An Estimation of Unemployment Hysteresis

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Abstract

This paper explores the degree of hysteresis in EU unemployment rates. The hysteresis hypothesis holds that actual (demand-determined) unemployment can turn into structural unemployment. The European Commission estimates and reports NAIRUs as part of the AMECO dataset, which also inform the EU fiscal policy rules. These exclude the possibility of hysteresis by assumption. We present a simple model to estimate hysteresis effects. We demonstrate that there is significant evidence for the existence of unemployment hysteresis in the majority of the EU15 countries. In the EU15 as a whole, we find the average degree of hysteresis to be 80%. Our findings suggest that the European Commission could profitably consider alternative NAIRU estimation strategies that allow for unemployment hysteresis. These results have two important consequences for policy makers. First, they indicate that a lack of government intervention in response to negative shocks has immediate effects in the form of increasing unemployment as well as long-lasting effects on the NAIRU. This is consistent with the *OECD Employment Outlook 2017*. Second, as the NAIRU estimates enter the calculation of the output gap and the structural deficit, the EU Fiscal Compact should be reconsidered.

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1. Some context and how this paper relates to Tom Michl's work

In spring 2014 Tom Michl visited Kingston University, which back then had an active non-mainstream economics group. One of us (Engelbert) had several discussions with Tom about Keynesian and Marxist theory in general and about unemployment hysteresis in particular. While we planned to do joint work on this, that unfortunately never materialised. Building on these discussions Tom published two papers on hysteresis on the three equation model (Michl 2018 and Michl and Oliver 2019) and Engelbert co-authored two theoretical papers with Hiroshi Nishi on unemployment hysteresis in post-Keynesian and neo-Goodwin models (Nishi and Stockhammer 2020a, 2020b) and some empirical work on unemployment hysteresis with Rob Calvert Jump. Tom's work on hysteresis explores how hysteresis works out in conventional three equation models, which are widely used for (mainstream) analyses of monetary policy. It is concerned with the effectiveness and monetary policy and the question whether path-dependent outcomes arise and whether (standard) monetary policy can prevent them.

The theoretical implications of unemployment hysteresis are potentially far-reaching. They are important for PKE as they ensure that in the long run, supply constraints respond to demand pressures. Nishi and Stockhammer (2020a) on unemployment hysteresis in post-Keynesian and neo-Goodwin models uses a weaker form of unemployment persistence and investigates cyclical dynamics of wage and profit-led demand regimes (in combination with different labour market regimes). It demonstrates that (under certain parameter constellations) pseudo-Goodwin cycles, can arise in wage-led demand regimes and pro-cyclical mark ups. Pseudo-Goodwin cycles are counter-clockwise movements in output and wage share space that are not causally related to the mechanisms of a Goodwin model (profit-driven investment and a reserve-army distribution). This finding complements an earlier finding that pseudo-Goodwin cycles can arise in a Minskyan model with a reserve army distribution function (Stockhammer and Michell 2017). This is a conversation within heterodox economics of the impact of hysteresis in PK and Marxist models.

On the empirical side the conversation is one (if unrequited) with the mainstream. While the NAIRU theory has gone out of fashion in academia, in statistical reporting it has solidified. Major institutions like the European Commission, the OECD and the IMF routinely report NAIRU estimates. In the Euro area this has a direct and important policy impact: it affects potential output estimates and thus cyclically adjusted budget balance estimates that form the basis of European fiscal criteria. They all assume that the NAIRU is exogenous and that there is no unemployment hysteresis. My research with Rob presents estimates for the extent of unemployment hysteresis in the EU. That resulted in two yet unpublished papers, one of which follows the standard methodology and uses a Kalman filter and one that uses a Bayesian approach (Calvert Jump and Stockhammer 2019). This paper reports our results with a Kalman filter that stays as close as possible to the methodology of the European Commission, OECD and IMF in estimating the NAIRU.

2. Introduction

Unemployment has increased sharply in many Euro Area member states since the beginning of the Global Financial Crisis in 2008. Much of the policy response to this has focused on labour market reform. This is based on the belief that unemployment is the result of labour

market rigidities (such as unemployment protection, strong unions and unemployment benefits). We will refer to this as the *exogenous NAIRU view*. It is standard practice to decompose unemployment into a cyclical (demand-side driven) and structural (supply-side driven) component. The structural component is also referred to as the NAIRU, the "Non-Accelerating Inflation Rate of Unemployment".

The European Commission regularly publishes estimates of the NAIRU.[1] Remarkably, these estimates show a sharp increase in the NAIRU for many countries, despite the absence of major changes in labour market institutions or the supply-side of the economy. A simple explanation for this is the presence of hysteresis in the labour market, meaning that persisting cyclical unemployment turns into structural unemployment. Thus, what was originally a demand shock persists longer than anticipated and affects the NAIRU. The existence of unemployment hysteresis has profound consequences for the conduct of economic policy. It means that supply-side oriented labour market reforms may be inappropriate for reducing unemployment. Instead, timely and determined fiscal as well as monetary policy measures are needed to maintain high levels of employment.

The existence of hysteresis also has implications for a number of key economic variables, most importantly (for this report) the output gap and the structural deficit. This is because the NAIRU is used in the estimation of potential output. Potential output, in turn, is used to calculate the structural deficit and the output gap of a country. It is important to realize that the NAIRU plays a significant role in the computation of such variables, even when it is not immediately visible or explicitly mentioned.

The main alternative approach is the *hysteresis* or *endogenous NAIRU view*. It holds that if there is hysteresis in the labour market, actual unemployment can influence the NAIRU. As a consequence, the NAIRU is determined by demand as well as supply-side factors (Stanley 2004, Stockhammer et al 2014). In these models, the NAIRU does *not* serve as an anchor for the long-run macroeconomic equilibrium, but rather it gets dragged along by demand conditions (Stockhammer 2011). The endogenous NAIRU hypothesis suggests that demand management policies are effective in fighting unemployment and recommends active demand management policies to prevent negative shocks such as the financial crisis from causing a permanent increase in the unemployment rate (DeLong & Summers 2012, Blanchard et al

[1] The European Commission and AMECO refer to the NAIRU as NAWRU (Non-Accelerating Wage Rate of Unemployment). We use the two concepts synonymously. Technically, the NAIRU takes stable consumer prices inflation as the reference point, whereas the NAWRU takes stable wage inflation as the reference point.

2015). This is in contrast to the exogenous NAIRU view, which holds that the unemployment rate will return to its long-run equilibrium regardless of the stance of fiscal and monetary policy.

In the 1980s, the hysteresis hypothesis was a reaction of the academic world to a sharp and persistent rise of unemployment rates in Western Europe (Stanley 2004). If the NAIRU was exogenous, this should have been accompanied by persistent deflation, which failed to materialize. Hysteresis became a common explanation for this phenomenon. However, interest in the topic subsided in the late 1990s and the early 2000s when unemployment rates decreased and inflation remained low. What brought hysteresis back into the discussion was the Global Financial Crisis and the weak recovery thereafter. Recent literature therefore tends to focus on output growth and less on the labour market itself (e.g., Fatas and Summers 2016, Blanchard et al 2015). However, unemployment hysteresis is the natural complement to output hysteresis. This is most evident for Europe, where unemployment rates have remained elevated in many countries.

This study will examine the extent of hysteresis in the EU15 countries, using annual data from 1960 to 2016.[2] It will use two models: That of the European Commission, which we replicate, and a model that allows for the possibility of hysteresis[3]. Measuring the degree of hysteresis is useful because it helps to assess how much damage an increase in current unemployment rates can do. If, for example, cyclical unemployment rises by 1 percentage point and the degree of hysteresis is estimated at 50%, then the NAIRU will increase by 0.5 percentage points going forwards. In turn, this will help in estimating the appropriate levels of fiscal and monetary policy stimulus to combat negative shocks.

Our main result is that a useful baseline degree of hysteresis for the EU is 80%. If, therefore, cyclical unemployment rises by 1 percentage point, then one can expect the NAIRU to increase by 0.8 percentage points going forwards. Precisely, we estimate hysteresis parameters for each country in the EU15, and find the average degree of hysteresis to be 80%. A number of countries, however, including Finland, Germany, Greece, and the UK, have degrees of hysteresis very close to 100%. Given our estimates of hysteresis, our NAIRU estimates are somewhat different to those of the European Commission. However, as explained below, it is worth noting that the European Commission suspects, but does not allow for, hysteresis in their NAIRU estimates.

[2] With the only exception of Luxembourg, where the sample runs from 1975 to 2016 due to data availability, and Germany, where some of the data has to be back-casted.
[3] We do not present the full results for our reproduction of the EC model; they are briefly discussed in appendix C.

Our estimates imply that, for the majority of the EU15 countries, negative demand shocks to the unemployment rate can lead to permanent increases in unemployment – i.e., increases in the NAIRU. Thus, fiscal and monetary policy should respond to negative shocks in a forceful and immediate way, to prevent large increases in the unemployment rate. In addition, the existence of hysteresis in the EU15 calls the Fiscal Compact into doubt. This is discussed in section 4, where it is argued that the Fiscal Compact can result in a vicious cycle of deflation if hysteresis effects are present. Thus, a final policy conclusion is for the European Commission to reassess, and ideally replace, the Fiscal Compact.

The paper is structured as follows. Section 3 reviews the literature on the NAIRU, contrasting the exogenous NAIRU view and the hysteresis hypothesis and explaining the key hysteresis mechanisms. Section 4 explains the estimation methodology and section 5 presents the empirical results for unemployment hysteresis. Section 6 outlines the policy implications of unemployment hysteresis and section 7 concludes.

3. The NAIRU theory and unemployment hysteresis

3.1 The exogenous NAIRU view

It is standard practice to decompose unemployment into a structural rate and a cyclical rate. The cyclical rate fluctuates with the business cycle and can be driven by demand shocks. The structural (or natural) rate, on the other hand, is a concept that was popularized by Milton Friedman and Edmund Phelps in the 1960s. It is a hypothetical unemployment rate determined solely by supply-side factors. In his 1968 paper on the role of monetary policy, Friedman argued that there is one level of unemployment that is consistent with potential (long-run) output, that is, output without any temporary frictions. However, the focus of his article is on the short-term versus long-term effects of monetary policy, not the labour market. He argued that monetary policy could affect unemployment in the short run but that this would create inflation in the long run, but does not offer an explicit model of the labour market.[4] The NAIRU (non-accelerating inflation rate of unemployment) concept as it is generally used today stems from Nickell and Layard (1986) as well as Layard et al (1991). These authors conceptualized

[4] Strictly speaking, Friedman's (1968) natural rate is not a NAIRU. Today's exogenous NAIRU theory is about involuntary unemployment being tolerated by policy authorities as the price for stable inflation. Friedman's natural rate, however, is found at the long run equilibrium of the labour- and the goods-market. Therefore, the remaining unemployment at Friedman's natural rate is frictional rather than involuntary, and the result of inflexible institutions, search costs, and informational costs.

the NAIRU as a medium-term equilibrium of the unemployment rate that resolved the “battle of the mark-ups” between workers and firms (Nickell & Layard 1986, p. 146). Nickell and Layard also explained the relation between the natural rate and inflation as follows:

> “For if wage-setters try to set real product wages higher than is consistent with employers' pricing behaviour, this generates ever-increasing inflation. Thus, the key to understanding unemployment in the medium term is the behaviour of wage-setters. If events occur that push them towards too-high real wages, then unemployment has to rise to offset these influences.” (Nickell & Layard 1986, p. S121).

A deviation of actual unemployment from the NAIRU leads to inflationary pressures. The NAIRU itself is regarded as determined by labour market institutions. This view has some Keynesian features in the short run: monetary and fiscal policy are effective in manipulating the actual unemployment rate, but at the price of changes in inflation. In the long-term, Layard et al. (1991) argue that actual unemployment will gravitate towards the NAIRU, because only when actual unemployment is equal to the NAIRU will there be stable inflation. The goods market adjustment mechanism they cite is changes in the real money supply due to inflation.[5] Importantly the NAIRU is not affected by demand factors, but only by supply-side factors as it solely depends on the structure of the labour market. In the long run the model thus has neoclassical features.

Today, an exogenous, supply-side determined NAIRU is part of most mainstream concepts of the labour market (see for example Gianella et al. 2009 for the OECD). This conceptualization of the natural rate owes its lasting influence, amongst other things, to the OECD Jobs Study of 1994 (McIntosh & Boychuk 1994). In this study, the exogenous NAIRU view was used to argue that whether unemployment will fall in an economy or not is chiefly driven by its capacity for structural adjustment in the labour market. From a policy perspective, the concept implies that the state should remove barriers that prevent wages from moving up or down, or reduce the bargaining power of organised labour. The Exogenous NAIRU view first and foremost considers rigid labour market institutions to be such barriers: minimum wages, employment protection regulation, strong unions and unemployment benefits. Therefore, if a government wishes to lower unemployment, it should weaken LMIs. This could be through reducing taxes, for example, and removing employment protection legislation, i.e., making it easier and

[5] Nowadays, New Keynesian economists would emphasise the role of the monetary authority in stabilising inflation in the context of an increasingly cashless economy.

cheaper for firms to hire and fire workers and reducing the coverage of collective bargaining agreements. If the NAIRU is indeed exogenous, that is, determined solely by supply-side factors, such a course of action should lower the NAIRU, which would decrease unemployment in the long run. Thus, the crucial question is whether the NAIRU is indeed exogenous.

3.2. The Hysteresis Hypothesis

In their seminal 1986 paper on the hysteresis hypothesis, Blanchard and Summers sought to explain high and rising unemployment in Western Europe in the 1970s and 80s. They argued that this development had called the existence of an exogenous NAIRU into question[6] and therefore explored the possibility of macroeconomic hysteresis. They used the term to describe situations in which the structural unemployment rate is permanently influenced by demand fluctuations. Hysteresis thus becomes the falsifying hypothesis of the (exogenous) natural rate of unemployment.[7] Through statistically exploring US and UK unemployment rates between the 1890s and 1980s, Blanchard and Summers found that a high persistence of unemployment is in fact not historically unusual (1986, p.21). They then formalized their concept of hysteresis to see whether it could help explain the development of unemployment rates in the US, the UK, France and Germany during the same period, and indeed it did. Effectively, their argument is that while demand and productivity shocks played a role in *creating* higher unemployment rates, it was hysteresis that held unemployment at those levels.

Since Blanchard and Summers (1986), a number of authors have empirically explored the possibility of hysteresis in unemployment. To name one influential example: In his 1997 paper on “Disinflation and the NAIRU”, Ball argues that disinflation was a major cause of high and rising (structural) unemployment in OECD countries during the 1980s. Using unemployment and inflation data as well as the then-new OECD NAIRU data, he further finds empirical evidence that “disinflation had a greater effect on the NAIRU in countries with long-lived unemployment benefits” (Ball 1997, p. 182). Ball argues that his evidence therefore supports a hysteresis hypothesis based on decreasing job search by the unemployed. Interestingly, however, while Blanchard & Summers (1986) and Ball (1997) both find evidence for the

[6] In the same year, R.M. Solow added: “A natural rate that hops around from one triennium to another under the influence of unspecified forces, *including past unemployment rates*, is not ‘natural’ at all. ‘Epiphenomenal’ would be a better adjective.” (Solow 1986, p. S33)

[7] Because of their 1986 paper, Blanchard and Summers are in fact generally credited with introducing the term ‘hysteresis’ to describe this macroeconomic phenomenon. The expression was loaned from physics, where it denotes situations with a path-dependent equilibrium.

existence of hysteresis, their arguments differed when it came to explaining where this effect came from. This is a crucial question. Any policy measure that tries to lessen hysteresis-effects will be determined by what is considered to be the original cause and working mechanism of hysteresis.

3.3. Hysteresis Mechanisms

We distinguish between labour market hysteresis mechanisms and goods market hysteresis mechanisms. Unemployment hysteresis was originally conceptualized as a path dependent structural unemployment rate, and most of the early hysteresis literature in the 1980s uses labour market mechanisms to explain hysteresis (Blanchard & Summers 1986, Ball 1997). More recently, especially in light of the global financial crisis, the concept of output hysteresis has also gained prominence in academic literature (DeLong & Summers 2012, Blanchard et al 2015), as have hysteresis mechanisms that are centred in the goods market. Table 1 gives an overview of the various mechanisms.

	Labour Market mechanisms			**Goods market mechanisms**		
Hysteresis mechanisms	Insider-outsider	De-skilling / duration mechanisms	Conventional wage norms	Capital accumulation / capital stock	Factor productivity growth	Deflationary monetary policy
References	Blanchard & Summers 1986, DeLong & Summers 2012, Gali 2015	Ball 1999, IMF 2009, Blanchard et al 2015, Lockwood 1991)	Skott 2005, Setterfield & Lovejoy 2006, Stockhammer 2008	Arestis & Biefang-Frisancho Mariscal 1998, Rowthorn 1995, 1999, Arestis et al 2007	Sawyer 2001, Arestis & Sawyer 2004; Blanchard et al 2015, IMF 2009, Ball 2014, Reifschneider 2015	Ball 1999, Stockhammer & Sturn 2012

Table 1: Overview of hysteresis mechanisms

The standard view relies on two closely interrelated mechanisms to explain hysteresis, both of which are labour market channels: insider-outsider effects and skill-loss in unemployment. The first, most prevalent approach argues that unions represent the employed population, the “insiders”, and bargain wages according to their needs as opposed to the needs of the unemployed (Blanchard & Summers 1986, 1987, 1988; Lindbeck & Snower 1988, DeLong & Summers 2012, Blanchard et al 2015). Thus, unions will focus on bargaining for higher wages and better working-conditions, which make it costlier for firms to hire additional workers and in consequence make current unemployment last longer. This explanation has been dominant

from the beginning, with Blanchard and Summers (1986) already arguing that the number of insiders influences equilibrium unemployment. This approach implies that unions and a high degree of unionization keep wages inflexible after demand shocks. This view does not necessarily disagree with the need for structural reform emphasised by the exogenous NAIRU view. Weakening unions would also reduce hysteresis. However, while unions still exist, demand policies should be used to prevent increases in unemployment.

Skill-loss in unemployment refers to the view that the short-term unemployed put more pressure on wages than the long-term unemployed because the long-term unemployed suffer a loss of skill during unemployment. In consequence, they are no longer able to compete on a similar level with the short-term unemployed and are less likely to find employment in the future (IMF 2009, Blanchard et al 2015). Ball's (1997, 1999) version of this are what he called "duration mechanisms." While he is also concerned with skill-loss and the length of unemployment periods, he believes that unemployment benefits, and more specifically the time period during which they can be received, are the decisive variable. Yet another version of this is Lockwood's (1991) view that, since screening potential employees is costly to firms, they use long-term unemployment as a signal of a lack of employability. Thus, a sustained increase in unemployment may become permanent if it pushes a significant number of people from short-term into long-term unemployment.

Both channels are strictly focused on the labour market and imply policy recommendations centred around de-regulation and active labour market policies (to reduce individual periods of unemployment). Institutions like the IMF and the OECD have taken up these arguments to advocate for less rigid labour market institutions, specifically naming strict employment protection and generous unemployment benefits as problematic (IMF 2009, Gianella et al. 2009).

Contrary to the first two labour market hysteresis mechanisms, the conventional wage norms channel tells its story in part from the point of view of employees. In his 2005 paper on "Fairness as a source of hysteresis in employment and relative wages", Skott argues that workers have influence on their wages and employment rates beyond the degree of unionization. Drawing from psychological studies and experiments on the topic, Skott (2005) shows that wages are strongly influenced by norms of fairness[8] and, in his opening paragraph, states why it even is in the employer's interest to act in accordance with these norms:

[8] Skott (2005) defines fairness both in relation to the worker's current wage and to the wages other groups receive: To this end, his model includes "'real-wage' and 'relative-wage' norms that relate wage offers to workers' own current wage and to the wages of other groups of workers" (p.305). The 'real-

> "As suggested by Solow (1990), Akerlof and Yellen (1990) and the burgeoning literature on reciprocity, workers may reciprocate unfair treatment by reducing their productivity. Experimental work as well as survey evidence support this expectation of reciprocity (e.g., Fehr and Gächter, 2000; Bewley, 1998). Fair wages, in other words, can be profit maximizing." (Skott 2005, p.305).

Skott then formalizes his concept of fairness and shirking in the absence of fair wages. He assumes that wage norms change endogenously, and that the general state of the labour market is part of this endogenous change. In consequence, unanticipated demand shocks result in lasting shifts in the equilibrium rate of unemployment: As demand (and thus the state of the labour market) changes, wage norms adapt. After the shock however, they go back to changing at their usual rate. The change in wage norms therefore permanently alters the equilibrium rate of unemployment as well as its growth path. The endogeneity of wage norms translates into the endogeneity of the NAIRU.

The second large group of hysteresis mechanisms looks less to the labour market to explain hysteresis, and instead focuses on the development of productivity, capital accumulation and monetary policy. The intuition behind factor productivity growth channels is that during a recession, a decrease in investment in research and development causes productivity growth to decline (see e.g. Sawyer 2001, 2002; Arestis & Sawyer 2004, 2005; Blanchard et al 2015, IMF 2009, Ball 2014, Reifschneider 2015). Capital accumulation affects the development of output and unemployment in three ways (Stockhammer 2004). First, decreased investment during a recession affects demand via the traditional multiplier, decreased demand in turn affects employment. Combined with unemployment hysteresis, this can prolong the effects of a recession. Second, there is some empirical evidence on the elasticity of the two production inputs capital and labour that suggests that current capital stock has considerable influence on the equilibrium rate of unemployment (Arestis & Biefang-Frisancho Mariscal 1998). Depending on the current capital stock and the elasticity of capital versus labour as an input factor, more or less labour will be needed to reach the same level of production. Third, Rowthorn (1995) has argued that there is a bargaining effect, where unemployment weakens the bargaining position of workers and excess capacity that of firms. An insufficient capital stock consequently can cause unemployment to rise if firms increase their mark up in

wage' is their own current real wage, which workers expect to either remain the same (meaning it has to be adapted to inflation) or to rise from time to time. The 'relative-wage' compares their wage to the wage of other groups in the labour market.

response to increased capacity utilisation.[9] These three capital accumulation channels are potentially complementary, and figure prominently in current literature on hysteresis (IMF 2009, Blanchard & Summers 2015, Ball 2014).

Our third goods markets mechanism argues that deflationary monetary policy can also be a cause of hysteresis. Ball suggested this already in a 1997 paper, when he showed empirically that (during recessions in the 1980s) the NAIRU rose more in OECD countries with larger and longer disinflation periods. He therefore concluded that tight monetary policy was a main cause of high and rising unemployment in OECD countries. He further argued this point in a 1999 paper, in which he found that the aggressiveness of monetary policy during the vulnerable crisis years significantly influenced how permanent the corresponding increases in unemployment were. Stockhammer and Sturn (2012) update and expand on Ball's approach. Regressing the degree of hysteresis on monetary easing, standard labour market institution variables and terms of trade shock, they found strong effects of monetary policy, but weak effects of labour market institution variables. More specifically, "[t]hose countries which more aggressively reduced their real interest rates in the vulnerable period of a recession experienced a much smaller increase in the NAIRU (relative to the maximum increase of unemployment) 5 years later" (p.2753).

4. Estimation Methodology for Hysteresis and the NAIRU

4.1. Testing for unemployment hysteresis

A common way to test for the presence of unemployment hysteresis is to test for a unit root in unemployment data. Intuitively, if there is unemployment hysteresis, the current unemployment rate is not anchored in the NAIRU; rather it is free to wander as it is pushed by demand shocks. Theoretically, this is based on NAIRU models with unemployment persistence (Nickell 1998). In these models, short-term and long-term unemployment have different effects on wages. Nickell (1998) demonstrates that under certain conditions unemployment hysteresis can only arise if the long-term unemployed have no effect on wages whatsoever. As long as the long-term unemployed have *some* effect on wages, unemployment will eventually revert to the NAIRU. If they do not, unemployment is likely to have a unit root. Under these circumstances, any change to actual unemployment will lead to a one-to-one

[9] Rowthorn assumes that mark ups respond to capacity utilisation. A lower capital stock for given level of demand means implies a higher rate of capacity utilisation.

change in the NAIRU. The unit root tests for hysteresis thus test a specific version of unemployment hysteresis: the case in which *all* cyclical unemployment turns into structural unemployment.

A partial survey of literature examining unemployment persistence mostly through unit root tests can be found in Stanley (2004). In this paper, Stanley also carries out a meta-regression analysis of 24 studies containing 99 national estimates of unemployment persistence. He finds that the studies that were supportive of the existence of a (stationary) natural rate of unemployment have come to this conclusion because of small-sample, misspecification or publication biases. He therefore argues that current economic literature should reject the idea of a natural rate of unemployment in favour of the hysteresis hypothesis.

Jaeger and Parkinson (1990, 1994) propose a different way to test for unemployment hysteresis based on an unobserved components method. They point out that unit roots in unemployment rates may be caused by actual, permanent supply-side or institutional changes, exactly like the exogenous NAIRU story would suggest. This would be a simple time-varying NAIRU, not hysteresis. A small empirical literature therefore explicitly disentangles equilibrium and cyclical unemployment rates (see e.g., Jaeger & Parkinson 1990, 1994, Logeay & Tober 2006, Di Sanzo & Perez-Alonso 2011). It then tests whether the equilibrium unemployment rate (or structural rate) depends on past values of the cyclical unemployment rate. If it does, we can say that there is hysteresis (or an endogenous NAIRU) present in the data. These studies rely on an unobserved components methodology, which utilises the Kalman filter and numerical maximum likelihood estimation. This is a relatively complicated estimation approach, which may explain the smaller number of studies compared to the literature using unit root tests. However, the methodology provides a more general estimate than unit root tests. It also allows the researcher to distinguish between the role of adverse demand shocks and changes in the institutional environment. For this reason, the methodology is superior to methods that rely on unit root tests only.

Recently, Blanchard et al. (2015) have proposed another approach to testing for hysteresis, focusing on output hysteresis. They ask the question whether after a recession output returns to its trend level or whether a recession leaves lasting scars (in the output level). They empirically examine a large set of past recessions in 23 advanced countries in the form of quarterly data starting in the 1960s. They consider two dimensions: First, how often recessions led to lower output relative to trend and lower trends in general. Second, they control for the cause of recessions and focus on recessions most likely to be caused by demand shocks. Thus, they focus on specific recessions rather than on fluctuations over time. They find that

about two-thirds of recessions are followed by a lower output than was to be expected due to pre-crisis trends (p.17).

4.2. NAIRU Estimation with an exogenous NAIRU

The NAIRU estimation approach of the European Commission (EC) is fairly standard in the sense that the EC, IMF and OECD share the same approach. However, it is far less prominent in academic research. The basic idea is to use changes in inflation to decompose (observed) unemployment rates into their (unobserved) cyclical and structural components. In the implementation of this, a stochastic trend is added to the NAIRU, whereas cyclical unemployment is modelled as a 2nd order autoregressive process. This generates what the EC considers a plausible NAIRU estimate. This estimation process has two important implications. First, it implies that the NAIRU has (at least one) unit root, which means that unit root tests cannot be used to test for hysteresis in unemployment. Second, it means that structural unemployment can be identified without making use of inflation data at all.[10] Interestingly, therefore, the EC NAIRU is arguably not a NAIRU in the strictest sense of the word, as it is not identified as the unemployment rate at which inflation is constant.

The model that the European Commission uses to estimate the NAIRU is as follows:

$$u_t = u_t^N + u_t^C$$

$$u_t^N = \mu_{t-1} + u_{t-1}^N + \epsilon_t^N$$

$$\mu_t = \mu_{t-1} + \epsilon_t^\mu$$

$$u_t^C = \beta_1 u_{t-1}^C + \beta_2 u_{t-2}^C + \epsilon_t^C$$

$$\Delta^2 w_t = f(\Delta^2 tot, \Delta^2 pr, \Delta^2 ws, u_t^C)$$

This model states that the actual unemployment rate u_t is the sum of a cyclical component u_t^C and the NAIRU u_t^N. The natural rate is a unit root process with a time varying drift, and the cyclical rate follows an exogenous autoregressive process. Finally, the model is augmented

[10] In practice, the Phillips curve estimates are used in the NAIRU estimation, but they are not essential as the models are identified without the inflation rate.

with a wage Phillips curve, in which the change in wage inflation is regressed on the cyclical unemployment rate and a set of exogenous variables. The set of exogenous variables changes from country to country, but in general includes the terms of trade, labour productivity, and the wage share in aggregate income. Orlandi (2012) provides a straightforward discussion of this model, and Havik et al (2014) provide further detail.

The European Commission NAIRU method does not allow for hysteresis effects running from the cyclical unemployment rate to the NAIRU. However, secondary estimates in Orlandi (2012), also discussed in Havik et al (2014), acknowledge that the European Commission NAIRU estimates do not correspond to structural unemployment - i.e., the European Commission NAIRUs can be affected by demand-side factors. These include, but are not limited to, housing boom-bust episodes and the real interest rate. Havik et al (2014) argues that,

> "[r]ecent increases in the euro-area's NAWRU should therefore not be interpreted as a sign of big structural change at the current juncture. Rather, in most countries, the increases reflect the effects of shocks that, in the presence of various rigidities, have a long-lasting impact on unemployment rates. Note that, despite uncertainties, the NAWRU remains a useful policy indicator. It is a well-defined concept that provides useful information on the nature of unemployment rate developments." (Havik et al 2014, p.28).

Clearly, a NAIRU that can be affected by demand-side factors - i.e., a NAIRU in which hysteresis effects are present - is useful as an indicator for certain types of policy. However, we do not believe that such a NAIRU is useful for the type of policies embodied in EU demand management policy or the EU Fiscal Compact, and in any case the degree of hysteresis needs to be estimated before rational policies can be developed. The model we use for our NAIRU estimation is extremely similar to that of the EC in many ways. Both the EC model and our hysteresis model use an unobserved components methodology, and both are estimated using maximum likelihood with the Kalman filter. However, we allow for hysteresis effects, balancing out this increase in complexity by removing the European Commission model's time varying drift. In this way, we can estimate the degree of hysteresis that the European Commission suspects exists, but does not allow for.

4.3. A NAIRU model with unemployment hysteresis

Our model is as follows:

$$u_t = u_t^N + u_t^C$$

$$u_t^N = \mu + \alpha u_{t-1}^C + u_{t-1}^N + \epsilon_t^N$$

$$u_t^C = \beta_1 u_{t-1}^C + \beta_2 u_{t-2}^C + \epsilon_t^C$$

$$\Delta^2 w_t = f(\Delta^2 tot, \Delta^2 pr, \Delta^2 ws, u_t^C)$$

Thus, we allow the cyclical unemployment rate to affect the NAIRU; the dependence (or degree of hysteresis) is given by the parameter α, which can be estimated.

The data we use to estimate this model are identical to the series used in the European Commission NAIRU models, and are taken from the AMECO database. The unemployment rate is coded ZUTN, nominal wages (nominal compensation per employee) are coded HWCDW, the terms of trade are coded APGS, labour productivity (gross domestic product at 2010 reference levels per person employed) is coded RVGDE, and the labour share (compensation per employee as a percentage of GDP at market prices per person employed) is coded ALCD0. All data are annual, and the sample runs from 1960 to 2016 for all countries in the EU15. The only exceptions to this are Luxembourg, where the sample runs from 1975 to 2016, and Germany, where some back-casting had to be performed due to re-unification.

The models are estimated for each country using maximum likelihood with the de Jong diffuse Kalman filter in Stata. This estimation method implies that the estimated parameters maximise the probability of observing the data, given the structure of the model. In addition – although this is of less interest in our specific application – it can be used to derive a 'best guess' of the unobserved NAIRU, which is how the European Commission produces its NAIRU estimates. Most importantly – and explained in more detail in appendix A – the unemployment block of our hysteresis model is unidentified without the Phillips curve. In other words, including the Phillips curve in our model is a necessary condition for estimating the degree of hysteresis (at least, without further parameter restrictions).

5. Estimation results

Point estimates of the hysteresis parameter α are presented for each country in table 2. Judging by these estimates, all countries with the possible exception of Spain appear to exhibit economically significant hysteresis effects. Unfortunately, due in part to the small sample size, the point estimates are relatively imprecise. Although in principle α could be greater than one, our prior is that α should lie between zero and one and thus we interpret the five point estimates of α that are greater than one as the result of sampling uncertainty. Given this, judging from the 95% confidence intervals, 60% of the EU15 countries appear to exhibit statistically significant hysteresis effects, with the average degree of hysteresis equal to 80% (or 0.8). As a number of the confidence intervals do not rule out $\alpha = 1$, table 2 also reports the results of likelihood ratio tests of this null hypothesis for those countries where the confidence intervals rule out $\alpha = 0$. Note that these are likely to be more precise than relying on the confidence intervals, and indeed the result of the likelihood ratio test for Belgium contradicts the confidence interval. Judging by these results, we can state with some confidence that hysteresis effects are prevalent, and in some cases strong, in the EU15, with the average effect well within the reasonable range. Our conclusion is therefore as follows: hysteresis is prevalent in the EU15, with a baseline degree of hysteresis of 80%.

For those countries in which $\alpha = 1$ cannot be rejected, in particular Finland, Germany, Greece, Ireland, Italy, and Sweden, a one percentage point increase in the cyclical unemployment rate this year is fully passed on into a one percentage point increase in the NAIRU next year, and any demand management policy is likely to be highly effective. These are higher than the point estimates found in Jaeger and Parkinson (1994), but more in line with those found in Assarsson and Jansson (1998) and Di Sanzo and Perez-Alonso (2011). In particular, Assarsson and Jansson (1998) estimate $\alpha = 0.728$ for Sweden, which is contained in our confidence interval in table 2. Di Sanzo and Perez-Alonso (2011) estimate a non-linear version of the model, and find values of α between 0.797 and 2.210 for Italy, France, and the USA, which contain our average α equal to 0.8.

The unusually low point estimate of α for Spain is of some interest, particularly as this is one of the more precisely estimated parameters in table 2. Spain might be considered an obvious contender for a country suffering from hysteresis effects, as the European Commission has estimated a large increase in its NAIRU since the mid-2000s, and the observed unemployment rate has remained persistently high over the last decade. Given this, the Spanish unemployment rate has remained stubbornly high since the early 1980s, aside from a

reduction to around 10% in the early 2000s, and this has been a persistent puzzle when compared to, for example, the Portuguese unemployment experience (see e.g., Blanchard and Jimeno 1995). Like the USA, there is no obvious mean shift or drift in the Spanish unemployment rate, at least since the early 1980s, which may explain why research tends to find little or no evidence of hysteresis in these countries.

	α point estimate	95% confidence interval	p-value (LR test)
Austria	0.64	[-0.17 1.45]	-
Belgium	1.62	[1.10 2.14]	0.14
Denmark	0.61	[0.12 1.11]	0.20
Finland	1.07	[0.45 1.69]	0.82
France	0.21	[-0.76 1.18]	-
Germany	1.00	[0.27 1.73]	0.99
Greece	0.97	[0.32 1.61]	0.92
Ireland	1.40	[0.63 2.17]	0.39
Italy	1.16	[0.70 1.63]	0.53
Luxembourg	0.31	[-0.50 1.12]	-
Netherlands	0.41	[-0.16 0.99]	-
Portugal	0.25	[-0.78 1.28]	-
Spain	0.08	[-0.09 0.24]	-
Sweden	1.28	[0.70 1.86]	0.34
UK	0.97	[0.34 1.59]	0.92
EU15 average	0.80	-	-

Notes: [a]All estimates are from the model described in equations (1) - (5) round to two decimal places. The confidence intervals correspond to the Z-distribution. The p-values from likelihood ratio tests of significance correspond to the null hypothesis, $H_0 : \alpha = 1$. Note that the LR test contradicts the confidence interval for Belgium - this is likely due to the inefficiency of the numerically approximated parameter variance-covariance matrix used to calculate the confidence intervals.

Table 2: Hysteresis parameter estimates

Thus, we can conclude with some confidence that hysteresis effects are important, and in some cases strong, in the EU15. The models satisfy the standard specification tests, and our conclusion is robust to alternative specifications of the model. The specification tests, robustness tests, and alternative specifications are discussed in appendix B. Given our results, a degree of hysteresis equal to 80% is a useful baseline figure for the EU15.

6. Policy Implications of Hysteresis

Confronted with sharply rising unemployment in the wake of the global financial crisis of 2008 and the subsequent Euro crisis, policy makers could draw on two policy strategies: Labour

market reform and active demand management. If hysteresis effects are present, as indicated by our results, then active demand management becomes considerably more important in the short run, as any increase in the unemployment rate will eventually feed through into a secular rise in joblessness. Authors adhering to this view draw attention to the fact that the compounding costs of cyclical unemployment imply that monetary policy should target both inflation and unemployment (Gali 2015, Summers 2015), with policy responses being aggressive and immediate (Blanchard et al 2015). This was not the case in the majority of continental EU countries, at least in comparison with the UK and USA.

As well as a more aggressive role for monetary policy, the presence of hysteresis implies that fiscal policy can also aid in reducing the costs of aggregate demand shocks. Whereas some authors argue that fiscal policy is only superior to monetary policy during periods of secular stagnation, or when interest rates are close to their lower bound (DeLong and Summers 2012, Fatas and Summers 2016), others argue that fiscal policy can and should be used as an ordinary tool of demand management (Stockhammer 2011, Ball 2014). Whichever point of view one takes, it is clear that the fiscal responses of EU member states to the 2008 crisis and subsequent Euro crisis were inadequate if hysteresis effects are present. As our results indicate that hysteresis effects are present in the EU, with around 80% of the current unemployment rate becoming permanent within a year's time, a clear policy implication is that the responsiveness of monetary and fiscal policy to changes in unemployment rates in the EU should increase.

The foregoing inadequacy of EU member states' fiscal responses to the crises of the last decade is related to the existence of the EU Fiscal Compact, in which structural deficits must not go beyond 1% of GDP, or 0.5% of GDP if the debt-to-GDP ratio is above 60%. Notwithstanding the fact that a number of EU member states do not adhere by it, the Fiscal Compact is an irrational constraint on policy when hysteresis effects are present. This is because the structural deficit is defined as the deficit that a country would have if it were operating at potential output. In turn, potential output is calculated as a Cobb-Douglas function of the actual capital stock and potential employment, where potential employment is determined by the working age population and the European Commission NAIRU estimates (Havik et al 2014). An increase in the estimated NAIRU therefore decreases potential employment, which decreases potential output. In turn, this decrease in potential output increases the size of the structural deficit, ceteris paribus.

The foregoing leads to the possibility of a vicious cycle if hysteresis effects are present, in which a negative shock to the unemployment rate increases the NAIRU, which decreases

potential output, which increases the structural deficit. At best, this gives the state less room for expansionary policy to counteract the negative demand shock, and at worst it leads the state to pursue a deflationary policy further depressing activity and increasing the unemployment rate. In the limit, a large upwards revision in the NAIRU during a period of high unemployment - when an economy is arguably in a recession - could reduce potential output to the level of actual output. In this case any existing fiscal deficit would be entirely structural according to the Fiscal Compact, and would be limited to 1% or 0.5% of GDP, depending on the debt-to-GDP ratio. Similar arguments are made in Lendvai et al (2015), Cottarelli (2015), Pisani-Ferry (2015), and Heimberger et al (2017). Thus, there is a deflationary bias built into the EU policy environment in the presence of hysteresis, which is compounded if interest rates are close to their lower bound and/or policy rates are not sufficiently responsive to increases in unemployment. Thus, a final policy implication - and one echoed by Lendvai et al, Cottarelli, Pisani-Ferry, and Heimberger et al - is a serious reconsideration of the EU Fiscal Compact.

7. Conclusion

This paper has explored the degree of hysteresis in EU unemployment rates. While the exogenous NAIRU view rejects hysteresis and regards equilibrium unemployment as solely determined by labour market institutions, the hysteresis hypothesis holds that actual (demand-determined) unemployment can turn into structural unemployment. Hysteresis mechanisms range from insider bargaining and social wages norms, to mechanisms operating through capital accumulation and productivity growth. The European Commission estimates and reports NAIRUs as part of the AMECO dataset, which also inform the EU fiscal policy rules. These exclude the possibility of hysteresis by assumption. We outline a simple model to estimate hysteresis effects, which, importantly, is very similar to the European Commission model, allowing our NAIRU estimates to be compared to the official AMECO series.

We demonstrate that there is significant evidence for the existence of unemployment hysteresis in the majority of the EU15 countries. For example, we find that the degree of hysteresis is 65% in Austria, 100% in Germany, and 97% in the United Kingdom. In the EU15 as a whole, we find the average degree of hysteresis to be 80%. Moreover, these estimates are robust to changing the specification of the Phillips curve, and robust to changes in estimation assumptions. On average, therefore, we can conclude that a 1 percentage point increase in the cyclical unemployment rate in the EU15 should lead, on average, to a 0.8 percentage point increase in the NAIRU.

Our findings have implications for the European Commission's NAIRU methodology. As noted in section 3.2, various European Commission papers (e.g., Havik et al 2014) indicate that their NAIRU is not independent of demand side factors, and might not constitute an adequate measure of structural unemployment. Our findings strongly confirm this suspicion. Our findings suggest that the European Commission could profitably consider alternative NAIRU estimation strategies. Experimenting with hysteresis effects in their model - perhaps by the construction of a "beta" version - would be a useful start to this process. It would seem that the evidence has mounted to a point at which the European Commission should consider its NAIRU estimation strategy to allow for the possibility of unemployment hysteresis.

These findings do have substantive implications for how one conceives of the macroeconomic medium-term equilibrium. While mainstream macroeconomics perceives the medium term equilibrium to be given by supply side factors (such as technology and labour market institutions), heterodox (and in particular, post-Keynesian) macroeconomics usually assumes that the supply side responds to some extent to demand pressure (often via induced technological progress, see e.g., Stockhammer 2008, Fazzari et al 2020). Our results suggest that these induced supply effects materialise fast and that they are large. The average coefficient of pass-through of lagged cyclical unemployment to current structural unemployment is 0.8, and in several countries the hypothesis that this coefficient is unity cannot be rejected. These effects are large indeed. Future research could explore potential non-linearities, in particular once economies get close to full employment. These estimates run counter to the broader notion that the ability of demand policy to manage the rate of unemployment may be limited by the role of unemployment in an economy's distributive equilibrium (whether that equilibrium is conceived in New Keynesian NAIRU terms or in a Marxist industrial reserve army sense). Results certainly suggest that expansionary fiscal policy would, at current unemployment rates, only lead to short-lived inflationary pressures (as the NAIRU adapts quickly).

Our results have two important consequences for policy makers. First, they indicate that a lack of government intervention in response to negative shocks has immediate effects in the form of increasing unemployment as well as long-lasting effects on the NAIRU. If the government does not react adequately to a rise in cyclical unemployment, structural unemployment will rise significantly in the following years. This finding is consistent with the *OECD Employment Outlook 2017* which concludes, “Fiscal support during downturns … promotes labour market resilience by stabilising aggregate demand. It also reduces the risk of hysteresis” (OECD 2017, 49). This creates an imperative for the state: governments should

use fiscal and monetary policy to counteract negative unemployment shock in order to prevent unemployment hysteresis from arising.

Second, our results indicate that the EU Fiscal Compact should be seriously reconsidered. The balanced budget rule in Title III of the Fiscal Compact states that the structural deficit must not go beyond 1% of GDP, or 0.5% if total debt-to-GDP is above 60%. This structural deficit is calculated using the official AMECO NAIRU series. As discussed in section 4, it follows that a rise the NAIRU also increases the structural deficit, which gives the state less room for expenditure within the rules of the Compact. Altogether, this can create a vicious cycle: One shock to unemployment can, if there are no countermeasures by policy makers, permanently increase the NAIRU in the presence of hysteresis. This in turn raises the structural deficit, which then gives the state less room for expenditure to counteract a continuing increase in unemployment rates.

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Appendix A: Further details concerning the model and estimation

As discussed in the main body of the report, we utilise the method introduced in Jaeger and Parkinson (1994) to specify our hysteresis models. Denoting the NAIRU by u_t^N, the cyclical unemployment rate by u_t^C, the observable unemployment rate by u_t, the second difference of the log nominal wage by w_t, the second difference of the log terms of trade by tt, the second difference of log labour productivity by pr, and the second difference of the log labour share by ws, the model is as follows,

$$u_t = u_t^N + u_t^C \tag{A1}$$

$$u_t^N = \mu + \alpha u_{t-1}^C + u_{t-1}^N + \theta_N \epsilon_t^N \tag{A2}$$

$$u_t^C = \beta_1 u_{t-1}^C + \beta_2 u_{t-2}^C + \theta_C \epsilon_t^C \tag{A3}$$

$$w_t = \gamma_0 + \gamma_1 u_t^C + \gamma_2 u_{t-1}^C + \gamma_3 w_{t-1} + \gamma_4 tt_{t-1} + \gamma_5 pr_{t-1} + \gamma_6 ws_{t-1} + \theta_w \epsilon_t^w \tag{A4}$$

with ϵ_t^N, ϵ_t^C, and ϵ_t^w mutually uncorrelated white noise processes with unit variance (note we have omitted Δ^2 notation to represent second differences in (A4) for brevity). The model is therefore very similar to the European Commission model discussed in the main body of the text, but a dependency of the NAIRU on the cyclical unemployment rate in our model replaces the time varying trend in the European Commission model.

Equation (A2) is a unit root process in the NAIRU, with a hysteresis effect present when $\alpha > 0$. Equation (A3) specifies the cyclical unemployment rate as a zero mean AR(2) process, allowing for complex unit roots and therefore a business cycle component in the unemployment rate. Finally, equation (A1) states that the observable unemployment rate is equal to the sum of the NAIRU and cyclical unemployment rate in each period, and is observed without measurement error.

In comparison with the European Commission unemployment rate, our model introduces a dependence of the NAIRU on the cyclical unemployment rate, and this additional source of model complexity is balanced by removing the European Commission's time varying drift. Thus our NAIRU estimates should, in principle, be less smooth than the European Commission estimates, particularly when α is large. The reader should also note that our model is not a more general model than the European Commission model, as the latter's time varying drift means that it is not nested by our model. In principle the inclusion of a time varying drift in our model would constitute an improvement, but given the difficulty in identifying the model as it stands (see below), in practice including a time varying drift made the models extremely difficult to estimate.

The drawback of the Jaeger and Parkinson (1994) method, and by extension our model, is that the unemployment block made up of equations (A1) - (A3) is unidentified by itself, as discussed in Jaeger and Parkinson (1994, 333). To see this, consider the special case in which $\beta_1 = \beta_2 = 0$, so $u_t^C = \theta_C \epsilon_t^C$ from (A3). With some rearranging, we have a reduced form IMA(2) process for the observable unemployment rate given by,

$$\Delta u_t = \theta_N \epsilon_t^N + \theta_C \epsilon_t^C - (1-\alpha)\theta_C \epsilon_{t-1}^C$$

From the data we have the variance and first autocorrelation of Δu_t, which are not sufficient to identify θ_N, θ_C, and α.

The foregoing leads most users of the method, including Jaeger and Parkinson (1994), Assarsson and Jansson (1998), and Di Sanzo and Perez-Alonso (2011), to rely on an auxiliary equation in an exogenous variable to identify the model. In our case, this role would be performed by the Phillips curve. However, the fact that the model is unidentified without the Phillips curve suggests that variations in the specification of the Phillips curve might alter the estimates of α considerably, and this conjecture was borne out in preliminary investigation. Moreover, even in a situation in which the model is identified, the estimation of the variance of a non-stationary state with small true variance is biased towards zero in this type of model - see Stock (1994) for a discussion of the pile-up effect that causes this problem.

The identification problem and the pile-up problem suggest that the signal to noise ratio $\lambda^2 = \theta_n^2/\theta_c^2$ may usefully be imposed a priori. Importantly for purposes of comparison, the European Commission also constrains variances a priori in the official NAIRU estimates, leading us to favour this approach. The method is utilised in the NAIRU estimations of Staiger et al (1997), Laubach (2001), and Llaudes (2005), and it is also used in Rusticelli (2014), which estimates the effect of hysteresis on the NAIRU using the observed long term unemployment rate. As in Llaudes (2005), and to simplify replication, we set λ equal for every country.

The reported estimates below utilise a value $\lambda = 0.1$, corresponding to a signal to noise ratio of 0.01, which reflects the standpoint that supply-side shocks to the unemployment rate should be significantly less variable than demand-side shocks, and is also appropriate for our model in which demand-side shocks directly affect the NAIRU via the hysteresis effect. It is also worth noting that the signal to noise ratio in the Hodrick-Prescott filter with annual data is commonly set to around 0.01 - see Ravn and Uhlig (2002), who report values suggested in the literature between 0.0025 and 0.16 for annual data. Finally, appendix B reports the results of a robustness analysis of the effects of changing λ on estimates of α, so our results are not dependent on a single a priori signal to noise ratio. In fact, as reported in appendix B, the results appear to be robust to the choice of λ, so we do not consider this to be a problematic approach.

The European Commission uses a variety of Phillips curve specifications in its NAIRU models, with the most important variation being the use of nominal wage inflation as the dependent variable versus the use of real unit labour costs as the dependent variable. The former is termed a traditional Keynesian Phillips curve, while the latter is termed a New Keynesian Phillips curve. At the same time, those country models that are estimated with a traditional Keynesian Phillips curve use different specifications for the exogenous regressors, including the terms of trade, labour productivity, and various transformations of the labour share of income.

In our models, we specify a relatively general form of the traditional Keynesian Phillips curve with nominal wage inflation as the dependent variable. This is mainly for reasons of simplicity

and reproducibility, and we utilise an identical Phillips curve specification for each country in our sample. At the same time, as we incorporate lagged nominal wage inflation in the specification, our Phillips curve in (A4) can in fact be interpreted as a New Keynesian Phillips curve with bounded rational (backwards looking) expectations. This approach is becoming more popular in the New Keynesian literature as criticisms of the strict rational expectations hypothesis have mounted in recent years - see Woodford (2013) or Dilaver et al (2017) for surveys.

In (A4), the cyclical unemployment rate is the only variable that enters into the Phillips curve contemporaneously, with all other regressors entering with a lag. This reflects the fact that wage contracts tend to be updated infrequently in the EU, and thus we expect the cyclical unemployment rate to affect nominal wages within the period, but not vice versa. As we do not wish to make strong timing assumptions for the other variables, particularly given the use of annual data, all other variables enter with a lag to avoid endogeneity problems. This means that we cannot interpret the parameter estimates in a structural manner, but as the main estimates of interest are for the unemployment rate parameters we do not consider this to be a major issue.

All data series are identical to the series used in the European Commission NAIRU models, and are taken from the AMECO database. The unemployment rate is coded ZUTN, nominal wages (nominal compensation per employee) are coded HWCDW, the terms of trade are coded APGS, labour productivity (gross domestic product at 2010 reference levels per person employed) is coded RVGDE, and the labour share (compensation per employee as a percentage of GDP at market prices per person employed) is coded ALCD0. All data are annual, and the sample runs from 1960 to 2016 for all countries in the EU15. The only exceptions to this are Luxembourg, where the sample runs from 1975 to 2016, and Germany, where some back-casting had to be performed due to re-unification.

Although the data series used in the present paper are identical to the series used by the European Commission, our sample periods are slightly different, with the European Commission samples starting in the early 1960s (typically 1965 or earlier), and ending in 2018. The last two observations in the European Commission samples are therefore short term forecasts, which is quite a common procedure when the main aim is long term forecasting that is required to be consistent with short term forecasts calculated elsewhere. As our purpose is not primarily to forecast the NAIRU, we choose to use the full length of the sample up to the last observed data.

The models are estimated for each country using maximum likelihood with the de Jong diffuse Kalman filter in Stata. All of the results below correspond to these estimates, with no post-estimation adjustment of the NAIRU series (which correspond to the smoothed estimates of u_t^N from the Kalman filter). However, when comparing our NAIRU estimates to the European Commission estimates, it is worth bearing in mind that the latter are centered post-estimation, and the later year estimates are affected to a small extent by a long term anchor imposed on the forecast horizon.

Appendix B: Robustness and Alternative Specifications.

The estimates presented in the main body of the text appear to be relatively satisfactory from the perspective of standard specification tests. In particular, no countries exhibit autocorrelation problems. However, a third of the sample exhibits heteroskedasticity problems and around two thirds of the sample exhibits non-normality in the Phillips curve residuals. The latter is not particularly surprising. Table B1 presents detailed results of the specification tests.

Details of robustness checks on the changes in point estimates and confidence intervals of the hysteresis parameter α caused by varying the parameter $\lambda^2 = \theta_n^2/\theta_c^2$ are available on request. The point estimates do not change significantly over the interval $\lambda \in [0, 0.3]$, with a slight tendency of the point estimates to increase as λ is increased. It is not entirely clear why increasing λ leads to an increase in the estimates of α. One possibility is that there is a moving average component in the unemployment rate process for most countries in the sample. The main conclusion from this robustness check is that we do not consider the use of an a priori signal to noise ratio to be a problematic approach.

The estimates presented in the main body of the text are relatively well behaved, and the point estimates of the hysteresis parameter fall within the intuitive range. However, bearing in mind that the model should be considered as an approximation to the underlying data generating process, it is worth considering alternative specifications as further robustness checks. In this section, therefore, we briefly consider estimates of the hysteresis parameter α for two alternative Phillips curve specifications: Compared to our main Phillips curve used in the text, the first alternative Phillips curve omits the exogenous variables (terms of trade, productivity, and the wage share), and the second alternative Phillips curve adds the lagged second difference of log consumer price. To estimate the second specification we use the AMECO ZCPIN series, which for a subset countries only runs to 2015.

The hysteresis parameter estimates using the alternative Phillips curves, along with 95% confidence intervals, are presented in table B2. The point estimates are not materially affected, with the exception of Portugal where the point estimates change somewhat compared with the baseline specification. In addition, the average over the point estimates does not change appreciably, with the estimates using the first alternative having a slightly lower average α, and the estimates using the second alternative having a slightly higher

	Autocorrelation		Heteroskedasticity		Normality
	1 lag	4 lags	1 lag	4 lags	
Austria	0.70	0.86	0.01	0.10	0.12
Belgium	0.99	0.99	0.42	0.75	0.30
Denmark	0.89	0.90	0.99	0.93	0.01
Finland	0.86	0.99	0.01	0.11	0.28
France	0.97	0.79	0.52	0.89	0.03
Germany	0.89	1.00	0.40	0.16	0.63
Greece	0.94	0.11	0.00	0.00	0.00
Ireland	0.84	0.77	0.33	0.81	0.00
Italy	0.92	0.92	0.53	0.87	0.01
Luxembourg	0.42	0.09	0.38	0.45	0.08
Netherlands	0.85	0.94	0.00	0.01	0.00
Portugal	0.80	0.54	0.73	0.91	0.00
Spain	0.92	0.40	0.19	0.27	0.02
Sweden	0.88	1.00	0.00	0.03	0.03
UK	1.00	0.96	0.39	0.68	0.10

Notes: [a]Tests employed: Autocorrelation=Ljung–Box test on residuals; heteroskedasticity=Ljung–Box test on squared residuals; normality=Shapiro-Wilk test; all reported statistics are *p*-values round to two decimal places. These tests are fairly standard in the literature, and are suggested in e.g. Harvey (1994).

Table B1: Misspecification tests over Phillips curve residuals

average α. We can therefore be fairly confident in the accuracy of our baseline results, if not their precision, and the conclusion that hysteresis effects are prevalent in the EU15. In particular, the use of $\alpha = 0.8$ as a reference level of hysteresis for the EU is a reasonable conclusion to draw.

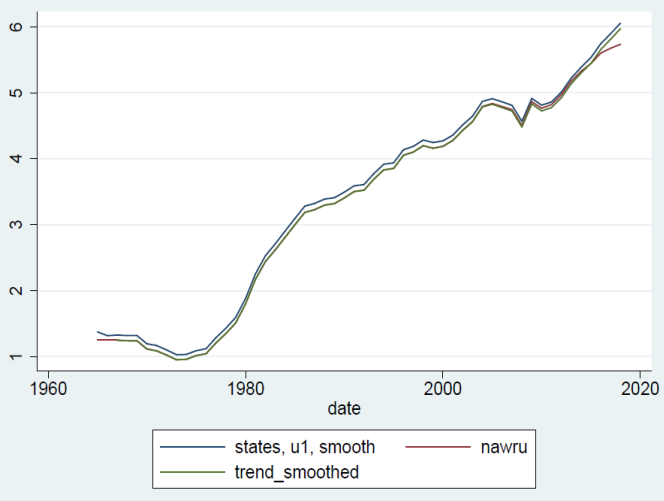
	α point estimate[b]	95% C.I.[c]		α point estimate[d]	95% C.I.[e]	
Austria	0.65	[-0.38	1.69]	0.63	[-0.23	1.50]
Belgium	1.42	[0.11	2.72]	1.62	[1.09	2.15]
Denmark	0.63	[0.05	1.20]	0.62	[0.13	1.11]
Finland	1.04	[0.46	1.62]	1.11	[0.53	1.70]
France	0.36	[-.049	1.21]	0.23	[-0.80	1.26]
Germany	1.09	[0.34	1.84]	0.92	[0.09	1.75]
Greece	0.97	[0.32	1.61]	0.96	[0.33	1.59]
Ireland	1.19	[0.53	1.85]	1.39	[-0.20	2.97]
Italy	1.10	[0.54	1.66]	1.15	[0.66	1.64]
Luxembourg[f]	0.23	[-0.67	1.12]	0.33	[-0.64	1.30]
Netherlands	0.35	[-0.13	0.83]	0.44	[-0.20	1.07]
Portugal	0.06	[-0.16	0.27]	0.43	[-0.19	1.04]
Spain	0.06	[-0.05	0.17]	0.07	[-0.09	0.23]
Sweden	1.21	[0.68	1.75]	1.25	[0.69	1.80]
UK	0.99	[0.64	1.34]	0.98	[0.36	1.61]
EU15 average	0.76	-		0.81	-	

Notes: [a]The confidence intervals correspond to the Z-distribution; [b,c] These estimates correspond to the model with the alternative Phillips curve (8); [d,e] These estimates correspond to the model with the alternative Phillips curve (9); [f]The Luxembourg model with (8) drops the Phillips curve intercept (to aid convergence; the intercept is statistically insignificant).

Table B2: Estimates using alternative Phillips curves

Appendix C: Reproducing the European Commission NAIRU model

As a preliminary exercise to our main estimations, we successfully reproduced the European Commission NAIRU estimates for the EU15 countries. We did this by programming their model in Stata, and using their excel model files available at https://circabc.europa.eu. Generally our reproduced NAIRU series were very close to the published ZNAWRU series in AMECO, with a small number of exceptions. This is likely due to three factors: First, the EC series are centred after estimation; second, the EC uses Fortran to estimate its models rather than Stata (which uses a different algorithm); and third, the EC uses a slightly different sample size with a long run anchor on the forecasts. However, we are satisfied that our reproduction exercise was adequate, and that our hysteresis models (which are very close to the European Commission models) result in NAIRU series that can usefully be compared to the AMECO official series. As an example, the Austrian ZNAWRU series and our reproduced series are shown below:



In the legend, "states, u1, smooth" is our reproduction, "nawru" is the official AMECO series, and "trend_smoothed" is the European Commission series without the long run anchor on the forecast. Clearly, our reproduced series is very close to the official series, with a small mean shift caused by the European Commission centering method[11].

[11] The centering method adjusts the sample mean of the NAWRU series to equal the sample mean of the actual unemployment rate.