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UNEMPLOYMENT: NATURAL RATE EPICYCLES OR HYSTERESIS?

BY

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Abstract

This paper argues that the natural rate of unemployment hypothesis, in which equilibrium unemployment is determined by "structural" variables alone, is wrong: it is both implausible and inconsistent with the evidence. Instead, equilibrium unemployment is haunted by hysteresis. The curious history of the natural rate hypothesis is considered, curious because the authors of the hypothesis thought hysteresis to be relevant. The various methods that have been used to model hysteresis in economic systems are outlined, including the Preisach model with its selective, erasable memory properties. The evidence regarding hysteresis effects on output and unemployment is then reviewed. The implications for macroeconomic policy, and for the macroeconomics profession, are discussed.

Keywords: unemployment, natural rate hypothesis, hysteresis

JEL Classification: B22, C60, E12, E24, E31, NO1

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Introduction

The flux in the popularity of economic ideas is particularly marked in relation to hysteresis. Recessions, such as those of the early 1980s, early 1990s and the post-2007 "great recession", bring a heightened interest in the idea that economic systems are haunted by hysteresis. When recoveries from recession occur, interest in hysteresis tends to abate, even though the evidence is that the output losses associated with recessions have a permanent component (Cerra and Saxena, 2008).

The term "hysteresis", from the Greek "to be behind", was coined for application to scientific phenomena in relation to the experimental evidence obtained by twisting iron and steel wires when magnetised, or magnetising them when twisted: "when the wire, after being normally polarised at $+\theta^0$, is twisted over to $-\theta^0$, the polarisation does not change to the full normal value for $-\theta^0$, but to something less, and this difference becomes still more apparent after several twistings from one side to the other… by dividing the full twist across into several steps, cyclical curves have been obtained, showing the relation of polarisation to torsion when the same magnetising force is kept up without interruption or reversal… these curves exhibit, in a striking manner, a persistence of previous state, such as might be caused by molecular friction… the curves for the back and forth twists are irreversible, and include a wide area between them… to this action… the author now gives the name Hysteresis" (J.A. Ewing, 1881, p.22).

Although hysteresis curves are not reversible, in the sense that the system does not retrace its steps when a force is applied and removed, it is clear from the original context that hysteresis applies in both directions. Thus the bad news story of hysteresis curses arising from recessions is matched by a good news story whereby hysteresis brings blessings, in the form of lasting benefits, when economies reach peaks in economic activity. Yet little tends to be heard about hysteresis during booms in economic activity. This puzzle may be attributed to "loss aversion" (Kahneman and Tversky, 1979), whereby the costs of recessions are weighted more than the benefits of booms in economic activity. Or, this tendency might be simply down to the fixation of mainstream economics with a simplistic neoclassical notion of equilibrium, in which the trend time path for output is invariant to cyclical fluctuations. Growing economies eventually experience levels of output that surpass the pre-recession peak, allowing economists afflicted by "cognitive dissonance" (Akerlof and Dickens, 1982) to conflate the beneficial effects of booms in economic activity with those of "equilibrium" growth, so as not to have their belief in a fixed point or time path neoclassical equilibrium disturbed.

The tendency in mainstream economics to think of recessions as temporary aberrations is matched by a tendency to see financial crises as exceptional rather than endemic. Economic history suggests that financial crises, including the build-up phases and the aftermaths, are more the rule than the exception, as documented in Kindleberger and Aliber (6th ed., 2011). The jacket cover for the 5th edition of this classic text (2005) has the prophetic quote from Samuelson: "Sometime in the next five years you may kick yourself for not reading and re-reading Kindleberger's *Manias, Panics and Crashes*". The financial crisis that started to explode with the "credit crunch" of 2007 was seen by some economists as reflecting "a systemic failure of the economics profession" (Colander et. al., 2009, p.1). Whereas to a mainstream economist such as Lucas, the challenge to the efficient markets hypothesis was merely part of "…a flood of criticism which has mainly served to confirm the accuracy of the

hypothesis… over the years exceptions and "anomalies" have been discovered… but for the purposes of macroeconomic analysis and forecasting these departures are too small to matter" (Lucas, 2009). This reaction from mainstream economists is akin to arguing that Russian roulette is normally a safe game to play.

In Section I of this paper the curious case of how the natural rate of unemployment hypothesis came to be established as conventional wisdom in mainstream economics is discussed, curious because both the originators of this hypothesis took hysteresis to be relevant.

Section II considers different methods of modelling hysteresis in economic systems.

In Section III the evidence regarding hysteresis effects on unemployment and output is discussed.

Section IV offers some concluding remarks.

I NATURAL AND NURTURAL UNEMPLOYMENT

The natural rate of unemployment hypothesis (NRUH) can be expressed as follows:

$$\ddot{p} = f(u - u^*) \text{ with } f'(u - u^*) < 0 \text{ and } f(0) = 0 \quad (1)$$

$$u^* = g(z) \quad (2)$$

$$u^* A u \quad (3)$$

Here p is the log of the price level, a dot indicates a time derivative, u is the actual unemployment rate, u^* is the natural rate, z is a vector of "structural" variables, such as unemployment benefits relative to wages, and *A* indicates "acts as an attractor for". Links to aggregate output can be added by specifying Okun's law type relationships between u and y, and between u^* and y^*, where y and y^* are the actual and natural levels of aggregate output.

This is the neat formulation of the NRUH that came to be the conventional wisdom in mainstream economics regarding unemployment and inflation interaction quite soon after the hypothesis was formulated by Phelps (1967) and Friedman (1968). The famous definition is that u^* is determined by "the actual structural characteristics of the labour and commodity markets, including market imperfections, stochastic variability in demands and supplies, the cost of gathering information about job vacancies and labour availabilities, the costs of mobility, and so on" (Friedman 1968, p.8). The policy message was that sustainable reductions in unemployment could only be achieved by micro policy interventions on the "structural characteristics of labour and commodity markets", the z variables, and not by macro policies. *Pace* Keynes, macro policies could only influence u or y, and $(u - u^*)$ or $(y - y^*)$ gaps would be associated with rising or falling rates of inflation, which would be unsustainable. When inflation targets came into fashion in the early 1990s this framework gave rise to the Taylor rule as to how central banks should set interest rates in order to achieve a target rate of inflation.

We will consider the basic question of whether the NRUH is consistent with the evidence in Section III of this paper. Here the issue of the plausibility of the hypothesis is considered.

One implausibility is that u^* is independent of the steady rate of inflation. Why bother whether the steady rate of inflation is -2%, +2%, +4%, +10% or +1,000% if u^* and y^* are the same? The evidence suggests that u^* tends to rise as steady rates of inflation fall below about 4% (Akerlof, Dickens and Perry, 2000; Blanchard, Dell'Ariccia and Mauro 2010; Ball, 2013); and that there are serious deleterious effects on the "real" economy from inflation rates in excess of about 20% (Barro, 1997). Another implausibility is that the *z* variables are not affected by macro policies. If, for example, unemployment benefits or minimum wages are not fully indexed to a relevant cost of living index, their real values will change with the rate of inflation, and so would u^*.

Economists often argue on the basis of the authority of leading figures in their discipline. In this respect the history of how the NRUH came to be adopted as conventional wisdom is curious. The NRUH apparently rules out hysteresis effects, whereby changes in actual unemployment lead to changes in the equilibrium rate. What did the co-originators of the natural rate doctrine have to say on the hysteresis issue?

With Phelps we have: "the transition from one equilibrium to the other tends to have long lingering effects on the labour force, and these effects may be discernible on the equilibrium rate of unemployment for a long time... the natural rate… at any future date will depend on the course of history in the interim… such a property is often called hysteresis" (Phelps 1972, p xxiii). In later work Phelps has continued to consider hysteresis as relevant to labour markets, but has tended to see "ratchet effects" on equilibrium unemployment as due to slowly decaying effects of oil price and real interest rate shocks: "…even if there are instances in which hysteresis was of quantitative importance, the evidence does not suggest that this importance is at all widespread" (Phelps, 1995, p.228).

Even more curious is what Friedman had to say on the subject of hysteresis. "I do not regard the natural rate hypothesis and the hysteresis hypothesis as in any way fundamentally incompatible hypotheses. The hysteresis hypothesis is simply a more sophisticated form of the natural rate hypothesis, and as such I have no doubt that it may well have a good deal of truth to it. It never has seemed to me that a crucial element of the natural rate hypothesis was a belief that the final equilibrium was independent of the path by which it was reached. Its crucial element it seems to me is a very different one. It is that nominal magnitudes must be sharply distinguished from real magnitudes, and that nominal magnitudes in and of themselves cannot determine real magnitudes. In applying this, it is necessary to recognise that the rate of change of the quantity of money or of prices is not a nominal magnitude in the sense that it is dependent on arbitrary units in the same sense that the stock of money is or the level of prices" (Friedman, November 2, 1990, letter to the author).

In the same letter Friedman highlighted Marshall's acknowledgement of the importance of hysteresis in economic systems. "I was struck with one feature of your discussion of the history of thought and the concept of equilibrium. You cite Schumpeter's comments in 1934 as an early precursor to the hysteresis notion. That clearly is wrong. Alfred Marshall, in the first edition of his *Principles* (1890), writes: "The chief cause of this divergence is the fact that, if the normal production of a commodity increases and afterwards again diminishes to its old amount, the demand price and supply price are not likely to return, as the pure theory assumes they will, to their old positions for that amount" (Marshall 1890, 1st ed., pp.425-426).

So it is clear that both of the originators of the NRUH thought that equilibrium unemployment would be influenced by the time path of actual unemployment, as well as by "structural" factors. This is an NNRUH, equilibrium unemployment being determined by

nurture as well as by nature. The question then is why the primitive NRUH came to dominate seminar room and policy discussion.

In his *General Theory* Keynes discussed how "the great puzzle of effective demand with which Malthus had wrestled vanished from economic literature… the completeness of the Ricardian victory is something of a curiosity and a mystery… professional economists, after Malthus, were apparently unmoved by the lack of correspondence between the results of their theory and the facts of observation… the celebrated optimism of traditional economic theory, which has led to economists being looked upon as Candides, who, having left this world for the cultivation of their gardens, teach that all is for the best in the best of all worlds provided we will let well alone, is also to be traced, I think, to their having neglected to take account of the drag on prosperity which can be exercised by an insufficiency of effective demand… for there would obviously be a natural tendency towards the optimum employment of resources in a society which was functioning after the manner of the classical postulates… it may well be that the classical theory represents the way in which we should like our economy to behave…but to assume that it actually does is to assume our difficulties away" (Keynes, 1936, pp.32-34). Note the adjective "natural" in this quotation.

Little of substance seems to have changed since Keynes wrote about the grip of the mainstream ideology in economics. Keynesian economics was first subsumed in the neoclassical synthesis, with Keynesian prescriptions gathering dust until recessions come along, and then marginalised in the new Keynesian short-runs of dynamic stochastic general equilibrium (DSGE) models. Some of the leading lights of the mainstream have been dismissive. "I think Keynes' actual influence as a technical economist is pretty close to zero, and it has been close to zero for 50 years… Keynes was not a very good technical economist… he didn't contribute much to the development of the field" (Lucas cited in Ibanez, 1999, p.180).

The basic question is why mainstream economics has been able to survive with doctrines that are out of touch with reality. One answer is anthropological. "Leading active members of today's economics profession… have formed themselves into a kind of Politburo for correct economic thinking… as a general rule—as one might generally expect from a gentleman's club—this has placed them on the wrong side of every important policy issue, and not just recently but for decades… they deny the possibility of events that then happen… they are always surprised when something untoward (like a recession) actually occurs… and when they finally sense that some position cannot be sustained, they do not re-examine their ideas…. They do not consider the possibility of a flaw in logic or theory… rather, they simply change the subject… no one loses face, in this club, for having been wrong" (Galbraith 2009, p.95).

It is difficult to make a career as an academic economist if you deviate too far from the assumptions of the mainstream. Take the representative agent assumption, for example. Kirman wrote a powerful critique of this assumption, "Whom or What Does the Representative Agent Represent?" (Kirman, 1992). In response "…this young economist, I think he was at UCLA, wrote "Dear professor, I really agree with what you said… I think it is intellectually absolutely right… unfortunately I am a young macroeconomist who is an assistant professor… I build models based on a representative agent… I know how to do that, and I know how to publish that… and I need to get tenure… once I have got tenure, maybe I will then be able to turn around and start to think about the sorts of models that do not use the representative agent, but unfortunately, what I think will happen is that by then I will have got into the habit of doing it… I will publish my articles, get a decent reputation, I will get a

promotion, and I will probably never think about this again… but anyway, thank you very much for the insight"" (Kirman, 2011, p.63).

To non-economists "Life among the Econ" (Leijonhufvud, 1973) can be quite puzzling. An editor for the science journal, *Nature*, reports how the economist referee reacted differently to non-economist referees in relation to an article submitted on industrial growth. The non-economists offered glowing recommendations to publish, based on the interesting statistical regularities reported. The economist, however, gave the thumbs down. "The data analysis presented in the paper is mildly interesting and the study offers a somewhat novel perspective on industrial growth. However, the theoretical argument is unconvincing. While it appears to account adequately for the statistical patterns observed in the data, the model lacks micro foundations. This makes the paper wholly unsuitable for publication" (Buchanan 2013, p.182). For a comprehensive and coruscating account of how mainstream economists reacted to, and have so far survived, the 2007 financial crisis and subsequent "great recession", see Mirowski (2013).

II MODELLING HYSTERESIS IN ECONOMIC SYSTEMS

As his biographer son commented, Ewing coined the term hysteresis "feeling the need of a word that should be sufficiently wide to include, not only the phenomena of magnetic retentiveness, but other manifestations of what seemed to be essentially the same thing" (A.W. Ewing 1939, p.62). The assessor for the Royal Society paper in which Ewing coined the term, Sir William Thomson (later Lord Kelvin), initially insisted that the phrase "effects of retentiveness"—Elastische Nachwirkung was a German phrase used in the literature of the time—be used instead. Ewing stuck to his term, sensing that effects that remained after their initial causes are removed would be relevant to a wider range of phenomena than just those involving electromagnetic fields in ferric metals. Arguably, applying the notion of hysteresis to economic systems would have helped Keynes in his "struggle to escape" from the tenets of (neo)classical economics. Ewing was a professor of mechanism and applied mechanics at the University of Cambridge, 1890-1903, where he established engineering as an academic discipline. He retained an honorary fellowship at King's College during his later career at the Admiralty, where he was head of the Room 40 signals intercept and decoding group during WW1, and as Principal of the University of Edinburgh. The only biographical record of contact with Keynes, however, comes in 1933: "Ewing spent much of his time at King's College, where Maynard Keynes provided those at the high table with interesting ideas about the Economic Conference, on which pessimistic views were general" (A.W. Ewing, 1939, p.277). It would take a playwright of Tom Stoppard's calibre to reconstruct a conversation that might have taken place between the two great men. What can be said is that key aspects of hysteresis—non-reversibility, remanence and heterostasis—would not have been alien to Keynes' *General Theory* depiction of the lack of self-adjustment in economic systems.

Simple Hysteresis

The simplest way to introduce hysteresis into the determination of equilibrium unemployment is to allow u to help determine u^*. Changes in u tend to be dominated by changes in the rates of outflow from unemployment into employment rather than by changes in the rates of inflow from employment into unemployment. Thus, with a shortish time lag, changes in u are associated with changes in the proportion of the unemployed who have been so for a long spell, say longer than six months. Long spells of unemployment tend to reduce

the employability of those affected, so changing the "structural" characteristics of the labour force. Hargreaves Heap (1980) and Cross (1980) put forward simple models that attempted to incorporate such effects. In contrast to the NRUH specification that

$$\dot{u^*} = g(\dot{z}) \tag{4}$$

we could have

$$\dot{u^*} = g(\dot{z}) + a\dot{u} \quad \text{with} \quad a > 0 \tag{5}$$

$$\text{or} \quad \dot{u^*} = g(\dot{z}) + b(u - u^*) \quad \text{with} \quad b > 0 \tag{6}$$

Equations (5) and (6) are simple ways of introducing the nurtural effects of the experience of actual and long-term unemployment into the determination of "equilibrium" unemployment. These modifications were plausible, backed by evidence on unemployment duration and re-employment probabilities (e.g. McGregor, 1978), and proved able to explain in a stylised way the upward ratchets in unemployment experienced by several countries in the 1980s. They, however, did not "catch on" amongst the Econ, a profession obsessed with representative agent microfoundations in which the different unemployment experiences of different workers cannot be accommodated.

There is now a body of post Keynesian literature that incorporates more sophisticated variants of such simple models of hysteresis, see Setterfield (1997). One innovation in this literature, in which hysteresis is seen as an endogenous, path-dependent source of change in economic systems, is to allow for changes in the coefficients relating "equilibrium" to actual unemployment (Katzner, 1999).

Evidence that the relationship between is not a simple linear one can be found in the work of Ball (1999, 2009). Ball's starting point is

$$u^* = (1 - c)u^*_{-1} + cu_{-1} \tag{7}$$

where *c* indicates the degree of hysteresis. This is the same specification used in Hargreaves Heap (1980, equation 4). Ball finds that "…it's clear that no such linear relationship exists…changes in u sometimes cause changes in u^* and sometimes don't… it seems to depend on the past history of u^* and the length of time that u is pushed away from u^* … hysteresis also appears asymmetric… e.g. an inflation run-up means it's very likely u^* is falling, while disinflations often occur without u^* rising" (Ball, 2009, p.24).

Short Run NAIRUs

An influential reformulation of the NRU as a NAIRU (Non Accelerating Inflation Rate of Unemployment) includes "partial" hysteresis, unemployment reverting to the NRU in the long run: "…there is short-term "hysteresis", in the sense that past events affect the current short-run NAIRU—but there is no long-term "hysteresis": there is a unique long-run NAIRU… in the end the unemployment rate always reverts" (Layard, Nickell and Jackman, 1991, p.10). This framework forms the bedrock of a widely used macroeconomics text (Carlin and Soskice, 1990), and it plays a key role in the forward guidance for the setting of interest rates introduced by the Bank of England in August 2013. Interest rates, unless "knockout" factors apply, are not to be cut until the ILO survey measure of unemployment falls below 7% (Bank of England, 2013a). "As the medium-term equilibrium unemployment rate depends on the composition of unemployment it will change over time… as demand

recovers, the number of long-term unemployed, and hence that equilibrium rate, should fall back, although that is likely to take time as some people may need to re-train or move in order to fill the available vacancies… once all the temporary factors have dissipated the equilibrium unemployment rate will fall back to the long-run equilibrium rate" (Bank of England, 2013b, p.28). In August 2013, actual UK unemployment stood at 7.8% compared to the interest-rate trigger of 7%, with the medium-run u^* estimated at 6.5% compared to a long-run u^* guesstimated at about 5% (Bank of England, 2013b, Chart A, p.29).

The NAIRU model is based on a "battle of the mark ups" specification of wage and price setting equations. Omitting the capital-labour ratio terms, the model can be written as:

$$p - w = \beta_0 - \beta_1 u - \beta_{11} \Delta u - \beta_2 \Delta^2 p \tag{8}$$

$$w - p = \gamma_0 - \gamma_1 u - \gamma_{11} \Delta u - \gamma_2 \Delta^2 p + z \tag{9}$$

Here p and w are the logs of the price level and money wages, Δ and Δ^2 are the first and second difference operators, $\Delta^2 p$ is a proxy for the unexpected price and wage terms and z is an index of "structural" variables reflecting wage pressure. The term Δu is designed to capture the idea that, after a short time lag, a rise in unemployment leads to a rise in the proportion of the long-term unemployed, who exert little pressure on wage or price setting behaviour. Setting $\Delta^2 p = 0$ and $\Delta u = 0$ yields the long-run NAIRU:

$$u^* = \frac{\beta_0 + \gamma_0 + z}{\beta_1 + \gamma_1} \tag{10}$$

"Hysteresis" arises in the case where $\Delta^2 p = 0$ but unemployment is changing, and so is long-term unemployment:

$$u_s^* = \frac{(\beta_1 + \gamma_1)u^* + (\beta_{11} + \gamma_{11})u_{-1}}{\beta_1 + \gamma_1 + \beta_{11} + \gamma_{11}} \tag{11}$$

Where u_s^* is the short-run NAIRU.

Whilst there is a substantial body of evidence that the long-term unemployed exert little pressure on wages (Nickell, 1987, for example), there is little evidence of cointegration between the *z* "structural" variables and unemployment (Jenkinson, 1988; Darby and Wren-Lewis, 1993). A key issue is whether "there is no long-term "hysteresis": there is a unique long-run NAIRU… in the end the unemployment rate always reverts" (Layard, Nickell and Jackman, 1991, p.10). Cross and Lang (2011) show that such reversion does not occur in this model, and that convergence on to a unique long-term unemployment proportion of the NRU does not occur, given the estimated parameter values. Cross and Lang regard the NAIRU as Not An Interesting Rate of Unemployment. Such issues have been off the radar in most of the voluminous NAIRU literature. The following quote is a rare exception: "…there is a fundamental issue as to whether equilibrium unemployment exists, is unique and is stable… if we… allow unemployment to influence wage and price setting in a suitable non-linear fashion, then we can have multiple equilibria" (Nickell 1993, p.137).

Unit Roots

Perhaps the most widely known model of hysteresis in unemployment is that of Blanchard and Summers (1986a, 1986b). The microfoundations are provided by an "insider-outsider" view of labour markets in which wages are negotiated to try and ensure continued employment of the currently employed "insiders", with those who become unemployed becoming "outsiders", disenfranchised from wage negotiations. If wages are negotiated caring only about the workers employed at the start of the bargaining period, the outcome is

$$n = n_{-1} + \epsilon \tag{12}$$

where n is the log of employment and ϵ is an unexpected innovation in aggregate demand (Blanchard and Summers 1986b, p.5, equation 5). This means that "for a given labour force, equilibrium unemployment is equal to the last period's value of actual unemployment… the economy shows no tendency to return to any fixed equilibrium value… after an adverse shock which reduces employment, workers who are still employed have no desire to cut the nominal wage so as to increase employment… after a favourable shock which increases employment, some outsiders are now employed and will have no desire to increase wages and to price themselves out of employment" (Blanchard and Summers 1986b, p.5).

The original Blanchard and Summers estimates (1986a) were that unemployment followed a near-unit process in the UK, France and Germany from 1953-1984, but less so in the US. This approach, however, has had less impact on policy debates than NAIRU models. Part of the problem is that "the unemployment rate (is) bounded between zero and 0.25 in all countries" (Nickell, 1993, p.137), and so cannot follow a pure unit process. Perhaps more important has been the reluctance of mainstream economists to abandon the NRUH version of the "neoclassical synthesis", wherein convergence to a fixed point neoclassical equilibrium, pinned down by "structural" variables, occurs.

In recent contributions both Blanchard and Summers have produced evidence that multipliers were higher in the post-2007 "great recession", in the range 0.9-1.7, than previous estimates, typically 0.5, suggested. The October 2012 World Economic Outlook of the IMF reported a significant negative relationship between fiscal consolidation forecasts and subsequent forecast errors regarding GDP and unemployment (IMF 2012, Box 1.1, pp.41-43). If the forecasters had, at least on average, a "correct" model, the coefficient on the fiscal consolidation forecast should have been zero (Blanchard and Leigh, 2012, p.3). As deLong and Summers (2012) point out, the downward revisions of these forecasts for potential GDP during the "great recession" implicitly involve hysteresis. "Economic forecasters' revisions of their projections of the US economy over the next decade certainly incorporate hysteresis effects into their projections" (deLong and Summers, 2012, p.32). Explicitly, hysteresis is modelled via a relationship $\Delta Y_f = \eta\, \Delta Y_n$, where Y_f is future output, which is taken to be supply determined, Y_n is present output, and η is a parameter indicating the degree of hysteresis, measured in inverse years. Hysteresis arises from both physical capital and labour market effects of recessions. There can also be institutional channels for hysteresis (Blanchard, 2005). As with the role of hysteresis in NAIRU models, however, the neoclassical or new Keynesian-DSGE synthesis regarding the long run, or "normal" times, is not far away: "we argue that, while the conventional wisdom rejecting discretionary fiscal policy is appropriate in normal times, discretionary fiscal policy, where there is room to pursue it, has a major role to play in the context of severe downturns that take place in the aftermath of financial crises" (deLong and Summers, 2012, p.3).

Preisach Models of Hysteresis

Since the early 1990s (Cross, 1993; Amable, Henry, London and Topol, 1995) a small group of economists have applied more formal mathematical methods of analysing economic systems with hysteresis. These methods involve the systems theory generalisation (Krasnosel'skii and Pokrovskii, 1989) of the original Preisach (1935) model of electromagnetic hysteresis, making particular use of the Mayergoyz (1991) geometric representation of this analysis. For a comprehensive account of the mathematical literature, see Bertotti and Mayergoyz eds. (2006); and for surveys of applications to economic systems, see Göcke (2002) and Cross, Grinfeld and Lamba (2009).

The simplest version of the Preisach model is scalar and involves "non-ideal" or "lazy" relays connecting an input variable to an output variable. The following exposition is based on a "real options" approach to the determination of economic activity (Piscitelli, Grinfeld, Lamba and Cross, 1999) that uses the Preisach framework to model the equilibrium unemployment rate that is consistent with a steady rate of inflation.

There are M potential operational units which, when active, produce one unit of output and employ one unit of labour; when inactive the units produce and employ zero. The number of active operational units is N. Each unit is characterised by an hysteresis operator F_{ab}, with the a and b switching triggers differing between operational units because of differences in sunk costs, uncertainty and the potential value of waiting to acquire more information. A unit requires a market price of $p \geq a$ in order to become active, and a price of $p \leq b$ to exit and become inactive. Hence the "lazy" relays relating the market price to economic activity or inactivity. In the range $b < p < a$ an operational unit can be either active or inactive depending on its previously acquired propensity, which turns on whether this range has been approached from above or below.

The market price is specified as:

$$p_t = x_t f(q_{t-1}) \tag{13}$$

where x is an aggregate demand shock, and $f(q)$ is the deterministic component of the inverse demand function, with $q_{t-1} = N_{t-1}/M$. The dynamics of (13) turn on how p_{t+1} determines q_{t+1}, which can be written as:

$$q_{t+1} = \frac{1}{M} \sum_{i=1}^{M} F_{a_i b_i} \left(x_{t+1} f(q_t) \right) \tag{14}$$

This specification of economic activity, as being determined by non-linear responses to aggregate shocks by heterogeneous units, yields the remanence and selective memory properties of Preisach models of hysteresis. Economic activity is determined not just by the current value of the aggregate shock variable, but also by the non-dominated extremum values that have been experienced. Thus the largest contractionary shock experienced, and any subsequent declining sequence of local extremum values, will retain an influence, until superseded by larger shocks. And similarly with expansionary shocks. Bygones are not bygones (see Mayergoyz, 1991, for a formal proof; and Cross, 1993 for an economic application).

An account of an equilibrium unemployment rate that is haunted by a selective memory of the extremum values of aggregate shocks can be derived from the relationship $q_t = N_t/M$. The rate of inactivity is $(M - N)/M$. Use this as a proxy for unemployment:

$$u = (M - N)/M \tag{15}$$

So equations (1), (2) and (3) for the NRUH are replaced by:

$$\ddot{p} = f(u - uh^*) \tag{16}$$

$$u = g(z, x) \tag{17}$$

$$uh^* = h\big(z, h(x)\big) \tag{18}$$

Where uh^* is the hysteresis-haunted equilibrium rate of unemployment and $h(x)$ is a hysteresis index of past shocks to aggregate demand. To compute the $h(x)$ index for some aggregate demand shock variable, such as "the" interest rate, exchange rate or oil price, requires specifying a Preisach weight function $w(a, b)$ describing the way the F_{ab} hysteresis operators are distributed amongst operational units. There is a problem here in that data on such switching values are not readily available. In some contexts, however, the selective memory, or "wiping out", properties are not sensitive to the choice of the Preisach weight function (see Mayergoyz, 1991, Ch.1 for discussion). Darby, Piscitelli and Cross (2006, pp.677-685) experimented with normal, Poisson and exponential distribution specifications of $w(a, b)$ for economic time series, and found that the hysteresis index was not particularly sensitive to the distributional assumption used.

This hysteresis-haunted specification of equilibrium unemployment has, for any given set of structural variables $\bar{z}$, a range of "equilibrium" unemployment rates—"equilibrium" in the sense of being consistent with steady inflation. Whether it is a high or low equilibrium unemployment rate will be determined by the non-dominated extremum values of the shocks to aggregate demand that have been experienced (see Darby, Cross and Piscitelli, 2006, Figure 8.6, p.676). The idea that the last major recessions and booms leave a legacy is not implausible, given the scarring effects on labour and capital of recessions, and the beneficial effects of booms. The preliminary evidence in terms of cointegration tests is encouraging. On UK data for 1959-1996, unemployment was found to be cointegrated with a vector of variables containing a z variable, the unemployment benefit replacement rate, and hysteresis indices for the nominal exchange rate, real interest rate and real price of oil (Darby, Cross and Piscitelli, 2006).

There are, however, difficulties. One is that low frequency economic time series for input variable shocks contain relatively few peaks and troughs, so leaving a small number of extremum value data points with which to calibrate the hysteresis index variables. A second problem is the specification is that the F_{ab} hysteresis operators are fixed, whereas it would be more plausible to allow them to be endogenously determined. A third problem, mentioned earlier, is that, ideally, data on the $w(a, b)$ cross-sectional distributions of switching points are required. A fourth issue is whether the rate independence assumption underlying the Preisach model holds. Rate independence means that the output of the system depends only on the non-dominated extremum values of the input variables, and not on their rate of change between extremum values. Finally, but by no means exhaustively, the existing applications to economic systems are scalar in nature. It would be useful to develop vector hysteresis models that could accommodate several exogenous input variables and several outputs.

An alternative way of capturing the memory properties of Preisach-type models is the linearised "play" dynamics approach of Göcke (1994, 2002). The reactions of the output variable to changes in the input are characterised by different "spurt" lines for upward and downward movements, with the "play" line being shifted vertically by "spurt" movements. This ingenious approximation has yielded promising empirical results, in relation to exchange rate threshold effects on German exports, for example (Belke, Göcke and Günther, 2009).

III EVIDENCE ON HYSTERESIS IN ECONOMIC SYSTEMS

In 1934 Keynes chose "Is the Economic System Self-Adjusting?" as his title for a radio talk on the pressing economic issues of the day (Keynes, 1934). The negative answer to this question given by Keynes contrasts with the positive answer provided by "neoclassical synthesis" and new Keynesian-DSGE models. In these mainstream models recessions and booms are taken to be cyclical fluctuations around growth paths unaffected by the deviations from the growth path. If hysteresis effects are present, recessions and booms would have lasting effects on the level, and maybe on the growth rate, of economic activity. What does the evidence suggest?

Partial Output Recoveries

In the Friedman (1993) "plucking" model of the business cycle, output is "plucked" below trend at random intervals and to various extents. In each episode the return to trend mirrors the previous fall. Capital per effective worker falls below its steady state level in a recession and, given diminishing returns to capital, the higher marginal productivity of capital generates an investment spurt that fuels the return to trend output. Hamilton (1989) tested this approach against alternative specifications, such as that there is a Markov process whereby an economy switches between positive and negative drift terms for output in "normal" times and recessions. This proved to be best empirical fit to US GNP data post-1945. *Contra* the "plucking" model, "the estimated parameter values suggest that a typical economic recession is associated with a 3% permanent drop in the level of GNP" (Hamilton, 1989, p.357). Using more informal methods, Dow estimated that the 1973-75, 1979-82 and 1989-93 recessions in the UK displaced capacity output downwards by 2.2%, 5.3% and 8.4% respectively (Dow, 1998, pp.385-386).

More comprehensive evidence is provided by the Cerra and Saxena (2008) study of the recoveries from recessions arising from financial and political crises in 190 countries over the period 1960-2001. Impulse-response functions are estimated from:

$$\dot{y}_{i,t} = a_i + \sum_{j=1}^{4} b_j \, \dot{y}_{i,t-j} + \sum_{s=0}^{4} c_s D_{i,t-s} + \epsilon_{i,t} \qquad (19)$$

where y is the log of real GDP, D is a dummy variable for each financial or political crisis, i indicates the country, and j and s give the number of time lags. Taking the impulse-response function at a 10 year time horizon, "the magnitude of persistent output loss ranges from around 4% to 16% for the various shocks" (Cerra and Saxena, 2008, p.456). Given the world recession following the 2007 "credit crunch", it is interesting to note that the estimated permanent output losses following banking crises ranged from 4% in Latin America and lower-middle income countries, to around 16% for Middle Eastern countries, with high

income, upper-middle income and transition countries being at the top end of the range at just less than a 15% permanent output loss (Cerra and Saxena, 2008, p.444). As with many estimates in economics, there needs to be an accuracy warning. For high income countries, for example, the 95% confidence interval around the 15% permanent output loss estimate is 10-20%.

NAIRU Tests

Many countries such as the UK saw an upward shift in unemployment in the early 1980s recession that persisted long after the recovery from this recession. If NRUH held, this upward shift would have been accompanied by an upward ratchet in the z "structural" variables that are taken to determine u^* (see Nickell, Nuziata and Ochel, 2005, for evidence). In the UK, however, the z variables that changed tended to move in a downward direction in the face of the market flexibility reforms of the Conservative government. As noted earlier, cointegration tests have, by and large, failed to find the cointegrating vectors that the NRUH implies (Jenkinson, 1988; and Darby and Wren-Lewis, 1993, for example).

Even in the US, which is often seen as more fertile ground on which to find evidence in support of the NRUH, cointegration evidence has been notable for its absence. Instead the tendency has been to model the variation over time of the NAIRU by a flexible polynomial or spline. In such models the NAIRU is specified as a ratio between estimated coefficients, so a non-standard approach to estimating confidence intervals is required. Staiger, Stock and Watson (1997) used the Fieller method to estimate such confidence intervals on US data, 1961-1995. The striking finding is that "…the 95 percent confidence intervals are wide enough to include most observed values of unemployment, with the exception of some cyclical peaks and troughs" (Staiger, Stock and Watson, 1997, p.38). As the authors point out, "… an extreme conclusion to draw from these results would be that a natural rate does not exist… a theoretical justification for such a position could be that the hysteresis that has been proposed as a description of European unemployment… is present in the US economy as well, so there is no rate of unemployment that is in general consistent with constant inflation" (p.47). The authors do not draw this conclusion, but others might, and have.

The conclusion in question is drawn in "The Natural Rate Hypothesis: an Idea Past its Sell-By Date" (Farmer, 2013). Farmer proposes a simple test of the NRUH, taking averages of inflation and unemployment in the decades from the 1950s to the 2000s, using quarterly US data. If inflation expectations are rational, he argues, we should see as many quarters when inflation is above expected inflation as quarters when it is below expected inflation. Over a decade of forty quarters it is unlikely that average inflation will differ much from average expected inflation. If the NRUH were true, and if rational expectations held, a plot of the decade averages of inflation against unemployment should reveal a vertical line at the NRU. Instead, "…there is no tendency for the points to lie around a vertical line and, if anything, the long run Phillips curve revealed by this chart is upward sloping, and closer to being horizontal than vertical… defenders of the natural rate hypothesis might choose to respond to these empirical findings by arguing that the natural rate is time varying… but they have not provided us, in advance, with a theory of how the natural rate of unemployment varies over time… in the absence of such a theory the NRUH has no predictive content… a theory like this, which cannot be falsified by any set of observations, is closer to religion than science" (Farmer, 2013, pp.248-249 and Chart 1).

The Return of Demand

It is reasonably clear that "structural" variables on their own cannot explain the shifts in steady-inflation unemployment rates observed (see Cross, McNamara and Pokrovskii, 2012). To resolve this problem there is now a body of literature that adds "shocks", including those to aggregate demand, to the "structural" variables in the explanation of equilibrium unemployment (Stockhammer and Sturn, 2012, provide a useful survey). The shocks involve real interest rates and oil prices (Phelps, 1995), capital accumulation effects (Rowthorn, 1995) and allow for the interaction between macroeconomic shocks and structural variables (Blanchard and Wolfers, 2000). Of particular interest is the pioneering work of Ball (1999) on how the way monetary policy is conducted during a recession affects the "equilibrium" rate of unemployment.

The Ball (1999) study used OECD estimates of NAIRUs in 20 countries for the 1979-1988 period to see if "structural" variables needed to be augmented by monetary policy variables to explain the cross-country distribution of changes in the NAIRU. The only significant "structural" variable proved to be the duration of unemployment benefits (DUB). The amount of monetary easing (ME) at the onset of recession, measured by the cumulative decrease in "the" real interest rate during the first year of the recession, also proved to be significant in explaining ΔNAIRU, the change in the NAIRU from the pre-recession peak to five years afterwards. The estimated regression was:

$$\begin{aligned} \Delta\text{NAIRU}_i &= 1.18 \; - \; 0.42\ \text{ME}_i \; + 0.64\ \text{DUB}_i \\ &\quad (0.99) \quad (0.20) \qquad (0.25) \end{aligned} \tag{20}$$

where $i = 1,2 \ldots 20$ indicates the country, standard errors are given in brackets, and $R^2 = 0.43$ (Ball, 1999, p.207, Table 5).

Stockhammer and Sturn (2012) extended the Ball results to cover the recessions experienced in 19 OECD countries 1980-2003, extending the set of "structural" variables examined, and using quarterly data. A "degree of hysteresis" variable is defined as the ratio between the increase in the NAIRU in the five years after a business cycle peak and the maximum increase in actual unemployment experienced in the same period. Regressions designed to explain this "degree of hysteresis" revealed "…strong effects of monetary policy, and depending on the specification, also of the change in the terms of trade, but weak (if any) effects of labour market institutions during recession periods… those countries which more aggressively reduced their real interest rates in the vulnerable period of recession experienced a much smaller increase in the NAIRU 5 years later" (Stockhammer and Sturn, 2012, p.2753).

Ball (2009) has extended his previous work with internally generated estimates of NAIRUs, using the equation

$$\dot{p} \quad = \quad \dot{p}_{-1} + \ \alpha(u - u^*) + \epsilon \tag{21}$$

to estimate α, treating u^* as a constant. The NAIRU is given by:

$$u^* - (1/\alpha)\epsilon = \ u - (1/\alpha)\ (\dot{p} - \dot{p}_{-1}) \tag{22}$$

where the second term on the LHS is interpreted as a supply shock. The LHS time series is then smoothed by a Hodrick-Prescott filter, and iterations are then used to re-estimate (20) until the results converge onto α and u^* time series that are consistent. The focus is on large

changes in the NAIRU, defined as changes that exceed 3% over a 10 year period. The data spans 1980-2007 and covers 20 countries. Using 9 quarter moving averages for trend inflation, a major disinflation is defined as a fall of at least 3%, and a major inflation run-up is similarly defined. Ball argues that, if hysteresis holds. NAIRU increases should be associated with disinflation, and NAIRU falls with inflation run-ups: "inflation and the NAIRU should move in opposite directions" (Ball, 2009, p.15). Ball finds that these associations tend to hold for the countries in his data set, but urges caution: "…it's clear that *some* form of hysteresis exists, but it's not clear why… the relationships among unemployment, the natural rate and inflation appear to be non-linear, but it's hard to pin down the non-linearities precisely" (Ball, 2009, p.3).

The Preisach models of hysteresis in unemployment, reviewed in Section II of this paper, are designed to take account of the non-linearities in the responses by economic agents to the shocks affecting economic systems. The selective memory property of Preisach models, whereby only the non-dominated extremum values of the shocks experienced continue to exert an influence, has echoes in the peaks and troughs used in the Ball analysis of hysteresis. Using hysteresis indices $h(x)$ to measure the influence that some shock variable x continues to exert, Darby, Cross and Piscitelli (2006, p.685) identified the following cointegration vector for UK unemployment 1959-1996:

$$\begin{aligned} u \;=\;& 2.30\ \mathrm{REPR} - 11.60h\ (\mathrm{NER}) + 0.0047h\ (\mathrm{RR}) \\ & (0.42) \qquad (2.00) \qquad (0.0006) \\ +\;& 3.87h\ (\mathrm{RPOIL}) \\ & (0.40) \end{aligned} \tag{23}$$

where u is the log of the actual unemployment rate, REPR is the replacement ratio for unemployment benefits, RR is "the" real interest rate, RPOIL is the log of the real price of oil, and standard errors are given in brackets. Again, an accuracy warning is in order, given the relatively few peaks and troughs in the x variables experienced in the period under consideration. This contrasts unfavourably with the large number of extremum values available to those conducting research on hysteresis in the physical sciences, using controlled experiments (see the contributions in Bertotti and Mayergoz eds., 2006). The high frequency data sets available for financial markets are more obviously suited to the application of Preisach models of hysteresis to economic phenomena. One way round the data problems would be to use experimental economics techniques to assess the non-linear responses of experimental subjects to simulated input variable shocks that involve a larger number of extremum values than those available from actual business cycles. Another way to expand the number of extremum value observations would be to pool data from a large set of countries, or enterprises.

IV CONCLUDING REMARKS

The NRUH is curious in that Phelps and Friedman, who coined the natural rate hypothesis, both thought hysteresis effects to be relevant. If hysteresis effects are present, nurture, in the form of the reactions of economic agents to macroeconomic policy and other shocks, as well as nature, in the form of "structural" variables indexing market flexibility, helps determine

the equilibrium unemployment rate. The evidence is that "structural" variables can explain relatively little of the major shifts in equilibrium unemployment rates, those consistent with steady inflation, that have been observed. Attempts to patch up the natural rate hypothesis to fit the data involve "epicycles", either in the form of unspecified forces leading natural rates to change over time, or in the form of *ad hoc* invocations of "partial" hysteresis effects that would disappear in a natural rate equilibrium golden age. As Solow put it, "…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, 1987, p.S33). Or take Blinder, "…a theory that allows the natural rate to trundle along after the actual rate is not a natural rate theory" (Blinder, 1987, p.132).

It is ironic that macroeconomics, whose foundations as an academic discipline owes much to the concerns about the high unemployment rates experienced between the two world wars of the 20th century, started the 21st century with a mainstream new Keynesian-DSGE model that, because of its representative agent microfoundations, can only talk about the number of hours worked by that agent, and not about the number of people who are unemployed. To have an account of unemployment, macroeconomics needs to have heterogeneous agents in its models. Preisach-type models in which economic agents respond non-linearly to shocks, provide such foundations. The models currently available have their limitations, but progress can be made in overcoming at least some of these difficulties if the economics profession places fitting the facts over the ideology of representative agent microfoundations when allocating research resources.

It may well be that macroeconomic policy concerns will drive such a reallocation of effort towards macroeconomic models that contain hysteresis. In terms of fiscal policy, work at the IMF has shown that multipliers in the post-2007 "great recession" were substantially higher than implied by pre-2007 forecasts (IMF 2012, Box 1.1, pp.41-43); and the downward forecasts of potential output during this recession implicitly involve hysteresis (deLong and Summers, 2013, p.32). Regarding monetary policy, the central banks of the US and UK have introduced "forward guidance" triggers for the unemployment rate, of 6.5% and 7% respectively, when setting interest rates. New Keynesian-DSGE models, which do not contain unemployment rates, will be of little use to central banks using such "forward guidance" triggers for their repo interest rates.

Admitting hysteresis into macroeconomic models will raise fascinating and important research problems, such as the appropriate proportional-integral-derivative mix of policy stance when the real economy has a selective, erasable memory of the past stances of policy. The challenge is there. The macroeconomics profession learned some useful things in the wake of the economic depressions of the 1920s and 1930s, but has forgotten much of what was learned. What will be learned from the post-2007 "great recession"? Maybe the selective, erasable memory property of Preisach models of hysteresis will also apply to theories in macroeconomics?

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