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Testing Wage and Price Phillips Curves for the United States

by

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Abstract

This paper demonstrates, contrary to what has been shown recently, that demand pressure, besides cost-pressure, matters both in the labor market and the market for goods in the determination of wage and price inflation. We consider and estimate both wage and price Phillips-curves for the U.S., using OLS and nonparametric estimation techniques. The finding is that on the whole wages are more flexible than prices with respect to their respective demand pressure terms and that price inflation determination gives (somewhat) more weight to medium term inflation than does wage inflation. This implies, as reduced form equation, a real wage dynamic that depends positively on the real wage, and thus an adverse real wage adjustment, if aggregate demand depends positively on temporary real wage changes (which is likely to be the case, at least in states of high economic activity). Monetary policy thus is not only facing adverse real rate of interest adjustments (destabilizing Mundell-effects), but also destabilizing real wage adjustments (adverse real-wage effects). Such effects have rarely been discussed and estimated in the literature. In comparing linear and nonlinear estimates we find that for some relationships nonlinearities are important for others not. Although overall the nonlinear estimates tend to confirm our linear estimates nonlinearities in some relationships of the Phillips-curve are important as well.

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1 Introduction

Since the 1980s it has become customary to express labor and goods market dynamics in a single Phillips curve. Yet as Fair recently correctly states this might be regrettable since it implies a considerable loss of predictive accuracy, see Fair (2000:69). Phillips (1958) still had strongly emphasized that two markets are involved in the unemployment-inflation trade-off. He viewed the relationship between unemployment (demand pressure) and wage change as a nonlinear one and stressed that product market prices (cost pressure) do effect the unemployment-wage relationship in certain time periods of his estimates. Although he did not estimate wage and price Phillips curves separately he points out that those two are interacting.

If one follows the above suggestions one should formulate and estimate separate wage- and price Phillips-curves where both demand and cost pressures, originating in the labor and the goods markets, should appear in their reduced form expressions. This is in particular needed if the two measures of demand pressure in these two markets, excess labor on the external labor market and excess capacity within firms, do not move in line with each other.

Following up the above considerations concerning two Phillips-curves we will estimate linear as well as nonlinear relationships. In contrast to Phillips (1958) who presumed a parametric form for the nonlinear estimation, we will apply nonparametric estimation techniques to capture nonlinearities. To test for nonlinearities appears to be useful, since recent theoretical and empirical studies seem to indicate that wage Phillips-curves are different for high and low unemployment rates. The studies by Stiglitz (1997) and Eisner (1997) suggest that inflation rates do not increase proportionally with lower unemployment and higher capacity utilization. Moreover, another nonlinearity has been stated with respect to periods of high and low inflation rates (see Akerlof, 2002, and Fehr and Tyran, 2001). Akerlof, for example argues, that at "a very low inflation, a significant number of workers do not consider inflation sufficiently salient to be factored into their discussions. However, as inflation increases, the losses from ignoring it also rise, and therefore an increasing number of firms and workers take it into account in bargaining" (Akerlof, 2002:421). Moreover, numerous empirical studies have documented downward stickiness of wages (see Fehr and Tyran (2001)) as Keynes originally had conjectured. This literature then implies that there is indeed a long-run trade-off between output and inflation and monetary policy matters (see also Mankiw and Reis, 2002, and Blanchard, 2003).

In order to evaluate the above statements correctly one needs separate wage and price Phillips-curves. Indeed, in comparing linear and nonlinear relationships we can highlight, as Fair (2000) correctly points out, that there is an essential weakness of the traditional Phillips-curve by studying only a reduced form relationship between unemployment and inflation rate. Fair (2000) correctly stresses the advantage of estimating two in the place of only one Phillips curve, be that in structural or in reduced form where two curves are to be estimated. But in his own estimates Fair uses level variables for wages and prices instead of rate of changes of wages. We will pursue estimates with rates of change of wages and prices. Another crucial point is the fact that the NAIRU itself, used to define an employment gap, may move over time (one may need to allow for a time varying NAIRU, see Gordon, 1997, and Eller and Gordon, 2003).

The remainder of the paper is organized as follows. In section 2 we will briefly reconsider the wage and price level based structural equations estimated in Fair (2000) and show that they may easily be turned into ordinary wage and price inflation Phillips-curves when account is taken of the parameter sizes estimated by Fair (2000). We would like to argue that such separate wage and price inflation Phillips curves can give rise to various real wage adjustment patterns, two normal or stabilizing ones and two adverse or destabilizing ones. In section 2 we will derive from Fair's equations quite general structural linear wage and price Phillips-curves. We compare these equations with various special types used in the literature. In section 3 we provide single equation OLS estimates for these various expressions in order to determine on this basis in particular whether a certain critical condition for real wage instability was fulfilled for the US economy over the period after World War II. In section 4 we explore nonlinearities in those two Phillips-curves on the structural level and will find that these curves may indeed be weakly nonlinear in the US.[1] Section 5 concludes the paper.

2 Wage and Price Phillips-curves

The stated observation by Fair (2000) that in the last two decades the work on the Phillips-curve has moved away from wage and price Phillips-curves to the estimation of reduced form price equations is certainly true for applied work. There it appears to be quite common to express labor market and goods market dynamics by a single Phillips curve with demand pressure based on the external labor market and with cost pressure in the two markets represented by a single expected rate of inflation (with markup pricing as a possible justification for such reduced form inflation dynamics, see Blanchard and Katz, 1999, for example). It seems, however, also to hold for theoretical work, in particular in the New Keynesian Phillips curve,[2] where beside the IS equation, only a single equation for wage-price inflation is included in the core macrodynamic equations.[3]

In order to derive our own two-dimensional formulation of the wage-price spiral[4] we start from the two structural wage and price equations in level provided and estimated in Fair (2000). His estimations, when written in terms of growth rates are basically of the form that the inflation rate helps to predict the wage change and the unemployment (with a delay) as well as the wage rate predicts well the inflation rate.

Yet such a structure of the two equations is not sufficient, from the theoretical perspective, to really represent a structural approach to the wage-price spiral. It represents an

[1] The nonlinearities are, however, of different type than estimated for European countries in Hoogenveen and Kuipers (2000). Other papers on nonlinearities in the Phillips-curve are Schaling (1999) and Semmler and Zhang (2003).

[2] See Gali (2000, 2003) for a recent survey on this approach.

[3] With respect to the use of a single curve it is stated in Mankiw (2001): "Although the new Keynesian Phillips curves has many virtues, it also has one striking vice: It is completely at odd with the facts." Eller and Gordon (2003) go a step further by declaring it an empirical failure. There are of course also exceptions, as for example the paper by Cohen and Farhi (2001) from the applied perspective, and from the theoretical perspective in the area of staggered wage and price setting, where however the concept of a wage-price spiral is rarely discussed, see Blanchard (1986) for its use and Huang and Liu (2002) for a recent contribution to this area.

[4] Giving rise to 2D dynamics when embedded into a larger macrodynamic framework.

interesting special hypothesis on the working of this spiral, which states that wages follow prices more or less passively and that demand pressure matters in the market for goods, but not in the market for labor. More generally, one can reformulate wage-price dynamics as follows.

$$
\begin{aligned}
Dw &= \beta_{w_1}(V^l - \bar{V}^l) + \beta_{w_2}(V^w - 1) + \kappa_w Dp + (1-\kappa_w)Dp^m && (1)\\
Dp &= \beta_{p_1}(V^c - \bar{V}^c) - \beta_{p_2}(V^n - 1) + \kappa_p Dw + (1-\kappa_p)Dp^m && (2)
\end{aligned}
$$

where Dw and Dp stand for wage and price inflation. We use two measures of demand pressure both in the labor and the goods market, $V^l - \bar{V}^l, V^w - 1$ denoting excess labor demand on the external labor market and (in terms of overtime worked) within firms, and $V^c - \bar{V}^c, V^n - 1$ denoting excess demand on the market for goods in terms of capacity and inventory use. As variable for expected price change we use an inflationary climate expression Dp^m which represents a 12 quarter moving average[5], see appendix 2. As concerns the NAIRU $\bar{V}^l$, we may allow, as Tobin (1998) suggest, that the NAIRU shifts over time as the relationship of unemployment, vacancies and wages varies and as the dispersion of excess demands and supplies across markets change over time.[6] But we may presume that $\bar{V}^l$, as well as $\bar{V}^c$, are fixed for certain time periods. We point out that we prefer to write in this section the various measures of demand pressure in terms of employment (V) and not in terms of unemployment ($U = 1 - V$), since rates of employment are more flexible in their treatment with respect to growth rate concepts and the integration of alternative measures of demand pressure. We shall return to straightforward reformulations in terms of rates of unemployment in the empirical part of the paper in order to be closer to common econometric practice.

In the following we will set β_{w_2}, β_{p_2} equal to zero and will thus only pay attention to employment and capacity utilization rates V^l, V^c in their deviation from the NAIRU type rates $\bar{V}^l, \bar{V}^c$. This simplification of wage and price Phillips-curves, in our view, represents the minimum structure one should start from. It should be simplified further only if there are definite and empirically motivated reasons to do so.

In macrotheoretic models the above type of wage and price Phillips curves (disregarding our inflationary climate expression Dp^m however) have played a significant role in the rationing approaches of the 1970's and 1980's. Yet, with some exceptions it was fairly unnoticed in theory that having specific formulations of demand and cost pressure on both the labor market and goods market would imply that either wage or price flexibility must always be destabilizing, depending on marginal propensities to consume and to invest with respect to changes in the real wage. In section 3 we will come back to this issue. Stressing the use of separate Phillips curves for wage and price dynamics one can find in the literature on the Phillips-curve even more general forms than represented in our equs. (1)-(2). In order to show this, the re-reading of the articles by Phillips is of great help. Phillips (1954) investigated three possible types of fiscal policies, proportional, derivative and integral feedback policy rules, which change for example government expenditures, broadly speaking, in proportion to output gaps, in proportion to their time rate of change

[5] See also Rudebush and Svensson (1999).

[6] For estimations of a time varying NAIRU, see Gordon (1997), Eller and Gordon (2003) and Semmler and Zhang (2003).

and in proportion to the accumulated differences of such gaps, of course with a negative feedback sign in order to counteract less than normal situations in particular. Similarly, inflation rates may be driven by factor utilization gaps, or, in the case of wage inflation specifically, by deviations of the rate of employment from its NAIRU level, but also by the rate of change of the employment rate or the accumulated differences (where positive and negative signs may occur) of the deviation of unemployment rates from normal levels, here again considered in continuous time. Some of those feedback effects can also be found in Phillips (1958).

Though not framed in the same language, all three possibilities are in fact also to be found in early and recent investigations of the PC approach. The proportional control can be found in this standard Phillips-curve. The derivative control often takes the form of the so-called Phillips loops, see Blanchflower and Oswald (1994), for a revival of this approach, where the level of wages or of the wage share, and not its growth rate, is related to the rate of unemployment. The integral control can be found in Stock and Watson (1997) where it is claimed that the rate of unemployment is not in fact determining the rate of inflation itself, but rather its time rate of change. Marrying Phillips (1954) with Phillips (1958) with respect to a treatment of wage and price inflation thus provides a fairly general framework on the basis of which the various findings in the literature on 'the' Phillips curve can be evaluated and investigated in a unified way.

Including the above feedback effects into a more general formulation of wage and price PC's yet, leaving aside here the issue for the cost-pressure terms which in principle could be treated in the same way the wage and price PC's extended in this way may then read:[7]

$$
\begin{aligned}
Dw &= \beta_{w_1}(V^l - \bar{V}^l) + \beta_{w_2}\dot{V}^l/V^l + \beta_{w_3}\int (V^l - \bar{V}^l)dt + \kappa_w Dp + (1-\kappa_w)Dp^m && (3)\\
Dp &= \beta_{p_1}(V^c - \bar{V}^c) + \beta_{p_2}\dot{V}^c/V^c + \beta_{p_3}\int (V^c - \bar{V}^c)dt + \kappa_p Dw + (1-\kappa_p)Dp^m\,. && (4)
\end{aligned}
$$

Both the wage and the price Phillips curve are characterized by three measures of demand pressure on their respective market, all working in the traditional way (as compared to the New Keynesian PC). There is also included an appropriate cost pressure term for example a weighted average inflation term, the inflationary climate Dp^m in which the economy is operating. Note finally that this approach guarantees that these equations – in contrast to the ones employed by Fair (2000) – are model consistent in the sense that they are compatible with a balanced growth path.

Note that our wage and price Phillips curves are of the general form

$$
\begin{aligned}
Dw &= \beta_{w's}(\cdot) + \kappa_w Dp + (1-\kappa_w)Dp^m\\
Dp &= \beta_{p's}(\cdot) + \kappa_p Dw + (1-\kappa_p)Dp^m
\end{aligned}
$$

and thus represent, when appropriately reordered, two linear equations in the unknowns $Dw - Dp^m$, $Dp - Dp^m$ that can be uniquely solved for $Dw - Dp^m$, $Dp - Dp^m$, when

[7] In these equations we denote by V^l, V^c the rate of employment for labor and capital and by $\bar{V}^l, \bar{V}^c$ their NAIRU levels, and finally by Dp^m the inflationary climate that surrounds the current state of the economy. Note that we disregard labor productivity growth here which in empirical estimates of such curves is not of much importance.

$\kappa_w, \kappa_p \in [0,1]$ fulfill $\kappa_w \kappa_p < 1$, giving rise then to the following reduced form expressions:

$$\begin{aligned} Dw - Dp^m &= \frac{1}{1-\kappa_w\kappa_p}[\beta_{w's}(\cdot) + \kappa_w \beta_{p's}(\cdot)] \\ Dp - Dp^m &= \frac{1}{1-\kappa_w\kappa_p}[\beta_{p's}(\cdot) + \kappa_p \beta_{w's}(\cdot)] \end{aligned}$$

with all demand pressure variables impacting positively the deviation of wage as well as price inflation from the inflationary climate variable Dp^m.

An even more general formulation of wage and price Phillips-curves can be obtained by including two measures for demand pressure[8] in the labor and goods market. Furthermore, making use of all the above three Phillips' (1954) types of controls the integrated PC's can be further differentiated, leading to 6 types of expressions in the wage and price Phillips-curve. This leads us to the following fairly complex reduced form expressions for expectations augmented PC's:

$$\begin{aligned} Dw = Dp^m &+ \frac{1}{1-\kappa_w\kappa_p}[\beta_{w_1}(V^l - \bar{V}^l) + \beta_{w_2}\dot{V}^l/V^l + \beta_{w_3}\int (V^l - \bar{V}^l)dt \\ &+ \kappa_w(\beta_{p_1}(V^c - \bar{V}^c) + \beta_{p_2}\dot{V}^c/V^c + \beta_{p_{31}}\int (V^c - \bar{V}^c)dt] \qquad (5) \\ Dp = Dp^m &+ \frac{1}{1-\kappa_w\kappa_p}[\beta_{p_1}(V^c - \bar{V}^c) + \beta_{p_2}\dot{V}^c/V^c + \beta_{p_{31}}\int (V^c - \bar{V}^c)dt \\ &+ \kappa_p(\beta_{w_1}(V^l - \bar{V}^l) + \beta_{w_2}\dot{V}^l/V^l + \beta_{w_3}\int (V^l - \bar{V}^l)dt] \qquad (6) \end{aligned}$$

Equ. (5) represents the most general wage Phillips-curve and equ. (6) represents the integrated or reduced form price Phillips curve including various measures of demand pressure, where the actual wage and price inflation cost-push cross reference has been removed by mathematical substitution.

Obviously, equ. (6) is much more complicated than the traditional expectations augmented price Phillips curve of the theoretical literature[9]. Furthermore, all demand pressures influence the inflation rate in the usual positive way, avoiding the empirically implausible inverse adjustment to demand pressure of the new Keynesian PC which there occurs, despite the assumed perfect forward-looking behavior of both wage earners and firms as far as the evolution of the short-run is concerned. We want to stress here that stabilizing results will very much depend on which types of demand pressure terms (proportional, derivative or integral) are present in the initial or reduced form PC's.

In view of equs. (5) and (6), we can now comment on applied approaches to PC measurements. Fair (2000), as already shown, provides one of the rare studies which starts from the two PC's, though he makes use of $\beta_{p_1} \neq 0$ solely as far as demand pressure variables are concerned. In his view the price Phillips curve is therefore the important one.

[8] see Laxton et al. (2000) for a typical example, where, as is customary, only one measure of demand pressure, on the labor market, is considered.

[9] see Laxton, Rose and Tambakis (2000) for example, or its Walrasian reinterpretation as a Lucas supply curve.

Laxton et al. (1998) use for the Multimod Mark III model of the IMF an integrated, or hybrid, PC of the type (6) with only $\beta_{w_1} \neq 0$, and thus the most basic type of PC approach, but stress instead the strict convexity of this curve and the dynamic NAIRU considerations this may give rise to. In their view, therefore, the wage Phillips-curve, with proportional term only, is the important one. On the other hand, Stock and Watson (1997) find evidence for a Phillips-curve of the type $\dot{\pi} = \beta_{w_3}(V^l - \bar{V}^l), \ \pi = Dp$, which – by the choice of notation here used – indicates that this view is in fact based on an integral control in the money wage Phillips-curve (solely) and possibly also on a specific, implicit treatment of inflationary expectations in addition. Roberts (1997) derives a conventional expectations-augmented price Phillips-curve from regional wage curves as in Blanchflower and Oswald (1994) and thus argues that proportional control is relevant on the aggregate level even if derivative control applies to the regional level.

Yet, there are few studies as regards the inside employment rates and inventory utilization rates. This might be possibly due to the lack of data. Only Fair (2000) takes account of the possibility that demand pressure on the goods market may be qualitatively and quantitatively different from demand pressure on the labor market. On the other hand, at least the possibility for proportional, derivative and integral control is taken into account by this literature, though not reflected and compared in these terms. Overall, we can see from our brief discussion that a variety of views have been developed originating in Phillips (1954, 1958) seminal work.

It must also be noted that the discussion on Phillips-curves is still unsettled, in particular with respect to the empirical significance of all those terms in the equs. (5)-(6). Indeed, not all of the expressions shown in equs. (5)-(6) must be relevant from the empirical point of view, at all times and in all countries. But this should be the outcome of a systematic investigation and not the result of more or less isolated views and investigations. Nevertheless, it appears that the analysis and investigation of those curves need to be approached from the extended perspective we have described above.

Furthermore we want to note that also the theory of inflationary expectations may be developed further along the lines suggested by our analysis of Phillips-curves. In this respect recall first that we have myopic perfect foresight in our wage - price dynamics of price and wage inflation respectively, but have also assumed that these rates of inflation enter wage and price formation processes only with a weight $\kappa_w, \kappa_p < 1$, respectively. In addition we have employed a uniform measure of average inflation, expected to characterize the medium run, which enters these processes with weight $1 - \kappa_w, 1 - \kappa_p$, respectively. We have thus, as recently also presumed in the hybrid New Keynesian Phillips-curve, a weighted average of forward and backward looking expectation dynamics,[10] where in the latter a one period ahead variable appears on the right hand side of the equation. We are inclined to assume that the expectation of medium-run inflation cannot be perfect, but that it is based on some time series method, simple adaptive expectations schemes, or, humped shaped weighting schemes of past observation expressing some price inertia. There is thus also considerable scope to extend the discussion on the expectational terms in the Phillips-curves which, however, is left here for future investigations.[11]

[10] See Gali, Gertler and Lopez-Salido (2003).

[11] We want to note that some empirical estimates of the two Phillips curve approach for the US and Germany are, with some success, already undertaken in Flaschel, Gong and Semmler (2001).

Although the above linear wage and price Phillips-curve permit a wealth of possibilities for the further empirical investigations, recent theoretical and empirical research has taken the path to investigate, as mentioned in the introduction, and as Phillips (1958) originally intended, nonlinearities in a few key relationships. The remainder of the paper will first present some empirical results on some simplified versions of the linear approach (5)-(6) and then explore nonlinearities of some key relationships.

3 Wage and Price Phillips-curves: OLS Estimates

Next, we provide some single equation OLS estimates for the wage and the price Phillips curve on the basis of the linear curves as above discussed. In these estimates we do not impose at first any steady state condition and thus estimate the Phillips curve (now, however, including a Price PC) nearly as in Phillips (1958). We will explore the question of its nonlinearity in the next section. Besides current price inflation Dp, we make use of the inflationary climate expression $Dp12 = Dp^m$, here simply based on the arithmetic mean over the past 12 quarters. We use the US-data as described in the appendix 2, for the range 1950:2 to 1999:4. On this data basis we estimate the two linear curves

$$Dw = a_o - a_1 U^l_{-1} + a_2 Dp + a_3 Dp12 + a_4 dyn, \tag{7}$$

$$Dp = b_o - b_1 U^c_{-1} + b_2 Dw + b_3 Dp12 + b_4 dyn \tag{8}$$

where $U^l = 1 - V^l, U^c = 1 - V^c$ with V^l, V^c as rates of utilization of the stock of labor and the capital stock and dyn representing the growth rate of labor productivity. Note that these two Phillips curves focus on the proportional influence of demand pressure terms and neglect derivative and integral terms which have been found to be of little significance, see also Flaschel and Krolzig (2003) in this regard. Note also that w, p now represent logarithms, i.e., their first differences Dw, Dp is the current rate of wage and price inflation. We use $Dp12$ to denote now specifically the moving average of price inflation over the past 12 quarters (as a simple measure of the employed inflationary climate expression), and denote by subscript -1 a time lag of one quarter. Finally, for notational simplicity we have carried out a slight change in notation by using coefficients a and b in (7) and (8) instead of β and κ. Together with the nonparametric approach in the next section this avoids double indexing and makes the model more readable, as now a-coefficients relate to the wage Phillips curve while b-coefficients occur in the price Phillips curve. The connection to the previous section is obvious. For instance $-a_1$ is a proxy for β_{w_1} or b_2 mirrors κ_p in (4).

Equ. (7) and (8) are estimated in three different forms:

$$Dw = a_o - a_1 U^l_{-1} + a_2 Dp + a_3 Dp12 + a_4 dyn,$$

$$Dw - Dp12 = a_o - a_1 U^l_{-1} + a_2 (Dp - Dp12) + a_4 dyn,$$

$$Dw - Dp12 = a_o - a_1 U^l_{-1} + a_2 (Dw - Dp12)_{-1} + a_3 (Dw - Dp12)_{-2}) + a_4 dyn$$

The first equation has already been discussed in sect. 2. The second considers wage and price inflation in terms of their deviation from the inflationary climate $Dp12$ lagged by one period with respect to current price inflation. This form of the equation imposes the restriction $a_3 = 1 - a_2$ on the first equation, and thus assumes a coefficient of unity with respect to total cost pressure in the wage inflation Phillips curve. The third equation finally must be considered as an approximation to the reduced form equation

$$Dw - Dp12 = a_o - a_1 U^l_{-1} - a_2 U^c_{-1}$$

considered in sect. 2. Empirically this does not produce good estimates, at least in the case of price inflation. In this latter equation we have replaced the indirect cost pressure $a_2 U^c_{-1}$ term by lagged direct expressions for cost pressure in the money wage PC in order to produce estimates that can reasonably be compared to the other ones. The estimation results for the three forms of the wage PC are provided in table 1. Data sources for the estimation are reported in appendix 2.

Dependent Variable: Dw		
variable	estimate	t-values
constant	0.0131	9.8395
U^l_{-1}	-0.1720	-6.2885
Dp	0.4464	6.0274
$Dp12$	0.6056	5.6103
dyn	0.1676	4.2577
R^2	0.5165	
$\bar{R}^2$	0.5099	
RSS	0.0047	
DW	2.0058	

Dependent Variable: $Dw - Dp12$		
variable	estimate	t-values
constant	0.0130	9.8394
U^l_{-1}	-0.1621	-7.1940
$Dp - Dp12$	0.4448	6.0386
dyn	0.1624	4.2218
R^2	0.4084	
$\bar{R}^2$	0.3995	
RSS	0.0047	
DW	2.0026	

Dependent Variable: $Dw - Dp12$		
variable	estimate	t-values
constant	0.0125	7.7373
U^l_{-1}	-0.1660	-6.4120
$(Dw - Dp12)_{-1}$	0.2196	3.2964
dyn	0.1202	3.0484
R^2	0.3474	
$\bar{R}^2$	0.3376	
RSS	0.0048	
DW	2.0092	

Table 1: *Estimates for Wage PC*

All three estimates for shown provide for the speed with which wages adjust to demand pressure β_w approximately the value 0.16. Estimates for a_3 corresponding to the term κ_w in (3) represent the short-sightedness of wage earners with respect to their cost-pressure variable. With respect to price inflation a value of approximately 0.44 results. Wage adjustment with respect to demand pressure in the labor market is thus fairly flexible (in particular in comparison to the respective price adjustment term, see below) and wage earners are fairly short sighted giving nearly 1/2 as weight to the present evolution of price inflation. The growth rate of labor productivity however does not play a significant role in the evolution of wage inflation (where from a theoretical and steady state perspective it should have the weight 1 in the place of approximately 0.15). We thus indeed find that price flexibility with repsect to demand pressure is very low and that firms are less short-sighted with respect to inflation and its climate than workers are.

An approximate expression for NAIRU unemployment rate $\bar{U}^l$ in the labor market can be obtained from the expression $-a_0/a_1$ given by $0.0132/0.1720 = 0.0767$. We thus in sum get – in contrast to what is obtained in Fair (2000) – that demand pressure (on the labor market) matters and that wage earners do not only use present information in order to formulate their wage claims, but in fact rely on the inflationary climate into which current goods price inflation is embedded to a larger degree. There is thus considerable persistence of price inflation with respect to formation of wage inflation in the wage PC (and even more in the price PC).

Dependent Variable: Dp		
variable	estimate	t-values
constant	0.0033	2.2133
U^c_{-1}	0.0226	-2.8190
Dw	0.3141	5.7673
$Dp12$	0.6788	8.9434
dyn	-.1117	-3.1725
R^2	0.6108	
$\bar{R}^2$	0.6030	
RSS	0.0041	
DW	1.6382	

Dependent Variable: $Dp - Dp12$		
variable	estimate	t-values
constant	0.0033	2.2198
U^c_{-1}	0.0229	-2.9968
$Dw - Dp12$	0.3149	5.8444
dyn	-0.1110	-3.2070
R^2	0.3083	
$\bar{R}^2$	0.2980	
RSS	0.0040	
DW	1.6404	

Dependent Variable: $Dp - Dp12$		
variable	estimate	t-values
constant	0.0043	3.4101
U^c_{-1}	-0.0213	-3.0764
$(Dp - Dp12)_{-1}$	0.3532	5.3405
$(Dp - Dp12)_{-2}$	0.1592	2.4517
dyn	-0.0874	-2.7907
R^2	0.3909	
$\bar{R}^2$	0.3786	
RSS	0.0038	
DW	2.0989	

Table 2: *Estimates for Price PC*

In table 2 we show the same calculations now for the price PC and get there too that demand pressure, now on the market for goods matters for the evolution of price inflation, yet compared to wage inflation – again opposite to findings in Fair (2000) – to a much smaller degree: $-a_1$ as a proxy for β_p takes value 0.0226. This is partly due to the fact that the volatility of capacity underutilization rate on the goods market which represent underutilization rates in the proper sense of the word, is much higher than on the labor market (where over- and undertime of the employed workforce is ignored). In addition, inertia with respect to wage pressure in the price Phillips curve is larger than in the wage PC, since current wage inflation only gets the weight 0.31 compared to the inflationary climate expression $Dp12$. We thus in sum get that wages are more flexible than prices with respect to demand pressure on their respective markets and that wage earners are more short-sighted than firms with respect to the cost-pressure items these two sectors in the economy are facing. For the NAIRU rate of capacity utilization on the market for goods we finally get, formally as in the case of wage inflation, now the value $\bar{U}^c = 0.147$.

Flaschel and Krolzig (2003) have already estimated the wage and price Phillips curves of this section. They used as lag structure in the estimation of a general model of the wage-price spiral of this paper a length of five lags on the right hand side in both the wage and price PC. They then obtained as specific result by the PcGets optimization routine that indeed only proportional terms with respect to demand pressure on the market for labor and for goods remained in operation as determinants of wage as well as price inflation (while cost pressure exhibits of course also integral control due to the inflationary climate expression used).

As in this earlier work we here have obtained that wages are again more flexible ($0.162 - -0.173$) than prices (approximately 0.02) with respect to their corresponding demand pressure, with workers now however more short sighted than firms with respect to current inflation in comparison to the inflationary climate surrounding the current level of wage and price inflation rates ($\kappa_w = 0.44$ and $\kappa_p = 0.31$, approximately).

These results imply as in this earlier work an adverse type of real wage effect if it is assumed that consumption is more responsive to real wage changes than investment (which is likely to be the case with respect to temporary real wage changes, in particular in periods of high economic activity). In this case economic activity depends positively on the real wage whose dynamics is then described by:[12]

$$\boxed{D\omega = \frac{1}{1-\kappa_w\kappa_p}[(1-\kappa_p)\beta_{w_1}(\bar{U}^l - U^l) - (1-\kappa_w)\beta_{p_1}(\bar{U}^c - U^c)]}$$

as can easily be shown by means of the reduced form expressions for wage and price inflation of the preceding section.

On the basis of the thereby obtained reduced form law of motion for the real wage $\omega = w - p$ one gets as critical α-condition for the establishment of a positive dependence of the growth rate of real wages on their current level (under the assumption of aggregate demand that

[12] with k_o the capital / full employment output ratio and $1/y^p$ the capital / full capacity output ratio, which are approximately equal to each other.

is wage-led, i.e, with $1 - U^l = V^c(\omega)$ strictly increasing in ω) the following term:

$$\alpha = (1-\kappa_p)\beta_{w_1}k_o - (1-\kappa_w)\beta_{p_1}/y^p \left\{ \begin{array}{c} < \\ > \end{array} \right\} 0 \iff \left\{ \begin{array}{c} \text{normal} \\ \text{adverse} \end{array} \right\} \text{RE},$$

The above is the critical α-condition for the occurrence of normal and adverse real wage effects, also called Rose effects (RE), in such wage-led regimes.[13] This critical α-condition applies to the estimation results as reported in tables 1 and 2. In all estimates provided in tables 1 and 2 this critical condition is always positive in sign (approximately 0.2 in size if $k_o = 2$ is used as reference capital-output ratio and its reciprocal value reflected in our measure of potential output).

Thus, real wage adjustment is always of adverse type in the cases where economic activity depends positively on the real wage. This implies that there is a mechanism at work that adds to the explanation of destabilizing wage-price spirals as they where observed in particular at least in 1960's and 1970's during the prosperity phase after World War II. Periods of low inflation as they are now discussed in the literature may be different in this regard. This is a topic that should be more extensively be addressed in future research, by extending the results we obtain in the next section of this paper, which still support the views of the present section even for low inflation regimes, at least as far as the US-economy is concerned.

4 Structural Wage and Price Phillips-curves: Exploring Nonlinearities

Next, we will now explore non-linearities in the Phillips curves. Following Phillips (1958) in exploring nonlinearities in some key relationships we replace all relationships by unspecified functional forms. For wage Phillips curve (7) this means we let U^l_{-1} enter the curve as function $A_1(U^l_{-1})$ say, where $A_1(.)$ is supposed to be estimated from the data. In the same fashion we allow the other quantities in (7) to have a non-linear effect so that (7) is replaced by the general form

$$Dw = a_0 + A_1(U^l_{-1}) + A_2(Dp) + A_3(Dp12) + A_4(dyn) \tag{9}$$

For the different functions we assume sufficient smoothness, i.e. we postulate that they are two times continuously differentiable but otherwise unspecified. Accordingly, the price Phillips curve is generalized to

$$Dp = b_0 + B_1(U^c_{-1}) + B_2(Dw) + B_3(Dp12) + B_4(dyn). \tag{10}$$

To keep the notation simple we subsequently also write $A(U^l)$ for $A_1(U^l)$ and likewise for the other functions. Let us explain the generalization (9) and (10) in more depth. First, if we assume that all functions in (9) and (10) are linear, that is $A_1(U^l_{-1}) = a_1 U^l_{-1}$, we obtain the Phillips curves (7) and (8). Hence, the Phillips curves (9) and (10) are natural and general extensions of (7) and (8). Secondly, it becomes obvious that further constraints are

[13] It has to be reversed in sign in the case of profit-led regimes.

necessary to make the functions in (9) and (10) identifiable. Note that for instance adding a constant to one of the functions $A(.)$ and subtracting it from a_0 gives another solution to (9). We therefore impose the constraint that the functions are centered around zero. For $A_1(U^l)$ this means for instance $A_1(U^l) - A_1(\bar{U}^l) = 0$, where $A_1(\bar{U}^l) = \sum_{i=1}^n A_1(U_i^l)/n$. Note that we have used similar constraints in the linear Phillips curves (7) and (8) by putting $\beta_w \bar{U}^l$ in the intercept a_0.

As aforementioned Phillips (1958) in his original article already considered non-linear functions. Unlike his approach however our functions are nonparametric, that is no parametric functional form is imposed. The idea behind (9) and (10) is to let the data decide upon the structure and form of the functions. This can be done by what is called nonparametric regression. Estimation of nonparametric models like (9) and (10) has been a major field of research in statistics over the last two decades with an initial milestone set by Hastie & Tibshirani (1990). An up to date demonstration of the state of the art including most recent references is found in Ruppert et. al. (2003). We provide a short sketch in the Appendix. The technique is numerically easily applicable and part of element of modern statistical software packages like S-PLUS (http://www.insightful.com) or R (http://www.r-project.org), see also Venables & Ripley (1999).

Nonparametric, smooth regression is carried out using a smoothing parameters steering the amount of smoothing. If the smoothing parameter is set large, in the extreme case infinity, the resulting fitting step breaks down to simple parametric fitting and the parametric models (7) and (8) arise. In contrast, if the smoothing parameters are set to small values, estimates will be highly structured and highly variable therefore. It is therefore necessary to choose a smoothing parameter which provides a good balance between flexibility and variability. This can be done data driven, so that nonparametric estimation not only allows to estimate functional relationships without stringent parametric assumptions, it also provides an estimate for the functional complexity of the model. This means that the functional form and complexity can be chosen data driven. A conventional tool for this is cross validation or the Akaike criterion (see Akaike, 1973). The latter has the form

$$AIC(\lambda) \;=\; \log\{\sum_{i=1}^{n}(Dw_i - \widehat{Dw}_i)^2\} + 2df(\lambda)/n \tag{11}$$

where $\widehat{Dw}_i$ are the fitted values. The first component (11) measures the goodness of fit as sum of squared residuals while $df(\lambda)$ is a measure for the degree of complexity of the fitted model. The parameter λ is thereby the tuning parameter steering the smoothness of the fitted functions. The Akaike criterion itself works as follows. Setting λ to zero leads to complex functions and hence small residuals $Dw_i - \widehat{Dw}_i$. Consequently the first component in (11) is small while the latter is large. Vice versa if λ is large, the sum of squared residuals will increase while the complexity $df(\lambda)$ is small, in the extreme case $df(\lambda \to \infty) = 1$. An optimal smoothing parameter now balanced out these two extremes and selects the minimum of $AIC(\lambda)$. The resulting fits are shown for wage and price Phillips curves in Figures 1 and 2, respectively. The solid curves show the nonparametric fitted functions with complexity degree chosen by the data. The degree is thereby stated on the y axes of the plots. For instance $A(U_{-1}^l, 5.25)$ is a function of complexity degree 5.25 while $A(Dyn, 1.03)$ has complexity 1.03 which is about linear line as can be seen from the bottom right plot of Figure 1. The dashed lines above and below the smooth curves indicate pointwise confidence intervals while the dotted line shows simple OLS estimates in the linear model that is function $A_1(U^l_1) \equiv a_1(U^l_{-1} - \bar{U}^l_{-1})$ as fitted in Section 3. The parameter estimates for the latter are listed in Table 3. The ticks in the bottom of the graphs indicate the observed values for the explanatory variables.

Before interpreting the curves in more depth we want to explore the reliability of the fits, in particular the chosen complexity of the functions. To do so we run a bootstrap / Jackknife simulation. We refit the model using 85% of the observation by omitting randomly 15% of the observations. This is repeated 200 times and the estimated degrees of complexity are recorded. These are shown in Figure 3 and 4, respectively. The two main features that can be observed are the following. For the wage Phillips curve there is indication of a hyper-linear structure for unemployment rate U^l_{-1} while the remaining components Dp, $Dp12$ and Dyn follow a linear structure.

The Phillips-curve for the inflation rate also shows some evidence for a nonlinear relation for U^c_{-1}, Dw and $Dp12$. The nonlinearity of the price change with respect to U^c_{-1} in Figure 2 confirms the position taken by Stiglitz (1997) and Eisner (1997) who have viewed the Phillips-curve as concave with respect to the output gap. As to U^c_{-1}, we can observe in Figure 2 that an increase in cpacity utilization increases prices less than proportional.

On the other hand the shape of the relationship of $Dp12$, our expression for inflation expectations, in Figure 2, does indicate only a slight nonlinearity for the price Phillips-curve, a nonlinearity that Akerlof (2002) referred to as "information stickiness" (see also Mankiw and Reis, 2002). As can be seen nominal wages (and inflation rates) react to anticipated variables only slightly more if the variable is high as compared to being low, see Figure 2.

In sum, the functional form of $A(U^l_{-1})$ as well as $B(U^c_{-1})$ shows a convex structure with a negative slope for small values of U^l_{-1} and U^c_{-1}, respectively. This means that with increasing capacity utilization prices do not rise unboundedly but inflation rates may become flat or even decline. On the other hand inflation rates, of course, will fall with very low capacity utilization.

Overall, the nonlinear estimates roughly confirm our linear wage and price Phillips-curves which are represented by the dotted lines in the figures 1 and 2. In addition, as our comparison of linear and nonlinear Phillips-curves show, for some relationships nonlinearities are important, for others not. In particular the nonlinearity in the relationship between wage change (price change) and unemployment (capacity utilization) is an important result.

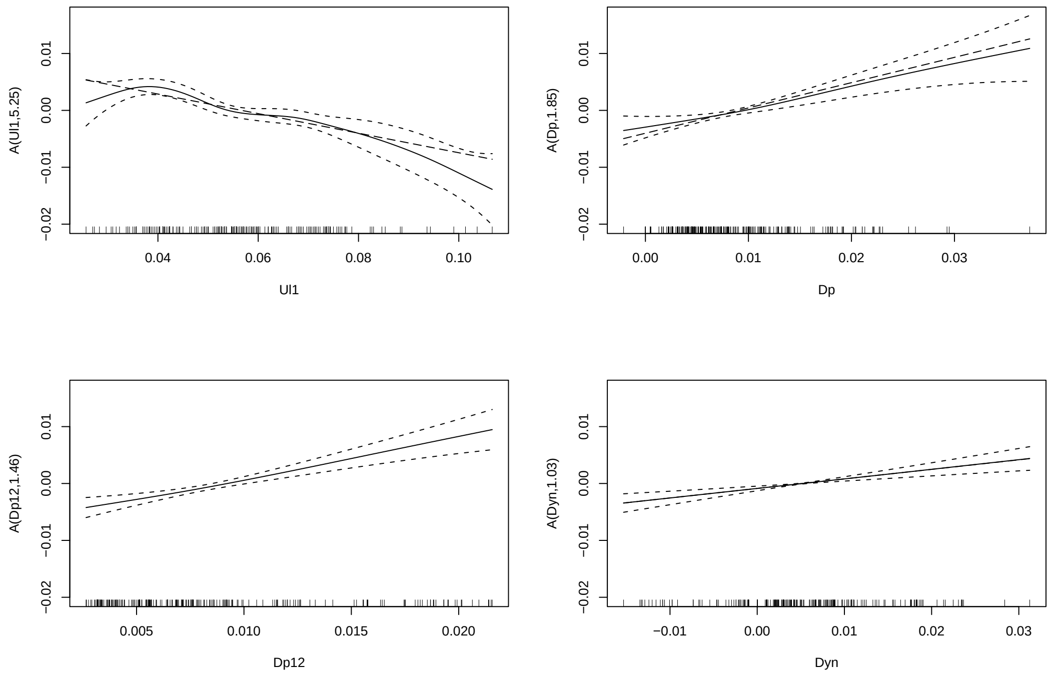

Figure 1: *Nonparametric estimates for wage PC*

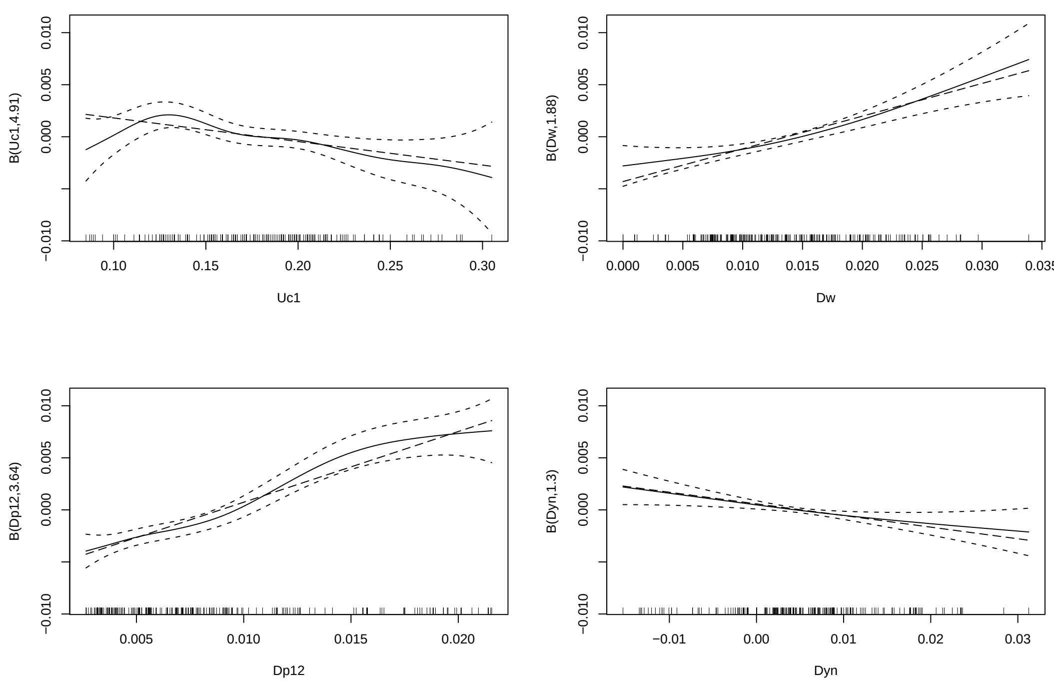

Figure 2: *Nonparametric estimates for price PC*

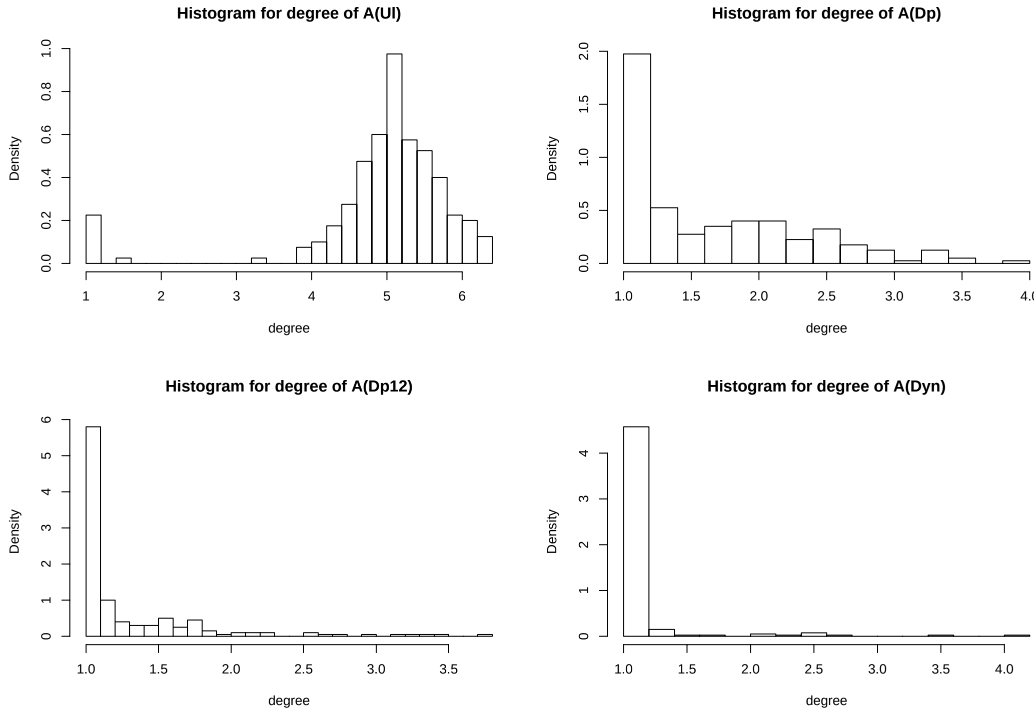

Figure 3: *Histogram for estimated degrees of wage PC based on the bootstrap resampling*

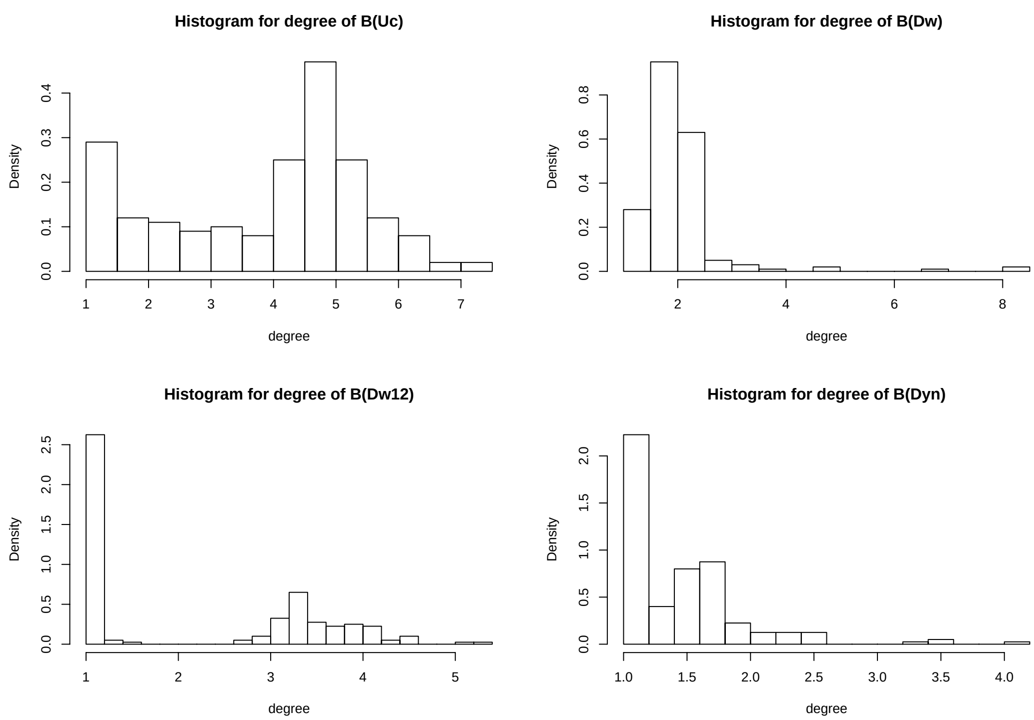

Figure 4: *Histogram for estimated degrees of price PC based on the bootstrap resampling*

5 Some Conclusions

We have investigated in this paper structural wage and price equations from the theoretical and the empirical point of view. From the theoretical perspective we found that their specification is generally much too simple in order to allow a thorough discussion and evaluation of the various approaches and statements in the literature. There are indeed various measures of demand pressure to be employed in this context and these measures may appear as Phillips (1954) suggests in proportional, derivative or integral form in certain countries and at certain times. Specifying PC's in this general format does indeed allow for a better comparative evaluation of the approaches, an improved predictive accuracy and for a better understanding of the role of labor and product market in macrodynamics. The general form for wage-price dynamics offered in sect. 2 therefore should indeed be used in order to move on to what specific forms of wage – and price – PC's may hold in certain countries in certain periods.

With regard to cost pressure variables we – by contrast – did choose a very specific, though also general format. In view of the literature on rational – and nowadays on forward and backward looking expectations – we assumed as cost pressure variable a weighted average of the currently perfectly foreseen cost pressure (price inflation in the case of workers and wage inflation in the case of firms) and the inflationary climate that is given by the past last twelve quarters. This allows us to formulate an expectation variable with enough inertia in the wage-price spiral as it is suggested by empirical observations. From the empirical perspective we found indications that separately specified and estimated linear as well as nonlinear wage and price PC's perform very well compared to the commonly employed reduced types of single Phillips-curve often characterized by the special assumptions $\beta_p = 0, \kappa_p = 1$ which are not supported by our empirical findings.

As to our linear estimates of our two curves, they imply a simple, yet important real wage feedback chain that appears to be destabilizing in periods where economic activity is positively dependent on the real wage. In terms of slopes the nonlinear estimation roughly confirm our linear estimates. Should such slopes really exist in some countries at some time, it should be taken account of in the formulation of monetary (and fiscal) policy, in particular in recent formulations of so-called Taylor or interest rate policy rules. Demand pressure matters both in the labor and the goods market and establishes a link between the current level of real wages and its rate of change that must be paid attention to in the conduct of monetary policy.

In terms of macrodynamics, the standard type of Taylor rule may perform well in the case of adverse real interest rate adjustments (based on the destabilizing Mundell effect in comparison to the stabilizing Keynes-effect), but may be quite impotent if an accelerating wage-price spiral becomes established. In such a situation a wage gap expression must enter the formulation of Taylor rules which when sufficiently strong in its operation may indeed tame the instability of this type of wage-price spirals. The analysis of this paper therefore suggest a redesign of interest rate policy rules at least in certain episodes of wage-price interactions.

Finally we want to note that the detected nonlinear relationship, in particular, between the unemployment rate and wage change and capacity utilization and price change is an important one as Stiglitz (1997) and Eisner (1997) have predicted. On the other hand, we find less evidence of significant nonlinearities for our expression for price (and wage) expectations and the change of wages (change of prices). This predicts, for example, that at low inflation rates, a wage stickiness with respect to inflation expectation would be observable as suggested by Akerlof (2002) and others (see Mankiw and Reis, 2002, and Blanchard, 2003). Although there is an overall wage and price stickiness, as the above literature argues, there is not an explicit "expectation stickiness" observable in our estimates. This may not reject the hypothesis of "expectation stickiness" at low inflation rates as stated for example, by Akerlof (2002), since the hypothesis might hold with other measures of price expectations and it might also hold for the reduced form of the Phillips-curve, as referred to in the statement by Akerlof (2002), which we have not tested here.

Appendix 1: Sketch of Nonparametric Estimation

The subsequent algorithm is based on Wood (2000) and implemented in the public domain software R (see Ihaka & Gentleman, 1996). The program and more information about it can be downloaded from http://www.r-project.org/. We exemplify the fit with the simplified model

$$Dw = \beta_0 + A(U^l).$$

Let Dw_i and U_i^l be the observed values for $i = 1, \ldots, n$ following the model

$$Dw_i = \beta_0 + A(U_i^l) + \varepsilon_i.$$

with ε_i as residual. For fitting we replace $A(U^l)$ by the parametric form

$$A(U^l) = a_1 U^l + Z(U^l)c \tag{12}$$

where $Z(U^l)$ is a high dimensional basis in U^l, for instance a cubic spline basis. Conventionally $Z(U^l)$ is 10 to 40 dimensional. That is, if a larger basis is in use this is reduced to a smaller basis using only those basis functions corresponding to the largest Eigenvalues of $Z^T(U^l)\, Z(U^l)$, see Wood (2000) for more details. In principle with replacement (12) one ends up with a parametric model. However, fitting the model in a standard OLS fashion is unsatisfactory due to the large dimensionality of $Z(U^l)$ which will lead to highly variable estimates. This can be avoided by imposing an additional penalty term on c, shrinking its values to zero. To be more specific, we obtain an estimate by maximizing the penalized OLS criterion

$$\sum_{i=1}^{n} \{Dw_i - a_1 U_i^l - 2(U_i^l)c + \lambda c^T P c$$

with λ called the smoothing or penalty parameter and $c^T P c$ as penalty. Matrix P is thereby chosen in accordance to the basis, but for simplicity one can assume P to be the identity matrix (see Ruppert et. al., 2003, for more detais). It is easy to see that choosing $\lambda = 0$ yields an unpenalized OLS fit, while $\lambda \to \infty$ implies $c = 0$ so that a simple linear fit results, since coefficient a_1 is unpenalized. Hence, λ steers the amount of smoothness of the function with a simple linear fit on the one side and a high dimensional parametric fit on the other side. The fitted function itself can be written as $\hat{A}(U^l) = H(\lambda)Dw$ where $Dw = (Dw_1, \ldots, Dw_n)$ here is the vector of observed values and likewise definition for U^l. The matrix $H(\lambda)$ results thereby as

$$H(\lambda) = \begin{pmatrix} U^l \\ Z(U^l) \end{pmatrix} \left(\begin{pmatrix} U^l \\ Z(U^l) \end{pmatrix}^T \begin{pmatrix} U^l \\ Z(U^l) \end{pmatrix} + \lambda \begin{pmatrix} 0 & 0 \\ 0 & P \end{pmatrix} \right)^{-1} \begin{pmatrix} U^l \\ Z(U^l) \end{pmatrix}^T.$$

The degree of complexity of the function is now defined as the trace of $H(\lambda)$. Note that as special case we get trace of $H(\infty)$ equals 1 while trace of $H(0)$ is $p+1$ with p as dimension of $Z(U^l)$. The degree can now be estimated from the data by minimizing a cross validation or the Akaike criterion (11) (see Wood, 2000, or Hastie & Tibshirani, 1990, for more details)

Appendix 2: Data Sources

The data are taken from the Federal Reserve Bank of St. Louis (see http://www.stls.frb.org/fred). The data are quarterly, seasonally adjusted and are all available from 1948:1 to 2001:2. Except for the unemployment rates of the factors labor, U^l, and capital, U^c, the log of the series are used (see table).

Variable	Transformation	Mnemonic	Description of the untransformed series
U^l	UNRATE/100	UNRATE	Unemployment Rate
U^c	1-CUMFG/100	CUMFG	Capacity Utilization: Manufacturing, Percent of Capacity
w	log(COMPNFB)	COMPNFB	Nonfarm Business Sector: Compensation Per Hour, 1992=100
p	log(GNPDEF)	GNPDEF	Gross National Product: Implicit Price Deflator, 1992=100
$y - l^d$	log(OPHNFB)	OPHNFB	Nonfarm Business Sector; Output Per Hour of All Persons, 1992=100
u	$\log\left(\frac{COMPRNFB}{OPHNFB}\right)$	COMPRNFB	Nonfarm Business Sector: Real Compensation Per Hour, 1992=100

For reasons of simplicity as well as empirical reasons, we measure the inflationary climate surrounding the current working of the wage-price spiral, see sections 2-4, by an unweighted 12-month moving average:

$$\pi_t = \frac{1}{12}\sum_{j=1}^{12} \Delta p_{t-j}.$$

This moving average provides a simple approximation of the adaptive expectations mechanism, which defines the inflation climate as an infinite, weighted moving average of past inflation rates with declining weights. The assumption here is that economic agents apply a certain window (three years) to past observations, here of size, without significantly discounting, see Rudebush and Svensson (1999).

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