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Three Wage-Price Macro Models and Their Calibration

by

Reiner Franke

University of Bielefeld
Department of Economics
Center for Empirical Macroeconomics
P.O. Box 100 131

33501 Bielefeld, Germany

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Reiner Franke

Faculty of Economics
University of Bielefeld
33501 Bielefeld
Germany

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Abstract

Within a business cycle context, three alternative theories of inflation are combined with an extended money wage Phillips curve and adjustments of inflationary expectations. The first approach, almost directly, amounts to countercyclical motions of the price level; the second utilizes an extended price Phillips curve; the third module formalizes adjustments of a variable markup on unit labour costs. Based on stylized oscillations of capacity utilization as the only exogenous variable, the paper studies the model-generated time paths of, in particular, the real wage and the price level. For all three model variants, the parameters can be set such that the cyclical properties come close to what is empirically observed. In a general comparison, the variable markup approach may be said to have a slight edge over the other two models.

JEL classification: E 12, E 24, E 25, E 32.

Keywords: wage-price dynamics; Phillips curve; inflation theory; variable markup rate; calibration.

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Contents

1 Introduction

Directly or indirectly, wage-price dynamics play a central role in all macroeconomic theories of the business cycle. The present paper is concerned with non-market clearing approaches to this issue, where labour and capital may be under- or overutilized and the economic variables respond with partial adjustments. Three (deterministic) submodels are put forward, with a view that they may be integrated into a broader framework of cyclical disequilibrium dynamics. The models themselves, however, as any theory, impose almost no restrictions. To have content, quantitative restrictions have to be added, that is, numerical specifications of the adjustment parameters have to be examined. Moreover, a complete macrodynamic model of which such a wage-price submodel forms part is most likely to become so complex that a purely mathematical treatment would not carry very far. A numerical analysis has therefore to be undertaken anyway.

Accordingly, after discussing the theoretical significance of the three submodels, the paper is also devoted to their calibration in a business cycle context. The aim of calibrating a model economy is to conduct (computer) experiments in which its properties are derived and compared to those of an actual economy. In this respect calibration procedures can be understood as a more elaborate version of the standard back-of-the-envelope calculations that theorists perform to judge the validity of a model. The underlying notion is that every model is known to be false. A model is not a null hypothesis to be tested, it is rather an improper or simplified approximation of the true data generating process of the actual data. Hence, a calibrator is not interested in verifying whether the model is true (the answer is already known from the outset), but in identifying which aspects of the data a false model can replicate.[1]

Our investigation of how well the wage-price models match the data follows the usual practice. We select a set of stylized facts of the business cycle, simulate each model on the computer, and assess the corresponding cyclical properties of the resulting time series in a more or less informal way. Since a (false) model is chosen on the basis of the questions it allows to ask, and not on its being realistic or being able to best mimic the data, we share the point of view that rough reproduction of simple statistics is all that is needed to evaluate the implications of a model.[2] In sum, our philosophy of setting the numerical parameters is similar to that of the real business cycle school, though the methods will be different in detail.

As it turns out, the three model variants give rise to a hierarchical structure in the calibration process. Some variables which are exogenous in one model building block are endogenous within another module at a higher level. Thus, the parameters need not all be chosen simultaneously, but fall into several subsets that can be successively determined. This handy feature makes the search for suitable parameters and the kind of compromises one has to accept more intelligible. On the other hand, the calibration hierarchies are different for each model, even with respect to those parameters that are common to all three models.

The endogenous variables whose cyclical behaviour is to be contrasted with the empirical data are labour productivity, the employment rate, the real wage rate, the wage share, and (derived from the rates of inflation) the price level. Detrending of the variables is, of course, presupposed. Besides procyclical motions of productivity and employment, we, in partic-

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[1] See also the introductory discussion in Canova and Ortega (2000, pp. 400–403).

[2] As Summers (1991, p. 145) has expressed his skepticism about decisive formal econometric tests of hypotheses, "the empirical facts of which we are most confident and which provide the most secure basis for theory are those that require the least sophisticated statistical analysis to perceive."

ular, seek to obtain a basically procyclical real wage and a countercyclical price level. A second aspect of the business cycle that has to be taken into account is the amplitude of the fluctuations, i.e., the standard deviation of the endogenous variables.

The models are driven by the motions of capacity utilization, which is the only exogenous variable. Since random shocks are neglected in the formulation of the models, these motions may well be of a regular and strictly periodic nature. Specifically, the simulation experiments underlying the calibration can be most conveniently organized if it is assumed that utilization oscillates like a sine wave. This perhaps somewhat unusual device is more carefully defended later in the paper. Nevertheless, at the end of our study we will also have to check whether the previous results of a base scenario are seriously affected if the exogenous sine wave is replaced with the more noisy time path of the empirical counterpart of the utilization variable.

At the theoretical level, the models have four building blocks in common: two simplified functional relationships concerning fixed investment (which will only have a minor bearing on the employment rate) and procyclical labour productivity; an extended nominal wage Phillips curve; and adjustments of a so-called inflation climate that enters the Phillips curve. On this basis, we advance three inflation modules. In the first one, changes in the rate of price inflation are postulated in such a way that a countercyclical price level (CCP) results almost directly by construction. The second module invokes a price Phillips curve (PPC), which is likewise somewhat more encompassing than the standard textbook versions. The third approach takes up a Kaleckian idea of a variable markup (VMK) on unit labour costs whose adjustments have a certain countercyclical element. Without going into further details, it can generally be said that, despite the conceptual as well as formal differences between the wage-price models thus defined, all three variants are similarly suited for calibration; though this does not rule out other reasons that the VMK approach may be preferred to CCP and PPC.

The remainder of the paper is organized as follows. Section 2 expounds the stylized facts of the business cycle that will be our guidelines. The building blocks around the nominal wage dynamics that are common to all three models are presented in section 3. Subsequently, section 4 introduces the three alternative inflation modules. It also works out the different levels at which the parameters can be determined in the calibration procedure. Section 5 provides an extensive discussion of the cyclical properties of the models and our strategy to arrive at a base scenario for each model. Employing these scenarios, section 6 gives an evaluation of the three model variants. Lastly, the stylized sine wave of capacity utilization is here dropped and the numerical simulation is re-run with empirical values of that variable. Section 7 concludes. An appendix makes explicit some details about the construction of the empirical data we use.

2   Stylized facts

Besides an unobservable inflation climate and capacity utilization, u, which serves as a measure of the business cycle, the wage-price models to be set up concentrate on five endogenous macroeconomic variables. These are the employment rate, e, labour productivity, z, the (productivity-deflated) real wage rate, ω, the wage share, v, and the price level, p. To see what a calibration should be aiming at, we first examine the cyclical features of their empirical proxies. (Source and construction of the empirical time series are described in the appendix.)
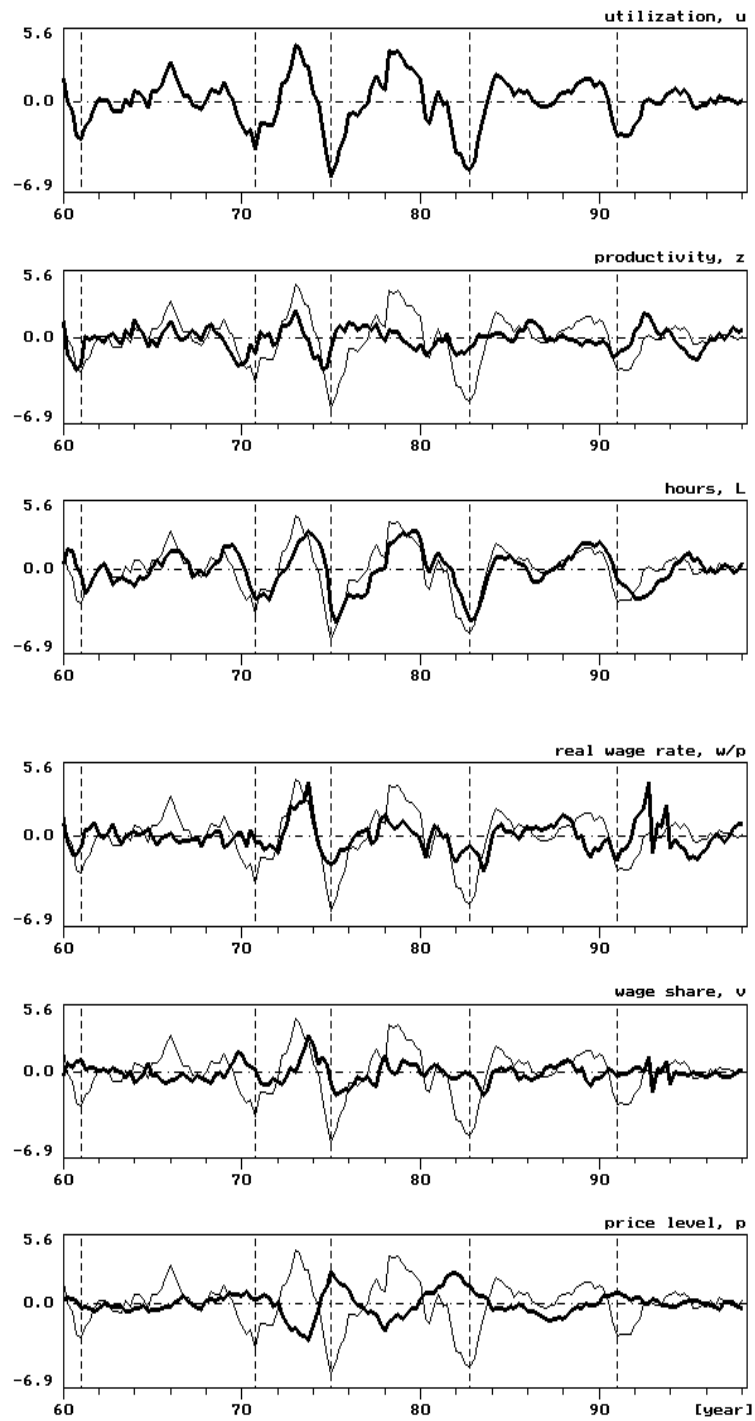
Figure 1: Cyclical components of empirical series.

Note: Deviations from trend (HP 1600) in per cent. The thin line is the cyclical component of utilization.

In modelling production, under- and overutilization of productive capacity is allowed for. The notion of capacity utilization rests on an output-capital ratio y^n that would prevail under 'normal' conditions. With respect to a given stock of fixed capital, K, productive capacity is correspondingly defined as $Y^n = y^n K$. Y being total output and y the output-capital ratio, capacity utilization is given by $u = Y/Y^n = y/y^n$. Against this theoretical background, we may take the motions of the output-capital ratio in the firm sector (nonfinancial corporate business) as the empirical counterpart of the fluctuations of u.

In the models' production technology, y^n is treated as a constant. In reality, there are some variations in y at lower than the business cycle frequencies. We therefore detrend the empirical series of y and, treating the 'normal' output-capital ratio as variable over time, set $y^n = y^n_t$ equal to the trend value of y at time t. In this way, the model's deviations from normal utilization, $u-1$, can be identified with the empirical trend deviations $(y_t - y^n_t)/y^n_t$.

To correct for the low frequency variation of y, the Hodrick-Prescott (HP) filter is adopted. Choosing a smoothing parameter $\lambda = 1600$ for the quarterly data and looking at the resulting time series plot, one may feel that the trend line nestles too closely against the actual time path of y. This phenomenon is not too surprising since the HP 1600 filter amounts to defining the business cycle by those fluctuations in the time series that have periodicity of less than eight years (cf. Rebelo and King, 1999, p. 934), whereas the US economy experienced two trough-to-trough cycles that exceed this period.[3] Other filters, such as HP with values of $\lambda = 6400$ or higher, or a segmented linear trend, correspond better to what one may draw freehand as an intuitive trend line in a diagram. However, the cyclical pattern of the trend deviations is in all cases very similar, only the amplitudes are somewhat larger. Because in the literature the HP filter employs $\lambda = 1600$ with almost no exception, we may just as well follow this conventional practice. The trend deviations of the output-capital series thus obtained, or of capacity utilization $u-1$, for that matter, are exhibited in the top panel of figure 1.

The HP 1600 filter is also applied to the other empirical series we are interested in. The fact that the trend deviations of these cyclical components might likewise appear somewhat narrow need not be of great concern to us. It will serve our purpose to express their standard deviations in terms of the standard deviation of u.

Let us begin by considering labour productivity. This variable will have to be taken into account since in the modelling framework it connects, on the one hand, the employment rate with utilization and, on the other hand, the real wage rate with the wage share. Labour productivity has since long been counted a procyclical variable. May it suffice to mention that Okun (1980, pp. 821f) lists it among his stylized facts of the business cycle. Procyclical variations of z can to some degree also be recognized in the second panel in figure 1, perhaps with a slight lead before u. The cross-correlation coefficients quantifying the comovements of z with u are given in table 1, whose sample period $1961-91$ covers four major trough-to-trough cycles. Reckoning in a lead of z between one and three quarters, these statistics

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[3]According to the NBER reference data, one is from February 1961 to November 1970, the other from November 1982 to March 1991. In recent times, the band-pass (BP) filter developed by Baxter and King (1996) has gained in popularity. On the basis of spectral analysis, this procedure is mathematically more precise about what constitutes a cyclical component. The BP(6,32) filter preserves fluctuations with periodicities between six quarters and eight years, and eliminates all other fluctuations, both the low frequency fluctuations that are associated with trend growth and the high frequencies associated with for instance measurement error. More exactly, with finite data sets the BP(6,32) filter approximates such an ideal filter. As it turns out, for the time series with relatively low noise (little high frequency variation) the outcome of the HP 1600 and the BP(6,32) filter is almost the same. For real national US output, this is exemplified in King and Rebelo (1999, p. 933, fig. 1).

indicate a stronger relationship between z and u than one might possibly infer from a visual inspection of the time series alone.[4]

Series x	σ_x/σ_u	cross correlations between u at time t and x at time						
		$t-3$	$t-2$	$t-1$	t	$t+1$	$t+2$	$t+3$
u	$--$	0.48	0.70	0.89	1.00	0.89	0.70	0.48
z	0.44	0.56	0.58	0.53	0.46	0.17	-0.06	-0.27
L	0.83	0.03	0.30	0.57	0.79	0.88	0.86	0.77
w/p	0.51	0.31	0.48	0.57	0.61	0.56	0.48	0.34
v	0.38	-0.21	-0.05	0.09	0.21	0.42	0.53	0.57
p	0.51	-0.59	-0.70	-0.73	-0.70	-0.62	-0.49	-0.32
gK	0.29	-0.06	0.20	0.48	0.72	0.84	0.86	0.80

Table 1: Descriptive statistics for cyclical components of quarterly series, 1961:1−91:4.

Note: All series detrended by Hodrick-Prescott (with smoothing factor $\lambda = 1600$). Except for gK, the cyclical components are measured in per cent of the trend values. σ denotes their standard deviation; u is the output-capital ratio, z labour productivity, L total hours, w the nominal wage, p the output price level, v the wage share, gK the capital growth rate.

To get information about the employment rate, we refer to total working hours, L. For simplicity, we directly interpret the trend line, $L^o = L^o_t$, as labour supply, i.e., as supply of normal working hours. In this view, the normal employment rate is given by $e = 1$, and the deviations from normal employment are proxied by $e_t - 1 = (L_t - L^o_t)/L^o_t \approx \ln(L_t - L^o_t)$, which is the series displayed in the third panel in figure 1. The juxtaposition with utilization in the same panel makes clear that this employment rate is markedly procyclical. The third line in table 1 details that it lags one or two quarters behind u.

The controversy surrounding the comovements of the real wage rate is usually summarized by saying that, if anything, it moves (weakly) procyclical, rather than countercyclical. Results about the cyclical properties of the real wage appear to be quite sensitive to precisely how it is constructed, depending on whether the numerator (w) includes various compensation items and on the index in the denominator (p). Since our modelling context is a one-good economy, we adopt the deflator of total output as our price level, so that w/p denotes the product real wage. On the other hand, we follow Ray Fair's procedure (see the appendix) and include a uniform 50% wage premium as a rough measure for overtime payment.

[4]Unfortunately, the statistics cannot be compared with the most recent comprehensive compilation of stylized business cycle facts by Stock and Watson (1999), since they employ real GDP as a measure of the business cycle. Over the sample period 1953−96, they report a cross-correlation coefficient as large as $\rho(z_{t-k}, \text{GDP}_t) = 0.72$ for a lead of $k = 2$. Curiously enough, we could not reproduce a similar number with the trend deviations of the GDP series taken from Ray Fair's database (see the appendix), which is due to the fact that (especially) over the subperiod 1975−82 this series is quite different from the Citibase GDP series used by Stock and Watson (statistically, it shows less first-order autocorrelation).

On the basis of this specification, figure 1 (fourth panel) shows that the real wage rate is fairly close connected to the motions of capacity utilization, while quantitative evidence for its procyclicality is given in table 1. Although this finding is in some contrast to what is reported in the literature, it should play an important role in the calibration later on.[5]

The variable that more directly describes the distribution of income between workers and capital owners is the wage share v. It is only rarely mentioned in the discussion of typical features of a business cycle. This might in part be due to the special difficulties that one encounters for this variable in separating the cyclical from some intermediate quasi-trend behaviour. The HP 1600 trend deviations depicted in the fifth panel in figure 1 may therefore be taken with some care.

Accepting them as they are, we see another explanation for the infrequent reference to the wage share: it does not exhibit a distinctive and unique cyclical pattern. Over the 1960s, v looks rather countercyclical, whereas from 1970 to 1990 it appears to be more or less procyclical. In fact, over the 1960s the highest (in modulus) correlation coefficient is negative, as large as $\rho(u_t, v_{t-1}) = -0.71$. Over the period $1970-91$ the maximal coefficient is positive; at a lag of three quarters it amounts to $\rho(u_t, v_{t+3}) = 0.67$. For this reason the cross-correlations given in table 1 over the full period $1961-91$ have to be cautiously interpreted. They do not summarize a general law of a systematic relationship between the business cycle and income distribution, but they reflect, in attenuated form, the relationship over a limited span of time. It will become clearer in the next section what is here involved.

As indicated in the introduction, we will discuss three modules to represent price inflation. Time series of inflation rates are, however, relatively noisy and so cannot be easily related to the motions of utilization with its high persistence.[6] It is therefore more convenient to study the variations of the price level directly. While prices were formerly treated as procyclical, there seems now to be general consensus that their cyclical component moves countercyclical; see, for example, Cooley and Ohanian (1991), Backus and Kehoe (1992), Fiorito and Kollintzas (1994). With respect to the price index for total output, this phenomenon is plainly visible in the bottom panel of figure 1. According to table 1, the inverse relationship between p and u is strongest at a lead of the price level by one quarter. Given the tightness of the relationship, countercyclical prices are a challenge for any theory of inflation within a business cycle context.[7]

Lastly, table 1 includes the growth rate of fixed capital, whose cyclical properties will be considered further below.

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[5]For example, King and Rebelo (1999, p. 938) obtain a contemporaneous correlation of compensation per hour with output of $\rho = 0.12$, and the coefficient for the correlation with GDP that is presented by Stock and Watson (1999, table 2) is similarly low. As regards the present data, with no overtime payment in the wage rate the contemporaneous correlation is reduced to 0.34 (and no lagged coefficients are higher), even though the correlation of the trend deviations of the two real wage time series is as high as 0.93. On the other hand, considering the issue more carefully, Barsky et al. (1994) argue that real wage indexes may fail to capture changes in the composition of employment over the cycle. They conclude that real wages are procyclical if the composition is held constant.

[6]Quarterly inflation rates have first-order serial correlation in the region of 0.35, which may be compared to the AR(1) coefficients for the trend deviations of u and p, which are 0.89 and 0.92, respectively.

[7]A discussion of the issue of countercyclical prices should make clear what in (structural and descriptive) economic theory the trend line is supposed to reflect: (a) the evolution of prices on a deterministic long-run equilibrium path around which the actual economy is continuously fluctuating, or (b) the time path of an expected price level. From the latter point of view, Smant (1998) argues that other procedures than HP detrending should be adopted and, doing this, concludes that the so specified (unexpected) price movements are clearly procyclical (p. 159). By contrast, our theoretical background is notion (a).

On the basis of the statistics in table 1, we summarize the cyclical features that one may wish a small (deterministic) macrodynamic model to generate — at least insofar as it exhibits smooth and regular oscillations. They are listed in table 2, which leaves some play in the numbers since a small model cannot be reasonably expected to match all the empirical statistics accurately. Moreover, when we state a zero lag for productivity z, then this is already due to the simplifying modelling assumption on the production technology in the next section.

variable x	σ_x/σ_u	Lag x
dev z	0.40	0.00
dev e	0.75	$0.00 - 0.75$
dev ω	$0.45 - 0.50$	$-0.50 - 0.50$
dev v	$0.30 - 0.40$	— —
$-$ dev p	$0.45 - 0.50$	$-0.75 - 0.25$

Table 2: Desirable features of macrodynamic oscillations.

Note: 'dev' means percentage deviations from trend or steady state values; e is employment rate, ω (productivity-deflated) real wage rate. The lags are measured in years.

The reason for fixing the standard deviation of z somewhat lower than the coefficient 0.44 given in table 1 is the apparently lower amplitude of z in the recent past. In fact, over the sample period $1975-91$, the ratio σ_z/σ_u falls to 0.33 (and the relationship with utilization becomes weaker). The reduction of σ_z/σ_u should carry over to the variations of employment, hence the proportionately lower value of σ_e/σ_u. We also should not be too definitive about the variation of the wage share, because the precise empirical construction of this variable and the outcome of the specific detrending mechanism may not be overly robust against alternative procedures. By the same token, it would not be appropriate to commit oneself to a particular phase shift of v. This is all the more true if the lead in labour productivity is neglected (the relationship between the wage share and productivity is made explicit in eq. (5) below). Given that $\sigma_v/\sigma_u = 0.31$ over the subperiod $1975-91$, we content ourselves with proposing the range $0.30 - 0.40$ for that ratio and leave the issue of desirable lags of v open.[8]

3 The common nominal wage dynamics

The nominal wage dynamics, which will be common for the three wage-price models here considered, is basically represented by a wage Phillips curve. It goes beyond the standard versions in that it includes the employment rate e as well as the wage share v. As is shortly made explicit, both variables are connected with capacity utilization u through average labour productivity $z = Y/L$. While we wish to account for the procyclicality of z, for a small macrodynamic model to be analytically tractable this should be done in a simplified way. We therefore neglect the lead of z in the comovements with u and postulate a direct positive

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[8]The ratios $\sigma_{w/p}/\sigma_u$ and σ_p/σ_u are more stable. For the same subperiod $1975-91$, they amount to 0.46 and 0.50, respectively.

effect of u on the percentage deviations of z from its trend value z^o.[9] Like the functional specifications to follow, we assume linearity in this relationship,

$$z/z^o \;\; = \;\; f_z(u) \; := \; 1 + \beta_{zu}\,(u-1) \tag{1}$$

β_{zu} and all other β-coefficients are nonnegative (in fact mostly positive) constants.

To deal with dynamic relationships, it is convenient to work in continuous time (where for a dynamic variable $x = x(t)$, $\dot{x}$ is its time derivative, $\hat{x}$ its growth rate; $\dot{x} = dx/dt$, $\hat{x} = \dot{x}/x$). Trend productivity is assumed to grow at an exogenous constant rate g_z,

$$\hat{z}^o \;\; = \;\; g_z \tag{2}$$

and the growth rate of actual labour productivity derives from (1) as

$$\hat{z} \;\; = \;\; g_z + \beta_{zu}\dot{u}/f_z(u) \tag{3}$$

Trend productivity also serves to deflate real wages, or to express them in efficiency units. We correspondingly define

$$\omega \;\; = \;\; w\,/\,p\,z^o \tag{4}$$

For short, ω itself may henceforth be referred to as the real wage rate. Obviously, if w/p continuously grows at g_z, the rate of technical progress, ω remains fixed over time. Since $v = wL/pY = (w/pz^o)\,(z^o L/Y) = (w/pz^o)\,(z^o/z)$, the wage share and the real wage rate are linked together by

$$v \;\; = \;\; \omega\,/\,f_z(u) \tag{5}$$

To express the employment rate by variables which in a full model would constitute some of the dynamic state variables, we decompose it as $e = L/L^s = z^o\,(L/Y)\,(Y/Y^n)\,(Y^n/K)\,(K/z^o L^s)$, where L^s is the labour supply (which in the previous section was proxied by the trend values of working hours, L^o). As indicated before, productive capacity is given by $Y^n = y^n K$ with y^n a fixed technological coefficient, and utilization is $u = Y/Y^n$. Hence, if we denote capital per head in efficiency units by k^s,

$$k^s \;\; = \;\; K\,/\,z^o L^s \tag{6}$$

the employment rate can be written as

$$e \;\; = \;\; y^n\,u\,k^s\,/\,f_z(u) \tag{7}$$

Assuming a constant growth rate, g_ℓ, for the labour supply,

$$\hat{L}^s \;\; = \;\; g_\ell \tag{8}$$

the motions of k^s are described by the differential equation

$$\dot{k}^s \;\; = \;\; k^s\,(\hat{K} - g_z - g_\ell) \tag{9}$$

We can thus turn to the adjustments of the nominal wage rate w, for which we adopt the device of a Phillips curve. As already remarked, besides the usual positive effect of the employment rate on the wage changes, we include the wage share as another variable that

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[9]Leaving aside (suitably scaled and autocorrelated) random shocks to the technology, an immediate explanation of the comovements of z and u may be overhead labour and labour hoarding.

might possibly exert some influence. A straightforward idea is that the parties in the wage bargaining process also have an eye on the general distribution of total income. At relatively low values of the wage share, workers seek to catch up to what is considered a normal, or 'fair', level, and this is to some degree taken up in the bargaining. By the same token, workers are somewhat restrained in their wage claims if v is presently above normal. Accordingly, if normal income distribution is (unanimously) characterized by a fixed value v^o, the deviations of v from v^o may have a negative impact on $\hat{w}$. It will be part of the calibration study to find out whether this additional mechanism must be active or whether it could be dispensed with, if the models are to be consistent with the stylized facts.

The feedback of e and v on $\hat{w}$ is the theoretical core of the present Phillips curve. Apart from that, the changes in the nominal wage rate are measured against the changes in prices and labour productivity. Regarding inflation, we allow for an influence of current inflation, $\hat{p}$, as well as a general "inflation climate", which is designated π; regarding labour productivity, we allow for the growth of actual productivity, $\hat{z}$, as well as trend productivity, $\hat{z}^o = g_z$. Taken together, our extended wage Phillips curve reads

$$\hat{w} \;=\; [\kappa_{wz}\hat{z} + (1-\kappa_{wz})\hat{z}^o] \;+\; [\kappa_{wp}\hat{p} + (1-\kappa_{wp})\pi] \;+\; f_w(e,v;\beta_{we},\beta_{wv}) \qquad (10)$$

$$f_w \;=\; f_w(e,v;\beta_{we},\beta_{wv}) \;:=\; \beta_{we}\,(e-1) \;-\; \beta_{wv}\,(v-v^o)/v^o \qquad (11)$$

where κ_{wz} and κ_{wp} are two weighting parameters between 0 and 1. To ease the exposition later on, the f_w-function makes explicit reference to the reaction coefficients, too. Similarly as with $\beta_{wv} = 0$, theoretical reasons or the need to simplify may require $\kappa_{wz} = 0$ (to avoid eq. (3)). Again, numerical simulations in a broader modelling context will have to reveal the cyclical implications when the 'degrees of freedom' in setting the parameters are thus constrained.

Eqs (10), (11) can also be given another and somewhat richer theoretical underpinning. Blanchard and Katz (1999) specify a wage setting model in which the tighter the labour market, the higher the level(!) of the real wage, given the workers' reservation wage. They go on to interpret the latter as depending on labour productivity and lagged wages. If we rescale their unemployment rate U such that $U = 0$ in a steady state and $U = 1-e$ with respect to the present employment rate, further invoke v^o as the wage share that would prevail on a steady state growth path, and write $\tilde{x}$ for $\ln x$, then eq. (6) in Blanchard and Katz (1999, p. 5) can be rearranged such that it reads (maintaining their coefficients):

$$\begin{aligned}\tilde{w}_t - \tilde{w}_{t-1} \;=\;& [\mu a - \mu\lambda\,\Delta\tilde{z}_t^o - (1-\mu\lambda)\tilde{v}^o] \;+\; (1-\mu\lambda)\Delta\tilde{z}_t \;+\; \mu\lambda\,\Delta\tilde{z}_t^o \\ & +\; (\tilde{p}_t^e - p_{t-1}) \;+\; \beta(e_t - 1) \;-\; (1-\mu\lambda)(\tilde{w}_{t-1} - \tilde{p}_{t-1} - \tilde{z}_{t-1} - \tilde{v}^o)\end{aligned}$$

Here the intercept in square brackets on the right-hand side can be shown to vanish, $a, \beta > 0$, and $0 \le \mu, \lambda \le 1$. Note that $\tilde{w}_t - \tilde{p}_t - \tilde{z}_t$ equals $\tilde{v}_t$, the log of the wage share. Hence, the discrete-time counterpart of eq. (10) would be compatible with the wage theory expounded by Blanchard and Katz if: $\kappa_{wz} = 1-\mu\lambda$; $\kappa_{wp} = 0$ and $\pi_t = \tilde{p}_t^e - p_{t-1}$ ($\tilde{p}_t^e$ is an expected price level to which the nominal wage rate is related in the original formulation of the wage equation, or 'wage curve'); $\beta_{we} = \beta$; $\beta_{wv} = 1-\mu\lambda$; and $(1-\mu\lambda)(\tilde{v}_{t-1} - \tilde{v}_t)$ is negligibly small.

Blanchard and Katz quote evidence from macroeconomic as well as from regional data that for the US the coefficient $1-\mu\lambda$ is close to zero. In most European countries, by contrast, $\tilde{w}_{t-1} - \tilde{p}_{t-1} - \tilde{z}_{t-1}$, which in the regression equations is usually referred to as an error correction term, comes in with a significantly negative coefficient; on average, $1-\mu\lambda$ is around 0.25.[10]

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[10]cf. also Plasmans et al. (1999, section 3). It may, however, be asked for the sensitivity of these results with respect to the measure of 'expected inflation', $\tilde{p}_t^e - p_{t-1}$, which might be possibly quite different from our concept of the inflation climate π_t.

The law of governing the variations of the inflation climate π entering (10) will also be the same across the three inflation modules. We make it a mix of two simple mechanisms. One of them, adaptive expectations, often proves destabilizing if the speed of adjustment is high enough. The other rule, regressive expectations, constitutes a negative feedback. Introducing the weight $\kappa_{\pi p}$, π^o as a 'normal' value of inflation (or the steady state value in a full model), and β_π as the general adjustment speed, we specify

$$\dot{\pi} \;\; = \;\; \beta_\pi \left[\kappa_{\pi p}(\hat{p} - \pi) \,+\, (1 - \kappa_{\pi p})(\pi^o - \pi) \right] \tag{12}$$

Though after the intellectual triumph of the rational expectations hypothesis, working with adaptive expectations has become something of a heresy, in a disequilibrium context there are a number of theoretical and empirical arguments that demonstrate that adaptive expectations make more sense than is usually attributed to them (see Flaschel et al., 1997, pp. 149–162; or more extensively, Franke, 1999). This is all the more true if π is not inflation expected for the next quarter, but if it is employed as a benchmark value in a bargaining process, alternatively to current inflation. Since, on the other hand, π should not be completely decoupled from the recent time path of inflation, it makes sense if π adjusts gradually in the direction of $\hat{p}$. The regressive mechanism in (12), by contrast, expresses a 'fundamentalist' view, in the sense that the public perceives a certain tendency of inflation to return to normal after some time.[11]

Taken on their own, both principles ($\kappa_{\pi p} = 1$ or $\kappa_{\pi p} = 0$) are of course rather mechanical. They are, however, easy to integrate into an existing macrodynamic framework and, in their combination of stabilizing and destabilizing forces, already allow for some flexibility in modelling the continuous revision of benchmark rates of inflation.

The time paths of $\pi(\cdot)$ from (12) will evidently lag behind $\hat{p}(\cdot)$. This, as such, is no reason to worry, it is even consistent with inflationary expectations themselves that are made in the real world. Here forecast errors are found to be very persistent and forecasts of inflation often appear to be biased (see, e.g., Evans and Wachtel, 1993, fig. 1 on p. 477, and pp. 481ff).

It has been mentioned in the introduction that our investigations are based on exogenous oscillations of utilization, to which we will also closely link the capital growth rate. Once the time paths $u = u(t)$ and $\hat{K} = \hat{K}(t)$ are given, the time path of the employment rate is determined as well, via (9) and (7) — independently of the rest of the economy. The only parameter here involved is β_{zu} from the hypothesis on labour productivity in eq. (1). This constitutes the first level in the hierarchy of calibration steps. We summarize:

Level 1:   employment rate e (parameter β_{zu})

$$\dot{k}^s \;\; = \;\; k^s \left(\hat{K} - g_z - g_\ell \right) \tag{9}$$

$$e \;\; = \;\; y^n \, u \, k^s \, / \, \left[1 + \beta_{zu} \, (u - 1) \right] \tag{7}$$

The evolution of the real wage and the wage share is determined at lower hierarchy levels. These, however, will differ from each other, depending on the particular inflation module applied.

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[11] The general idea that an inflation expectations mechanism, which includes past observed rates of inflation only (rather than observed increases in the money supply), may contain an adaptive and a regressive element is not new and can, for example, already been found in Mussa (1975). The specific functional form of eq. (12) is borrowed from Groth (1988, p. 254). It has since then been repeatedly applied in modern, non-orthodox macroeconomic theory; see Chiarella et al. (2000, p. 64), or Chiarella and Flaschel (2000a, p. 131; 2000b, p. 938).

4 Three alternative inflation modules

4.1 Inflation module CCP: countercyclical prices

In the first of the three submodels determining inflation and prices, we postulate counter-cyclical movements of the price level in an almost direct way. In macrodynamic models, there is of course no scope for detrending procedures. A countercyclical price level (CCP) can, however, be brought about by referring to the rate of inflation. To this end, it is not $\hat{p}$ that is to be linked to utilization, but its time rate of change, $d\hat{p}/dt$ (the second derivative of the level, so to speak). It is worth noting that this type of relation is a positive one. Since no other variable interferes, we have a second hierarchy level for determining inflation or the price level, for that matter, where only a reaction coefficient $\beta_p > 0$ enters:

CCP Level 2: price level p (parameter β_p)

$$d\hat{p}/dt \;=\; \beta_p \, (u - 1) \tag{13}$$

Incidentally, because (13) has the time path of utilization as its only input, it might also be considered a level-1 equation. We have assigned it the second level to be more in line with the discussion of the other two inflation modules.

Making $\hat{p}$ itself a dynamic state variable, an equation like (13) will also be analytically tractable in a small macro model. (13) implies that the variations of $\hat{p}(\cdot)$ lag $u(\cdot)$ a quarter of a cycle (at least if the oscillations of utilization are sufficiently regular). From this pattern one infers that the series of the induced price level moves indeed countercyclically. Owing to the simplicity of (13), there are no leads or lags in this relationship. So (13) cannot account for the finer details of table 1 in the cross correlations between u and p. On the other hand, we will have no difficulty in setting the coefficient β_p such that the resulting standard deviation of the percentage deviations of $p(\cdot)$ from a HP 1600 trend line matches a desired ratio from table 2.[12]

Theoretically, (13) may be conceived as a behavioural equation. Being aware that they live in an inflationary environment, firms see some room for adjusting their current rate of price inflation upward if utilization is above normal, while they feel some pressure to revise it downward if they have excess capacity. If this point of view does not appear convincing, (13) can be regarded as a reduced-form expression for the price adjustments of firms. The inflation module would then be given the status of a semi-structural model building block.

Given the motions $e(\cdot)$ at hierarchy level 1, and $\hat{p}(\cdot)$ at level 2, besides of course the oscillations of capacity utilization, one can next compute the time path of the inflation climate by solving the differential equation (12). Involved are here the two parameters β_π and $\kappa_{\pi p}$:

CCP Level 3: inflation climate π (parameters β_π, $\kappa_{\pi p}$)

$$\dot{\pi} \;=\; \beta_\pi \left[\kappa_{\pi p}(\hat{p} - \pi) \,+\, (1 - \kappa_{\pi p})(\pi^o - \pi) \right] \tag{12}$$

Subsequently, the time paths of the real wage rate is obtained by differentiating (4) with

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[12] A discrete-time version of (13), by the way, has been empirically tested with success by Gittings (1989).

respect to time, $\hat{\omega} = \hat{w} - \hat{p} - \hat{z}^o$, and using (10) together with (2), (3), (5). This constitutes the fourth level:

CCP Level 4:   real wage ω, wage share v (parameters κ_{wz}, κ_{wp}, β_{we}, β_{wv})

$$\dot{\omega} \;=\; \omega\left[\,\kappa_{wz}(\hat{z} - g_z) \;-\; (1 - \kappa_{wp})(\hat{p} - \pi) \;+\; f_w(e, v; \beta_{we}, \beta_{wv})\,\right] \qquad (14)$$

$$v \;=\; \omega\,/\,f_z(u) \qquad (5)$$

$$\hat{z} \;=\; g_z \;+\; \beta_{zu}\dot{u}/f_z(u) \qquad (3)$$

As hinted at before, many models may not wish to include eq. (3) because the time derivative of u would cause too many complications.

4.2   Inflation module PPC: a price Phillips curve

Despite its — by construction — pleasant property of a countercyclical price level, eq. (13) may not be reckoned fully satisfactory from a theoretical point of view, since it somewhat lacks in structure. An immediate alternative with its long tradition in economic theory is a Phillips curve governing the rate of price inflation. Besides its great flexibility, the concept of a price Phillips curve (PPC) may in the present context be particularly appealing, because it puts nominal wage and price adjustments on an equal footing.[13]

The core of the price Phillips curve we put forward includes a demand-pull and a cost-push argument. We specify them by the adjustment function

$$f_p \;=\; f_p(u, v; \beta_{pu}, \beta_{pv}) \;:=\; \beta_{pu}(u - 1) \;+\; \beta_{pv}[(1 + \mu^o)v - 1] \qquad (15)$$

As our framework allows for under- and overutilization of capacity, u can also be seen as representing the pressure of demand. So, the term $\beta_{pu}(u - 1)$ signifies a demand-pull term. The other component, $\beta_{pv}[(1 + \mu^o)v - 1]$, is a cost-push term proper, by which we mean that it goes beyond taking the present inflationary situation into account (this aspect is considered in a moment). In detail, μ^o is devised as a target markup rate over unit labour cost. Accordingly, prices tend to rise (more than what is captured by the other terms) if labour costs are so high that, at current prices, $p < (1 + \mu^o)wL/Y$, which is equivalent to $0 < (1 + \mu^o)wL/pY - 1 = (1 + \mu^o)v - 1$. For the numerical simulations, we will assume that the target markup is consistent with the normal level v^o of the wage share in eq. (11), i.e., $(1 + \mu^o)v^o = 1$.

Since including the wage share in a (price) Phillips curve is still somewhat unusual, it may be mentioned that a positive impact of v on $\hat{p}$ has nevertheless already a certain indirect empirical support. Thus, Brayton et al. (1999, pp. 22–27) find that adding the markup $\tilde{\mu}$ of prices over trend unit labour costs (ULC) to the other explanatory variables is significant in all versions of their estimations. This is to say that when the price level is high relative to trend ULC, downward pressure is exerted on inflation. To relate this effect to our setting, observe that trend ULC are w/z^o and that the markup $\tilde{\mu}$ over this expression is given by the equation $p = (1 + \tilde{\mu})w/z^o$. Accordingly, p is high relative to trend ULC and impacts negatively on the rate of inflation if $\tilde{\mu}$ or, equivalently, $p/(w/z^o)$ is high. Using the relationship

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[13]Another argument is that, more or less easy to recognize, price Phillips curves are at the theoretical core of a variety of macroeconometric models; for this and the general flexibility of the Phillips curve concept, see the discussion in Chiarella et al. (2000, pp. 52ff).

$p/(w/z^o) = 1/\omega = 1/v f_z(u)$ (the latter inequality by virtue of (5)), the empirical results are therefore seen to imply that a *ceteris paribus* increase in the wage share has a positive effect on $\hat{p}$, just as this is stated in eq. (15).

Let us then return to the present Phillips curve. Regarding the influence of the inflationary tendencies in the economy, firms employ as their benchmark a weighted average of wage inflation $\hat{w}$ and the inflation climate π. Wage inflation has to be corrected for technical progress. Here the same mix of the growth rates of actual and trend productivity is used as in eq. (10). The price Phillips curve thus reads,

$$\hat{p} \;=\; \kappa_{pw} \left\{ \hat{w} - [\kappa_{wz}\hat{z} + (1-\kappa_{wz})\hat{z}^o] \right\} \;+\; (1-\kappa_{pw})\,\pi \;+\; f_p(u,v;\beta_{pu},\beta_{pv}) \qquad (16)$$

(of course, $0 \le \kappa_{pw} \le 1$).

Since in (10) and (16), $\hat{w}$ and $\hat{p}$ are mutually dependent on each other, in the next step the two equations have to be solved for $\hat{w}$ and $\hat{p}$. This yields the following reduced-form expressions for wage and price inflation, where it is presupposed that the weights κ_{pw} and κ_{wp} are not both unity. Obviously, wage inflation depends on the core terms in the price Phillips curve, and price inflation on the core terms in the wage Phillips curve:

$$\hat{w} \;=\; \kappa_{wz}\hat{z} + (1-\kappa_{wz})\hat{z}^o \;+\; \pi \;+\; \kappa\left[\kappa_{wp}f_p(u,v) + f_w(e,v)\right] \qquad (17)$$

$$\hat{p} \;=\; \pi \;+\; \kappa\left[f_p(u,v) + \kappa_{pw}f_w(e,v)\right] \qquad (18)$$

$$\kappa \;=\; 1/(1 - \kappa_{pw}\kappa_{wp}) \qquad (19)$$

It is then seen that in the growth rate of the real wage, $\hat{\omega} = \hat{w} - \hat{p} - \hat{z}^o$, the inflation climate π cancels out. The income distribution dynamics is therefore determined at a higher level than in the CCP module. Its independence from inflationary expectations may be considered another attractive feature of the PPC approach. On the other hand, in general seven parameters are entering at this level:

PPC Level 2: real wage ω, wage share v $(\kappa_{pw}, \kappa_{wp}, \kappa_{wz}, \beta_{pu}, \beta_{pv}, \beta_{we}, \beta_{wv})$

$$\dot{\omega} \;=\; \omega\left\{ \kappa_{wz}(\hat{z}-g_z) + \kappa\left[(1-\kappa_{pw})f_w(e,v;\beta_{we},\beta_{wv}) - (1-\kappa_{wp})f_p(u,v;\beta_{pu},\beta_{pv})\right] \right\} \quad (20)$$

$$v \;=\; \omega / f_z(u) \qquad (5)$$

$$\hat{z} \;=\; g_z + \beta_{zu}\dot{u}/f_z(u) \qquad (3)$$

$$\kappa \;=\; 1/(1 - \kappa_{pw}\kappa_{wp}) \qquad (19)$$

Also, the relationship between $\hat{p}$ and π is different from that in the CCP module. While there the computation of the time path of $\pi(\cdot)$ requires the computation of the time path of $\hat{p}(\cdot)$, it is here the other way round. The time paths of $\omega(\cdot)$ and $v(\cdot)$ being computed at level 2, eq. (18) can be plugged in the dynamic equation (12) for the adjustments of π. Subsequently, the solution of $\pi(\cdot)$ can be used in (18) to get the time path of the inflation rate. Apart from the two parameters β_π, $\kappa_{\pi p}$, all parameters have already been set at level 2. We summarize these operations in one step:

PPC Level 3: price inflation $\hat{p}$, inflation climate π (parameters β_π, $\kappa_{\pi p}$)

$$\dot{\pi} \;=\; \beta_\pi\left[\kappa_{\pi p}(\hat{p} - \pi) + (1-\kappa_{\pi p})(\pi^o - \pi)\right] \qquad (12)$$

$$\hat{p} \;=\; \pi \;+\; \kappa\left[f_p(u,v) + \kappa_{pw}f_w(e,v)\right] \qquad (18)$$

4.3 Inflation module VMK: a variable markup

The third approach seeks to translate a Kaleckian line of reasoning on a variable markup (VMK) into formal language, where the adjustments are basically of a countercyclical nature. The markup rate μ applies to unit labour costs and gives rise to the price level

$$p \quad = \quad (1 + \mu)\, wL\, /\, Y \tag{21}$$

μ is a dynamic variable that is assumed to respond negatively to utilization and its own level. It is convenient to use a growth rate formulation, so that we have

$$\dot{\mu} \quad = \quad (1+\mu)\, f_\mu(u, \mu; \beta_{\mu u}, \beta_{\mu\mu}) \quad := \quad (1+\mu)\, [-\beta_{\mu u}(u-1) - \beta_{\mu\mu}(\mu - \mu^o)/\mu^o] \tag{22}$$

The gradual adjustments of μ toward μ^o expresses the notion of a target markup. The central issue, however, is the negative impact of capacity utilization. Kalecki observes that in a recession overheads are increasing in relation to prime costs, and then goes on to argue: "there will necessarily follow a 'squeeze of profits', unless the ratio of proceeds to prime costs is permitted to rise. As a result, there may arise a tacit agreement among firms of an industry to 'protect' profits and consequently to increase prices in relation to prime costs" (Kalecki, 1943, p. 50). Another reason for the reluctance of firms to reduce prices is their fear to unchain cut-throat competition (Kalecki, 1939, p. 54), whereas the danger of new competitors will appear much lower in a recession. As for the opposite phase of the business cycle, Kalecki states that this "tendency for the degree of monopoly [which corresponds to the present markup rate μ] to rise in a slump ... is reversed in the boom" (1943, p. 51). An argument here may be to deter new entry into the industry.[14]

Eq. (21) connects the markup factor with the wage share. Solving it for v, and subsequently solving (5) (which relates the wage share to the real wage) for ω, it turns out that the income distribution dynamics is already fully determined by the markup variations in (22). Remarkably, the wage Phillips curve has no role to play at that stage. Taken together, level 2 of the VMK model variant is described by:

VMK Level 2:   real wage ω, wage share v (parameters $\beta_{\mu u}$, $\beta_{\mu\mu}$)

$$\dot{\mu} \quad = \quad (1+\mu)\, f_\mu(u, \mu; \beta_{\mu u}, \beta_{\mu\mu}) \tag{22}$$
$$v \quad = \quad 1\, /\, (1+\mu) \tag{23}$$
$$\omega \quad = \quad f_z(u)\, /\, (1+\mu) \tag{24}$$

The wage Phillips curve contributes to the price inflation dynamics. Similarly as before, the target wage share v^o in (11) should be supposed to be consistent with the target markup μ^o in (22), $v^o = 1/(1+\mu^o)$. Writing (21) as $p = (1+\mu)w/z$, the rate of inflation is obtained from logarithmic differentiation, $\hat{p} = \dot{\mu}/(1+\mu) + \hat{w} - \hat{z}$. Plugging in (22), (10) and (2), and ruling out a unit weight κ_{wp} for current inflation in the wage Phillips curve, the motions of $\hat{p}$ and π are computed at level 3 as follows:

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[14]See also the discussion in Steindl (1976, p. 17). Kalecki himself undertook an elementary empirical analysis, where the Polish and American time series he examined showed weak support of his theory (Kalecki, 1939, p. 71; 1943, p. 57). Without the target markup, eq. (22) has been introduced in macroeconomic theory by Lance Taylor; see, e.g., Taylor (1989, p. 7). For a small macrodynamic model of the business cycle that integrates (22), see also Flaschel at al. (1997, ch. 11).

> *VMK Level 3:*   price inflation $\hat{p}$, inflation climate π (β_π, $\kappa_{\pi p}$, κ_{wp}, κ_{wz}, β_{we}, β_{wv})
>
> $$\dot{\pi} \;=\; \beta_\pi \left[\kappa_{\pi p}(\hat{p} - \pi) \,+\, (1-\kappa_{\pi p})(\pi^o - \pi) \right] \tag{12}$$
>
> $$\hat{p} \;=\; \pi \,+\, \frac{1}{1-\kappa_{wp}} \left[-\,(1-\kappa_{wz})(\hat{z} - g_z) + f_\mu(u, \mu) + f_w(e, v; \beta_{we}, \beta_{wv}) \right] \tag{25}$$
>
> $$\hat{z} \;=\; g_z \,+\, \beta_{zu}\dot{u}/f_z(u) \tag{3}$$

Notice that the resulting hierarchy is the same as in the PPC approach: ω and v are determined at level 2, π and $\hat{p}$ at level 3. However, the number of parameters entering at these levels is very different: in the PPC approach, there are seven (additional) coefficients at level 2 and two at level 3; in the present VMK approach, level 2 is based on just two parameters, while six are required at level 3.

It is also worth mentioning that in a full macroeconomic model, certainly $\kappa_{wz} = 1$ would be desirable in (25). In contrast, the polar case $\kappa_{wz} = 0$ would be preferred in the other two modules; see eqs (14) and (20), respectively.

5   Calibration of the wage-price dynamics

5.1   The exogenous oscillations

As indicated by table 2, among the endogenous variables in the three model variants, we are interested in the cyclical features of five variables: z, e, ω, v and p. Their time paths are fully determined by the variations of utilization u and the capital growth rate $\hat{K}$. The influence of u is apparent at various places. By virtue of (9), $\hat{K}$ governs the evolution of k^s, which in turn enters eq. (7) for e. For both u and $\hat{K}$, we will assume regular oscillations, which may take the convenient form of a sine wave.

Sine waves would be the outcome in a linear deterministic model, but such undamped and persistent oscillations will there only occur by a fluke. Self-sustained cyclical behaviour in a deterministic modelling framework will accordingly be typically nonlinear, so that even if the solution paths were quite regular, they would still be more or less distinct from a sine wave motion. Unfortunately, we have no clue in what form these nonlinearities may be taken into account. Any proposal in this direction would have to introduce additional hypotheses, for which presently no solid indications exist. Note that the detrended empirical time series in figure 1 do not seem to exhibit any systematic asymmetries, a visual impression which is largely confirmed by the literature.[15] At least the symmetry in the sine waves would therefore be no counter-argument.

It may, on the other hand, be argued that the exogenous variables be driven by a random process. An obvious problem with this device is that our modelling approach has not intended to mimic the random properties of the time series under study. As a consequence, the three model versions could not be evaluated statistically, unless they were augmented by some random variables (cf. Gregory and Smith, 1993, p. 716). Similar as with the nonlinearities just mentioned, however, there are no clear options for such stochastic extensions. Thus, a stochastic fluctuations method would here be no less arbitrary than the deterministic sine

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[15]A standard reference is DeLong and Summers (1986). For a more sophisticated appproach, see Razzak (2001).

wave method.[16]

There is also another pointwhy random perturbations cannot be readily introduced into the present deterministic framework. It relates to the fact that the exogenous sine waves bring about (approximately) symmetrical oscillations of the endogenous variables around the steady state values, provided the initial conditions are suitably chosen. This phenomenon is more important than it might seem at first sight, because it allows us to maintain π^o, v^o, μ^o as constant benchmark values in the adjustment functions (11), (12), (15), (22). By contrast, in a stochastic setting there may easily arise asymmetric fluctuations in the medium term, especially if, realistically, the exogenous random process has a near-unit root. The asymmetry that over a longer time horizon u, for example, would be more above than below unity would lead to systematic distortions in the adjustment mechanisms. The distortions may be even so strong that they prompt the question if the adjustment rules still continue to make economic sense.[17]

Our methodological standpoint, therefore, is that in lack of a superior alternative, sine wave motions of the exogenous variables are a reasonable starting point to begin with. At the end of our investigations, we will nevertheless also have a first look at a special 'random' series of the exogenous variables: in selected parameter scenarios we will replace the sine wave of utilization with the empirical trend deviations over the sample period underlying the stylized facts of table 1.

After these introductory methodological remarks, we can turn to the numerical details of the sine wave oscillations. As the US economy went through four cycles between 1961 and 1991, and another cycle seems to have expanded over roughly the last ten years, we base our investigations on a cycle period of eight years. For utilization, we furthermore assume an amplitude of ±4%, so that we have

$$u(t) \quad = \quad 1 + 0.04 \cdot \sin(\phi t) \;, \qquad \phi = 2\pi/8 \qquad (26)$$

The amplitude amounts to a standard deviation of $u(\cdot)$ over a full cycle of 2.84%, while the corresponding empirical value is 2.05%. We opt for the higher amplitude because of our feeling expressed in section 2, that the HP 1600 trend line of the empirical output-capital ratio absorbs too much medium frequency variation. The choice of the amplitude is, however, only for concreteness and has no consequences for setting the parameters since the amplitudes, or standard deviations, of the endogenous variables will always be related to that of utilization.

In contrast, it should be pointed out that for some variables the cycle period (i.e. the parameter ϕ) does matter. It obviously makes a difference for the amplitude whether, with respect to a fixed adjustment coefficient and thus similar rates of change per unit of time, a variable increases for 24 months or only for, say, 18 months.

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[16]To underline that stochastic simulations are no easy way out, we may quote from a short contribution to an econometric symposium: "Most econometricians are so used to dealing with stochastic models that they are rarely aware of the limitations of this approach", a main point being that "all stochastic assumptions, such as assumptions on the stochastic structure of the noise terms, are not innocent at all, in particular if there is no a priori reasoning for their justification" (Deistler, 2001, p. 72). More specifically, regarding a random shock term in a price Phillips curve, which (especially in the context of monetary policy) may possibly have grave consequences for the properties of a stochastic model, McCallum (2001, pp. 5f) emphasizes that its existence and nature is an unresolved issue, even when it is only treated as white noise.

[17]To avoid dubious adjustments in these circumstances, the benchmark values might themselves be specified as (slowly) adjusting variables, similar as, for example, a time-varying NAIRU in empirical Phillips curve estimations. While this device may be appealing, it would add further components — and parameters — to the model.

Regarding the motions of the capital growth rate, we see in table 1 that it lags utilization by one or two quarters. In economic theory, this delay is usually ascribed to an implementation lag, according to which investment decisions respond quite directly to utilization or similarly fluctuating variables, but it takes some time until the investment projects are completely carried out and the plant and equipment has been actually built up. For simplicity, most macro models neglect the implementation lag, so that utilization and the capital growth rate tend to move in line (though this will have to be an endogenous feature of any particular model). For this reason, we assume that $\hat{K}$ is perfectly synchronized with u. According to the ratio of the two standard deviations reported in table 1, the amplitude of $\hat{K}$ is a fraction of 0.29 of the 4% in (26). Thus, denoting the level around which $\hat{K}$ oscillates by g^o,

$$\hat{K}(t) \;=\; g^o \;+\; 0.29 \cdot [u(t) - 1] \tag{27}$$

g^o has the status of a long-run equilibrium growth rate. By a most elementary growth accounting identity, it is given by adding up the (constant) growth rate of labour supply, g_ℓ, and the productivity trend rate of growth, g_z. Numerically, we specify,

$$g_z \;=\; 0.02\,, \qquad g_\ell \;=\; 0.01\,, \qquad g^o \;=\; g_z + g_\ell \tag{28}$$

5.2 Productivity and employment

The highest level of our hierarchy, eqs (9) and (7), determines the evolution of the employment rate. The only parameter entering here is β_{zu}, which indicates the percentage increase in labour productivity when capacity utilization rises by one per cent. Settling on β_{zu} is tantamount to settling on the ratio of the standard deviations σ_z and σ_u of the oscillations of the two variables. In laying out the desirable features of a model calibration in table 2 above, we have already decided on a definite value in this respect. We therefore set

$$\beta_{zu} \;=\; 0.40 \tag{29}$$

$e^o = 1$ is what in a full model would constitute the long-run equilibrium value of the employment rate. The corresponding level of capital per head is $(k^s)^o = e^o/y^n = 1/y^n$; cf. eq. (7).[18] By virtue of $g^o - g_z - g_\ell = 0$ from (28), the variations of k^s resulting from (9) are stationary, so that a suitable choice of the initial value of k^s at $t=0$ can make the oscillations symmetrical around $(k^s)^o$. Owing to the nonlinearity in (7), the induced oscillations of the employment rate are only approximately symmetrical around e^o; the precise value of the time average of $e(\cdot)$ over a cycle is 0.9998 .

As it turns out, the amplitude of the employment rate is lower than desired. The relative standard deviation is $\sigma_e/\sigma_u = 0.69$, while in table 2 we aspired to a ratio 0.75. Regarding the second cyclical characteristic, the motions of e exhibit a lag of three quarters behind utilization; this is just at the upper end of the range given in table 2.

There are three reasons why these statistics do not accurately match the target values put forward in table 2: the hypothesis that labour productivity is directly a function of utilization; the neglect of any lead or lag in this relationship; and the assumption that the variations of the capital growth rate are strictly synchronous with u. For a wider perspective, let us relax the latter two assumptions for a moment and introduce a lead τ_z for productivity in eq. (1), and a lag τ_k for the capital growth rate in eq. (27):

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[18]Concretely, we use $y^n = 0.70$, but this value does not affect the results in any way.

$$z(t)/z^o(t) \quad = \quad 1 \; + \; \beta_{zu} \, [\, u(t+\tau_z) - 1 \,]\tag{1a}$$

$$\hat{K}(t) \quad = \quad g^o \; + \; 0.29 \cdot [\, u(t-\tau_k) - 1 \,]\tag{27a}$$

These relationships, especially (1a), are by no means supposed to be a theoretical contribution, they only serve exploratory purposes.

In the light of the empirical cross correlations in table 1, consider $\tau_z = 0.62$ and $\tau_k = 0.37$. Table 3 summarizes the impact of these modifications on the cyclical properties of employment in eqs (9) and (7).[19] It is thus seen that the lag τ_k in the capital growth rate reduces the amplitude in the oscillations of e, whereas the lead τ_z in productivity increases it appreciably. Combining the two effects, a standard deviation σ_e results that is just what we were aiming at. On the other hand, the lag of e seems to become unduly long in this way. The last row in table 3 especially reveals the merits and demerits of the approach of eq. (1) to labour productivity.

τ_k	τ_z	σ_e/σ_u	Lag e
0.00	0.00	0.69	0.75
0.37	0.00	0.60	0.83
0.00	0.62	0.84	0.92
0.37	0.62	0.75	1.08

Table 3: Cyclical properties of the employment rate.

Note: τ_k and τ_z are the time delays in eqs (1a) and (27a). The lags are measured in years.

In the remainder of the paper, we again disregard the time delays τ_k and τ_z and proceed to work with eqs (1) and (27) as convenient modelling simplifications. We accept the coefficient β_{zu} in (29) together with the three-quarter lag in employment and the standard deviation $\sigma_e/\sigma_u = 0.69$. Even if the latter ratio is considered too low, this is just a matter of scale and does not seriously affect the calibration of the other model components. Notice to this end that e only enters the wage Phillips curve in eqs (10), (11). Since its influence there is linear, a possible downward bias in the variability of $e(\cdot)$ can be readily compensated by a correspondingly higher value of the coefficient β_{we} in the function f_w.[20]

5.3   The model with inflation module CCP

The CCP model variant has the advantage that, accepting a price level that moves strictly countercyclically, the amplitude of the price oscillations is directly determined by eq. (13) at the hierarchy level 2. By the same token, with the parameter β_p in this adjustment equation for the rate of inflation, one has full control over the standard deviation σ_p.

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[19] In the simulations the differential equations are approximated by their discrete-time analogues with an adjustment period of one month. Correspondingly, the lags reported from table 3 onwards can only be measured on a monthly basis.

[20]More precisely, the issue is the following. Suppose, for the sake of the argument, the Phillips curve (10), (11) is a correct description of the nominal wage adjustments and the parameter β_{we} is correctly estimated. Then, within the present theoretical framework, we would increase this coefficient by a factor 0.75/0.69 to make good for the lower amplitude of the employment rate.

In detail, we solve (13) for the rate of inflation, which gives us a monthly series in the simulations (cf. footnote 19), reconstruct from it the time path of the log of the price level, extract a quarterly series, detrend it by Hodrick-Prescott with $\lambda = 1600$, and interpolate these trend deviations to get the same number of monthly data points as we have available for $u(\cdot)$. It is the standard deviation of the thus resulting time series to which we refer and that we designate σ_p. By virtue of the smoothness of the time paths, interpolation is here no problem. Also, differences between the standard deviations of the monthly and the quarterly series are negligible.

It should be remarked that the HP 1600 trend is not a straight line, so that these trend deviations are different from the theoretically appropriate expressions $\ln p(t) - \ln p^o(t)$, where $\ln p^o(t) = \pi^o t + \text{const.}$ are the steady state equilibrium prices that would rise at the constant equilibrium rate of inflation π^o. While, with the sine wave in (26), one can analytically work out that the ratio of the standard deviation of the time path $\ln p(t) - \ln p^o(t)$ to that of $u(t)$ is given by $\beta_p/\phi^2 = \beta_p \cdot 1.621$, the present ratio σ_p/σ_u, which is based on the HP 1600 filter, is smaller.[21] Numerically, the latter relationship comes out as $\sigma_p/\sigma_u \approx \beta_p \cdot 1.10$.

In calibrating the price level, we wish to obtain a ratio $\sigma_p/\sigma_u = 0.50$. This is accomplished by setting

$$\beta_p = 0.45 \tag{30}$$

In order to limit the number of free parameters, we take an *a priori* decision about the adjustments of the inflation climate π at CCP level 3. Given the benchmark character of π, which is *not* just expected inflation for the next quarter, the adjustments toward current inflation should not be too fast. Likewise, agents will not expect inflation to return to normal too quickly. We therefore choose a moderate size of the adjustment speed β_π in eq. (12). As for the role of adaptive and regressive expectations, let us assume equal weights. Correspondingly, if not otherwise stated, for the following investigations we posit

$$\beta_\pi = 1.00 \qquad \kappa_{\pi p} = 0.50 \tag{31}$$

Similar motions of π, by the way, can also be generated by quite different parameter combinations of β_π and $\kappa_{\pi p}$. A more ambitious study could proxy π by empirical inflation forecasts, the Livingston survey of professional forecasters or the Survey Research Center survey of individuals from a random population sample, for example, and try to obtain estimates of β_π and $\kappa_{\pi p}$ on this basis. The ensuing calibration of the model components could then proceed along the same lines as with eq. (31).

Employing (30) and (31), the problem now is whether the countercyclical motions of the price level are compatible with the cyclical properties of the real wage and the wage share at which we aimed in table 2. At CCP level 4, there are still four parameters to achieve this goal: κ_{wp}, κ_{wz}, β_{we}, β_{wv}. After some explorations, we take a first step and lay a grid of 6825 points over this parameter space, run a simulation for each quadruple, and after each simulation compute the statistics we are concerned with. For κ_{wp} and κ_{wz} the five values 0.00, 0.25, 0.50, 0.75, 1.00 are considered; for β_{we}, 21 equally spaced values between 0.200 and 0.700 (stepsize 0.025); for β_{wv}, 13 equally spaced values between 0.000 and 1.500 (stepsize 0.125). The most important result of this grid search is a negative one, namely, not all desirable features can be simultaneously realized.

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[21] The simulated log series of the price level may be viewed as arising from a first-order integrated process. On the other hand, it is well-known that the HP filter is an optimal signal extractor for univariate time series x_t in an uncorrelated components model which implies that x_t would be an I(2) process. Hence, by construction, the HP filter removes too much as trend from the price series.

To see the nature of the hindrance, assign highest priority to the amplitude of the real wage rate, demanding $0.45 \leq \sigma_\omega/\sigma_u \leq 0.50$. Generally it may then be said that if this range is met, either the lag of the real wage is too long, or the amplitude of the wage share is too low. A shorter lag of ω is accompanied by lower standard deviations σ_v, and higher values of σ_v are accompanied by longer lags of ω. To give a few examples, lag $\omega \leq 0.50$ admits no higher ratio σ_v/σ_u than 0.203 (over the entire grid, there are just three parameter combinations with lag $\omega = 0.50$ and $\sigma_v/\sigma_u \geq 0.200$). Increasing the delay, lag $\omega = 0.75$ admits no higher ratio σ_v/σ_u than 0.284 (there being just five parameter combinations with lag $\omega = 0.75$ and $\sigma_v/\sigma_u \geq 0.275$). Likewise, $\sigma_v/\sigma_u \geq 0.300$ requires lag $\omega \geq 0.83$ (with lag $\omega = 0.83$, there are three combinations entailing $\sigma_v/\sigma_u = 0.300, 0.300, 0.304$, respectively), while $\sigma_v/\sigma_u \geq 0.350$ even requires the real wage rate to lag utilization by at least one year.

Following these results, we have to lower our sights. To proceed with our work, we put up a set of 'second-best' criteria that the model should satisfy. They are collected in table 4, where with respect to the employment rate the discussion in the previous subsection is already taken into account. Regarding the other endogenous variables, in comparison with the desired features in table 2 we here admit a longer lag for the real wage, and a lower standard deviation for the wage share. Parameter combinations giving rise to the features in table 4 may be called *admissible*.

variable x	σ_x/σ_u	lag x
dev z	0.40	0.00
dev e	0.69	0.75
dev ω	$0.45 - 0.50$	$-0.50 - 0.75$
dev v	$0.25 - 0.40$	$-\ -$
$-$ dev p	$0.45 - 0.50$	$-0.75 - 0.25$

Table 4: Second-best criteria for the macrodynamic oscillations.

Knowing that admissible parameter combinations exist, let us turn to some numerical details concerning the level-4 coefficients κ_{wp}, κ_{wz}, β_{we}, β_{wv}. Three questions are of particular interest: (1) Given that a positive weight κ_{wz} in eq. (14) would make the growth rate of actual labour productivity and, thus, the time derivative of utilization enter the model's reduced-form equations, which certainly will impede a mathematical analysis, do admissible combinations with $\kappa_{wz} = 0$ exist? (2) Since wage Phillips curves usually do not make reference to the wage share, do combinations with $\beta_{wv} = 0$ exist? (3) Are the values of the core coefficient of the wage Phillips curve, β_{we}, within a familiar range, say, $0.30 \leq \beta_{we} \leq 0.50$? Information about these points is illustrated in figure 2.

The '+' symbol in figure 2 records the (β_{we}, β_{wv}) component of admissible parameter combinations that are obtained from the grid search just mentioned. While the answer to question (3) is in the affirmative, the coefficient β_{wv} may be low, but is still bounded away from zero. Hence, for the condition $\beta_{wv} = 0$ to be fulfilled, the coefficients β_π and/or $\kappa_{\pi p}$ have to be chosen more skillfully. This issue is taken up shortly.

To deal with point (1), we fix $\kappa_{wz} = 0$ and set up a finer grid of the other three coefficients κ_{wp}, β_{we}, β_{wv}. On the basis of this battery of simulation runs, we can conclude that for
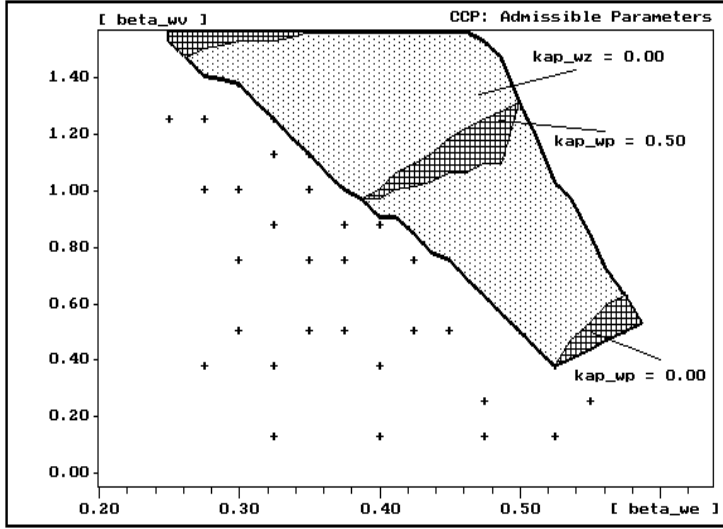
Figure 2: Admissible pairs (β_{we}, β_{wv}) under CCP.

Note: Pairs (β_{we}, β_{wv}) in dotted area match second-best criteria of table 4 for eqs (30), (31), $\kappa_{wz} = 0$, and some suitable $\kappa_{wp} \in [0,1]$; pairs in the hatched area, in addition, are associated with $\kappa_{wp} = 0$, $\kappa_{wp} = 0.50$, $\kappa_{wp} \geq 0.95$ (as seen from below). '+' indicates (β_{we}, β_{wv}) meeting the criteria for some $\kappa_{wz} \in \{0.25, 0.50, 0.75, 1.00\}$ and $\kappa_{wp} \in \{0.00, 0.25, 0.50, 0.75, 1.00\}$ (coarse grid search).

all pairs (β_{we}, β_{wv}) in the dotted area in figure 2 there is a value between 0 and 1 of the coefficient κ_{wp} such that the corresponding parameter combination satisfies the second-best criteria.[22] The subsets of the hatched areas indicate admissible pairs (β_{we}, β_{wv}) that, besides $\kappa_{wz} = 0$, are combined with $\kappa_{wp} = 0$ (the lower region), $\kappa_{wp} = 0.50$ (the middle region), or $\kappa_{wp} \in [0.95, 1.00]$ (the region in the north-west corner). Regarding the dynamic equation (14) that governs the motions of the real wage rate, note that as κ_{wp} increases from zero to unity, the influence of the gap between the current rate of inflation and the general inflation climate diminishes. Figure 2 shows a tendency that, going along with a moderate decline in the coefficient β_{we}, this is mainly made up by a considerable increase in β_{wv}.

Before we inquire into the existence of admissible parameter combinations with $\beta_{wv} = 0$, it is useful to set up a base scenario to which the outcomes of alternative parameters in this and the following sections can be compared. For theoretical reasons, we still want the employment rate to play a dominant role in the wage Phillips curve *vis-à-vis* the wage share. As will be more rigorously verified in a moment, this is achieved by pairs (β_{we}, β_{wv}) in the lower part of the dotted area in figure 2, where $\kappa_{wp} = 0$. We therefore choose

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[22]There may nonetheless exist other values of κ_{wp} and $\kappa_{wz} > 0$ for which the same pair (β_{we}, β_{wv}) establishes an admissible parameter combination.

The first row in table 5 reports the precise statistics that are generated by this reference set of coefficients. Beyond the previous discussion of their order of magnitude, the two-years lag in the wage share, which amounts to a quarter of the cycle, is worth pointing out. Similar lags of v are encountered for all other admissible parameter combinations. This type of comovements between measures of economic activity and income distribution is equally obtained in Goodwin's (1967) seminal growth cycle model and its various extensions. Hence the present framework is well compatible with this approach and could, indeed, provide a richer structure for its wage-price dynamics.

In order to compare the influence of the employment rate and the wage share in the wage Phillips curve, one has to take the amplitudes of these variables into account. Employing the standard deviations for this purpose, v can be said to be less influential than e if $\sigma_v \, \beta_{wv} < \sigma_e \, \beta_{we}$, that is, if $\beta_{wv} < \beta_{we} \, (\sigma_e/\sigma_u)/(\sigma_v/\sigma_u) = 0.55 \cdot 0.69/0.26 = 1.49$ (cf. the first row in table 3 for σ_e/σ_u). It is thus established that the influence of the wage share is weaker by a factor of three. Incidentally, for a pair (β_{we}, β_{wv}) in the middle hatched region of figure 2, the influence of e and v would be about equal.

β_{wv}	β_{we}	$\kappa_{\pi p}$	σ_ω/σ_u	lag ω	σ_v/σ_u	lag v
0.50	0.55	0.50	0.48	0.75	0.26	2.00
0.00	0.55	0.50	0.35	1.00	0.29	2.75
0.00	0.55	0.25	0.49	1.00	0.35	2.17
0.00	0.45	0.25	0.48	0.75	0.27	2.00
0.00	0.35	0.25	0.49	0.58	0.21	1.75

Table 5: Parameter variations in base scenario CCP.

The second row in table 5 shows the consequences of a *ceteris paribus* drop of β_{wv} to zero, which has two unpleasant effects for the real wage: a decrease in the standard deviation and a longer lag.[23] The decrease in σ_ω can be undone by giving regressive expectations in the adjustments of the inflation climate a greater weight, i.e., by reducing $\kappa_{\pi p}$ to 0.25. Subsequently, the lag of the real wage can be shortened by lowering the coefficient β_{we}. At the same time, this *ceteris paribus* change diminishes the (previously increasing) standard deviation of the wage share considerably, while under the given circumstances, perhaps somewhat surprisingly, the impact on σ_ω is very weak. At $\beta_{we} = 0.45$, all second-best criteria are met again. A further reduction of β_{we} would be desirable insofar as the real wage becomes more procyclical. However, as we have observed above, this decreases σ_v too much.

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[23]The adverse effects would be even more dramatic for admissible parameter combinations with a positive value of κ_{wp}.

There are additional examples of admissible parameter combinations with a vanishing coefficient β_{wv}. As in the exercise of table 5, however, they always call for a specific conjunction of, especially, β_π and $\kappa_{\pi p}$. This is to say that the condition $\beta_{wv} = 0$, which relates to the wage Phillips curve, requires conditions to be met which have their place in another part of the model. In this sense, the assumption $\beta_{wv} = 0$ rests on rather shaky grounds and, in the present context with the CCP inflation module, may better be avoided.

5.4 The model with inflation module PPC

It has already been noted before that the inflation module with the price Phillips curve has the pleasant property that the real wage dynamics is determined independently of the inflation climate π, at hierarchy level 2. On the other hand, this goes at the cost of seven parameters being involved. Macro models working with two Phillips curves usually concentrate on the utilization measures on the goods and labour markets and ignore a possible influence of the wage share (or a related variable), which in the present setting amounts to $\beta_{wv} = \beta_{pv} = 0$. If technical progress is included, $\kappa_{wz} = 0$ is assumed as well. In this way, eq. (20) for the changes in the real wage becomes[24]

$$\dot{\omega} \;=\; \omega\,\kappa\,[\,(1-\kappa_{pw})\beta_{we}(e-1) \;-\; (1-\kappa_{wp})\beta_{pu}(u-1)\,] \tag{20a}$$

Since the employment rate is a nearly procyclical variable, it is immediately seen that the oscillations of the real wage will be shifted by about a quarter of a cycle; whether forward or backward depends on the relative magnitudes of $(1-\kappa_{pw})\beta_{we}$ and $(1-\kappa_{wp})\beta_{pu}$. It follows from this elementary observation that the approach of two standard Phillips curves is not compatible with the stylized fact of a procyclical real wage rate.

Taking it for granted that the two general Phillips curves (10), (11) and (15), (16) should not be prematurely simplified, we would nevertheless like to limit the variations of the seven parameters at PPC level 2. In addition, it should be possible to relate the investigations to our previous results. To this end, we begin the simulations with the wage Phillips curve parameters $\kappa_{wp}, \kappa_{wz}, \beta_{we}, \beta_{wv}$ from the CCP base scenario. There are thus only three parameters left for calibrating $\omega(\cdot)$ and $v(\cdot)$, namely, the price Phillips curve coefficients $\kappa_{pw}, \beta_{pu}, \beta_{pv}$. Regarding the price dynamics at PPC level 3, we also continue to fix the parameters $\beta_\pi, \kappa_{\pi p}$ at the values assigned to them in the same scenario. The underlying belief is that, given the wage Phillips curve that has already turned out to be feasible, the price Phillips curve with its three coefficients has sufficient degrees of freedom to generate a satisfactory income distribution dynamics. It is furthermore hoped that then, with the likewise proven values of β_π and $\kappa_{\pi p}$, the implied price dynamics exhibits similar properties as before.

Figure 3 shows the outcome of a three-dimensional grid search across the parameters κ_{pw}, β_{pu}, β_{pv}. The diagram shows the set of pairs (β_{pu}, β_{pv}) for which at least one value of κ_{pw} exists such that these coefficients, together with the parameter values just mentioned, meet the six conditions for dev ω, dev v, dev p in the lower half of table 4. For each pair (β_{pu}, β_{pv}) in the dotted area there is mostly a wider range of κ_{pw} with that property. The diagram also indicates the sets where the accompanying κ_{pw} can be 0.00 or 0.50, respectively. An insignificant subset of (β_{pu}, β_{pv}) has associated with it $\kappa_{pw} = 0.55$, which is the maximum value of all admissible κ_{pw} we find.

The most important feature to note in figure 3 is that the coefficient β_{pu} may well vanish.

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[24]For example, equation (20a) is a constituting part of the models in Chiarella and Flaschel (2000a, pp. 182, 298; 2000b, p. 937), or Chiarella et al. (2000, p. 63).
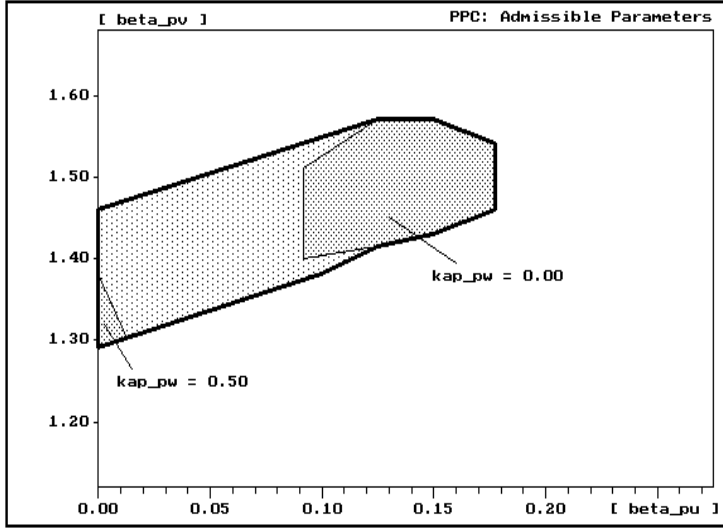
Figure 3: Admissible pairs (β_{pu}, β_{pv}) under PPC.

Note: Pairs (β_{we}, β_{wv}) in dotted area meet second-best criteria of table 4 for some suitable value of $\kappa_{pw} \in [0,1]$. The pairs in the closely dotted area are associated with $\kappa_{pw} = 0.00$ or $\kappa_{pw} = 0.50$, respectively. The values of the other parameters are taken over from the CCP base scenario.

Furthermore, even the highest admissible values of β_{pu} appear rather undersized. The influence of utilization in the price Phillips curve is in fact always markedly inferior to the wage share. That is, β_{pv} is always much larger than $\beta_{pu}/(\sigma_v/\sigma_u) \approx \beta_{pu}/0.26 > 0.18/0.26 = 0.69$ (which means $\sigma_u \beta_{pu} \ll \sigma_v \beta_{pv}$). Actually, a Phillips curve with such a dominant influence of the wage share might no longer be considered a Phillips curve proper.

While the parameter combinations illustrated in figure 3 meet the second-best criteria of table 4, they also do no better than that. Thus, the shortest lag of the real wage is lag $\omega = 0.75$ years, and the maximum standard deviation of the wage share is $\sigma_v/\sigma_u = 0.283$. The oscillations of the price level are without exception strictly countercyclical, i.e., lag$(-$ dev $p) = 0$.

In deciding on a base scenario, we may therefore go anywhere in the dotted area in figure 3. Let us choose a combination with a relatively high coefficient β_{pu}. So we arrive at

Base Scenario PPC:								
					β_π	$=$	1.00	$\kappa_{\pi p}$ $=$ 0.50
β_{zu}	$=$	0.40	κ_{pw}	$=$	0.00	β_{pu}	$=$ 0.15	β_{pv} $=$ 1.50
κ_{wp}	$=$	0.00	κ_{wz}	$=$	0.00	β_{we}	$=$ 0.55	β_{wv} $=$ 0.50

The cyclical features of this scenario resemble very much those of the CCP base scenario. In detail, $\sigma_\omega/\sigma_u = 0.47$, lag $\omega = 0.75$, $\sigma_v/\sigma_u = 0.26$, lag $v = 2.08$, $\sigma_p/\sigma_u = 0.48$, lag$(-$ dev $p) =$

0.00.

In concluding the discussion of the PPC module, it may again be asked whether parameter combinations with $\beta_{wv} = 0$ in the wage Phillips curve are possible. We investigated this question by fixing $\beta_{wv} = 0$, $\kappa_{wz} = 0$ (besides $\beta_{zu} = 0.40$, of course) and laying a 7-dimensional grid over the parameters $\beta_{pu}, \beta_{pv}, \kappa_{pw}, \beta_{we}, \kappa_{wp}, \beta_{\pi}, \kappa_{\pi p}$. Invoking a random mechanism, 50,000 of these grid points were checked, with the result that not one parameter combination satisfied the second-best criteria. For example, if all criteria are fulfilled except for lag ω, then the minimal lag of the real wage is 0.83 years, which is realized by no more than three combinations. If, instead, we relax the condition on the standard deviation of the wage share, there are only four combinations with $\sigma_v/\sigma_u \geq 0.20$, where three of them rest on very slow adjustments of the inflation climate, $\beta_{\pi} = 0.20$ or $\beta_{\pi} = 0.40$.[25] The evaluation of the assumption $\beta_{wv} = 0$ in the wage Phillips curve is therefore similarly, if not even more, negative than for the wage-price dynamics under the CCP inflation module.

5.5 The model with inflation module VMK

At its highest hierarchy level, the VMK model variant has only two parameters, $\beta_{\mu u}$ and $\beta_{\mu \mu}$, to regulate the three statistics of the real wage dynamics: σ_ω, lag ω, and σ_v. It is thus a nontrivial problem whether $\beta_{\mu u}$ and $\beta_{\mu \mu}$ are really capable of generating satisfactory cyclical properties in this respect.

After checking for an upper boundary of $\beta_{\mu u}$ and $\beta_{\mu \mu}$ beyond which there is no further scope for reasonable values of all three statistics, we set up a grid of 21 values of $\beta_{\mu u}$ that range from 0.050 to 0.350 (stepsize 0.015), and 21 values of $\beta_{\mu \mu}$ that range from 0.000 to 0.300 (likewise, stepsize 0.015). Among these 441 combinations, it turns out, there are four pairs that meet the second-best conditions. Three of them exhibit $\beta_{\mu u} = 0.200$, together with $\beta_{\mu \mu} = 0.000, 0.015, 0.030$; the fourth one is not very much different with $\beta_{\mu u} = 0.215$ and $\beta_{\mu \mu} = 0.015$. The latter pair implies $\sigma_v/\sigma_u = 0.271$, for the remaining three the ratio σ_v/σ_u is between 0.253 and 0.258. One pair, $\beta_{\mu u} = 0.200$, $\beta_{\mu \mu} = 0.030$, entails a lag of the real wage of 0.67 years, while lag $\omega = 0.75$ in the other cases. Since this is the shortest lag that we have encountered so far for admissible parameter combinations, we accept the slightly lower standard deviation of the wage share with which it goes along, i.e. $\sigma_v/\sigma_u = 0.254$, and base the following investigations on

$$\beta_{\mu u} = 0.20 \qquad \beta_{\mu \mu} = 0.03 \tag{32}$$

Shorter lags of the real wage are possible, but similarly as in the other modules, only at the price of higher values of σ_ω and lower values of σ_v.

It should also be pointed out that, apart from the precise numerical implications, another reason for choosing a strictly positive coefficient $\beta_{\mu \mu}$ may arise in the context of a full macroeconomic model. Here $\beta_{\mu \mu} > 0$ could help ensure uniqueness of a steady state position, which is reflected by a regular Jacobian matrix. Otherwise, if utilization appears, not only on the right-hand side of (22), but also in other reduced-form equations of the full dynamic system, the Jacobian might be singular.

As in the organization of the preceding simulations, we maintain the parameters β_{π}, $\kappa_{\pi p}$ as stated in (31). An obvious question, then, is for the integration of the wage Phillips

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[25]The fourth combination exhibits $\beta_{\pi} = 1.00$. It also yields the 'best' combination, with $\sigma_v/\sigma_u = 0.247$. For completeness, the other coefficients are $\beta_{pu} = 0.05$, $\beta_{pv} = 1.80$, $\kappa_{pw} = 0.20$, $\beta_{we} = 0.45$, $\kappa_{wp} = 0.00$, $\kappa_{\pi p} = 0.19$.

curve from the CCP and PPC base scenarios: will VMK, at level 3, yield similar cyclical statistics for the price level? The answer is, nearly so. The standard deviation amounts to $\sigma_p/\sigma_u = 0.50$, but there is a short lag of $-\mathrm{dev}\,p$ of one quarter.

Even if this result is reckoned satisfactory, there are two coefficients in the Phillips curve that we would like to change. The first one is κ_{wz}, which is set to zero in the CCP and PPC scenarios. Referring to eq. (25), we recall that under VMK, $\kappa_{wz} = 1$ would be the preferred value in order to eliminate the growth rate $\hat{z}$ of actual productivity from the model. A direct *ceteris paribus* increase of κ_{wz} from zero to unity has, however, a drastic consequence for the price dynamics: while now $-\mathrm{dev}\,p$ leads utilization by three quarters, which might still be agreeable, the standard deviation falls down to $\sigma_p/\sigma_u = 0.18$. This is another example of the strong influence that a weighting parameter may possibly have.

Much in line with the discussion of the CCP and PPC model, the second parameter which one perhaps would wish to determine *a priori*, i.e. fix at zero, is β_{wv}. Thus, set

$$\kappa_{wz} = 1.00 \qquad \beta_{wv} = 0.00 \tag{33}$$

and let us see what the two remaining free parameters, β_{we} and κ_{wp}, can achieve. The outcome of a detailed grid search is shown in figure 4. In the dotted area it depicts the pairs $(\beta_{we}, \kappa_{wp})$ that, given (29) and (31)–(33), imply $0.45 \leq \sigma_p/\sigma_u \leq 0.50$ and a lag of the price level (i.e., of $-\mathrm{dev}\,p$) between 0.25 and -0.50 years (the latter as indicated in the four subsets). The diagram, in particular, demonstrates that again the admissible slope coefficients β_{we} in the Phillips curve lie in a familiar range. Associated with suitable values of the weight parameter κ_{wp}, β_{we} may vary between 0.34 and 0.81. On the other hand, it is clear from (25) that κ_{wp} must be bounded away from unity. The precise upper bound in figure 4 is $\kappa_{wp} = 0.63$.
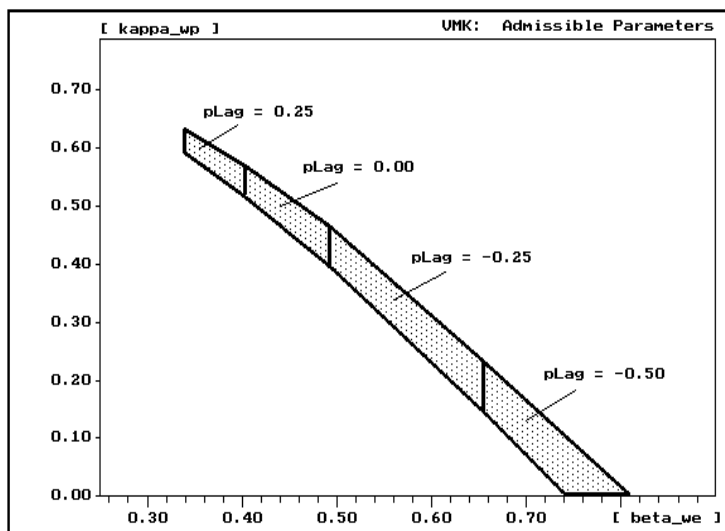
Figure 4: Admissible pairs $(\beta_{we}, \kappa_{wp})$ under VMK.

Note: Pairs $(\beta_{we}, \kappa_{wp})$ in dotted area meet second-best criteria of table 4, given (29), (31)–(33). 'pLag' stands for lag($-\mathrm{dev}\,p$), in years.

In the light of the stylized facts in table 1, we may, for setting up a base scenario, choose a

pair $(\beta_{we}, \kappa_{wp})$ that entails a one-quarter lead of the countercyclical oscillations of the price level. In this way, we can even retain the previous slope coefficient β_{we}. In sum, we specify

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Base Scenario VMK:

$$\beta_\pi = 1.00 \qquad \kappa_{\pi p} = 0.50$$
$$\beta_{zu} = 0.40 \qquad\qquad\qquad \beta_{\mu u} = 0.20 \qquad \beta_{\mu\mu} = 0.03$$
$$\kappa_{wp} = 0.35 \qquad \kappa_{wz} = 1.00 \qquad \beta_{we} = 0.55 \qquad \beta_{wv} = 0.00$$

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6 Evaluation of the base scenarios

A main motive for undertaking the numerical simulations was to investigate whether the three wage-price submodels have sufficiently reasonable properties to be integrated into a broader modelling framework. A closely related question is which of the three versions may be best suited for this purpose. To ease the discussion of the topic, each model variant is represented by its base scenario. For convenience, the cyclical features produced by them are summarized in table 6.

	σ_ω/σ_u	lag ω	σ_v/σ_u	lag v	σ_p/σ_u	lag $(-p)$
CCP	0.48	0.75	0.26	2.00	0.50	0.00
PPC	0.47	0.75	0.26	2.08	0.48	0.00
VMK	0.49	0.67	0.25	1.92	0.47	−0.25

Table 6: Cyclical properties of the base scenarios.

Note: $x = \mathrm{dev}\,\omega, \mathrm{dev}\,v, \mathrm{dev}\,p$ indicates percentage deviations from steady state values (variables ω and v) or from HP trend (variable p). The statistics are computed over a full cycle.

The table reiterates that all three submodels satisfy the second-best criteria established in table 4, where, in particular, a certain lag of the real wage rate has to be accepted. Since also no model can do any better than that, the three are so far on an equal footing. In finer detail, one might perhaps say that VMK has a weak edge over CCP and PPC, insofar as it admits a slightly shorter lag of ω and a slight lead in the countercyclical motions of the price level. But given the still relatively simple structure of the modelling equations, this aspect should not be overrated.

Since the three submodels have the same functional specification of a wage Phillips curve underlying, one may ask for the compatibility of the inflation modules. That is, one may ask if one module can be exchanged for another while maintaining the coefficients of the wage Phillips curve (and, of course, β_{zu}, β_π, $\kappa_{\pi p}$). As it can be once again seen from the synopsis of the adjustment coefficients in table 7, this is certainly true for the CCP and PPC base scenarios.

Thus, a decision between CCP and PPC would have to be made on other grounds. One

argument supporting CCP is that this inflation module involves only one further parameter, *vis-à-vis* three for PPC. On the other hand, the approach of a price Phillips curve has theoretical content, while one may tend to view the CCP equation as a reduced-form representation of a price adjustment process that is not fully made explicit.

	β_{we}	β_{wv}	κ_{wp}	κ_{wz}	β_p	β_{pu}	β_{pv}	κ_{pw}	$\beta_{\mu u}$	$\beta_{\mu\mu}$	KC
CCP	0.55	0.50	0.00	0.00	0.45	—	—	—	—	—	4
PPC	0.55	0.50	0.00	0.00	—	0.15	1.50	0.00	—	—	6
VMK	0.55	0.00	0.35	1.00	—	—	—	—	0.20	0.03	4

Table 7: Synopsis of base scenario coefficients.

Note: For all three model variants, the remaining parameters are given by eqs (29) and (31). KC is the number of 'key coefficients' (see text).

Regarding the third inflation module, it has already been pointed out in section 5.5 that the wage Phillips curve with the CCP and PPC base scenario coefficients, when employed in the VMK model, leads to results that are only slightly inferior. Given suitably chosen numerical values of β_p, of $(\beta_{pu}, \beta_{pv}, \kappa_{pw})$, or $(\beta_{\mu u}, \beta_{\mu\mu})$, respectively, it can therefore be noted that the three inflation modules are indeed well compatible; in the sense that combining them with the same (suitably chosen) wage Phillips curve gives rise to very similar cyclical features. This is a remarkable conclusion since theoretically as well as formally, the three modules are quite distinct.

Two reasons have, however, been mentioned why in the VMK model we would prefer alternative coefficients for the wage Phillips curve. The first reason concerns the weighting coefficient κ_{wz} and its consequences for the analytical tractability of the model. Under CCP and PPC, the growth rate of labour productivity, $\hat{z}$, would show up in the dynamic equations unless $\kappa_{wz} = 0$ (cf. eqs (14) and (20)); under VMK, $\hat{z}$ would feed back on the dynamics unless $\kappa_{wz} = 1$ (cf. eq. 25)). Second, adopting this value $\kappa_{wz} = 1$ in the VMK model, it was found that a coefficient $\beta_{wv} = 0$ becomes admissible, whereas under CCP and PPC, this is only the case for very special combinations of β_π and $\kappa_{\pi p}$. Hence, if one wishes to work with a familiar wage Philips curve in which possible effects from the wage share are excluded, $\beta_{wv} = 0$ in the base scenario is a strong point in favour of VMK.

The VMK approach also fares well if one considers the number of 'key coefficients' in table 7. By this we mean the number of coefficients here examined that cannot be *a priori* set equal to their desirable polar values, such as this is possible with $\kappa_{wz} = 0$ for CCP and PPC, or $\kappa_{wz} = 1$ and $\beta_{wv} = 0$ for VMK. Thus, there remain four key coefficients for CCP $(\beta_{we}, \beta_{wv}, \kappa_{wp}, \beta_p)$, six for PPC $(\beta_{we}, \beta_{wv}, \kappa_{wp}, \beta_{pu}, \beta_{pv}, \kappa_{pw})$ for PPC, and four for VMK $(\beta_{we}, \kappa_{wp}, \beta_{\mu u}, \beta_{\mu\mu})$. If the pure number of coefficients is the only concern, it might even be argued that VMK requires no more than three key coefficients, since putting $\beta_{\mu\mu} = 0$ would not violate the second-best criteria.[26]

Regarding a possible integration of CCP, PPC, or VMK in a more encompassing macrodynamic model, we can summarize the brief discussion as follows. Either version may be employed if additional aspects come into play. A price Phillips curve, for example, may

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[26]Recall the argument that $\beta_{\mu\mu} > 0$ could be needed in order to obtain a unique steady state within a full model.

be chosen because it allows one to study various feedback effects in a familiar framework. Similarly, a theoretical interest in the Kaleckian elements of oligopolistic price setting may be a forceful argument for VMK. Or the CCP specification, despite its parsimony, may be discarded since it has less theoretical content than PPC and VMK. By contrast, if there is no other decisive argument in favour of one version, then the VMK model variant appears most attractive to us.

To conclude our calibration study, we return to the issue of the exogenous fluctuations of utilization. Though one might be rather content with the above cyclical features, the base scenario parameters would earn more confidence if this outcome would not deteriorate too much when the regular sine waves of u are replaced with the empirical observations of this variable.

Let us to this end concentrate on the VMK model (the results for CCP and PPC would make no great difference). In detail, we took the quarterly data on u (1961:1 $-$ 91:4), which is depicted in figure 1, and interpolated it to get a monthly series. As before, the simulation itself was run for the monthly discrete-time analogues of the model. Referring to the percentage deviations from their steady state values (or from the HP 1600 trend values, as far as the price level is concerned), it remained to compute the same statistics as in table 1 for the empirical variables (again on a quarterly basis). The results are reported in table 8.

		cross correlations between u at time t and x at time						
Series x	σ_x/σ_u	$t-3$	$t-2$	$t-1$	t	$t+1$	$t+2$	$t+3$
u	——	0.48	0.70	0.89	1.00	0.89	0.70	0.48
e	0.66	0.18	0.45	0.70	0.90	0.91	0.83	0.70
ω	0.45	0.19	0.45	0.70	0.90	0.91	0.84	0.71
v	0.19	-0.55	-0.39	-0.19	0.06	0.30	0.50	0.65
p	0.32	-0.71	-0.83	-0.89	-0.87	-0.78	-0.64	-0.47

Table 8: Statistics obtained from VMK base scenario under empirical utilization series.

Note: Quarterly series of percentage deviations from steady state values (u, e, ω, v) or from HP trend (p). Same sample period of u as in table 1.

The cyclical statistics evince a positive and a negative facet. Due to the deterministic modelling framework, the relationship between utilization and the other variables is, of course, closer than observed in reality. Apart from that, however, the profile of the cross correlation coefficients is not so much different from table 1. In particular, the lags that we have obtained in the sine wave setting for the employment rate and the real wage have almost disappeared. As in table 1, the negative trend deviations of the price level lead utilization by one quarter, if we take the maximal correlation as an indicator of this feature. Even the wage share comes out nicely as qualitatively it exhibits the same pattern of correlation coefficients.

A negative point is that some of the standard deviations of the variables bear less resemblance to table 1 and also to table 6. As for as the employment rate, σ_e/σ_u is the same order of

magnitude as in the sine wave experiment (cf. table 3, first row), but lower than in table 1. The kind of this shortcoming has already been discussed in section 5.2. While σ_ω is only slightly smaller than in table 6, σ_v and especially σ_p deviate more severely from what we have been aiming at. The latter standard deviation has a certain downward bias because of the end-of-period effects in the HP filtering procedure of the price level,[27] but this is clearly not sufficient to explain the 'fall' from $\sigma_p/\sigma_u = 0.47$ in table 6 to $\sigma_p/\sigma_u = 0.32$ in table 8.

A hint on this discrepancy may be the observation that in the simulated time series from the seventies until the beginning of the eighties, the turning points have a lower amplitude than in figure 1. At those times, the economy went through two trough-to-trough cycles over a period of 12 years, and it has already been indicated in section 5.1 above that the duration of the cycles may have a bearing on the standard deviations. To check this possible effect, we re-run the sine wave simulation of the VMK model with a period of six years. The standard deviations here obtained come remarkably close to the ratios in table 8: $\sigma_e/\sigma_u = 0.66$, $\sigma_\omega/\sigma_u = 0.46$, $\sigma_v/\sigma_u = 0.19$, $\sigma_p/\sigma_u = 0.35$. Also the lags in e and ω are shorter than in table 6, both being reduced to five months.

On the other hand, back to the empirical utilization series, one can try out other numerical parameters for a better match of the standard deviations. Changing two parameters will do. A suitable increase of $\beta_{\mu u}$ and κ_{wp} yields the results displayed in table 9 (note that the employment rate is not affected by this variation). The standard deviations of (briefly expressed) ω, v and p reach almost perfectly the values of table 6, while only mildly modifying the cross correlation coefficients. The coefficients of the wage share have not even changed, although the pattern of the real wage has somewhat shifted (and differs now more from the cross correlations of e than in table 8).

A visual impression of what the VMK model may achieve and where it fails may be gained from figure 5, which contrasts the simulated with the empirical data. Besides, the time series that are obtained with the original base values of $\beta_{\mu u}$ and κ_{wp} do not look much different. Figure 5 shows that still the simulated series have difficulties in tracing out the the turning points of the actual series in 1973 and 1974. If, on the other hand, we are willing to discount for this feature and also take the elementary nature of the model into account, the cyclical properties of the base scenario or of this 'enhanced' scenario can be deemed rather satisfactory.

		cross correlations between u at time t and x at time						
Series x	σ_x/σ_u	$t-3$	$t-2$	$t-1$	t	$t+1$	$t+2$	$t+3$
ω	0.49	0.10	0.36	0.62	0.84	0.89	0.85	0.75
v	0.26	-0.55	-0.39	-0.19	0.06	0.30	0.50	0.65
p	0.47	-0.52	-0.68	-0.80	-0.85	-0.84	-0.77	-0.66

Table 9: Same experiment as in table 8, with $\beta_{\mu u} = 0.27$, $\kappa_{wp} = 0.60$.

Of course, an exact match of the simulated time series would be unduly restrictive since the

[27]In table 1, HP was performed over 1953:1 − 98:2, while the price series here computed is confined to the sample period 1961:1 − 91:4.
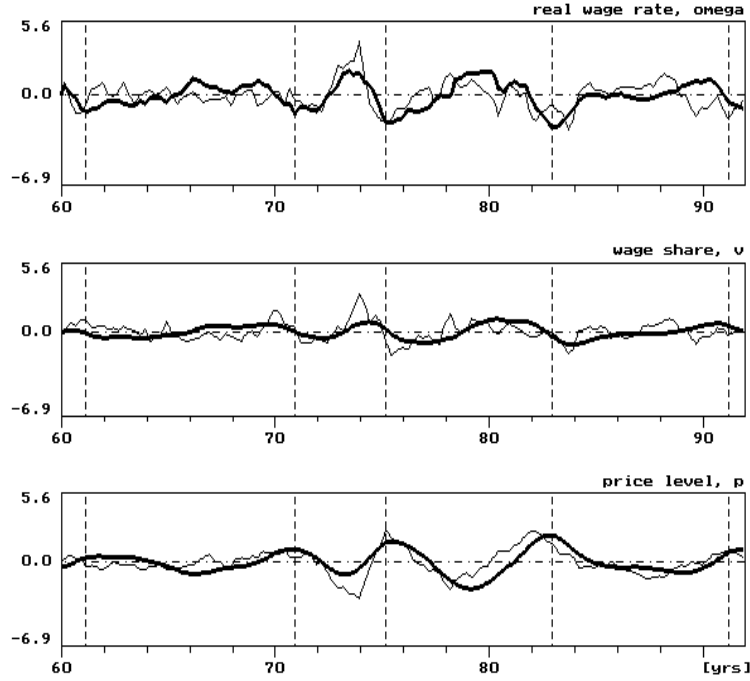
Figure 5: Time series of experiment in table 9.

Note: Bold (thin) lines are the simulated (empirical) data.

historical moments have sampling variability and so can differ from the model's population moments — even if the model happened to be true. As a matter of fact, the significance of a good match of the simulated and empirical sample moments is an unsettled issue. Given that a model cannot be expected to exactly duplicate reality, we can distinguish between a model variable, denote it by x^m_t, and its empirical counterpart, x^e_t, with error $\varepsilon_t = x^e_t - x^m_t$. To compare the standard deviations of x^m and x^e, i.e. their variances, the identity $\mathrm{var}(x^e)$ $= \mathrm{var}(x^m) + 2\,\mathrm{cov}(x^m, \varepsilon) + \mathrm{var}(\varepsilon)$ has to be taken into account. As a consequence, if the difference between $\mathrm{var}(x^m)$ and $\mathrm{var}(x^e)$ is viewed as a statement about $\mathrm{var}(\varepsilon)$, as it mostly is, this would require $\mathrm{cov}(x^m, \varepsilon) = 0$ to be fulfilled, which amounts to making an assumption that *a priori* is not really obvious. But if one allows for potential correlation between x^m and ε, it might even be possible that $\mathrm{var}(x^m) = \mathrm{var}(x^e)$ despite large errors ε_t. The interpretation of a comparison between, say, table 9 and table 1 is thus a deep methodological problem, which certainly goes beyond the scope of this paper.[28]

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[28]The problem is hinted at in Kim and Pagan (1995, p. 371). The authors conclude, "the method of stylized facts really fails to come to grips with what is the fundamental problem in evaluating all small models, namely the assumptions that need to be made about the nature of the errors ζ_t" (ζ_t corresponds to ε_t in our notation). On pp. 378ff, Kim and Pagan elaborate more on the problems connected with the fact that generally the errors ζ_t cannot be recovered.

7 Conclusion

The paper has put forward three submodels of (deterministic) wage-price dynamics which, in future work, may be integrated into a more encompassing macro model. The models have in common a positive functional relationship between capacity utilization and labour productivity; a positive relationship between capacity utilization and the capital growth rate; an adjustment mechanism for a so-called inflation climate; and a nominal wage Phillips curve. Regarding the three alternative model components determining inflation and the price level, the first one postulates a relationship between utilization and changes in the rate of inflation which almost directly implies a countercyclical price level (CCP). The second approach advances a price Phillips curve (PPC). The third module formalizes adjustments of a variable markup rate on unit labour costs (VMK) that bear a certain countercyclical element. Based on stylized sine wave oscillations for utilization as the only exogenous variable, it has been the main goal to find plausible numerical parameter values for each model variant such that the endogenous variables exhibit cyclical properties comparable to those that have been previously established as stylized facts for the corresponding (detrended) empirical time series.

The most important cyclical features we sought to reproduce are a procyclical real wage rate, a countercyclical price level, and the order of magnitude of their standard deviations. Accounting for the latter two characteristics, it turned out that all three models generate a lag of the real wage that is somewhat larger than desired. The main reason for this shortcoming seems to be the simplified modelling of labour productivity. However, once we are willing to accept the lag in a set of 'second-best' criteria of the cyclical statistics, each model can be calibrated in a satisfactory way.

The models include several coefficients that weight the influence of certain benchmark terms, such as, for example, the influence of actual inflation *versus* the inflation climate in the wage Phillips curve. These parameters appear quite innocuous at the theoretical level. It is a side result of the numerical analysis that they nevertheless have a strong impact on the cyclical features of the endogenous variables, so that they, too, must be carefully considered in the calibration procedure. In addition, this finding suggests that the weighting coefficients may also have a nonnegligible bearing on the stability properties of a full macrodynamic system

Adopting suitable parameters, the three inflation modules are well compatible. That is, given the wage Phillips curve and the other common model components, one inflation module can be exchanged for another without affecting the cyclical properties too much. This is remarkable since theoretically and in their consequences for the model structure, the three modules are quite disparate.

In finer detail, however, we set up three base scenarios, one for each model variant, where the wage Phillips curve combined with VMK has different parameters from the curve in the CCP and PPC context. One reason for this are different polar values that, desirably, a weighting parameter should attain in order to eliminate the analytically rather inconvenient influence of the growth rate of actual productivity from the model. Another reason concerns the core of the wage Phillips curve, in the general version of which we allowed for a negative feedback of the wage share. Though being relatively weaker than the influence of the employment rate, the effect must be significant in the both the CCP and PPC model. Besides, the price Phillips curve, too, must incorporate a (positive) feedback of the wage share (which even dominates capacity utilization). In the VMK model variant, on the other hand, it is possible to dispense with the wage share effect and so to employ a traditional wage Phillips curve. If

there are no other arguments, then this theoretical and analytical simplification could be a crucial point for a model builder to choose the VMK inflation module.

The base scenarios rely on parameters governing the adjustments of the inflation climate π which, to limit the degrees of freedom, were fixed freehand at *a priori* plausible values. Comparing the implied time path of this unobservable variable with survey data, perhaps even proxying π with such data, alternative coefficients might be preferred in this respect. We suspect that the base scenarios need not much be changed then, but in any case the calibration could be redone along the same lines as discussed in this paper.

Finally, we replaced the exogenous sine wave motions of capacity utilization with the corresponding empirical time series. It is an encouraging feature of the base scenarios, and of the modelling approach altogether, that the qualitative cyclical behaviour of the endogenous variables was not seriously destroyed. On the contrary, we even obtained slight improvements concerning the lags of the employment rate and the real wage. The main shortcoming was that the standard deviation of the price level became too low, a phenomenon that could be explained by the duration of the most volatile cycles involved. Concentrating on the VMK model variant, a moderate change of two parameter values was sufficient to raise the standard deviation up to the desired level without the other statistics being essentially affected. On the whole, we may conclude that the wage-price submodels here presented are a useful workhorse in the (non-orthodox) modelling of small macrodynamic systems.

8 Appendix: the empirical time series

The time series examined in table 1 are constructed from the data that are made available by Ray Fair on his homepage (http://fairmodel.econ.yale.edu), with a description being given in Appendix A of the US Model Workbook. Taking over Fair's abbreviations, the following time series of his database are involved. They all refer to the firm sector, i.e., non-financial corporate business.

HN	average number of non-overtime hours paid per job
HO	average number of overtime hours paid per job
JF	number of jobs
KK	real capital stock
PF	output price index
SIFG	employer social insurance contributions paid to US government
SIFS	employer social insurance contributions paid to state and local governments
WF	average hourly earnings excluding overtime of workers
	(but including supplements to wages and salaries except
	employer contributions for social insurance).
Y	real output

The variables in table 1 are then specified as follows. For Fair's assumption of a 50% wage premium for overtime hours, see, e.g., his specification of disposable income of households (YD in eq. (115), Table A.3, The Equations of the US Model).

$$
\begin{aligned}
u &= \text{Y / KK} \\
z &= \text{Y / [JF} \times \text{(HN + HO)]} \\
L &= \text{JF} \times \text{(HN + 1.5×HO)} \\
w &= \text{WF} \times \text{(HN + 1.5×HO) / (HN + HO)} \\
p &= \text{PF} \\
v &= \text{[WF} \times \text{(HN + 1.5×HO)} \times \text{JF + SIFG + SIFS] / [Y} \times \text{PF]}
\end{aligned}
$$

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