Testing Wage and Price Phillips Curves for the United States

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Abstract

This paper demonstrates of how the labor and product markets interact in determining the outcome of a generalized reduced-form price Phillips-curve. For the labor market we consider a wage Phillips-curve and for the product market a price Phillips-curve. We estimate separately the wage and price Phillips-curves for the U.S., using OLS, nonparametric estimation and Three-Stage Least Squares techniques. The finding is that wages are always more flexible than prices with respect to their respective demand pressure and that price inflation responds somewhat more to a medium run cost-pressure than does wage inflation. This implies, as reduced form equation, a real wage dynamic that depends positively on the level of economic activity and thus, if the economy is wage-led, an adverse type of real wage adjustment. Monetary policy is in this case not only facing adverse real rate of interest adjustments (destabilizing Mundell-effects), but possibly also destabilizing real wage adjustments (adverse real-wage effects), We however also provide some evidence that the U.S. economy may have been profit-led after World War II, at least on average. We also study the link between product and labor markets by estimating of how employment is related to output, as Okun's law states. In comparing linear and nonlinear estimates of the wage and price Phillips-curves we find furthermore 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 formulate and estimate labor and goods market dynamics by a single reduced-form Phillips curve, relating price inflation directly to excess demand on the market for labor. Yet, as Fair has stated recently this might be regrettable, since it – in his views – implies a considerable loss of predictive accuracy, see Fair (2000:69). Phillips (1958) already 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 (WPC,PPC) separately he pointed out that those two are interacting. Fair (2000) then indeed employs and estimates two PC's, in fact for wage and price levels in the place of wage and price inflation rates, instead only a the conventional single price-inflation unemployment trade-off relationships. He finds that demand pressure (measured by the employment gap) matters in the market for goods, but not in the market for labor, where money wages are following the evolution of the price level more or less passively.

In Chen and Flaschel (2005) it has been shown that Fair's level estimates can however be translated back into wage and price inflation rates. One should, however, use only the employment gap in the WPC and the capacity utilization rate in the PPC. The hybrid expectations formation should be allowed for in the cost pressure items of these two PC's in order to include both forward as well as backward-looking behavior, i.e. in our case, myopic perfect foresight coupled with a slowly evolving measure of the inflationary climate surrounding these short-run error free expectations. Extending the two structural PC's of Fair in this way will allow us in the present paper to further improve Fair's estimates significantly, giving rise to a real-wage feedback channel in addition, and furthermore to consider again the old and new question of how much nonlinearity is present, here in both wage and price Phillips curves. If one follows this approach, one thus should formulate and estimate separate wage- and price PC's, where both demand and cost pressures, originating in the labor and the goods markets, should then 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.

New Keynesian approaches generally also only employ one Phillips curve in theory and in practice, a structural PPC based on the assumption of labor market equilibrium. Yet, their approach to staggered price setting with purely forward-looking expectations has been heavily criticized on empirical grounds, see in particular Mankiw (2001), Eller and Gordon (2003). As in our above approach they therefore now generally also use some backward-looking behavior in their estimation of their PPC. Furthermore, they also allow to some extent, primarily in empirically oriented work, for both staggered wage and price setting and thus for structural wage and price PC's (see Woodford (2003) for their formulation) as in our following approach to the wage-price dynamics. Yet, it is a unique feature of our approach to a gradual wage and price adjustment dynamics that a real-wage channel will be established by it that can be stabilizing or destabilizing as we shall show in this paper.

One argument that allows for such conclusions is generally discussed under the heading of wage-led or profit-led goods market behavior in the Post Keynesian literature, see Barbosa-

Filho and Taylor (2004) for example. In the body of the present paper we will assume, in line with what is generally assumed in the Post-Keynesian literature, but not always in the literature on procyclical real wages,[1] that goods market dynamics are indeed wage-led, meaning that aggregate demand and the output of firms thus depend positively on the real wage. Together with our empirical findings on the two PC's of this paper, which in particular imply that the adjustment speed of wage inflation with respect to the employment gap is higher than the one of price inflation with respect to the capacity utilization gap (and workers more short-sighted with respect to cost pressure than firms), this results in the fact that the real wage growth will depend positively on the level of real wages (for wage-led periods) and will thus be of a destabilizing kind (cumulative in nature) from this partial perspective. [2]

Taken together, the findings of this paper can therefore usefully contrasted with achievements in the RBC-, the New-Keynesian- and the Post- Keynesian literature and it introduces into such discussions that real wage dynamic depends positively on the level of economic activity (measured by capacity utilizations rates of both labor and capital) and thus positively on their own level in a wage-led regime as it may have been the case for certain periods in the U.S. economy after World War II. Our modeling approach of the wage-price dynamics is definitely close in structure (but not in implications) to the New Keynesian one, see Taylor (2003) and Woodford (2003) for the latter approach and Flaschel and Schlicht (2005) for a comparison between our gradual and their staggered wage adjustment. By contrast, our formulation of the wage and price dynamics substantially differs from the RBC-modeling of such a module, see King and Rebelo (2003) for a detailed discussion of this latter type of theory.[3]

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, 2005). In order to evaluate the above

[1] See Chiarella, Flaschel and Franke (2005, Ch.5), but also Stock and Watson (2003), Rotemberg and Woodford (2003) on this latter matter.

[2] This feedback channel is generally overlooked in the set of all macroeconomic feedback channels discussed in the literature.

[3] For a critical evaluation of the treatment of the labor market in RBC models, see Gong and Semmler (2004).

statements correctly one needs separate wage and price Phillips-curves and apply nonlinear estimation techniques. 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), an issue which however will not be investigated in the present paper, see Semmler and Zhang (2005) and Semmler, Greiner and Zhang (2005, ch.3) on this matter.

The remainder of the paper is organized as follows. In section 2 we will extend Fair's WPC and PPC equations to two general structural linear wage and price Phillips-curves. We compare these equations with various special types used in the literature. We 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 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 somewhat nonlinear with respect to specific explaining variables in the US.[4] Section 5 presents some extensions pertaining to system estimates of Okun‘s law, an IS-equation and wage-price dynamics. Section 6 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 on the New Keynesian Phillips curve,[5] where beside the IS equation and a Taylor policy rule only a single inflation equation, for price inflation, is included in the core macrodynamic equations.[6]

In order to derive our own two-dimensional formulation of the wage-price spiral[7] we start from the two structural wage and price equations in level form provided and estimated in

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[4] The established nonlinearities are, however, of different type than estimated for European countries in a parametric approach in Hoogenveen and Kuipers (2000). Other papers on nonlinearities in the Phillips-curve are Schaling (1999) and Semmler and Zhang (2005).

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

[6] 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 by all measures. 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.

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

Fair (2000:68). His estimations, when rewritten in terms of growth rates, are basically of the form that the inflation rate predicts the wage inflation rate and that the unemployment rate as well as the wage inflation rate predicts well the price 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 interesting special hypothesis on the working of this spiral, which states that wages follow prices more or less passively and that demand pressure (measured by the unemployment rate) matters in the market for goods, but not in the market for labor. More generally, one can reformulate wage-price dynamics as follows.[8]

$$Dw = \beta_{w_1}(V^l - \bar{V}^l) + \beta_{w_2}(V^w - 1) + \kappa_w Dp + (1 - \kappa_w)Dp^m \quad (1)$$

$$Dp = \beta_{p_1}(V^c - \bar{V}^c) - \beta_{p_2}(V^n - 1) + \kappa_p Dw + (1 - \kappa_p)Dp^m \quad (2)$$

where Dw and Dp stand for wage and price inflation (the time derivative of the log of wages and prices). 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 variables for expected cost pressures in the wage and the price Phillips curves we use a weighted average of perfectly foreseen price and wage inflation rates (representing temporary effects), respectively, and an inflationary climate expression Dp^m (meant to represent permanent effects and inflation inertia) which in our estimates is provided by a 12 quarter moving average[9], 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.[10] 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^l) and not in terms of unemployment ($U^l = 1 - V^l$), 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 PC's (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

[8] For reasons of simplicity we here neglect the growth rate of labor productivity which – from a straightforward steady state perspective – would have to be added with a coefficient of unity to the wage equation and with the coefficient of $-\kappa_p$ to the price equation. In the empirical estimates in the next section, however, the role of labor productivity growth is much smaller than suggested by such steady state considerations.

[9] See also Rudebush and Svensson (1999) for such a measure.

[10] For estimations of a time varying NAIRU, see Gordon (1997), Eller and Gordon (2003) and Semmler and Zhang (2005) and Semmler, Greiner and Zhang (2005, ch. 3).

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 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 PC approaches. The proportional control can be found in the standard approaches to the 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 – when derivative expressions are integrated – 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 (2003) 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 which – when integrated again – leads us to an integral control mechanism. 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 similarly, the wage and price PC's extended in this way may then read:

$$Dw = \beta_{w_1}(V^l - \bar{V}^l) + \beta_{w_2}\dot{V}^l/V^l + \beta_{w_3}\int(V^l - \bar{V}^l)dt + \kappa_w Dp + (1-\kappa_w)Dp^m \quad (3)$$

$$Dp = \beta_{p_1}(V^c - \bar{V}^c) + \beta_{p_2}\dot{V}^c/V^c + \beta_{p_3}\int(V^c - \bar{V}^c)dt + \kappa_p Dw + (1-\kappa_p)Dp^m \quad (4)$$

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 also on the reduced form level (compared to the New Keynesian staggered wage and price PC's where – due to the specific type of forward-looking behavior of workers and firms – a sign reversal is implied when the reduced form of these PC's are calculated, see Chiarella, Flaschel and Franke (2005, Ch.1) for details). In the above wage and price PC's we include again appropriate cost pressure terms, as weighted averages based on currently established price and wage inflation rates and 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 balanced growth.

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

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

with all demand pressure variables impacting positively the deviation of wage as well as price inflation from the inflationary climate variable Dp^m and with real wage growth being independent of this climate expression (since $\omega = w - p$).

In view of equs. (3) and (4), we can now briefly 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. Laxton et al. (1998) use for the Multimod Mark III model of the IMF an integrated, or hybrid, PC of the conventional type 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. As already noted, Stock and Watson (2003) 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 the relevant one on the aggregate level even if derivative control applies to the regional level.

At least the possibility for proportional, derivative and integral control is thus 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. In a companion paper to the present one, Flaschel, Kauermann and Semmler (2005) establish in the context of the two PC approach that proportional control is the relevant one on the basis of econometric model selection criteria. In the present paper we therefore will use proportional control solely in the estimation of our two structural wage and price Phillips curves. It must be noted nevertheless that the discussion on Phillips-curves is still an unsettled one, in particular with respect to the empirical significance of all those terms in the equs. (1)-(2),(3)-(4). Indeed, not all of the expressions shown in equs. (1)-(2),(3)-(4) will generally 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 perspectives. It therefore 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, viewed 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.[11] We are inclined to assume that the expectation of medium-run inflation cannot be perfect (is not a matter of removing small errors from current inflationary expectations), 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 considerable scope to extend the discussion on the expectational terms in the Phillips-curves which, however, is left here for future investigations.[12] The remainder of the paper will now present some empirical results on proportional control version of the linear approach to WPC's and PC's and then explore nonlinearities in these structural PC relationships.

3 Wage and Price Phillips-curves: OLS Estimates

in this section, we provide some single equation OLS estimates for the structural form of our wage and the price Phillips curves on the basis of the linear curves as above discussed. We will explore the question of their 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[13]

$$Dw = a_o - a_1 U^l_{-1} + a_2 Dp + a_3 Dp12 + a_4 dyn, \quad (5)$$

$$Dp = b_o - b_1 U^c_{-1} + b_2 Dw + b_3 Dp12 + b_4 dyn \quad (6)$$

where $U^l = 1 - V^l, U^c = 1 - V^c$ with V^l, V^c are the rates of utilization of the stock of labor and the capital stock and dyn representing the growth rate of labor productivity. Note that

[11] See Gali, Gertler and Lopez-Salido (2003). Note that we use neoclassical dating of forward looking expectations in the place of the New Keynesian dating of expectations, see Chiarella, Flaschel and Franke (2005) for details.

[12] We want to note here 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).

[13] where a_4 should be equal to one from a straightforward steady state perspective, but significantly less than one however when the Blanchard and Katz (1999) approach to the wage PC is adopted.

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 in Flaschel, Kauermann and Semmler (2005), see also Flaschel and Krolzig (2005) in this regard. Note again that w, p represent logarithms, i.e., their first differences Dw, Dp is the current rate of wage and price inflation. Besides model-consistent short-term expectations, we use now $Dp12$ 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 for estimation purposes coefficients a and b in (5) and (6) instead of the $\beta's$ and $\kappa's$ of the theoretical model. Together with the nonparametric approach in the next section this avoids double indexing and makes the model more readable from the empirical point of view, 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. (5) and (6) 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 section 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 can 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 section 2. Empirically this equation does not produce good estimates, at least in the case of price inflation. In this latter equation we have therefore 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.

All three estimates shown in table 1 provide for the speed with which wages adjust to demand pressure β_w approximately the value 0.16, for quarterly data. 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, price inflation, where a value of approximately 0.44 results. Wage adjustment with respect to demand pressure in the labor market is thus fairly high (in particular in comparison to the respective price inflation adjustment term, see table 2) 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). Comparing these results with the ones for the PPC in table 2 we thus find that demand pressure matters more on the labor market than on the goods market (contrary to what has been found out by Fair) and now in addition that firms are less short-sighted with respect to current inflation and its surrounding climate than are workers. The consequence of these results will be – as shown below – that real wages will increase with economic activity, though not instantaneously but with a time delay.

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*

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) for the money wage PC – that demand pressure (on the labor market) matters and that wage earners do not only use present or recent information in order to formulate their wage claims, but in fact also rely on the inflationary climate into which current goods price inflation is embedded, at least to a certain degree. There is thus considerable persistence of wage inflation with respect to price 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	-0.1117	-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*

We in sum get that wages are more flexible than prices with respect to demand pressure on their respective markets (even if the higher volatility of capacity utilization compared to the employment rate is taken into account, see the plots top left in figures 1 and 2) and that wage earners are more short-sighted than firms with respect to the cost-pressure items these two sectors in the economy are subject to. 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 (2005) have also estimated the wage and price Phillips curves of this section, with by and large similar results and with the additional result that Blanchard and Katz (1999) error correction terms are not significant in the wage-price spiral of the U.S. economy.[14] They used as lag structure in the estimation of an extended 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 primarily 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 some integral

[14] We have neglected here such error correction mechanisms right from the start.

control due to the inflationary climate expression used). We also note here that three-stage least squares simultaneous equations estimates of the wage and price PC do not significantly alter the result we obtained above in the case of OLS, see the concluding section for such a system approach which also includes Okun's law and a dynamic IS-curve in order to get a more complete picture of the real wage feedback structure considered in this paper. Yet, since a simultaneous equations approach is not yet available in the case of non-parametric estimation procedures, we have used here simple OLS estimation in order to be directly comparable to the estimates that are provided in the next section of the paper.

The results here obtained imply as in earlier work an adverse type of real wage effect if it is assumed[15] that consumption is more responsive to real wage changes than investment (which appears likely to be the case with respect to temporary as opposed to permanent real wage changes, in particular in periods of high economic activity). In such a case economic activity would depend positively on the real wage whose dynamics are described according to section 2 by:[16]

$$D\omega = \frac{(1-\kappa_p)\beta_{w_1}(\bar{U}^l - U^l(\omega)) - (1-\kappa_w)\beta_{p_1}(\bar{U}^c - U^c(\omega))}{1-\kappa_w\kappa_p}, \quad (U^l)'(\omega), (U^c)'(\omega) < 0$$

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 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 conventional Postkeynesian assumption of aggregate demand that is wage-led, i.e, with $V^l = 1 - U^l, V^c = 1 - U^c$ strictly increasing in ω) the following term:

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

The above is the critical α-condition for the occurrence of normal or adverse real wage effects,[17] in such wage-led regimes.[18] 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. Thus, real wage adjustment is of an adverse type in the U.S economy in the case where its economic activity depends positively on the

[15] as it often is the case in the Post Keynesian literature, see Barbosa-Filho and Taylor (2004) on this matter.

[16] with $k_o = 1/\bar{y}$ the capital / full employment output ratio and $1/y^p$ the capital / full capacity output ratio, which are approximately equal to each other. Underlying this situation, we assume for simplicity a technology with fixed proportions (with Harrod neutral technical change her ignored for simplicity) and abstract for the time being from the distinction between employment in terms of heads and employment in terms of hours, see the concluding section of this paper for a more general approach.

[17] also called Rose effects (RE) referring to Rose (1967) seminal contribution to the theory of the employment cycle.

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

real wage. This would imply then that there is a mechanism at work that can explain the occurrence of destabilizing or cumulative wage-price spirals as they where observed 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 however in this regard, see also the concluding section. This is a topic that should be addressed more extensively in future research, by extending the results on nonlinearity we obtain in the next section of this paper, which still to some extent support the views of the present section even for low inflation regimes, at least as far as the U.S.-economy is concerned. We will come back to the issue of whether the U.S. economy was on average wage-led or profit-led in the final section of this paper where we provide further evidence for our above finding $\alpha > 0$ in the working of the wage-price spiral for the U.S. economy on an average.

4 Wage and Price Phillips-curves: Exploring Nonlinearities

Next, we will explore non-linearities in the two Phillips curves. Following Phillips (1958) in exploring nonlinearities in some key relationships, we here replace all relationships by unspecified functional forms. For wage Phillips curve (5) 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 (5) to have a non-linear effect so that (5) is replaced by the general form

$$Dw = a_0 + a_1(U^l_{-1}) + a_2(Dp) + a_3(Dp12) + a_4(dyn) \tag{7}$$

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

$$Dp = b_0 + b_1(U^c_{-1}) + b_2(Dw) + b_3(Dp12) + b_4(dyn). \tag{8}$$

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 (7) and (8) in more depth. First, if we assume that all functions in (7) and (8) are linear, that is $a_1(U^l_{-1}) = a_1 U^l_{-1}$, we obtain the Phillips curves (5) and (6). Hence, the Phillips curves (7) and (8) are natural and general extensions of (5) and (6). Secondly, it becomes obvious that further constraints are necessary to make the functions in (7) and (8) identifiable. Note that for instance adding a constant to one of the functions $a(.)$ and subtracting it from a_0 gives another solution to (7). 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 $a_1(\bar{U}^l) = \sum_{i=1}^n a_1(U^l_i)/n$. Note that we have used similar constraints in the linear Phillips curves (5) and (6) 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 (7) and (8) 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 (7) and (8) 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 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 to infinity, the resulting fitting step breaks down to simple parametric fitting and the parametric models (5) and (6) 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

$$AIC(\lambda) = \log\{\sum_{i=1}^{n}(Dw_i - \widehat{Dw_i})^2\} + 2df(\lambda)/n \tag{9}$$

where $\widehat{Dw_i}$ are the fitted values. The first component (9) 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 (9) 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 balances 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 $a(U^l_{-1}, 5.25)$ 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 capacity 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.

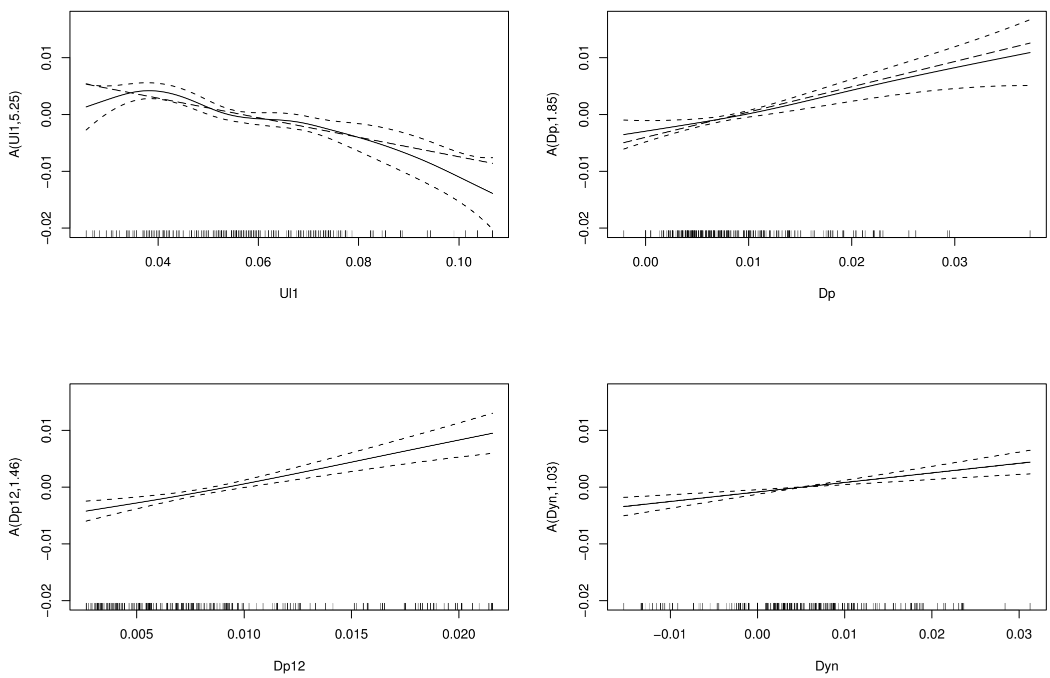

Figure 1: *Nonparametric estimates for wage PC*

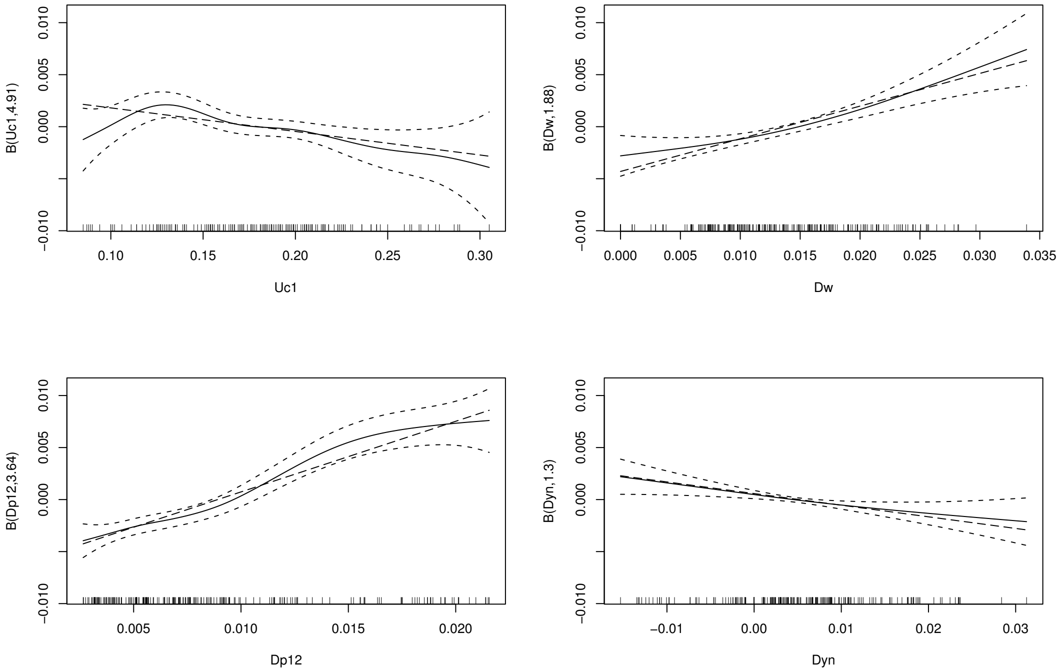

Figure 2: *Nonparametric estimates for price PC*

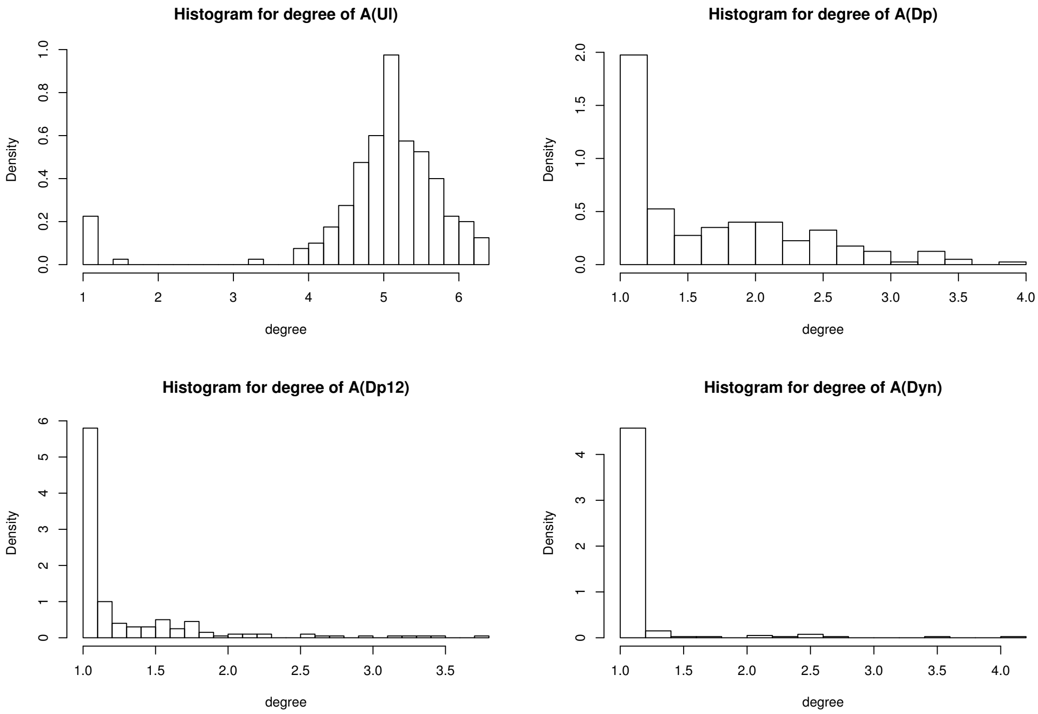

Figure 3: *Histogram for estimated degrees of wage PC based on the bootstrap resampling*

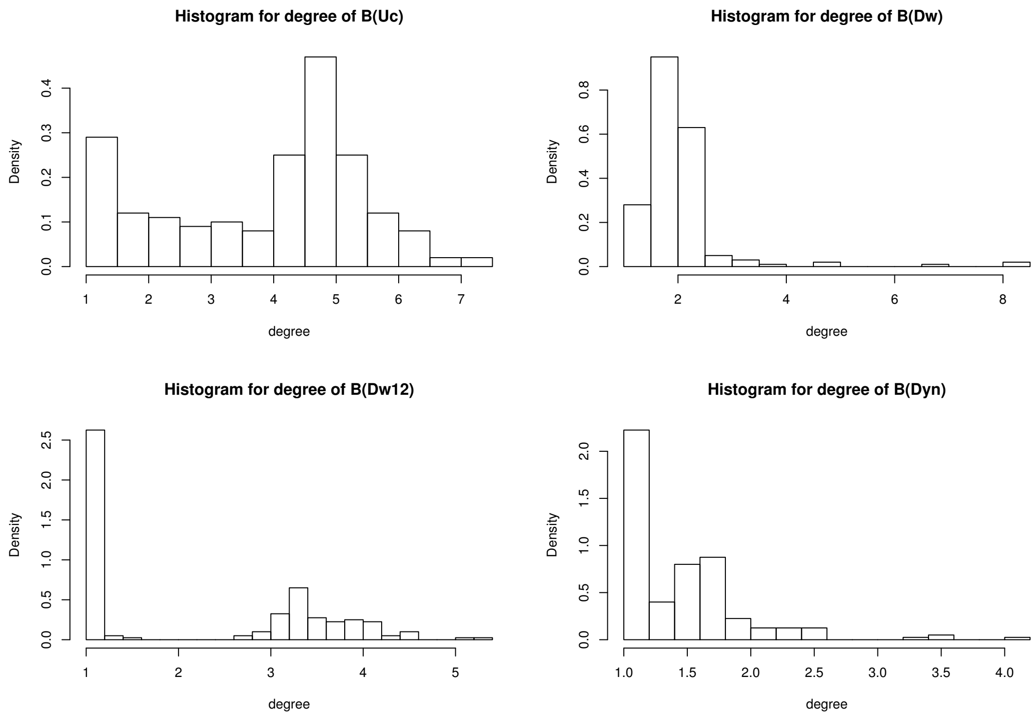

Figure 4: *Histogram for estimated degrees of price PC based on the bootstrap resampling*

We conclude from the above that nonlinearities in the wage-price spiral are of some importance in the U.S. economy, but are not at all comparable in kind to the ones found to exist in Hoogenveen and Kuipers (2000) for six European countries in the case of the WPC, see also Laxton et al. (2000) on this matter. The implications of the critical condition considered in the preceding section thus do not seem to depend very much on the specific inflationary regime the economy may be in for some time.

5 Some Extensions

The question might be raised of how our estimates perform when simultaneity issues are taken into account. This is the case when note is taken of the fact that the rate of employment and the rate of capacity utilization are related by an estimate of Okun's law and the Blanchard and Katz (1999) error correction terms are considered in a more complete model of a wage-price spiral as explored in this paper. In general, as in Blanchard and Katz (1999), we could not find evidence for wage share error correction terms in both the wage and the price Phillips curve, but could obtain statistically significant system estimates for our wage-price spiral mechanism that were in all respects close to the OLS estimates of section 3 of the paper. We do not report these estimates here, but extend them here immediately towards an inclusion of Okun's law in the following growth rate form

$$D \ln V^l = bD \ln V^c, \quad b > 0 \qquad [i.e.,\ \ln V^l = const + \ln V^c]$$

an IS-equation of the following type:

$$\ln V^c = c_1 \ln V^c_{-1} + c_2(r_{-1} - Dp) + c_3 \ln v_{-1} + c_4 + c_5 D75 \tag{10}$$

where V^c is the rate of capacity utilization, $r_{-1} - Dp$ last quarter's real rate of interest, v_{-1} last quarter's wage share and $D75$ (and also $D74$ below) a dummy variable. This goods market adjustment equation represents a reduced form equation that reflects consumption and investment behavior in aggregate form only, where we therefore cannot determine the sign of the parameter c_3 on purely theoretical grounds. The sign of c_2 should of course be negative, while the assumption that the marginal propensity to spend is less than one is reflected by assuming $c_1 \in (0,1)$. We will find below that the wage share has a significant influence on this dynamic multiplier process though it does not appear as error correction mechanism in the two equations that describe the wage-price spiral itself.

We have already excluded from the following summary of the system estimate of our extended model of the wage-price spiral the insignificant parameters in the displayed quantitative representation of the model and also the stochastic terms. By putting furthermore the NAIRU expressions and all other expressions that are here still assumed as constant into overall constant terms, we finally obtain the following (approximate) three-stage least squares estimation result (with t-statistics in parenthesis, $V^l = 1 - U^l, V^c = 1 - U^c$):[19]

$$
\begin{array}{rclllll}
Dw & = & 0.10 \ln V^l_{-1} & +0.80Dp & +0.20Dp12 & -0.12 & \\
 & & (-3.67) & (6.00) & (--) & (5.23) & \\
Dp & = & 0.02 \ln V^c_{-1} & +0.44Dw & +0.56Dp12 & -.003 & -.008D74 \\
 & & (-3.28) & (5.19) & (--) & (1.91) & (4.59) \\
D \ln V^l & = & 0.16 D \ln V^c & & & & \\
 & & (17.56) & & & & \\
\ln V^c & = & 0.84 \ln V^c_{-1} & -1.05(r_{-1} - Dp) & -0.82 \ln v_{-1} & -0.03 & -0.10D75 \\
 & & (31.24) & (-4.29) & (-6.50) & (-4.80) & (-6.23)
\end{array}
$$

Table 3: The wage-price spiral, Okun's law and goods market dynamics: A system estimate

We obtain from the above estimate of the above the IS-equation evidence that the dynamic multiplier is – as is usually assumed – stabilizing (from its partial perspective) and that economic activity depends – again, as it is usually assumed – negatively on the evolution of the real rate of interest. New in this estimate is the result of a strong negative dependence of the change of capacity utilization on the wage share (or real unit wage costs) which – in contrast to our earlier assumption a positive level relationship between economic activity and real wages – implies that the U.S. economy was on an average profit-led in the considered time period (with a certain delay however). Combined with our finding: $\alpha > 0$ for the critical condition introduced in section 3, i.e., combined with a positive dependence of real wage growth on economic activity we thus would here get as result for the U.S. economy that real wage growth by and large depended negatively on the level of real wages, which thus now provides a stabilizing check to for example positive real wage shocks – due to the declining economic activity that is accompanying such real wage increases. This is an

[19] Note here that utilization gaps can also be approximated by logarithmic terms in the wage and price law of motion.

important, for the authors of this paper unexpected, result on the real wage channel in the U.S. economy. Yet, the presence of the real rate of interest in this estimate indicates that a more complete macroeconomic framework must still be chosen in order to investigate such questions in more depth. We also stress here again that the distinction between consumption and investment effects of real wage increases is still missing here which might alter the situation again.

We have already stated that the system estimate of the wage-price spiral itself is very close to the OLS estimate of the laws of motion for wages and prices. Yet, with Okun's law, and the IS equation, included into these system estimates we are getting parameter estimates that are no longer very close to the OLS estimates of the main part of this paper as a comparison of the above parameter estimates with those of section 3 (as far as the first two equations are concerned) immediately shows.[20] When Okun's law is used in the above form in the place of a fixed proportions technology moreover, the critical conditions for a normal or adverse dependence of the growth rate of real wages on their level reads – now in the case of a profit-led regime as it was estimated above:

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

Inserting the estimated parameter values then gives approximately $\alpha = 0.009 - 0.004 = 0.005$ and thus a very weak, but still positive influence of activity changes on real wage growth. Though there is a strong effect of real wage changes on activity changes on the market for goods the overall result is in this case that the real wage feedback channel is only in a very weak sense a stabilizing one, leading from real wage increases to activity decreases and from there to decreases in the growth rate of real wages. The results of the main part of the paper are therefore weakened in this extended version of the model (due to the low value that now relates percentage capacity utilization changes with percentage changes in the rate of employment) and the assumption of a wage-led economy is here changed into the opposite assumption (supported by the above estimate) that at least the U.S economy was profit-led on an average after World War II. The above results of the system estimates thus imply the need for further research which is however beyond the scope of the present paper.

Yet, roughly speaking, we may however state that we have investigated in this paper a relationship of the type $D\omega = f(e,u)$ with $f_1 > 0, f_2 < 0$ and found that the signs of the partial; derivatives are confirmed by all of our estimates. Moreover, the first partial derivative seems to dominate to a certain degree the second one if a link between these two utilization rates is added to the model. This dominance may be a weak one, and may thus explain to a certain degree why real wages are much less volatile than the business cycle itself as stated as an empirical fact in Rotemberg and Woodford (2003). The next step of the investigation should then be whether we have a further, goods-market oriented relationship of the wage-led type $u(\omega), u' > 0$ or of the profit-led type $\hat{u}(\omega), \hat{u}' < 0$, i.e., whether our estimated wage - price module gives rise to (unstable!) Post-Keynesian macrodynamics or a stable dynamics of the Goodwin (1967) growth cycle type. As stated this must however

[20] Note that we are considering in this section only the case where the weights in cost pressure terms sum up to unity – by an imposed restriction of this type.

be left for future research, see Chen, Chiarella, Flaschel and Semmler (2005) for first steps into such a direction.

6 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 or specific 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 in the literature, an improved predictive accuracy and for a better understanding of the role of labor and product market distinctions in macrodynamics. The general form for wage-price dynamics offered in section 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. In this paper we have, following Flaschel, Kauermann and Semmler (2005), used a proportional approach to demand pressure variables in our estimations throughout, but have used market specific characteristics in the specification of both the labor market oriented WPC and the goods market oriented PPC.

With regard to cost pressure variables we also did choose a specific, though fairly general format. In view of the literature on rational – and nowadays on both 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 an inflationary climate expression that was given as a moving average over the past last twelve quarters in the empirical estimates. This allowed us to obtain – despite forward looking variables in both the wage and the price PC – 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.

Our linear and nonlinear estimates of the two Phillips curves in the main part of the paper in principle imply an important real wage feedback chain that will only be destabilizing in periods where economic activity is positively dependent on the real wage. In terms of slopes the nonlinear estimation roughly confirmed our linear estimates. Should such slopes really exist in some countries at some time, it should therefore 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, at least in periods where demand is definitely wage-led. 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 then simplified stabilizing Keynes-effect), but its inflation targeting may be quite impotent if an accelerating wage-price spiral becomes indeed established, by either prices becoming more flexible than wages or by consumption becoming more responsive to real wage changes than investment. In such a situation a wage gap expression should therefore 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, see also Flaschel and Krolzig (2005) in this regard. The analysis of this paper therefore suggests a redesign of interest rate policy rules at least in certain episodes of wage-price interactions as maybe was the case in the late 1960 and 1970's.

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. This would predict, 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, 2005). 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.

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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

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

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

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

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

$$A(U^l) \quad = \quad a_1 U^l + Z(U^l)c \tag{11}$$

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 (11) 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 details). 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 $Dw = (Dw_1, \dots, Dw_n)$ here is the vector of observed values and likewise definition for U^l. The matrix $H(\lambda)$ results thereby as

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

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 (9) (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).