CEM
Center for Empirical Macroeconomics

Working Paper No. 67

Testing the Dynamics of Wages and Prices for the US Economy

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February 3, 2004

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Abstract

This paper demonstrates, contrary to what has been shown recently, that demand pressure, besides differentiated cost-pressure, matters both in the labor market and the market for goods in the determination of wage and price inflation. We consider from the theoretical perspective and estimate for the USA, using OLS and more advanced methods, both separately and simultaneously wage and price Phillips curves based on demand pressure measures in the market for labor and for goods, respectively, using weighted averages of short- and medium-run cost-pressure terms in addition. The suggested 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 economic activity, and thus an adverse real wage adjustment, for example 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), and has to take into account in addition an important nonlinearity in money wage formation, their downward rigidity, the subject of section 5 of this paper.

JEL CLASSIFICATION SYSTEM FOR JOURNAL ARTICLES:
E24, **E31**, **E32**, **J30**.

KEYWORDS: Wage and price Phillips curves, adverse real-wage adjustments, cumulative instability, downward wage and price rigidities, economic stagnation.

1 Introduction

This paper builds on the results obtained in Flaschel and Krolzig (2004). It uses the same theoretical framework and attempts to demonstrate in line with what has been suggested by Fair (2000) that the estimation of two structural wage and price Phillips curves, one for the labor market and one for the goods market, produces significantly better results – compared to reduced form estimates of a single Philips curve – in particular if it is taken into account in addition that cost pressure measures must also be based on medium run averages besides the current (possibly perfectly foreseen) evolution of price and wage cost pressure items (for wage earners and firms, respectively).

This is not due to the fact that reduced form PC's must generally perform less good when estimated, but simply results from an unjustified simplification of the reduced form expression of interacting wage and price dynamics or the wage-price spiral. If demand and cost pressure in wage and price Phillips curves are specific to the market that is under consideration in these two curves, then demand pressure in both the labor and the goods market and cost pressure for both workers and firms must appear in the reduced form expressions somehow and make this expression much more involved than in the standard reduced form price inflation Phillips curve, solely based on demand and cost pressure in the labor market. This is in particular the case 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.

Fair (2000) in our view correctly stresses the advantage of estimating two in the place of only one Phillips curve, be that in structural or in reduced form (where also two curves are to be estimated as we will show below). But in his own estimates he uses the rate of unemployment in the market for goods as well and also does not include much cost pressure persistence into his two equations, in the form of further lagged terms or – as we will call it – in the form of an expression for the inflationary climate within which the economy is currently operating. This introduces a significant amount of inertia into the estimated wage-price spiral that appears to improve estimated curves significantly in comparison to his own estimates.

In the next section 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 then argue that such separate wage and price inflation Phillips curves, when reformulated in sufficiently general terms, can give rise to various real-wage adjustment patterns, two normal or stabilizing ones and two adverse or destabilizing ones. In section 3 we start again from Fair's equations and derive from there and our structural linear wage and price Phillips curves reduced form representations in the form of an advanced real wage dynamic and a reduced form price Phillips curve of a fairly general type (compared to the conventional reduced form price Phillips curve). We compare these equations with various special types used in the literature. In section 4 we then provide detailed estimates for our representations of two structural wage and price Phillips curves (and their reduced form analogs) in order to determine on this basis in particular, whether a certain critical condition for real wage instability or adverse real wage adjustment was fulfilled for the US economy over the period after World War II. In section 5 finally we test for nonlinearity of these two Phillips curve on the structural level and will find there as a first step towards a series of future investigations that these curves may be nonlinear in the USA, but maybe not of the type as estimated for European countries in Hoogenveen and Kuipers (2000). In section 6 we close the paper by drawing some conclusion for the role of monetary policy in view of its findings and provide an outlook on effects of real wage and productivity changes on economic activity and thus on the here still missing link for the wage-price spiral that determines when it will work in an adverse and when in a normal, i.e., in a fashion that corresponds to the orthodox point of view on the working of the labor market.

2 Structural Wage–price dynamics: Normal or adverse real wage adjustments?

> In the early 1980s, there began a movement away from the estimation of structural price and wage equations to the estimation of reduced-form price equations ... The current results (see below, P.F.) call into question this practice in that considerable predictive accuracy seems to

> be lost when this is done. R. Fair (2000, p.69): Testing the NAIRU model for the United States.

This observation of Fair is certainly true for applied work where it appears to be quite natural, even in the most recent works, to express labor market and goods market dynamics by a single Phillips curve with demand pressure based on the external labor market (the rate of employment on this market, not hours worked within the firms) and with cost pressure in the two markets represented by a single expected rate of inflation. Rigid markup pricing is a possible justification for such reduced form inflation dynamics, see Blanchard and Katz (2000) for example.

It seems however also to hold for theoretical work where the formulation of two – from the dynamical point of view non-reducible – Phillips curves,[1] for wage and price dynamics, is not a standard procedure, but where microfoundations, in particular of the new Keynesian Phillips curve,[2] seem still to justify the use of a single equation for wage-price inflation (there even reversing the role played by demand pressure, due to an assumed purely forward-looking behavior of inflationary expectations).[3] There are 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.

In order to derive our own 2D formulation of the wage-price spiral we start from the two structural wage and price equations provided and estimated in Fair (2000). These structural equations for wage and price formation are there of the form

$$w_t = \gamma_0 + \gamma_1 w_{t-1} + \gamma_2 p_t + \gamma_3 p_{t-1} + \gamma_4 U^l_{t-1} + \gamma_5 t + \epsilon^w_t \tag{2.1}$$

$$p_t = \beta_0 + \beta_1 p_{t-1} + \beta_2 w_t + \beta_3 pm_{t-1} + \beta_4 U^l_{t-1} + \beta_5 t + \epsilon^p_t \tag{2.2}$$

where we as Fair use logarithms for wages w and prices p, where pm denotes import price inflation and where we use U^l to denote the unemployment rate u in Fair's two structural equations. We note that these two equations have been specified in level form by Fair (2000, p.68) which is given justification in the appendix of his paper. These two equations are identified in that pm_{t-1} is excluded from equation (2.1) and w_{t-1} from equation (2.2). The estimation of these two equations by two-stage least-squares (with a specific constraint in addition) gives in Fair's (2000) paper the result:

The result of this estimation thus provides us with the following two structural relationships for the US economy:

$$\begin{aligned} w_t &= -0.0709 - 0.0104U^l_{t-1} + 0.9887w_{t-1} \\ &+ 0.7513p_t - 0.7546p_{t-1} + 0.000181 \cdot t + \epsilon^w_t \\ p_t &= 0.0778 - 0.1795U^l_{t-1} + 0.9225p_{t-1} \\ &+ 0.0200w_t + 0.0403pm_{t-1} + 0.000088 \cdot t + \epsilon^p_t \end{aligned}$$

In terms of growth rates $dx = \dot{x},;\ x = w, p$ they can be simplified and approximated by[4]

$$\begin{aligned} dw_t &= -0.0709 + 0.7513dp_t \\ dp_t &= 0.0778 - 0.1795U^l_{t-1} + 0.0200w_t \end{aligned}$$

[1] giving rise to 2D dynamics when embedded into a larger macrodynamic framework.

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

[3] With respect to this 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." We shall show in this respect later on that forward-looking behavior need not be in conflict with traditional views on the role of demand pressures when wage dynamics is indeed distinguished from price dynamics and when a role for medium-run expectations (the inflationary climate within which the economy is operating) is given besides a short-run myopic perfect foresight assumption.

[4] Note here that this paper will ignore import price inflation pm and the time variable t throughout and thus remove aspects of Fair's (2000) estimation, that may be important in further investigations of our approach.

$$p_t = \beta_0 + \beta_1 p_{t-1} + \beta_2 w_t + \beta_3 pm_{t-1} + \beta_4 u_{t-1} + \beta_5 t + \epsilon_t$$
$$w_t = \gamma_0 + \gamma_1 w_{t-1} + \gamma_2 p_t + \gamma_3 p_{t-1} + \gamma_4 u_{t-1} + \gamma_5 t + \mu_t$$

	Estimate	t-Stat.		Estimate	t-Stat.
β_0	0.0778	1.65	γ_0	-0.0709	-1.6
β_1	0.9225	284.47	γ_1	0.9887	109.53
β_2	0.0200	2.51	γ_2	0.7513	8.86
β_3	0.0403	13.61	γ_3	-0.0104	-0.28
β_4	-0.1795	-8.51	γ_4	0.000181	2.61
β_5	0.00088	1.01	γ_5	-0.7564	*
SE	0.00294		SE	0.00817	

* Coefficient constrained
Estimation period: 1954:1 - 1998:1
Estimations method: 2SLS
First stage regression: constant, t, p_{t-1},w_{t-1},u_{t-1},pm_{t-1}

Table 1: Estimated Equation (10) and (11)

We do not think that the structure represented by these two equations is developed enough from the theoretical perspective to really represent a structural approach to the wage-price spiral. The following points can be put forth to justify this observation:

- The estimated curves indeed seem to suggest that there is no need for an approach in terms of levels for wages and prices, but that we can proceed by way of their inflation rates as it is normally the case.
- Demand pressure seems only to matter in the goods market, but is measured there by means of the unemployment rate and not by the rate of capacity utilization of the capital stock or the stock of labor employed by firms (hours worked as deviation from normal work-time).
- There is no explicit role given to the growth rate of labor productivity

We conclude that Fair's recommendation to use two structural wage and price Phillips curves in the place of the standard single reduced form Phillips curve for price inflation is an appropriate one, but that one should use inflation rates in these two curves right from the start and employ for each market his own measure of demand pressure and not a single one for both. Furthermore, inflationary expectations should enter the wage – price spiral in an explicit way. We shall fulfill this latter demand by a mixture (a weighted average) of short-run perfectly foreseen inflation rates and an expression for the medium-term inflationary climate into which these short-run expectations are embedded. This adds persistence to an approach which is known to be destabilizing when only myopic perfect foresight expectations are considered.

Fair's (2000) estimated proposal however represents an interesting special hypothesis on the working of the wage-price 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. Chiarella, Flaschel, Groh and Semmler (2000, Ch.2) have briefly considered the consequences of such an observation for the concept of the NAIRU and its interpretation, in particular the result that the NAIRU is here the outcome of product market behavior and not of labor market disequilibrium processes.

More generally, these authors have formulated the wage-price spiral as follows:

$$dw = \beta_{w_1}(V^l - \bar{V}^l) + \beta_{w_2}(V^w - 1) + \kappa_w dp + (1-\kappa_w)dpm \quad (2.3)$$
$$dp = \beta_{p_1}(V^c - \bar{V}^c) + \beta_{p_2}(V^n - 1) + \kappa_p dw + (1-\kappa_p)dpm \quad (2.4)$$

by using two separate measures of demand pressure in the labor and the goods market. Here, $V^l - \bar{V}^l = \bar{U}^l - U^l, V^w - 1$ is denoting (if positive) excess labor demand on the external labor market (in terms of labor market utilization) and excess labor demand (in terms of overtime worked) within firms, and $V^c - \bar{V}^c = \bar{U}^c - U^c, V^n - 1$ (if positive) is denoting excess demand on the market for goods in terms of again utilized capacity V^c and inventory usage. With respect to the second demand pressure terms in these two equations one may assume in addition that they are positively correlated and can thus be substituted by the rate of change of the employment rate V^l and by the rate of change of the capacity utilization rate V^c, respectively, which gives rise to two Phillips curves with both a proportional demand pressure influence and a derivative one (in the language of Phillips (1954) and in line with Phillips (1958) as far as the wage inflation rate is concerned). In terms of utilization rates this thus gives rise to:

$$\begin{aligned} dw &= \beta_{w_1}(V^l - \bar{V}^l) + \beta_{w_2}\dot{V}^l + \kappa_w dp + (1-\kappa_w)dpm \qquad (2.5)\\ dp &= \beta_{p_1}(V^c - \bar{V}^c) + \beta_{p_2}\dot{V}^c + \kappa_p dw + (1-\kappa_p)dpm, \qquad (2.6) \end{aligned}$$

i.e., wage and price PC's, each with their own twofold measures of demand pressure as well as cost pressure.

In the following theoretical and empirical investigation of this wage - - price spiral we will still set β_{w_2}, β_{p_2} equal to zero and will thus only pay attention to capacity utilization rates V^l, V^c on the labor and the goods market in their deviation from the NAIRU type rates $\bar{V}^l, \bar{V}^c$. This simplification of wage and price Phillips curves stays to some extent close to Fair's (2000) approach and represents in our view the minimum structure one should start from in a non-reduced-form investigation of wage and price dynamics, which therefore should only be simplified further – for example on the reduced form levels it implies – if there are definite and empirically motivated reasons to do so.[5] Generally however all parameters of the structural wage and price Phillips curves will show up in their reduced form representations which therefore cannot be interpreted in terms of labor market phenomena or goods market characteristics alone. In macrotheoretical models, the above type of wage and price Phillips curves (disregarding our inflationary climate expression *dpm* however) have played a significant role in the rationing approaches of the 1970's and 1980's, see in particular Hénin and Michel (1982) in this regard. Yet, up to work of Rose (1967, 1990), it was fairly unnoticed in theory that having specific formulations and measures of demand and cost pressure on both the labor market and the market for goods would in sum 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.

The following two figures attempt to illustrate this assertion for the case of falling prices and wages, i.e., for periods of depression and deflationary wage – price spirals. Their implications however are even easier to understand for inflationary periods (inflationary wage-price spirals) where wage and price adjustment processes may be more pronounced than in the case of economic recession or even depression. We have – broadly speaking – normal real wage reaction patterns (leading to converging real wage adjustments and thus economic stability form this partial point of view), if investment is more responsive to real wage changes than consumption <u>and</u> if wages are more flexible with respect to demand pressure on their market than prices with respect to their measure of demand pressure, the rate of underutilization of the capital stock (with additional assumptions concerning the forward looking component in the cost pressure items as will be shown later on).

In this case, aggregate demand depends negatively on the real wage and real wages tend to fall in the depression (thereby reviving economic activity via corresponding aggregate demand changes), since the numerator in real wages is reacting stronger than their denominator. The opposite occurs, of course, if there holds – in the considered aggregate demand situation – that wages are less flexible than prices with respect to demand pressure, which is not unlikely in cases of a severe depression. In such cases it would therefore be desirable to have that consumption responds stronger than investment to real wage changes, since the implied real wage increases would then revive the economy. There is a fourth case – in the latter demand situation – where wages are more flexible than prices, where again an adverse real wage adjustment would take place leading the economy via falling real wages into deeper and deeper depressions as long as situation remains in existence.

[5] A study of derivative influences (and integral ones) in their comparative explanatory power of wage and price inflation is provided in Flaschel, Kauermann and Semmler (2004a), where it is basically found that the traditional proportional measure of demand pressure items seems to be the most relevant one.

The figure 1 below provides a graphical illustration of two of the discussed forms of the wage-price spiral and which are thus to be supplemented by two further cases to provide a complete presentation of all possible outcomes of the wage-price spiral in the case of deflation (and which of course apply in the case of inflation as well, with arrows concerning w and p then pointing into the upward direction). They immediately suggest that the exact form of the wage-price spiral can only be determined by empirical investigations and – in the then observed form – depend in addition on the short sightedness of workers and firms with respect to the current rate of price respectively wage inflation.

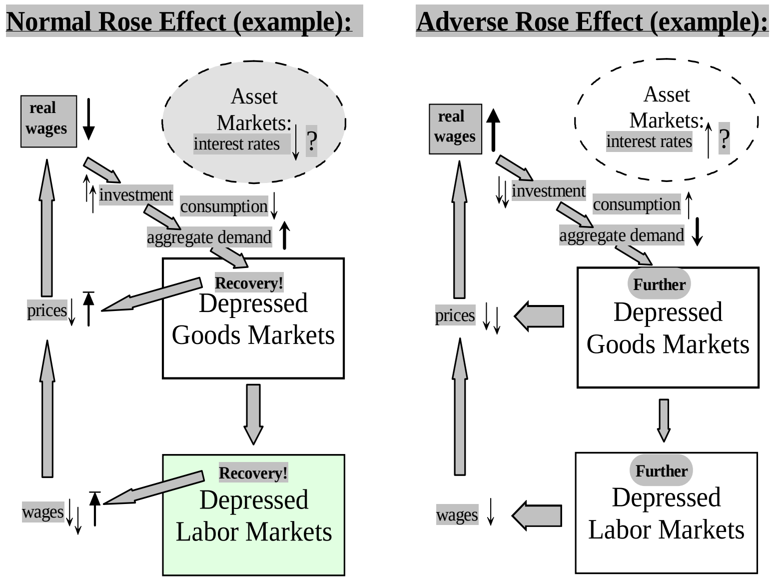


Figure 1: Normal vs. adverse real wage effects in a deflationary environment.

We conclude that wage and price Phillips curves which pay sufficient attention to demand as well as cost pressure items on the market for labor as well as on the market for goods may give rise to interesting dynamic phenomena with respect to the real wage adjustments they imply. This definitely deserves closer inspection than was the case so far in the macrodynamic literature. The present paper wants to discuss in this respect possible theoretical and (for the US economy after World War II) empirical outcomes, and thus wants to provide a definite answer for a specific country over a specific time interval. The hope is that interest in further investigation of the questions raised in this paper may be stimulated by its results on the type and form of the wage-price spiral obtained for the US economy, for other countries, for high versus low inflation regimes, for more refined measures of demand pressure, for integral besides derivative influences and more.

3 Reduced-form real-wage and price Phillips curves and the critical $\alpha-$condition

We have stressed in the last section the importance of using two separate Phillips curves for wage and price dynamics. Indeed, there exists a long, mainly non main-stream, tradition to make use of two such curves in economic theorizing, in particular in the growth cycle literature. We have already referred to this tradition in the previous section. There is an early article by Solow and Stiglitz (1968) where symmetrically formulated wage and price PC's are used, both with demand pressure and cost-pressure terms, to investigate medium run dynamics where regime switching can occur. There is the related macroeconomic literature of non-Walrasian type, Malinvaud (1980), Benassy (1986, 1993), Picard (1983), Hénin and Michel (1982) and others, where such PC's have often been used in conjunction with both labor and goods market disequilibrium, see Malinvaud (1980) for a typical example. Rowthorn (1980) makes use of a dynamic price PC coupled with a static wage PC in order to show how the conflict over income distribution allows for an endogenous determination of the NAIRU rate of capacity utilization of both labor and capital. There is finally the seminal work by Rose (1967), see also Rose (1990), where PC's of the type to be considered below were first introduced. The two PC's approach has also been used extensively in Chiarella and Flaschel (2000) in a series of hierarchically structured models of monetary growth.

Turning to applied work on Phillips curves, we have already considered in simplified form the approach by Fair (2000). Fair's model exhibits further arguments in the structural wage and price equations, such as import prices, not to be considered in the present paper. Furthermore, as already discussed, he stresses, based on his earlier work, that these PC's are better specified in level form rather than in terms of rates of growth, as wage and as price equations and not as equations describing wage and price inflation rates immediately. Yet, in his structural macroeconometric models and their wage-price block in particular, short- and medium-run aspects are dominant, which is a common feature in such applied structural models. Long-run aspects and in particular a full-fledged steady state analysis is not present and presented, just as in many other works of this type.

Undertaking a steady state analysis in applied macroeconomic work is however very important, since it provides one with a consistency check of the employed model as far as model formulation is concerned. Should the used model structure, in its deterministic part, not allow for a well-defined balanced growth path, the question of whether there is convergence to a point attractor in the long run cannot be sensibly addressed. By contrast, current macroeconometric model building indeed generally assumes such convergence or shock absorber behavior as a non-questionable fact when building their models and try to incorporate it into them by making appropriate changes to the structure, if such convergence does not seem to hold initially. From this perspective it, therefore, seems natural to demand that all equations of the model must be formulated in a way such that they allow a specialization to situations of steady growth (or decline) of the real and the nominal magnitudes that are involved.

We thus end up with the conclusions that

- specifying wage and price dynamics as two separate equations is highly desirable in theoretical as well as applied macroeconomic analyses. This makes explicit the reasons that may or may not lead to a single integrated Phillips curve later on,
- that demand pressure variables should be specific to the price variable to be considered and only be substituted by measures referring to other markets if there is good reason to do so,
- that theory-based level form formulations of such wage and price equations should be reducible to rates of growth or ratios, considering demand as well as cost pressure terms,[6]
- that the application of steady state restrictions should be made step by step and compared to the situations where less or no such restrictions are being made.

If the period after World War II is considered as one prolonged upswing followed by one with low productivity growth there is probably need for another long upswing in order to really allow for the application of steady state analysis and all the restrictions that can be derived from it.

Let us now derive reduced form expressions from the wage and price PC's of the preceding section, one for the real part of the overall dynamics (in terms of the real wage) and one for the nominal part of a complete dynamics (in terms of the price inflation rate), where both reduced form dynamics are now driven by mixtures of excess demand expressions on the market for goods and for labor solely, and – in the case of the price inflation rate – by the inflationary climate with a unity coefficient in addition. This latter fact again shows that our approach is also applicable to situations of steady growth (where productivity growth may be taken into account in addition). Note first that the wage and price Phillips curves of the preceding section are of the general form

$$\begin{aligned} dw &= \beta_{w's}(\cdot) + \kappa_w dp + (1-\kappa_w)dpm \\ dp &= \beta_{p's}(\cdot) + \kappa_p dw + (1-\kappa_p)dpm \end{aligned}$$

[6] It is easy to show that a given real wage curve a la Blanchflower and Oswald (1994) can be reformulated as wage inflation PC if expected real wages are distinguished from actual ones and if money wage claims are based on such a real wage curve and price level expectations, see for example Carlin and Soskice (1990, p/148). The wage curve approach is thus not in conflict with the money wage PC approach. This is also implied by a money wage PC that is based on a derivative control term (the Phillips loops term)) solely which when integrated leads us again to a wage curve representation.

where demand pressure expressions $\beta_{w's}, \beta_{p's}$ for the labor and the goods market may be formulated as advanced or numerous as possible and sensible. Appropriately reordered, these equations are just two linear equations in the unknowns $dw - dpm$, $dp - dpm$, the deviations of wage and price inflation from the inflationary climate currently prevailing. They can be uniquely solved for $dw - dpm$, $dp - dpm$, when the weights applied to current inflation rates, $\kappa_w, \kappa_p \in [0,1]$, fulfill $\kappa_w \kappa_p < 1$, then giving rise to the following reduced form expressions for wage and price inflation detrended by our concept of the inflationary climate into which current inflation is embedded:

$$dw - dpm = \frac{1}{1-\kappa_w \kappa_p}[\beta_{w's}(\cdot) + \kappa_w \beta_{p's}(\cdot)] \tag{3.7}$$

$$dp - dpm = \frac{1}{1-\kappa_w \kappa_p}[\beta_{p's}(\cdot) + \kappa_p \beta_{w's}(\cdot)] \tag{3.8}$$

with all demand pressure variables acting positively on the deviation of wage as well as price inflation from the inflationary climate variable *dpm*. Integrating across markets for example the two PC's approach (2.3), (2.4) would thus imply that two qualitatively different measures for demand pressure in the markets for labor as well as for goods have to be used both for money wage and price level inflation for describing their deviation here from the prevailing inflation climate, formally seen in the usual way of an expectations augmented PC of the literature, see Laxton et al. (2000) for a typical example (where in addition only one measure of demand pressure, on the labor market, is again considered solely). Making furthermore use of all of Phillips' (1954) three types of control (proportional, derivative and integral, here applied to wage and price PC's), the obtained integrated PC's will be further differentiated, leading to 6 types of expressions that may then appear in the traditional integrated, spanning across markets, price level PC that dominates the mainstream literature. Furthermore, as before, two different types of NAIRU's will then be present in the integrated (wage and) price PC which in general cannot be identified with each other.

As a special case of the general reduced form (3.7) and (3.8) – with now only proportional terms present for our subsequent empirical analysis – we obtain now the following equations for real wage growth and price inflation dynamics, in line with what was obtained in Flaschel and Krolzig (2003).[7] Note that these two equations are equivalent to the two structural equations (with only proportional demand pressure terms) we started from.

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

$$dp = \frac{1}{1-\kappa_w \kappa_p}[\beta_{p_1}(V^c - \bar{V}^c) + \kappa_p \beta_{w_1}(V^l - \bar{V}^l)]$$

On the basis of the law of motion for the real wage $\omega = w - p$ we then get as critical condition for the establishment of a positive dependence of the growth rate of real wages on economic activity 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 critical α condition for the occurrence of **normal (respectively: adverse) real wage effects**. If economic activity depends positively on the real wage, we get a positive feedback of the real wage on its rate of growth if $\alpha > 0$ holds true (and a negative, i.e., partially stabilizing one if activity depends negatively on the real wage). In the latter case, the situation $\alpha < 0$ will however again imply a destabilizing effect of real wages on their rate of growth, while the case $\alpha > 0$ is now coupled with a stabilizing feedback chain if aggregate demand and thus economic activity are negatively correlated with each other. The conventional literature on the Phillips curve generally focuses on the above reduced form for price inflation, and this in the special case where only the labor market matters and price inflation

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

is more or less passively following wage inflation. It thus only provides a very partial representation of the wage-price spiral and complete ignores the resulting effects on income distribution and their laws of motion (represented by the law of motion for real wages).

Conventional AS-AD growth dynamics thus is of a very one-sided nature, taking account of the stabilizing Keynes – effect and (sometimes) of the destabilizing Mundell - effect, both working through the (expected) real rate of interest channel in investment (and also consumption) behavior. It however completely ignores another real rate feedback mechanism, the real wage adjustment process which comes into being when consumption (positively) and investment (negatively) are made dependent on the real wage and when wage and price dynamics are distinguished from each other. Furthermore, it is known (see Chiarella and Flaschel (2000) for example) that the real rate of interest channel becomes destabilizing when the interest rate sensitivity of money demand is chosen sufficiently high combined with an adaptive revision of inflationary expectations that works sufficiently fast. In this case the Mundell effect dominates and creates an accelerating inflationary spiral and thus an unstable nominal adjustment mechanism. In the case of the real-wage channel – or the Rose effect, as it was named in Chiarella and Flaschel (2000) – the situation is even more complicated and thus also more interesting, since their are now four possible configurations, two of which provide a stable partial scenario and the other two an unstable one. It is obvious that empirical analysis is needed in order to determine which type of Rose effect is the dominant one in a particular country at a particular time.

In view of this, let us briefly consider various applied approaches to PC measurements on the basis of the equations (3.9), (3.9). Fair (2000), as already shown, provides one of the rare studies (disregarding structural macroeconometric model building) which start from 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, while nominal wages follow the price level dynamics more or less passively. We thus have a law of motion for the price level and nothing interesting on the side of real wage dynamics.

Concerning modern macroeconometric model building, we find in Powell and Murphy (1997) a money wage Phillips curve with $\beta_{w_1}, \beta_{w_2} \neq 0$ and a price Phillips curve that appears to be based on cost-push terms solely, but which (when appropriately reformulated, see Chiarella, Flaschel, Groh, Köper and Semmler (2003), in fact also makes use of $\beta_{p_1} \neq 1$ implicitly. Furthermore, the parameter β_{w_2} is about 8 times larger than β_{w_1} when the nonlinear wage Phillips curve measured in this work is linearized at the steady state, which there supports Kuh's (1967) early assertion that the wage Phillips curve is a level relationship rather than one concerning rates of inflation, and which at the same time stresses the importance of Phillips loops as already observed by Phillips (1958) himself. Indeed, if $dw = \beta_{w_2}\dot{V}^l/V^l$ represents the dominant part of the money wage Phillips curve, we get by simple integration $w = const \cdot (V^l)^{\beta_{w_2}}$ and thus a wage curve as considered on the microlevel by Blanchflower and Oswald (1994) in particular. In this view, the wage Phillips curve, with derivative control solely, is therefore the important one. Nevertheless, Keynesian macroeconometric model building seems to come closest to our structural and reduced form wage-price dynamics without however taking note of the fact that real wage adjustment may then be adverse and either wage or price flexibility with respect to demand pressures in the markets for labor or for goods must then be destabilizing.

Laxton et al. (1998) use for the Multimod Mark III model of the IMF an integrated, or hybrid, PC of the type (3.9) 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. 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.

We thus find in this brief discussion of applied approaches a variety of opinions. Yet, there are few studies as regards the inside employment rates and inventory utilization rates. This is possibly due to the lack of data. Only Fair (2000) takes verbally 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. It must, therefore, be noted that the discussion on Phillips curves is at present again a lively one, but also still a very unsettled one. Of course, not all of the expressions representing demand pressure variants 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.

We mention in passing 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 $\kappa_w, \kappa_p < 1$. 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 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. Finally 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, 2002) as well as in Flaschel and Krolzig (2004) and Flaschel, Kauermann and Semmler (2004a).

We conclude with the observation that much remains to be done in the theoretical and empirical discussion of the form and the implications of PC approaches to labor and goods market behavior, where more hybrid outcomes may be obtained than is generally believed. The same also holds true for empirical studies of Phillips curves, where there is a lack of systematic investigation of the wealth of possibilities to which we have indicated above. Due to this the role of normal or adverse real-wage effects in macroeconomic dynamics is basically overlooked in theory as well as in empirical investigations of the wage-price spiral. In the next section we therefore now present our own empirical study of the two separate PC approach of this paper and will indeed obtain results that are comparable to those obtained in the recent studies mentioned in the preceding paragraph.

4 Estimating wage and price Phillips curves for the US economy

So far we have argued from the theoretical perspective that PC's approach to describe labor and goods market behavior is better modelled as a 2D dynamic system instead of a single labor market oriented PC. In this section we are now going to provide empirical answers to the issues raised in the last two sections, i.e.

- Do the 2D PC's as described in (2.3) and (2.4) provide a suitable model structure to capture the dynamics of wage-price spiral implied in the empirical data?
- How can we evaluate diverse specifications of PC's?
- What is an appropriate empirical specification of PC's?
- What is the implication of the single equation approach to PC dynamics?

To answer the above questions we formulate at first a general linear[8] VAR system of relevant variables to mimic the DGP. We then test: (1) whether the DGP can be presented by a conditional process of wage and price adjustment, i.e. we test if the other variables are strongly exogenous for the parameters of the conditional process; (2) We compare diverse specifications of PC's based on corresponding likelihood ratios for the general model estimated in step (1); (3) After having evaluated diverse specifications of our PC's we choose a parsimonious and interpretable specification of PC's that is compatible with the data. Finally: (4) We investigate the implications of the modelling with a single equation PC.

According to the investigation in the previous sections we postulate that the relevant variable for our wage and price PC's are $dw_t, dp_t, V_t^l = 1 - U_t^l, V_t^c = 1 - U_t^c, dyn_t, dwm_t$ and dpm_t. These variables denote the wage inflation rate, the price inflation rate, the rate of labor underutilization, the rate of capacity underutilization, the rate of productivity growth, the expectation of medium-run wage inflation and price

[8]An alternative and nonlinear specification of the model will be investigated in the next section.

inflation. Assuming that the expectation formation process is based on information of the other variables, we may construct a general system consisting of five variables: $dp_t, dw_t, V_t^l = 1 - U_t^l, V_t^c = 1 - U_t^c, dyn_t$.

4.1 Data Description

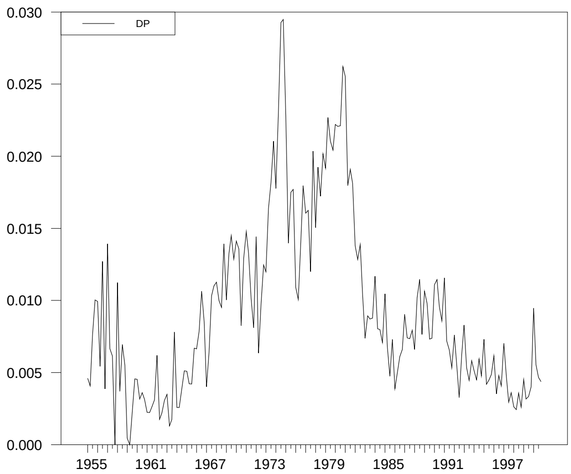
The empirical data of the concerning time series are taken from the Federal Reserve Bank of St. Louis (see http:/www.stls.frb.org/fred). The data are quarterly , seasonally adjusted and are all available from 1948:1 to 2001:2. Except for the unemployment rates of the factors labor, U^l, and capital, U^c, the log of the series are used (see table). These data were already employed in Flaschel and Krolzig (2004), there for the range 1955:2 to 2000:4.

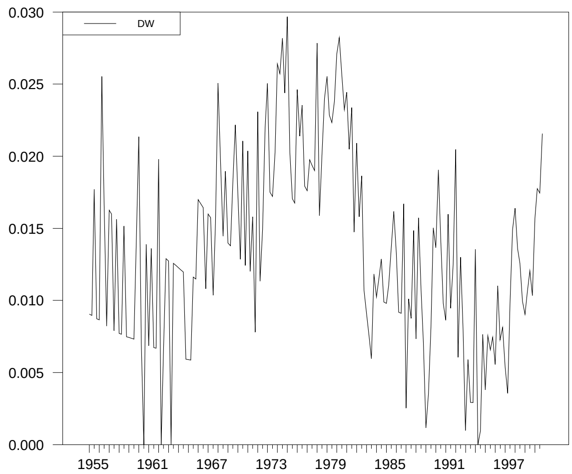
Variable	Transformation	Mnemonic	Description of the untransformed series
$U^l = 1 - V^l$	UNRATE/100	UNRATE	Unemployment Rate
$U^c = 1 - V^c$	1-CUMFG/100	CUMFG	Capacity Utilization: Manufacturing, Percent of Capacity
w	log(COMPNFB)	COMPNFB	Nonfarm Business Sector: Compensation Per Hour, 1992=100
p	log(GNPDEF)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

Table 2: Data used for empirical investigation

Note again that w, p represent logarithms, i.e., their first differences dw, dp 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 an especially simple measure of the employed inflationary climate expression), and denote again by V^l, V^c the rates of utilization of the stock of labor and the capital stock. The graphs of the time series of these variables are shown in figure 2.

There is a pronounced downward trend in part of the employment rate series (over the 1970's and part of the 1980's) and in the wage share (normalized to 0 in 1996). The latter is not the topic of this paper, but will be briefly considered in the concluding section. Wage inflation shows three to four trend reversals, while the inflation climate representation clearly show two periods of low inflation regimes and in between a high inflation regime.





We expect that these five time series are stationary. The graphs of the series wage and price inflation, capacity utilization rates and labor productivity growth, $dw_t, dp_t, V_t^l, V_t^c, dyn_t$, confirm our expectation. In additional we carry out DF unit root test for each series. The test results are in Table 3.

The unit root test confirms our expectation with the exception of V_t^l. Although the test cannot reject the null of unit root, there is no reason to expect the rate of unemployment as being a unit root process.

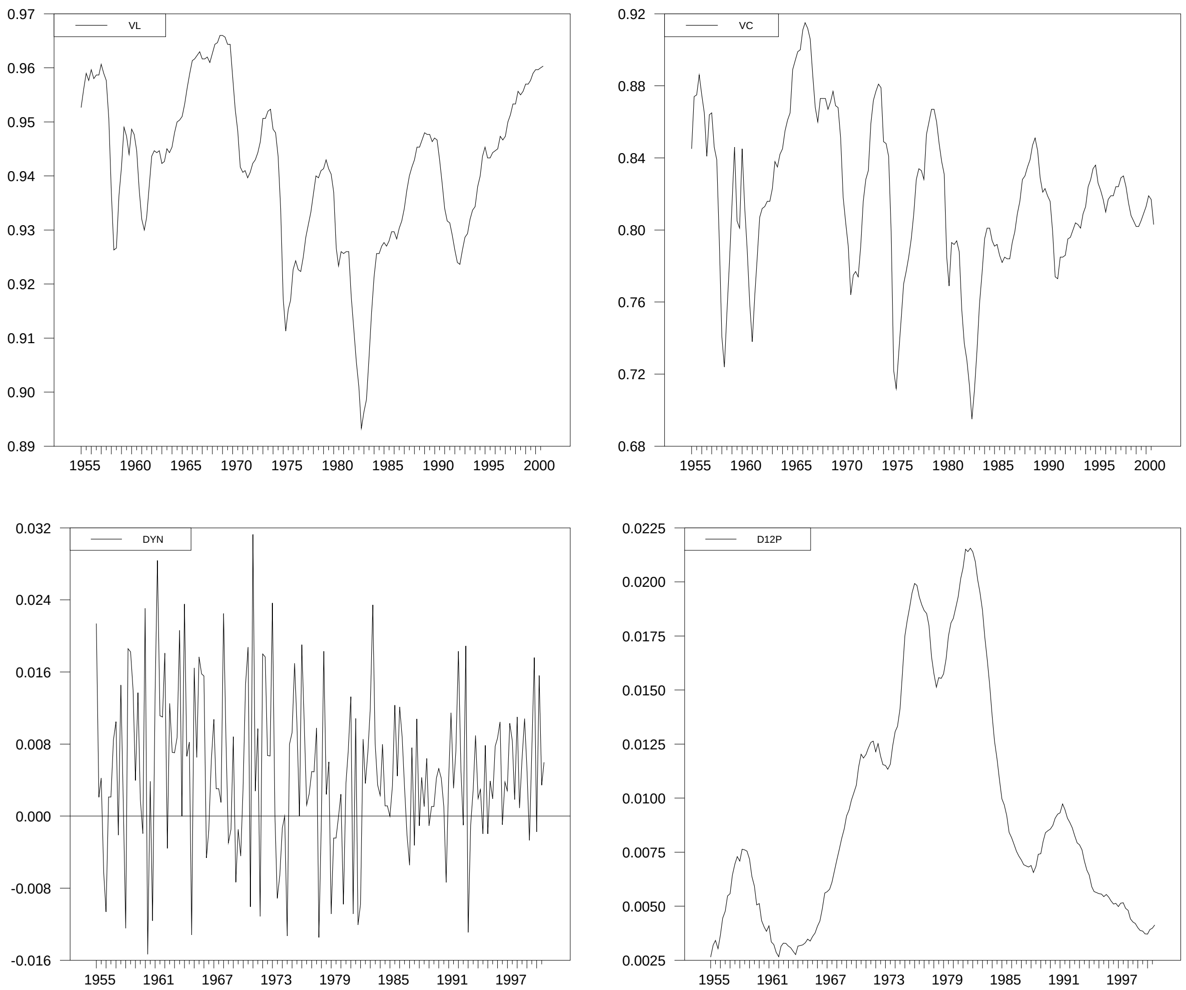


Figure 2: The fundamental data of the model.

Much more we expect this rate to be constrained in certain limited ranges, say from zero to 0.3. Due to the lower power of DF test, the test result should only provide hints that the rate of unemployment has a strong autocorrelation. Based on the above data description we construct a VAR system as follows, where $d74$ is a dummy variable for the oil crisis in 1974.

$$\begin{pmatrix} dw_t \\ dp_t \\ V_t^l \\ V_t^c \\ dyn_t \end{pmatrix} = \begin{pmatrix} c_1 \\ c_2 \\ c_3 \\ c_4 \\ c_5 \end{pmatrix} + \begin{pmatrix} b_1 \\ b_2 \\ b_3 \\ b_4 \\ b_5 \end{pmatrix} d74 + \sum_{k=1}^{P} \begin{pmatrix} a_{11k} & a_{12k} & a_{13k} & a_{14k} & a_{15k} \\ a_{21k} & a_{22k} & a_{23k} & a_{24k} & a_{25k} \\ a_{31k} & a_{32k} & a_{33k} & a_{34k} & a_{35k} \\ a_{41k} & a_{42k} & a_{43k} & a_{44k} & a_{45k} \\ a_{51k} & a_{52k} & a_{53k} & a_{54k} & a_{55k} \end{pmatrix} \begin{pmatrix} dw_{t-k} \\ dp_{t-k} \\ V_{t-k}^l \\ V_{t-k}^c \\ dyn_{t-k} \end{pmatrix} + \begin{pmatrix} e_{1t} \\ e_{2t} \\ e_{3t} \\ e_{4t} \\ e_{5t} \end{pmatrix} \tag{4.9}$$

Variable	Sample	Critical value	Test Statistic
dw	1947:02 TO 2000:04	-3.41000	-3.74323
dp	1947:02 TO 2000:04	-3.41000	-3.52360
V^l	1947:02 TO 2000:04	-1.95000	-0.73842
V^c	1947:02 TO 2000:04	-3.41000	-4.13323
dyn	1947:02 TO 2000:04	-3.41000	-7.28940

Table 3: Summary of DF-Test Results

To determine the lag length of the VAR we apply sequential likelihood tests. We start with a lag length of 24, at which the residuals can be taken as WN process. The sequential likelihood ratio test procedure gives a lag length of 9. The test results are listed below.

- $H_0 : P = 20$ v.s. $H_1 : P = 24$
  Chi-Squared(100)= 105.349157 with significance level 0.33773310
- $H_0 : P = 16$ v.s. $H_1 : P = 20$
  Chi-Squared(100)= 92.860010 with significance level 0.68081073
- $H_0 : P = 12$ v.s. $H_1 : P = 16$
  Chi-Squared(100)= 92.327928 with significance level 0.69481872
- $H_0 : P = 11$ v.s. $H_1 : P = 12$
  Chi-Squared(25)= 27.197244 with significance level 0.34610316
- $H_0 : P = 10$ v.s. $H_1 : P = 11$
  Chi-Squared(25)= 33.314049 with significance level 0.12340179
- $H_0 : P = 9$ v.s. $H_1 : P = 10$
  Chi-Squared(25)= 26.713233 with significance level 0.37036104
- $H_0 : P = 8$ v.s. $H_1 : P = 9$
  Chi-Squared(25)= 44.707373 with significance level 0.00902793

According to these test results we use $VAR(12)$[9] to present a general model that should be an approximation of the DGP. Because we are interested in the wage price dynamics and its dependence on the unemployment rate, the capacity utilization rate and productivity growth, we factorize the $VAR(12)$ process into a conditional process of dw_t, dp_t, given V_t^l, V_t^c, dyn_t and the lagged variables, and the marginal process of V_t^l, V_t^c, dyn_t, given the lagged variables:

$$\begin{aligned}\begin{pmatrix} dw_t \\ dp_t \end{pmatrix} &= \begin{pmatrix} c_1^* \\ c_2^* \end{pmatrix} + \begin{pmatrix} b_1^* \\ b_2^* \end{pmatrix} d74 + \begin{pmatrix} b_{13} & b_{14} & b_{15} \\ b_{23} & b_{24} & b_{25} \end{pmatrix} \begin{pmatrix} V_t^l \\ V_t^c \\ dyn_t \end{pmatrix} \\ &+ \sum_{k=1}^{P} \begin{pmatrix} a_{11k}^* & a_{12k}^* & a_{13k}^* & a_{14k}^* & a_{15k}^* \\ a_{21k}^* & a_{22k}^* & a_{23k}^* & a_{24k}^* & a_{25k}^* \end{pmatrix} \begin{pmatrix} dw_{t-k} \\ dp_{t-k} \\ V_{t-k}^l \\ V_{t-k}^c \\ dyn_{t-k} \end{pmatrix} + \begin{pmatrix} e_{1t}^* \\ e_{2t}^* \end{pmatrix}\end{aligned} \tag{4.10}$$

$$\begin{pmatrix} V_t^l \\ V_t^c \\ dyn_t \end{pmatrix} = \begin{pmatrix} c_3 \\ c_4 \\ c_5 \end{pmatrix} + \begin{pmatrix} b_3 \\ b_4 \\ b_5 \end{pmatrix} d74 + \sum_{k=1}^{P} \begin{pmatrix} a_{31k} & a_{32k} & a_{33k} & a_{34k} & a_{35k} \\ a_{41k} & a_{42k} & a_{43k} & a_{44k} & a_{45k} \\ a_{51k} & a_{52k} & a_{53k} & a_{54k} & a_{55k} \end{pmatrix} \begin{pmatrix} dw_{t-k} \\ dp_{t-k} \\ V_{t-k}^l \\ V_{t-k}^c \\ dyn_{t-k} \end{pmatrix} + \begin{pmatrix} e_{3t} \\ e_{4t} \\ e_{5t} \end{pmatrix} \tag{4.11}$$

Now we examine if V_t^l, V_t^c, dyn_t can be taken as "exogenous" variable. The partial system (4.10) is exactly identified. Hence the variables V_t^l, V_t^c, dyn_t are weakly exogenous for the parameters in the partial system.[10] For the strong exogeneity of V_t^l, V_t^c, dyn_t, we test whether dw_t, dp_t Granger cause V_t^l, V_t^c, dyn_t.

The test is carried out by testing the hypothesis: $H_0 : a_{ijk} = 0, (i = 3, 4, 5; J = 1, 2; k = 1, 2, ..., 12)$ in (4.9) based on likelihood ratio. The result is:

[9] $VAR(9)$ would also be a valid approximation of the DGP, However, we prefer to use a lag length of 3 year than 2 years and one quarter. Moreover, in the $VAR(12)$ we can conveniently nest the variable $dp12$.

[10] For a detailed discussion of this issue, see Chen (2003)

- Chi-Squared(72)= 62.459885 with significance level 0.78138659.

According to this result, V_t^l, V_t^c, dyn_t can be taken as strongly exogenous in the partial system (4.10). Therefore, the wage-price dynamics can be well described in the 2D partial system with V_t^l, V_t^c, dyn_t as 'exogenous' variables.

We shall now test the following specific PC models by comparing this variable selection with the general model (4.10).

Model (1)

$$dw_t = -a_o + a_1 V_{t-1}^l + a_2 dp_t + a_3 dp12_t + e_{1t} \tag{4.12}$$

$$dp_t = -b_o + b_1 V_{t-1}^c + b_2 dw_t + b_3 dp12_t + b_4 d74_t + e_{2t} \tag{4.13}$$

We use $dp12_t$ to denote now specifically the moving average of price inflation over the past 12 quarters (as an especially simple measure of the employed inflationary climate expression). The basic feature here is that we now use market specific demand pressure measures V_t^l and V_t^c in two PC's.

Model (2)

$$dw_t - dp12_t = -a_o + a_1 V_{t-1}^l + a_2(dp_t - dp12_t) + e_{1t} \tag{4.14}$$

$$dp_t - dp12_t = -b_o + b_1 V_{t-1}^c + b_2(dw_t - dp12_t) + b_3 d74_t + e_{et} \tag{4.15}$$

Model (2) is formulated as deviation from the inflationary climate. This is equivalent to imposing two linear restrictions on a_2, a_3 and b_2 b_3 respectively.

Model (3)

$$dw_t = -a_o + a_1 V_{t-1}^l + a_2 V_{t-1}^c + a_3 dw12_t + a_4 dp12_t + a_5 d74_t + e_{1t} \tag{4.16}$$

$$dp_t = -b_o + b_1 V_{t-1}^l + b_2 V_{t-1}^c + b_3 dw12_t + b_4 dp12_t + b_5 d74_t + e_{2t} \tag{4.17}$$

$$\tag{4.18}$$

Model (3) is the unconstrained reduced form that takes V_{t-1}^l, V_{t-1}^c $dw12_t$, $dp12_t$ and $d74_t$ – with a constant term – as predetermined variables.

Model FK

$$\begin{aligned}
dw_t &= \beta_{w_1}(V^l - \bar{V}^l)_t + \kappa_w dp_t + (1-\kappa_w) dp12_t + r \cdot dyn_t \\
&= -0.193 \cdot (V^l - 0.915)_t + 0.266 dp_t + 0.734 dp12_t + 0.005 dyn_t \\
dp_t &= \beta_{p_1}(V^c - \bar{V}^c)_t + \kappa_p dw_t + (1-\kappa_p) dp12_t - s \cdot \kappa_p dyn_t \\
&= -0.039 \cdot (V^c - 0.817)_t + 0.290 dw_t + 0.710 dp12_t - 0.064 dyn_t
\end{aligned}$$

Model FK is the long run relation that is also considered in Flaschel and Krolzig (2003). where they used a general model with five lags to model the wage-price spiral. They then obtained as specific result by the PcGets optimization routine that indeed only current 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).[11]

Model FL

$$dw_t = a_0 + a_1 dp_t + a_2 dpm_t + a_3 V_t^l + a_4 dyn_t + e_{1t} \tag{4.19}$$

$$dp_t = b_0 + b_1 dw_t + b_2 dwm_t + b_3 V_t^c + b_4 dyn_t + b_5 d74 + e_{2t} \tag{4.20}$$

[11] dyn the growth rate of labor productivity and $V^l = 1 - U^l, V^c = 1 - U^c$ the utilization rates in the place of underutilization rates U^l, U^c.

Model	P-value	DW	R^2	Sign	
Model 1.	0.03	1.78/1.81	0.53/0.74	+	
Model 1.0	0.15	1.76/1.84	0.53/0.81	+	
Model 2.	0.03	1.81/1.76	0.38/0.43	+	
Model 2.0	0.18	1.76/1.82	0.31/0.43	+	
Model 3.	0.06	1.83/1.51	0.53/0.79		
Model 3.0	0.23	1.94/1.71	0.54/0.81		
Model FK	0.08	1.53/1.81	0.43/0.77	+	
Model FK.0	0.42	1.73/1.93	0.57/0.81	+	
Model FK.p	0.00			+	
Model FL	0.13	1.67/1.57	0.53/0.62		

Table 4: Summary of LR Test Results

Model FL is characterized by using market specific inflationary climate variables besides the market specific demand pressure measures. dwm_t and dpm_t are linearly decreasing weighted sums of dw_t and dp_t in the previous 12 periods, variables that express the inflationary climate on the labor market and the commodity market with decreasing memory of past inflation rates now. The variable $d74$ is a dummy variable catching up the effect of the oil crisis in 1974. All the structural models considered above are nested in the general model (4.10). Each of these structural models implies a set of restrictions on the parameters of the general model (4.10). Under the assumption of homoscedastic normally distributed residuals, we carry out FIML estimation for all these models. We apply LR method to test each set of restrictions. If a LR test does not reject the hypothesis of a set of restrictions, the corresponding structural model under investigation can be then taken as a valid parsimonious presentation of the DGP. Table 4 provides a summary of the estimation and test results.[12]

In this table we can see that the overidentification restrictions implied by Model 1.0, model 2.0, model 3.0, model FK.0 and model FL are not rejected. Obviously, the decreasing weights of the lagged dp_t and dw_t in the variables dpm_t and dwm_t catch up much better the dynamics, as was intuitively expected. Hence we will use dpm_t and dwm_t instead of $dp12_t$ and $dw12_t$ as the inflationary climate variables. A surprising result is that Model FK.0 fits the data better than Model FL, where the the only difference is that the inflationary climate variables in Model FK.0 are the same (dpm_t), while in Model FL they are dpm_t and dwm_t in the wage equation and in the price equation, respectively. A remarkable feature is that all these models show certain first order autocorrelation in the residuals, expressed by low DW statistics.

Based on these results we now consider the following specification:

Model FF

$$dw_t = \rho_w dw_{t-1} + a_0 + a_1 dp_t + a_2 dpm_t + a_3 V_t^l + a_4 dyn_t + e_{1t} \tag{4.21}$$
$$dp_t = \rho_p dp_{t-1} + b_0 + b_1 dw_t + b_2 dpm_t + b_3 V_t^c + b_4 dyn_t + b_5 d74 + e_{2t} \tag{4.22}$$

Again the above model (4.21) and (4.22) can be taken as (4.10) under restrictions and we apply again a LR test for the restrictions implied in the model (4.21) and (4.22). The result is:

- Chi-Squared(116)= 111.619379 with significance level 0.59769222

Now we can test in Model FF the restrictions implied by the theory developed in section 2:

$$\rho_w + a_1 + a_2 = 1 \tag{4.23}$$
$$\rho_p + b_1 + b_2 = 1 \tag{4.24}$$

As result we here obtain:

[12]Model x.0 (x=1, 2, 3) is a modification of Model x, obtained by replacing $dp12$ by dpm and $dw12$ by dwm, respectively.

- Chi-Squared(2)= 0.757485 with significance level 0.68472204

Finally we estimate Model FF under restrictions (4.23) and (4.24) by applying FIML:

$$dw_t = \underset{2.16}{0.15} dw_{t-1} \underset{-4.9}{-0.11} + \underset{1.79}{0.40} dp_t + \underset{2.2}{0.44} dpm_t + \underset{3.66}{0.14} V_t^l + \underset{4.3}{0.13} dyn_t + \hat{e}_{1t} \tag{4.25}$$

$DW = 2.07$, $R^2 = 0.58$

$$dp_t = \underset{7.53}{0.18} dp_{t-1} \underset{-1.7}{-0.02} + \underset{0.21}{0.27} dw_t + \underset{3.5}{0.53} dpm_t + \underset{2.64}{0.02} V_t^c \underset{-2.44}{-0.10}\, dyn_t + \underset{3.7}{0.008} d74 + \hat{e}_{2t} \tag{4.26}$$

$DW = 2,24$ $R^2 = 0.82$.

Model FF under restrictions is an overidentified structural model where there are 5 restrictions on the reduced form, and a LR test is performed with following result:

- Chi-Squared(5)= 2.874610 with significance level 0.71930993

The estimation and test results confirm the findings in Flaschel and Krolzig (2003). Wages are here again more flexible (0.14) than prices (0.02) with respect to their corresponding demand pressure item (with capacity utilization being more volatile than the unemployment rate), but workers and firms are roughly equally short-sighted ($0.4 = 0.34/(1 - 0.15), 0.33 = 0.27/(1 - 0.18)$) with respect to current inflation in comparison to the inflationary climate surrounding the current level of wage and price inflation rates. This is by and large in line with what was shown in Tables 1 for the US-economy. It moreover still implies an adverse type of real wage adjustment if it it is assumed that consumption is more responsive to real wage changes than investment, with a critical value $\alpha = 0.07$. In the case where economic activity depends positively on the real wage we thus obtain a partial unstable dynamical system as in Flaschel and Krolzig (2004), here described by:

$$\alpha = (1 - \kappa_p)\beta_{w_1} k_o - (1 - \kappa_w)\beta_{p_1}/y^p$$

where the value of α determines the strength with which real wage dependent economic activity $y(\omega)$ is driving the growth rate of real wages.

We note that Fair's estimates imply in particular $\beta_{w_1} = 0$ which would imply in the presently considered model that price flexibility is stabilizing in the case where aggregate demand depends positively on the real wage and destabilizing in the other case, the case most often assumed in policy discussions used to characterize the working of modern market economies.

Now we turn to the question what is the empirical implication of modelling the PC as a single price inflation equation. To answer this question we have to make sure what we mean when we model PC as a single equation. In the single equation approach we take all the explaining variables, specifically dw_t, as "exogenous" and we estimate the parameters via OLS conditional on these variables. Further we may forecast the value of dp_t based on given value of these "exogenous" variable.

Following Engle, Hendry, and Richard (1983) the concept of exogeneity can be classified according to its implication for efficient statistical inference, forecasting and policy simulation into weak exogeneity, strong exogeneity and supper exogeneity respectively. In our context we are asking whether dw_t is strongly or weakly exogenous for the parameters in such a PC equation.

Because the concept of exogeneity of the variable dw_t is always associated with a model and the DGP, we have to look at each concrete model to discuss the exogeneity of dw_t. For all the models listed in this section, dw_t is not weakly exogenous for the parameters of the concerning price equation, because all the models listed above are 2D simultaneous equations model with dw_t as jointly dependent variable. To get an efficient estimator we have to take the process for dw_t into account. Hence dw_t is not weakly exogenous for all the price equations listed above. But we cannot conclude that dw_t is not weakly exogenous for any PC equation based on these few examples. For example, if the model 3.0 shown below would represent the DGP:

Model (3.0)

$$dw_t = -a_o + a_1 V^l_{t-1} + a_2 V^c_{t-1} + a_3 dpm_{t-1} + e_{1t} \tag{4.27}$$
$$dp_t = -b_o + b_1 V^l_{t-1} + b_2 V^c_{t-1} + b_3 dpm_{t-1} + e_{2t}, \tag{4.28}$$

then

$$dp_t = -c_o + c_1 V^l_{t-1} + c_2 V^c_{t-1} + c_3 dpm_t + c_4 dw_t + e^*_t \tag{4.29}$$

will be a single equation PC in which dw_t is weakly exogenous for the parameters: c_1, c_2, c_3, c_4. Here we can apply OLS to get the efficient estimates. In other words the OLS estimates is the same as the FIML of (4.29) and (4.27).

A general condition for dw_t to be weakly exogenous in a single PC can be formulated like follows.

If the reduced form of a 2D structural model represents the DGP correctly:

$$dw_t = -a_o + a_1' X_t + e_{1t} \tag{4.30}$$
$$dp_t = -b_o + b_1' X_t + e_{2t}, \tag{4.31}$$

where X_t the vector of the predetermined variables of the 2D structural model and $(e_{1t}, e_{2t})' \sim$ iid $N(0, \S igma)$, then

$$dp_t = -c_o + c_1' X_t + c_2 dw_t + e^*_t \tag{4.32}$$

is a single equation PC in which dw_t is weakly exogenous.(For proof see Chen (2003))

To investigate whether dw_t is strongly exogenous we have to test in the model (4.30) and (4.32) if dp_t Granger causes dw_t. Without concrete specification of (4.30) we cannot carry out the test. However, we can get a strong hint when we test the Granger causality of dp_t for dw_t in (4.25) and (4.26). The test result here is:

- Chi-Squared(2)= 72.272940 with significance level 0.00000000.

This result implies that in predicting dw_t we have to take into account the process that generates dp_t, hence a system of dw_t and dp_t must be considered to get valid predictions. We thereby confirm the statement made in Fair (2000) that the 2D structural approach to PC theory will improve the predictive accuracy compared to the single reduced form analysis that still characterizes the conventional approach in the empirical oriented literature. Moreover, we have also improved significantly Fair's approach to structural wage and price equations with respect to theoretical structure as well as empirical accuracy.

5 Structural wage and price Phillips curves: Exploring nonlinearities

After we have investigated in detail linear specifications of the wage and price PC's and identified a 2D system as appropriate representation of the wage-price spiral, we now turn to the question of a possible downward rigidity of the wage and price dynamics. The linear specification of wage-price dynamics implies of course that there is no downward wage and price rigidity, since the speed parameters β are kept constant there. Therefore, to explore downward rigidity in wage and price dynamics, we have to explore in fact the nonlinearity of our PC's for low inflation regimes. Such rigidity describes the phenomenon that below certain level the still resulting wage and price inflation do not react (as strongly) to demand pressure terms as well as to cost pressure terms any more, in other words, rigidity of wage inflation and price inflation imply that there exists lower floors for wage inflation and price inflation. Therefore the target of our investigation is identifying whether the wage inflation function and the price inflation function have a lower floor, and to attempt to estimating if and where such lower floors to the nominal dynamics within disequilibrium macrodynamics indeed exists.

5.1 The Model

Let Z_t denote the vector of determinants of wage inflation. We consider the following model:

$$dw_t = \begin{cases} Z_t'\gamma + \epsilon_{1t}, & E(dw_t) > dw_0; \\ dw_0 + \epsilon_{2t}, & E(dw_t) = dw_0. \end{cases} \tag{5.33}$$

where $\epsilon_{1t} \sim iid(0, \sigma_1)$ and $\epsilon_{2t} \sim iid(0, \sigma_2)$.

The variable dw_0 is the lower floor of the wage inflation dynamics. If the joint influence of the determinants $Z_t'\gamma$ is over a certain level (the lower floor) the wage inflation rate will react to the joint influence of the exogenous variables. In case the joint influence is however below this level the wage inflation rate will not react to the determinants, but be kept at its lower floor value. We understand as a specific formulation the downward rigidity of money wages.

The employed model type falls into the set up of switching regression models introduced by Goldfeld and Quandt (1973b). We employ a dummy variable D_t to indicate the regression regime.

$D_t = 1 : dw_t = Z_t'\gamma + e_{1t}$

$D_t = 0 : dw_t = dw_0 + e_{2t}$

The log likelihood function is:

$$\log L(\gamma, \sigma_1^2, \sigma_2^2|Z) = -\frac{1}{T}\log(2\pi) - \frac{1}{2}\log\left[D_t^2\sigma_1^2 + (1-D_t)^2\sigma_2^2\right] \tag{5.34}$$

$$-\frac{\sum_{t=1}^{T}\left[dw_t - D_t Z_t'\gamma - (1-D_t)dw_0\right]^2}{2\left[D_t^2\sigma_1^2 + (1-D_t)^2\sigma_2^2\right]} \tag{5.35}$$

We have to estimate the parameter $\gamma, \sigma_1^2, \sigma_2^2$ and D_t simultaneously. Goldfeld and Quandt (1973) suggest to approximate the dummy variable D_t by a continuous distribution function, e.g. $D_t = \Phi((Z_t'\gamma - dw_0)/\sigma)$, where the log likelihood function becomes a continuous function in the unknown parameters. Standard method can be used then to get the MLE. However, according to our experience, this method will exhibit two problems: 1) the problem of numerical instability; and 2) that there is no guarantee that the estimated expected value $Z_t'\hat{\gamma}$ will always be larger than the estimated lower floor $\hat{dw}_0$. Therefore, we estimate the parameters using the iterative procedure shown below:

1. Pre estimation of $\hat{\gamma}^{(i)}$
2. Ordering data decreasingly according to $Z_t'\hat{\gamma}^(i)$
3. Calculating following maximization problem:

$$\max_{\gamma,\sigma_1^2,\sigma_2^2,dw_0,t_0} \sum_{t=1}^{t_0}\log\left(\phi\left(\frac{dw_t - Z_t'\gamma}{\sigma_1^2}\right)\right) + \sum_{t=t_0+1}^{T}\log\left(\phi\left(\frac{dw_t - dw_0}{\sigma_2^2}\right)\right) \tag{5.36}$$

   under the restriction $\hat{dw}_0 < Z_{\hat{t_0}}'\hat{\gamma}$

4. Goto step 2 if $|\hat{\gamma}^{(i+1)} - \hat{\gamma}^{(i)}| > \delta$ otherwise stop, where δ is a chosen convergence criterion.

Comments:

- In step 2 we separate the sample into two parts each belonging to different regimes by ordering according to $Z_t'\hat{\gamma}$.
- The iterative procedure and the stopping rule at step 4 make sure that the ordering is consistent with the estimation results.
- The maximization problem at step 3 may contain more than one local solutions. Practically, we choose the maximum of the local solution as the global solution by checking it with the graph of the likelihood function.

5.2 Statistical Inference

This model consists of two simple regression models. The statistical properties of the estimator depend crucially on whether the sample points can be sorted correctly. If the sample points can be sorted correctly, we would have two simple regression models, for which the statistical results are standard: the estimator would be BLUE, consistent and asymptotically efficient. In fact the estimation procedure can sort sample points correctly asymptotically. Hence we get standard asymptotical results for this switching model: the estimator is consistent and asymptotically efficient.

Proposition 5.1 *Let T_1 and T_2 be the numbers of sample points of the switching regression model (5.33) of the regime 1 and regime 2. respectively. From following condition:*

1. $\lim_{T\to\infty} \frac{T_1}{T_2} = \alpha_0$
2. $\{\log(f_1(dw_t^{(1)}))\} = \{\log\left(\phi\left(\frac{dw_t^{(1)} - Z_t'\gamma}{\sigma_1^2}\right)\right)\}$,

   $\{\log(f_2(dw_t^{(1)}))\} = \{\log\left(\phi\left(\frac{dw_t^{(1)} - dw_0}{\sigma_2^2}\right)\right)\}$,

   $\{\log(f_1(dw_t^{(2)}))\} = \{\log\left(\phi\left(\frac{dw_t^{(2)} - Z_t'\gamma}{\sigma_1^2}\right)\right)\}$, *and*

   $\{\log(f_2(dw_t^{(2)}))\} = \{\log\left(\phi\left(\frac{dw_t^{(2)} - dw_0}{\sigma_2^2}\right)\right)\}$ *follow the weak uniform law of large numbers(WULLN) respectively,*

where α_0 is a constant and $dw_t^{(1)}$ and $dw_t^{(2)}$ denote observations sampled from regime 1 and regime 2, respectively.

The maximum likelihood procedure will sort the sample points correctly in the sense that the probability of the correctly sorted points will converge to 1, and the MLE of the parameter γ, σ_1^2, and σ_2^2 is consistent and asymptotically efficient.

Proof: Let T_{21} be the number of sample points that are incorrectly sorted from regime 1 to regime 2 and T_{12} be the points that are incorrectly sorted from regime 2 to regime 1. Let T_{11} and T_{22} be the number of correctly sorted sample points. For the total sample points we have : $T = T_{11} + T_{12} + T_{22} + T_{21}$. From the definition of maximum likelihood estimation we have:

$$\begin{aligned}
& \sum_{t=1}^{t_0} \log\left(\phi\left(\frac{dw_t - Z_t'\hat{\gamma}}{\hat{\sigma}_1^2}\right)\right) + \sum_{t=t_0+1}^{T} \log\left(\phi\left(\frac{dw_t - \hat{dw_0}}{\hat{\sigma}_2^2}\right)\right) \\
= & \sum_{T_{11}} \log(f_1(dw_t^{(1)})) + \sum_{T_{12}} \log(f_1(dw_t^{(2)})) + \sum_{T_{22}} \log(f_2(dw_t^{(2)})) + \sum_{T_{21}} \log(f_2(dw_t^{(1)})) \\
\geq & \sum_{T_{11}} \log(f_1(dw_t^{(1)})) + \sum_{T_{12}} \log(f_2(dw_t^{(2)})) + \sum_{T_{22}} \log(f_2(dw_t^{(2)})) + \sum_{T_{21}} \log(f_1(dw_t^{(1)}))
\end{aligned} \tag{5.37}$$

Dividing the above equation by T and taking the limit in probability we get:

$$\begin{aligned}
& \alpha_{12} E_2 \log(f_1(dw_t^{(2)})) + \alpha_{21} E_1 \log(f_2(dw_t^{(1)})) \\
\geq & \alpha_{12} E_2 \log(f_2(dw_t^{(2)})) + \alpha_{21} E_1 \log(f_1(dw_t^{(1)}))
\end{aligned} \tag{5.38}$$

According to Jensens Inequality we furthermore have:

$$\begin{aligned}
& \alpha_{12} E_2 \log(f_1(dw_t^{(2)})) + \alpha_{21} E_1 \log(f_2(dw_t^{(1)})) \\
\leq & \alpha_{12} E_2 \log(f_2(dw_t^{(2)})) + \alpha_{21} E_1 \log(f_1(dw_t^{(1)}))
\end{aligned}$$

Hence, the inequality (5.38) holds only when $\alpha_{12} = 0$ and $\alpha_{21} = 0$. This implies that

$$\operatorname*{plim}_{T\to\infty} \frac{T_{12}}{T} = \alpha_{12} = 0 \tag{5.39}$$

and

$$\operatorname*{plim}_{T\to\infty} \frac{T_{21}}{T} = \alpha_{21} = 0 \tag{5.40}$$

Using the results of (5.39) and (5.40) the asymptotical probability of the estimator can be easily calculated. □

Note on small sample properties: The small sample properties of the estimator depends on how well the sample points are sorted correctly. In the model as specified in (5.33) there are always positive probabilities for a sample point to be sorted to either regime. Hence the small sample probability of the estimator is quit untraceable. We can try however to access this probability property via simulation.

5.3 Specification Tests

In empirical research, it is naturally appealing to ask whether a linear regression model can fit the data equally well as the switching regression model? This motivates a specification test of the model (5.33) against: H1: $dw_t = Z_t'\gamma + \epsilon_t$ or against H2:$dw_t = dw_0 + \epsilon_t$.

To test the alternative H1, we can apply J Test in the setting of nonnested alternative models. Denote the fitted value of dw_t in model (5.33) by $\hat{y}_t$. We have the super nesting model:

$$dw_t = (1-\alpha)Z_t'\gamma + \alpha\hat{y}_t + \epsilon_t \tag{5.41}$$

Following Davidson and McKinnon (1981) we can use the t-statistic for α in the regression model (5.41) to test the alternative model H1.

Testing H2 falls into the conventional setting of nested models. We get the H2 model by restricting the slopes in (5.33) to zero and restricting the constant to be equal in two regimes. Therefore the F-test can be applied.

5.4 Simultaneity and Endogeneity

As we know some elements of the regressor vector Z_t may depend on the regressant dw_t, for example dp_t as a regressor may be correlated with the disturbance ϵ_t. We then have the classic problem of a simultaneous bias. In this case have to take the endogeneity of dp_t into account. The model can then be modified as follows:

$$\begin{aligned} dw_t &= \begin{cases} \kappa_w dp_t + X_t'\beta + \epsilon_{1t}, & E(dw_t|X_t) > dw_0; \\ dw_0 + \epsilon_{1t}, & E(dw_t|X_t) = dw_0. \end{cases} && (5.42) \\ dp_t &= \kappa_p dw_t + X_t'\gamma + \epsilon_{2t} \end{aligned}$$

where $\begin{pmatrix} \epsilon_{1t} \\ \epsilon_{2t} \end{pmatrix} \sim \text{iid } N(0,\Sigma)$.

If the variable dp_t has a lower floor, too, we will have a model with two simultaneous switching equations (model 3):

$$dw_t = \begin{cases} \kappa_w dp_t + X_t'\beta + \epsilon_{1t}, & E(dw_t|X_t) > dw_0; \\ dw_0 + \epsilon_{1t}, & E(dw_t|X_t) = dw_0. \end{cases} \tag{5.43}$$

$$dp_t = \begin{cases} \kappa_p dw_t + X_t'\gamma + \epsilon_{2t}, & E(dp_t|X_t) > dp_0; \\ dp_0 + \epsilon_{2t}, & E(dp_t|X_t) = dp_0. \end{cases} \tag{5.44}$$

(5.45)

where $\begin{pmatrix} \epsilon_{1t} \\ \epsilon_{2t} \end{pmatrix} \sim$ iid $N(0, \Sigma)$.

In case the DGP contains lower floor, classic estimation methods cannot be applied. Similar to the case of model (5.33) we can however apply the following iterative maximum likelihood estimation procedure to get consistent and asymptotically efficient estimators. We define two dummy variables D_{1t} and D_{2t} to indicate the regression regimes.

$$D_{1t} = 1 : dw_t = \kappa_w dp_t + X_t'\beta + \epsilon_{1t}$$

$$D_{1t} = 0 : dw_t = dw_0 + \epsilon_{1t}$$

$$D_{2t} = 1 : dp_t = \kappa_p dw_t + X_t'\gamma + \epsilon_{2t}$$

$$D_{2t} = 0 : dp_t = dp_0 + \epsilon_{2t}$$

The log density function can then be written as:

$$\begin{aligned} & \log f(\beta, \gamma, \kappa_w, \kappa_p, \Sigma, dp_0, dw_0; D_{1t}, D_{2t}, dw_t, dp_t | X_t) \\ = \; & -\frac{1}{2}\log(2\pi) - \frac{1}{2}\log|\Sigma| + D_{1t}D_{2t}\log(|1 - \kappa_p\kappa_w|) \\ & -\frac{1}{2}\begin{pmatrix} D_{1t}(dw_t - \kappa_w dp_t - X_t'\beta) + (1 - D_{1t})(dw_t - dw_0) \\ D_{2t}(dp_t - \kappa_p dw_t - X_t'\gamma) + (1 - D_{2t})(dp_t - dp_0) \end{pmatrix} \Sigma^{-1} \\ & \times \begin{pmatrix} D_{1t}(dw_t - \kappa_w dp_t - X_t'\beta) + (1 - D_{1t})(dw_t - dw_0) \\ D_{2t}(dp_t - \kappa_p dw_t - X_t'\gamma) + (1 - D_{2t})(dp_t - dp_0) \end{pmatrix} \end{aligned} \tag{5.46}$$

The iterative procedure is:

1. Pre estimation of $\hat{\theta}^{(i)} = (\hat{\beta}, \hat{\gamma}, \hat{\kappa}_w, \hat{\kappa}_p, \hat{\Sigma})^{(i)}$
2. Calculate the expected value of dw_t and Z_t based on $\hat{\theta}^i$

$$E^{(i)} \begin{pmatrix} dw_t \\ dp_t \end{pmatrix} = \begin{pmatrix} 1 & -\hat{\kappa}_w^{(i)} \\ -\hat{\kappa}_p^{(i)} & 1 \end{pmatrix}^{-1} \begin{pmatrix} X_t'\hat{\beta}^{(i)} \\ X_t'\hat{\gamma}^{(i)} \end{pmatrix} \tag{5.47}$$

3. Define the switching variables: S_{1j} and S_{2k} such that S_{1j} and S_{2k} assume the values of the series $\{\hat{E}(dw_t)\}$ and $\{\hat{E}(dp_t)\}$ in a decreasing order, respectively.

   For any given values of S_{1j} and S_{2k} these sample points can be divided into four groups:

   $I_{11} = \{dw_t, dp_t, X_t | \hat{E}^{(i)}(dw_t) > S_{1j}$ and $\hat{E}^{(i)}(dp_t) > S_{2k}\}$

   $I_{12} = \{dw_t, dp_t, X_t | \hat{E}^{(i)}(dw_t) > S_{1j}$ and $\hat{E}^{(i)}(dp_t) \leq S_{2k}\}$

   $I_{21} = \{dw_t, dp_t, X_t | \hat{E}^{(i)}(dw_t) \leq S_{1j}$ and $\hat{E}^{(i)}(dp_t) > S_{2k}\}$

   $I_{22} = \{dw_t, dp_t, X_t | \hat{E}^{(i)}(dw_t) \leq S_{1j}$ and $\hat{E}^{(i)}(dp_t) \leq S_{2k}\}$

4. Calculating following maximization problem we get $\hat{\theta}^{(i+1)}$:

$$\max_{\theta, S_{1j}, S_{2k}} \sum_{t=1}^{T} \log f(\theta; dw_t, Z_t, X_t | S_{1j}, S_{2k}) \tag{5.48}$$

$$= \max_{\theta, S_{1j}, S_{2k}} -T\log(2\pi) - \frac{T}{2}\log|\Sigma| + T_{11}\log(|1-\kappa_w\kappa_p|) \tag{5.49}$$

$$-0.5\sum_{I_{11}} \begin{pmatrix} dw_t - \kappa_w dp_t - X_t'\beta \\ dp_t - \kappa_p dw_t - X_t'\gamma \end{pmatrix}' \Sigma^{-1} \begin{pmatrix} dw_t - \kappa_w dp_t - X_t'\beta \\ dp_t - \kappa_p dw_t - X_t'\gamma \end{pmatrix}$$

$$-0.5\sum_{I_{12}} \begin{pmatrix} dw_t - \kappa_w dp_t - X_t'\beta \\ dp_t - S_{2k} \end{pmatrix}' \Sigma^{-1} \begin{pmatrix} dw_t - \kappa_w dp_t - X_t'\beta \\ dp_t - S_{2k} \end{pmatrix}$$

$$-0.5\sum_{I_{21}} \begin{pmatrix} dw_t - S_{1j} \\ dp_t - \kappa_p dw_t - X_t'\gamma \end{pmatrix}' \Sigma^{-1} \begin{pmatrix} dw_t - S_{1j} \\ dp_t - \kappa_p dw_t - X_t'\gamma \end{pmatrix}$$

$$-0.5\sum_{I_{22}} \begin{pmatrix} dw_t - S_{1j} \\ dp_t - S_{2k} \end{pmatrix}' \Sigma^{-1} \begin{pmatrix} dw_t - S_{1j} \\ dp_t - S_{2k} \end{pmatrix}$$

5. Goto step 2 if $|\hat{\theta}^{(i+1)} - \hat{\theta}^{(i)}| > \delta$ otherwise stop, where δ is chosen convergence criterion.

Remark: For the two PC equations, both with a lower floor, we have to identify the lower floors using sorting procedure over two variables. If there is only one equation with lower floor the sorting procedure concerns only one variable. Similar to the model (5.33) it can then be shown that the MLE from the procedure is consistent and asymptotically efficient.

5.5 Single Equation Estimation

We use the specification of Model FF in the switching model (5.33) for the wage inflation function:

$$dw_t = \begin{cases} a_0 + a_1 dp_t + a_2 dpm_t + a_3 V_t^l + a_4 dyn_t + \rho_w dw_{t-1} + \epsilon_{1t}, & E(dw_t|X_t) > dw_0; \\ dw_0 + \epsilon_{2t}, & E(dw_t|X_t) = dw_0. \end{cases} \tag{5.50}$$

The estimation is performed over the period 1955:1 t0 2000:4. Among 184 estimation periods 166 are identified to be in the linear regime and only 18 periods are identified to be in the lower floor regime. Nevertheless, J test result shows strong indication of lower floor in the wage inflation equation. The estimation and test results are shown in the following table.

Parameter	a_0	a_1	a_2	a_3	a_4	ρ_w	dw_0
estimate	-0.15	0.36	0.59	0.16	0.18	0.14	0.008
T-statistic	-4.9	3.2	3.9	5.0	4.6	1.9	6.6

Table 5: Estimation Results of the Single Wage Inflation PC

	Statistic	P-value
J statistic	2.28	0.02
$F_{6,177}$ statistic	43.14	0.0
DW	1.98	

Table 6: Test Results of the Single Wage Inflation PC

Similarly, we can do the same for the price inflation equation:

$$dp_t = \begin{cases} b_0 + b_1 dw_t + b_2 dpm_t + b_3 V_t^c + b_4 dyn_t + \rho_w dp_{t-1} + b_5 d74 + \epsilon_{1t}, & E(dp_t|X_t) > dp_0; \\ dp_0 + \epsilon_{2t}, & E(dp_t|X_t) = dp_0. \end{cases} \tag{5.51}$$

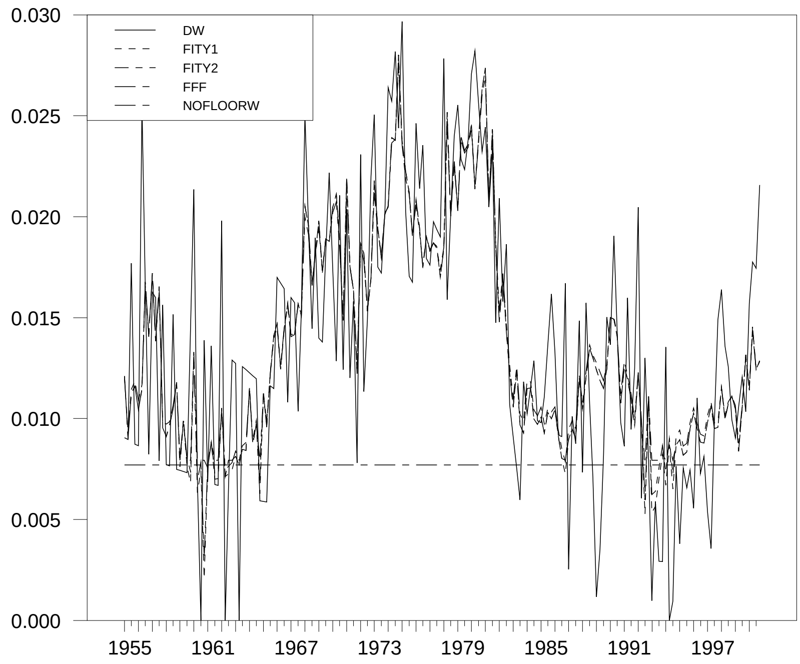


Figure 3a: Single equation estimation of the wage inflation.

Among 184 estimation periods 170 are identified to be in the linear regime and only 14 periods are identified to be in the lower floor regime. Here the lower floor of inflation is not very significant. J test statistic will not reject the null for significance level of 10 percent. The estimation and test results are as follows:

Parameter	b_0	b_1	b_2	b_3	b_4	b_5	ρ_p	dp_0
estimate	-0.02	0.13	0.69	0.03	-0.09	0.008	0.19	0.003
T-statistic	-5.1	3.1	7.2	5.1	-3.9	4.4	2.3	8.6

Table 7: Estimation Results of the Single Price Inflation PC

	Statistic	P-value
J statistic	1.75	0.08
$F(7, 176)$ statistic	129.81	0.0
DW	1.87	

Table 8: Test Results of the Single Price Inflation PC

5.6 Simultaneous Switching Equations

The above estimation results indicate that both dw_t and dp_t may depend simultaneously on each other. Consequently, the single equation estimation procedure will be inconsistent due to the existence of simultaneous biases. We have to consider dw_t and dp_t to be endogenous variables in the following switching equations system, where X_t denotes the vector of all predetermined variables.

$$dw_t = \begin{cases} a_0 + a_1 dp_t + a_2 dpm_t + a_3 V_t^l + a_4 dyn_t + \rho_w dw_{t-1} + \epsilon_{1t}, & E(dw_t|X_t) > dw_0; \\ dw_0 + \epsilon_{2t}, & E(dw_t|X_t) = dw_0. \end{cases} \tag{5.52}$$

$$dp_t = \begin{cases} b_0 + b_1 dw_t + b_2 dpm_t + b_3 V_t^c + b_4 dyn_t + \rho_w dp_{t-1} + b_5 d74 + \epsilon_{1t}, & E(dp_t|X_t) > dp_0; \\ dp_0 + \epsilon_{2t}, & E(dp_t|X_t) = dp_0. \end{cases} \tag{5.53}$$

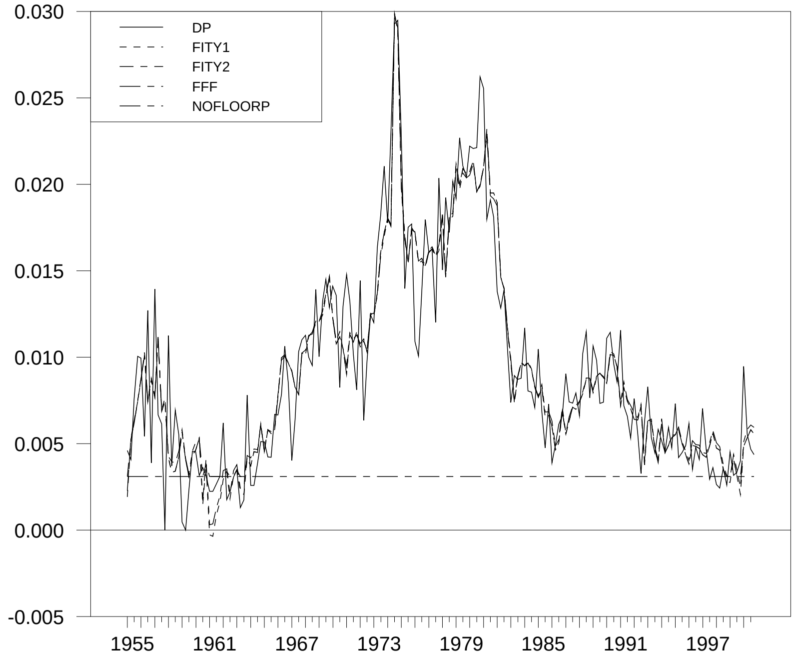


Figure 3b: Single equation estimation the price inflation.

Parameter	a_0	a_1	a_2	a_3	a_4	ρ_w	dw_0	
estimate	-0.16	0.31	0.68	0.18	0.16	0.17	0.0077	
Parameter	b_0	b_1	b_2	b_3	b_4	b_5	ρ_p	dp_0
estimate	-0.02	0.23	0.61	0.02	-0.11	0.008	0.17	0.0057

Table 9: Estimation Results of the Simultaneous PC's

	Statistic	P-value
J statistic:	Chi-Squared(2)=11.97	0.0025
DW	1.95/2.19	

Table 10: Test Results of the Simultaneous PC's

The estimation and test of lower floors in the 2D PC model provides us with the significant hint that the data will not reject the hypothesis of the existence of such lower floors. The evidence in the wage equation is however much stronger than that in the price equation. Although the existence of lower floors is significant, they exist most of the time only in a latent way. Approximately only 10 percent of the sample points are identified to be in the rigidity regime. The estimation results obtained for the linear regime confirm the results that were obtained without a consideration of the existence of the rigidity regime. Therefore, if one is not specifically interested in the property of the rigidity regime, one can take a linear specification to model the 2D PC's. If one wants to know however what lower floors may apply one can apply the switching regression model as done in this section.

6 Summary, unit wage-cost development and policy implications

We have investigated in this paper structural wage and price growth rate 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 the literature in order to allow a thorough discussion of the wage-price spiral mechanism and its implications. There are in this context two fundamentally different measures of demand pressure to be distinguished carefully, one on the labor market (a stock measure) and one on the market for goods (a flow measure), that are to be employed to the issues of wage inflation and price inflation separately. These measures may appear as determinants of wage and price inflation in principle in proportional, derivative or integral form, in certain countries and at certain times. Specifying PC's in this general format indeed allows a comparative evaluation of approaches that favor the wage level curve or the change in the wage inflation rate over the usual specification of the left hand side of the money wage Phillips curve. The general format for wage-price dynamics briefly discusses in section 3 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.[13]

With regard to cost pressure items we – by contrast – we 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 items a weighted average of the current perfectly foreseen cost pressure item (price inflation in the case of workers and wage inflation in the case of firms) and an inflationary climate item that characterizes, for example, the past last twelve quarters of the working of the economy on an average. Here we insist on myopic perfect foresight in order to show that the purely forward-looking rational expectations methodology need not be the implication of the myopic perfect foresight assumption and, moreover, that there can be enough inertia in the wage-price spiral despite the non-existence of systematic errors in the prediction of current wage and price inflation – as it is indeed suggested by empirical observations.

From the empirical perspective we found indications that separately specified and estimated wage and price PC's perform very well compared to the commonly employed reduced types of single price inflation Phillips curve approaches, characterized by the special assumptions $\beta_p = 0, \kappa_p = 1$ in view of our more general approach, which are not supported by our empirical findings. These two curves – here still of the proportional control type with respect to demand pressure items – induce a simple, yet very important real feedback chain that appears to be destabilizing in periods where economic activity is positively dependent on the real wage on the basis of our estimates. This feedback channel can be usefully compared to another related feedback chain, the real rate of interest mechanism of old and new Keynesian approaches to economic dynamics, and is indeed even richer in its stability implications than the real rate of interest channel (which concerns the interaction of the so-called Keynes with the so-called Mundell effect). Should such a mechanism really exist in some countries at some time, it must be taken account of in the formulation of monetary (and fiscal) policy, in particular in their recent formulations as so-called Taylor or interest rate policy rules. Our findings here are that demand pressure matters in specific ways both in the labor and the goods market and thereby 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.

Flaschel and Krolzig (2004) show in this regard that 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 such a Rose (1967) type 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 Rose type wage-price spirals. The analysis of this paper therefore suggests a redesign of interest rate policy rules at least for certain episodes of wage-price interactions.

The necessity to take account of a wage share gap in interest rate policy rules in addition to inflation and output gaps is further motivated by the phase plot shown in figure 4 which shows moving averages of the wage share (here measured by unit-wage costs, see the data description in section 4) on the horizontal axis and of the employment rate on the vertical axis. This figure indicates that the data may support the view of a clockwise movement of these variables in the very long run in the spirit of Rose's (1967) analysis of the employment cycle, that in certain aspects is closely related Goodwin's (1967) growth cycle model. There is no indication of asymptotic stability in this figure, but instead some sort of bounded economic dynamics that may repeat itself in the very long-run. Indeed, the graphs seems to suggest that sooner or later unit wage costs will start rising again and may then fully show the overshooting mechanism of the Goodwin (1967) growth cycle model, with a unit wage-cost rise and a rate of employment decline as it was observed for the first time in the 1970's. In our view, monetary and fiscal policy must be prepared to cope

[13]See Flaschel, Kauermann and Semmler (2004b) for a study of this topic for the US economy after World War II.

with such a renewed situation of overshooting wage shares and thus must pay attention to accelerating or decelerating wage-price spirals, adverse real wage adjustments of this paper and thus be prepared to deal with the stagflationary or depressed episodes resulting from them in the future evolution of – in this paper – the US-economy.

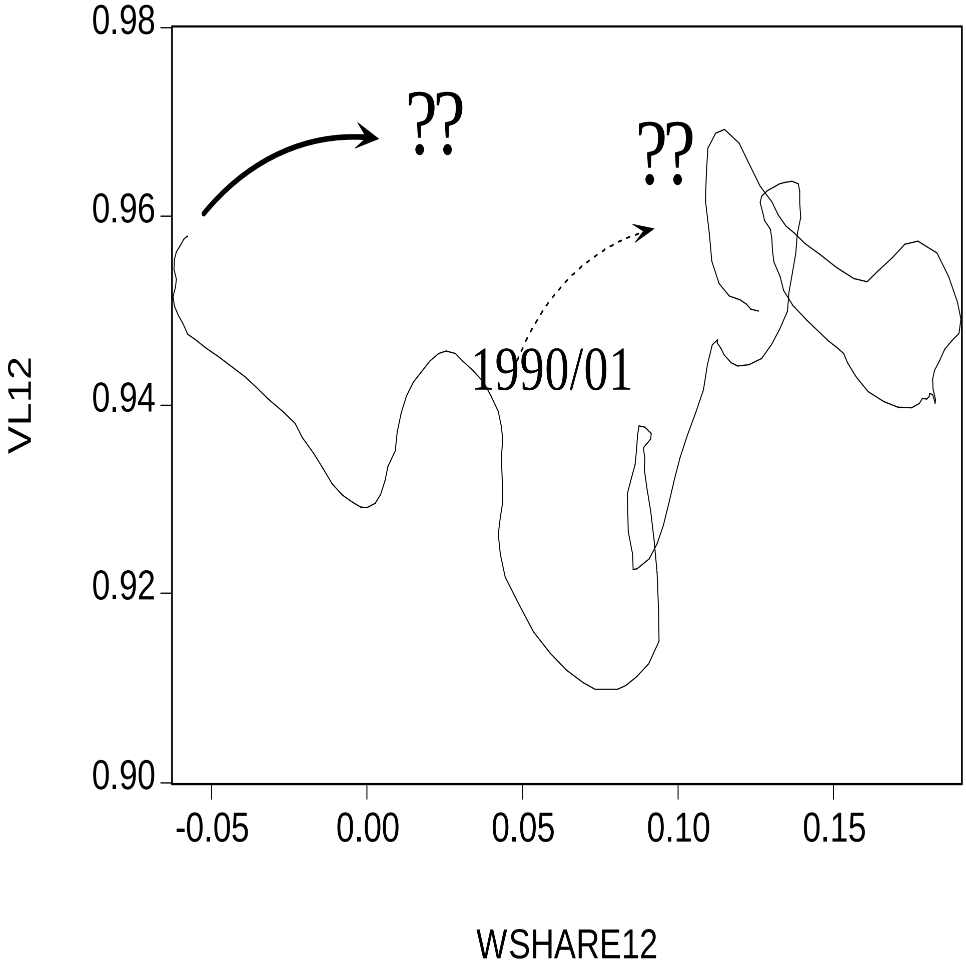


Figure 4: The dynamics of employment and income distribution

In two companion papers we will introduce, analyze and estimate a complete baseline model of wage and price inflation dynamics in a dynamic AS-AD framework and will therefore then fully approach the real wage feedback channel, which was here investigated in isolation from any theory of effective goods demand and the role of income distribution changes in such a context. In periods where effective demand responds positively to real wage changes we could however conclude from our empirical results that an adverse wage-spiral will then come into being that can lead the economy into an accelerating inflationary boom or – if not overcome by downwardly rigid wages dynamics as they studied in the preceding section – into an accelerating deflationary spiral that could even lead to economic breakdowns if, for example, a Fisherian debt deflation mechanism comes into being in addition.

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