key variable needed to determine potential output in the production function approach. Unlike the EU Commission, we estimate an equation that allows for total factor productivity to be partly determined by other economic variables. This makes it possible to model structural breaks. Total factor productivity (TFP) is estimated by using the investment ratio, per-capita expenditure on research and development and U.S. total factor productivity. An increase in the investment ratio by

[1] The term tax wedge is used in the literature to include not only taxes but also duties and social security contributions.

one percentage point is estimated to increase total factor productivity by 1.2%. An increase in expenditure on research and development (per capita) by 1% raises TFP by barely 0.1%. An increase in U.S. TFP by 1% increases German TFP by 0.9%. We also find monetary policy to have an effect, albeit an indirect one via the investment ratio. Potential TFP is determined by plugging equilibrium values for the investment ratio and research and development expenditure into the TFP equation.

Both the NAIRU and potential TFP greatly affect the estimate of potential output. Potential TFP varies substantially depending on how the equation is specified. Since there is a one-to-one correspondence between potential TFP and potential output in the production function, the possible estimates and forecasts of potential output differ just as much. The NAIRU, although relatively robust, ultimately depends to a large extent on the assumed econometric properties of both the NAIRU itself and the unemployment gap. Furthermore, estimates and forecasts of the labor force and hours worked are highly uncertain.

Chapter 6 indicates that the difference in per-capita growth between Germany and the United States is primarily caused by the greater decrease in working time and the large increase in unemployment in Germany. It is argued that the increase in unemployment is at least partly the result of the macroeconomic policy response to different adverse shocks that affected the German economy during the past 15 years, including German unification and the drastic increase in oil prices, as well as the stock market crash and the downswing of the US economy at the beginning of this decade. Unlike the U.S. Federal Reserve, the ECB did not act aggressively enough to counter faltering aggregate demand. This is manifest in the fact that, despite drastic increases in the price of oil, the medium-term inflation target was missed only minimally; in Germany inflation was much lower in most years. Given a common European monetary policy, German fiscal policy should have taken an active role in the face of weak aggregate demand.

The ultimate lack of knowledge about the precise values of the NAIRU and potential total factor productivity allow for the estimation of many different levels of potential output. It is therefore problematic to use this theoretically compelling concept as a basis for economic policy advice. It is possible to identify factors that positively affect potential output, as for example, the investment ratio. But no estimate of potential output can claim to be accurate or precise, so that several different estimates must be used as policy indicators. This, however, vastly complicates fiscal planning and the use of monetary policy rules, such as the Taylor rule. Given the difficulties involved in robustly estimating potential output, economic policy makers need to learn to pursue their policy objectives without relying on this variable. In the face of a benign inflation outlook and high unemployment economic policy should strive to test the limits of potential output and to set in motion a virtuous cycle of a decreasing NAIRU, a rising participation rate, higher productivity growth and an improvement in fiscal balances.

Certain structural reforms can no doubt increase potential output and possibly even potential output growth. But also in this context, macro policy has an important role to play.

Furthermore, it is important to weigh possible economic and social side effects of any given structural reform and to realize that not every labor market reform has unambiguously positive results. This applies not only to different systems of wage bargaining and employment protection but also to the generosity of unemployment benefits.

2 Potential output from a theoretical perspective

2.1 Introduction

Potential output is a key category in economics and economic policy because it measures the sustainable living standard. Accordingly, economic theory, on the one hand, analyses adjustment mechanisms set in motion once actual production diverges from potential output and derives policy recommendations from the speed and stability of these processes. On the other hand, economic theory analyses the way in which individual structural characteristics of the economy affect potential output and devises structural reforms that enhance potential output. Differences in the theoretical analyses and policy recommendations primarily result from the underlying assumptions concerning, *firstly*, the inherent stability of adjustment mechanisms, *secondly*, the persistency of output gaps and, *thirdly*, the endogeneity of potential output.

From a Keynesian perspective, the effectiveness of endogenous mechanisms that return the economy to equilibrium is uncertain at best. Keynesians therefore tend to advocate active stabilization policies and to regard macroeconomic policy as a necessary adjunct to structural reform. In contrast, monetarists and proponents of new classical theory are stability optimists and, at the same time, policy pessimists: market-endogenous adjustment mechanisms are thought to guarantee a return to equilibrium, whereas stabilization policies are considered more or less ineffective. Given market frictions, they nonetheless plead for macroeconomic stabilization policies, albeit rule-based ones. Structural reforms to increase flexibility are at the fore of policy recommendations to enhance potential output. New classical theorists furthermore interpret business cycles as resulting from technological shocks, and therefore as cycles of potential output, and reject all forms of stabilization policy.

Besides the questions of how to bring actual production in line with potential output and how to increase the level of potential output, there is the additional question of what determines potential growth. Since the mid-nineties, real GDP has increased on average by 3.3% annually in the United States, compared to 1.3% in Germany. Higher population growth in the US (+1.1% vs. +0.1% in Germany) and the increasing difference in working time (-0.2% and -0.6% in the US and Germany, respectively) explain this divergence to a great extent. However, productivity per hour also increased somewhat faster in the United States (+2.8%) than in Germany (+2.2%). The key question is whether the low productivity growth in Germany is the result of weak economic activity – a disequilibrium phenomenon – or the consequence of a low growth path due to a slower buildup of capital stock or a lower increase in total factor productivity. In the following section, we first discuss the term potential output and place it in a historical context. Section 2.2 then provides an overview of the factors generally thought to determine the level of potential output and the relationship between actual production and potential output according to the different schools of economic thought. The determining factors of potential growth according to current growth theories are discussed in section 2.3.

2.2 Definition and history

Potential output is the sustainable level of real (inflation-adjusted) GDP. It is limited due to scarce natural resources (population, raw materials), institutional factors (e.g. those in labor markets) and factor endowments (especially capital stock and human capital). A given level of output is sustainable if it does not generate inflationary or deflationary tendencies. The concept of potential output therefore implies a concept of the non-accelerating inflation rate of unemployment (NAIRU).

The term potential output was coined in 1962 by Arthur M. Okun and describes the level of production at full employment. In the words of Okun: „How much output can the economy produce under conditions of full employment?" Okun's aim was to show the material loss resulting from an increase in unemployment and to develop a measure for full capacity utilization that could be used to gauge the need for economic policy action. In this vein, he devised the Okun coefficient that quantifies the inverse relation between changes in the unemployment rate and changes in GDP. For the United States, Okun estimated a coefficient of 3.3: An increase in the unemployment rate by one percentage point accordingly corresponds to a reduction in GDP by 3.3%. It should be noted, however, that there is an error in Okun's estimation. Okun first estimated the coefficients with the unemployment rate as the dependent variable and GDP as the independent variable, and then used the reciprocal to quantify the desired dependency of GDP growth on the unemployment rate.[2] Estimating the coefficient on the basis of his data directly – as is correct – yields a coefficient of only 2.[3] An increase in the unemployment rate causes GDP to be 2% lower. A corresponding estimate for Germany (1995-2005) yields an Okun coefficient of 1.1, so that an increase in the unemployment rate by one percentage point reduces GDP by approximately 1%.[4]

The concept of a sustainable level of output devoid of inflationary and deflationary tendencies is much older than the terms "sustainable", "potential output" and "NAIRU". Okun interpreted the term potential output as indicating the degree of utilization of factor inputs, especially labor, that did not generate any inflationary pressure. As the following quote shows, according to Okun, full employment was reached at an unemployment rate of 4%.

> "Potential GNP is a supply concept, a measure of productive capacity. But it is not a measure of how much output could be generated by unlimited amounts of aggregate demand. The notion would probably be most productive in the short-run with inflationary pressure pushing the economy. But the social target of maximum employment and production is constrained by a social desire for price stability and free markets. The full employment goal must be understood as striving for maximum production without inflationary pressure; or more precisely, as aiming for a point of balance between more out-

[2] Such an inversion is not legitimate because the equation is a stochastic equation rather than an identity. The original equation and the inverted equation are based on different assumptions about the error terms.

[3] Cf. Barreto/Howland (1993): http://www.wabash.edu/dept/economics/Faculty%20Work/Okun/index.html.

[4] Authors' calculations based on national account data and AMECO data as well as a Cobb-Douglas production function.

> put and greater stability, with appropriate regard for the social valuation of these two objectives.
>
> It is interesting and perhaps surprising that there seems to be more agreement that a four percent unemployment rate is a reasonable target under existing labor market conditions than on any of the analytical steps needed to justify such a conclusion.
>
> …I shall now state that it [the four per cent unemployment rate] is the target rate of labor utilization underlying the calculation of potential GNP in this paper."
>
> (Okun 1962: 98)

Joan Robinson also emphasized that full employment does not imply the complete absence of unemployment because „overfull employment"gives rise to a wage-price spiral.

> "From the first it was obvious that if we ever reached and maintained a low level of unemployment, with the same institutions of free wage bargaining and the same code of proper behaviour for the trade unions that then obtained, the vicious spiral of rising prices, wages, prices would become chronic. […] it is very troublesome ideologically, for both Full Employment and stable prices are Good Things. The solution sometimes found is to say that when wages are rising there is overfull employment and to define Full Employment so as to include enough unemployment to prevent money wage-rates from rising faster than productivity."
>
> (Robinson 1962: 88f.)

More than a century ago, Wicksell (1936 [1898]) in his analysis of the "natural" rate of interest asserted that the ratio of output to potential output affects the price level and that inflation theory must analyze the development of aggregate demand and supply. Although Wicksell did not use the term potential output or the obvious term "natural" output level, the concept is evidently implicit in his analysis.[5]

> There is a certain rate of interest on loans which is neutral in respect to commodity prices, and tends neither to raise nor to lower them.
>
> (Wicksell 1936 [1898]: 102.)

Accordingly John Williams, economist at the Federal Reserve Bank of San Francisco, asserts in reference to Wicksell that

> „…the natural rate is defined to be the real fed funds rate consistent with real GDP equaling its potential level (potential GDP) in the absence of transitory shocks to demand. Potential GDP, in turn, is defined to be the level of output consistent with stable price inflation, absent transitory shocks to supply. Thus, the natural rate of interest is the real fed funds rate consistent with stable inflation absent shocks to demand and supply."
>
> (Williams 2003)

The concept of potential output thus always entails an unemployment rate greater than zero and, in consequence, analysis of potential output requires an analysis of the *non-*

[5] An interesting point worthy of further investigation is that Wicksell was of the opinion that the so-called bank rate does not have to equal the natural rate of interest even in the long run.

accelerating inflation rate of unemployment (NAIRU).[6] The NAIRU is based on the idea that a specific level of unemployment is compatible with price level stability. A higher unemployment rate will lower the rate of inflation; a lower unemployment rate will increase the rate of inflation. In the present context, it is important to note that the NAIRU may be affected not only by institutional factors, but also by macroeconomic policy as indicated by the quotes below.

> "In some countries, such as the United States, the rise in unemployment was transitory; in others, including many European countries, the Nairu rose and has remained high ever since. I argue that the reaction of policymakers to the early 1980s recessions largely explain these differences. ... In countries where unemployment rose permanently, it did so because policy remained tight in the face of the 1980s recessions."
>
> (Ball 1999: 190)

> "... the long-run aggregate supply curve may be vertical, but its location is endogenous to macroeconomic policy."
>
> (Solow 1998: 11)

Originally, measures of potential output were developed for monetary and fiscal policy in the short and medium run. The sixties were characterized by optimism about the fine-tuning of the macro economy, inspired by Keynesianism. The mainstream view was that monetary or fiscal policy should react to an under- or overutilization of capital and labor with expansionary or restrictive measures, respectively, to ensure a speedy return of the output level to its potential. In the following decades the stability optimism declined in the wake of the rise of monetarism. Friedman's theoretical framework showed that the time lags of monetary policy can be long and variable implying the risk of pro-cyclical economic policy. It follows that policy measures that were intended to be anti-cyclical, but actually turned out to be pro-cyclical, could actually render the economy less stable. Friedman (1968) therefore advocated a rule-based monetary policy strategy. Other economists pointed out a tendency for business cycles to be politically induced prior to elections. In the seventies and eighties, the dominant view of economic policy maintained that real effects of macro policy are solely the result of expectation errors on the part of economic agents. In this view, monetary policy can raise employment only if there is at least temporarily some money illusion. The rational-expectations theory effectively undermined the legitimacy of this theoretical position. Since then advocates of rules in fiscal and especially monetary policy have dominated the field. The institutional independence of the German Bundesbank, its primary orientation on price level stability and its (proclaimed) strategy of monetary targeting are a manifestation of these developments. The same applies by and large to the present-day ECB.

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[6] The NAIRU concept was developed by Modigliani and Papademos (1975), who, however, called it NIRU (noninflationary rate of unemployment). The term NAIRU was first used by Tobin (1980). Unlike the term "natural rate of unemployment" introduced by Friedman in his Presidential Address to the American Economic Association in 1968, the NAIRU is not a purely neoclassical concept; see Carlin / Soskice (1990: 166). Friedman borrowed the term "natural" from Wicksell.

Potential output is still an important concept for monetary and fiscal policy. The ECB uses the output gap as an inflation indicator and the potential growth rate to determine its reference value for monetary growth. For central banks that pursue a strategy of inflation targeting, the output gap is a key variable[7] and for some, such as the US Federal Reserve, it is a variable that directly indicates a need for economic policy action (Greenspan 2005). Potential growth is also of great importance for fiscal policy and in particular for medium-term fiscal planning, i.e. to determine the development of the structural deficit. In the United States it is therefore the Congressional Budget Office (CBO) that provides policy makers with estimates of potential output and potential growth.

2.3 Structural factors and economic policy

The constraints of potential output can have natural, institutional or historical causes. Natural constraints are, for example, population growth and the scarcity of raw materials. The existing capital stock is a historical constraint as long as the per-capita capital stock does not correspond to its long-term equilibrium level (the steady state). The stock of human capital is also a historical constraint. The participation rate and the non-accelerating rate of unemployment (NAIRU) can have institutional and historical roots. The same applies to the degree of competition in an economy. Hence, economic policy measures that affect these factors can also affect the level of potential output.

Net investment in physical capital raises potential output and without any change in labor input increases the marginal productivity of labor and real wages. The same applies to human-capital investment. According to our calculations based on a Cobb-Douglas production function, net investment amounting to 5% of GDP raises the German capital stock by 1.5% and consequently in itself increases potential output by 0.7%.[8] An increase in the participation rate by 5 percentage points (to 81.1%) could in itself imply an increase in potential output by up to 2.6%. The equilibrium wage would remain unchanged if the capital stock were to increase accordingly. Similarly, a reduction in the NAIRU by 3 percentage points would raise potential output by up to 1.7%.

Whereas the above-mentioned relationships are largely uncontested in the literature, the question of how and under what circumstances demand-side policies may affect potential output is hardly discussed and in general such effects are categorically negated. It is therefore this latter question that we focus on here. As described below, neoclassical, monetarist and new classical theories are based on the assumption of an inherent stability of economic processes. Consequently, they postulate an automatic mechanism between changes that potentially affect potential output and changes in actual production. From a Keynesian perspective, on the other hand, factors that may potentially affect potential output may be ineffective

[7] For an overview of the monetary policy strategy of inflation targeting see Svensson (1999) and Mishkin (1999) as well as Bernanke and Mihov (1997).

[8] The calculation is based on data in the AMECO data base, according to which the capital stock in Germany is three times as large as GDP, and an assumed output elasticity of capital of 0.4.

if they do not induce a change in actual production. Hysteresis in the labor market or the capital stock may then lower potential output again.

2.3.1 Neoclassical theory[9]

In neoclassical theory of the late 19th and early 20th century – rooted in the writings of Marshall, Pigou, Fisher and Walras – potential output is determined by the existing capital stock, the labor force and the preference for leisure over work, given the level of technology. The consumption-saving decision depending on the real interest rate determines the increase in the capital stock and thereby future potential output.

The neoclassical dichotomy between the real sphere and the monetary sphere guarantees that within this theoretical framework an adequate adjustment in relative prices will ensure a return to the full utilization of potential output in the event of a disturbance that moves the economy away from equilibrium. Money is only used as a medium of transaction and constitutes a „veil“ that lies above but does not affect the real economy. The quantity theory of money $(M\overline{V} = P\overline{Y})$ describes the proportional relation between money supply and price level.

2.3.2 Monetarism

Monetarism further advanced neoclassical theory by reformulating the quantity theory of money in terms of money demand and by introducing the concept of the natural rate of unemployment. In this context, the natural rate of unemployment is:

> “the level [of unemployment] that would be ground out by the Walrasian system of general equilibrium equations, provided there is imbedded in them the actual structural characteristics of the labor and commodity markets, including market imperfections, stochastic volatility in demands and supplies, the cost of gathering information about job vacancies and labour availabilities, the costs of mobility, and so on.”
>
> (Friedman 1968: 8)

Wage and price rigidities were included in the model so that, in the short run, actual output may deviate from its potential. Within the monetarist framework, these deviations are, however, ultimately based on money illusion resulting from adaptive expectations and delayed adjustments; in the long run, all real variables such as the real interest rate and the unemployment rate have a natural level that is determined by economic fundamentals.

According to monetarism, monetary policy may permanently affect the real economy only if the growth rate of money is continuously increased. This will eventually result in higher rates of inflation. Given the assumption of adaptive expectations, economic agents repeatedly, albeit temporarily, succumb to money illusion.

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[9] The naming of different schools of thought is not always unambiguous. Here we refer to the theory in the tradition of Smith and Ricardo in the 18th and 19th century as classical theory. It was the mainstream before neoclassical theory.

2.3.3 New classical theory

The assumption that economic agents are unable to learn – implicit in adaptive expectations – was an important motivation for developing the new classical theory of rational expectations. According to this theory, monetary policy has hardly any real effects, even in the short run, because economic agents with rational expectations essentially anticipate the inflationary consequences of monetary policy actions and adjust their behavior accordingly.

The real business cycle theory is a version of this modern neoclassical macroeconomic framework. Its founders Kydland/Prescott (1982) and Nelson/Plosser (1982) explain the cyclical pattern of recessions and expansions almost entirely as resulting from real shocks, such as technological progress, changes in taxation or unforeseeable changes in economic fundamentals. The business cycle is hence interpreted as an optimal reaction to shocks to the real economy.

2.3.4 New Keynesianism

New Keynesianism embraces the neoclassical proposition of long-term neutrality. The various New Keynesian strands have microeconomic foundations but essentially the same adjustment mechanisms apply as in neoclassical theory. A theoretical difference exists, however, in the analysis of the short run. In New Keynesian theories unavoidable wage and price rigidities exist that allow an equilibrium with underemployment to persist in the short run.

In agreement with monetarist and some new classical approaches, nonneutrality of money is therefore a possibility in the short run,[10] in particular due to long-term wage contracts (Fischer 1977, Taylor 1980) and the costs of price adjustments (Rotemberg 1982, Mankiw 1985, Ball/Romer 1990).

In the more recent literature a theoretical strand has emerged that combines arguments of New Keynesianism with certain Keynesian results.[11] These theoretical and empirical analyses question the microeconomic rationality of the complete absence of money illusion. Information costs are deemed to exceed the benefits at least at sufficiently low inflation rates.[12] It follows that even in a theoretical framework that is specified in a neoclassical fashion in all other ways, it is rational for wage earners not to react with higher wage demands to a small increase in inflation because the potential real wage loss is minor. The consequence is that monetary policy may also affect the real economy in the long run, provided the inflation rate stays within certain bounds. This implies, however, that monetary policy not only affects the short-term business cycle but also the position of the long-term growth path – a

[10] In the 1980s the literature began to distinguish between neutrality of money and superneutrality of money. Neutrality is given if a one-time unexpected change in the money supply has no effect on the level of GDP. Superneutrality entails that a one-time unexpected change in the growth rate of money has no affect on the level of GDP. Lucas (1972) used the term neutrality to mean what is now called superneutrality. In 1986 Geweke (1986) was the first to make this distinction, by the mid-nineties it had become standard usage.

[11] See Akerlof (2002), Karanassou et al. (2002).

[12] See Akerlof (2002).

genuine Keynesian outcome. If, on the other hand, inflation accelerates too much, the usual neoclassical neutrality characteristics apply – in this case it is rational for wage earners to gather more precise information about the development of inflation to avoid potentially large real wage losses.

2.3.5 Neoclassical and New Keynesian adjustment mechanisms

From the viewpoint of neoclassical theory and most New Keynesian approaches the endogenous adjustment towards a full utilization of potential output is relatively simple.[13] Let us assume, for example, that potential output rises due to an unperceived increase in technological progress. The resulting excess supply will cause prices and wages to fall until, at given nominal demand, real demand increases sufficiently to match it. Say's law is valid in all variations of neoclassical theory: supply creates its own demand. The adjustment mechanism is analogous in case of an increased labor supply resulting, for example, from a higher participation rate. At the outset with a given capital stock, competition between workers causes real wages to fall to a level compatible with full employment.[14] The increase in employment implies an increase in the marginal productivity of capital which generates higher investment and a corresponding increase in the capital stock.[15] When adjustment is completed, both employment and the capital stock are higher than before and real wages have returned to their initial level.[16]

2.3.6 Keynesianism

The relationship between prices, wages and aggregate demand sketched above is also a key topic in the General Theory and those strands of Keynesian theory that focus on the instability of adjustment mechanisms (see, for instance, Spahn 1997, Tobin 1993, Greenwald/Stiglitz 1993, Leijonhufvud 1990, Riese 1986). The proposition challenged by these authors is that aggregate demand remains unchanged in face of falling wages:

> „For, whilst no one would wish to deny the proposition that a reduction in money-wages *accompanied by the same aggregate effective demand as before* will be associated with an increase in employment, the precise question at issue is whether the reduction in money-wages will or will not be accompanied by the same aggregate effective demand as before measured in money, or, at any rate, by an aggregate effective demand which is not reduced in full proportion to the reduction in money-wages."
>
> (Keynes [1936] 1964: 259 - 260)

[13] King (2000: 49) calls the New Keynesian model the „New Neoclassical Synthesis" because of the similarities between New Keynesian theory and neoclassical-monetarist theory.

[14] The underlying assumptions in the following are perfect markets, a production function with factor substitution, constant returns to scale and a given international level of interest rates.

[15] Cf. Bean (1997: 100), Burda/Wyplosz (1994: 204) and Gordon (1997: 439/441).

[16] Real wages reach their original level if interest rates remain unchanged despite the higher level of investment; see, for example, Burda/Wyplosz (1994: 203ff.).

If price adjustments are not instantaneous and perfect, as assumed in the neoclassical model, quantities will adjust which, in turn, affects production, employment and income (Tobin 1993: 46). If new hiring is not immediate, aggregate demand will fall as a result of lower nominal income.

> „The relevant labor demand curves are the nominal values of marginal products. These values will fall, the demand curves will shift down, if and as product prices fall. Product prices will fall because nominal labor incomes decline along with wage rates; as a result workers' money demand for the products they produce will decline too. Here, then, is a case in which demand and supply schedules do not stay put while the price adjustment to excess supply takes place. It is illegitimate to appeal to the intuition that seems so credible for single markets."
>
> (Tobin 1993: 58)

The main point of theoretical contention is the question of what happens when the price level or the rate of inflation falls unexpectedly. Does the relative decline in the price level raise real aggregate demand thus providing for an endogenous stabilization, as argued by neoclassical theory? Or is it likely, as put forth by Keynesians, that endogenous expansionary forces fail to take hold, implying no positive developments in the labor market? In this case, the restrictive effects of the relative decline in the price level may even dominate and cause a recession or cumulative destabilization.

> „(T)he question is whether proportionate deflation of all nominal prices will or will not increase aggregate effective real demand."
>
> (Tobin 1993: 58)

The literature cites two potential expansionary effects: the Keynes effect and the real balance effect. Both effects assume a constant (expansion of the) money supply.

Given a constant money supply, the Keynes effect postulates a decline in the interest rate resulting from a decline in demand. The decline is triggered by a decline in money demand in face of falling prices. If the money supply remains unchanged, the interest rate must fall to bring the money market back into equilibrium. In consequence, investment increases. Keynes himself provided two counter-arguments to this effect: firstly, a low interest elasticity of investment and, secondly, a high interest elasticity of money (liquidity trap). Furthermore, if disinflation is expected to continue, the marginal efficiency of capital may decline thus lowering investment.[17]

The real balance effect goes back to Pigou and Patinkin. According to this effect economic agents consume and invest more, as the real value of their cash balances and financial assets increases as a result of falling prices (Patinkin 1992, Tobin 1993). This wealth effect is central to neoclassical theory because it is an endogenous mechanism that stabilizes the

[17] This Mundell-Tobin effect is also mentioned by Keynes (1936). Post-Keynesians furthermore stress the income-distribution effect: The lack of aggregate demand is aggravated by the fact that in the process of falling wages and prices, income is redistributed at the expense of wage earners, who have a higher propensity to consume (Kalecki 1939 und 1942).

economy. It may, however, be countered by the Fisher effect. According to the Fisher effect, a falling price level or a falling rate of inflation (relative to expected values) increases the debt burden of enterprises thus negatively affecting production and investment.[18]

Given risk aversion, the acticity level of firms and banks declines as a result of negative liquidity and wealth effects emanating from the increased real debt burden, as analyzed, for example, by Greenwald/Stiglitz (1993). In the words of Patinkin (1992: 297):

> „the question remains whether it [the real-balance effect] is strong enough to offset the adverse expectations generated by a price decline, including those generated by the wave of bankruptcies that might well be caused by a severe decline. In brief, the question remains whether the real-balance effect is strong enough to assure the stability of the system: that is, to ensure that automatic market forces will restore the economy to a full-employment equilibrium position ...“
>
> Patinkin (1992: 297)

What are the consequences of a lack of endogenous stabilizing mechanisms, in particular the real balance effect, when demand falters? Initially only a negative output gap emerges, i.e. a deviation of production from its potential, but potential output itself is unaffected.[19] The destabilizing process of falling wages and falling aggregate demand will eventually come to an end in the face of nominal wage rigidity, but there is no endogenous tendency that brings output back to its potential – the economy is stuck in unemployment equilibrium. This output gap either persists or it closes as a result of diminished potential output.

The former case is the one Keynes focused on in The General Theory. It led him to conclude that

> “(A)n increase in the quantity of money will have no effect whatever on prices, so long as there is any unemployment”
>
> (Keynes [1936] 1964: 295).

Similarly Blanchard/Summers (1986) analyze the case of unemployment equilibrium in the insider-outsider model. In both cases expansionary macro policy or some other exogenous macroeconomic impulse is necessary and sufficient to close the gap. However, policy makers are faced with serious obstacles in adequately diagnosing the problem. In the absence of disinflation, policy makers may falsely conclude that potential output has diminished and fail to identify the unemployment equilibrium.

An output gap that persists over a long period is unlikely from a theoretical perspective. Eventually capital stock adjustments (Bean 1997: 93; Gordon 1997: 439) and hysteresis on the labor markets[20] will lower potential output until the gap disappears. Underutilization of capital at this point is small, if it exists at all, and the long-term unemployed may not be

[18] Creditors and debtors exist also in the case of base money since base money primarily enters circulation when firms take loans from commercial banks which in turn borrow money from the central bank.

[19] The case of an output gap caused by supply-side shocks is touched upon below because the adjustment mechanisms are more ambiguous.

[20] See section 5.3.3 for an overview of the different sources of labor-market hysteresis.

hired at the going wage even if aggregate demand picks up. Since monetary policy is generally believed to be powerful enough to cause output gaps in the short and medium run, the implication for monetary policy is apparent: If output gaps close as a result of labor market hysteresis and capital stock adjustments, i.e. changes in potential output, macro policy is not neutral but rather affects the real economy in the long run.

> "…If monetary policy can affect real economic activity by means other than money illusion then it may be possible for money to be nonsuperneutral in the long run."
>
> Espinosa-Vega (1998: 13)

The effects of supply-side changes on potential output are also viewed differently from a Keynesian perspective and from a neoclassical one. Structural reforms that increase labor supply in themselves exert downward pressure on wages and hence curb demand and production. Without an expansionary impulse there will be no increase in production. An expansionary impulse does not have to come from macro policy, but it is unlikely to be the result of the real balance effect. As shown above in the context of a downward adjustment of potential output, a temporary decrease in real wages is a necessary but not sufficient condition for an increase in potential output.

A somewhat different situation arises when higher technological progress is the cause of an unexpected increase in potential output. Higher technological progress raises the equilibrium real wage but does not immediately lead to a change in the actual real wage. Profits are therefore temporarily higher and may generate additional investment and demand. If the central bank does not accommodate this rise in potential output, the economy will necessarily undergo a period of disinflation.

2.4 Potential growth

As discussed in the previous chapter, higher unemployment that starts out as a short-term temporary phenomenon may affect not only the current level of GDP but also the level of potential output via hysteresis effects and a decrease in investment. At given labor inputs, cumulative net investment – the capital stock – determines the level of a country's potential output. Growth theory analyses long-term changes in the capital stock.

Assuming diminishing rates of return and a given savings rate, neoclassical growth theory – originated by Solow – finds that a certain capital stock per employee exists at which investment equals depreciation. It follows that the capital stock per employee remains constant. This is the steady-state level of the capital stock. If the capital stock is greater, depreciation exceeds investment and the capital stock will decline over time. A capital stock below the steady-state level implies that investment exceeds depreciation resulting in an increase in the capital stock. It is immediately evident that in neoclassical growth theory, the savings rate does not affect the long-term rate of growth but rather the size of the capital stock and consequently the level of GDP.[21] The savings rate only affects the growth rate in periods during which the capital stock is adjusting in response to a change in the savings rate, for example. However, such an adjustment period may go on for twenty years.[22]

Neoclassical growth theory cannot explain long-term divergences in economic growth between countries or regions. Divergent levels of per-capita income can be motivated, in particular if the propensities to save differ, which gives rise to different equilibrium capital stocks; this, however, applies only if international capital movement is restricted (McCallum 1996). The long-run growth rate of potential output (per capita) is determined only by technological progress which in the model is given exogenously. This fact is not changed by the theoretical modifications due to Mankiw et al. Mankiw et al. (1992) added human capital to the neoclassical growth model. Increasing human capital counters the diminishing rate of return of capital but thereby only slows down the convergence of the steady state.

The limited ability of the neoclassical growth model to explain the stark differences in the levels and growth rates of GDP evidenced in the real world and the theoretically nonsatisfactory exogeneity of technological progress in the eighties led to the formulation of models with endogenous growth.

The *leitmotiv* of endogenous or new growth theory is long-term technological progress as well as a corresponding productivity growth and therefore an absence of diminishing marginal rates of return. In a steady state with endogenous technological progress, labor increases at the rate of population growth, while effective labor, the capital stock and output increase at a rate in the amount of the sum of population growth and technological progress.

Endogenous growth theory encompasses three different paradigms (Aghion/Howitt 2005): the AK model, the model of product diversity, and the Schumpeterian approach.

The AK model does not differentiate between capital accumulation and technological progress but rather equates human capital with technological progress (Lucas 1988). Given this assumption marginal returns to capital need not diminish because human capital increases together with the stock of physical capital. In contrast, in the standard model, marginal returns diminish because labor or hours worked are limiting factors. In the AK model human capital is accumulated at the same rate as physical capital and potential output grows at the same rate as the capital stock. This latter growth rate, in turn, depends on the savings rate.

---

[21] In the Solow model the growth rate of the per-capita capital stock (k) is dependent on exogenous technological progress (g), the savings rate (s), population growth (n) and the depreciation rate (δ). Therefore it is given by $\frac{\dot{k}}{k} = s\frac{f(k)}{k} - (n + \delta + g)$. In the steady state the following applies: $\dot{k} = 0 \Leftrightarrow sf(k) = (n + \delta + g)k$. It follows that a change in the savings rate only affects the growth rate $\frac{\dot{k}}{k}$ when the economy is not in a steady state. In the steady state the savings rate only affects the level of the capital stock and thus of GDP; see also Lucas (1988).

[22] The golden-rule capital stock is the one that maximizes consumption in the long run or, more precisely, the per-capita capital stock at which additional output is equal to the increased depreciation. Blanchard (1997) shows that most economies have not reached the golden-rule capital stock: Assuming a depreciation rate of 10% the golden-rule capital stock is reached in the long run at a savings rate of 50%.

The product-diversity model originated with the founder of “new” growth theory, Paul Romer. Romer also viewed human capital as the motor of growth and assumed increasing marginal returns of knowledge accumulation. In this model, productivity is dependent on the degree of product diversity. Innovation through new products raises productivity, the productivity increase being larger, the greater the existing product diversity.

The third strand of new growth theory is the Schumpeterian growth theory that focuses on quality-increasing innovations that replace old products and spur a process of creative destruction (Aghion/Howitt 2005). The model incorporates a Cobb-Douglas production function and the growth rate depends on total factor productivity, as in neoclassical theory; total factor productivity, however, is determined by the endogenous rate of innovation.

Aghion/Howitt (2005) argue that imperfect credit markets may prevent firms from implementing innovations and reorganization measures in recessions. If the liquidity of firms depends on their current revenues and loans, and access to loans is restricted in recessions because loan grants depend on current revenue, then long-term investment will be lower than without this restriction (Aghion/Howitt 2005: 26). The authors show that anti-cyclical investment-oriented fiscal policy can positively affect the rate of growth. The authors reject an analogous monetary policy effect because of a lack of empirical evidence. This is noteworthy because such an effect is theoretically compelling and the analysis is explicitly based on Stiglitz/Greenwald.

It follows that in addition to the NAIRU and the capital stock per se, endogenous technological progress is a further potential channel through which macro policy may affect the level of potential output.

> “There is a common prejudice in macroeconomics, which is widely shared among policy makers, which they learned in their undergraduate education years and which we still see being developed in most textbooks of intermediate macroeconomics: namely, that there is a perfect dichotomy between, on the one hand macroeconomic policy (budget deficit, taxation, money supply) taken to affect primarily the short-run and whose primary aim is to stabilize the economy; and on the other hand, long-run economic growth, which is either taken to be exogenous or to depend only upon structural characteristics of the economy (property right enforcement, market structure, market mobility and so forth). The only link between macropolicy and long-run growth that most policy makers believe in, is that growth requires macroeconomic stability everything else remaining equal.”
>
> (Aghion/Howitt 2005: 24)

2.5 Conclusions

At first glance the concept of potential output appears to be quite simple: The maximum non-inflationary level of production depends on the existing factor inputs and the given technology level; the increase in potential output accordingly depends on changes in the capital stock and the labor force as well as technological progress. Already at the theoretical level, however, there are some essential and complex questions:

- How high is the NAIRU, and what factors influence the NAIRU?
- How flexible is the participation rate?
- Is an increase in the savings rate necessary and sufficient for higher capital growth?
- How can technological progress be conceptualized?

Given unemployment equilibrium, a decrease in unemployment – however induced – will raise GDP so that with a given savings rate, savings will be higher. Consequently investment and the capital stock may also be higher.

If technological progress is endogenous, unemployment may be decreased at the given nominal and real wage level even if underutilized productive capacities have already been eliminated.

From an empirical perspective, the key problems are estimating and forecasting the NAIRU and technological progress. A reliable estimate of medium-term potential output requires both results to be stable. The answers to these questions and problems are of great importance, especially for economic policy makers. Volatile outcomes resulting from small changes in the specification or the estimation period pose a problem for policy makers because estimation errors can have dire consequences for unemployment and inflation. The following two chapters therefore describe and critically assess the prevailing methods of estimating potential output.

Medium-term projections must rely on sound forecasts of the development of factor inputs and technological progress. They must furthermore be based on assumptions about macro policy since macro policy may affect potential output.

The widely accepted filter methods are unable to satisfy above conditions because of the way they are constructed. This is shown in the next chapter. If estimates of potential output derived from these methods are used as indicator variables for economic policy, there is the danger that they may become a self-fulfilling prophecy:

> "… if I understand the Bundesbank's method adequately, it is required always to make the average level of potential output during each four or five year period equal the average level of output actually observed during that same period. This means that the calculation can never conclude that there has been a persistent gap in either direction. This method is not confirming the dogma; it is part of the dogma.
>
> If this method had been applied in the 1930s, it would have reported a much smaller Depression than we believed then and believe now to have occurred; it would have claimed that the Depression was only about half as bad as it appeared to be. In addition, it would have come to the truly remarkable conclusion that some of those long depression years … were actually years of excess demand and overemployment. The Bundesbank, if it had existed then, would have felt impelled to contract the already desperate economy; and the Sachverständigenrat would have agreed."
>
> (Solow 2000: 10-11)

3 Empirical methods of estimating potential output

3.1 Introduction

In this chapter we describe the methods applied by various German and international organizations – International Monetary Fund (IMF), OECD, European Central Bank (ECB), EU Commission, German Council of Economic Experts (SVR), German economic research institutes and U.S. Congressional Budget Office (CBO) – and how strongly these methods reflect the actual development of GDP. Methods to estimate potential output can be categorized into three groups: first, purely *statistical* methods, second, methods that determine potential output primarily on statistical grounds but make use of the interaction between certain economic variables (*semi-structural* methods), and third, methods that determine potential output on the basis of economic factors (*structural* methods).

It will become apparent that only structural methods allow for a distinction between the different theoretical approaches discussed in the previous chapter. They are also better suited for projections and simulations exercises, especially in the case of changes in the structural or macroeconomic environment towards the end of the observation period. They are superior to univariate methods because they provide an economic explanation of movements in potential output.

The usefulness of individual forecasting methods is one of the criteria used in chapter 4 to evaluate the methods. One aspect in this context is the frequency and magnitude of revisions. Large revisions greatly lower the usefulness of the estimated level of potential output for projections and for economic policy because of its low reliability. Another criterion to evaluate the methods is the quality of ex ante forecasts. It is self-evident that revisions of data provided by the national statistical offices can not be anticipated by any method.

Given the multitude of estimation methods one would expect the estimates for each country provided by the various institutions to differ considerably. This is not the case (see chapter 4). At different points in time, however, the estimates for a given year vary substantially. The International Monetary Fund, for instance, published in 2005 retrospectively a positive output gap of 1.7% for Germany in 2000. The corresponding figure published by the OECD was 2.0%; in 2001 both institutions had estimated the output gap in 2000 to be 0%.[23] In retrospect both institutions have considerably changed their view of the economic situation in 2000.

The discussion of the various methods in this chapter shows that this congruence does not reflect any robustness of the individual estimation outputs but rather a substantial uncertainty surrounding all estimates as well as the fact that even in the case of complex econo-

[23] Cf. IMF, World Economic Outlook September 2005 and December 2001; OECD, Economic Outlook 78/2005, December 2005 and December 2001.

metric methods, such as the production-function approach, simple filter methods such as the Hodrick-Prescott filter often play a role in determining the factor inputs.

Table 3.1
Estimation methods used by different international organizations

	statistical methods		structural methods		comments
	HP filter	other univariate filters	production function	Kalman filter	
International Monetary Fund	TFP, participation rate		potential (private sector)		wide scope of country desks, public sector unfiltered
EU Commission	TFP, participation rate		potential (entire economy)	NAWRU	
European Central Bank	TFP (Area Wide Mode (AWM))		Potential (MB)	potential (MB), NAIRU (AWM)	MB = Monthly Bulletin
OECD	TFP, working time, participation rate		potential (private sector)	Nawru (früher MV-HP)	public sector unfiltered
Research institutes participating in the biannual joint economic forecast	potential	potential			
German Council of Economic Experts	potential	potential	potential (discontinued)		also partly uses estimates of the OECD and the EU Commission
Congressional Budget Office			potential (private sector)	NAIRU (married men)	TFP trend with a deterministic (broken) trend, NAIRU of other groups extrapolated from NAIRU of married men, other sectors estimated based on simpler methods and using broken deterministic trends

3.2 Definitions of potential output

The definition of the term potential output may affect empirical estimates in two ways: in the choice of method and in the choice of exogenous variables.

Is the development of potential output equated with the observed growth trend, the term potential output has statistical rather than economic meaning. In this case statistical methods of estimating potential output satisfy the empirical requirements and vice versa: The statistical methods adequately capture the subject matter only if potential growth is equated with trend growth.

The economic institutes participating in the German Joint Economic Forecast do not provide a definition or discussion of the terms potential output or potential growth. They do, however, frequently use the term, in particular in the context of monetary policy. As exemplified by the following quote, the texts show that (the majority) of the institutes assume the neoclassical automatic mechanism from a supply-side change to potential output:

> "If the wage increase is lower than the rate amounting to the sum of medium-term productivity growth and the target inflation rate, the country's potential output will temporarily increase more rapidly because supply-side conditions are improving"
>
> (Institute 2002a: 65, translated from German)

In contrast, the DIW Berlin at that time emphasized in numerous minority opinions the connection between economic policy and economic development:

> "Which economic policy strategy is best suited to transcend the weakness of the German economy depends on the market side that is perceived to face major problems. In contrast to the majority of the institutes, the DIW Berlin views a lack of demand as the main cause for the weak economic growth and high unemployment. This problem of insufficient aggregate demand was not met with adequate economic policy measures and subsequently got worse. It is this persistent weakness in demand that has lowered the growth trend."
>
> (Institute 2004: 96, translated from German)

In "Institute" (2005), the institutes explain for the first time the methods they use to estimate potential output. These are exclusively statistical methods and in the text they refer to trend output rather than potential output. The authors are therefore in all likelihood fully aware of the distinction between the two terms – in their economic policy analysis they nevertheless make statements about potential output based on the statistical estimation of trend output.

The other institutions define potential output in economic terms. These definitions essentially correspond to the one used by the CBO. The CBO distinguishes between potential output and trend output in the usual manner. Thus trend output is a purely statistical concept that cannot be interpreted as the „maximum sustainable output" (CBO 2004: 2), because pertinent economic variables such as inflation and capacity utilization are not taken into account. According to the CBO, one can interpret potential output in economic terms only if it is estimated from an economic model that includes all relevant economic variables.

> „That measure—known as potential output—is an estimate of "full-employment" gross domestic product, or the level of GDP attainable when the economy is operating at a high rate of resource use.
>
> Although potential output measures the productive capacity of the economy, it is not a technical ceiling on output that cannot be exceeded. Rather, it is a measure of sustainable output, in which the intensity of resource use is neither adding to nor subtracting from inflationary pressure. If actual output exceeds its potential level, then constraints on capacity begin to bind, restraining further growth and contributing to inflationary pressure. If output falls below potential, then resources are lying idle and inflation tends to fall."
>
> (CBO 2004: 1)

The ECB defines potential output similarly, but in addition emphasizes that the definition of potential output, and thus of output gap, is ambiguous already on the theoretical level:

> "Concerning the output gap, measurement errors are likely to be significant in view of the unavailability of a precise theoretical definition of this aggregate variable."

(Angeloni et al. 2001: 43)

The ECB and all other institutions that embed their potential output estimation in a macroeconometric model, furthermore make one assumption that affects the choice of explanatory variables. This assumption, which is in no way a theoretical necessity, is the long-term neutrality of money.

> "In the long run, there is therefore a clear dichotomy between the real and nominal variables in the economy."

(Angeloni et al. 2001: 8)

The possibility that demand-side policies may affect potential output is therefore excluded by assumption.

3.3 Statistical estimation methods

The statistical methods are univariate methods. They are based on the idea that potential output and actual GDP follow the same trend in the long run. Using a statistical filter, potential output is therefore directly extracted from the GDP time series without reference to other economic time series such as inflation (hence the term univariate). In essence, these methods divide the observed GDP data series into a trend component and a cyclical component based on assumptions about the usual cycle length. The former is usually interpreted as potential output. A prominent example of this approach is the Hodrick-Prescott filter (HP filter). The HP filter is a two-sided moving average which necessarily turns into a one-sided filter at the beginning and at the end of the observation period. Other univariate filters are the Rotemberg filter, the Christiano-Fitzgerald filter, the Baxter-King filter, the Beveridge-Nelson filter, deterministic trends and the univariate version of state-space models. Univariate methods are used, for example, by the German Council of Economic Experts[24] and in many econometric studies in which potential output although a variable is not the focus of the analysis. Univariate filters have a so-called endpoint problem due to the one-sidedness at both ends of the time series. This generally causes estimates to be strongly revised as new data points become available, making it very difficult to reliably estimate potential output. This problem is aggravated by equating trend output with potential output, as is often the case. A temporarily lower growth trend then implies lower potential output and economic policies that may cause it to stay low. Similarly higher potential output is captured econometrically only with considerable delay. Since there is no room for any economic interpretation of potential output in these methods the risk of misestimating is great; the trend provides information about past developments, not, however, about future potential growth. This section describes the Hodrick-Prescott filter and the Rotemberg filter, the former being the most popular univariate filter; for a discussion of the other filters the reader is referred to Schumacher (2002) and Logeay (2006).

[24] Cf. Sachverständigenrat (2000) as well as Jondeu and Le Bihan (2005).

3.3.1 Hodrick-Prescott filter

The Hodrick-Prescott filter (HP filter) is the most popular method of estimating potential output. It filters the time series by creating a moving average. The HP filter was described in a working paper of Carnegie-Mellon University already in 1980 but became popular only after the article by Hodrick and Prescott was published in 1997. The HP filters provided for the first time a simple alternative to the deterministic, linear determination of potential output that splits nonstationary time series into a stationary and a nonstationary component. This is also one possible outcome of the HP filter, namely when the key control variable, the smoothing variable λ, goes to infinity.

Mathematically expressed the HP filter solves the following minimization problem for y* (potential output), given the smoothing parameter (λ):

(3.1) $$min_{t=1\ldots T} \langle \Sigma_{t=1\ldots T} \{ (y_t - y^*_t)^2 + \lambda(\Delta y^*_{t+1} - \Delta y^*_t)^2 \rangle$$

The letter T stands for the number of observations, y_t for GDP and y_t^* for potential output. The first term in equation (3.1) is the output gap, the second term the second difference of potential output. This second term is an indicator for the smoothness of potential output. The smoothing parameter λ determines the weight of the smoothness of potential output relative to the smoothness of the output gap (Boone 2000), that is how great the variations of the output gap are compared to those of potential output. It therefore also determines how fast GDP is brought in line with potential output and how long the business cycle is on average.

(3.2) $$\lambda = \frac{\sigma^2_{y-y*}}{\sigma^2_{\Delta y*}}$$

If λ is zero, the numerator (σ^2_{y-y*}) must be zero, so that potential output always equals actual GDP. If, on the other hand, λ is set to infinity, the denominator ($\sigma^2_{\Delta y*}$) tends towards zero implying a constant and hence deterministic rate of potential growth.

When using business cycle data the parameter λ is usually set to 100 for annual data, 1600 for quarterly data and 14400 for monthly data. The smoothing indicator indicates how long oscillations must be, in order to be attributed to the trend component. In the case of quarterly data, this means that a 5% change in the cyclical variable has the same weight as a $^1/_8$% change in potential growth.[25] Potential output derived with HP(1600) therefore only contains fluctuations of GDP that exceed a period of 32 quarters. These standardized values

[25] The calculation is as follows: $5^2/(^1/_8)^2 = 1600$. “Our prior view is that a 5 percent cyclical component is moderately large, as is a one-eighth of 1 percent change in the growth rate in a quarter.” (Hodrick and Prescott 1997: 4)

for λ are controversial.[26] Different λ values not only generate different variances of potential output but also different turning points and relative peaks and troughs.

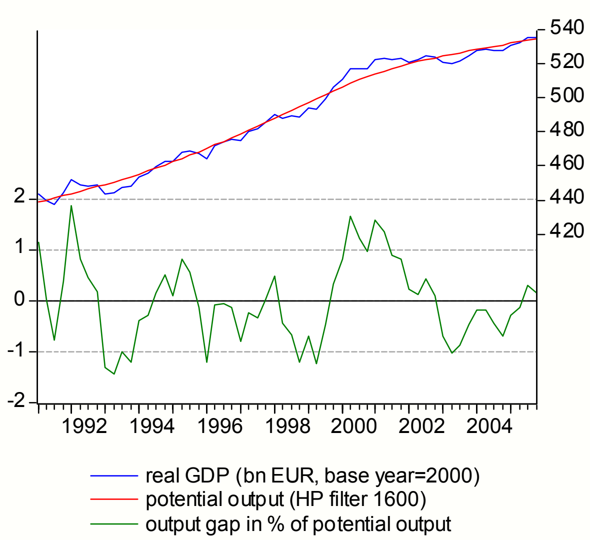
Proposals for alternative λ values in the case of annual data range from 6.25 to 400 (Maravall and del Río 2001, Ravn and Uhlig 2002), which shows how difficult and ultimately indeterminate the choice of smoothing parameter is.

Solving the minimization problem (3.1) shows that the HP filter is a symmetric moving average which would ideally go infinitely into the past and the future. As this infinity is not given in reality, the filter becomes more and more one-sided the closer one gets to the beginning or the end of a time series. It is therefore intuitively clear that potential output estimates are greatly affected by new data points. The German Council of Economic Experts and the European Commission deal with the problem by adding at least three data points generated with ARIMA forecasts to the time series. However, this is unsatisfactory because the past cycle is merely extrapolated. The endpoint problem is the basic conceptual flaw of the HP filter. Studies have furthermore shown that in the case of nonstationary time series the HP filter may generate artificial cycles

All in all, the HP filter has many drawbacks. First and foremost there is the endpoint problem. This, however, is a problem faced by all filters since the future is always unknown. Secondly, choosing a value for the smoothing parameter is problematic because the precise length of the business cycle has to be specified. Furthermore, the HP filter exhibits fuzziness in the region of eight years and may generate artificial cycles in the case of nonstationary time series. An additional drawback of this method is that it is not possible to create confidence bands to determine the uncertainty of the estimation.

[26] Guay/St-Amant (1996) and St-Amant/van Norden (1997) criticize the standard λ values because given these values the HP filter does not satisfy the NBER's definition of an ideal separation of cycle and trend. According to the authors it would be ideal if long fluctuations (more than 32 quarters) were attributed to the trend and short fluctuations (less than 32 quarters) to the business cycle. However, they demonstrate empirically that the HP filter exhibits fuzziness in the threshold region of 32 quarters, making clear-cut allocation impossible.

Chart 3.1
Germany's potential output and output gap according to the HP filter (1600)



3.3.2 Rotemberg filter

The Rotemberg filter belongs to the family of Hodrick-Prescott filters (Rotemberg 1998: 3). The Rotemberg filter splits the time series of GDP in such a way that within a specified time horizon, the cyclical component is independent of changes in trend growth. The filter is specified to find a cyclical and a trend component that are as independent from each other as possible. Two parameters have to be set in advance. The first is the number of periods m, for which the covariance of the cycle is minimized between t and t+m for a given smoothness. The objective function to be minimized is:

$$\Sigma_{t=2\ldots T-1}\ \{(y^*_{t+1} - y^*_t) - (y^*_t - y^*_{t-1})\}^2 + 1/\lambda\ \Sigma_{t=m+1\ldots T}\ (y_t - y^*_t)(y_{t-m} - y^*_{t-m}) \qquad (3.3)$$

where y^* := trend component and y := cyclical component.

The second variable to be set exogenously is the time period ν during which the cyclical component and changes in the trend component are to be uncorrelated. Hence, the objective function (3.3) has the following constraint:

$$\Sigma_{t=m+\nu\ldots T-m-\nu}\ [(y_t - y^*_t)\ \{(y^*_{t+\nu} - y^*_t) - (y^*_t - y^*_{t-\nu})\}] = 0 \qquad (3.4)$$

It is possible to construct the HP filter using equations (3.3) and (3.4) by setting m=0 and ν in such a way that λ=1600. The variance of the cycle then enters the objective function at each point t, not the covariance of the cycle between t and t+m as in the Rotemberg filter.

For quarterly data Rotemberg (1998: 9) recommends the values 16 for m and 5 for ν. An estimate of λ results from the selection of ν and m given the objective that trend and cycle should be largely independent. Given Rotemberg's recommended values, λ becomes 600500. In principal, a higher λ implies a lower weight of the covariance criterion in the objective function and that the constraint will be satisfied more rapidly. In the context of potential output this means that the Rotemberg filter uses the GDP time series to generate potential output as the trend and a cyclical component under the condition that potential growth should be largely independent of the output gap.

As a result of this condition the trend generated by the Rotemberg filter is considerably smoother than a trend generated by a comparable HP filter. The Rotemberg filter faces the same endpoint problem as the HP filter. In addition, two parameters have to be specified ex ante so that the Rotemberg filter cannot be viewed as a fundamental improvement compared to the conventional HP filter unless theory leads one to favor a strong independence of potential output from actual GDP in the short and medium term.

Unlike the HP filter, the Rotemberg filter is not automatically included in most econometric software packages. On his website, Julio Rotemberg supplies a Matlab program to calculate his filter (http://www.people.hbs.edu/jrotemberg/).

3.3.3 Conclusion

Univariate filters are used by all institutions, albeit only by the German economic research institutes as the sole method of estimating potential output. Other institutions generally use the HP filter to estimate individual components of potential output such as labor force or NAIRU. The German Council of Economic Experts furthermore applies univariate filters to directly estimate potential output in addition to estimates based on the production function approach. The German Council deals with the endpoint problem by extending the time series using ARIMA models (Sachverständigenrat 2003: Z.756).

The German research institutes incidentally only provided potential output estimates once, in a recent report; and there they estimated not the level of potential output but rather of potential growth (Institute 2005: 299). Only univariate methods were applied, namely HP filter, Rotemberg filter, Baxter-King filter, Christiano-Fitzgerald filter and a univariate Kalman filter. The institutes emphasize the wide range of estimation results – from 0.6% to 1.8% in 2004. In the context of their economic analysis they use the median outcome.

3.4 Semi-structural methods

The arbitrary and imprecise nature of the trend-cycle decomposition of univariate filters was a motivation to augment some of these filters to include other economic variables such as inflation. Examples of such multivariate or semi-structural methods are the multivariate Hodrick-Prescott filter, the multivariate Kalman filter and the Beveridge-Nelson filter. In the following section the first two of these filters are discussed.

3.4.1 Multivariate Kalman filter

The multivariate Kalman filter is also referred to as unobserved component model (UCM) or state-space model. The OECD, the EU Commission and the area-wide model of the ECB use this method to estimate the NAIRU. The International Monetary Fund has used it occasionally to estimate potential output. The Kalman filter is gaining prominence in the literature (International Monetary Fund 2001 and Apel/Jansson 1999). An important advantage of the Kalman-filter method is that it allows for maximum-likelihood estimates and forecasts.

To apply the Kalman filter, one has to first construct a system of behavioral equations (also called observation equations) consisting, for example, of a Phillips curve, Okun's law and/or a wage equation. Then assumptions have to be made about the stochastic properties of potential output. This assumption is represented in the state equation. The space equation contains the stochastic properties of the unobserved variable. The system is written is state-space form and estimated with the Kalman algorithm.

The model used to estimate the NAIRU with the Kalman filter is generally specified as follows:

(3.5) Phillips curve (triangle model): $\pi_t = a(L)\pi_{t-1} + b(L)(u-u^N_t) + c(L)\Delta z_t + e_t$

NAIRU equation: $u^N_t = u^N_{t-1} + \varepsilon_t$

where π_t is the inflation rate, $u-u^N$ the unemployment gap and u^N the NAIRU; z_t are the supply-side variables, e_t and ε_t are white-noise error terms, and a(L), b(L) and c(L) are lag polynomials, the coefficients of which are estimated.

Often the restriction a(1)=1 is imposed, i.e. inflation is estimated in differences, but this is not imperative. Restrictions are also frequently imposed on the error terms, especially on σ_ε. The exogenous supply-side variables in Δz_t are generally weighted import prices, weighted energy prices and the deviation of productivity from its trend, all in first differences. It is important to include supply-side variables (z variables) in the Phillips curve because the results are greatly affected by their omission.[27]

Models using the Kalman filter have the advantage that tests (e.g. of the significance of the variables in the observation and state equations) can be run, confidence bands can be calculated (using the p values) and forecasts can be made. This is not possible or very complicated within the framework of univariate methods, structural methods and the multivariate HP filter. An additional benefit is that it is possible to identify explanatory variables of the state variables (X_2,t). This use of exogenous variables has so far received little attention in the literature, but is an important aspect of this report.

The Kalman filter has the drawback that it reacts quite strongly to the particular starting values and the specification of the estimated equations. Stock and Watson (1998) furthermore demonstrated that the Kalman filter tends to underestimate the variance matrix of the

[27] Eller and Gordon (2003) strongly criticize New Keynesian Phillips curves: As these do not include important supply-side variables, they are misspecified with the result that output gaps are often found to be insignificant or to have the wrong sign. This criticism also applies to Phillips curves estimated with marginal costs. Eller and Gordon (2003) empirically compare both versions of the Phillips curve and find that backward-looking Phillips curves (including supply-side variables) better explain inflation and yield better out-of-sample forecasts. They therefore refer to the New Keynesian Phillips curve as „an empirical failure by every measure“ (p. 48).

state variables in small samples if the variance is small. This implies that the variability of the state variables is rated too low. However, this only applies if the state equations are combined with only one observation equation. To side-step this problem the variance of the state variables or the signal-to-noise ratio (the smoothness of the state variables relative to that of the observation variable) can be specified. Alternatively, one can add more observation equations (e.g. Okun's law) and thus more information as in Apel/Jansson (1998) and Fabiani/Mestre (2000 and 2001).

The EU Commission also uses a Kalman filter to estimate country-specific NAIRUs (Denis et al. 2002).[28] It is assumed that the unemployment rate can be divided into a trend and a cyclical component (in the following we omit the subscript t and only subscript lags):

$u = (u - u^*) + u^*$,

where u = unemployment rate, $(u - u^*)$ = cyclical component, u^* = trend component

This decomposition is supplemented by a Phillips curve that links the cyclical component to changes in wage inflation making it possible to interpret it in economic terms:

$\Delta\pi^w = \mu^{phillips} + \beta(u - u^*) + \gamma X + \nu^{phillips}$,

where $\nu^{phillips} = \Sigma_{i=0 \ldots I} \theta_i \varepsilon_{-i} \sim MA(I)$; MA:= moving average

The cyclical component is subject to the following constraints:

$(u - u^*) \sim AR(2)$, $(u - u^*) \sim I(0)$, $E[(u - u^*)] = 0$.

The following process can now be specified for the unemployment gap:

$(u - u^*) = \Phi_1(u - u^*)_{-1} + \Phi_2(u - u^*)_{-2} + \nu$, where $\Phi_1 + \Phi_2 < 1$

The trend component is specified as a random walk with drift, the drift term also able to follow a random walk:[29]

$u^* = \mu^{nairu} + u^*_{-1} + \nu^{nairu}$,

where $\mu^{nairu} = \mu_{-1}^{nairu} + \nu^{drift}$

The disturbance terms ν^{nairu} and ν^{drift} are assumed to be independent and distributed identically.

Denis et al. (2002) estimate equations (3.6) to (3.10) for each member state of the EU15 using annual data for the period 1963–2003.

The estimation procedure was maximum likelihood (numerical optimizing algorithms: Newton algorithm and simulated annealing algorithm). The authors constrained the variance of trend innovations to the lower bound of 0.1 to smooth the NAIRU series.

[28] Denis et al. (2002) reference Kuttner (1994), Gerlach and Smets (1999), Gordon (1997), Apel and Jansson (1999a, 1999b) and OECD (2000), who describe similar Kalman-filter estimates of the output gap and the NAIRU.

[29] These processes are called "local linear model" and identical to I(2) processes.

The OECD has also adopted the state-space modeling to estimate the NAIRU (Turner et al. 2001). The NAIRU is modeled as a random walk or an integrated AR(2), the Phillips curve as a triangle model (Gordon 1997). The model is almost identical to the one used in the ECB's area-wide model.

Phillips curve: $\Delta\pi_t = \alpha_1\Delta\,\pi_{t-1} + \alpha_1\Delta\,\pi_{t-2} - \beta(u-u^*)_t - \theta\Delta u_t + \gamma ZT_t + \varepsilon_t$

$u_t = u^*_t + (u-u^*)_t$

NAIRU: $u^*_t = (1+\varphi)u^*_{t-1} + \varphi u^*_{t-2} + \nu_t$

where ZT are as before exogenous variables such as weighted import price inflation and the rate of change in energy prices.

The IMF appears to have used a state-space model to estimate potential output only for the Euro Area and only in one paper (IMF 2001). It was estimated on the basis of aggregated data for the Euro Area and specified as follows:

$\Delta\pi_t = \Sigma_{i>0}\,\rho_i\Delta\pi_{t-i} + \Sigma_{j\geq 0}\,\eta_{0j}(u-u^*)_{t-j} + \Sigma_{k\geq 0}\,\omega_k\Delta z_{t-k} + \varepsilon_t^{pc}$ Phillips curve

$(y-y^*)_t = \Sigma_{l\geq 0}\,\varphi_l(u-u^*)_{t-l} + \varepsilon_t^{okun}$ Okun's law

$u^*_t = u^*_{t-1} + \varepsilon_t^{nr}$ natural rate (random walk)

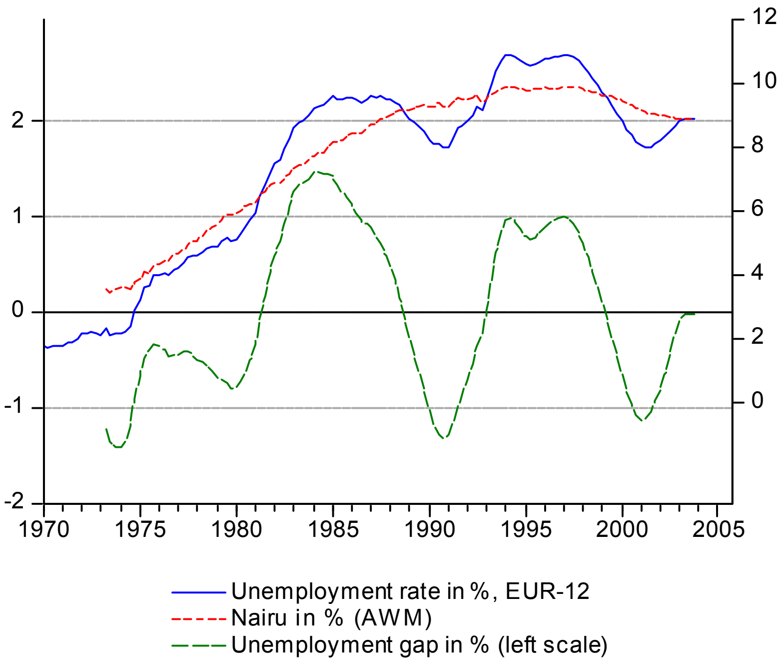
$y^*_t = \alpha + y^*_{t-1} + \varepsilon_t^{po}$ potential output (random walk with drift)

$(u-u^*)_t = \Sigma_{m>0}\,\delta_m(u-u^*)_{t-m} + \varepsilon_t^{ug}$ unemployment gap (AR(2))

with $(\varepsilon_t^{pc}, \varepsilon_t^{okun}, \varepsilon_t^{nr}, \varepsilon_t^{po}, \varepsilon_t^{ug}) \sim iid\,(0, \Sigma)$

The term α is the growth rate of potential output, the sum η_0 the level effect of the unemployment gap (it should have a negative sign). The z variables are effective real exchange rates, real oil prices, real import prices and productivity. The estimate is based on quarterly data for the period 1980 to 2004. Several different price indices (consumer price index, GDP deflator and unit labor costs) were used with similar results.

Chart 3.2
Kalman-filter estimate of the Euro-Area NAIRU



3.4.2 Multivariate Hodrick-Prescott filter (MVHP filter)

Laxton and Tetlow (1992) proposed an extension of the Hodrick-Prescott filters that allows for the use of information from other time series to estimate unobserved variables such as potential output. This "external" information enters the minimization problem in the shape of macroeconomic relationships like the Phillips curve. When solving the minimization problem, i.e. determining potential output, the relative smoothness of potential output and GDP is no longer the only decisive factor but also the inflation effect of the output gap, i.e. of the gap between the estimated potential output and GDP.

In mathematical terms the multivariate HP filter solves the minimization problem for y^* (potential output), given the smoothing parameter, under the constraint that the Phillips curve in the second equation holds:

$$min_{t=1...T} \langle \Sigma_{t=1...T} \{ (y_t - y^*_t)^2 + \lambda(\Delta y^*_{t+1} - \Delta y^*_t)^2 + \lambda_2(\varepsilon_{2,t})^2 \} \rangle$$

$$with \ \ \pi_t = -\beta_0(y_t - y^*_t) + \beta X_t + \varepsilon_{2,t}$$

In the equations T stands for the number of observations, y_t for GDP, y_t^* for potential output and π_t for the rate of inflation. X_t stand for other explanatory variables of inflation such as productivity growth and the oil price. The term $\varepsilon_{2,t}$ is included in both equations. It contains the residuals of the economically meaningful equation, in this case the Phillips curve. There are two equations and two unknowns to be estimated: potential output and the residuals. Small residuals imply a large effect of the output gap on inflation, large residuals a small one, inflation here being the inflation rate excluding the effects of the X variables. The coefficient λ_2 in the first equation specifies the weight of the second equation in the minimization problem of the first equation, i.e. how much the residuals are allowed to fluctuate and thus how strongly the output gap is linked to inflation. If λ_2 equals zero, the filter becomes a univariate HP filter. If, on the other hand, λ_2 tends towards infinity, $\varepsilon_{2,t}$ is equal to zero and y_t^* reflects all changes in inflation that are not explained by X_t. The smoothing parameter λ determines the weight of the smoothness of potential output relative to that of GDP as in the univariate HP filter (Boone 2000). This method creates an explicit link between the estimated values and the concept of sustainable output.

It is somewhat laborious to implement the MVHP filter. Laxton and Tetlow (1992) propose an iterative mechanism whereby the second, economically meaningful equation is estimated first by using ordinary least squares. (A first approximation of potential output is made using, for example, the HP filter.) The residuals are then put into the minimization problem of the first equation which is solved for y^*. The potential output thus obtained then enters the second, economic equation and the process is repeated until convergence is achieved. (An EViews program for the MVHP filter can be found in Annex I.)

The selection of the smoothing parameters λ and λ_2 is ultimately arbitrary, as in case of the univariate HP filter. The endpoint problem also still exists. However, the criticism directed at univariate filters that they are merely a sophisticated moving average does not apply in the case of the multivariate HP filter. The estimation outcome is at least in part based on economic relations. Furthermore, in theory the model permits output gaps to persist over longer periods. If one uses a Phillips curve as the second equation and estimates from 1980 to 2001, one would expect to find a predominantly negative MVHP output gap because of the almost continuous decline in inflation. It follows that unlike the HP filter the MVHP filter would not indicate a (strong) decline in potential output. Like the HP filter the MVHP filter can also be perfectly reproduced using a Kalman filter – this does not, however, make its application any easier.

3.5 Structural methods

The third group of methods to estimate potential output are the structural methods which rely predominantly on the economic determinants of potential output. These are in particular production functions, state-space models with exogenous variables and SVAR analyses.

3.5.1 Production functions

The production function approach generally uses Cobb-Douglas or CES functions with two factor inputs, capital (K) and labor (L), as well as technological progress (A). GDP (Y) is then described as follows: $Y_t = A_t\, K_t^{1-\alpha}\, L_t^{\alpha}$ (Cobb-Douglas) or $Y_t = A_t\, [\alpha L_t^{\rho} + (1-\alpha) K_t^{\rho}\,]^{1/\rho}$ (CES). The coefficients α and ρ are simply assumed or, for example, estimated using a cointegration equation. Potential output is then determined by entering the equilibrium values for the factor inputs.

The weak points of this method are the limited ability to explain the development of the factor inputs and that the equilibrium path of these factors can not be determined unambiguously. The production function approach is the most popular structural method, applied by all the institutions discussed here with the exception of the German economic research institutes (Denis et al. 2002 and Giorno et al. 1995).

The theoretical foundation of this approach is growth theory, generally the neoclassical model (Solow 1956). Advantages of the production function approach are its flexibility and the ability to determine the contribution of each factor input to potential output (Musso 2004). It is furthermore possible to determine the effect technological progress has on potential output or potential growth.

Generally a Cobb-Douglas production function such as the following is used:

(3.6) $Y = A_t L_t^{\alpha} K_t^{1-\alpha}$, in logarithms: $y_t = a_t + \alpha l_t + (1-\alpha)k_t$

where Y stands for GDP, α for the partial output elasticity of labor, A_t for total factor productivity, L_t for hours worked and K for the capital stock. Small letters stand for logarithms. Usually the production function approach is only applied to the private sector. To determine potential output it is necessary to estimate the potential values of the three explanatory variables (hours worked, capital stock and TFP).

The main advantage of using a Cobb-Douglas production function is the ease with which the coefficients can be interpreted. Assuming competitive markets or rather that each factor receives its marginal product, the partial elasticities of output with respect to labor and capital (α and (1- α)) can be equated with the wage share and the profit share, respectively (Denis et al. 2002).[30,31]

Hours worked is ultimately made up of four factors: working-age population, participation rate, average working time and NAIRU. The first three are usually projected according to a calculated trend (for example, with the HP filter); for the past the observed values are used. To determine the NAIRU, on the other hand, different methods are used, the predominant one being the multivariate Kalman filter. The capital stock is usually measured; it is generally not smoothed (Denis et al. 2002: 8).

Total factor productivity (the Solow residual) is generally determined by assuming a value for α, usually by equating α with the wage share (for example, in logarithms as follows: α=wage share = 0.65 → a = y-0.65*l-0.35*k). There are three types of technological progress, namely technological progress according to Harrod $\left(Y_t = (A_t L_t)^{\alpha} K_t^{1-\alpha} = [A_t^{\alpha}] L_t^{\alpha} K_t^{1-\alpha}\right)$, according to Hicks $\left(Y_t = A_t L_t^{\alpha} K_t^{1-\alpha} = [A_t] L_t^{\alpha} K_t^{1-\alpha}\right)$ and according to Solow $\left(Y_t = A_t\right.$

[30] The constant elasticity of substitution of 1 in the Cobb-Douglas production function is appropriate according to the EU Commission because aggregated labor is made up of more qualified and less qualified workers, who have a labor elasticity of either smaller than 1 or greater than 1 (Denis et al. 2002, Krusell et al. 2000).

[31] It should be noted that Proietti et al. (2002) state that, in general, the wage share can serve as a proxy for α, given the assumption of competitive markets. As the "accelerationist model" applied by Proietti et al. (2002) rests upon the assumption of monopolistic markets, this approximation is not valid. The authors, however, do not mention an alternative method of estimating α.

L_t^{α} $(A_tK_t)^{1-\alpha}$ =$[A_t^{1-\alpha}]$ L_t^{α} $K_t^{1-\alpha}$). Although technological progress according to Harrod is a precondition for the steady state, it is ultimately irrelevant which approach (Harrod, Hicks or Solow) is used when empirically deriving a time series for technological progress. The time series produced is constructed as $B_t = Y_t /(L_t^{\alpha} K_t^{1-\alpha})$, B_t being the term in the square brackets. Whether this time series is interpreted as A_t, A_t^{α} or $A_t^{1-\alpha}$ is a mere technicality. For simplicity reasons, the Hicks version of technological progress is usually employed, without consequences for the results.

The OECD originally used a CES production function with the three factors labor, capital and energy to estimate potential output (of the private sector of each country). In the late eighties, the OECD scaled the model down to include only labor and capital, and in 1994, the CES production function was abandoned in favor of a Cobb-Douglas production function.[32] Until the mid-nineties the OECD furthermore estimated an output trend to calculate the structural deficits of the government. The growth trend of output was defined as the average growth rate between two peaks („split time trends“). For the Cobb-Douglas production function, the OECD determines potential employment by multiplying the working-age population by the HP-filtered participation rate and (1-NAIRU). Only the NAIRU is determined with more complex methods that were modified over the years.[33] Currently, the OECD is using the state-space method (see the section state-space models). The OECD uses its own data on the private sector to calculate the capital stock. Potential total factor productivity is the HP-filtered residual. As the production function is estimated only for the private sector, actual gross value added of the public sector is added to produce aggregate potential output.

The ECB explicitly makes reference to Prioetti et al. (2002) (European Central Bank 2005b) who describe a multivariate production-function approach. It therefore seems reasonable to assume that this is the approach the ECB favors, especially because the cited paper compares this approach in detail with statistical, univariate and bivariate models. Additional information on the ECB's methodology is found in Musso (2004) und Musso und Westermann (2005).

The ECB's area-wide model (AWM) also includes a Cobb-Douglas production function with constant return to scale to determine potential output (Fagan et al. 2001). The AWM distinguishes between medium-term potential output and long-term potential output because of the slow adjustment of the capital stock. The latter is the steady-state potential output.

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[32] A CES production function is used only in the case of Japan.

[33] Until recently the OECD applied the Elmeskov method based on a simple Phillips curve written in terms of wage inflation: $\Delta w - \Delta w^e = a\,(u-u^*)$. To identify the parameter a, the NAWRU is initially viewed as a constant, so that $a = [\Delta^2 w-\Delta^2 w^e]/\Delta u$. Expectations are calculated with an HP filter or with the first lag of wage inflation. The NAWRU then becomes: $u^* = u - \Delta u \times [\Delta w-\Delta w^e]/[\Delta^2 w-\Delta^2 w^e]$. This time series is then filtered with an HP filter ($\lambda = 25$) because it is quite volatile (OECD 1999c: 169-174). For a short time, the Elmeskov method was abandoned in favor of a multivariate Hodrik-Prescott filter and the NAIRU was estimated instead of the NAWRU:

$$\min_{u^*} \Sigma_t \{(u-u^*)^2_t - \lambda_{1t}(\Delta^2 u^*_{t+1})^2 + \lambda_2 \varepsilon_t^2\}$$

$$\pi_t = -\beta_0(u-u^*)_t + \beta ZT_t + \varepsilon_t ,$$

where ZT are exogenous variables such as weighted import price inflation and the rate of change of energy prices.

Potential output or GDP in the steady state (Y^{**}) is derived from a production function under conditions of profit and utility maximization. Exogenous variables are used exclusively, namely the HP trend of total factor productivity (A), the profit share ((1-λ) or β set to 0.41), the steady-state real interest rate (r^* set on the basis of historical data), the depreciation rate (δ set to 0.01 which is 4% p.a.), a risk premium set according to historical data (λ) and the inflation stable labor force (L^*), derived from the labor force and a NAIRU. The latter is exogenous in that sense that it is estimated outside the model with a Kalman filter including a Phillips curve (see section multivariate Kalman filter)

$$Y^{**} = A^{1/(1-\beta)} (\beta/(r^*+\delta+\lambda))^{\beta/(1-\beta)} L^*$$

The supply curve is vertical in the long run because the explanatory variables of long-run potential output are determined outside the model. This is an intended feature of the model which is designed in such a way that „… structural relationships are constrained to be consistent with a basic neo-classical steady-state, in which in the long-run output is determined by technological progress and the available factors of production. Thus, the long-run of the model has been designed with a view to ensuring that money is both 'neutral' and 'superneutral' with respect to output." (Fagan et al. 2001: 9). It follows that the long-run neutrality of stabilization policies with respect to the real economy is given ex ante as part of the model's assumptions.

Medium-term potential output (Y^*), in contrast, furthermore depends on the given capital stock. Therefore a conventional Cobb-Douglas production function is estimated (with the exception that the profit share β rather than wage share α is set exogenously):

(3.7) $$Y^* = A^* K^{\beta} L^{*1-\beta}$$

The capital stock is calculated as follows:

(3.8) $$K = (1-\delta)K_{-1} + \text{investment}$$

The EU Commission also applies a typical Cobb-Douglas production function (Denis/McMorrow/Röger 2002).[34] The elasticities of Y with respect to the factor inputs is given by α and (1- α), respectively. Denis et al. (2002) estimate a production function for the European Union in aggregate rather than for each country. They calculate an average wage share for the EU15 countries, arriving at α = 0.63 and per definition at 1-α = 0.37 for the period 1960 to 2000.[35] The efficiency trend is approximated by the HP-filtered trend of the Solow residuals.[36] The actual capital stock and the potential capital stock are taken to be equal. The

[34] Extensions of this approach are found in McAdam / McMorrow (1999), McMorrow / Röger (2000) and McMorrow / Röger (2001).

[35] If the assumption of strongly competitive markets is not valid and factors do not receive their marginal product, the estimate is biased; cf. Annex III.

[36] McMorrow and Röger (2001: 30ff.) discuss in greater detail the problems that arise when measuring TFP. The authors use an in-depth approach to determine the trend of TFP. Labor efficiency is assumed to follow a deterministic trend; capital efficiency is modeled with a vintage model. A short discussion of the vintage capital approach is found in Annex II of this report.

time series used by Denis et al. (2002) for the EU15 and the United States are relatively stable over time.[37]

The German Council of Economic Experts follow the Bundesbank's so-called non-parametric approach (Sachverständigenrat 2003: Z. 748). It uses a general production function, albeit with variable output elasticities and estimated in first differences rather than in levels.[38]

(3.9) $\Delta y = \alpha\ \Delta l + (1 - \alpha)\ \Delta k + \Delta a$ (in logarithms)

Given the assumption that the factor inputs are remunerated according to their marginal product, α is approximated by the wage share. If the output elasticities are assumed to be invariable over time, this production function is identical to the Cobb-Douglas production function.

The estimation is done in three stages: First, the Solow residual is determined: $\Delta a \equiv \Delta y - \alpha\ \Delta l - (1 - \alpha)\ \Delta k$. Then the trends for labor, capital and total factor productivity are generated using the HP filter. These trends are entered into the production function above which yields the growth rate of potential output: $\Delta y^* = \alpha\ \Delta l^* + (1 - \alpha)\ \Delta k^* + \Delta a^*$. Summation then leads to the level of potential output: $y^* = y^*_{-1} + \alpha\ \Delta l^* + (1 - \alpha)\ \Delta k^* + \Delta a^*$, whereby the initial value y^*_0 is specified in a manner that renders the output gap zero on average during the estimation period.

The SVR's approach is advantageous in that one does not have to specify a particular production function. On the other hand, the fact that several parameters are not estimated but merely set in an ad hoc manner is a drawback.

In addition, the German Council of Economic Advisors estimates a Cobb-Douglas production function. Technological progress is given exogenously so that the function in logarithms may be written as:

$$y = \gamma + \delta_0 t + \alpha\ l + (1 - \alpha)\ k + \varepsilon$$

Technological progress is estimated as a spline regression to account for possible structural breaks:

$y = \gamma + \delta_0 t + \Sigma\delta_i d_i + \alpha\ l + (1 - \alpha)\ k + \varepsilon$ and in growth rates:

$\Delta y = \delta_0 + \Sigma\delta_i e_i + \alpha\ \Delta l + (1 - \alpha)\ \Delta k + u$ with $u = \varepsilon - \varepsilon_{-1}$

and $e_i = 0$ for $t < t_i$, 1 for $t > t_i$

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[37] Cf. Mc Morrow / Röger (2001).

[38] It follows from $Y = A\ F(K,L)$ and $\ln Y = \ln A + \ln F(K,L)$ that $\Delta \equiv d/dt$: $\Delta \ln Y = \Delta \ln A + \Delta \ln F(K,L)$.

$\Leftrightarrow \Delta \ln Y = \Delta \ln A + 1 / F(K,L)\ [F_K\ \Delta K + F_L\ \Delta L] \Leftrightarrow \Delta \ln Y = \Delta \ln A + e_K\ \Delta \ln K + e_L\ \Delta \ln L$,

where $e_K := F_K\ [K / F(K,L)]$ and $e_L := F_L\ [L / F(K,L)]$ are the partial elasticities of output with respect to the respective factor input. Is the function also homogeneous of degree one, so that: $e_K + e_L = 1$, then it follows from $e_L \equiv \alpha$ and $e_K \equiv 1 - \alpha$, that $\Delta \ln Y = \Delta \ln A + [(1 - \alpha)\ \Delta \ln K\ ] + [\alpha\ \Delta \ln L]$. In the notation of the German Council of Economic Experts (SVR) the rate of change $(dY/dt) / Y$ is written as Δy, where $y \equiv \ln Y$.

Potential output is, once again, estimated in three steps:

The parameters of the equation are estimated in first differences using ordinary least squares. The trends of Δl^* and Δk^* are determined using the HP filter and then included in the production function. The level of potential output is gained through summation, as before, and the initial value of y^* is such that the output gap is zero on average during the estimation period.

The US Congressional Budget Office (CBO) also applies a Cobb-Douglas production function. In a description of the method used, the CBO also discusses the effect that changes in the savings rate have on potential growth, stating that „a higher projected rate of saving will lead to faster accumulation of capital and faster growth of potential output" (CBO 2001: 3). Given the Solow model as underlying theoretical framework, this assertion only holds as long as the economy is not in a steady state.[39] Changes in the savings rate do not lead to a change in long-run growth rates in the steady state; they only affect the variables in levels. Ceteris paribus, changes in the savings rate only give rise to a higher rate of capital accumulation during the period of transition to the new steady state.

All in all, production functions are a theoretically motivated and promising approach for estimating potential output; they are, however, difficult to implement and confronted with several problems. Data problems arise when measuring the capital stock and hours worked and there is no consensus as to what exactly the production function should look like. The problem of determining technological progress is not solved. Are technological progress and economic growth viewed as endogenous, the explanatory variables have to be examined more closely. Potential candidates are human capital and the degree of innovation but also the actual development of GDP. The same applies to the NAIRU, which has to be known in order to determine inflation-stable employment. In general, however, filter methods are used to determine these two key variables.

3.5.2 Multivariate Kalman filter including exogenous variables

Structural multivariate state-space models differ from their semi-structural counterpart in that they make use of exogenous variables in explaining potential output.[40] Different modeling strategies are conceivable. Following the prevalent macroeconomic model, however, three equations are generally estimated simultaneously: a Phillips curve with the output gap as an explanatory variable of inflation, an equation for the output gap and an equation for potential output. Exogenous variables that are thought to affect potential output, such as real interest rates, are explicitly included in the system of equations. Such a system could be constructed as follows:

Phillips curve: $(\Delta)\pi = \Sigma_i \alpha_i (\Delta)\pi_{t-i} + \beta(y-y^*)_t + \gamma Z_t^1 + \varepsilon_t$

[39] Capital growth (per capita) in the Solow model depends on the savings rate, population growth and the depreciation rate. In the steady state, the per-capita capital stock is constant, implying that the savings rate affects capital growth and thus GDP growth only outside the steady state. In the steady state, the savings rate affects only the level of potential output; for further reading see Lucas (1988) and section 2.2 of this report.

[40] See, for example, Jaeger/Parkinson (1994) and Salemi (1999).

Output gap: $(y-y^*)_t = \delta_1(y-y^*)_{t-1} + \delta_1(y-y^*)_{t-2} + \mu_t$

Potential output: $y^*_t = y^*_{t-1} + \eta_t + \lambda Z_t^2 + \nu_t$

The term η_t stands for a random walk, y for log GDP, y^* for log potential output, and Z^1 and Z^2 are exogenous variables. So far, this method has rarely been applied to potential output itself, but rather to one of its important determinants, the NAIRU (Jaeger/Parkinson 1994, Salemi 1999 and Logeay/Tober 2005, 2006).

3.5.3 Structural vector autoregressive (SVAR) analysis

In SVAR analyses all included variables are treated as endogenous variables. In this way, reaction and interaction are taken into account which in itself is an asset. The main drawback of this method is the difficulty in identifying and interpreting the so-called structural shocks that play a key role in determining potential output. SVARs are increasingly popular and are receiving much attention in the literature, especially from authors linked to the ECB (Gerlach/Smets 1999 and King/Morley 2003).

SVAR models are faced with the same problem as the other structural approaches: In general it is impossible to test the underlying theories. They do, however, have the great advantage of being easy to handle and providing a good econometric fit.[41] Recently, SVAR models have become a popular instrument in empirical macroeconometrics. There are several reasons for this popularity: Firstly, SVAR models are not subject to the criticism directed at traditional structural models that important dynamic interaction is neglected (Sims 1980). Secondly, these models satisfy the demands made by modern theory and are able to incorporate rational expectations. Thirdly, they allow for a look at the data from a theoretical perspective in that the required restrictions of the model are based in theory.

It was Sims (1980) who brought forth the charge that traditional structural macro models ignored important interaction between variables. This criticism primarily referred to the assumed exogeneity of certain variables. It is, in fact, very difficult to find variables that are truly exogenous. Sims cites the example of a model of supply and demand for agricultural products. This model traditionally uses a climate variable for identification which by definition is applied only to the supply equation, but not to the demand equation. Sims argues:

> „However certain we are that the tastes of consumers in the U.S. are unaffected by the temperature in Brazil, we must admit that it is possible that U.S. consumers, upon reading of a frost in Brazil in the newspapers, might attempt to stockpile coffee in anticipation of the frost's effect on price. Thus variables known to affect supply enter the demand equation, and vice versa, through terms in expected price."
>
> (Sims 1980: 14-15)

This argument naturally also applies to economic policy: Fiscal and monetary policy measures are to a great extent endogenous reactions to the business cycle and affect the behavior

[41] A good introduction to SVAR models is found in Enders (1995).

of other economic subjects. According to Sims estimated models should therefore, from the outset, treat as many variables as possible as endogenous.[42]

> „Because existing large models contain too many incredible restrictions, empirical research aimed at testing competing macroeconomic theories too often proceeds in a single- or few equation framework. For this reason alone it appears worthwhile to investigate the possibility of building large models in a style which does not tend to accumulate restrictions so haphazardly... It should be feasible to estimate large-scale macromodels as unrestricted reduced forms, treating all variables as endogenous."
>
> (Sims 1980: 14-15)

An unrestricted VAR analysis first estimates all possible interactions between the system's variables. In an SVAR system, a vector of lagged variables explains all other variables. It is a reduced-form model. Further analysis requires that restrictions are made because the reduced form cannot be interpreted directly. The transition from reduced-form to structural model requires restrictions that specify the characteristics that certain variables are to have in the structural model.[43] These restrictions are based on theoretical considerations.

Equation (3.11) shows a model in its structural form, assuming a VAR(1)[44] for simplicity reasons.

(3.10) $BXt = \Gamma 0 + \Gamma 1Xt\text{-}1 + \varepsilon t, \qquad \varepsilon \sim N(0,\Sigma\varepsilon)$

Vector B contains the instantaneous interactions, vector Γ_1 the lagged interactions. It is not possible to estimate this form unless one introduces at least normalizing restrictions. Even if one does, the equation remains meaningless because the error terms and the instantaneous endogenous variables on the right-hand side of the equation are correlated. Therefore the OLS estimator is biased and inconsistent. Only the so-called reduced form (3.12) can be estimated in a meaningful manner.

(3.11) $X_t = A_0 + A_1X_{t-1} + e_{t,} \qquad e \sim N(0,\Sigma_e)$

The relationship between the reduced-form model and the structural model is given by $A_0 = B^{-1}\Gamma_0$, $A_1 = B^{-1}\Gamma_1$ and $e_t = B^{-1}\varepsilon_t$.

The parameters of equation (3.11) cannot easily be derived from those in equation (3.12). So as to be able to determine the parameters unambiguously, it is necessary to impose n^2 restrictions. This can be illustrated with the dimensions of the matrices and vectors:

Taking the vectors X, Γ_0, ε_t and e_t to be of dimension (n,1) and the matrices B, Γ_1, Σ_ε und Σ_e to be of dimension (n,n), it is possible to summarize the number of unknown parameters as follows:

---

[42] The demands of rational expectation theory are incidentally also satisfied, for example, because the interaction between certain macroeconomic variables and economic policy instruments are estimated as feedback relations.

[43] Cf. Favero (2001) and Gottschalk (2001). In traditional structural macro models interactions were excluded and certain variables defined exogenously.

[44] A first-order autoregressive process is a process that depends only on the first lags of the included variables and a constant, see equation (3.23).

Table 3.2
Number of parameters in SVAR models

Structural model		Reduced model	
	Number of unknown parameters		Number of unknown parameters
B	n^2		
Γ_0	n	A_0	n
Γ_1	n^2	A_1	n^2
Σ_ε	n(n+1)/2	Σ_e	n(n+1)/2
Sum	$(5n^2+3n)/2$	Sum	$^3/_2\ (n^2+n)$

From the table it is evident that $(5n^2+3n)/2 - {}^3/_2\ (n^2+n) = n^2$ restrictions are required. SVAR analysis is primarily interested in structural shocks and their transmission. Therefore the restrictions are imposed directly on the shocks ε and the relation ε = Be. First, the structural shocks are orthonormalized whereby n(n+1)/2 restrictions are set ($\Sigma_\varepsilon = I$). The structural shocks to be identified are then uncorrelated (orthogonal), i.e. they are independent[45] and have the same variance (normalized). Second, further analysis is usually based on the Blanchard/Quah (1989) method of setting long-run restrictions.[46] The restrictions serve to differentiate between long-term and transitory effects of shocks. Blanchard/Quah assume from the outset that demand shocks have only short-term effects whereas supply shocks affect the economy also in the long run.

The structural-form model is rewritten as a moving average:

(3.12) $X_t = \mu + C(L)\varepsilon_t,$

$$\text{with } \mu = [I-B^{-1}\Gamma_1 L]^{-1}B^{-1}\Gamma_0$$

$$\text{and } C(L) = [I-B^{-1}\Gamma_1 L]^{-1}B^{-1} = \Sigma_{i=0\ldots\infty} A_1^{\,i} B^{-1} L^i = \Sigma_{i=0\ldots\infty} C(i)L^i$$

The long-term restrictions are then imposed directly on the properties of C(L). As is well-known in the macroeconomic literature, multipliers such as the consumption multiplier can be written as a geometric progression. A long-term restriction of zero then implies that in sum the effects in each period must be zero, so that the long-term effect disappears (whereas short-term effects are possible). Which structural effects are to have long-term effects is decided on the basis of theoretical considerations. If, for example, the first variable of X is to be unaffected by the first shock ε in the long run the following restriction is imposed:

(3.13) $\Sigma_{i=0\ldots\infty} C_{11}(i) = 0,$ where $C_{11}(i)$ is the term (1,1) of matrix C(i).

45 Independence and non-correlation are equivalent here because the residuals are distributed normally.

46 For other identification schemes cf. Favero (2001), chap. 6.

To exactly identify the system, n(n-1)/2 such restrictions must be imposed.

The effects of the multipliers can also be interpreted as impulse-response functions. Impulse-response functions depict the multiplier effects of structural shocks on the time axis, i.e. they are the geometric progression mentioned above.[47] They show the dynamic interactions within the system. When interpreting the impulse-response functions of an SVAR system, it is important to bear in mind that endogenous economic policy reactions are estimated as an integral part of the VAR system. The impulse responses therefore show, how the effects of „exogenous" shocks are transmitted through the system given the estimated endogenous reaction of economic policymakers.

> „(...) the VAR approach *[meaning SVARs]* concentrates on *deviations* from the rule. In fact such deviations provide researchers with the best opportunity to detect the response of macroeconomic variables to monetary impulses that are not expected by the market."
>
> (Bagliano/Favero 1998: 1074)

SVAR analysis thus satisfies two demands of modern economic theory: it derives the imposed restrictions from theory and it distinguishes between anticipated and unanticipated economic policies. A typical problem analyzed with SVARs is, for example, what happens when an external shock, e.g. a negative demand shock from abroad, impacts on the economy and propagates, given the reaction functions of monetary policy and private households. The effects of systematic policy are not ignored; the endogenous functions are always already included in the system. The focal point of structural VAR analysis is how a system with estimated feedback relations settles down after a shock.

The output gap or unemployment gap can then be defined as the sum of the effects of different shocks in the past (e.g. $Y_t - Y^*_t = \Sigma_{to\ t}$ demand shocks and $Nairu_t = \Sigma_{to\ t}$ all shocks other than the demand shock).

The original model by Blanchard/Quah (1989) is based on neoclassical assumptions: demand shocks do not have long-term effects on real production and therefore also not on potential output. In contrast, supply shocks may affect both real output and potential output. It follows that a change in potential output is the sum of estimated supply shocks and the output gap is the deviation of GDP from this potential output. The latter corresponds to the sum of the estimated demand shocks. (This is necessarily so because there are only two types of shocks in the model). As the transitory nature of the effects of demand shocks is assumed a priori and used to identify the system, the output gap is necessarily stationary in the model of Blanchard/Quah (1989). If one does not from the outset want to assume the neutrality of demand policies with respect to potential output one can turn to other models that allow for nonneutrality due to hysteresis effects resulting from insider-outsider phenomena (Balmaseda/Dolado/López-Salido 2000).

[47] Cf. for example Christiano/Eichenbaum/Evans (1999) for an application of SVAR analysis to monetary policy.

The identification strategy may be changed by adding a third shock (a labor supply shock) to the supply shock and the demand shock and by assuming complete hysteresis. Rather than having one long-term shock (the supply shock) and one short-term shock (the demand shock), the model now has two long-term shocks that may be interpreted as supply and demand shocks, respectively. It should be noted that the long-run coefficients are estimated freely – they do not have to be zero as in Blanchard/Quah (1989).

The usual application of SVARs is restrictive, given that changes in potential output are modeled only with reference to the trend and supply shocks. However, if demand shocks affect real output in the long run, they also affect potential output. SVAR models decompose the endogeneous variable – GDP – into the sum of orthonormal shocks and a baseline scenario; they do not, however, provide a direct estimate of potential output. SVAR models are problematic in that they are based on assumptions that cannot be tested. If, for instance, the superneutrality assumption is not valid then the usual identification of shocks as long-run and short-run is wrong and the trend-cycle decomposition does not correspond one-to-one to the long-run short-run decomposition. It is only possible to test hypotheses in a model with overidentifying restrictions. This is usually not the case.

3.6 Conclusion

The vast majority of international organizations apply a production function to estimate national potential outputs. Unlike univariate filters, production functions do not merely extend past trends. They are also superior to semi-structural, multivariate methods because they not only estimate potential output in an economic context – especially by taking into account the effect of the output gap on inflation –, but also directly quantify the contribution of each factor input. Production functions are therefore better suited for identifying and incorporating structural breaks. In practice, however, production function estimates are ultimately also largely based on univariate techniques – especially HP filters –, which are used to determine the potential values of the factor inputs. It is therefore hardly surprising that the potential output estimates of different organizations are quite similar and, as shown in chapter 4, that they are more alike than the estimates of each individual organization at different points in time.

Chart 3.3
International estimates of Germany's growth potential (in %)

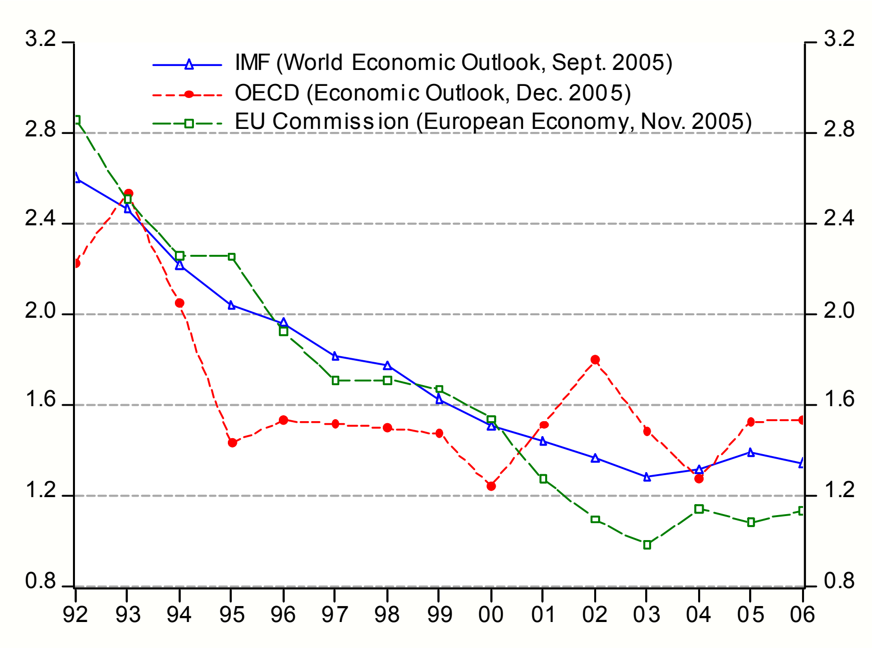


Table 3.3
Output gaps and NAIRU as calculated by different international organizations

	output gap in % of potential output				NAIRU in %			
	2003	2004	2005	2006	2003	2004	2005	2006
IMF	-1.3	-1	-1.6	-1.7	n.a.	n.a.	n.a.	n.a.
OECD	-1.5	-1.6	-2.1	-1.9	n.a.	7.4	7.3	7.3
EU Commission	-1.1	-0.6	-0.9	-0.8	8.4	8.5	8.6	8.7

Sources: IMF: World Economic Outlook, Sept 2005. - OECD: Economic Outlook, Nr. 78/2005. - EU Commission: European Economy, Nov 2005, Nr. 5/2005 and AMECO. NAIRU=NAWRU

4 Estimates of potential output in retrospect

4.1 Introduction

During the past ten years output gap estimates and corresponding potential growth estimates have been revised substantially – at times during the course of a year as illustrated by the charts below which show output gap and potential growth as estimated in spring 2006, in spring 2000 and in realtime by the International Monetary Fund, the OECD and the EU Commission, respectively. In the charts, Germany's realtime output gap is the output gap in a given year as published by the respective organization in the spring of the following year. Calculating potential growth is somewhat more difficult because the institutions mostly do not report it directly. The growth in realtime potential output is calculated based on the GDP and output gap of a given year and the previous year as reported by the respective institution in the spring of the following year.

The difference in potential output estimates in realtime and in retrospect can be exemplified best using the years 1999 and 2001. In the spring 2000 the International Monetary Fund (IMF) estimated Germany's output gap in 1999 to be -2.8%; in the spring of 2006 the IMF puts the output gap in 1999 at +0.1%: this is not only a difference of almost 3 percentage points but also a change from negative to positive. The realtime estimate of Germany's output gap in 2001, i.e. the estimate in the spring of 2002, was -1.2%; from the perspective of spring 2006 the IMF estimates the output gap in 2001 to have been 1.5% and thus markedly positive. An equally stark picture emerges when looking at the figures provided by the EU Commission and the OECD.[48] The revisions are not only quantitatively large but also reveal a qualitatively different view of the business cycle. Revisions of this magnitude invalidate the use of measures of output gaps and potential output growth as indicators for economic policy. To illustrate the problem, we calculated Germany's output gap for 2005 on the basis of the rate of potential growth that the IMF estimated in spring 2000 for period from 1992 to 2001, that is 2.1%.[49] According to this calculation, the output gap in 2005 would have exceeded 8%.[50] A glance at the IMF's estimates of the output gap in other countries shows that the problem of marked revisions is a general one (Chart 4.4).

The consequences of these revisions for assessing structural budget deficits are obviously great as the examples of Germany and Ireland illustrate. In April 2000 the International Monetary Fund reported a structural budget surplus of 0.6% of potential GDP for Germany in 1999; for the year 2000 the IMF expected a structural budget surplus of 0.5%. Two years

---

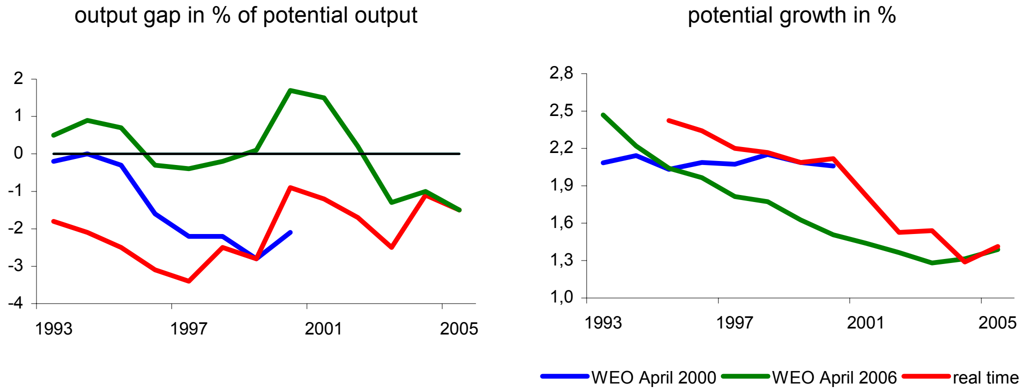
[48] See also Orphanides and Williams (2002) as well as Döpke (2004), who analyse this discrepancy between potential output estimates in real time and in retrospect for the United States and for Germany, respectively.

[49] The potential growth rate deviates from 2.1% in only two years, namely in 1995 (2.0%) and in 1998 (2.2%). This is probably due to rounding errors.

[50] This calculation is meant to be illustrative only, since the repercussions of the prolonged economic weakness on potential output are not considered. The output gap thus calculated cannot be closed immediately but rather only over a period of several years.

later the respective figures came to -0.8% and -1.3%, and in the spring of 2006 the IMF estimated Germany to have structural budget deficits in 1999 and 2000 amounting to -1% and -1.2%, respectively. For Ireland, the International Monetary Fund currently reports structural budget surpluses of 0.8% and 2.6% respectively for the years 1999 and 2000 (spring 2006). In spring 2002 these surpluses were estimated to amount to 3.1% and 2.8% and in spring 2000 the IMF had calculated a structural surplus of 1.9% for 1999 and 2.1% for 2000.[51]

Chart 4.1
Germany's output gap and potential growth: IMF estimates at different points in time[1]

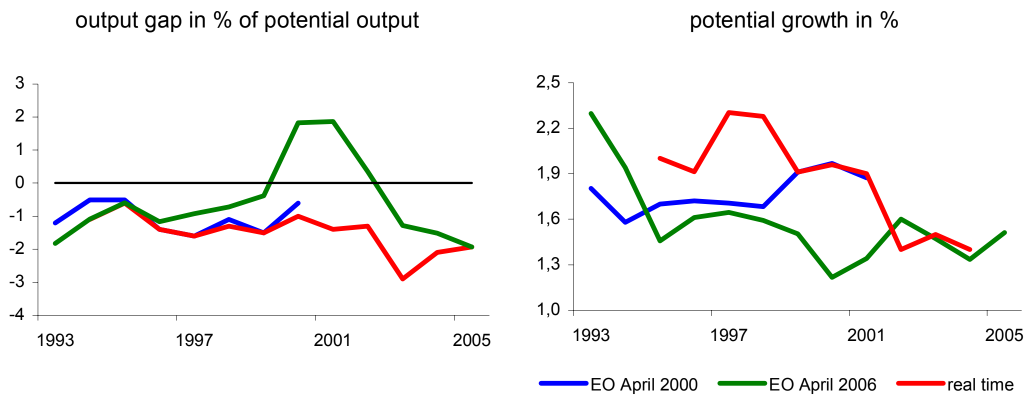


1Real time denotes the estimate of the output gap and potential growth for the year preceding the publication year. The rate of change of real-time potential output is calculated on the basis of the GDP and the output gap of a given year and the preceding year as published in the following year.

Sources: International Monetary Fund, World Economic Outlook, spring editions, 1994 bis 2006.

[51] For the high uncertainty surrounding estimates of Ireland’s structural budgetary balance see also European Commission (2006, especially p. 233).

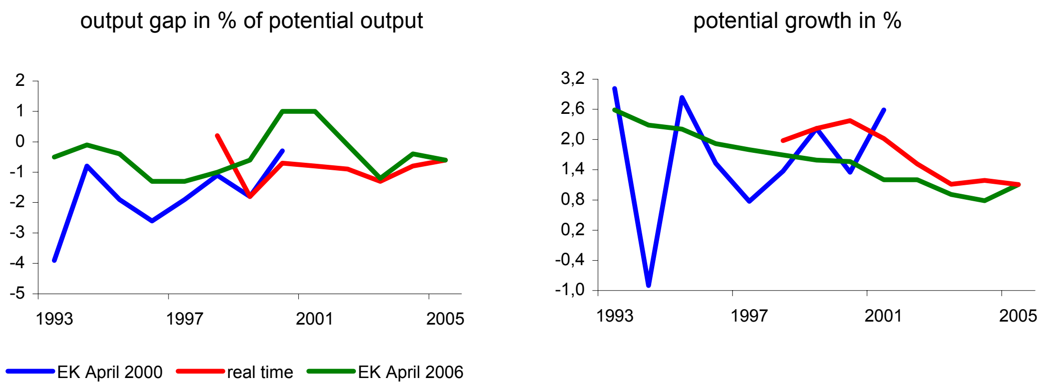
Chart 4.2
Germany's output gap and potential growth: OECD estimates at different points in time[1]



1Real time denotes the estimate of the output gap and potential growth for the year preceding the publication year. The rate of change of real-time potential output is calculated on the basis of the GDP and the output gap of a given year and the preceding year as published in the following year: as of 2001 the OECD publishes potential growth rates.

Sources OECD, Economic Outlook, spring editions, 1999 to 2006.

Chart 4.2
Germany's output gap and potential growth: EU Commission estimates at different points in time[1]

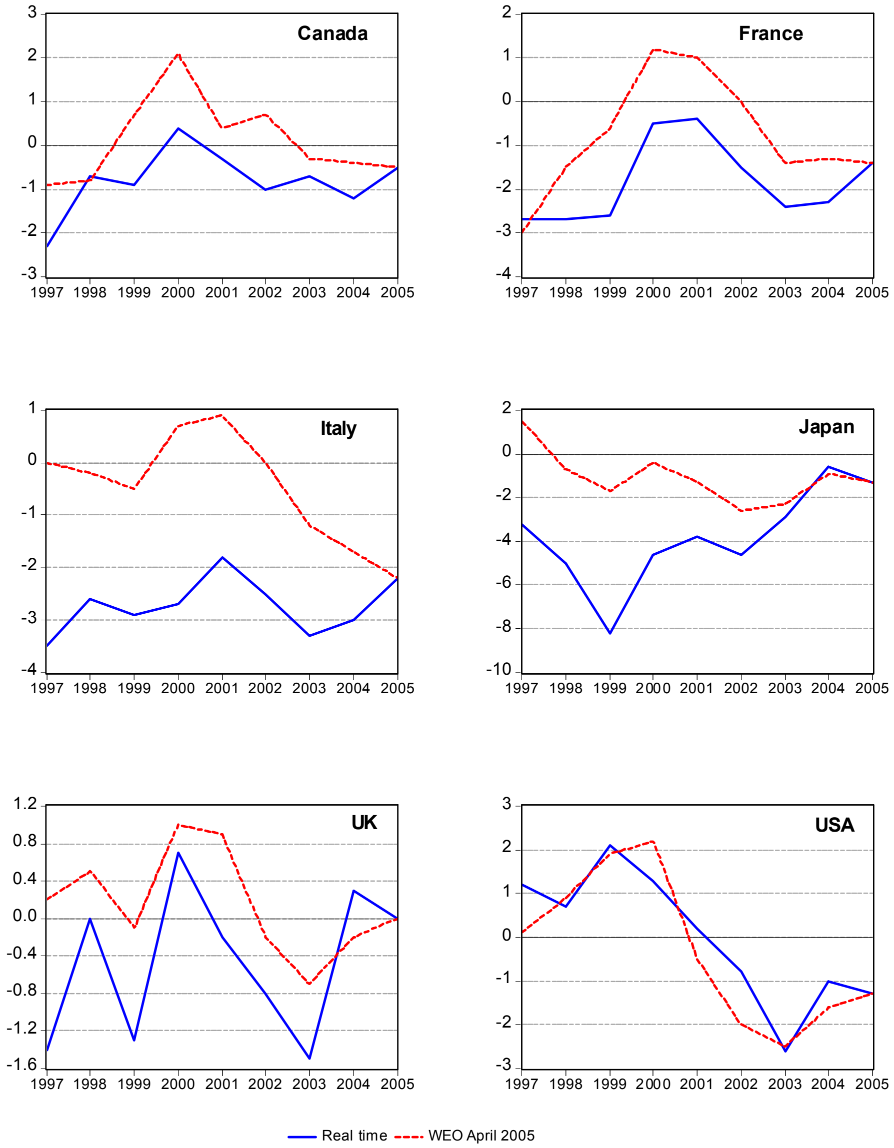


1Real time denotes the estimate of the output gap and potential growth for the year preceding the publication year. The rate of change of real-time potential output is calculated on the basis of the GDP and the output gap of a given year and the preceding year as published in the following year.

Sources: EU Commission (EC), European Economy, Stat. Annex, spring editions, 1999 to 2006; AMECO database.

Chart 4.3
IWF estimates of the output gap in different countries at different points in time[1]

in % of potential output

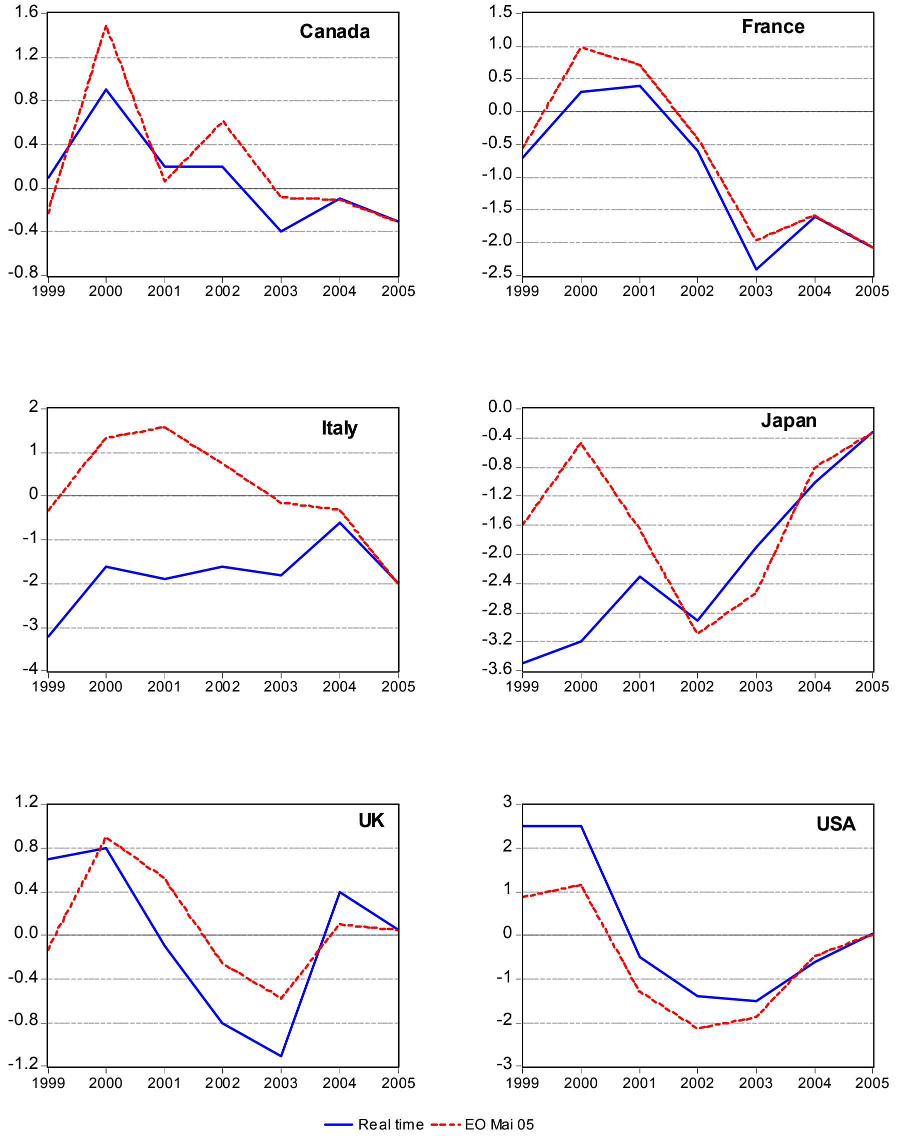


[1] Real time is the estimate of output gap for the respective year.

Sources: International Monetary Fund, World Economic Outlook, spring editions, 1997 to 2005.

Chart 4.4
OECD estimates of the output gap in different countries at different points in time[1]

in % of potential output



[1] Real time is the estimate of output gap for the respective year.
Sources: OECD, Economic Outlook, December editions, 1999 to 2004.

4.2 Econometric causes

From an econometric viewpoint, there are four key reasons for the marked revisions of potential output estimates: revision of the data published by the statistical offices and of the corresponding forecasts, parameter uncertainty, endpoint uncertainty and model uncertainty.

4.2.1 Statistical revision of data and forecasts

This effect emerges because the statistical data used to estimate potential output is revised by statistical offices and other data-generating institutions as new information becomes available. However, the difference between actual growth in realtime and in retrospect is much smaller than the revisions of potential growth. This is especially pronounced in the case of the EU Commission. Surprisingly, the Commission nonetheless maintains that data revisions are the main cause for revisions of the output gap.[52]

The effect should be much more pronounced in the case of forecast data. Many methods of estimating potential output use forecast data to calculate the most recent values of individual components of potential output, e.g. of total factor productivity and the labor force. Especially for components that are calculated using the HP filter, forecasts are markedly revised from year to year implying that the values of the HP-filtered time series change and hence also the current potential output estimate.

4.2.2 Parameter uncertainty

An estimation model is re-estimated when new data points become available. This may cause the parameters to change resulting in different estimation values. This effect should be relatively small for precisely estimated models and in the absence of structural breaks at the end of the time series, since, in this case, the functional relationships change only little over time.

4.2.3 Endpoint uncertainty

Many of the models presented use methods afflicted with endpoint uncertainty to calculate individual components of potential output. The HP filter is the best-known method in this respect but Kalman-filter estimates are also affected, when the smoothed components are used, as is generally the case.

The problem can be reduced for the HP filter by adding forecasts as data points to the time series under consideration. These forecasts are usually based on simple ARIMA models and lower the weight of the last actual data point in the filtered component. However, this only partially solves the problem because by construction the filtered component towards the end of the series is revised as new data points are added. The revision results from the change in the weights and occurs even if the forecast values remain unchanged. The forecast values are furthermore also revised giving rise to the source of great uncertainty mentioned above.

[52] Cf. Denis et al. (2006: 17-18); this discrepancy is also pointed out by the ECB (European Central Bank 2005a: 43ff.).

In case of the Kalman filter the problem is diminished by including additional information (time series). The effect cannot, however, be eliminated completely. We conclude from an analysis of the data for our NAIRU estimate that the degree of endpoint uncertainty strongly depends on the particular NAIRU model used. Endpoint uncertainty does not, however, appear to be the key reason for the major revisions of the NAIRU.

4.2.4 Model uncertainty

Model uncertainty pertains to the fact that different models produce different results. This effect naturally does not arise when the same model and the same specifications are used year in year out. As mentioned earlier when describing the different methods of estimating potential output, the modelling strategies used evolved over time. The EU Commission, for example, started in 2005 to measure labor input in hours rather than persons (i.e. the Commission now takes working time into account). This effect may therefore play a role in the revisions but it is difficult to quantify.

4.3 Economic causes

Economic reasons most frequently cited for the economic slowdown in Germany since the mid-nineties are the consequences of German unification as well as labor market rigidities and high wage costs. But these factors cannot explain the considerable revisions of potential output estimates. They cannot explain why the International Monetary Fund in 2000 expected potential output to grow by 2.1% in 2001 and in 2006 estimated potential growth in 2001 at 1.4% also revising growth in the previous years downward.

The economic organizations discuss German macro policy primarily with a view to price stability and consolidation of government finances. In this context it is striking that high foreign demand is always deemed beneficial for Germany's economic development. The German Council of Economic Experts (Sachverständigenrat), for example, based its positive outlook at the turn of the century, among other things, on the additional stimulus coming from the long lasting (trouble free) expansion in the United States (Sachverständigenrat 2000: 1, 3). From the ensuing economic downswing in the United States the Council did not, however, conclude that macropolicy should try to compensate for the resulting lack in demand. Strongly expansionary monetary and fiscal policies are always given as one reason for the dynamic development in the US during the first part of the century despite massive external shocks. This insight does not, however, result in a plea for more expansionary policies in Germany. And this despite the fact that, for example, the EU Commission attributes Germany's economic weakness specifically to weak domestic demand:

> "Weakness in domestic demand has been the principal factor explaining the growth gap between Germany and its European partners since the mid-1990s. In particular, private consumption has been dragged down by sluggish growth of households' disposable income as employment growth was anaemic and the purchasing power of households was dented by an increasing tax burden.
>
> *[...]*

> Finally, the hypothesis of a sustained loss in competitiveness as a major factor in the growth slowdown of the 1990s is difficult to confirm on the basis of the evolution of the external sector and needs to be analysed in more detail."
>
> (European Commission 2002b: 29)

The EU Commission on the basis of growth-accounting analysis then identifies as the key problem "[…] the insufficient capacity of generating employment" (European Commission 2002b: 26).

Because the economic institutions do not recognize the macroeconomic reasons behind the low ability to generate new employment, excessive wages and labor market rigidities are left to explain the slowdown. Taking the time period from the early nineties to 2002, it becomes apparent that cumulated real wages increased slower than the cumulated increase in labor productivity. In individual years during the unification period and also in 1995, wage growth did exceed productivity growth, but at least since 1995 the picture of a marked wage restraint emerges, which from a neoclassical viewpoint should have positively affected employment. If one subtracts the so-called layoff productivity from reported productivity and uses effective wages rather than bargained wages, one sees cumulative wage restraint relative to this "full-employment productivity" (IMK 2006b). Furthermore, there are some basic theoretical objections to the use of this lower "full-employment productivity". In a Keynesian model, employment primarily depends on the development of aggregate demand. A dependance on real wages in employment functions arises only at the level of partial analysis, not at macroeconomic level at which all domestic economic factors are endogenous. Therefore, a look at domestic demand is warranted. Subsequent to German unification, domestic demand displays a fundamental weakness which strongly depressed employment. Viewed from this angle, it was not sluggish employment that caused domestic demand to be weak but rather weak domestic demand that caused the poor employment development.

It is often argued that labor market rigidities matter especially in the aftermath of economic shocks; ratchet effects then prevent or delay adjustments necessary to bring the economy into equilibrium. Two counter-arguments are Germany's high flexibitilty in working time and the limited use of labor market flexibility in absorbing shocks (Sachverständigenrat 2002, minority opinion). Even if ratchet effects did make the German economy more vulnerable than other economies, this would not imply that structural reforms are the best or only solution.[53] As shown in the section on hysteresis in chapter 5, unemployment becomes sclerotic if it lasts for some time. If there is a risk of hysteretic effects, it is the responsibility of macro policy to counter negative demand shocks. When monetary policy is actively fighting an increase in inflation, the monetary reins have to be loosend again once the inflationary outlook has improved in face of higher unemployment.

[53] See also the discussion in section 6.3.

4.4 Conclusion

The frequent and large potential output revisions are largely due to the econometric methods used for estimating potential output, in particular the endpoint problem and forecast mistakes, rather than to data revisions or a changing view of underlying structural factors. Below we shall show how revisions come about by estimating the potential labor force, potential TFP and the NAIRU based on the following time series of the current AMECO database for the period 1970-2007 and 1970-2000, respectively: real GDP, net capital stock, total employment, standardized unemployment rate, wage share and NAIRU. As discussed in chapter 5, the time series for West Germany and unified Germany are linked using growth rates in order to eliminate the unification break. Based on these data the average wage share from 1970 to 2005 is calculated (62%) and – by rearranging the production function equation – a time series for total factor productivity (TFP).

How prone the methods are to revision can be illustrated with the three time series potential labor force, potential TFP and NAIRU. First, we apply an HP filter to the labor force and to TFP to produce their respective potential values and, subsequently, a series for potential output. Focusing again on the year 2000, we calculate an output gap of +1%. Second, we go back in time to 2001, a time when the time series above included data up to only 2000. To extend the series to 2007, we apply the two methods most commonly used by international organizations: simple ARIMA models and ad-hoc extensions. In the ARIMA version, TFP and labor force are estimated in log levels, more specifically with an AR(2) model with trend and a simple AR(2) model, respectively. The new data points thus generated exceed the trend observed in 1995-2000 and are thus “optimistic”. Therefore, we estimated a second version in which the trend in 1995-2000 is extrapolated to 2007 and an HP filter (100) is applied to the extended time series. In both cases, the NAIRU is generated according to the method used by the EU Commission, i.e. we increase (decrease) the NAIRU by half of the change in the preceding year. Based on these artifical realtime data for potential TFP, potential labor force and the NAIRU, we recalculate potential output. The time series generated by the AR model yields an output gap of 0.4% in 2000, which although positive, is substantially smaller than the output gap for 2000 calculated above on the basis of the actual development up to the present. The “conservative” second model, that extends the trend, yields a negative output gap of 0.3%. Our example shows that potential output estimates greatly depend on the expected values of its components which, in turn, largely depend on the respective previous development in the estimation models used (chart 4.6).[54] It follows that the current estimates of Germany’s potential output may prove to be far too pessimistic if the economic weakness in the first part of the decade proves to be a temporary phenomenon.

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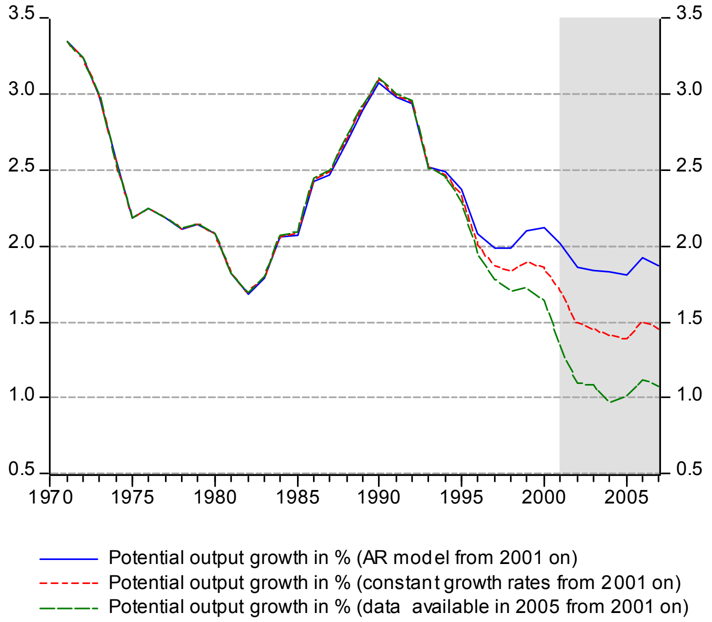
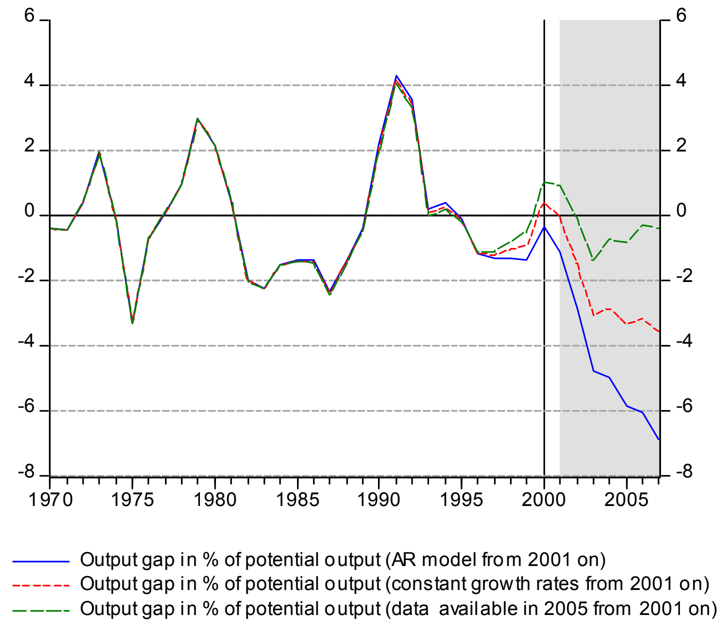
[54] The revisions are not the result of changes in the data provided by the Federal Statistical Office or a different interpretation of the existing wage pressure. The revisions of Germany’s growth rates for 1999, 2000 and 2001 amount to 0.5 percentage points, 0.1 percentage points and 0.7 percentage points, respectively. Although these revisions can partly explain the revisions of the output gap, they offer no grounds for *downward* revisions of potential output (calculations of the authors based on data provided by the Federal Statistical Office.)

Chart 4.5
Output gaps and potential growth rates in artificial realtime





5 IMK production-function estimate of potential output

5.1 Introduction

In this chapter we use a production-function approach to estimate potential output. The NAIRU is estimated using a Kalman filter. Compared to other methods the production function approach has the advantage that potential output is derived from growth factors which, at least in principal, also explain its development. This firstly ensures that the estimated potential output corresponds to some degree to the theoretical definition of potential output and secondly allows for a differentiated, economically meaningful projection of potential output (chapter 3).

For various reasons we stick relatively close to the modeling strategy of the EU Commission (Denis et al. 2002), one being its relevance for the national governments in the Euro Area when, for instance, formulating their stabilization programmes. Furthermore, in recent times the methods used by international organizations have hardly differed from one another. The modeling approach presented here differs from that of the EU Commission marginally with respect to the data employed, and considerably in the way the potential levels of individual components of the production function are calculated. The latter applies in particular to the NAIRU and potential total factor productivity. For the NAIRU estimate, we use a Kalman filter as does the Commission and even the Commission's GAP program. However, we specify the Phillips curve differently and quantify the effects of exogenous variables. In the case of total factor productivity we also attempt to identify economic factors that explain its development, whereas the EU Commission adopts a purely econometric approach – a mix between random walk and deterministic trend.

We estimated the following Cobb-Douglas production function:

$Y^*_t = A^*_t L^{*\alpha}_t \cdot K^{*\,1-\alpha}_t$,

where Y^* is potential output, A^*_t potential total factor productivity, L^*_t potential hours worked, α the partial elasticity of production with respect to labor and K_t^* the capital stock.

The NAIRU is needed to calculate the potential hours worked. More specifically (1-NAIRU) is multiplied by the potential labor force (HP-filtered actual labor force) to determine the non-inflation-accelerating level of employment. The latter is then multiplied with the average potential hours worked (HP-filtered actual average hours worked) to calculate potential total hours worked. The coefficient α is usually set exogenously and is here equated with the average wage share in the given period (0.65). The potential capital stock is taken to be identical to the actual capital stock, which is also common practice. Potential total factor productivity (A^*_t) is then determined by first solving the production function for A_t using actual employment and actual GDP rather than their potential levels. Total factor productivity (A_t) is then estimated as dependent on several determining factors as discussed in chapter 5.4 and potential total factor productivity is calculated by plugging the potential levels of these factors into the equation.

In the following, we first describe the data used and then present our estimates of the NAIRU and total factor productivity. The chapter closes with a presentation of the potential output estimates and some thoughts on the projection of potential output.

5.2 Data

We mainly use annual data provided by the German Federal Statistical Office (Destatis). These are by and large identical to the data for Germany used by the EU Commission, because the data in the Commission's AMECO database is mainly provided by Eurostat, which in turn does not generate data itself but collects them from the national statistical offices. At the time this paper was written, no official time series for the German capital stock existed, so we used the AMECO time series but recalculated it using time series for depreciation and gross fixed investment to make it compatible with the German system of national accounts. Our time series for the capital stock therefore differs minimally from the AMECO time series.

The unemployment rate is the standardized unemployment rate as defined by the ILO; i.e. the unemployment rate (Erwerbslosenquote) provided by the Federal Statistical Office Destatis, rather than the official national unemployment rate published by the Federal Emplomen Agency. The latter rate is currently of limited use because of several statistical artifacts resulting from the Hartz-IV labor-market reforms and other policy measures affecting the labor market since 2000. The ILO unemployment rate provided by the German Federal Statistical Office differs marginally from the rate Eurostat publishes. For the monetary policy indicators we require quarterly data and therefore use the OECD as a source.

We deal with German unification, as does the EU Commission, by linking the time series in growth rates: the growth rate of the West-German time series up to 1991 is extended using the growth rates of the time series for unified Germany. We use this series linked with growth rates to calculate (artificial) levels for unified Germany prior to 1992.

Institutional variables used in estimating the NAIRU are taken primarily from the dataset of Nickell et al. (2001),[55] Bassanini/Duval (2006) – which the OECD's Employment Outlook 2006 is based on –, the OECD's databank (OECD.Stat database, available under: http://stats.oecd.org/wbos/default.aspx), Martinez-Mongay (2000, 2003), Destatis, AMECO and Visser (2006). Nickell et al. (2001) provide a time series on employment protection which we extended beyond 1995 using data from Bassanini/Duval (2006) – based on growth rates as the levels of the two series do not correspond. Since this series only goes up to 2003, the last two data points were estimated making adjustments for the reforms in employment protection in 1996, their subsequent retraction in 1999 and eventual reintroduction in 2004 and to take into account the Hartz-IV labor market reforms in 2004 and 2005. (For instance, it is now possible to offer older applicants temporary contracts without stating the reasons

[55] Labour Market Institutions Database (LMID), online access: http://cep.lse.ac.uk/pubs/author. asp? author=nickell.

already at the age of 52 rather than 58 as before.)[56] The time series for union density was taken from Nickell et al. (2001), which by and large corresponds to the series provided by the OECD. This time series was extended using data from Visser (2006); the last year is our estimate based on the assumption that the decreasing trend continued. We continued the series on replacement rates provided by Bassanini/Duval (2006) with two estimated data points, taking into account that replacement rates are lower in 2005 due to the partial merging of welfare benefits and unemployment benefits (Hartz-IV reform) and that the OECD's net replacement ratio registered a decrease for all household groups in 2004 (partly by more than 10%) (OECD.Stat database). The tax wedge is derived from two different time series: the first is the absolute difference between compensation of employees and the net wage sum in percent of employee compensation (national accounts data). The second series is an updated version of the effective tax burden (taxes, duties, social security contributions) on labor as calculated by the EU Commission (Martinez-Mongay 2000 and 2003). It is the ratio of the sum of non-wage labor costs and wage tax to gross wages and salaries.

The monetary indicators used to estimate the NAIRU are based on national accounts data and data from the German Bundesbank. The overnight rate and "indicator of the German economy's price competitiveness against 19 countries based on the deflators of total sales" were used as provided by the Bundesbank. The real short-term interest rate is the overnight rate minus the change in the GDP deflator, the latter calculated on the basis of the Destatis time series on real and nominal GDP (before 1992: West Germany).

To estimate total factor productivity additional data sources used are the Congressional Budget Office (U.S. potential total factor productivity), AMECO database, OECD Main Science and Technology Indicators (per-capita expenditure on research and development) as well as Ifo and OECD (capacity utilization in manufacturing).[57]

5.3 Kalman-filter estimate of the NAIRU

The Kalman-filter method is a superior tool compared to cointegration and other statistical approaches because it relates the unemployment gap to a measure of inflation and thus satisfies the theoretical definition of the NAIRU. Furthermore it allows for quantifying the effect of exogenous variables such as a monetary policy indicator or hysteresis. It should be noted, however, that the results of the Kalman-filter estimate strongly depend on the specification of the estimated equations so that is is necessary to exercise caution. For example, the fact that the NAIRU is specified as an AR(2)-process implies that it is necessarily a stationary variable. Although this is a sensible assumption, it would have been preferable to find this characteristic as a result rather than plugging it in as an assumption.

[56] Cf. Deutsche Bundesbank (2005: 23) for an overview of these reforms.

[57] Neither the Federal Statistical Office nor the OECD provides a long time series of the educational attainment of the population.

The Elemeskov method is an alternative method that also links wage inflation and the unemployment gap but is based on fewer assumptions. The OECD applied this method until a few years ago. The Elmeskov method is furthermore easy to apply and to follow.

The Elmeskov method starts with a simple Phillips curve formulated in terms of wage inflation:

$$\Delta w - \Delta w^e = \alpha (u-u^*).$$

Reformulation yields the NAWRU (non-accelerating wage rate of unemployment):

$$u^* = u – [\Delta w - \Delta w^e] / \alpha.$$

The equation cannot be solved directly because it has two unknowns. The OECD proceeds as follows: First the parameter α is identified by modeling the NAWRU as a constant. It follows that:

$$\alpha = [\Delta^2 w - \Delta^2 w^e] / [\Delta u].$$

Expectations are calculated using an HP filter or the first lag of wage growth. This yields the following NAWRU:

$$u^*=u - \Delta u [\Delta w - \Delta w^e] / [\Delta^2 w - \Delta^2 w^e], \text{ with } \Delta w^e = \Delta w_{-1} \text{ or } HP_{25}(\Delta w).$$

In the first case, the NAWRU reduces to:

$$u^*=u - \Delta u[\Delta^2 w]/[\Delta^3 w].$$

Unfortunately, the estimated NAWRU is so volatile, that one is forced to use an HP-filter or the like in order to obtain a sensible time series. The HP-filtered Elemeskov NAIRU, however, is hardly distinguishable from a plain HP-filtered NAIRU, leading us to reject this approach.

Chart 5.1 demonstrates why we had to reject the Elmeskov approach. The resulting NAIRU is so volatile that HP filtering is necessary. The NAWRU so closely resembles the actual unemployment rate that there is hardly a difference between the HP-filtered NAWRU (after eliminating outliers) and a NAIRU generated by simply HP filtering the unemployment rate.

Chart 5.1
NAWRU estimate according to the original Elmeskov method

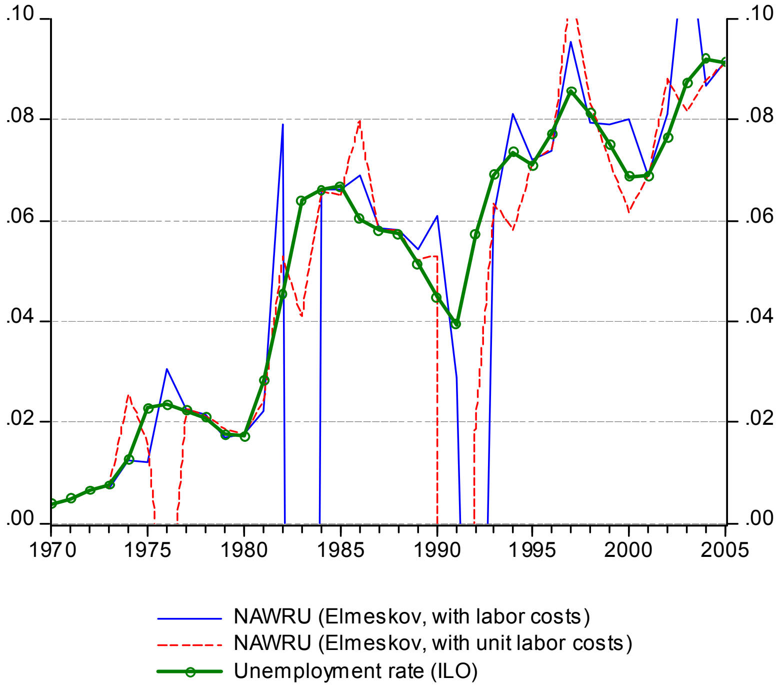
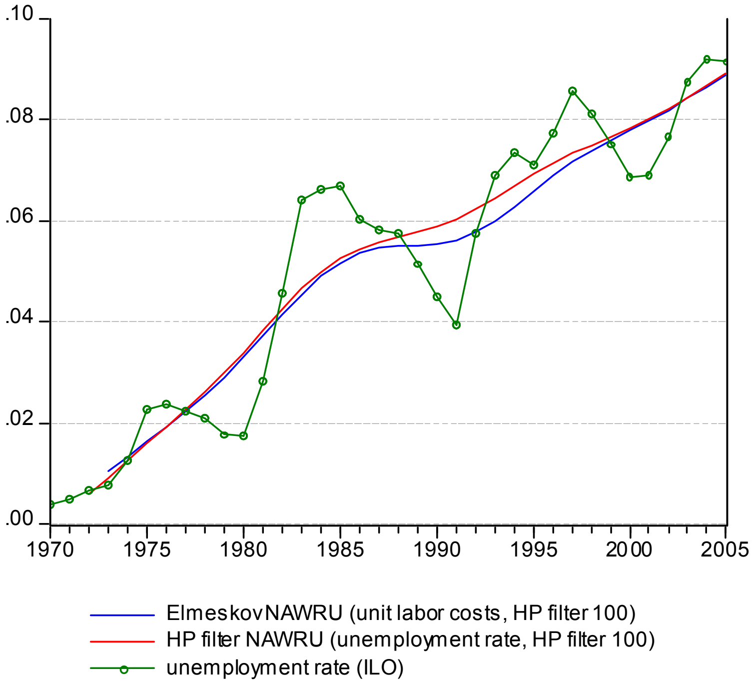


Chart 5.2
HP-filter NAWRU and Elemeskov NAWRU[1] in comparison

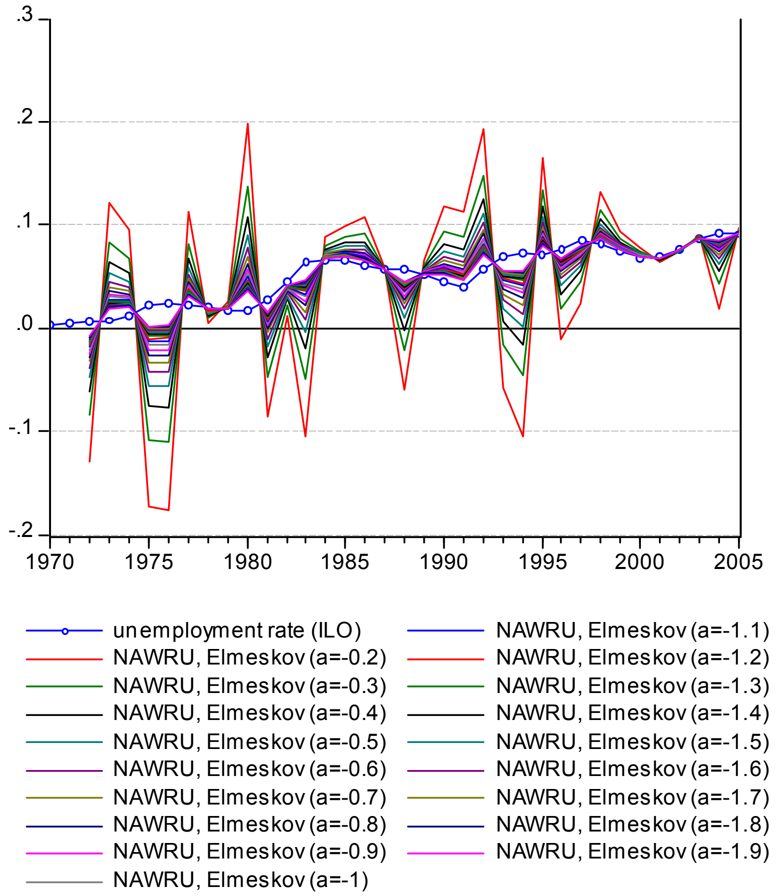


[1)] Calculated with unit labor costs and smoothed with HP-100 after eliminating two outliers.

The method cannot be salvaged even if one estimates the parameter α differently. In the following we attributed to α values ranging from -0.2 and -1.9 in steps of 0.1.[58] Chart 5.3 shows the NAWRUs calculated with these values for α. The volatility has hardly diminished so that these NAWRUs are unsuited as orientation points for medium-term economic policies.

[58] In this case the NAWRU is calculated as $u^* = u - [\Delta^2 w / \alpha]$.

Chart 5.3
Elmeskov NAWRU for Germany with different values of α[1]



1) Values from -0.2 to -1.9 in steps of 0.1.

Since we had to reject the Elemeskov method, the Kalman-filter remains as the only method of estimating the NAIRU that draws on economic relationships. In the next three sections, we present three Kalman-filter estimates of the NAIRU. The first estimate is based on a Kalman-filter without exogenous variables. In the second estimate institutional variables and a monetary policy indicator are included and their effects quantified. The third Kalman-filter estimate tests for hysteresis effects. Subsequently we discuss the projection of the NAIRU and offer some conclusions.

5.3.1 Kalman-filter estimate of the NAIRU without exogenous variables

The Kalman-filter approach is well suited to estimate the NAIRU because it was developed specifically to estimate unobservable variables and the NAIRU is such a variable. In order to estimate the unobservable NAIRU with the Kalman filter it is necessary to make an assumption about how the NAIRU interacts with other economic variables that are observable, i.e. exist as time series, as well as the econometric properties of the NAIRU. We estimate the

NAIRU as a nonstationary trend (statistical property), or more precisely, as a local linear model,[59] and assume that the unemployment gap (u-u*) significantly affects inflation. To use the information contained in this economic relation – the Phillips curve – the NAIRU is estimated simultaneously with the Phillips curve. The unemployment gap is modeled as an AR(2) process.[60]

State equations:

$(u-u^{*})_t = ar_1\,(u-u^{*})_{t-1} + ar_2\,(u-u^{*})_{t-2} + \varepsilon^{ugap}_t$

$Nairu^{implizit}_t = Nairu^{implizit}_{t-1} + trend_t + \varepsilon^{nairu}_t$

$trend_t = trend_{t-1} + \varepsilon^{trend}_t$

$Nairu_t = Nairu^{implizit}_t + \delta Z^{nairu}_t$

Definition equation:

$u_t = (u-u^{*})_t + Nairu_t$

Phillips curve equation:

$\Delta^2 w^h_t = \beta(u-u^{*})_t + \gamma X^{Phillips}_t + \varepsilon^{phillips}_t$

$X^{phillips}_t$ denotes exogenous variables that affect hourly wages (w^h).

First we estimate the NAIRU without exogenous variables ($\delta=0$) similarly to the EU Commission and the OECD (Denis et al. 2002, Turner et al. 2001). Like the EU Commission, we estimate the Phillips curve in terms of wage inflation, rather than price inflation as is the norm, so as to exclude price shocks that are unrelated to the labor market. Unlike the Commission we do not include the wage share in the Phillips curve equation. In the Commission's estimates the wage share has great explanatory power which in our opinion is the result of an error: in deriving the Phillips curve, an economic equilibrium condition is replaced by a definition.[61] This probably gives rise to an endogeneity problem that lets the equation appear to be much better than it actually is. Our Phillips curve further differs from that of the Commission in that import and export prices are entered separately. Including these variables in the Phillips curve can be justified but it is not a given that they have the same (absolute) sign which would be a prerequisite for including them as one terms-of-trade variable. However, these differences do not substantially affect the actual estimate of the NAIRU.

The Phillips curve is derived from standard wage and price setting curves. The former strongly resembles that of the EU Commission. The price setting curve replaces the Com-

[59] A local linear model is de facto equivalent to an ARIMA(0,2,1). Depending on the variances of the two error terms, it can be either a simple random walk or an I(2) process. Many authors use this approach because it allows for a smooth trend; cf. Harvey und Jaeger (1993).

[60] This is a typical way of modeling the unemployment gap; cf. Fabiani/Mestre (2001) and Apel/Jansson (1999).

[61] The authors will provide the derivation of the Phillips curve on demand.

mission's wage demand curve for the reasons cited above. The rules for expectations and the reservation wage correspond to those of the EU Commission. Based on a Cobb-Douglas production function the Phillips curve is specified as follows:

$\Delta^2 w_t = a_1 \Delta^2 prodh_t - \Delta^2 s_t - \beta(u\text{-}u^*)_t + \varepsilon_t$,

where s_t are supply shocks other than unit labor costs that affect prices, and in our case import and export prices.

The estimation begins only in 1973 despite the actual start of the time series in 1970, because the series are differenced and lags are considered. Lags of the endogenous variables are insignificant and thus not included. There is no autocorrelation, which supports the decision to estimate without lagged endogenous variables. Hourly productivity is significant only at lag one and is included in the Phillips curve accordingly. Export and import prices enter the equation without lags and – as was to be expected – with opposite signs. In contrast to the EU Commission's estimate, both variables enter the equation, not a terms of trade variable, because estimates that restricted the coefficients to have the same absolute value were markedly inferior. The results are shown in the table 5.1.

The coefficients can simply be read off the table because there are no lagged endogenous variables in the Phillips curve: a decline in the output gap by one percentage point for one year (three years), permanently lowers wage inflation by about 0.5 percentage points (about 1.4 percentage points). A permanent increase in productivity growth by one percentage point permanently raises wage inflation by 0.7 percentage points; at the same time, the increase in unit labor costs is permanently lowered by 0.3 percentage points. An increase in export price inflation by one percentage point increases wage inflation by 0.4 percentage points, a corresponding increase in import prices lowers it by 0.1 percentage points. This latter result can partly be explained by the different size of imports and exports. Import prices may be interpreted as price supply shocks in s_t, whereas export prices indicate the economic condition of the export industry which is reflected in correspondingly higher wages.

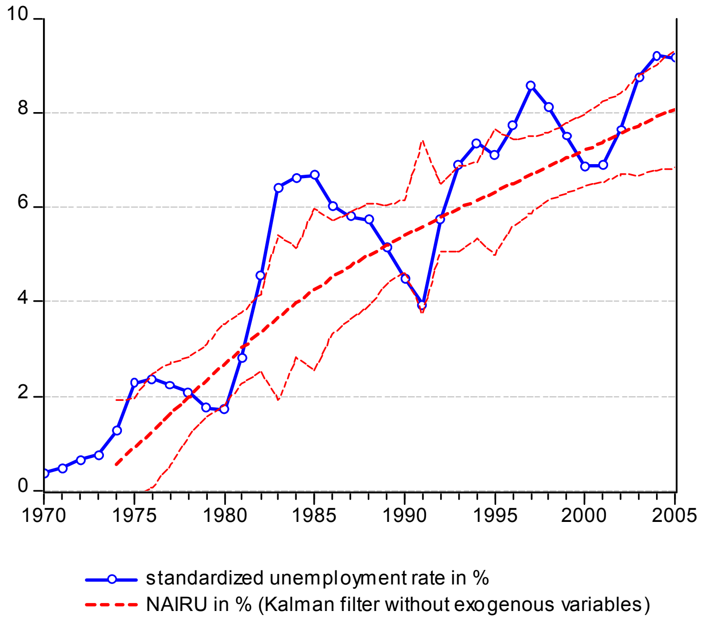
The AR-coefficients of the unemployment gap imply an average cycle length of nine years (9.3). The unemployment gap is estimated with a constant of 0.3 percentage points implying deflationary pressure in the order of 0.1%. (The constant is not significant but improves the quality of the estimate.) This is compatible with the two disinflationary periods during the estimation period: The increase in hourly wages diminished from 12% in the early seventies to 5% in the late eighties and again since the mid-nineties to nearly 0% in 2005. The variances of the error terms are not restricted, the local linear model of the NAIRU is therefore not necessarily a simple random walk. This is a common way of modeling the NAIRU (Fabiani/Mestre 2000 and 2001, European Commission 2002c and 2006). The residuals of the NAIRU equation exhibit no autocorrelation. The main motivation for this modeling approach is that unlike a pure random walk, it produces a smooth NAIRU. The distribution of the residuals of the Phillips curve is normal, that of the state equations, however, probably not.

Table 5.1
Results of the Kalman-filter estimate of the German NAIRU

Maximum likelihood equation and statistics estimation periods: 1973-2005 (33 observations)			
Variables	coefficients	s.e.	t-stat
State equations			
ar_1	1.264	0.128	9.860
ar_2	-0.655	0.124	-5.289
constant	0.003	0.002	1.145
$Var(\varepsilon^{nairu})$	1.88E-04		
$Var(\varepsilon^{trend})$	1.95E-04		
$Var(\varepsilon^{gap})$	2.51-02		
Phillips curve			
$(u-u^*)$	-0.462	0.198	-2.327
$d^2prodh_{(-1)}$	0.658	0.225	2.927
d^2pex	0.403	0.192	2.098
d^2pim	-0.127	0.074	-1.713
R^2	0.464		
-2*log-likelihood	-418.368		
$Var(\varepsilon^{phillips})$	1.266E-04		
residual tests			
State equations			
Ljung-Box Q(4) statistic	1.463	prob:	83.3%
Jarque-Bera statistic	9.599	prob:	0.8%
Phillips curve			
Ljung-Box Q(4) statistic	4.237	prob:	37.5%
Jarque-Bera statistic	1.285	prob:	52.6%

The estimated NAIRU and unemployment gap are depicted in the charts below.

Chart 5.4
Kalman-filter estimate of the NAIRU and the unemployment gap



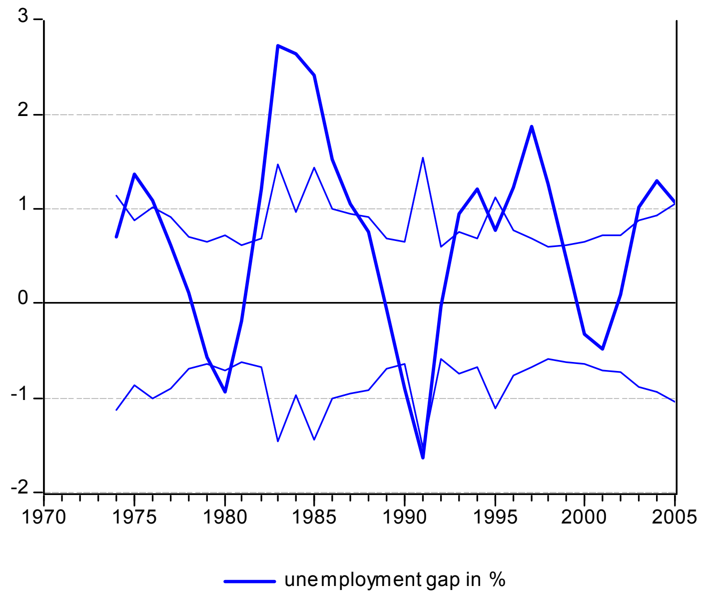
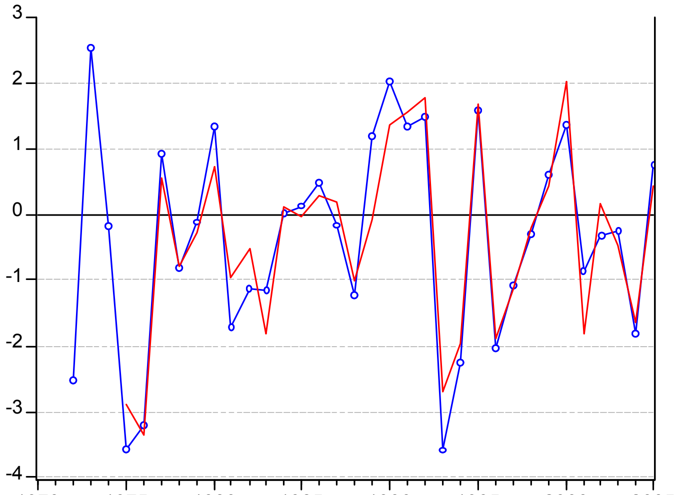


Chart 5.5
Wage costs: actual values and Phillips curve estimates



The Commission's GAP program not only permits us to simultaneously estimate the NAIRU and the Phillips curve but in principle also to include exogenous variables. The advantage of using exogenous variables is the increased economic content of the estimate. The GAP program's approach is, however, somewhat problematic because the state equations are split into three independent groups: the unemployment gap, a statistical process (here: local linear model) and the exogenous variables. In the literature, estimates rarely use exogenous variables and if they do, they usually take the form of nested decomposition (Salemi 1999 and Jaeger/Parkinson 1994). Here unemployment is split into unemployment gap and NAIRU, the latter in turn being modeled as a function of itself (random walk approach) and the exogenous variables. Table 5.2 outlines the two modeling strategies to emphasize their differences:

Table 5.2
Modeling the influence of exogenous variables

EU Commission (GAP)	Modeling as in Jaeger/Parkinson (1994), Salemi (1999)
$u_t = (u-u^*)_t + nairu_t^{implicit} + \delta Z^{nairu}_t$ $(u-u^*)_t \sim AR(2)$ $nairu_t^{implicit} \sim$ local linear trend $nairu = nairu_t^{implicit} + \delta Z^{nairu}_t$	$u_t = (u-u^*)_t + nairu_t$ $(u-u^*)_t \sim AR(2)$ $nairu_t = nairu_{t-1} + \delta Z^{nairu}_t$
Effect on the NAIRU of a one-percent, one-year increase in Z^{nairu}:	
The NAIRU increases by δ(%) in t and returns to baseline in t+1.	The NAIRU permanently remains δ(%) above baseline.

From the table it follows that in the modeling strategy of the GAP program the exogenous variables can only affect the NAIRU temporarily. Only if Z^{nairu}_t is modeled to include the lagged unemployment rate, can cumulative effects be derived as in the alternative strategy. Including lagged unemployment only partly solves the problem since the GAP program then regresses the unemployment rate rather than the NAIRU on the exogenous variables. We therefore applied this one-step Kalman-filter approach primarily when testing for hysteresis. Institutional and monetary policy variables were, in addition, tested for in a two-step approach: We first estimated the NAIRU applying the Kalman filter without exogenous variables (Z^{nairu}_t) – the common approach in the literature. We then used OLS to regress this NAIRU on the exogenous variables. Compared to other studies using OLS, ours has the advantage of using an estimated NAIRU rather than resorting to longer term averages of the unemployment rate like, for example, Blanchard/Wolfers (2000) or forgoing degrees of freedom like Nickell et al. (2002) who include an inflation variable in the regression to exclude cyclical movement.

5.3.2 Kalman-filter estimate of the NAIRU amd exogenous variables

In this section we quantify the effects of various exogenous variables, namely institutional variables and a proxy variable for monetary policy. The estimates are based on the two-step approach discussed above as well as a Kalman filter with exogenous variables. Subsequently we test for hysteretic effects in a Kalman-filter model with exogenous variables.

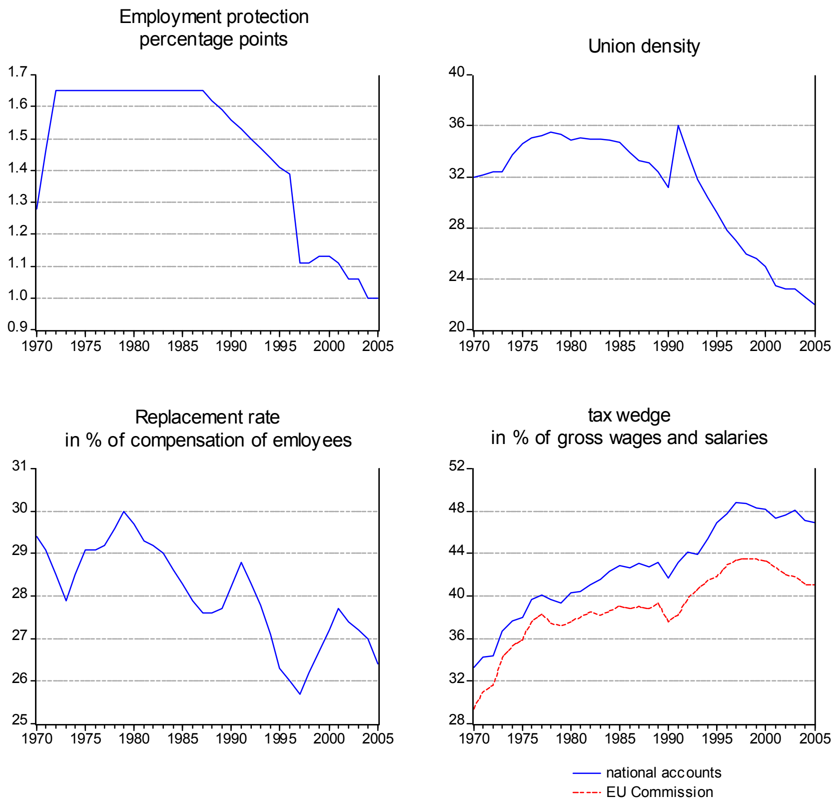
5.3.2.1 Institutional variables

We tested the NAIRU for the possible effects of four institutional variables, namely employment protection, union density, replacement rate and tax wedge. These variables feature greatly in the literature, are available as long time series and largely reflect Germany's recent labor market reforms. Labor market deregulation manifested in changes in employment protection and regulation concerning fixed-term contracts is captured by the variable employment protection. One-person businesses (Ich-AGs), mini-jobs and the exit from collective bargaing are reflected in the variable union density. The variable replacement rate is affected by reforms that increase the incentive to work (from Job-Aqtiv to Hartz IV). The tax wedge is currently the focus of several reforms or reform proposals (for example in the coalition agreement 2005) and was strongly affected by German unification.

We included the variables in the NAIRU estimation individually and together using both the Kalman filter with exogenous variables and OLS. With the exception of the tax wedge, the outcomes of the estimations with institutional variables were not robust. The other variables were, for example, significant in the Kalman-filter model but not in OLS estimates of various specifications (employment protection), or they were significant only when the equation was specified in one particular manner or they had an implausible sign, as in the case of wage replacement rates.

Union density has high contemporaneous explanatory power in only one specific Kalman-filter specification (NAIRU modeled as a local linear trend) and only if an impulse or step dummy is included for the year 1991. In the OLS estimate in first differences, union density is insignificant in various different specifications which correct for German unification. Were one to accept the Kalman-filter estimate nonetheless, it would follow that the NAIRU increased by 0.5 percentage points due to union density in the seventies and fell by 3 percentage points since the early eighties as a result of declining union density (Chart 5.6). The OECD (2006, chap. 7) incidentally does not find a robust negative effect for this variable because most specifications do not produce significant results.

Chart 5.6
Labor market variables for Germany (1970-2005)



Sources: Destatis, EU Commission, Martinez-Monguay (2000), Nickell et al. (2001), OECD (2006, Bassanini/Duval-Datenbank), Visser (2006), authors' calculations.

Replacements rates have a negative sign in both the Kalman-filter and the OLS-estimates. This is theoretically and empirically implausible.[62] The significance of this variable in the OLS regression furthermore depends largely on the specific deterministic structure, e.g. whether a trend is used or an impulse or step dummy variable.

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[62] Empirical studies usually find that replacement rates are either insignificant or positively related to unemployment; cf. OECD (2006: 61) for a literature survey as well as Bassanini/Duval (2006, Table A1.1).

The tax wedge (based on national accounts data) was found to be significant in both the Kalman-filter estimate and the OLS estimate. Due to possible endogeneity, it was introduced with a lag. The Kalman filter finds a coefficient of 0.18 for the first lag, OLS a comparable one of 0.15. The latter changes only minimally when a different deterministic structure is used. Our results are at the lower end of the range of 0 to 0.6 found in the literature (Planas/Röger/Rossi 2006). The coefficient of 0.18 implies that 2.5 percentage points of the increase in the NAIRU between 1973 and 1998 were the result of a widening tax wedge; after 1998 the tax wedge led to a small reduction in the NAIRU of 0.3 percentage points. In contrast, the tax wedge as calculated in line with the EU Commission was insignificant.

Employment protection was insignificant in both the OLS and Kalman-filter estimates (NAIRU modeled as a random walk).[63]

When all four variables are included simultaneously, which is the more sensible empirical approach, the results are once again highly unstable. The Kalman-filter estimate merely finds union density and an impulse dummy variable for 1991 to be significant. If the NAIRU is modeled as a random walk, then employment protection is significant (with the wrong sign) as are the tax wedge (coefficient: 0.23) and the impulse dummy variable for 1991. The OLS results greatly depend on the deterministic structure. If one includes impulse dummies for 1991 and 1992, none of the institutional variables are significant. Inclusion of an impulse dummy for only 1983 leads three variables to be significant: employment protection (again with the wrong sign), union density with a coefficient of 0.2 and the tax wedge with a coefficient of 0.1. The problem of choosing between the different models is aggravated by the fact that an impulse dummy can more than double the adjusted R^2.

All in all, none of the institutional variables except the tax wedge proved to be highly significant in explaining the German NAIRU. In part this may be due to statistical problems arising from German unification. Furthermore, since the late seventies the examined variables – again with the exception of the tax wedge, should have lowered the German NAIRU if they affected it at all (chart 5.6). The limited explanatory power of institutional variables for unemployment is also pointed out in the literature (Blanchard/Katz 1997: 68, Machin/ Manning 1999: 3107). Blanchard/Wolfers (2000: 2), for example, argue that

> "...many of these institutions were already present when unemployment was low (and similar across countries), and, while many became less employment-friendly in the 1970s, the movement since then has been mostly in the opposite direction. Thus, while labour market institutions can potentially explain cross country differences today, they do not appear able to explain the general evolution of unemployment over time."

Blanchard and Wolfers 2000: 2

It is therefore hardly surprising hat a recent OECD study cannot explain the unemployment rate with developments in labor market institutions (OECD 2006: 214 and Bassanini/Duval 2006: 63).

[63] Similar results are found in Bassanini/Duval (2006) and OECD (2006b: 96).

5.3.2.2 Monetary policy variables

In line with part of the literature monetary policy was also analyzed as a factor affecting long-term unemployment.[64] There is no doubt that the restrictive monetary policy in the late seventies as well as the early eighties and nineties played a big role in the increase of the unemployment rate.[65] Whether this effect was only of a short-term nature – thus not affecting the NAIRU – is however quite controversial.[66] If monetary policy gives rise to hysteresis in labor markets, for example, and thereby changes the effective labor supply, its short-term effects may extend to the long run. Our hypothesis is that in addition to exogenous shocks and institutional change, macro policy and hysteresis contributed to the increase in unemployment since the mid-seventies. Therefore, we introduced an exogenous variable as a proxy for monetary policy. We tested four versions of this monetary policy variable:

- The overnight rate which is greatly affected by the central bank and according to many studies a good indicator for the monetary policy stance.
- The real overnight rate which is also affected by the central bank in the short run due to lagged changes in inflation.
- A monetary condition index (MCI) including the real short-term interest rate and the real exchange rate. The MCI is the weighted sum of the difference between the actual real interest rate and a real interest rate of 2%[67] and the relative deviation of the real exchange rate from the exchange rate in the fourth quarter of 2003. The weights for the MCI correspond to those used by the Bundesbank; the weight of the real interest rate relative to the real exchange rate is 3:1 (Deutsche Bundesbank 1999: 58).
- The deviation between the real short-term interest rate and real GDP is an indicator for the monetary policy stance (Filc 2002).

We checked the suitability of these variables as monetary policy indicators using Granger causality tests (Blinder/Bernanke 1992) and applying them to the standardized unemployment rate. In order to be able to determine the lead of the monetary policy variables, we used quarterly data rather than annual data as in the rest of the paper. The tests were performed for the period from 1978 to 2005 because the ILO unemployment rate is available on a quarterly basis only from 1978 onwards.

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[64] Cf. Ball and Mankiw (2002), Ball (1999), Blanchard and Katz (1997) as well as Fitoussi, Jestaz, Phelps, and Zoega (2000), who relate the marked increase in unemployment and the fact that it remained high to the restrictive stance of monetary policy in Europe.

[65] Modern monetary policy is based on the notion that money is not neutral in the short term. Nominal rigidities give rise to short-term non-neutrality; cf. Clarida, Galí, and Gertler (1999), McCallum (2001), Mankiw (1985), Akerlof, Dickens, and Perry (2000). In the short term, monetary policy is thought to have an effect on real interest rates, aggregate demand and inflation. Unemployment is the key variable through which monetary policy affects inflation (Layard, Nickell, and Jackman 1991: 13).

[66] Contrary to the mainstream view, the view that monetary policy has long-term real effects is put forth, for example, by Cross (1995) and Ball (1999).

[67] Often MCIs use the difference between the real interest rate and the interest rate of a base period. This is of no consequence for the calculation.

The unit root test (augmented Dickey Fuller test) shows that the unemployment rate is an I(1) variable. The same applies to the nominal overnight rate whereas the MCI, the real overnight rate and the real interest rate-growth deviation are stationary variables (I(0)). Following Blinder/Bernanke (1992) we applied the Granger causality tests first in levels and then in the case of the stationary variables again with the nonstationary unemployment rate in first differences. This way the variables have the same order of integration in the Granger causality test. The appropriate lag length for the Granger causality test was determined in a VAR according to the usual criteria.

In case of the real interest rate, the causality goes from unemployment to the real interest rate which implies that it cannot be used as a monetary policy indicator. Repeating the test with unemployment in first differences yields causality in both directions. The same picture emerges for the MCI. The nominal overnight rate was tested for only in levels as this time series is nonstationary like the unemployment rate. Once again, causality runs in both directions. The VAR with two lags – indicated by all criteria – has autocorrelation (lag 1). The only variable to perform well was the deviation between the real short-term interest rate and the rate of economic growth. The causality is unambiguous and runs in the right direction for a monetary policy indicator, i.e. from the monetary policy indicator to the real economy variable. This is true both for unemployment in levels and in first differences. In both cases we used lag length 4 for the Granger causality test. In the case of first differences most criteria pointed to lag 1, but the VAR exhibited autocorrelation until 4 lags were used, the number indicated by the LR criterion.[68] This monetary policy indicator is also superior to the other three for economic reasons (Filc 2002). It has the advantage of being unaffected by fundamental changes in the real interest rate, in particular as a result of a change in the potential growth rate. It is superior to the nominal overnight rate because the effects of monetary policy are not independent of inflation: an increase in interest rates that lags behind the increase in inflation is likely to have an expansionary effect just as a declining nominal rate during a period of disinflation may act restrictively.[69] Compared to the MCI, the real interest rate-growth deviation does, however, have the drawback that it ignores the exchange rate as an important monetary condition.

The MCI was not found to be significant in any specification, be it as exogenous variable in the Kalman filter or in the two-step OLS estimate for both NAIRUs (as a random walk of second and first order).

In contrast, the real interest rate-growth deviation always proved to be significant, the coefficient always being of the same magnitude, no matter how the estimated equation was specified. We analysed the effect of this variable in two different Kalman-filter models and one OLS regression using our Kalman-filter NAIRU. In each case the variable was significant and robust, albeit with a relatively low coefficient of 0.1. Previous estimates using the

[68] In view of the lag exclusion test we tested for autocorrelation in a VAR with lag 1 and lag 4.

[69] This aspect is highlighted by the Taylor rule, for example (Taylor 1999; Ball 1999).

real long-term interest rate concluded that an increase by 1 percentage point permenantly raises the unemployment rate by about 0.3 percentage points.[70]

In the first Kalman-filter specification the NAIRU is a second order random walk (local linear trend). The coefficient of the first lag of the monetary policy indicator is 0.07. The second difference of import and export prices is not significant. The coefficient remains 0.07 after the corresponding adjustment of the Phillips curve. The variance of the first error term of the NAIRU equation (ε^{nairu}) is estimated to be zero. A comparison between an estimation in which this variance is constrained to zero and one in which the other error term (ε^{trend}) is constrained to zero shows that the log likelihood of the latter is greater (the other coefficients are unchanged). Therefore we estimated a second model in which the NAIRU is specified as a random walk without drift. The coefficient is robust at 0.09 irrespective of how unification is dealt with. The second difference of import and export prices is once again not significant. The results are presented in the table below.

Table 5.3
Kalman-filter estimate of the NAIRU (random walk without drift) with the real interest rate-growth deviation as exogenous variable

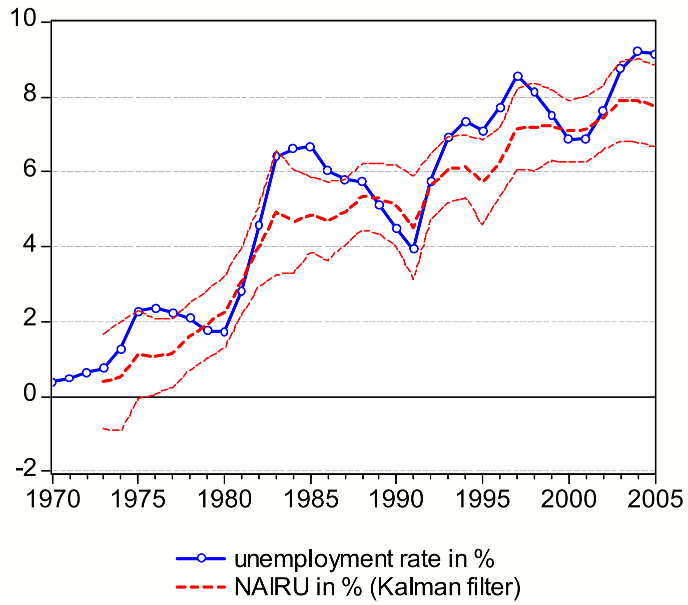
Maximum likelihood equation and statistics estimation periods: 1973-2005 (33 observations)			
Variables	coefficients	s.e.	t-stat
State equations			
ar_1	1,419	0.125	11,399
ar_2	-0.820	0.100	-8,236
constant	0.002	0.002	1,240
Var(ε^{nairu})	2.301E-05		
Var(ε^{gap})	7.729E-06		
rgdp(-1)/100	0.091	0.047	1,921
Phillips curve			
(u-u*)	-0.647	0.327	-1,977
$d^2prodh_{(-1)}$	0.788	0.234	3,363
R^2	0.326		
-2*log-likelihood	- 425.180		
Var($\varepsilon^{phillips}$)	1440E-04		
residual tests			
State equations			
Ljung-Box Q(4) statistic	7,071	prob:	13.2%
Jarque-Bera statistic	13,552	prob:	0.1%
Phillips curve			
Ljung-Box Q(4) statistic	5,338	prob:	25.4%
Jarque-Bera statistic	2,017	prob:	36.5%

70 Cf. Blanchard and Wolfers (2000), Fitoussi et al. (2000), Nickell et al. (2002) and IMF (2003).

The coefficients can be interpreted as follows: A decline in the unemployment gap by one percentage point for one year (three years) results in a permanent reduction in wage inflation by 0.6 percentage points (about 1.9 percentage points). A permanent increase in productivity growth by one percentage point permanently lowers wage inflation by 0.6 percentage points. The AR coefficients of the unemployment gap imply an average cycle length of nine years (9.4). The unemployment gap (the cycle) was estimated with a constant of 0.2 percentage points which implies a deflationary pressure of 0.1% generated by the unemployment gap. (As before, the constant is insignificant but improves the quality of the estimate.)

The effect of the real interest rate-growth deviation amounts to 0.09. Therefore an increase in the real interest rate-growth deviation by one percentage point increases the NAIRU by nearly 0.1 percentage points. According to this estimate, monetary policy caused the NAIRU to increase by 1.1 and 0.5 percentage points in the restrictive periods 1977-82 and 1989-94, respectively.

Chart 5.7
NAIRU and unemployment gap in the Kalman-filter estimate with the implicit NAIRU as a random walk without drift and the monetary policy indicator as exogenous variable



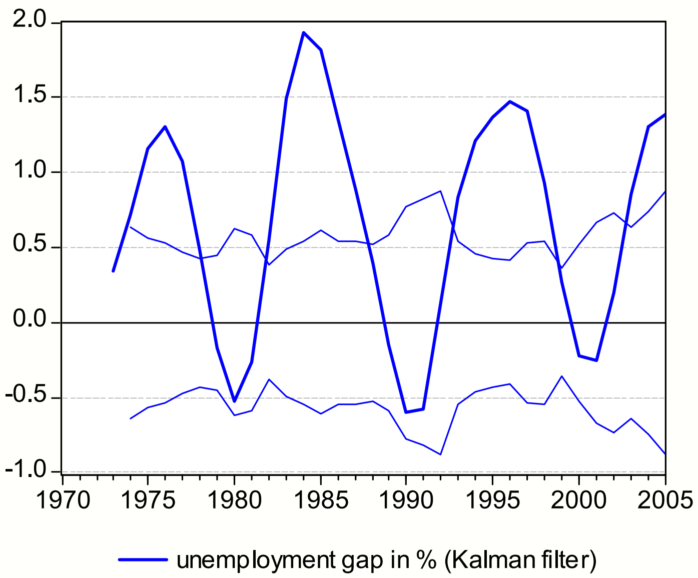
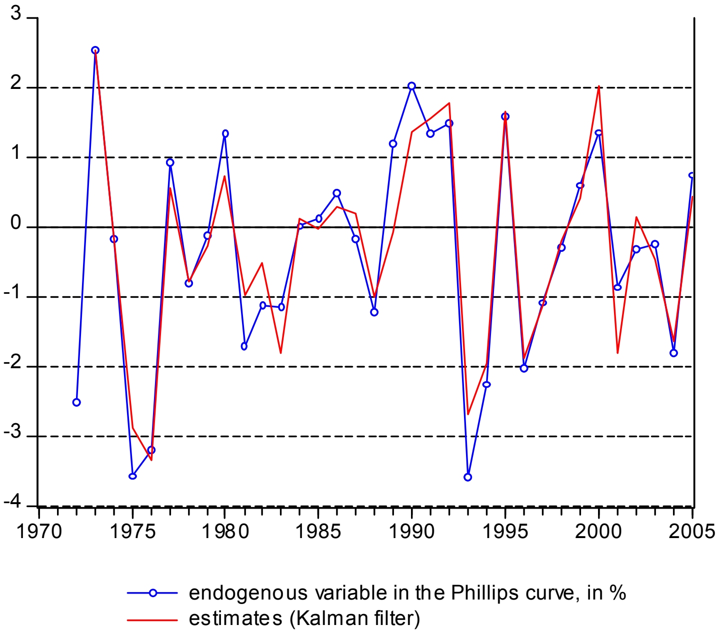


Chart 5.8
Phillips curve estimates of the Kalman-filter estimation with the implicit NAIRU as a random walk without drift and the monetary policy indicator as exogenous variable



As a third model specification, we entered the real interest rate-growth deviation as exogenous variable in an OLS regression of the NAIRU obtained from a Kalman-filter model without exogenous variables (random walk without drift). With this approach we avoid the problem discussed above, namely that the Kalman-filter program may actually use the exogenous variable to explain the unemployment rate rather than the NAIRU. First, we therefore estimate the NAIRU modeled as a random walk without drift using a Kalman filter without exogenous variables. The results are shown in the table and the chart below.

Table 5.4
Kalman-filter estimate without exogenous variables, NAIRU modeled as random walk without drift

Results of the Kalman-filter estimate for Germany
Maximum likelihood estimate and statistics
estimation period: 1973-2005 (33 observations)

Variables	Coefficients	s.e.	t-stat
State equations			
ar_1	1,332	0.156	8.547
ar_2	-0.775	0.115	-6.748
constant	0.002	0.002	1.285
$Var(\varepsilon^{nairu})$	2.476E-05		
$Var(\varepsilon^{gap})$	1.153E-05		
Phillips curve			
$(u-u^*)$	-0.767	0.340	-2.254
$d^2prodh_{(-1)}$	0.777	0.225	3.454
R^2	0.367		
-2*log-likelihood	-422		
$Var(\varepsilon^{phillips})$	1.303E-04		
Residual tests			
Phillips curve			
Ljung-Box Q(4)-stat:	5.160	prob:	27.1%
Jarque-bera-stat:	6.866	prob:	3.2%
Phillips curve			
Ljung-Box Q(4)-stat:	4.673	prob:	32.3%
Jarque-Bera-stat:	1.824	prob:	40.2%

Chart 5.9
NAIRU and unemployment gap in the Kalman-filter estimation without exogenous variables (NAIRU specified as a random walk without drift)

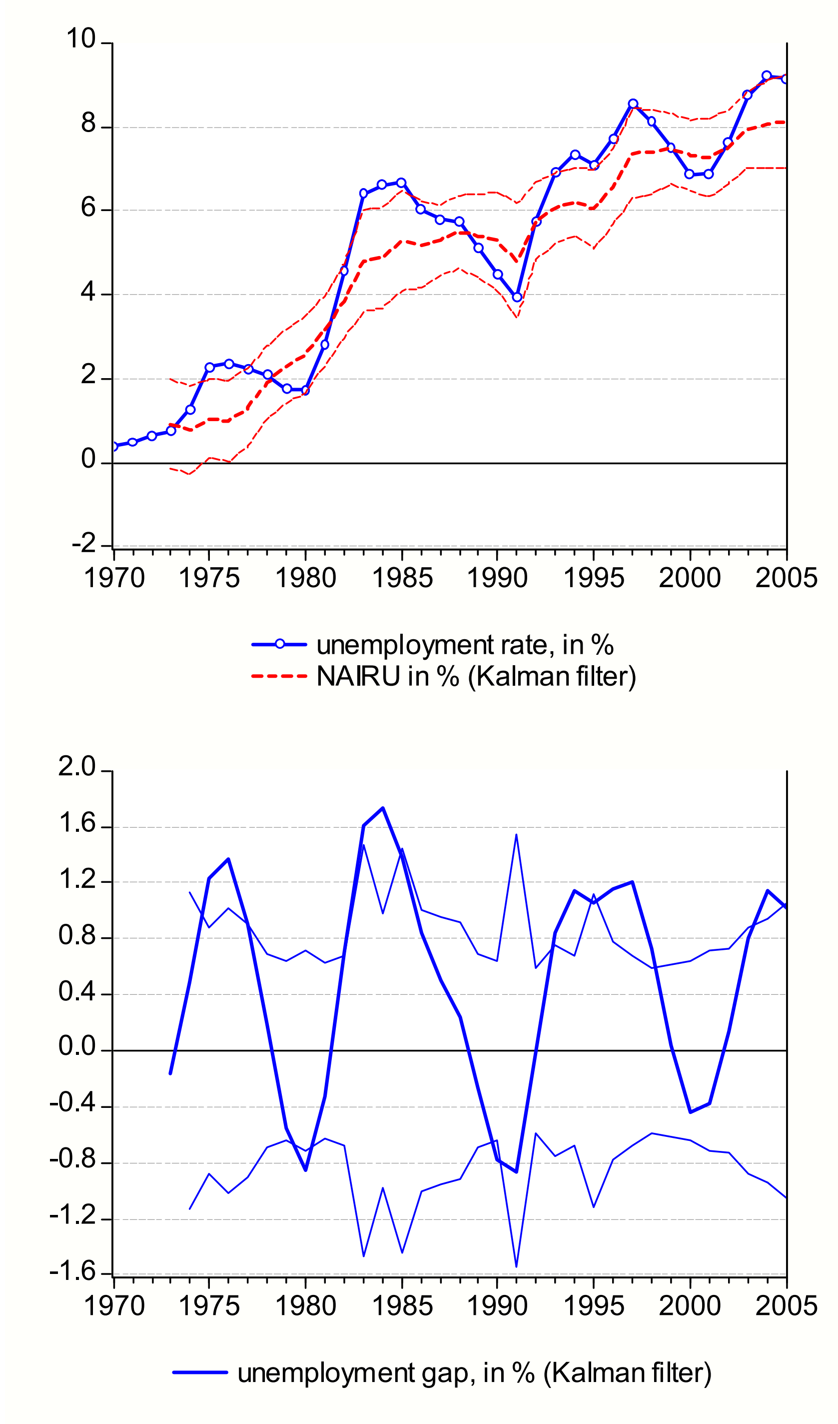


Chart 5.10
Phillips curve estimates of the Kalman-filter estimation without exogenous variables (NAIRU specified as a random walk without drift)

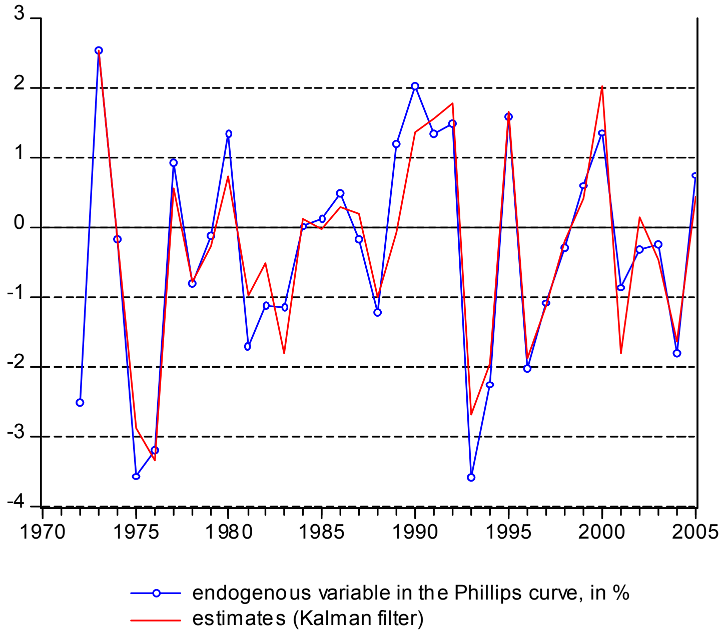
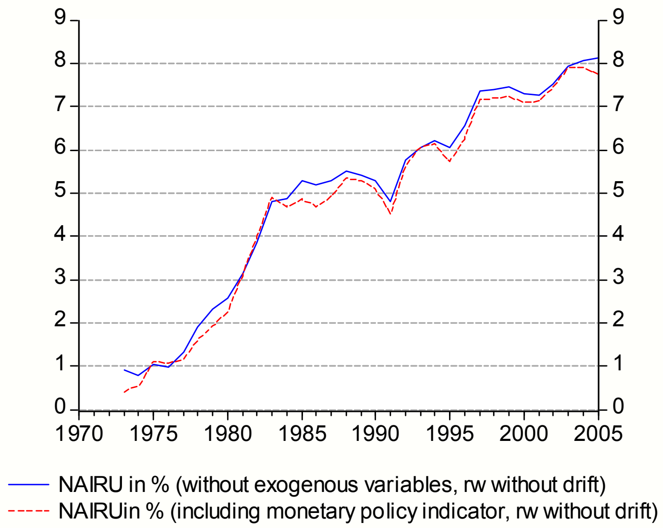


Chart 5.11
NAIRUs in the first and second specifications



Next we estimated an OLS equation. The estimated NAIRU is an I(1) variable whereas the monetary policy indicator is a stationary variable. It is therefore necessary to either include sufficient lags of the NAIRU when estimating in levels or to enter the NAIRU in first differences.

In levels the following equation was found:

$nairu_t = 0.42 + 0.94*nairu_{t-1} + 0.06*rgdp_{(-1)} +0.89*i92 + 0.64*i97;$
DW=1,50 and adj. R^2=0.986.

Tests for a unit root in the lagged NAIRU and for no long-term effect of the monetary policy indicator (0.06/1-0.94:=0) were both rejected. The long-term effect of a one-percentage point increase in the interest rate-growth deviation is thus estimated at -0.1 percentage point. In first differences, the model produced the following results:

$d(nairu_t) = 0.28 + 0.06*rgdp_{(-1)} + 0.90*i92 – 0.22*s90$; DW= 1.43 and adj. R^2 = 0.279.

The coefficient of the indicator is significant implying a long-term effect different from zero. A simulation in which the monetary policy indicator was set at zero (implying a neutral monetary policy stance) shows that monetary policy reduced the NAIRU by 0.8 percentage points in the seventies. Between 1980 and 1983 this effect was completely reversed. In the early nineties the NAIRU increased by 0.4 percentage points due monetary policy and an additional 0.5 percentage points until the end of the observation period.

One reason for the relatively low coefficient of -0.1 may be the relative smoothness of our Kalman-filter estimate of the NAIRU. As a check, we therefore estimated another OLS regression in which we determine the long-term monetary policy effect on the unemployment rate directly, rather than the effect on the NAIRU. Conceptually the two are obviously identical. The stationary monetary policy indicator enters the equation in levels, the nonstationary unemployment rate in first differences. The long-term coefficient is here estimated as 0.22. According to this estimate, a temporary increase in the real interest rate-growth deviation by one percentage point for one year results in a long-term increase in the unemployment rate by 0.2 percentage points. The effect is thus twice as high as the one derived from an equation including our estimated NAIRU. The results are robust to different specifications of the deterministic structure. Our preferred specification was derived using the general-to-specific approach and includes a trend that can be interpreted to proxy omitted variables. It exhibits no econometric problems.

5.3.3 NAIRU and hysteresis

The term hysteresis stems from physics and decribes a situation in which equilibria are path-dependent. This term is not always strictly distinguished from the term persistency which entails a return to the original equilibrium given sufficient time. In the present context, we do not feel that is is important to make this distinction for two reasons: Firstly, it is primarily the medium-term NAIRU that is policy-relevant. Secondly, in a world with uncertainty it may be impossible to distinguish between hysteresis and persistency because effects that would only be persistent in a world with complete information may affect the equilibrium position in a world with uncertainty (Katzner 1993: 343f.).

Hysteresis can have different causes[71] but the key factor seems to be that the number of long-term unemployed persons increases and that these influence labor market developments and wages, in particular, less than do the temporarily unemployed. There are several reasons why the long-term unemployed may have a hard time finding a job:

- The human capital of the unemployed tends to diminish over time. If the productivity of the long-term unemployed falls below their reservation wage or wages are set by insiders, the long-term unemployed will remain unemployed (Blanchard and Summers 1991 and Pissarides 1992).
- Testing of potential employees is costly. Therefore employers rank potential employees according to the frequency and duration of unemployment spells and favor those with less occurrences of unemployment (Lockwood 1991 and Blanchard and Diamond 1994).
- Unemployed persons lose contact to those employed, inter alia because they lack sufficient financial resources to participate in certain social activities or because they feel stigmatised. As a consequence they do not even find out about some job offers and are not considered for some jobs available. Machin and Manning (1999: 3120) found that about one third of all jobs in the UK are filled with friends and relatives of those already employed in the firm. This is a cost effective way of hiring since it is unlikely that an employee will put forth someone unqualified to do the job.
- A long period of high unemployment can raise the social acceptance of unemployment which could increase the reservation wage of the unemployed (Lindbeck 1995).
- Rising long-term unemployment increases the political pressure to implement public job creation schemes which in turn may increase unemployment by reducing the negative aspects of unemployment (Blanchard and Katz 1997: 68-69); on the other hand, they tend to reduce the Nairu by preserving the human capital of the persons involved.

If, for the reasons cited above, the long-term unemployed are no competition for those holding jobs, they do not exert downward pressure on wages.[72]

A further mechanism that may cause hysteresis is an adjustment of the capital stock as mentioned in chapter 2.

Numerous studies have found empirical evidence for hysteresis (Logeay/Tober 2006; Røed 1997). Our approach is similar to that used by Salemi (1999) and Jaeger/Parkinson (1994) and superior to unit root test (Léon-Ledesma 2002; Léon-Ledesma/McAdam 2004), cointegration (Johansen 1995), lagged unemployment in wage-price systems (Layard, Nickell, and Jackman 1991) and Markov switching (Léon-Ledesma/McAdam 2004). The popular unit

[71] A survey on hysteresis is found in Røed (1997).

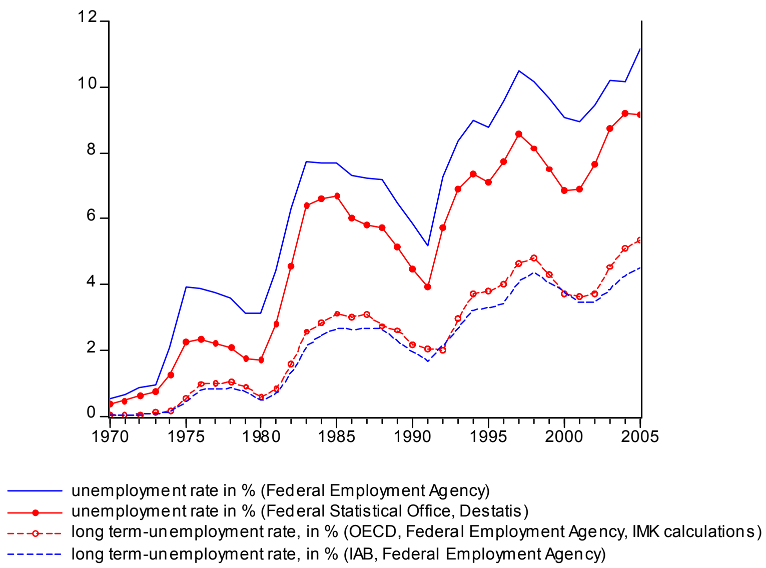
[72] Numerous studies on the UK find empirical evidence that only short-term unemployed not, however, long-term unemployed individuals have an influence on the wage bargaining process; cf. Machin and Manning (1999) and the references cited therein.

root tests are especially dubious because they require the assumption of a certain invariance of the institutional structure. If, however, the unit root is the result of structural change, then the unemployment rate is integrated of order 1, without this in any way being evidence of hysteresis because in this case the unemployment rate follows the NAIRU not vice versa. State-space modeling is superior to the other methods because unlike unit root tests and Markov switching, it can accommodate ongoing structural change, and unlike cointegration and panel estimations, it does not require full specification of the determinants of the NAIRU.

The time series for long-term unemployment was constructed from two sources. For the period 1983 to 2004, we used OECD data which corresponds more closely to the standardized unemployment rate than does the long-term unemployment rate provided by the German Federal Employment Agency. The missing years were estimated using data from the Federal Employment Agency and the IAB.

German unification may have played an important role in economic and statistical terms. We therefore tested for several different specifications to account for German unification. Immediately after unification, East-German employees probably had relatively low qualifications, given the requirements of West-German firms. They therefore exerted only limited pressure on wages. Coupled with the steep increase in unemployment resulting from the breakdown of East-German industries this should mean that the NAIRU increased. However, as a result of labor market policies the unemployment rate did not rise abruptly but rather over a period of several years resulting in a phase shift between the number of long-term unemployed and the number of unemployed.

Chart 5.12
Germany's unemployment rate according to different definitions

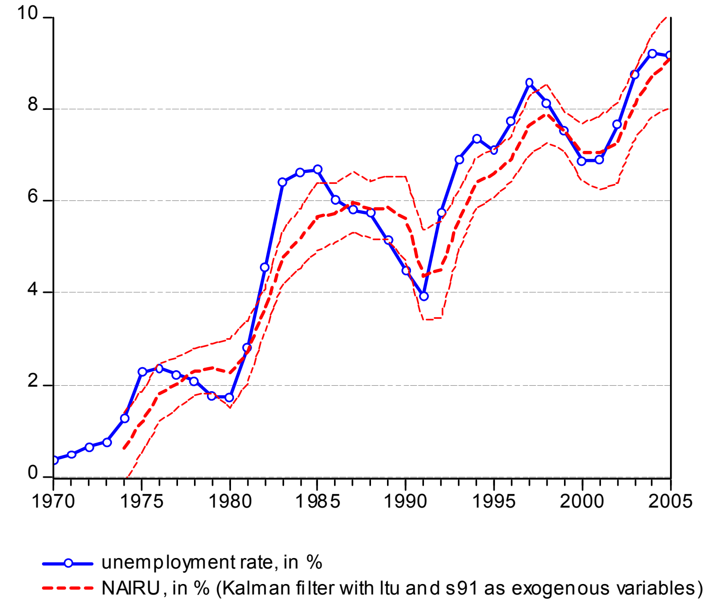


The best specifications included a step or impulse dummy variable for 1991. In both estimations, the coefficient of the rate of long-term unemployment is 1. Below we present the estimate including the step dummy variable which is the more sensible approach to modeling unification from an economic point of view.

Table 5.5
Kalman-filter estimate of the NAIRU using the rate of long-term unemployment and a step dummy for 1991 as exogenous variables

Maximum likelihood equation and statistics estimation periods: 1973-2005 (33 observations)			
Variables	coefficients	s.e.	t-stat
State equations			
ar_1	1.145	0.128	9.860
ar_2	-0.616	0.124	-5.289
constant	0.002	0.002	1.145
$Var(\varepsilon^{nairu})$	0.000E+00		
$Var(\varepsilon^{trend})$	5.744E-08		
$Var(\varepsilon^{gap})$	1.406E-05		
ltu	0.955	0.232	41.236
s91	-0.012	0.004	-33.438
Phillips curve			
$(u-u^*)$	-0.889	0.297	-2.996
$d^2prodh_{(-1)}$	0.577	0.215	2.685
d^2pex	0.471	0.179	2.633
d^2pim	-0.157	0.070	-2.228
R^2	0.536		
-2*log-likelihood	-439.768		
$Var(\varepsilon^{phillips})$	1.136E-04		
residual tests			
State equations			
Ljung-Box Q(4) statistic	0.812	prob:	93.7%
Jarque-Bera statistic	2.605	prob:	27.2%
Phillips curve			
Ljung-Box Q(4) statistic	5.587	prob:	23.2%
Jarque-Bera statistic	2.580	prob:	27.5%

Chart 5.13
NAIRU and unemployment gap with the long term-unemployment rate and a step dummy variable s91 as exogenous variables



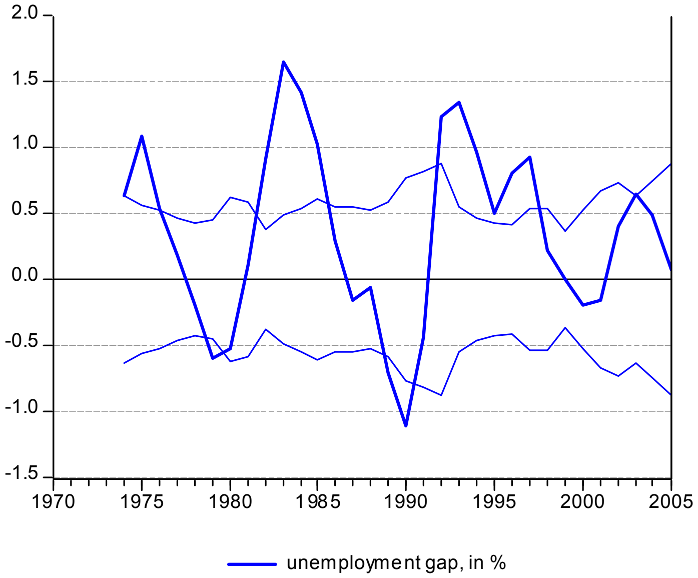
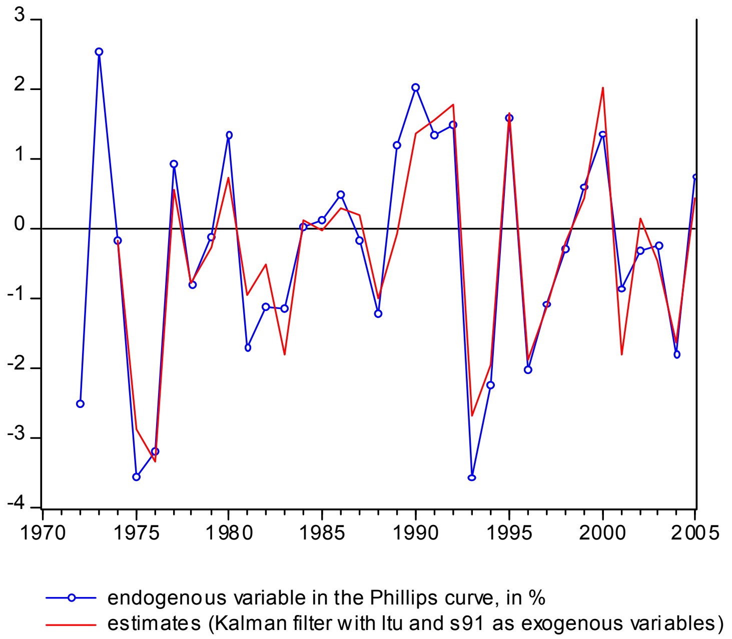


Chart 5.14
Estimates of the endogenous variable in the Phillips curve of the Kalman-filter estimation with the rate of long-term unemployment (ltu) and a step dummy (s91) as exogenous variables



The interpretation of the coefficients is analogous to that of the estimate without exogenous variables. The differences in the Phillips curves are minimal. A decline in the unemployment gap by one percentage point for one year (three years) causes a permanent lowering of wage inflation by about 0.9 percentage points (2.7 percentage points). A permanent increase in productivity growth by one percentage point permanently raises wage inflation by 0.6 percentage points, the increase in unit labor costs being permanently reduced by 0.4 percentage points. The data consequently show a trend of redistribution towards profits. A one-percentage point higher increase in export prices raises wage inflation by 0.5 percentage points, a one-percentage point higher increase in import prices lowers wage inflation by 0.2 percentage points.

The AR coefficients imply a cycle length of 8.3 years which is slightly shorter than in our other NAIRU estimates. The unemployment gap is again estimated with a constant of 0.2 percentage points implying deflationary pressure of 0.1%. (As in the other estimates the coefficient is not significant but improves the quality of the equation.) The variances of the error terms are unrestricted and the variances of the NAIRU error term is estimated at zero implying a second-order random walk.

Our coefficient is approximately twice as large as that in Jaeger/Parkinson (1994), who apply a similar method but use lagged unemployment and find coefficients of 0.22 and 0.18

for the UK and West Germany, respectively. It does, however, correspond to the coefficient in Jaeger/Parkinson (1990). Translated into the effect of lagged unemployment, which is often used to measure hysteresis effects, the coefficient is 0.4, given that the share of long-term unemployment in total unemployment is roughly 50%.

The fact that the rate of long-term unemployment proved to be significant in the estimation of the NAIRU indicates the presence of hysteresis. Hysteresis, in turn, implies that variables will affect the NAIRU, if they cause unemployment to stay high or low for a prolonged period. It follows that a restrictive monetary policy stance maintained over a longer period of time will generate hysteresis, thereby affecting the real economy not only in the short run but also in the long run.

5.3.4 Projecting the NAIRU

Projecting potential output requires that the individual components of potential output are projected as well. To forecast the NAIRU, we used three different approaches, namely the method employed by the EU Commission, the Kalman filter and an OLS equation with projected values for the exogenous variables tax wedge and monetary policy indicator.

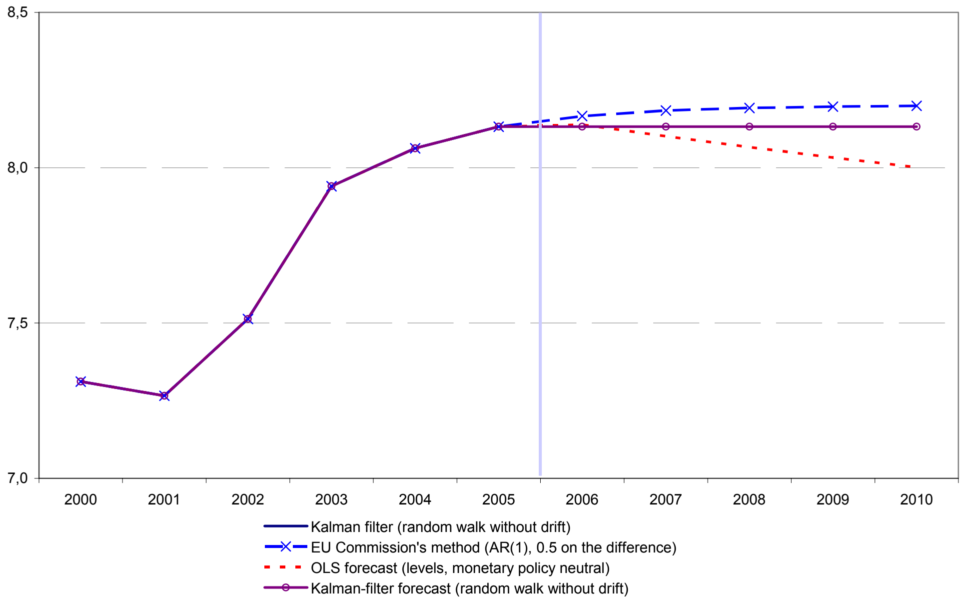
The EU Commission uses half of the previous year's rate of change to project the NAIRU. Compared to filtering methods the advantage is that data points estimated for the observation period, especially those for the endpoints from 2000 to 2005, do not change as projected data points are added. It does, however, have the drawback that it merely projects the underlying structure: The forecast values of the NAIRU follow an attenuated version of the past trend.

The second method calculates forecast values of the NAIRU with a Kalman filter. To do this, one requires forecast values of the exogenous variables in the Phillips curve (hourly wages, hourly productivity and, as the case may be, import and export prices) as well as for the exogenous variables that affect the NAIRU (in our case, the long-term unemployment rate or the monetary policy indicator). The obvious drawback is that one has to have an idea of how the economy will evolve over the next years. On the other hand, it has the advantage of being able to include foreseeable structural changes pertaining to the exogenous variables in the Phillips curve or in the NAIRU equation. Like all filtering methods, the Kalman filter also has an endpoint problem that occurs when new data points are added and the filtered time series is recalculated. It should, furthermore, be noted that the GAP program does not produce true Kalman-filter forecasts but rather univariate forecasts. This means essentially that the NAIRU is projected as a random walk or a local linear trend. In the first case, the NAIRU remains constant at 8%, in the second case it continues to increase and reaches 9% in 2010.

The third method, favored by us, is a compromise between the other two. The NAIRU is estimated as a random walk without drift until 2005 using a Kalman filter and is then regressed on exogenous variables using OLS. The NAIRU is then projected using forecasts of the exogenous variables. Both endpoint problem and mere trend extrapolation are thus avoided.

Chart 5.15 shows the projection of the NAIRU according to all three methods.

Chart 5.15
NAIRU projections



Despite the methodological differences, the NAIRU projections only range from 8% to 8.2%. It follows that the different methods of estimating the NAIRU do not greatly affect the projection of potential output. As indicated above, this does not imply that the projection of the NAIRU is particularly accurate but rather that the statistical characteristics of the NAIRU (and the unemployment gap) – which are identical in all the cases presented here – dominate the results. The fact that a univariate estimate of the NAIRU, i.e. without a Phillips curve, does not greatly differ from the multivariate one also shows that the assumed statistical characteristics of the NAIRU dominate the result.

5.3.5 Conclusion

Our analysis thus shows that the unemployment gap and the NAIRU are not independent of each other: to a certain degree the structure of unemployment hardens or loosens, thus causing the unemployment gap to close partly through an increase or decrease in the NAIRU.

An important difference between studies of unemployment is that only some take into account the specific monetary policy reactions. Layard/Nickell/Jackman (1991) and Clarida/Galí/Gertler (1998), for example, do not include the macroeconomic policy stance in the countries analysed but only the international level of interest rates. In contrast, Fitoussi et al. (2000), Ball/Mankiw (2002), Ball (1999) as well as Blanchard/Katz (1997) analyse the distinct behavior of the respective central banks and conclude that the restrictive monetary policy stance in Europe caused unemployment to increase and to remain at high levels. Whereas the productivity slowdown after the early seventies, the oil price shocks and in part also the increase in global real interest rates in the eighties affected all industrialized countries, there was a marked difference in monetary policy reaction. The Federal Reserve, for example, rapidly lowered interest rates in case of an economic downturn, thereby largely confining it.[73] As a result, higher unemployment remained a temporary phenomenon. In contrast, the monetary policy of the German Bundesbank (later the ECB) and that of most other European countries maintained a restrictive stance longer. Economic downswings were more pronounced and the slow growth was not compensated for in subsequent years so that the growth path was lower than allowed for by the production possibilities.

Monetary policy needed to be restrictive to bring down the high inflation of the seventies. Disinflation is generally achieved through an increase in unemployment. A temporary increase in unemployment was therefore also unavoidable. However, the results presented in this report support Ball's conclusion that monetary policy in Europe remained restrictive for too long:

> In some countries, such as the United States, the rise in unemployment was transitory; in others, including many European countries, the Nairu rose and has remained high ever since. I argue that the reaction of policymakers to the early-1980s recessions largely explain these differences. (...) In countries where unemployment rose permanently, it did so because policy remained tight in the face of the 1980s recessions.
>
> Ball (1999: 190)

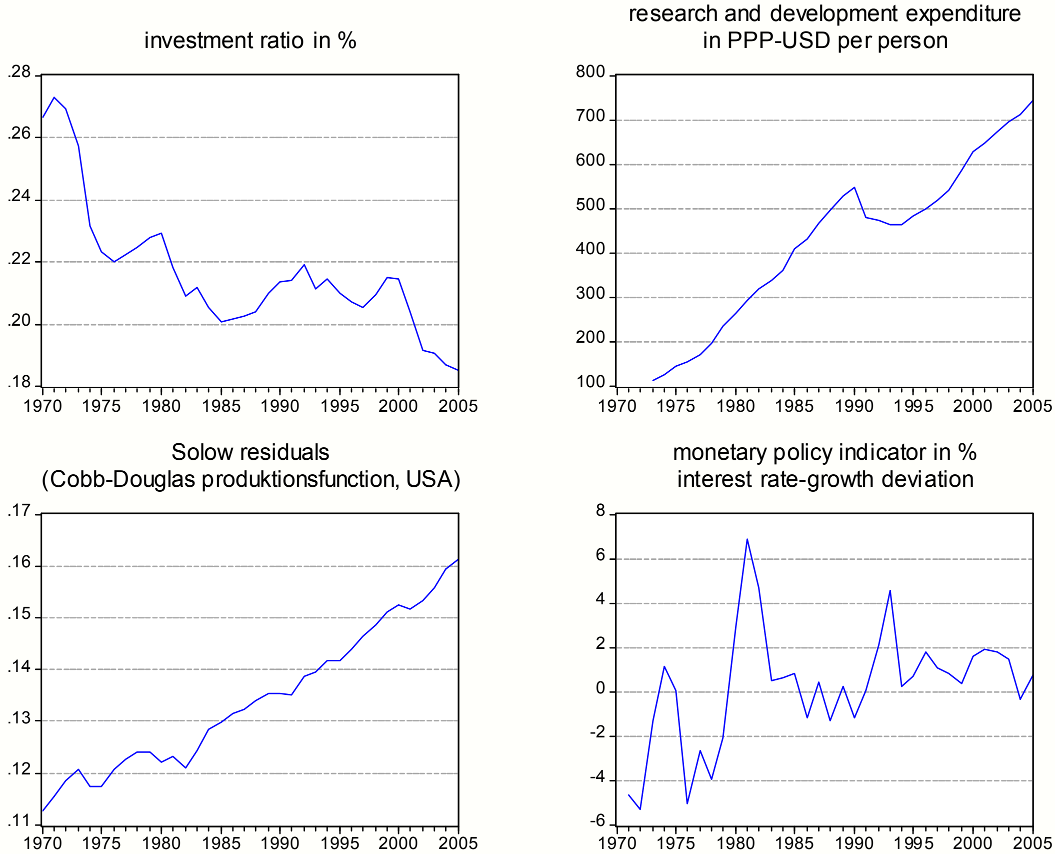
5.4 Total factor productivity

Potential total factor productivity (TFP^*) is the second key variable to be estimated to determine potential output in the production function approach. Because this variable is of key importance we do not follow the modeling strategy of the EU Commission as described by Denis et al. (2005) and Carone et al. (2006). The EU Commission determines potential total factor productivity by HP filtering. To project potential total factor productivity the EU Commission extends the Solow residuals, i.e. the TFP time series, using a sparse ARIMA model and then applies an HP filter; earlier a deterministic trend was used. In contrast, our aim was to estimate an economically meaningful equation that allows for TFP to be in part determined endogenously. This also makes it easier to model structural breaks and to take into account or simulate changes in the exogenous variables during the forecast period.

[73] The Federal Reserve has practiced active monetray policy in downswing and in face of expected overheating since the late seventies; earlier in the seventies it tended to remain passive and thus exacerbated the simultaneous rise of inflation and unemployment (cf. Beyer and Farmer 2002).

We therefore estimated TFP as being dependent on other economic variables. We examined the influence of three variables[74] that are thought to considerably affect TFP: investment ratio, per-capita expenditure on research and development[75] and U.S. total factor productivity. These variables are shown in chart 5.16.

Chart 5.16
Possible explanatory variables of total factor productivity



Sources: AMECO, Destatis, German Bundesbank, OECD, authors' calculations.

The equation presented here is representative of the differently specified equations we estimated; the elasticities correspond to the average of all estimates. Because there are only 30 data points, we estimated specific to general rather than vice versa. The estimate is in levels even though the variables are nonstationary. This is permissible because sufficient lags of each nonstationary variable are included. An increase in the investment ratio by one percentage point is estimated to increase total factor productivity by 1.1%. An increase in expenditure on research and development (per capita) by 1% raises TFP by barely 0.1%. An increase in U.S. TFP by 1% raises German TFP by 0.9%. All three effects are significant

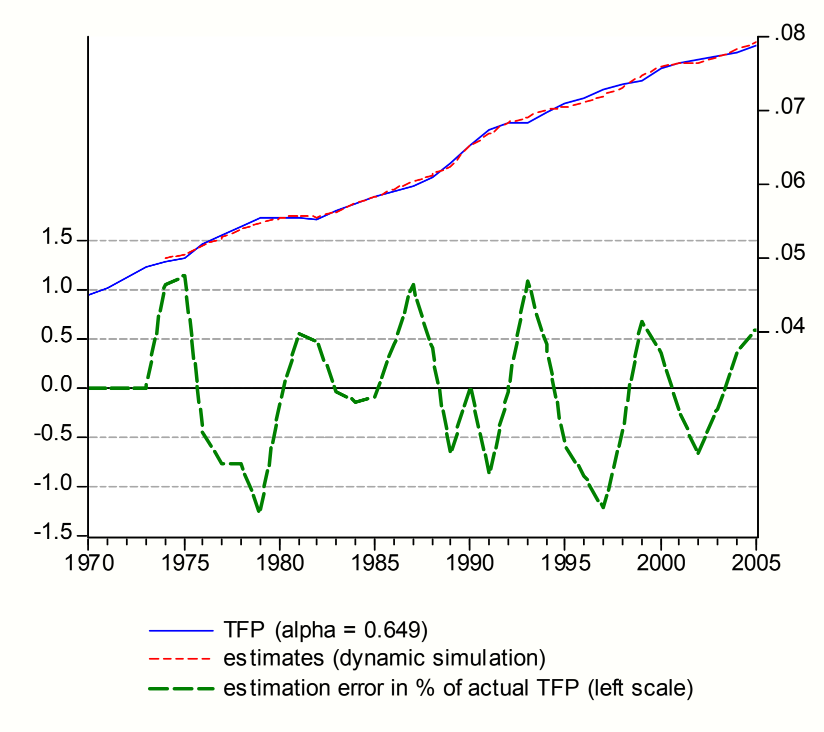
[74] Two other variables were considered at first but then rejected: capacity utilization and the ratio of working-age population to total population. These two variables were either not significant, had the wrong sign or caused the equation to be unstable.

[75] The time series ends in 2004; the value for 2005 was estimated using the previous growth rates of 4.4%.

on the 5%-level. A step dummy variable was included for 1990. There is no autocorrelation in the residuals up to order 3 and they are distributed normally. None of the other usual tests indicate any problems. The in-sample fit is very good.

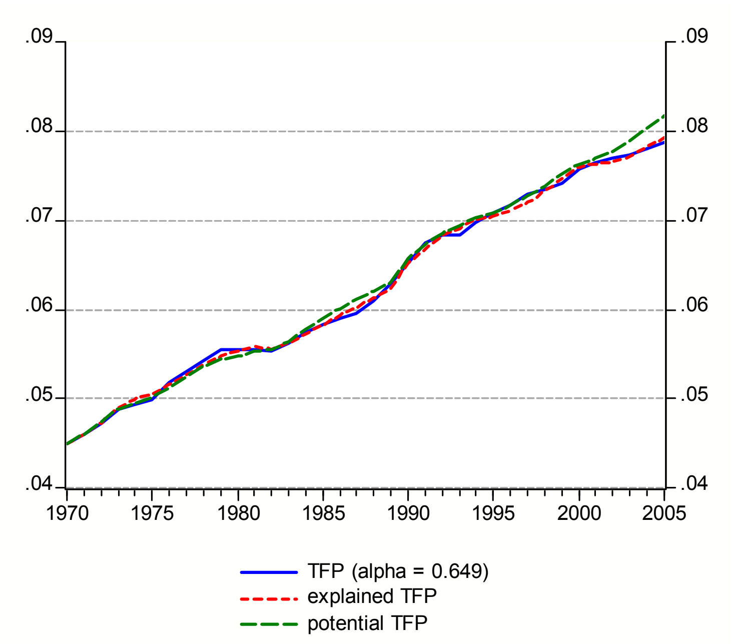
We also find monetary policy to have an effect, albeit an indirect one via the investment ratio. An OLS regression with the investment ratio in first differences as dependent variable and the monetary policy indicator as independent variable yields an elasticity of -0.1. According to this estimate, a three-year monetary restriction that keeps the real overnight rate one percentage point above the growth rate of GDP would permanently lower the investment ratio by 0.3 percentage points. Estimating the investment ratio in levels rather than in differences produces the result that the monetary policy effect is only temporary, albeit very persistent: Only after 15 years does the effect markedly diminish.

Chart 5.17
Quality of fit of the TFP equation



Potential TFP – needed to calculate potential output – is determined by plugging equilibrium values for the investment ratio and research and development expenditure into the TFP equation. We define the “equilibrium” investment ratio as the average investment ratio during the observation period (21.7%) which roughly corresponds to the recent investment ratios in the other countries of the Euro Area. The equilibrium path for research and development expenditure is generated with a broken deterministic trend. We distinguish between four periods: the seventies with an annual per-capita R&D expenditure exceeding 10%, the eighties when the growth rate was almost half as high; the unification years which saw a decline in the absolute level, and the period since 1995 with relatively low growth rates of 4 to 5%. For US TFP, we took the actual levels, because these are unaffected by developments in Germany.

Chart 5.18
Actual, explained and potential TFP[1]



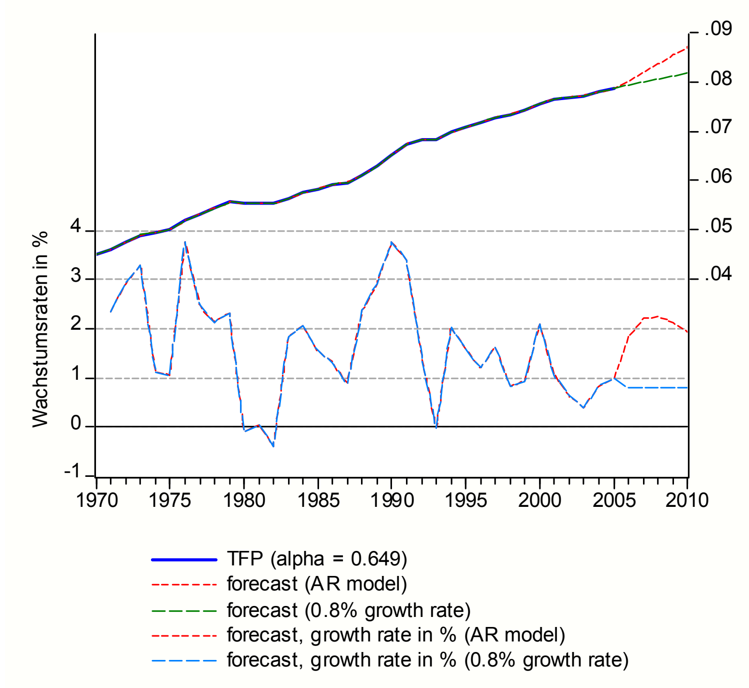
[1] Actual TFP is calculated by rearranging the production function, explained TFP is estimated using three exogenous variables and potential TFP is the estimate of TFP with the investment ratio and R&D expenditure in equilibrium.

5.4.1 Projecting potential TFP

There are different methods of forecasting potential TFP. The EU Commission uses a univariate model to estimate and forecast actual TFP and then an HP-filter to generate an estimate and forecast of potential TFP. Our approach differs in that we use the OLS regression to project potential TFP. This approach requires forecasts of the exogenous variables which may include structural breaks. If, for example, the investment ratio is expected to be 21.7%, given an adequate macroeconomic policy mix, then one can use this value for the projection of potential GDP. In contrast, if there is cogent evidence that the investment ratio will remain low in the medium term, i.e. that the trend since 2001 will not be reversed, then the potential investment ratio has to be adjusted accordingly.

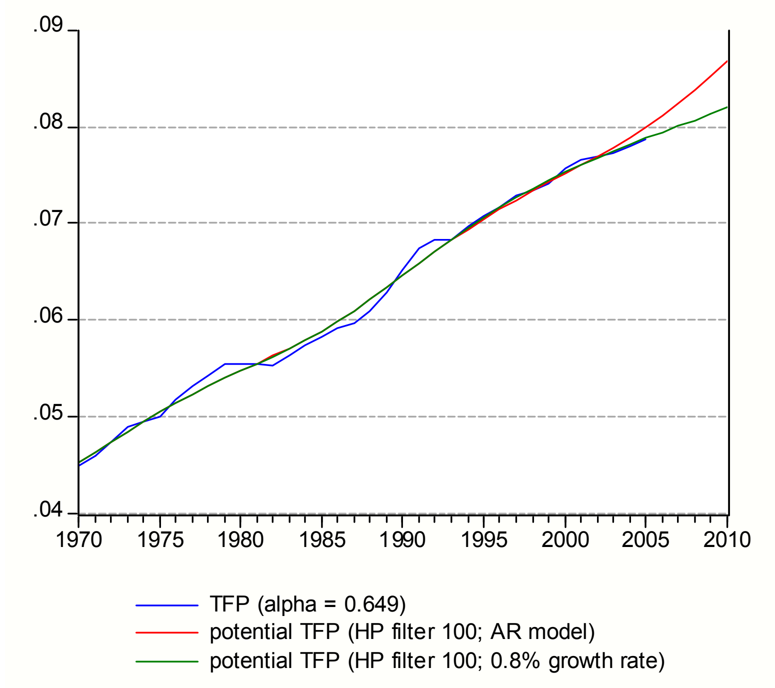
The forecast method of the EU Commission models potential TFP as an AR(2) process with a constant and a trend. The forecast values are quite optimistic and exceed the value used by the EU Commission (Carone et al. 2006). Therefore, we also include in Chart 5.19 the constant TFP growth rate of 0.8% assumed by the EU Commission.

Chart 5.19
Forecasts of German TFP with an AR model and forecasts by the EU Commission



HP filtering these forecast values yields the time series shown in chart 5.20.

Chart 5.20
HP filtering of the two deterministic forecast versions



For the IMK estimate we assumed the following for the forecast period: The potential investment ratio is again assumed to be 21.7%, the potential increase of per-capita R&D expenditure 4.6% which corresponds to the average of the period 1995 to 2004. US TFP corresponds to the CBO's forecast of 1.4%.

Chart 5.21
Exogenous variables of TFP during the forecast period (2006-2010)

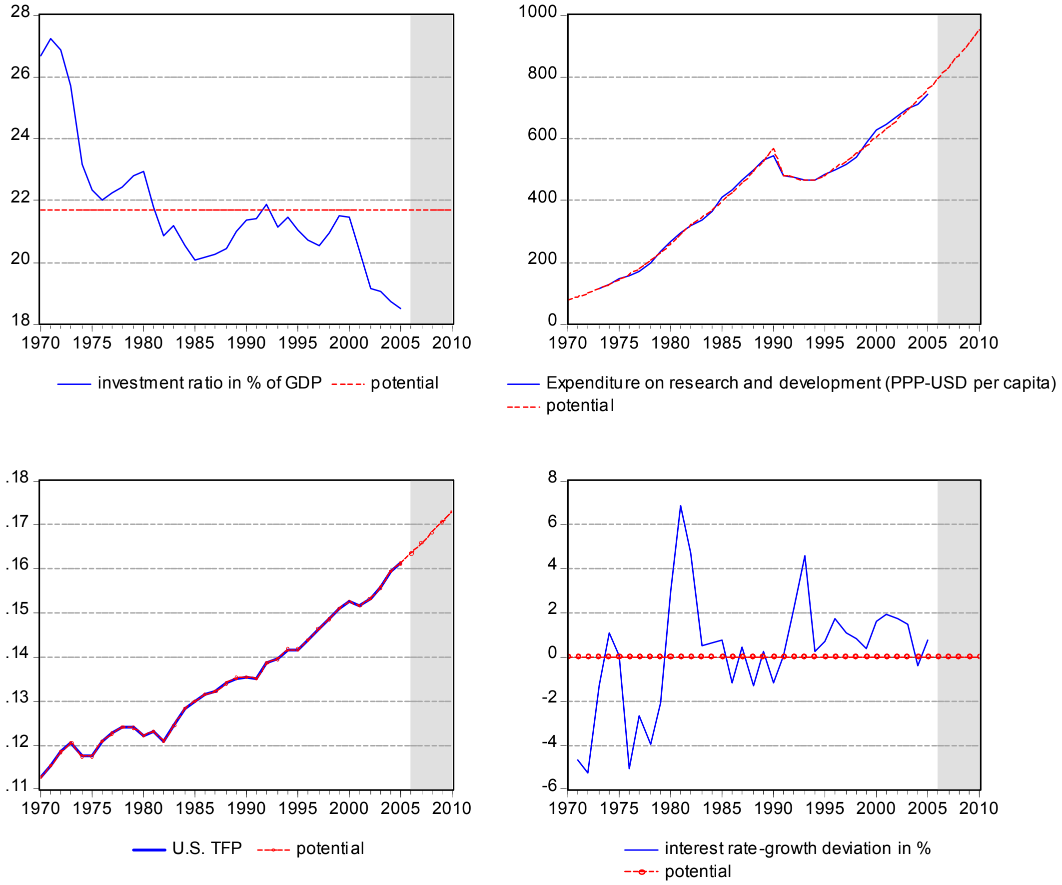
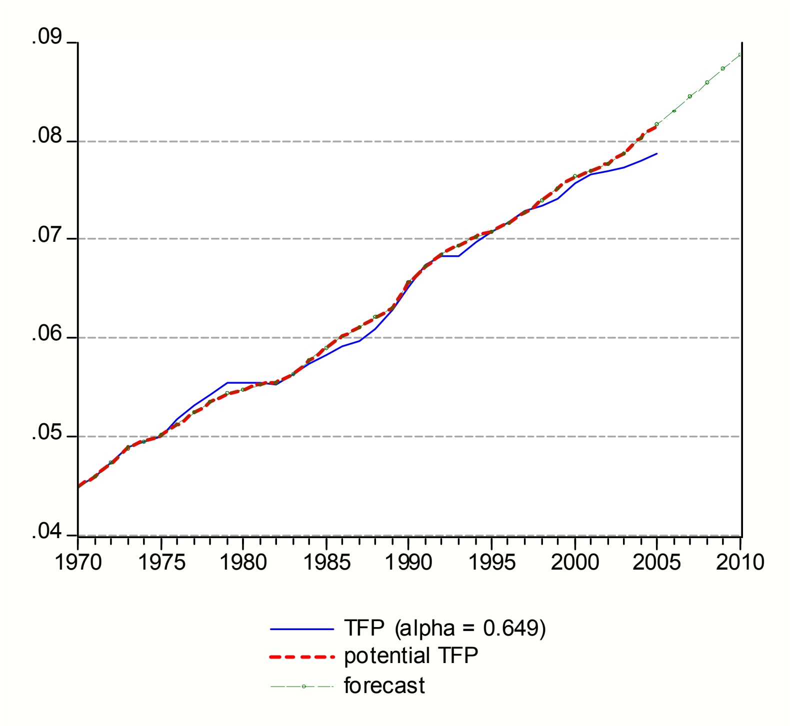


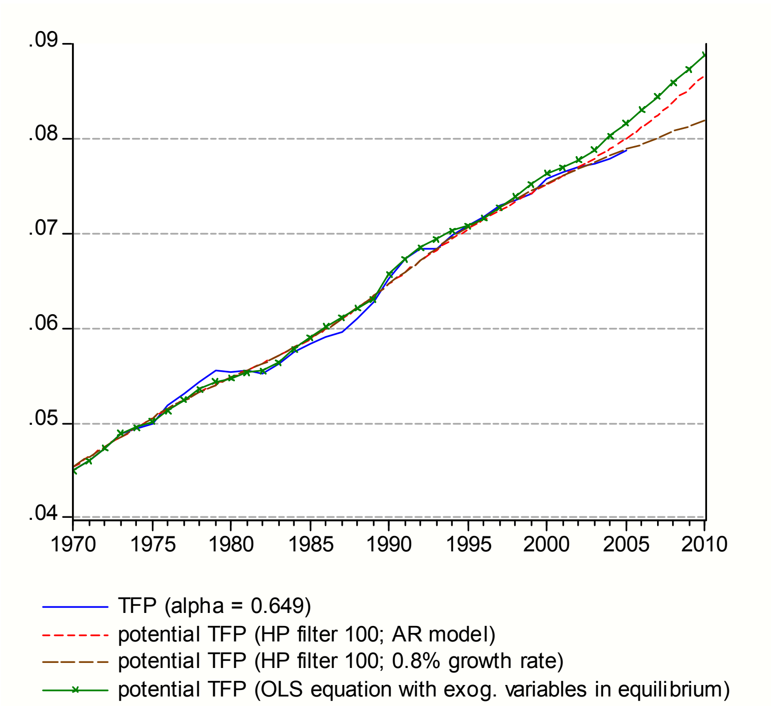
Chart 5.22 shows potential TFP given these assumptions.

Chart 5.22
TFP forecast (OLS regression)



The following chart shows the different results produced by the three methods of projecting potential TFP.

Chart 5.23
TFP projections



According to the forecast of the EU Commission potential TFP will increase at an annual rate of 0.8%, the AR model yields 1.6% and our OLS regression forecasts an annual increase in potential TFP of 1.7%. The estimated levels of potential TFP in 2010 differ by up to 8%. Because TFP in the production function translates one to one into potential output estimates of the latter will differ just as much.

5.5 Estimating and projecting potential output

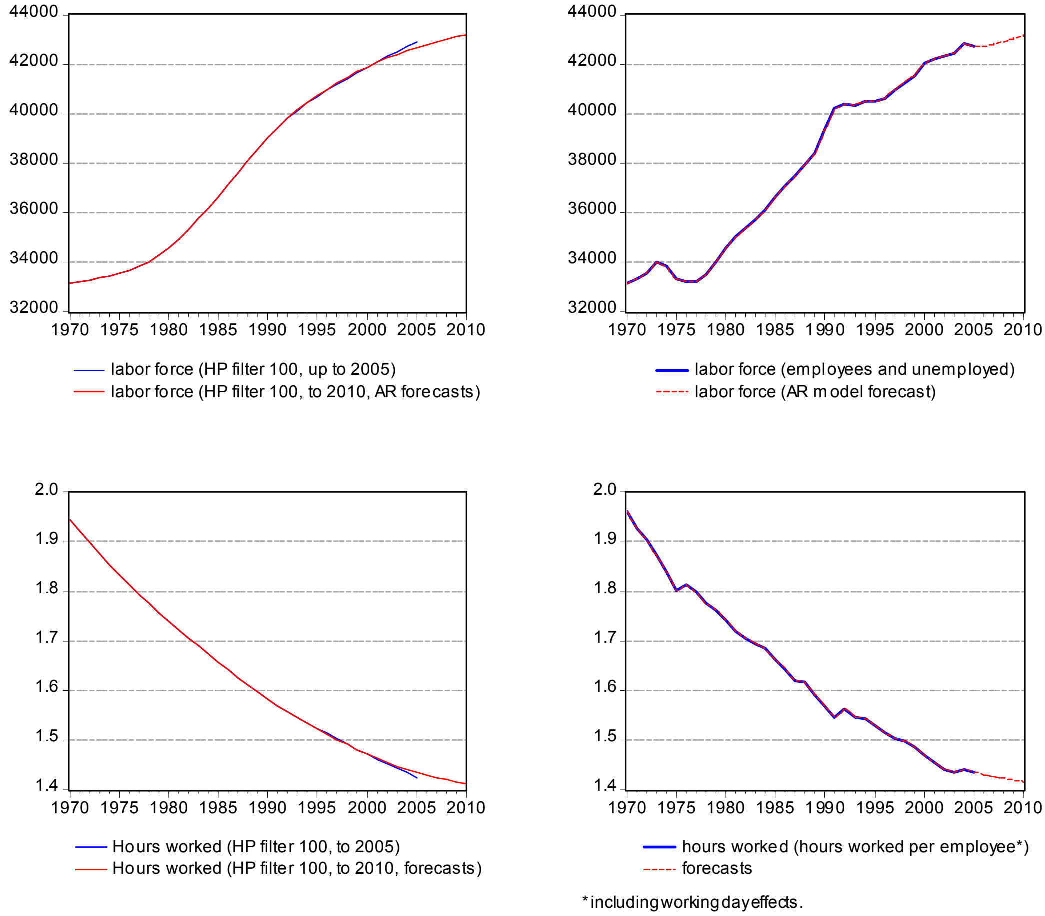
Given the estimates and projections of the NAIRU and TFP discussed in the previous chapter, we calculated potential output using the following production function:[76]

$$Y_t^* = TFP_t^* \text{ (laborforce}_t^* \text{ average hours worked}_t^* \text{ [1-Nairu])}^{0.65} (K_t)^{1-0.65}$$

To determine potential output, estimated and projected values of the labor force and average hours worked are also needed. These time series were prolonged using AR models. Obviously different versions of these time series are feasible and the uncertainty surrounding the estimate of potential output is therefore high. Since we apply the HP filter here, the endpoint problem is particularily problematic.

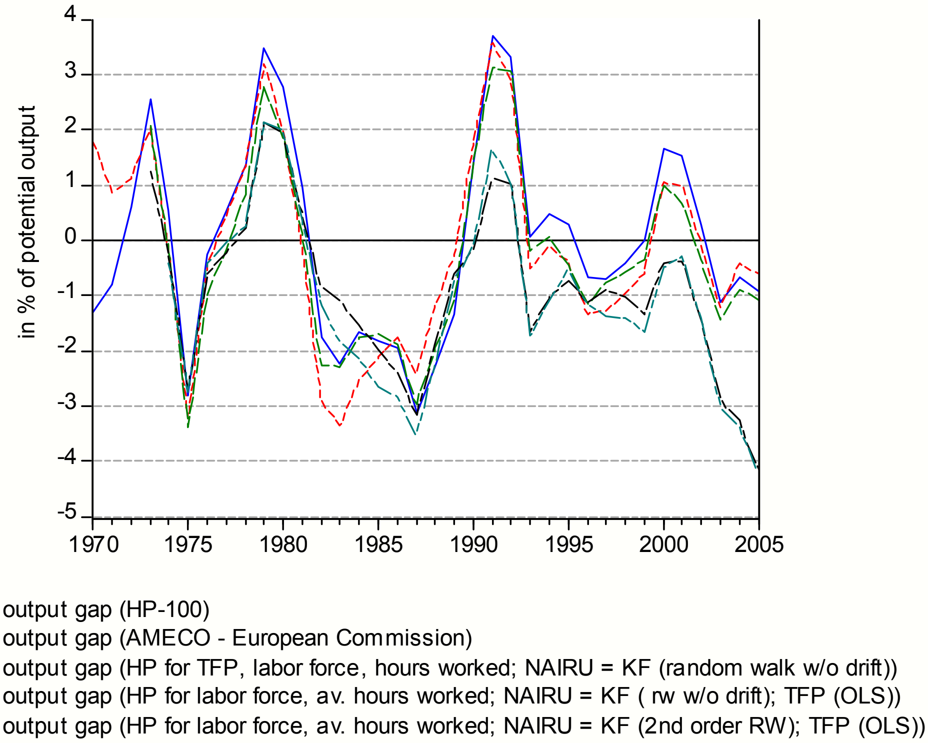
[76] See also the introduction to this chapter.

Chart 5.24
Estimates and forecasts of labor force and average hours worked



For the period 1970-2005, we determined four potential output paths using two different estimations of potential TFP (potential TFP as described in the previous section and HP-filtered TFP) as well as two estimates of the NAIRU time series. Chart 5.25 shows three output gaps based on these potential output paths along with that estimated by the EU Commission and an output gap series based on potential output calculated with an HP filter (100).

Chart 5.25
Estimates of Germany's output gap using different NAIRUs and potential TFPs



The considerable differences between the estimates arise primarily from the different series for potential TFP. At the end of the estimation period our estimates show large negative output gaps resulting from the fact that the recent slowdown in economic activity is not attributed to a change in potential output growth.

Potential output was then projected using the following equation: $Y_t^* = TFP_t^*$ (labor force$_t^*$ average hours worked$_t^*$ [1-Nairu])$^{0.65}$ $(K^*_t)^{1-0.65}$. As we have several versions of the NAIRU and of potential TFP, we show an upper, lower and middle version. The upper version is based on estimated equations of potential TFP and the NAIRU, the middle version on AR models and the lower version on the respective methods used by the EU Commission. The capital stock is determined endogenously based on the potential investment ratio of 21.7%. In accordance with its definition the capital stock is calculated as follows.

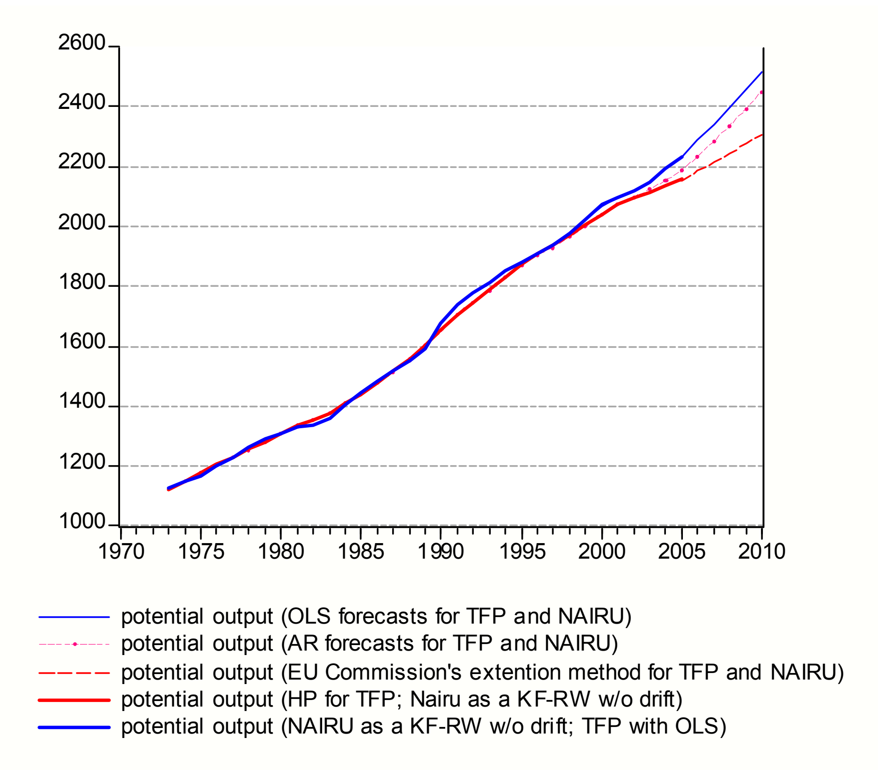
$K_t = K_{t-1}$ + (gross fixed investment – depreciation)

To project the capital stock, the equation is rewritten using the equilibrium investment ratio and a depreciation rate of 4.71%:

$K_t^{forecast} = (1\text{–depreciation rate}_{=4.71\%}) * K_{t-1}^{forecast} + \text{investment ratio}_{=21.7\%} * Y_t^*$.

Combined with the equation for Y^*_t, this is a system that can be solved. The results are shown in chart 5.26.

Chart 5.26
Potential output: different versions[1]



[1] All estimates are based on HP filters of the labor force and working time with forecasts until 2010.

Estimation differences result primarily from the following: For the observation period (1970-2005) there is only one source of differences, namely the methods of calculating potential TFP. The blue line is based on the OLS regression of potential TFP with the exogenous variables (exception: US TFP) in equilibrium. The orange and red lines reflect a simple HP filter of TFP; because of the endpoint problem, different paths in the forecast period also affect the observation period, especially the year 2005. All estimates have the same NAIRU in the observation period, not, however, in the forecast period. The upper, middle and lower versions of potential output growth imply an annual increase of 2.4%, 2.3% and 1.4%, respectively, for the period from 2006 to 2010.

The effect the NAIRU has on potential output corresponds approximately to the elasticity of labor. In other words, a decrease in the NAIRU by one percentage point increases potential output by nearly 0.7%. It follows that a decline in the NAIRU by three percentage points to about 5% would raise potential output by about 2%. The effect of different estimates of total factor productivity is more pronounced for two reasons: firstly, the results differ more, and secondly, TFP translates into potential output one to one.

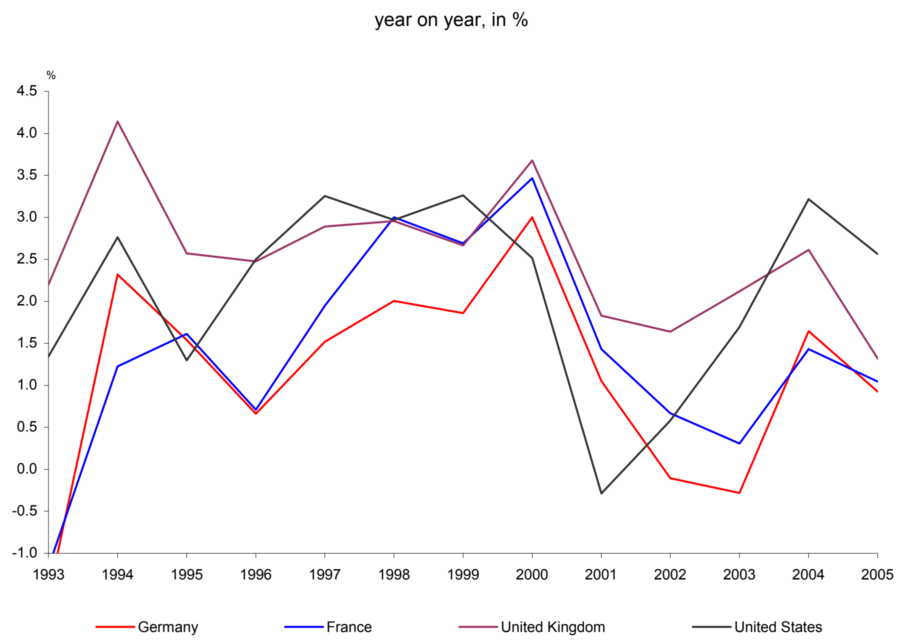
The ultimate lack of knowledge about the levels of the NAIRU and TFP results in potential output estimates that differ considerably from each other, as illustrated in chart 5.26. This makes it difficult to use this theoretically compelling concept as a basis for economic policy advice. It is possible to identify factors that positively affect potential output as, for example, the investment ratio through its impact on potential total factor productivity. But no estimate of potential output can assert a claim to accuracy and correctness, so that several different estimates have to be used as policy indicators. This, however, vastly complicates fiscal planning and the use of monetary policy rules, such as the Taylor rule (IMK 2006: 22ff.). Given the difficulties involved in robustly estimating potential output, economic policy makers should pragmatically test the limits of potential output when the inflation outlook is benign, i.e. when underlying inflation is on target or low. An expansionary policy stance (or an accommodating one when demand is strong) could then set in motion a virtuous cycle of decreasing NAIRU, rising participation rate, higher productivity growth and improving fiscal balances. Unit labor costs are in this context a suitable indicator of future inflation.

6 Germany's potential growth

6.1 International comparison of Germany's potential growth

An international comparison of potential output can be based on different indicators. The level of GDP is an indicator for the relative economic might of a country. In contrast, per-capita GDP indicates the living standard. GDP per hour is an indicator for labor productivity. GDP per capita is greatly affected by the participation rate, unemployment, hours worked and productivity. The latter measures the efficiency with which labor and capital are used. Ultimately, it is labor productivity that determines the standard of living. However, the higher is TFP growth, the more the living standard can be raised without additional capital investment.

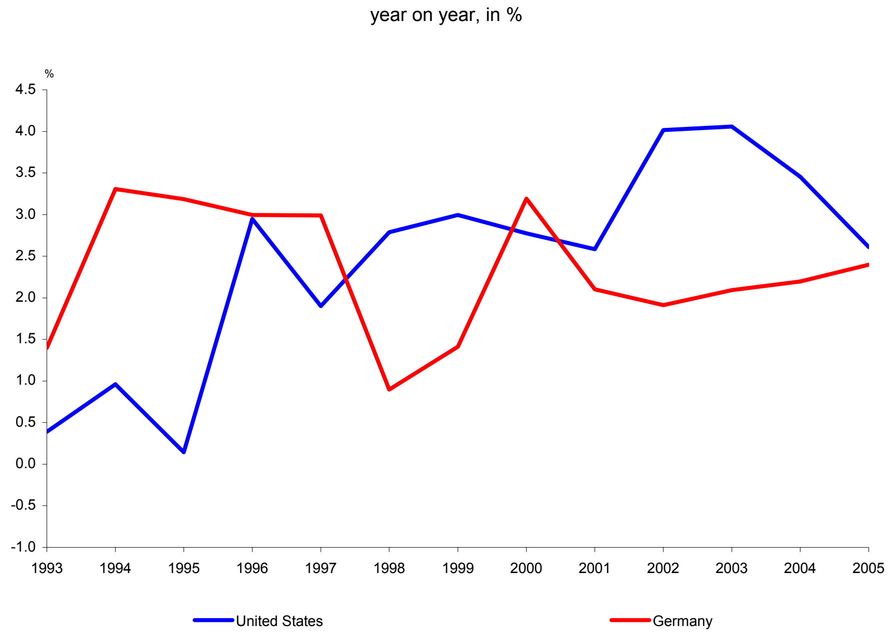
Chart 6.1
International comparison[2] of per capita[1]-income growth[2]



[1] working-age population. - [2] Germany: West Germany until and including 1991.

Source: International Monetary Fund.

Chart 6.2
Labor productivity (hours) in international comparison[1)]



[1] Business sector (without public sector and quasi-public services); Germany: West Germany until and including 1991.

Source: German Federal Statistical Office; U.S. Department of Labor.

During the past ten years, Germany's GDP increased on average by 1.3% per year, the population grew by 0.1% p.a. and hours worked per employee (manufacturing and market services) declined by 0.6% (Destatis). The corresponding figures for the United States are 3.3%, 1.1% and -0.2%. These figures indicate two key reasons for stronger US growth: higher population growth and the slower decline in average hours worked. However, hourly productivity also increased less in Germany since 1995 (2.2%) than in the United States (2.8%). In contrast, Germany's productivity had increased annually by an average of 3% from 1971 to 1994, U.S. productivity by 2%. Especially in the seventies, productivity growth was considerably higher in Germany than in the United States.

One reason for currently stronger productvity growth in the United States may be the greater impact of information and communication technologies in the United States.[77] For the second half of the nineties, Oliner/Sichel (2000) find empirical evidence that two thirds of the one percentage-point increase in productivity growth compared to the first part of that decade result from the use of new technologies and technological progress in computer manufacturing. Greater capital input and increased total factor productivity contributed

[77] A comparative international study concludes that total factor productivity growth excluding cyclical effects increased by half a percentage point in the United States, in Canada, in Australia and in the Scandinavian countries during the nineties whereas it declined in the large European economies and in Japan (Bassanini et al. 2000).

equally to the increase in productivity growth. Despite large investments, the share of new technologies in the capital stock is probably still lower in Germany than in the United States, making a future productivity surge likely. The German Bundesbank (2002) offers two more reasons for the growth divergence between the United States and Germany: different methods of price adjustment and high depreciation rates in the United States because of the steep increase in investment in information and communication technologies. The first, statistical reason has become largely irrelevant with the introduction of the new System of National Accounts 2005, but the second still applies because, despite the bursting of the new economy bubble, the depreciation rate has increased much more in the United States since 1995 than in Germany. The depreciation formulas are also different in the two systems of national accounts. The growth divergence in per-capita net domestic product, i.e. the distributable national income devoid of population growth and depreciation effects, should be smaller than the one based on GDP.

The main reason why per-capita income in Germany is lower is that people work less in Germany.[78] Average working time is shorter and the unemployment rate is higher. In contrast, the participation rate is actually higher in Germany than in the United States (OECD). Whereas high unemployment unambiguously represents a squandering of resources, this is not necessarily the case for shorter average working time. The latter is a matter of preferences and, in particular, of the utility derived from leisure time relative to material goods. Blanchard (2004) and Gordon (2002), for example, point out that the divergent living standards do not adequately mirror the divergent welfare levels if people in Germany indeed value leisure time more than do people in the United States. Similarily, higher expenditure on crime protection and expenditure made necessary because of the more extreme weather conditions in the United States increases the US GDP but not the level of welfare.

The comparison above qualifies the economic and sociopolitical significance of the divergence in the living standards between Germany and the United States. The question of why Germany's growth decreased both in absolute terms and relative to the United States, however, remains. The key question in this context is whether potential growth has slowed down.

6.2 Reasons for Germany's economic slowdown

The economic policy reactions to several adverse shocks are key factors in Germany's economic slowdown. The first amd most dramatic shock of the past 15 years was German unification – an abrupt merging of the East-German economy with its West-German counterpart against the backdrop of the constitutional precept of uniform living conditions throughout the federal territory. The way in which unification was handled, amounted to a severe nega-

[78] It is estimated that the average person in the United States works 40% more in his or her lifetime than the average person in Germany (and also in France and in Italy; cf. The Economist, Mirror, mirror on the wall, June 17th 2004.

tive supply shock for the East-German economy; for the West-German economy it initially entailed a positive demand shock that petered out over time.

- Virtually overnight the East-German capital stock became largely obsolete as a result of the new competitive market conditions and, in particular, the implicit severe appreciation of the East-German mark.
- East-German wages nevertheless increased sharply and thereby aggravated the supply-side problems of the East-German economy.
- The demand push emanating from East Germany impacted on West Germany during an economic upswing causing the economy to overheat and monetary policy to become restrictive.
- Large financial transfers to modernize the East-German capital stock and bolster the incomes of East-German households were a tremendous fiscal burden and gave rise to tax increases.
- The East-German population was also subsidized through social security which caused an increase in social security contributions and thus the tax wedge.

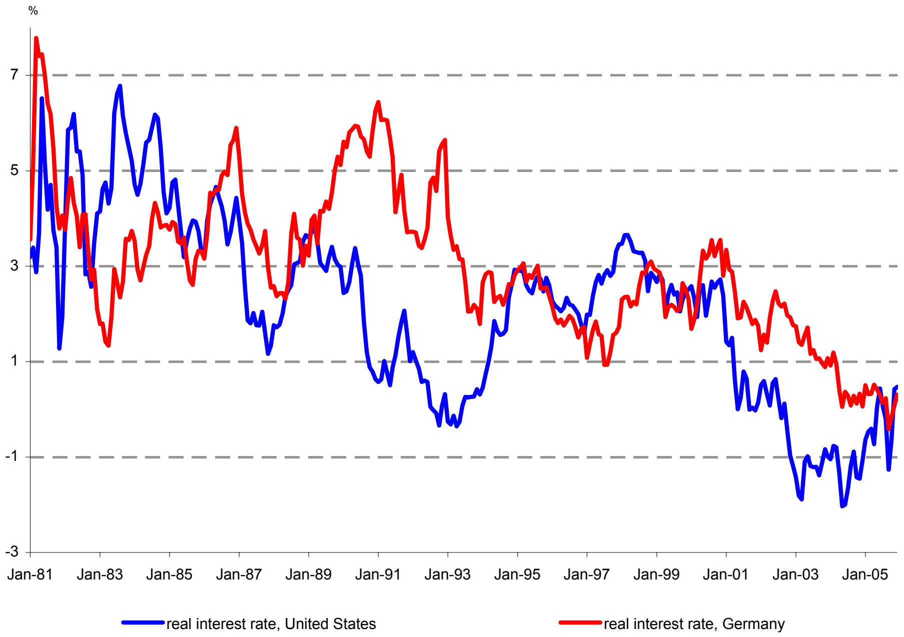
The tax wedge does not necessarily have a negative effect on the economy, if, for example, higher contributions are matched by higher individual benefits that are also perceived as such by the wage earners. As the latter does not apply to the unification period, however, the increased tax wedge clearly had negative effects. The fiscal burden of unification prevented fiscal policy from fulfilling its task of ensuring macroeconomic stability, all the more so because the EU treaty limited the scope for budget deficits and public debt and it became increasingly difficult to maintain a federal budget that was in accord with the German constitution.

German unification was not the only negative shock the German economy encountered during the past 15 years. There was also the Asian crisis of 1998/99, the oil price shock and the international collapse of stock prices at the beginning of the century, the US recession of 2000/2001, the terrorist attacks of 9/11 and the geopolitical uncertainties entailed by the war in Iraq, as well as the the further drastic increase in oil prices well into the year 2006.

Combined negative supply and demand shocks pose a particular challenge for economic policy because they result simultaneously in economic slowdown and higher inflation. During the past five years, inflation only marginally exceeded the ECB's inflation target despite several price shocks including a four-fold increase in oil prices, the BSE crisis and crop failures. In Germany, annual inflation actually averaged only 1.6%. This indicates that monetary policy maintained price stability but did not react to the demand shocks offensively enough. Furthermore, German fiscal policy should also have stimulated the weak economy, especially since Germany, unlike most of the other Euro-Area countries, did not benefit from a substantial decline in real interest rates as a result of European Monetary Union.

Chart 6.3
Short-term interest rates[1] in Germany and in the United States

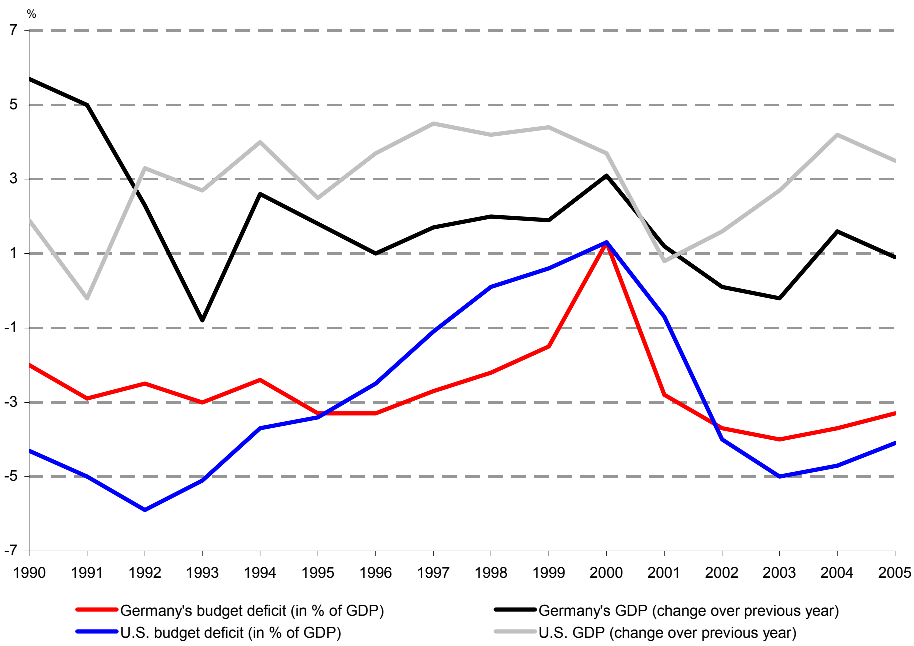
in %



[1] Real 3-month money market (Germany) and real 3-month treasury bills rate (US), based on consumer price indices.
Sources: German Bundesbank; Federal Statistical Office; Federal Reserve.

Chart 6.4
Budget deficits and GDP growth in Germany and the United States

in %



Source: International Monetary Fund.

The economic upswing in the United States subsequent to the global slowdown in 2000 and 2001 is in no way a reflection of higher labor market flexibility but rather the result of pronounced monetary and fiscal stimulation. Whereas in Germany fiscal policy was predominantly restrictive with a view to the stability and growth pact, in the US it was markedly expansionary. The considerable increase in the German budget deficit in percent of GDP was mainly the result of the economic downturn rather than fiscal expansion. In the United States, monetary policy acted rapidly and aggressively, whereas the ECB hesitated at first and then lowered interest rates to a much lesser extent.

In the eighties after the second oil price shock and in the nineties after the unification boom the German economy underwent long periods of disinflation during which economic upswings were repeatedly brought to a halt by monetary policy. Monetary policy acted restrictively over longer periods of time and policy reactions to negative demand shocks were restrained. In contrast to the United States, unemployment in Germany did not fall again after an increase but rather hardened. Higher unemployment and predominantly restrained wage increases made for low increases in domestic incomes leading to a vicious cycle of low domestic demand, strained labor market conditions, failed consolidation attempts on the part of the government and relatively high real interest rates in view of low inflation.

Solow answers his own question as to why domestic demand was not stronger in Germany as follows:

> "I suspect that the answer might be that monetary and fiscal policies have been excessively contractionary during the past decade." (Solow 2007: 13)

The inadequate monetary policy reaction to adverse shocks was only in part the result of a restrictive bias (Arbeitskreis Konjunktur 2002). Monetary policy was not expansionary enough for Germany, in particular, because Germany's inflation rate and GDP growth lagged behind the Euro-Area's average. A central bank with a focus on Germany alone would have had even fewer reasons in the year 2000 to increase interest rates by a total of 1¾ percentage points, especially because the German economy had already come to a halt in the third quarter of 2000 and the inflation outlook was benign. Had the central bank increased rates by only one quarter of a percentage point, economic growth in Germany could have amounted to almost 2% in 2001 according to most estimates of the real effects of monetary policy.[79] In this case, the persistent economic slump may have been avoided without further macroeconomic policy measures. However, such an expansionary monetary policy would not have been appropriate for the Euro Area as a whole. Therefore German fiscal policy should also have taken responsibility for macroeconomic stability. In the case of shocks that affect the member states asymmetrically, national fiscal policies play an important role in

[79] A change in interest rates by one percentage point results in an opposite change of real GDP by about 0.4% (relative to baseline) (Van Els et al. 2001: 41 and 58, Hayo et al. 2004: 50). In the specific circumstances of the year 2000, the effect may have been even stronger given that econometric studies have shown that monetary policy effects are greater in downswings than in upswings (Kuzin/Tober 2004, Peersman/Smets 2001, Kakes 2000).

stabilizing the economy because monetary policy has to focus on the average developments in the Euro Area.[80]

Analogous to monetary policy, fiscal policy can affect the level of aggregate demand – and possibly also of potential output.[81] Some theories negate fiscal policy's influence on aggregate demand but the postulated effects should, if at all, merely diminish the influence of fiscal policy in the real world. The Ricardian equivalence theorem, for example, states that government debt depresses private consumption because consumers raise their savings rate in anticipation of additional future taxes (Barro 1989). The fiscal impulse may also be reduced by an increase in interest rates resulting from higher government debt which diminish private investment and consumption (crowding-out effect). Econometric studies have shown, however, that such non-Keynesian effects seem to be of minor importance (Leibfritz et al. 2001). Two IMF studies calculate expenditure multipliers in the range of 0.6 to 1.4 (Hemming/Mahfouz/Schimmelpfennig 2002, Hemming/Kell/Mahfouz 2002). Even in the case of tax-financed increases in government expenditure the effect on demand is likely to be positive because government funds are spent fully whereas private households accumulate savings. (The tax multipliers presented in the studies mentioned above range from 0.3 to 0.8).

By increasing public investment, the government can furthermore directly affect potential output. It follows that fiscal policy was clearly in a position to effectively counter the weakness in demand, at least if one abstracts from the constraints imposed by the stability and growth pact.

The German example also demonstrates that wage restraint in individual countries of the Euro Area may not have the desired effects because the central bank sets monetary policy according to average developments in the Euro Area and may therefore not react adequately, i.e. expansionary enough, from the viewpoint of the country with wage restraint.[82] In a monetary union, it is fiscal policy that must accept the responsibility for macroeconomic stability in the face of wage restraint. In a monetary union, monetary policy can also not correct real interest rate differentials that may give rise to regional slumps or overheating. The consequences for regional labor markets and regional balance of payments call for fiscal policy to act, not only in those regions where the economy is weak but also in those where capacities are overutilized.

In Germany at the beginníng of the century, an adequate policy mix would have consisted in wage restraint coupled with a more expansionary monetary policy stance and a fiscal policy that was expansionary enough to compensate for the shortfall in demand resulting from wage restraint. Given such a policy mix Germany's growth rate could have been sub-

[80] The absence of centralized European fiscal policy makes it more difficult for fiscal policy to react to symmetric shocks, not, however, to asymmetric shocks.

[81] Allsopp/Vines (2005) provide an overview of the literature on the macroeconomic role of fiscal policy.

[82] For a discussion of the strategy of wage restraint and the importance of an accommodating monetary policy, see Tober (1998).

stantially higher.[83] In light of unit labor cost increases of 0.2% on average from 2000 to 2005, GDP could have increased by a minimum of 2½% per year without causing inflationary pressure – the growth rate would then have been 1½ percentage points higher annually than it actually was. The growth rate would then have exceeded the rate we calculated for potential growth by 0.1 percentage points per year, and unemployment and the Nairu would not have increased but instead would have declined markedly from the levels in 2000 of 6.9% and 7.2%, respectively. Higher actual growth would have caused the usual methods of estimating potential output to arrive at correspondingly higher potential growth rates.

A longer period of economic weakness, as experienced by Germany from 2000 onwards, may impact on potential output and even potential growth:

- A higher NAIRU in itself only curtails potential output, not, however, potential growth.
- If a period of economic weakness is not followed by a period of above-average growth most econometric methods will indicate a reduction in potential growth. The danger then arises that fiscal and monetary policy makers use this statistical artifact as basis for economic policy decisions and put the economic brakes on too early.
- A weaker economy implies less investment and also less innovation. Total factor productivity may then increase more slowly, leading to reduced productivity growth.

In addition to these mechanisms of the long-run nonneutrality of monetary policy, another one is pointed out by the OECD: long periods of economic expansion usually give rise to higher participation rates (OECD 2006: 49) which is equivalent to an increase in the labor supply.

These macroeconomic effects are rarely discussed in the literature because most economic and econometric models are based on the assumption of long-run neutrality. Debates on unemployment in Germany often take this one step further: Not only is the economy assumed to return to a specific equilibrium in the long run regardless of macro policy but also, in the short run, macro policy measures are deemed unnecessary beyond safeguarding price level stability because the automatic correction of disequilibria is assumed to be rapid. Consequently, unemployment is viewed as being caused solely by excessive wages and labor market reforms appear to be the only solution (Solow 2007: 17).

In contrast, the OECD discusses the role of macro policy in its recent Employment Outlook. Although this discussion takes place in the context of structural reforms which may produce a negative output gap, the mechanisms should be identical in the case of demand-induced output gaps. The following quote summarizes simulations involving an increase in potential output due to structural reforms under different assumptions about macro policy:

> By construction, the impact on potential growth is basically identical under the three alternative monetary policy assumptions. However, the short-term impact is quite differ-

[83] An analysis of macroeconomic policy coordination with a focus on Germany is found in Hein et al. (2005).

ent. In the scenario with unchanged nominal interest rates, the output and labour market gains from reforms are slow to materialise because real interest rates rise as a negative output gap emerges causing inflation to decelerate. The output gap remains below the baseline path for five years, reinforcing deflationary pressures. Conversely, in the real-interest-rate-cut scenario output gains accrue more rapidly. Indeed, the output gap is above baseline during the entire simulation period. The constant-real-interest-rate scenario lies in an intermediate position between these two scenarios.

(OECD 2006: 54)

In contrast to the simulation with active monetary policy, in the scenario without monetary policy reaction the output gap remains negative for five years. The assumption that macro policy does not impact on potential output is not convincing: It is hard to imagine that higher unemployment over a period of five years does not affect the NAIRU, all the more so as the OECD emphasizes in a different section of the report that stabilizing macro policies are important in that they lower cyclical fluctuations and thereby also „the scope for hysteresis-type mechanisms that turn cyclical unemployment into structural unemployment“ (OECD 2006: 49). In the simulations, however, a long-term effect is by assumption impossible as seen in the quote above. The EU Commission also excludes the possibility of long-term effects of monetary policy and interprets this assumption as inherent in the logic of the NAIRU concept:

Since the famous Phelps (1967) and Friedman (1968) contributions in the late 1960s a consensus has emerged that with long run flexible prices and wages, there should be no long run trade off between the rate of inflation and the rate of unemployment. Consequently, wage and price dynamics must be formulated in terms of changes in wage and price inflation. With this formulation it is assured that the unemployment rate will always return to its equilibrium value, regardless of the level of the long run (wage) inflation rate. This is the rationale behind the NAIRU concept.

(Denis et al. 2006: 19)

This assumption is, however, not necessary, either from a theoretical or an empirical perspective as shown, for example, by a study by DeGrauwe and Storti:

Thus we find that econometric methods that use structural VARs and econometric models produce results that are in accordance with the consensus view. This is not really surprising. These methods typically impose the long-term condition that the output effect is zero. In contrast the econometric methods that do not impose such a long run restriction, the “plain vanilla” VAR, find that in the long run (after five years) there are still significant output effects of monetary policies in most countries. Put differently, if one “allows the data to speak” the consensus view of monetary policy neutrality does not seem to hold.

(De Grauwe/Storti 2007: 13)

6.3 Structural reforms in Germany

There is no doubt that structural reforms may raise potential output or even potential growth. But even in this context macro policy has an important role to play as pointed out in 1997 by Bean (1997) and Fischer (1997) and more recently by the OECD (2006). Initially structural reforms tend to depress economic activity (International Monetary Fund 2004; Duval/Elmeskov 2005). In this vein, Auer (2000) and OECD (2006b: 55) emphasize that in the past two decades successful labor market reforms – as in Austria, Denmark, Ireland and the Netherlands – were always supported by fiscal expansion.

Furthermore, it should be noted that some structural reforms may not fit into the larger economic, political and cultural context. To what extent individual structural reforms are expedient, depends on their side effects. More competition in product markets may in principal be beneficial and may increase potential output through higher efficiency and lower relative prices. However, in the case of natural monopolies and production with considerable external effects this result is ambiguous.

The need for action is not even clear when it comes to unemployment benefits – the one area that is almost exclusively discussed in the context of generous unemployment benefits causing unemployment.[84] Not only may generous unemployment benefits positively affect potential output, but their adverse incentive effects may be reduced by supplementary measures and they stabilize aggregate income development. The latter may rank high for socio-political reasons and is a stabilizing factor from a macroeconomic perspective.[85] In contrast, unemployment benefits are generally and in particular in Germany simply viewed with regard to the reservation wage, and a clear negative labor market effect is derived. The following arguments dispute this simple view:

1. From a microeconomic perspective the smoothing of consumption after layoffs can be interpreted as an insurance policy that would generally not be offered by the private sector (OECD 2006: 61; Gruber 1997)
2. Aggregate efficiency gains may result from improved matching (Polachek/Xiang 2005) and from the incentive to strive for high-productivity jobs (Acemoglu/Shimer 1999, 2000; OECD 2006: 61)
3. Recent empirical studies demonstrate that the negative incentives resulting from generous unemployment benefits may be compensated for by measures to activate unemployed people, in particular when vocational training measures are combined with monitoring (Bassanini/Duval 2006; OECDb 2006)
4. Generous unemployment benefits stabilize the economy in case of adverse shocks (Keynes 1930, International Monetary Fund 2002: 31)

The effect of union density on unemployment is equally ambiguous. Since the pioneering work of Calmfors/Driffill (1988) it has been well-known that centralized or coordinated union activity may internalize possible negative externalities of unionization. Therefore they do not have drawbacks compared to decentralized wage bargaining; they

[84] For OECD countries, econometric studies conclude that a decrease in the wage replacement rate by 10% would lower the equilibrium unemployment rate by 1.2 percentage points and raise the employment ratio by 1.7% for men and 3.2% for women (prime age) (OECD 2006: 59).

[85] This point is also made by the International Monetary Fund, albeit only in passing (International Monetary Fund 2002: 31).

may, however, in addition act in a way as to stabilize the economy, be it through coordinated wage restraint in an upswing or in view of adverse price shocks, or through a certain nominal wage rigidity in an economic downturn. In this context, the following conclusion drawn by the OECD in a recent Employment Outlook from a literature survey is noteworthy:

> "Overall, recent empirical research, including evidence provided in Bassanini and Duval (2006), suggest that high corporatism bargaining systems tend to achieve lower unemployment than do other institutional set-ups."
>
> (OECD 2006: 86)

In contrast, collective bargaining processes on the industry level without coordination on a higher level has negative effects on the labor market and economic development (Calmfors/Driffill 1988; OECD 2006: 85).

The frequently postulated negative effect of employment protection on labor markets can also hardly, if at all, be found in the data (Bassanini/Duval 2006; OECD 2006: 96).

6.4 Rewards and risks of potential output estimates

The basic problem faced by all potential output estimations is the fact that potential output and potential growth are not directly observable.[86] Whether and to what extent current production provides information on production possibilities is hard to determine. As discussed in the previous chapters the inaccuracy of potential output estimates precludes their use in formulating economic policy.

From a theoretical perspective, potential growth is clearly important for the economy and for economic policy. According to the definition established by Okun, potential output indicates how fast an economy can grow without running into stability problems. This definition is not a mere technical one based on the limited availability of the factors of production. Potential growth must be sustainable and therefore also depends on price and wage formation. It is, furthermore, affected by the degree of competition in goods markets and by labor market institutions.

In theory, potential growth therefore provides important information for monetary policy makers who can tighten the monetary reins to maintain price level stability when current output exceeds potential output or better still, if it is expected to. Similarily the central bank can be accommodative as long as the potential has not been exhausted. If central banks had accurate estimates of potential output and potential growth, they could always act in a timely fashion. Accurate potential output estimates would also be helpful for fiscal policy, in determining the structural budget deficit, for example. Similar uses exist for social security and labor market policies.

[86] The arguments put forth in the following with respect to potential output equally apply to the NAIRU which has to be quantified implicitly or explicitly in order to estimate potential output.

Economic policy can reap these benefits only if empirical estimates are accurate and reliable over the medium term. However, these two conditions are not met. Empirically it is not possible to pinpoint potential output with a sufficient degree of certainty. It goes without saying that it is difficult to accurately estimate something that is unobservable. This is only possible in an indirect manner using economic concepts and statistical-econometric methods. New classical theory disposes of the matter in a fashion that is elegant but at the same time tragic for the concept of potential output. Ultimately, new classical theory equates potential output with actual output because economic agents are assumed to behave rationally at all times and to be fully aware of the systematic economic relationships. Therefore production is always at optimum save for stochastic fluctuations that economic policy is unable to influence. The observation problem is thus solved. At the same time, the concept of potential output is superfluous because it contains no significant information not already provided by actual GDP. Most importantly, there is nothing for economic policy makers to gain from knowing how high potential output is.

New classical theory holds an extreme position. As described in chapter 2, the current macroeconomic mainstream assumes in line with monetarism and new Keynesian theory that considerable deviations of actual production from potential output (output gaps) may occur. These deviations are interpreted as cyclical movements, whereas potential output is thought to be determined by structural factors. In this context, the observation problem is severe. It is solved in part by making the assumption that cyclical fluctuations do not affect potential output. In addition, more or less ambituous assumptions are made concerning the usual length and shape of the business cycle. Frequently it is furthermore assumed that the deviations of actual production from potential output are stationary and zero on average. Based on these assumtions, it is possible to apply statistical and econometric methods to separate and quantify current production from the level of production that is devoid of irregular or cyclical movement. The latter is then interpreted as potential output. In actual fact, however, it is only the growth trend that is determined. Equating the growth trend with potential growth is questionable. This is only valid if cycles are generally regular and the adjustment mechanism is one-sided towards the trend (and not vice versa). The former condition does not apply. Every cycle has its particularities. The methods used automatically attribute these particularities to potential output. If a period of economic weakness lasts especially long compared to earlier cycles – as was the case between 2001 and 2005 – then the growth trend is automatically revised downwards. Similarily, the unusally long expansion of the US economy since the mid-nineties led to an upward revision of the trend. The number of unusual circumstances is great in every cycle and large annual trend revisions are the norm. This is not a problem when one is dealing with the trend; it becomes a problem, however, if this trend is interpreted as potential output. The corrections are then interpreted as corrections of potential output and potential growth, which – if taken seriously – will lead to an adjustment in the stance of monetary and fical policies which in turn could prove to be wrong if the following year brings new revisions. In other words, already the design of the methods used to estimate potential output preclude its use as a reliable guide for economic policy. There is also the risk that a low estimate of potential output will turn into a self-fulfilling prophecy if economic policy makers use it as a guide for macro policy and therefore put little effort into boosting the economy or, as the case may be, prematurely put the brakes on an upswing.

It is also problematic that the output gap is usually assumed to be stationary and zero on average. Some sort of magnetic force is seen to bring potential output and actual output in line over time thus ensuring that the output gap closes. To all intents and purposes the new classical proposition that actual production contains all relevant information is brought in again by the backdoor. This is not only controversial on a theoretical level because longer-term disequilibia are ruled out in advance. In addition, there is the risk of misinterpretating the results because the measured output gap according to theses methods is necessarily small. However, it would be wrong to take this small output gap to indicate the scope for macro policies because the fact that the output gap is small is determined by the particular stationarity assumption made, rather than being a new insight gleaned from the data. Consequently, these methods are unable to provide pointers for macroeconomic policy: Ultimately they contain no information about potential growth or the state of the business cycle.

The weak points of this class of methods have been known for some time. Nonetheless, they continue to be applied. As shown in the previous chapters, however, there have been new developments both in theory and in empirical methods. More recent Keynesian approaches argue that potential output adjusts to actual production as a result of hysteresis but do not really solve the problem. They rightly postulate that deviation from potential output may actually affect potential output itself. But if this is the case, the terms “potential output” and “output gap” lose their meaning because one can no longer strictly distinguish between current production and potential output. Whereas this applies in new classical theory because the level of current production is optimal, here neither current production nor potential output, which is distorted by current production, may be at an optimal level. Expansionary macro policy may in this case give rise to “positive” hysteresis effects that cause potential output to adjust upwards to higher actual production. It is then impossible to determine potential output in the sense of Okun and the whole concept loses its meaning. “Positive” hysteresis does not necessarily imply higher inflation. Although integrating long-term unemployed people into the work place generates an inflationary impuls in itself, faster productivity increases in an upswing and rising participation rates reduce wage pressure.

The assumption of stationarity can be modified so that the average output gap is not restricted to zero but estimated instead. This allows for longer-term disequilibria. Conceptually this is a big step forward. As shown in this report, estimates based on this assumption can actually produce the interesting result that output gaps persisted over longer periods of time. It also shows that most theories may be too optimistic when it comes to the adjustment of the economy to equilibrium. According to these newer estimates, there is a tendency to underestimate the scope for macro policy. Compared to statistical methods, more modern approaches allow for economically more meaningful estimates that take into account inflation and wage developments, and in our case also the effects of monetary policy and other exogenous variables.

Despite these theoretical and empirical improvements, however, the estimates are still too volatile to form a reliable basis for economic policy decisions. Partly this may have to do with the filtering methods that are used and the irregularities of the business cycle. In the case of Germany the data base furthermore contains several structural breaks, especially because of German unification the the emergence of the European Common Market and European Monetary Union. Comparing estimates for Germany with those for the Euro Area indicates that the quality of the results may be thus impaired.

In general, the methods used to estimate potential output only answer the question of whether current growth corresponds to the growth rate that could have been expected, assuming typical cycle lengths and a typical development of all factors that affect the economy. Such an exercise may produce results that offer some insight but they can not be used to justify a certain stance of monetary and fiscal policy. None of the estimation methods are able to overcome the basic problem that potential output is unobservable. Potential output in part depends on complex endogenous relationships. For example, as production increases over a longer period of time, both productivity and the participation rate increase, and in turn affect potential output. This is a virtuous cycle of self-reinforcing growth as observed in the United States since the mid-nineties. In the United States potential output estimates did not capture and could have not captured these developments because of their complexity and the limitations of available econometric methods.

This presents a serious problem for economic policy. It would be helpful to have empirical potential output estimates because there are periods, after all, in which economies overheat or slow down.

This applies especially to monetary policy which does not have reliable estimates of potential output and potential growth to use as a yardstick when interpreting monetary growth or making inflation forecasts. In its written analyses, albeit less so in its monetary policy decisions, the ECB rightly refers to inflation indicators such as unit labor costs which signal risks to price stability in both directions. Inflation and disinflation are always a sign that capacities are over- or underutilized. However, here too, caution must be exercised: A temporary increase in inflation during an upswing does not necessarily warrant any fiscal or monetary restriction. It could be a temporary phenomenon that quickly dissipates as the formerly long-term unemployed increase their qualifications and the capital stock is adjusted to the increased labor force (positive hysteresis and higher participation rate). Fiscal policy and in particular European fiscal policy is also negatively affected by the lack of reliable potential output estimates. On the recommendation of the EU Commission and in line with the stability and growth pact, ECOFIN focuses on the reduction of structural deficits. To calculate these, one needs information about potential output and potential growth. This problem would be considerably smaller if fiscal policy adhered to a longer-term government spending path instead. To conclude: Given the difficulties involved in robustly estimating potential output, economic policy makers need to learn to pursue their policy objectives without reference to this variable.

7 Annex

Annex I:

Guides to estimating potential output

In this annex three estimation methods are described step by step: Cobb-Douglas production function, HP filter and multivariate HP filter. The multivariate Kalman filter with exogenous varibales is not included in this annex because it does not run on the popular programs Excel and EViews.

Cobb-Douglas production function

Uness specified differently the data sources are the German Federal Statistical Office and, for the Euro Area, the area-wide model (AWM, Elvira.Rosati@ecb.int).

Table 7.1
Data description for Germany and EMU-12

Germany	Abbrev.	Unit	Source
Employment	de_et	thousand persons	
total hours worked	de_hwet	million hours	
GDP, real	de_gdp00	billion €-2000	Destatis: series 18, time series 1.3 (SNA, seasonally adjusted quarterly data)
Compensation of employees	de_coe	billion €	
GDP, nominal	de_gdp	billion €	
Employees	de_ee	thousand persons	
Hours worked by employees	de_hwee	million hours	
Capital stock (AMECO)	de_k	billion €-1995	AMECO (annual data
NAWRU (AMECO)	de_nawru	%	data transformed to quarters)
Standardized unemployment rate (Eurostat)	de_ur	%	Eurostat
Euro Area	**Kürzel**	**Einheit**	**Source**
GDP, real	YER	million €-1995	
GDP, nominal	YEN	million €	
Compensation of employees	WIN	million €	
Labor force	LFN	thousand persons	AWM data base
Unemployment rate	URX	%	
NAIRU	URT	%	
Capital stock	KSR	million €-1995	

The following Cobb-Douglas productin function is estimated:

(A.1) $Y^*_t = A^*_t L^{*\alpha}_t K^{*1-\alpha}_t$ and in logarithms: $y^*_t = a^*_t + \alpha l^*_t + (1-\alpha)k^*_t$

where Y^* is potential output, A^*_t potential total factor productivity, L^*_t potential hours worked (Germany) or non-inflation accelerating total employment, α the partial elasticity of output with respect to labor, and K_t^* the capital stock.

The potential labor force needed to determine non-inflation accelerating total employment is usually determined with an HP filter: lf^*_t = HP(labor $force_t$). Potential hours worked per person (H^*) is in general also estimated by HP filtering actual hours worked.

Non-inflation accelerating total employment **(L_t^*)** is calculated by multiplying the potential labor force by (1-Nairu). To determine potential hours worked (Germany) the non-inflation accelerating labor force is multiplied by potential hours worked per person.

The **NAIRU** required to determine the non-inflation accelerating total employment may be estimated by filtering or, for simulation purposes, simply assumed. The Kalman filter we employ to estimate the NAIRU is a complicated method. We therefore advise to take a NAIRU time series provided by one of the international organizations.

The coefficient α is generally not estimated but assumed to equal the average wage share during the estimation period. The latter is the average compensation of employees/nominal GDP during the observation period multiplied by a correction factor. During the period 1970-2003, for example, the wage share in the Euro Area was 0.54; in Germany it was 0.53 during the period 1991-1995. (The correction factor relates the volume of work of persons in work to that of employees and is 1.18 on average).

The potential capital stock is usually equated with the actual capital stock: $K^*_t = K_t$, the motivation being that the physical capital measured can be employed entirely. Annual capital-stock data for Germany can be found in the AMECO database, starting in 1960 for West Germany and in 1991 for unified Germany. As of August 2006, the German Federal Statistical Office also supplies an up-to-date time series of the capital stock.

Take the logarithm of all the time series: Y_t, L_t, L^*_t and K^*_t.

The log of **total factor productivity, also called the Solow residual (a_t),** is determined by solving the production function a_t using actual employment rather than non-inflation accelerating employment and actual GDP rather than potential output (k_t is assumed to equal k^*_t):

$\hat{a}_t = y_t - \alpha l_t - (1- \alpha)k_t$

Potential total factor productivity **(a^*_t)** is then usually approximated with an HP filter (1600).

Entering the variables (a^*_t, l^*_t and k^*_t) obtained above into the production function (A1) yields a time series of potential output for the period analyzed.

To project potential output, the following time series have to be prolonged: capital stock (K^*_t), non-inflation accelerating employment labor (L^*_t) and potential total factor productivity (A^*_t). Generally this is done in the following manner: The capital stock is carried forward using (expected) net investment. Non-inflation accelerating employment is projected by extending the labor force (trend) and the NAIRU, the latter being more complicated. For total factor productivity, the most recent potential value is used (the alternative approach used by the IMK is described in chapter 5).

Chart 7.1
Technological progress (A_t) in the EU12 according to the Cobb-Douglas production function

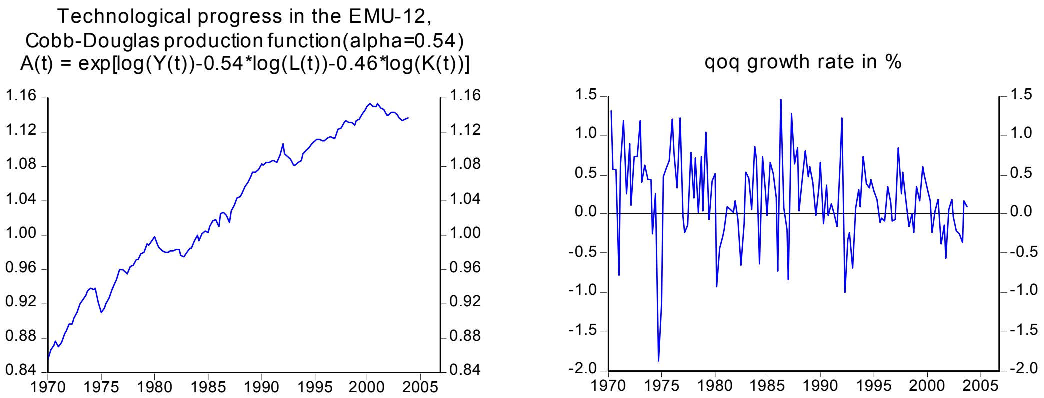


Chart 7.2
Technological progress (A_t) in Germany according to the Cobb-Douglas production function

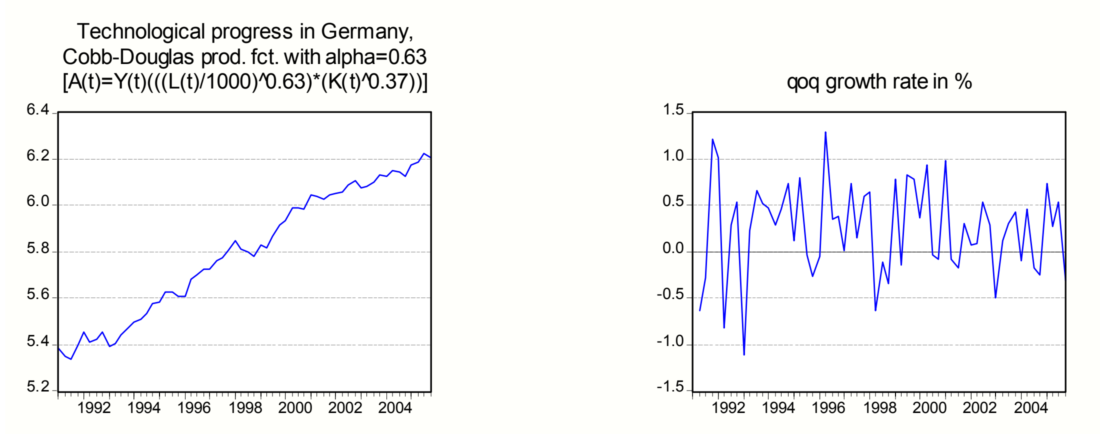


Chart 7.3
Output potential and output gap in the EMU-12 according to the Cobb-Douglas production function

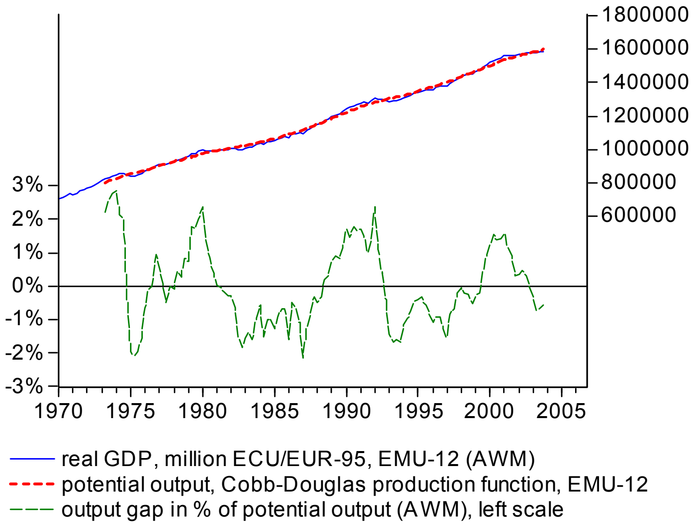
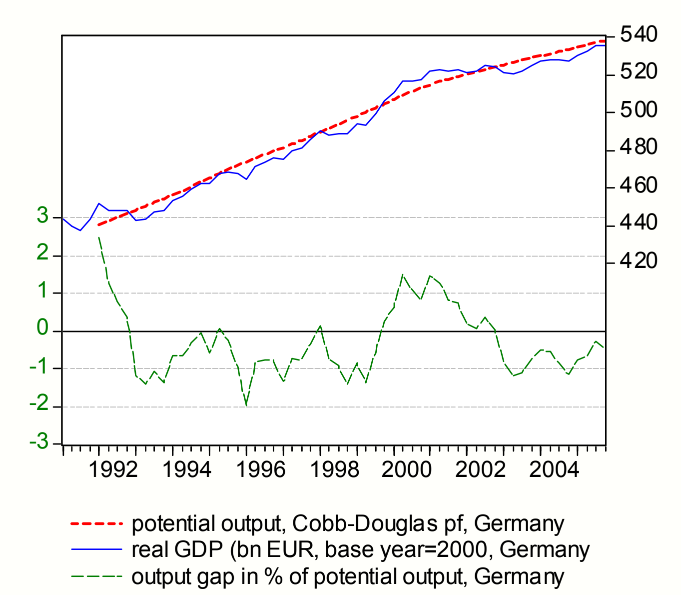


Chart 7.4
Germany's potential output and output gap according to the Cobb-Douglas production function



HP filter

The HP filter designed by Hodrick and Prescott (1997) decomposes a time series into a non-stationary and a stationary component. The nonstationary part is sometimes referred to as the permanent component, the stationary one as the transitory component. The path of the nonstationary component is smoothed using its weighted second differences as the smoothing parameter. In addition, the stationary component is defined to be zero on average. It can be shown that the permanent component then corresponds to a moving average with weights reaching infinitely back in time. Because time series are finite, endpoint problems emerge that bias filtering results at the beginning and at the end of the time series. The endpoint problem can be solved by extending time series with forecasts. To make forecasts, the times series has to be fitted to a process, however, which is a drawback because it gives rise to forecast errors. Furthermore, because the transitory component converges to zero at the end of the (forecast) period (in order for the estimated process to satisfy the usual stability requirements), the arrival of new data points can lead to considerable revision.

The nonstationary component of the time series GDP can be interpreted as potential output y^*. The transitory component is the difference between actual, observed output (y) and the permanent component output, i.e. the ouput gap (ygap). The parameter λ is the so-called penalty term which helps to control the smoothing of y_t. For $\lambda \rightarrow \infty$, y^*_t follows a linear trend, for $\lambda \rightarrow 0$, y^*_t corresponds to the observed time series. The value of λ depends on the data frequency. In general, $\lambda = 100$ for annual data, $\lambda = 1600$ for quarterly data and $\lambda = 14440$ for monthly data; despite much research, there is, however, no consensus on these values.

Most econometric software packages include the HP filter as a standard feature. Applying the HP filter is relatively easy and demonstrated here using the software EViews:

1. Start program and under File/Open/Workfile open a file containing the GDP time series.
2. A new window opens showing the available data sets. The series to be filtered may be opened with a double left click. A new window then shows the data (spreadsheet).[87]
3. In this window, select the HP filter under Procs/HP filter. The series to be filtered may be named (otherwise EViews names it) and the smoothing parameter λ can be entered according to the frequency of the data or other criteria. EViews 5 automatically also saves the transitory component as a time series.
4. EViews then computes the HP filter and displays the permanent component and the initial time series in a chart.
5. Upon closing the chart, EViews saves the permanent component; in the workfile window the time series is available under the name it has been given.
6. To retrieve the transitory component, the following command must be entered in the command line:

[87] The data should be seasonally adjusted because the HP filter is unable to distinguish between seasonal and cyclical movements.

Genr *„variable_name“=“original_time_series“ – „permanent_component“*. In EViews 5 one only has to open the time series create in step 3.

ARIMA model

The endpoint problem mentioned above may in part be solved by adding optimal forecasts to the time series. The optimal forecast is the conditional expected value. To determine the conditional expected value, the time series has to be fitted to a process. The following procedure is expedient:

Testing the data for stationarity or instationarity using a unit root test: open the file, double click the desired time series. Under *View/Unit Root Test* several tests may be selected. Often the augmented Dickey Fuller (ADF) test is used. Here the model to be tested must be specified, i.e. with or without trend and/or constant.

Once the order of integration of the time series has been determined, an ARIMA model may be fitted.[88] For instance, an ARIMA (1,1,1) process is given by:

(A.2) $$(1-\alpha L)(1-L)y_t = \delta + (1-\beta L)\varepsilon_t$$

L denotes the lag operator.

The corresponding EViews command is:

ls d(y) c ar(1) ma(1).

Here the operator d(.) is the first-difference operator.

Once the model has been specified and found to be good according to the usual criteria, the optimal forecast is made by clicking the button “forecast”.

EViews allows the user to forecast data in levels and in first differences.

The forecast is then displayed in a new window (initially as a graph). Under *View/Spreadsheet* the corresponding data may be viewed. The forecast data may be copied and pasted into the spreadsheet of the original time series. As a rule of thumb eight projected data points are sufficient to alleviate the endpoint problem (i.e. for quarterly data two years). The HP filter may then be applied to the prolonged time series (as described under 3.).

Multivariate HP filter

The multivariate HP filter cannot easily be applied in standard econometrics software like EViews and RATS because they do not include it. Therefore we include here a MVHP filter program written for EViews and explain how to use it.

To estimate with the MVHP filter, it is necessary to construct a matrix of weights which depends on the specification of the Phillips curve, the HP parameter and the length of the observation period. The procedure presented here follows Stamford (2005) who derives the

[88] See, for example, Hamilton (1998) as well as Kirchgässner and Wolters (2005).

matrix of weights for the univariate HP filter. Starting points are the functions to be minimized by both HP filters (all capital letters are matrices):

Univariate HP filter:

$$Min_{t=0\ldots T+1}\ \Sigma_{t=T}\ \{\ (u_t - u^*_t)^2 + \lambda^*(u^*_{t+1}\ -2\ u^*_t + u^*_{t-1})^2\ \}$$

The function is minimized by differentiating it with respect to u^*_t (although completely only for t=3…T-2; for t=1,2,T-1 and T some terms are omitted):

$$0 = -2(u_t - u^*_t) + 2\lambda(u^*_{t+2}\ -2\ u^*_{t+1} + u^*_t) - 4\lambda(u^*_{t+1}\ -2\ u^*_t + u^*_{t-1}) + 2\lambda(u^*_t\ -2\ u^*_{t-1} + u^*_{t--2})$$

In matrix form the equation above is:

$$U = HPMat(\lambda,T)\ U^*,$$

where U and U^* are two column vectors containing the data points for the unemployment rate and the NAIRU.

To determine the NAIRU time series, the matrix HPMat(λ,T) must be inverted which all standard software packages permit with minmal programing effort. The inverted matrix is:

$$U^* = HPMat^{-1}(\lambda,T)\ U$$

Multivariate HP filter:

$$Min_{t=0\ldots T+1}\ \Sigma_{t=T}\ \{\ (u_t - u^*_t)^2 + \lambda^*(\ u^*_{t+1}\ -2\ u^*_t + u^*_{t-1})^2\ +\ \lambda_2(y_t\text{-}\alpha(u_t - u^*_t)\text{-}\beta X_t)^2\}$$

where y_t-$\alpha(u_t - u^*_t)$-βX_t are the (estimated) residuals of a predefined Phillips curve.[89]

The function is minimized analogously to the univariate case:

$$0 = -2(u_t - u^*_t) + 2\lambda(u^*_{t+2}\ -2\ u^*_{t+1} + u^*_t) - 4\lambda(u^*_{t+1}\ -2\ u^*_t + u^*_{t-1}) + 2\lambda(u^*_t\ -2\ u^*_{t-1} + u^*_{t--2})$$
$$+\ 2\alpha\lambda_2(y_t\text{-}\beta X_t) - 2\alpha^2\lambda_2(u_t - u^*_t)$$

This can be simplified to:

$$0 = -\ (u_t - u^*_t) + \lambda(u^*_{t+2}\ -2\ u^*_{t+1} + u^*_t) - 2\lambda(u^*_{t+1}\ -2\ u^*_t + u^*_{t-1}) + \lambda(u^*_t\ -2\ u^*_{t-1} + u^*_{t--2})$$
$$+\ \alpha\lambda_2(y_t\text{-}\beta X_t) - \alpha^2\lambda_2(u_t - u^*_t)$$

The multivariate case in matrices is somewhat more complex than the univariate case:

$$U = HPMat(\lambda,T)\ U^* +\ \alpha\lambda_2(Y\text{-}\beta X) - \alpha^2\lambda_2(U - U^*)$$

$$\Rightarrow (1+\alpha^2\lambda_2)U - \alpha\lambda_2(Y\text{-}\beta X) = (HPMat(\lambda,T) + \alpha^2\lambda_2 I)\ U^*\ \text{(I = identity matrix).}$$

$$\Rightarrow U^* =\ [(HPMat(\lambda,T) + \alpha^2\lambda_2 I)]^{-1}\ [(1+\alpha^2\lambda_2)U - \alpha\lambda_2(Y\text{-}\beta X)]$$

$$\Rightarrow U^* =\ [HPMat\mathbf{M}(\lambda,\lambda_2,\alpha^2,T)]^{-1}\ [(1+\alpha^2\lambda_2)U - \alpha\lambda_2(Y\text{-}\beta X)]$$

The last equation is calculated by the EViews program below. Several parameters have to be supplied:

[89] An example of a Phillips curve is given in section 5.3.

λ and λ_2 — HP smoothing parameters

T — number of observations

α and β — estimated coefficients of the Phillips curve

For this equation the coefficients of the Phillips curve are initially exogenous. They are endogenized using the following loops (denoted as i):

Step 1: The initial values of the NAIRU are determined with a univariate HP filter:

$$U_{i=0}^{*} = HPMat^{-1}(\lambda,T)\ U.$$

Step 2: This initial NAIRU time series is used to estimate the Phillips curve. This yields the initial coefficients of the Phillips curve ($\alpha_{i=0}$ and $\beta_{i=0}$).

Step 3: On this basis, the first multivariate estimate of the NAIRU is made:

$$U_{i=1}^{*} = [(HPMat(\lambda,T) + \alpha_{i=0}^{2}\lambda_2 I)]^{-1}\ [(1+\alpha_{i=0}^{2}\lambda_2)U - \alpha_{i=0}\lambda_2(Y-\beta_{i=0}X)]$$

Step 2 is repeated and the Phillips curve is estimated with the new NAIRU series. The loop process between step 2 and step 3 ends if a certain convergence criterion is satisfied, e.g. if the log likelihood does not change much between two loops. The MVHP NAIRU is then given by the last loop ($U_{i=I}^{*}$).

The program uses the following parameters:

λ = 100 (in the chart also 500 and 10).

λ_2 = 4 (in the chart also 1, 6 and 16).

T = 33 (the time period 1973-2005 has exactly 33 observations).

Y = hourly wages in second differences ($\Delta^2 w_h$)

X = a constant and hourly productivity in second differences, lagged by one period ($\Delta^2 prodh_{-1}$)

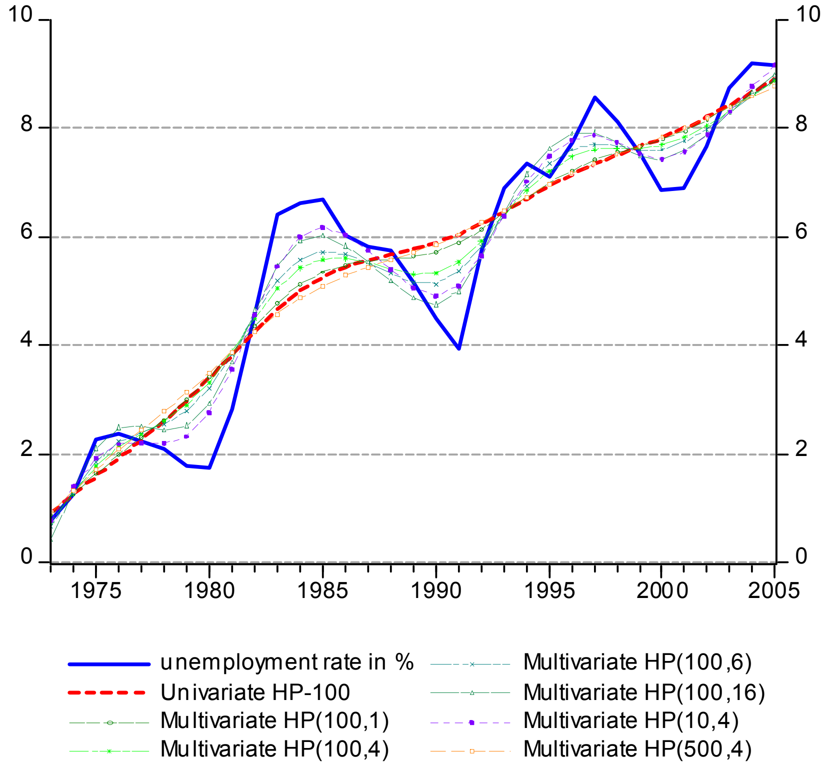
β = coefficient vector with two coefficients (β_1,β_2)

HPMat(λ,T) is constructed analogous to Stamfort (2005: 27).

The convergence criterion states that the loop process should end if the difference between the log likelihood values of two consecutive loops is smaller than 10^{-7} in absolute terms.

Chart 7.5 shows several MVHP NAIRUs (with different combinations of λ and λ_2) in comparison with a NAIRU derived from a univariate HP filter.

Chart 7.5
MVHP NAIRUs (with different combinations of λ and $λ_2$)



Commented EViews program to estimate the NAIRU with a multivariate Hodrick-Prescott filter

Information that has to be entered at the beginning is highlighted in yellow.

Comments are marked '***

```
'*********************************************************************************
'*** Program to derive the weights of a multivariate HP filter
'*** as in Stefan Stamfort Bundesbank Working Paper 19/2005.
'*** written by Camille Logeay (IMK, 2006)
'*********************************************************************************

if @isobject("smp") then
delete smp
endif
sample smp 1973 2005        '*** observation period

!T = @obs(obs,smp)          '*** number of observations in the period under review
smp  (the number must exceed 5).


!lambda = 100          '*** HP parameter
!lambda2 = 4           '*** HP parameter (Phillips curve)
```

!konkri=0.0000001 '*** convergence criterion

%eqname = "phillips" '*** Name of the Phillips curve. Note: a change in the equation has implications further along in the program which must be adjusted by hand.
'*** Here the multivariate HP filter is initialized

smpl @all

'*** Initially the MVHP NAIRU equals the univariate HP NAIRU.

if @isobject("de_urilo_mvhp") then
delete de_urilo_mvhp
endif
de_urilo.hpf(100) de_urilo_mvhp

'*** The Phillips curve is reestimated using this first MVHP NAIRU. The coefficients alpha and beta are saved. The log likelihood value is also saved. [If changes are made in the Phillips curve, adjustments have to be made here!]

phillips.ls
!alpha = phillips.@coefs(1)
!c2 = phillips.@coefs(2)
!c3 = phillips.@coefs(3)
!loglik = phillips.@logl

'*** As EViews handles the format of objects strictly, an intermediary program step is necessary in which the time series of the unemployment rate and the exogenous variables of the Phillips curve are saved as column vectors [If changes are made in the Phillips curve, adjustments have to be made here as well!]

smpl 1973 2005
stom(de_urilo,alq,smp)
stom(de_d2lkh,d2lkh,smp)
stom(de_d2prodhlag1,d2prodh,smp)

'**
'*** Generating the univariate HP matrix as in Stamfort (2005: 27).
'*** Univariate HP: U = HPMat U*

if @isobject("HPMat") then
delete HPMat
endif
matrix(!T, !T) HPMat=0 '*** symmetrical matrix: sym(!T)

'*** First and last rows because the general equation applies only to t=3…T-2! The starting point and endpoint values have to be calculated as below.

HPMat(1,1) = 1+!lambda
HPMat(1,2) = -2*!lambda

```
HPMat(1,3) = !lambda

HPMat(!T,!T-2) = HPMat(1,3)
HPMat(!T,!T-1) = HPMat(1,2)
HPMat(!T,!T) = HPMat(1,1)

'*** Second and second-to-last rows
HPMat(2,1) =   -2*!lambda
HPMat(2,2) = 1+5*!lambda
HPMat(2,3) = -4*!lambda
HPMat(2,4) = !lambda

HPMat(!T-1,!T-3) = HPMat(2,4)
HPMat(!T-1,!T-2) = HPMat(2,3)
HPMat(!T-1,!T-1) = HPMat(2,2)
HPMat(!T-1,!T) = HPMat(2,1)

'*** For the other rows the values are determined according to the general equation.
for !k=3 to !T-2

HPMat(!k,!k) = 1+6*!lambda
HPMat(!k,!k+1) = -4*!lambda
HPMat(!k,!k+2) =!lambda

HPMat(!k,!k-1) = HPMat(!k,!k+1)
HPMat(!k,!k-2) = HPMat(!k,!k+2)

next


'*** Here the first loop of the MVHP filter is calculated
'*** First HPMatm(λ,λ_2,α^2,T) is generated for i=0.

if @isobject("HPMatm") then
delete HPMatm
endif
matrix(!T, !T) HPMatm=0      '*** symmetrical matrix: sym(!T)

HPMatm = (HPMat + !lambda2*!alpha^2*@identity(!T))

if @isobject("HPMat_inv") then
delete HPMat_inv
endif
matrix(!T, !T) HPMat_inv=@inverse(HPMatm)

'*** Calculation of the NAIRU for the multivariate case and for the first loop. [If the
Phillips curve is altered, the last term here must be adjusted!]

vector alq_mvhp = HPMat_inv*((1+!alpha^2*!lambda2)*alq-
((!lambda2*!alpha^2)*(d2lkh -!c2*d2prodh -!c3)))

'*** Converting the NAIRU vector into a time series and using it to overwrite the first
MVHP NAIRU, which in actual fact is a univarite NAIRU.
```

```
mtos(alq_mvhp,de_urilo_mvhp,smp)

'*** This new NAIRU is used to update the Phillips curve and its coefficients. The
previous log likelihood value is not immediately overwritten.

phillips.ls
!alpha = phillips.@coefs(1)
!c2 = phillips.@coefs(2)
!c3 = phillips.@coefs(3)

'*** Loop process for the MVHP NAIRU

'*** loops automatically specifies the number of executed loops; it is initialized to
zero.
scalar loops=0

if @abs(!loglik-phillips.@logl)> !konkri then '*** convergence criterion

!loglik = phillips.@logl          '*** updating of the log likelihood value only now

'*** Recalculation of the HP matrix for the multivariate case

HPMatm = (HPMat + !lambda2*!alpha^2*@identity(!T))
if @isobject("HPMat_inv") then
delete HPMat_inv
endif
matrix(!T, !T) HPMat_inv=@inverse(HPMatm)

'*** Recalculation of the MVHP NAIRU

vector alq_mvhp = HPMat_inv*((1+!alpha^2*!lambda2)*alq-
((!lambda2*!alpha^2)*(d2lkh -!c2*d2prodh -!c3)))
mtos(alq_mvhp,de_urilo_mvhp,smp)

'*** Updating the Phillips curve

phillips.ls
!alpha = phillips.@coefs(1)
!c2 = phillips.@coefs(2)
!c3 = phillips.@coefs(3)

loops=loops+1
else

stop

endif

'*** Unnecessary objects are automatically deleted from the workfile.

delete ALQ ALQ_MVHP D2LKH D2PRODH HPMAT HPMAT_INV HPMATM SMP
```

'*** The final MVHP NAIRU is saved in the EViews workfile under de_urilo_mvhps.

Annex II:
Vintage models

Vintage models used to determine the capital stock relate the technology inherent in the capital stocks to the age structure of the capital stock.

The age structure of the capital stock can be important in measuring the trend of total factor productivity (TFP). McMorow and Röger (2001) use a simple vintage specification to relate past changes in TFP to changes in the age structure of the capital stock. According to this approach, technological progress is embodied in the latest models of machinery and equipment. Investment may therefore not only impact on capacity but also on productivity. McMorrow and Röger (2001) capture these effects with the ratio of the life of the capital stock to the capital stock, i.e. the average age of the capital stock. Early articles on vintage modeling are D. Jorgenson (1966), „The Embodiement Hypothesis“, *Journal of Political Economy*, 74,1, February, 1-17 and several articles by R. Solow (in particular „Technical Change and the Aggregate Production Function“, *Review of Economics and Statistics*, 39, 3, 312-20, as well as „Investment and Technical Progress“, Arrow, Karlin, Suppes eds., *Mathematical Models In The Social Sciences*, 1959, Stanford University Press).

Annex III:

Returns to factor inputs in monopolistic markets

Denis et al. (2002) assume highly competitive markets. This justifies the assumption that factor inputs are paid the values of their marginal products. The wage rate therefore corresponds to $w^c = p^* MP(L)$, where w^c := nominal wage in a perfectly competitive and MP(L) := $\partial Y/\partial L$. To assume that the markets in the European Union are perfectly competitive, is surely unrealistic. Such an assumption could nonetheless be accepted if the assumption of monopolistic markets led to the same estimation results as the assumption of perfectly competitive markets. Below we show that this is not the case:

For the monopolistic case, theory states: $w^m = MRP(L)$, where w^m := nominal wage in monopolistic markets, $MRP(L) := p^*(1 + 1/\varepsilon_n)^* MP(L)$ with ε_n := price elasticity of demand.[90]

Without assuming a specific demand function, it follows that

(A.3) $w^m < w^c$.

For the assumed Cobb-Douglas function the following holds:

(A.4) $MP(L) = \alpha(Y/L)$

(A.5) $MRP(L) = \alpha(Y/L)\mu$, where $\mu := (1 + 1/\varepsilon_n)$

For this type of production function the partial elasticities of output with respect to the factor inputs are α and 1-α. If the wage rate equals the value of the marginal product, the wage share is given by:

(A.6) $WS^c = w^c L / (pY) = (p\alpha\ Y/L\ L) / (pY) = \alpha$

Therefore it is legitimate to use the wage share as a proxy for the partial elasticity in competitive markets.

In contrast, in monopolistic markets the following holds for the wage share:

(A.7) $WS^m = w^{m*} L/(pY) = (\alpha p\ Y/L\ \mu\ L)/(pY) = \alpha\mu < \alpha$

Assuming negative price elasticity of demand (normal goods), the wage share is therefore smaller in monopolistic markets than in competitive markets. It follows that the partial elasticity α is greater than the wage share. In the case of monopolistic markets, using the wage share as a proxy for the partial elasticity introduces a bias into the estimate. The exponent of labor would be too small, that of capital too high.

[90] $-1<\varepsilon_n<0$; $\varepsilon_n=-1 \Leftrightarrow$ perfectly elastic demand, $\varepsilon_n = 0 \Leftrightarrow$ perfectly inelastic demand.

8 Glossary

Adaptive expectations

The concept of adaptive expectations was made popular in the sixties by Milton Friedman in the debate about the Phillips curve. Economic agents with adaptive expectations revise their expectations in period t by making an error adjustment to partially reflect the forecast error made in the previous period. The "mechanical" correction mechanism and the fact that new information played no role in expectation formation was strongly criticized and in the seventies led to the increased use of rational expectations (see rational expectations). Mathematically adaptive expectations may be written as $x_t^{e,adap.} = x_{t-1}^{e,adap.} + \gamma\left(x_{t-1} - x_{t-1}^{e,adap.}\right)$, where $0 < \gamma \leq 1$. Empirical studies show that adaptive expectations are often a good representation of reality.

Literature: **Lucas, Robert and Sargent, Thomas** (eds.) (1981), *Rational Expectations and Econometric Practice*, George Allen & Unwin Ltd. 1981; **Friedman, Milton** (1968), The Role of Monetary Policy, American Economic Review, Vol. 58, Issue 1, 1968: 1 – 17; Roberts (1995), Nielsen (2003), Grant and Thomas (1999) and Mankiw (2001); Grant, A. P. and Thomas, L. B. (1999), Inflationary expectations and rationality revisited, *Economic Letters* 62(3): 331-338; Nielsen, H. S. (2003). *Essays on expectations*, Shaker, Aachen.

Autoregressive process (AR process)

An autoregressive process of order k can in general be written as $x_t = \delta + \sum_{j=1}^{k} \alpha_j x_{t-j} + \varepsilon_t$, where ε_t is a random white noise process. Therefore the variable at time t is dependent on its own lags and a disturbance term (consisting of the absolute term and the error term). An essential characteristic of autoregressive processes is that the autocorrelation function is an infinite zero sequence and the partial autocorrelation function stops after order k.

Classical dichotomy

The term classical dichotomy denotes the idea that the economy may be split into two spheres that do not affect each other: a real one and a monetary one. Nominal variables are thought to affect only the price level but not the economically relevant relative prices. The latter are only influenced by real shocks (e.g. technology shocks, raw material shocks or preference shocks). Money and monetary policy are neutral in this paradigm.

Further reading: **Tobin, J.** (1992), Essay On Money, in Newman, P., Milgate, M. and Eatwell, J. (Eds.) *The New Palgrave Dictionary of Money and Finance*, London MacMillan Press 1992, **Ackley, G.** (1978), *Macroeconomics: Theory and Policy*, MacMillan New York 1978.

Cointegration

Two or more variables of the same order are said to be cointegrated if there is at least one non-trivial linear combination of these variables that is integrated of a lower order. If variables are cointegrated they have a common long-term stochastic trend.

Dummy variable

A dummy variable is an artificially created variable that takes the values 0 or 1. In general dummy variables are used in regressions to capture phenomena that cannot be measured, such as characteristics like gender. They can be used in particular to model discrete changes such as structural breaks and to eliminate seasonal fluctuation. Time series analysis distinguishes between step dummy variables and impulse dummy variables. Step dummy variables take the value 0 for a specific time period and in the following periods the value 1. Impulse dummy variables take the value 1 only in one point in time; otherwise they take the value zero. It follows that step (or shift) dummy variables shift the entire time series, whereas impulse dummy variables only provide a short impulse. Impulse dummy variables can be generated by first-differencing step dummy variables.

Introductory reading: **Wooldridge, J.** (2006), *Introductory Econometrics: A Modern Approach*, 3rd ed. Thomson South-Western 2006; Further reading: **Greene, W.** (2003), *Econometric Analysis*, 5th ed., Pearson Education / Prentice Hall 2003.

Elasticity of substitution

The elasticity of subsitution indicates how strongly the factor input ratio reacts to a change in the price of the inputs; see production function.

Endogeneity

The term endogeneity derives from the Greek word "endogen" which means to come from inside. In economic modeling variables are considered endogenous if they are to be explained or determined by the model itself.

In contrast, variables are classified as exogenous if they are determined a priori and remain unchanged during the model run.

Ergodicity

Statistical time series can be interpreted as data generating processes. The assumption of ergodicity is made because for non-experimental data usually only one time series exists and in general this is insufficient for statistical inference. This assumption says that the longitudinal moments (time dimension) and the cross-sectional moments (spatial dimension) converge. The ergodicity of dependent random variables cannot be tested for empirically. A condition for the validity of the assumption of ergodicity is stationarity of the underlying process. Wolters (2005: 13): "A stochastic process can only be ergodic if it is in some kind of equilibrium, i.e. it must be stationary." (Quote translated from German).

General-To-Specific approach

General-to-specific modeling, popularized by David Hendry, is an approach to correctly specifying econometric models or, in other words, to determine the relevant explanatory variables. The reasoning is that an estimate suffers more quality loss if relevant variables are omitted than if irrelevant variables are included. Therefore one should start with a large model including many explanatory variables and a complex lag structure and then proceed to eliminate insignificant variables and lags one by one to arrive at an accurate specification.

Further reading: **Hendry, D.** (1995), *Dynamic Econometrics*, Oxford University Press 1995.

Least square analysis

Least square analysis is one of the most popular methods of estimating coefficients in regression model. Because of the disturbance term ε_t in relations of the form $y_t = \alpha + \beta x_t + \varepsilon_t$, the values of y_t disperse around a straight line $\alpha + \beta x_t$ (determined by the regression function). The least square method minimizes the sum square deviations of the deterministic component. (The deviations are squared because otherwise they would cancel each other in sum.) The function to be minimized is:

$min_{\alpha,\beta}\ \Sigma_{t=1...T}\ \varepsilon^2_t = \Sigma_{t=1...T}\ (y_t - \alpha - \beta x_t)^2$

Minimization yields the following estimators:

$\alpha^{ols} = y^{mean} - \beta^{ols}\ x^{mean}$ *and* $\beta^{ols} = [Cov(x,y)] / [Var(x)]$

For regressions of the form $y_t = \alpha + \beta x_t + \varepsilon_t$, least square analysis provides the best linear unbiased estimator (BLUE). The estimators are consistent.

Introductory reading: **Wooldridge, J.** (2006), *Introductory Econometrics: A Modern Approach*, 3rd ed. Thomson South-Western 2006. Further reading: **Greene, W.** (2003), *Econometric Analysis*, 5th ed., Pearson Education / Prentice Hall 2003.

Maximum likelihood estimation

A popular estimation method on par with least squares analysis, the method of maximum likelihood (ML method) requires a certain assumption about the probability distribution of observations (e.g. Gaussian distribution). The corresponding probability density can then be interpreted as a function of specific parameters (e.g. mean and variance in the case of Gaussian distribution). For given observations $y_1,...,y_T$ and a density function $f(.)$ the function $L(\theta) = f(y_1,...,y_T;\theta)$ is called the likelihood function. The ML principle now says that the parameter(s) $\hat{\theta}$ should be used as estimation functions for the given observations that satisfy the condition $\hat{\theta} = \arg\max L(\theta)$. For regression models (see regression analysis) such as $y_t = \alpha + \beta x_t + \varepsilon_t$ the ML estimation arrives at the same estimators for α, β as the method of least squares.

Neutrality of money

The concept of money neutrality is closely related to the classical dichotomy paradigm (see classical dichotomy), which divides the economy into a monetary and a real sphere. Given the classical dichotomy, nominal variables do not affect real variables; they are neutral. Real economic activity is therefore independent of the monetary policy regime and only real variables can affect real variables. In the eighties, the distinction was first made between neutrality and superneutrality. Neutrality refers to the real ineffectiveness of a change in the money volume and superneutrality to that of a change in the growth rate of money. The current mainstream allows for the short-term nonneutrality of money, long-term nonneutrality remains a matter of dispute.

Further reading: **Tobin, J.** (1992), Essay On Money, in Newman, P., Milgate, M. and Eatwell, J. (Eds.) *The New Palgrave Dictionary of Money and Finance*, London MacMillan Press 1992, **Ackley, G.** (1978), *Macroeconomics: Theory and Policy*, MacMillan New York 1978.

Nonstationarity

A process is nonstationary if it does not have a stationary mean. If the covariance is nonetheless stationary, the process has a deterministic trend and is termed trend-stationary because deviations from this trend are (weakly) stationary. Another kind of nonstationary processes are integrated processes that are neither stationary in mean nor in covariance but rather have a stochastic trend. A process is integrated of order q [I(q)] if it becomes stationary after differencing q times. In econometric analyses integrated processes with $q > 2$ are rare.

Okun's law

Okun's law was named after A. Okun and describes the negative relationship between the relative deviation of real production from potential output and the deviation of the unemployment rate from the natural rate. A ratio of 3 to 1 was estimated by Okun (for U.S. data, 1947-1960) (see also page 11 of this report). An increase in the output gap by one percentage point would accordingly involve a reduction in the unemployment gap by 0.3 percentage points.

Literature: http://www.clevelandfed.org/Research/com97/0515.htm#1b; Okun, A. M. (1962): Potential GNP: Its measurement and significance, Proceedings of the American Statistical Association, Business and Economics Section, p. 92–103.

Ordinary Least Squares (OLS) s. least square analysis

Phillips curve

A.W. Phillips (1958) of New Zealand discovered the Phillips curve as an empirical phenomenon. Initially it described the negative relation between changes in money wages and in unemployment. Samuelson and Solow (1960) later substitute inflation for the increase in money wages. The trade-off between inflation and unemployment was considered relatively stable until Phelps (1967) and Friedman (1968) introduced expectations into the Phillips curve and derived a vertical Phillips curve for the long run. The Phillips curve has been the subject of numerous theoretical and empirical studies and controversies. Several recent empirical studies indicate that the Phillips curve may shift over time or that it is not vertical in the long run.

Literature: Friedman, M. (1968): The role of monetary policy, American Economic Review 68: 1-17; Phelps, E. S. (1967): Phillips Curves, Expectations of Inflation and Optimal Unemployment Over Time, Economica, Vol. 34: 254-81; Phillips, A. W. (1958): The relation between unemployment and the rate of change of money wage rates in the United Kingdom 1861-1957, Economica 25: 283-299.

Production function

Production functions show the maximum output levels that may be produced with given factor inputs. A frequent characteristic used to distinguish between different production functions is the elasticity of substitution, i.e. to what extent factor inputs may be substituted for each other given a constant production level.

Production function, Leontief (fixed-proportions production function)

Leontief production functions are characterized by fixed proportions of the factor inputs. Substitution is not possible. Output can only be raised if all factor inputs are increased in fixed, constant proportions (zero elasticity of substitution). Scarce factor inputs are the limiting factors of production because they limit the increase of output due to the fixed ratio of factors. Mathematically, Leontief production functions with the production factors capital and labor are given by $Y = \min [K/v, L/u]$, where v and u may be interpreted as the respective factor productivities.

Production function (factor substitution)

It is characteristic of this type of functions that factor inputs are at least in part substitutable (given the level of output) implying a variety of efficient factor proportions. Generally positive but diminishing marginal returns are assumed. Mathematically, this type of function may be expressed as: $Y_t = A_t F(K_t, L_t)$, where $\partial Y/\partial L > 0$, $\partial Y/\partial K > 0$, $\partial^2 Y/\partial L^2 < 0$, $\partial^2 Y/\partial K^2 < 0$, $F(0,K) = 0$, $F(L,0) = 0$ and K_t stands for capital, L_t for labor and A_t for technological progress.

Production function, CES

CES functions are a subgroup of production functions with factor substitution. The abbreviation CES stands for constant elasticity of substitution. CES functions with the factors capital and labor may be written mathematically as: $Y_t = A_t[aK_t^{-\rho} + bL_t^{-\rho}]^{-1/\rho}$, where a and b are arbitrary constants. The elasticity of substitution is given by $\sigma = 1/(1 + \rho)$. CES functions have constant returns to scale.

Production function, Cobb-Douglas

Cobb-Douglas functions have a constant elasticity of substiution of one and are therefore CES functions. Mathematically, Cobb-Douglas functions with the factors capital and labor are generally expressed as $Y_t = A_t K_t^{\alpha} L_t^{\beta}$. If $\beta = 1 - \alpha$, returns to scale are constant and the parameters β and α represent the profit share and the wage share, respectively.

Samuelson, P. A. / Solow, R. M. (1960): Problem of archieving and maintainig a stable price level. Analytical aspects of anti-inflation policys, American Economic Review, Papers and Proceedings 50: 177-194.

Rational expectations

The concept of rational expectations was introduced by John Muth in the sixties of the last century but was only popularized in the seventies by Robert Lucas Jr. In contrast to adaptive expectations (see glossary entry), rational expectations are formed using all available information. Economic agents' expectations thus correspond to the optimal forecast of the model used to describe these economic agents. Mathematically rational expectations about time t+1 are formulated as the expected value in time t $x_{t+1}^{e,rat.} = E\left[x_{t+1} \middle| I_t\right]$, where I_t is the information available in t.

R² and adjusted R²

The coefficient of determination, R^2, is a standardized measure to evaluate how well an estimated model fits the data. It specifies how much of the total variance is explained by the model: $R^2 = \frac{\frac{1}{T}\sum_{t-1}^{T}\left(\hat{y}_t - \bar{\hat{y}}\right)^2}{\frac{1}{T}\sum_{t-1}^{T}\left(y_t - \bar{y}\right)^2}$, where $0 \le R^2 \le 1$. $R^2 = 0$ means that none of the explanatory variables are significant and the model explains nothing, whereas $R^2 = 1$ indicates that the model can explain the entire variance. Given the sample size T, the coefficient of determination increases with the number of explanatory variables. It can therefore only be used to compare models of the same order and with the same dependent variable.

The adjusted R² partially addresses this problem by taking into account the number of independent variables (k including constants): $\overline{R^2} = 1 - \frac{T-1}{T-k}\left(1 - R^2\right)$.

The following holds: $\overline{R^2} = R^2 \Leftrightarrow R^2 = 1$ and $\overline{R^2} < R^2$ for $R^2 < 1$. Both measures are invariant with respect to linear transformations.

Regression analysis

A regression model can be written as $y_t = f(x_t) + \varepsilon_t$, where $f(x_t)$ is a deteministic regression function and ε_t an error term that can not be explained by the deterministic part of the function. Because ε_t is a stochastic variable, the entire function is stochastic. This, in turn, implies that for every value of x_t there exists not only one but an entire probability distribution of values for y_t. The most frequently used deterministic regression function is the linear function $f(x_t) = \alpha + \beta x_t$. The resulting model is often called a simple linear regression model: $y_t = \alpha + \beta x_t + \varepsilon_t$. The coefficients of this function can be statistically estimated with different methods (e.g. least squares and maximum likelihood) given assumptions about the stochastic nature of the disturbance term.

Replacement rates

Replacement rates are social security payments designed to compensate for a loss in earnings. In Germany, these include sick pay once the employer no longer needs to pay wages/salaries (after six weeks), unemployment benefits and, more recently, parent money.

Say's law

Say's law is attributed to Jean-Baptiste Say and states that supply creates its own demand. The reasoning is that the production of goods is only planned if there is also a plan to use the generated income for investment or consumption purposes. Say's law implies a fully flexible interest rate mechanism which causes savings to be matched by credit demand.

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Solow residual

The so-called Solow residual was originated by Solow (1957). In this article, Solow showed how to solve the problem of estimating an aggregate production function with time series data.

A production function relates one or more factor inputs to output at a particular point in time (see glossary entry). Generally, only aggregate production data are statistically available as time series so that the observations only represent one point on the production function prevailing at each point of time. As the production function is not constant over time but shifts as a result of technological progress, estimating requires a prior correction for this shift.

Using a general production function with neutral technological progress

$Y = A(t)F(K,L) \Leftrightarrow \partial \ln(Y)/\partial t = \partial \ln(A)/\partial t + \partial \ln F(K,L)/\partial K * \partial K/\partial t + \partial \ln F(K,L)/\partial L * \partial L/\partial t$

Solow was able to express the growth rate of the unobservable technological progress [dA(t)/dt]/A(t) as a function of observed variables. Using this growth rate, Solow then determined the level A(t) for each point in the observation period and adjusted the level of output by this factor. His analysis resulted in a concave production function, i.e. one with diminishing marginal returns.

The variable A(t) is called the Solow residual because it emerges as the residual of observed variables. Theory and imagination led economists to interpret this (statistical) residual as technological progress. Schulz (1961) interpreted the Solow residual as human capital. Uzawa (1965) and Lucas (1988) incorporated this idea in a theoretically sound model and thereby lay one of the cornerstones of modern growth theory.

Stationarity

A stochastic process is termed strictly stationary if its probability distribution is time-invariant.

For practical use, the concept of weak stationarity is more appropriate. A stochastic process is weakly stationary if its mean is constant for all time periods and autocovariances are only a function of the distance of the observed random variables on the time axis and therefore independent of the precise time of their realization (covariance stationarity). Unlike ergodicity, stationarity can be empirically tested (e.g. ADF test and tests for heteroscedasticity).

9 References

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