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Abstract

We study endogenous employment and distribution dynamics in a Post-Keynesian model of Kalecki-Steindl tradition. Productivity adjustments stabilize employment and the labour share in the long run: technological change allows firms to replenish the reserve army of workers in struggle over income shares and thereby keep wage demands in check. We discuss stability conditions and the equilibrium dynamics. This allows us to study how legal working time and its reduction affect the equilibrium. We find that a demand shock is likely to lower the profit share and increase the employment rate. A supply shock in contrast tends to have detrimental effects on employment and income distribution. Labour market institutions and a working time reduction have no long-term effect on growth, distribution and inflation in the model. The effects on the level of capital stock and output however are positive in a wage-led demand regime. Furthermore, an erosion of labour market institutions dampens inflation temporarily. The model provides possible explanations as to the causes of several current economic phenomena such as secular stagnation, digitalisation, and the break-down of the Philips curve.

Keywords: Post-Keynesian economics, productivity, technological change, income distribution, employment

JEL codes: D33, E12, E24, O40

1 Introduction

Recent economic developments have raised a number of issues for economists and policy makers alike.

First, many industrialized countries experienced a slow recovery and weak productivity growth in the years after the Great Recession. This provoked a lively debate between the proponents of various theories of 'secular stagnation' (Hansen, 1932). Supply-side explanations of this phenomenon vary from slower population growth and market frictions to the absence of path-breaking innovations compared to previous periods. Demand-side explanations on the other hand highlight a lack of (investment) demand as the main cause of secular stagnation. Although the debate has abated somewhat during the latest economic upswing, the economics profession is still far from reaching a consensus on this matter.

Second, these developments are even more puzzling in view of the recent trends towards increasing digitalisation and automatization. Technological change is supposed to increase growth in mainstream models by shifting out the production function. Furthermore, the 'digital revolution' has drawn attention to the unequal effects of technological change with regard to labour markets and income distribution. Theories of 'polarisation' as a consequence of digitalisation and automatization have been put forward, but the implications for the relative power of workers and capitalists and thus functional income distribution have remained underexplored so far. Furthermore, the question whether technological change is likely to lead to higher unemployment in the future is hotly debated between 'techno-optimists' and 'techno-pessimists'. Given its supply-side focus, mainstream theory is not well suited to clarify this issue.

Third, even after growth rates picked up in recent years and unemployment declined markedly, wage and price inflation remained unexpectedly subdued. Labour markets apparently failed to react as predicted by standard Philips curve theory. This 'break-down of the Philips curve' has triggered a debate on whether inflation targeting by central banks in general or a specific target still make sense. Underlying reasons and the macroeconomic consequences remain under discussion.

Post-Keynesian theory can explain these phenomena. Unlike neoclassical models, growth in Post-Keynesian models is not determined by the supply side (i.e., labour supply and productivity growth) but by interactions with aggregate demand. Low investment due to low 'animal spirits', excessive capacities, or low returns are among the main causes of weak economic growth. Functional income distribution plays a major role in these models due to its effects on saving of workers and capitalists and firms' profitability. The income distribution in turn is determined by the relative power of the two classes.

While the relations between growth and distribution has been subject of careful study in Post-Keynesian theory, less attention has been paid to labour markets and the impact of technological change. Though some contributions include employment and productivity growth into Post-Keynesian theory in different ways (e.g. Dutt, 1994; Naastepad and Storm, 2012; Palley, 2012, 2014, 2019; Taylor et al., 2019), no model has yet been put forward to explain the abovementioned phenomena in a coherent way. This is the gap the paper intends to close.

We build a Post-Keynesian model in the tradition of Kalecki (1971) and Steindl (1952), in which economic growth, functional income distribution, productivity and employment are all endogenously determined. As conventional in Post-Keynesian models, growth is driven by capital accumulation. Functional income distribution determines saving and investment. In the model, growth can thus either rise (‘profit-led’) or fall (‘wage-led’) when the profit share increases.

The contribution of the paper is threefold: First, we bring various elements of Post-Keynesian theory together to build a model which simultaneously explains growth, income distribution, employment and productivity growth. Second, we thereby provide a coherent framework to explain recent phenomena such as ‘secular stagnation’, the macroeconomic impact of the ‘digital revolution’ and the 'break-down of the Philips curve'. Third, we include legal working time into the model and discuss the effects of its reduction as a means to increase employment and incomes.

To do so, we add two more building blocks to the standard model: First, changes in the labour market are the result of demand (i.e., capital accumulation) and supply factors (i.e., labour supply and productivity growth). Second, wages and prices and thus ultimately also the functional income distribution are determined by the state of the labour market, i.e. some kind of reserve army effect. Furthermore, technological change is co-determined by the wage or profit share. This reflects Marx’s insights that firms use productivity gains to replenish the reserve army and thereby keep wage demands in check (Marx, 1867). Productivity growth adjusts so as to balance the labour market in the long run and thus ‘solves’ the first Harrodian instability problem, i.e. an imbalance between actual and ‘natural’ growth (Harrod, 1939).

In the short run, productivity growth, the employment rate and functional income distribution are fixed in the model and determine aggregate demand. In the long run however, these variables are allowed to vary. We discuss the properties of the model and the conditions for the stability of a possible long-term equilibrium. Furthermore, we analyse the effects of changes in various demand and supply factors in the short and long run.

We extend the model to assess the impact of a legal working time reduction. This measure is often brought up when considering how to deal the with potential adverse employment effects of technological change. The macroeconomic effects of a working time reduction however have not been analysed so far, in particular not with regard to employment, income distribution and growth.

The main findings of our paper are: First, low investment demand (e.g. due to a fall in ‘animal spirits’) dampens growth, lowers employment, and increases income inequality. This lends support to demand-sided explanations of ‘secular stagnation’ even though supply-side factors can potentially also contribute in certain cases. Second, faster technological change and higher labour supply growth have potential detrimental effects on employment and the income distribution although they possibly increase growth.

Third, an erosion of workers' bargaining power increases employment in the long run but reduces inflation in the short run and has temporally potential adverse effects on growth, depending on the growth regime. Fourth, a legal working time reduction does not lead to changes in employment and distribution in the long run. In the short run however, the employment rate rises, and the profit share falls. This possibly leads to a temporary increase in the growth rate, so that the economy ends up at a higher output level.

The paper is structured as follows: Section 2 discusses the relevant literature. Section 3 describes the model. Section 4 assesses the dynamics and the stability of the model. Section 5 analyses the long-term effects of changes in various model parameters. Section 6 introduces the legal working time and analyses the impact of its reduction. Section 7 concludes.

2 Literature

Our model integrates the demand and supply side (i.e., labour supply growth and technological change) of an economy and allows for endogenous employment and distribution dynamics. The demand side builds on a long tradition of Post-Keynesian models in the spirit of Kalecki (1971) and Steindl (1952). In these models, growth is demand-driven and determined by functional income distribution (i.e., the wage or profit share). We follow Bhaduri and Marglin (1990) and the vast literature thereafter in allowing for both wage-led and profit-led demand and growth regimes.[1] An increase in the wage share can thus raise ('wage-led') or reduce ('profit-led') capacity utilization and the growth rate of an economy.

As regards to the supply-side and the dynamics of employment and distribution, three strands of the Post-Keynesian literature are particularly relevant for this paper. First, several contributions extend the neo-Kaleckian model by endogenous technological change. In these models, productivity growth usually depends on the profit share (i.e. a 'Marx effect', see above) and output growth (i.e., the 'Verdoorn effect').[2] Since a change in the functional income distribution affects output *and* productivity growth, employment growth can be both wage-led or profit-led, regardless of the output growth regime. Naastepad and Storm (2006, 2012) pioneered this line of work by empirically estimating output and productivity growth regimes in European countries and discussing their consequences for the employment regimes.[3] These contributions however explicitly focus

[1] This kind of models is now well established in the literature. For a recent overview, see Stockhammer (2011), Lavoie and Stockhammer (2012) and Setterfield (2016). For empirical analyses of wage-led/profit-led regimes see e.g. Barbosa-Filho and Taylor (2006), Stockhammer and Ederer (2008), Stockhammer et al. (2009), Onaran and Galanis (2014), Kiefer and Rada (2015).

[2] Verdoorn (1949) empirically investigated the relation between productivity growth and output growth. Kaldor (1957) later included it into his technical progress function. See McCombie et al. (2002) for a more detailed discussion.

[3] Hein and Tarassow (2010) and Hartwig (2013) are similar contributions.

on the medium-run analysis and impose no steady-state condition for the employment rate. They thus do not provide a solution for Harrod's first instability problem.[4]

Second, several contributions introduce a labour market balance as a condition for steady-state growth into neo-Kaleckian models. In the long run, employment and effective labour supply must grow at the same rate to ensure a constant employment rate. The earliest contribution along these lines is Dutt (1994), who however uses an unambiguously wage-led 'stagnationist' model. Furthermore, the model includes no mechanism to stabilize the employment rate since productivity growth only depends on capital accumulation via the Verdoorn effect. Consequently, there is a positive feedback loop between an ever-rising employment rate and an ever-increasing wage share.[5,6] Taylor et al. (2019) on the other hand include a similar employment dynamic into a neo-Kaleckian model and add a Marx effect on productivity growth. They further assume that growth is profit-led. This results in a stable employment dynamic, since any positive deviation from the long-term equilibrium increases the wage share and thus both reduces capital accumulation and raises productivity growth.[7]

Palley (2019) allows for both wage-led and profit-led demand and includes an endogenous employment dynamic along the lines sketched above.[8] Productivity growth and the profit share both depend on the unemployment rate. The model can thus be reduced to a single differential equation, which yields a long-term equilibrium for the employment rate. The main finding in Palley (2019) is that demand-stimulating policy measures have a positive impact on the employment rate, whereas measures increasing the effective labour supply have a negative impact. However, a decrease in firms' profitability due to higher labour costs would not induce them to raise productivity in the model of Palley (2019), so Marx-biased technical change is absent.

Naastepad and Storm (2012) assume an exogenous profit share as is conventional in neo-Kaleckian models. Consequently, the relationship between functional income distribution and employment only goes one way. Some of the other contributions mentioned above endogenize the functional income distribution simply by making it dependent upon the employment rate, which is usually justified by some notion of a Marxian reserve army

[4] Naastepad and Storm (2012, chapter 6) extend their analysis into the long run, which they define by a stable employment rate. In that case however, the model loses its neo-Kaleckian properties since growth only depends on the exogenous growth rates of autonomous (i.e. investment, export and public) demand.

[5] The model is neo-Kaleckian only in the case of excessive capacity. Dutt (1994) combines it with a (stable) full-capacity neo-Marxist model, so that the economy oscillates between excess and full capacity. Furthermore, Dutt (1994) discusses the stability and dynamic behavior of the model but does not consider effects on a long-term equilibrium.

[6] Lima (2004) extends the model by including a non-linear effect of functional income distribution on productivity growth. The model however is too stylized to analyze the effects on the long-term equilibrium.

[7] Taylor et al. (2019) focus on analyzing the dynamics between employment and the wealth distribution. This is beyond the scope of our paper.

[8] Similar contributions are Palley (2012, 2014). They however decouple capacity utilization from employment and assume that variations in demand are absorbed by a change in hours worked. This is not the road we want to follow.

effect. The profit share (or the profit rate) and the employment rate can thus be treated as interchangeable, which greatly simplifies the analysis (e.g. Palley, 2019; Taylor et al., 2019). This however is at the expense of a detailed modelling of the labour market dynamics, in which wage and price setting as well as productivity growth all play a major role.

Dutt (1994), building on models of conflict inflation and distribution, takes a different route. In his model, the wage and price dynamics (and thus the dynamics of the functional income distribution) are modelled separately and are determined by the conflicting claims of workers and capitalists. Since he assumes a complete pass-through of productivity growth onto wages, this results in an exclusive dependency of the profit share on the employment rate similar to the above-mentioned models. Other contributions (e.g. Taylor, 2004; Flaschel, 2009; Rezai, 2011) allow for incomplete pass-through in their models of wage- and price-setting so that productivity growth has an immediate distributional impact. These contributions form a third strand of the literature relevant for the paper. Allowing for an incomplete pass-through along these lines opens up the possibility of more complicated employment and distribution dynamics.

We bring these various building blocks of the literature together and build a consistent Post-Keynesian model which includes both a demand and a supply side and imposes a stable employment rate as a condition for the long-term equilibrium. In the model, productivity growth is co-determined by functional income distribution and acts as the main balancing element to overcome Harrod's first instability problem. Equally important, we add fully specified distribution dynamics and thereby allow for a two-way dynamic interaction between the functional income distribution and employment. We discuss the stability of the model and analyse various effects on the long-term equilibrium. Our model closely follows the empirical specification of many structural macroeconomic models and illustrate its innovative quality by studying changes in the legal working time and simulate the effects of a working time reduction on growth, employment and distribution.

3 Model

The model is Post-Keynesian in the tradition of Kalecki (1971) and Steindl (1952). Capital accumulation and growth are determined by investment. Consumption and investment together add up to aggregate demand. The functional distribution of income, i.e. the wage or profit share, affects both demand components due to profitability considerations in the investment function and differential saving rates of workers and capitalists.

Gross investment, I, increases with output, Y, and profits, R. We specify the investment function in relation to the capital stock, K, to facilitate long-run analysis. With $g = I/K$, $u = Y/K$, and $\pi = R/Y$,

$$g = I/K = \beta_0 + \beta_1 u + \beta_2 \pi, \tag{1}$$

where $\beta_0, \beta_1, \beta_2 > 0$.

Households save a constant fraction of their income, but saving rates differ with households receiving wage income saving a lower fraction than those receiving capital income, i.e. $s_w < s_r$:

$$s = S/K = [s_w(1-\pi) + s_r\pi]\, u \tag{2}$$

Total demand and thus capacity utilization adjust so that the equality between saving and investment is always fulfilled. Since we abstract from government expenditures and net exports, macro balance requires that

$$u^* = \frac{\beta_0 + \beta_2\pi}{s_w + (s_r - s_w)\pi - \beta_1} \tag{3}$$

$$g^* = \frac{(\beta_0 + \beta_2\pi)[s_w + (s_r - s_w)\pi]}{s_w + (s_r - s_w)\pi - \beta_1} \tag{4}$$

Because it follows from the equality between investment and saving, equation (3) is called 'IS curve' for further reference. Both capacity utilization and capital accumulation increase in the profit share when the difference in saving rates is low or the investment response to profitability is high. They can thus be either wage-led, i.e. they react negatively to an increase in the profit share, or profit-led.

Labour productivity $a = Y/L$, with L being actual employment, and the labour supply N are assumed constant in the short run. The employment rate, $e = L/N$, is determined residually and, given labour productivity, directly follows from aggregate demand. In the long run however, labour productivity, the capital stock and labour supply are allowed to vary. To capture these developments, we follow Dutt (1994) and Taylor et al. (2019) in defining the auxiliary variable $\zeta = (K/N)/(X/L) = \kappa/a$. ζ is the ratio of the capital stock to labour supply in productivity units, or the capital-effective labour supply ratio. Using its definition, it is easy to see that ζ is positive and fixed in the short run and the employment rate only varies with demand, u, and thus ultimately the distribution of income, π:

$$e = \frac{L}{N} = \frac{L}{Y}\frac{K}{N}\frac{Y}{K} = \zeta u. \tag{5}$$

Taking time derivatives of the capital-effective labour supply ratio ζ, we get:

$$\dot{\zeta} = (g - n - \hat{a})\zeta \tag{6}$$

The differential between capital accumulation, the labour supply, and productivity growth thus changes ζ over time.

Productivity growth is modelled depending on the rate of capital accumulation and profitability. The first effect follows Kaldor's (1957) technical progress function, in which labour productivity depends on investment in new capital and is labelled 'Verdoorn effect'. The second effect follows the reasoning of Marx (1867): a decreasing profitability spurs firms to implement new labour-saving technologies and speed productivity growth. Technological change and productivity growth are thus a means of firms for class struggle.

$$\hat{a} = \phi_0 + \phi_1 g - \phi_2 \pi \quad (7)$$

The third building block of our model determines the functional income distribution. In neo-Kaleckian models, the profit share is typically treated as exogenous. We however follow Dutt (1994) in modelling functional income distribution as the outcome of conflicting claims of workers and firms mediated through a wage bargaining process. In such a model, wage inflation depends on the deviation of the actual wage share from workers' target. In addition, workers are able to keep their share from eroding by offsetting a certain fraction of price inflation $\hat{p}$, and labour productivity growth, $\hat{a}$ (Flaschel, 2009). The target wage share follows Goodwin's (1967) interpretation of Marx' reserve army argument: workers increase their target when unemployment is low, i.e. the employment rate is high. With $0 \leq \mu_{1,2,3} \leq 1$, the target profit share being $\pi_{Tw} = 1 - \Omega_{Tw} = \gamma_0 - \gamma_1 e$, and the profit share given by the identity $\pi = 1 - \Omega$, wages grow by

$$\hat{w} = \mu_1(\Omega_{Tw} - \Omega) + \mu_2\hat{p} + \mu_3\hat{a} = \mu_1[\pi - \gamma_0 + \gamma_1 e] + \mu_2\hat{p} + \mu_3\hat{a} \quad (8)$$

Firms want to maintain their target profit share in a similar manner and, when it is decreasing, adjust prices, pushing costs on to consumers. For simplicity, we assume a constant target profit share $\pi_{Tr} = \delta_0$, independent of demand:[9]

$$\hat{p} = \tau(\pi_{Tr} - \pi) = \tau(\delta_0 - \pi). \quad (9)$$

Taking time derivatives of the profit share, we get:

$$\begin{aligned} \dot{\pi} &= -(\hat{w} - \hat{p} - \hat{a}) \\ &= [\mu_1\gamma_0 - \mu_1\gamma_1 e + (1 - \mu_2)\tau\delta_0 - [\mu_1 + (1 - \mu_2)\tau]\pi + (1 \\ &\quad - \mu_3)(\phi_0 + \phi_1 g - \phi_2\pi)]\pi \end{aligned} \quad (10)$$

The dynamic of the profit share thus depends on the employment rate, the growth rate and the level of the profit share itself.

4 Stability analysis

Equations (6) and (10) form a two-dimensional differential equation system in π and ζ:

$$\begin{pmatrix} \dot{\pi} \\ \dot{\zeta} \end{pmatrix} = A \begin{pmatrix} \pi \\ \zeta \end{pmatrix} \quad (11)$$

with

$$A = \begin{pmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{pmatrix}.$$

The signs of the entries in the second column of matrix A, i.e. the effects of ζ on changes in π or ζ, are straightforward: Since the employment rate (and thus also the capital-effective

[9] For an extension of the model to include a firms' target share depending on capacity utilization, see appendix A.

labour supply ratio) has a negative sign in equation (10), it follows that $a_{12} < 0$. All other things equal, a higher ζ increases the employment rate and thus workers' bargaining power, which translates into a lower profit share dynamic. Furthermore, the dynamic of the capital-effective supply ratio does not depend on itself, because ζ neither affects capital accumulation, the labour supply or productivity growth, i.e. $a_{22} = 0$. The stability of the differential equation system thus depends on the signs of the entries in the first column of matrix A, i.e. on how the profit share affects the two dynamic equations. The system is stable if all Eigenvalues have negative real parts, i.e. if $a_{11} < 0$ and $a_{21} > 0$.[10]

Both signs depend on several effects which can work in opposite directions: First, both capacity utilization and capital accumulation are co-determined by the profit share. However, u and g can be either wage-led or profit-led, so that the effect of π is a priori ambiguous. We therefore must distinguish between the two cases. Second, capital accumulation does not only enter the equation for the capital-effective labour supply ratio directly but also has an indirect effect on both dynamic equations via the Verdoorn effect. Third, through the Marx effect, the profit share directly affects productivity growth. This effect is negative by definition and affects both dynamic equations.

For simplicity, we start with the assumption that price inflation and productivity growth are completely passed through onto wages, i.e. $\mu_2 = \mu_3 = 1$. The dynamic equation for the profit share is then reduced to

$$\dot{\pi} = [\mu_1(\gamma_0 - \mu_1\gamma_1 e - \pi)]\pi = [\mu_1(\gamma_0 - \mu_1\gamma_1\zeta u - \pi)]\pi \tag{12}$$

The sign of the derivative with respect to π, i.e. a_{11}, thus depends on the demand regime: With profit-led demand, i.e. $\partial u/\partial\pi > 0$, it is unambiguously negative. In a wage-led regime, a positive sign is theoretically possible. The negative direct effect of the profit share however is most likely higher than the indirect effect via capacity utilization. We thus assume that $a_{11} < 0$. When the profit share rises, it deviates from workers' target and thus increases wage inflation. Consequently, the dynamics of the profit share fall, all other things being equal.

For the capital-effective labour supply ratio, we get

$$\frac{\partial\dot{\zeta}}{\partial\pi} = \left(\frac{\partial g}{\partial\pi} - \frac{\partial\hat{a}}{\partial\pi}\right)\pi \tag{13}$$

near the long-term equilibrium defined by $\dot{\zeta} = 0$. The right-hand side of this expression represents the Marx effect and is positive since a higher profit share reduces productivity growth and thus increases the dynamics of the capital-effective labour supply ratio. The sign of this expression depends on the growth regime: If growth is profit-led, i.e. $\partial g/\partial\pi > 0$, the sign of $\partial\dot{\zeta}/\partial\pi$ is unambiguously positive, i.e. $a_{21} > 0$, and the conditions for the dynamic stability of the model are met. An increase in the profit share raises capital accumulation and thus increases the dynamic of the capital-effective labour supply ratio.

[10] In the case of $a_{11} = 0$ and $a_{21} > 0$, we get a stable limit cycle around a center. This would create an endless Goodwin (1967)-like cycle for π and ζ.

In the wage-led case however, i.e. $\partial g/\partial\pi < 0$, a potential instability arises. The system is stable if growth is only weakly wage-led or the Marx effect is relatively strong.[11]

The Verdoorn effect potentially stabilises the system in the case of a wage-led growth regime and destabilises it if capital accumulation is profit-led, because it reduces the effect of the profit share on the capital-effective labour supply ratio dynamics.

If the system is stable, it either directly approaches the equilibrium monotonically or oscillates towards it in a Goodwin (1967) cycle-like predator-prey manner, depending on whether the Eigenvalues have imaginary parts. A rising capital-effective labour supply ratio and thus a rising employment rate reduce the profit share ($a_{12} < 0$),[12] whereas a rising profit share increases the capital-effective supply ratio ($a_{21} > 0$). Furthermore, because $a_{11} < 0$, a rising profit share directly reduces its own dynamics.

We identify several specifications in which the system is unstable, i.e. any deviation from the equilibrium leads to an explosive trajectory. If the demand and growth regime is strongly wage-led or the Marx effect is weak, a higher profit share reduces capital accumulation more than it increases productivity growth, which leads to fall in the dynamics of the capital-effective labour supply ratio ($a_{21} < 0$). A lower ζ ceteris paribus increases the profit share dynamics, because the bargaining position of workers is weakened. We thus get an ever-increasing profit share and an ever-falling employment rate. Depending on the starting point, the trajectory can also explode in the opposite direction with a falling profit share and an ever-increasing employment rate.

Adding an incomplete pass-through of price inflation and/or productivity growth onto wages adds realism but also analytical complexity to the model. The dynamics of the profit share is now given by equation (10). The Marx effect increases the stability of the system since it adds negatively to a_{11}. The Verdoorn effect on the other hand is potentially destabilising, since capital accumulation can be either wage-led or profit-led. In the first case, g reacts negatively to the profit share so that a_{11} is unambiguously negative; the Verdoorn effect is stabilizing. In the profit-led case, the Verdoorn effect potentially destabilises because g depends positively on the profit share. As a consequence, a_{11} can theoretically become positive if the Verdoorn effect is strong.

Table 1 characterizes the stabilising and destabilising configurations of the model. The wage bargaining effect and the Marx effect (via the dynamics of the capital-effective labour supply ratio) stabilise the system, independently of whether the demand regime is wage-led or profit-led. Because of the direct effect via capital accumulation, the system can be unstable in the wage-led case. The Verdoorn effect potentially stabilises the system if growth is wage-led and destabilises it if growth is profit-led. If productivity gains are not fully passed through to wages, the Marx effect contributes to stability via the dynamic

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[11] This is the main difference of our model to that of Dutt (1994): His model does not include a Marx effect and only allows for wage-led growth. Hence it is always unstable.

[12] Strictly speaking, the effect of ζ on the employment rate is overlain by changes in capacity utilization. If the system is stable however, this effect does not change the results of the analysis.

profit share equation whereas the Verdoorn effect is also ambiguous through this channel, depending on the character of the growth regime.

Effects on $\dot{\pi}$			
Demand/Growth regime	Wage bargaining effect (μ_1)	Verdoorn effect (ϕ_1) only with incomplete pass-through!	Marx effect (ϕ_2) only with incomplete pass-through!
Wage-led	stabilising	stabilising	stabilising
Profit-led	stabilising	destabilising	stabilising
Effects on $\dot{\zeta}$			
Demand/Growth regime	Direct effect via g	Verdoorn effect (ϕ_1)	Marx effect (ϕ_2)
Wage-led	destabilising	stabilising	stabilising
Profit-led	stabilising	destabilising	stabilising

Table 1: Effects on the dynamic stability of the model

5 Long-term equilibrium

5.1 Baseline model

To analyse the effects of a change in the parameters on the long-term equilibrium we reduce the model to a three-equation system. Equation (3) represents the relationship between capacity utilization and the profit share, i.e. the IS curve. Depending on the demand regime, it is either falling (wage-led) or rising (profit-led) in the u-π plane (Figure 1, right-hand side).

Second, putting equations (1) and (7) into equation (6), we get

$$\bar{\pi} = \frac{n + \phi_0 - (1 - \phi_1)\beta_0 - (1 - \phi_1)\beta_1 u}{(1 - \phi_1)\beta_2 + \phi_3} \tag{14}$$

This curve represents the loci of all combinations of u and π for which the employment rate is constant ('EE curve'). The EE curve is falling in the u-π plane because a higher rate of capacity utilization ceteris paribus raises capital accumulation and thus increases the dynamics of the capital-effective labour supply ratio. The profit share must fall to increase productivity growth and stabilise ζ. The presence of a Verdoorn effect ($0 \leq \phi_1 \leq 1$) does not change the qualitative behaviour of the EE curve as it only reduces the effect of capital accumulation on the dynamics of the capital-effective labour supply ratio.

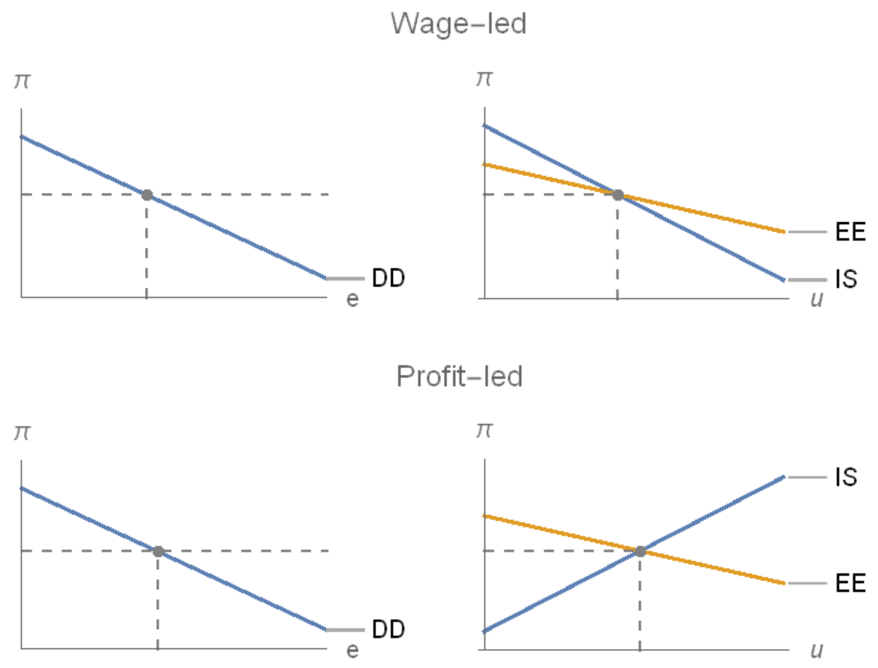

Figure 1: Long-term equilibrium

Third, setting the dynamic equation for the profit share equal to zero, i.e. $\dot{\pi} = 0$, and solving for the employment rate, we get

$$\bar{e} = \frac{\mu_1\gamma_0 + (1-\mu_2)\tau\delta_0 - [\mu_1 + (1-\mu_2)\tau]\pi + (1-\mu_3)\hat{a}}{\mu_1\gamma_1} = \frac{\mu_1\gamma_0 + (1-\mu_2)\tau\delta_0 - [\mu_1 + (1-\mu_2)\tau]\pi + (1-\mu_3)(\phi_0 + \phi_1 g - \phi_2\pi)}{\mu_1\gamma_1} \tag{15}$$

This curve represents the combinations of e and π for which the functional distribution of income is stable ('DD curve').

To see how the model works, we start with the assumption of a complete pass-through of price inflation and productivity growth onto wages, i.e. $\mu_2 = \mu_3 = 1$. In this case the DD curve is reduced to

$$\bar{e} = \frac{\gamma_0 - \pi}{\gamma_1} \tag{16}$$

The employment rate is thus a negative function of the profit share and only depends on the wage bargaining parameters γ_0 and γ_1.[13]

The long-term equilibrium for capacity utilization and the profit share is determined by the intersection of the IS and the EE curve (Figure 1, right-hand side). Since the slope of

[13] This is the simple relationship which is often stated without explicitly modelling the income distribution process, see e.g. Palley (2019) and Taylor et al. (2019). As we see from equation (15), the relation crucially hinges on the assumption of a complete pass-through of price inflation and productivity growth on wages. We give up this assumption in the following subsection.

the IS curve depends on the demand regime, we have to distinguish between a wage-led and a profit-led case. Once the long-term equilibrium for the profit share is determined, the employment rate is given by the DD curve (Figure 1, left-hand side). The IS, EE and DD curves all depend on several exogenous parameters. Any changes in the latter affect the curves differently and thus lead to different model results. There are several demand- and supply-side effects that are of interest:

a) Faster labour supply growth (higher *n*)

An increase in the growth rate of labour supply does not change the IS or the DD curve, since neither aggregate demand nor the profit share dynamic directly depend on *n*. The EE curve however shifts upwards: All other things equal, the profit share must rise to decrease productivity growth (via the Marx effect) or increase capital accumulation[14] to compensate for higher labour supply growth (Figure 2).

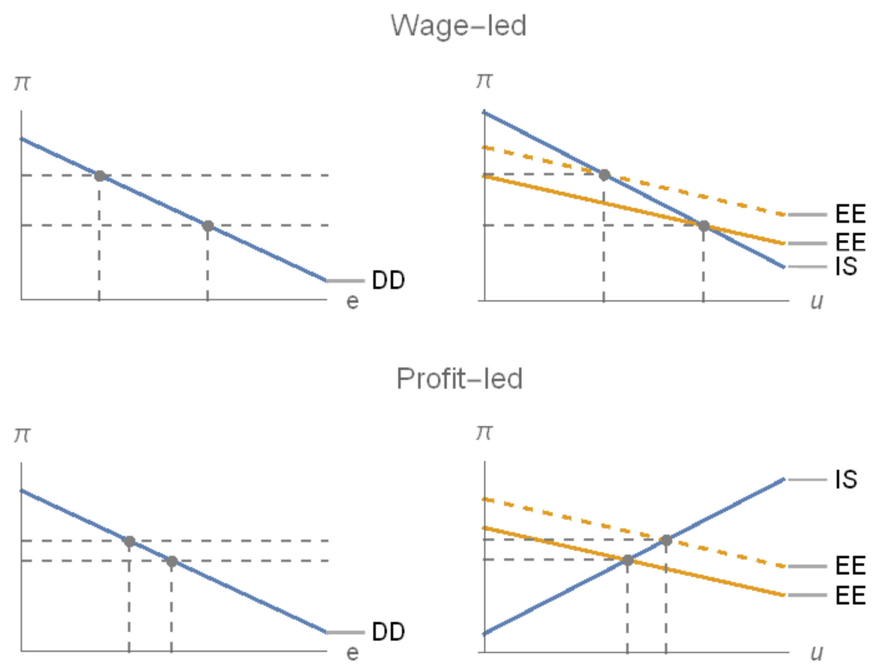

Figure 2: Effects of higher labour supply growth and faster technological change in the baseline model

The effects however depend on the slope of the IS curve and thus on the demand regime. In the wage-led case, the rising profit share leads to a falling capacity utilization. At the same time, it decreases the employment rate via the DD curve, because a lower employment rate is necessary to reduce workers' income claims and thus to balance the

[14] Note that the total effect of the profit share on capital accumulation involves a direct effect via β_2 and an indirect effect via β_1 and u. Thus, leaving capacity utilization unchanged, the direct effect of the profit share on capital accumulation is positive by definition.

profit share dynamic. In the profit-led case, capacity utilization increases. However, the employment rate still falls because the profit share rises.

b) Faster underlying technological change (higher ϕ_0)

An increase in the rate of autonomous technological change has the same effect as a rise in labour supply growth. The EE curve shifts upwards because a higher profit share is necessary to compensate the higher rate of autonomous technological change (via productivity growth and the direct effect on capital accumulation, as before). Both the IS and the DD curve do not change. In the wage-led case, capacity utilization falls, and the profit share rises. In the profit-led case, both the profit share and capacity utilization rise. The employment rate declines in both regimes.

c) Higher investment demand (higher β_0)

Higher autonomous investment demand, e.g. due to a lightening of 'animal spirits', shifts the IS curve to the right (Figure 3). The EE curve however moves downwards because a lower profit share is necessary to balance the effect of a higher capital accumulation on the employment rate. In the wage-led case, capacity utilisation rises, and the profit share falls. In the profit-led case, the profit share also declines. The effect on capacity utilization however is ambiguous since the falling profit share ceteris paribus decreases capacity utilization. The employment rate declines in both cases as the DD curve remains unchanged and the profit share falls.

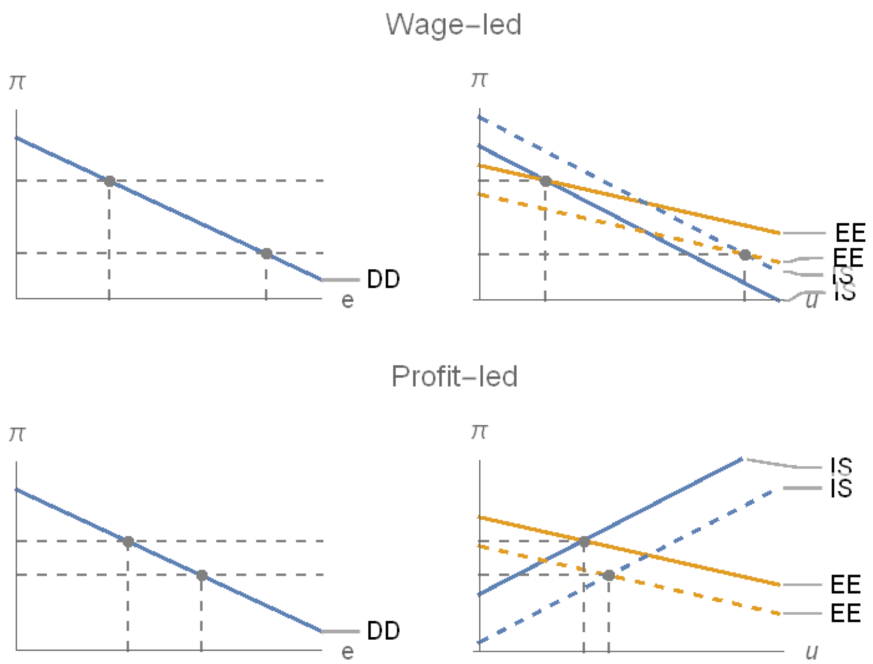

Figure 3: Effects of higher autonomous investment demand

d) Wage bargaining parameters

Any changes in the wage bargaining parameters γ_0, γ_1 or μ_1 leave the IS and the EE curve unchanged. The profit share and capacity utilization thus remain as before. The DD curve shifts downwards in the case of a higher target wage share because it increases wage inflation and thus the dynamics of the profit share. The employment rate consequently declines in the long run, because a constant profit share is only maintained if the employment rate falls. The reason for this outcome is that in the model the profit share is determined by the condition of a stable employment rate and thus the balance between capital accumulation, labour supply growth and productivity growth. Firms use productivity increases as a means to keep their income share constant. Consequently, if the relationship between employment and distribution changes by any shift in the wage bargaining parameters, it is the former that has to give way in the long run.[15]

Table 2 summarizes all these effects: Higher labour supply growth and a higher exogenous rate of technological change have detrimental distribution and employment effects, regardless of whether demand is wage-led or profit-led. Higher autonomous investment demand has exactly the opposite effect. Generally speaking, a supply shock decreases employment and increases the profit share, whereas a demand shock does the opposite, regardless of the demand/growth regime.[16] Any change in the wage bargaining parameters has no effect on capacity utilization and the profit share whatsoever. Employment however falls if workers increase their target for the wage share or their targeted share reacts more strongly to any change in employment.[17]

Shock	IS	EE	DD	Wage-led			Profit-led		
				u	π	e	u	π	e
n	=	↑	=	-	+	-	+	+	-
ϕ_0	=	↑	=	-	+	-	+	+	-
β_0	→	↓	=	+	-	+	±	-	+
$\gamma_0, \gamma_1, \mu_1$	=	=	↓	0	0	-	0	0	-

Table 2: Summary of the effects on the long-run equilibrium with a complete pass-through

[15] The outcome of our model for the employment effects of changes in the wage bargaining parameters resemble those of a standard NAIRU model. It is important to note however, that output and employment are determined by the interaction of demand and supply. The model is thus far from a mainstream model in which 'potential output' is given by the labor supply and technological change.

[16] This is similar to Palley (2019) and Naastepad and Storm (2012). The unambiguous outcomes however hinge on the assumption of a complete pass-through of productivity growth onto wages, as we will see below.

[17] This is different from Palley (2019) since we include a Marx effect in the productivity growth equation.

5.2 Incomplete pass-through of productivity growth

The results of the above analysis change if we assume an incomplete pass-through of productivity growth onto wages. Both the IS and the EE curve remain unchanged with respect to the baseline model. As a consequence, the equilibria for capacity utilization and the profit share do not change, since these two variables are exclusively determined by the IS and the EE curve. The DD curve however changes and is now given by

$$\bar{e} = \frac{\mu_1\gamma_0 + (1-\mu_2)\tau\delta_0 - [\mu_1 + (1-\mu_2)\tau]\pi}{\mu_1\gamma_1} + \frac{+(1-\mu_3)[\phi_0 + \phi_1(\beta_0 + \beta_1 u + \beta_2\pi) - \phi_2\pi]}{\mu_1\gamma_1} \tag{17}$$

Because of the incomplete pass-through of productivity growth onto wages, the DD curve depends on the rate of autonomous technological change, autonomous investment demand and capacity utilization.[18] Any changes in these parameters, and, equally important, in the model outcome for capacity utilization now shift the DD curve. The assumption of an incomplete pass-through consequently affects the outcome of the model for the employment rate, but not for capacity utilization or the profit share.[19]

An increase in labour supply growth increases the profit share, as before. Capacity utilization rises or falls, depending on the demand regime. In the wage-led case, the fall in u shifts the DD curve to the left (Figure 4, left-hand side). The negative effect on the employment rate is thus exacerbated. A lower capacity utilization reduces capital accumulation, which in turn reduces productivity growth via the Verdoorn channel. With an incomplete pass-through, this increases the dynamics of the profit share. Consequently, a lower employment rate is necessary to counterbalance this effect.

In the profit-led case, the DD curve shifts to the right. The effect on the employment rate is thus ambiguous. The increase in the profit share reduces the employment rate. At the same time however, it increases capacity utilization, which in turn increases productivity growth, which is only passed through partially on wages and thus reduces the profit share dynamic. This leads to a rise in the employment rate.

[18] The latter two hinge on the inclusion of the Verdoorn effect as they enter equation (17) via the growth rate g. Without the Verdoorn effect, the DD curve only depends on the rate of autonomous technological change (in addition to the parameters of the baseline model).

[19] The reason is the same as before: the income distribution is determined by the condition of a balance between capital accumulation, labor supply growth and productivity growth, all of which depend on the profit share.

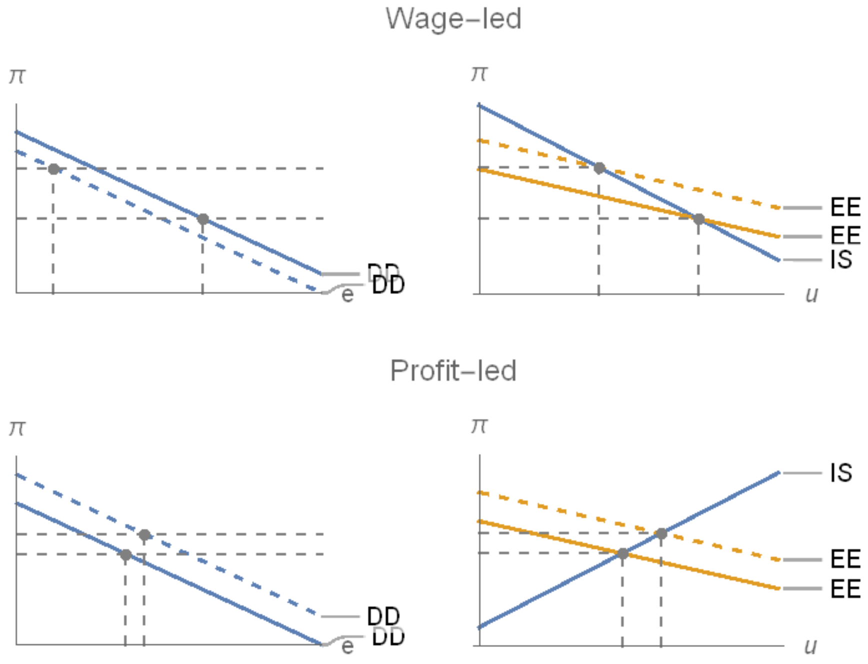

Figure 4: Extended model

An increase in autonomous technological change increases the profit share. Capacity utilization rises or falls, depending on the demand regime. Furthermore, ϕ_0 directly affects the DD curve. Faster technological change is only partially passed through to wages, so that the profit share dynamics decline. Consequently, a higher employment rate is now compatible with a stable functional income distribution.

In the wage-led case, the DD curve can shift right or left, depending on which of the two effects dominates. The employment rate can thus rise or fall. The direct effect of a rise in the profit share (i.e., a movement along the DD curve) and the fall in capacity utilization decrease the employment rate. The higher rate of technological change raises it. In the case of profit-led demand, the rise in capacity utilization contributes to an increase in the employment rate, so that the DD curve unambiguously shifts to the right. The overall outcome however is still ambiguous because the profit share rises.

An increase in autonomous capital accumulation reduces the profit share. The fall in the profit share ceteris paribus increases the employment rate. Capacity utilization unambiguously rises in the case of wage-led demand and is ambiguous in a profit-led regime. The shift of the DD curve due to changes in u thus depends on the demand regime. Lastly, the DD curve shifts to the right because of a direct effect of β_0. The employment rate thus rises in the wage-led case and is ambiguous in the profit-led case. The wage bargain parameters only affect the DD curve, as before. The effects remain the same.

Table 3 summarizes the effects. An incomplete pass-through of productivity growth onto wages changes the outcomes of the model in some cases. A higher labor supply growth can now possibly increase the employment rate in a profit-led regime because capacity utilization rises and ceteris paribus increases productivity growth via the Verdoorn effect. Higher productivity growth is only partially passed through to wages, so that the profit share dynamic falls and a constant profit share is compatible with a higher employment rate.

Furthermore, the effect of a higher rate of technological change on the employment rate is now ambiguous, because it directly reduces the profit share dynamic due to the incomplete pass-through of productivity growth. Technological change can have both positive and negative employment effects, regardless of whether demand is wage-led or profit-led.

Finally, an increase in autonomous investment demand has now an ambiguous outcome for employment in a profit-led regime since the effect on capacity utilization can either be positive or negative, with the DD curve shifting correspondingly. This possibly interferes with the increase in the employment rate due to the fall in the profit share. Lighter 'animal spirits' are thus more likely to raise capacity utilization and employment even though the demand regime is profit-led.

The unambiguous outcomes of our baseline model are thus partially diluted by the incomplete pass-through of productivity growth onto wages. In particular, a supply shock can now also have a positive employment effect even though it still increases functional inequality. A demand shock on the other hand can now have positive effects on employment and capacity utilization even in a profit-led regime. Furthermore, the model now opens up the possibility that a rising profit share is accompanied by a positive employment.[20]

Shock	IS	EE	Wage-led				Profit-led			
			u	π	DD	e	u	π	DD	e
n	=	↑	-	+	↓	-	+	+	↑	±
ϕ_0	=	↑	-	+	⇅	±	+	+	↑	±
β_0	→	↓	+	-	↑	+	±	-	⇅	±

Table 3: Summary of the effects on the long-run equilibrium with an incomplete pass-through

The above analysis allows us to draw some tentative conclusions as to the causes of the economic developments mentioned at the beginning. First, low 'animal spirits' lead to low rates of growth and capacity utilization, to a low employment rate, and to a more unequal distribution of income, in particular in wage-led regimes. At the same time, productivity growth declines. This lends some support to demand-side explanations of 'secular stagnation'. Supply-side causes such as lower population growth or slower

[20] This makes the model less restrictive than our baseline model and the results thus more similar to those of Naastepad and Storm (2012), even though our model goes well beyond theirs.

technological change could possibly also lead to secular stagnation in our model, albeit only in a profit-led regime.

Second, in contrast to what mainstream models tell us, higher labor supply growth and faster technological change can possibly reduce employment, depending on the demand regime. Both the 'techno-optimist' and the 'techno-pessimist' perspective on the employment effects are thus supported, however with a strong tendency for the latter. A positive effect on the employment rate is only possible in the presence of an incomplete pass-through of productivity growth in a profit-led regime. In any case, technological change makes the functional income distribution more unequal. This is very well in line with the hypotheses of polarizing effects of digitization and automatization. Furthermore, the productivity boost of an increase in autonomous technological change is weakened by the increase in the profit share. This is a possible explanation as to why the current digitalization is not reflected adequately in an increase in productivity growth.

6 Working time and labour institutions

A legal working time reduction is sometimes proposed as a means to raise the employment rate and make income distribution more equal, often in the context of potential negative effects of technological change. We therefore extend the model to include the legal working time and show the effects of its reduction on the model outcome.

First, we redefine wages and productivity in hourly terms, both of which depend on the same variables as before. Second, we now differentiate between employment in hours, i.e. L_h, and in persons, L. The employment rate thus amounts to

$$e = \frac{L}{N} = \frac{L_h}{Nh} = \frac{L_h}{Y}\frac{1}{h}\frac{K}{N}\frac{Y}{K} = \frac{\zeta u}{h} \tag{18}$$

with h being the legal working time.[21]

The dynamic equation for ζ (equation (6)) remains unchanged because the definition of this variable is the same as before. The only modification is that productivity growth is now defined in terms of hours. The dynamic equation for the profit share amounts to

$$\dot{\pi} = \Big[\mu_1\gamma_0 - \mu_1\gamma_1\frac{\zeta u}{h} + (1-\mu_2)\tau\delta_0 - [\mu_1 + (1-\mu_2)\tau]\pi + (1-\mu_3)(\phi_0 + \phi_1 g - \phi_2\pi)\Big]\pi \tag{19}$$

Note that the working time h is now included in equation (19).

[21] Since we abstract from the public sector, we implicitly assume that unemployment benefits are taken from employed workers, so that the income share of all workers (employed and unemployed) does not change. Since most of the contributions to social security are paid by employees anyway, this is not too far from reality. We do not capture however the effect of unemployment benefits as an 'automatic stabilizer', i.e. a decrease in government expenditures due to a fall in the unemployment rate.

The Eigenvalues of the differential equation system remain unchanged compared to the baseline model since the partial derivatives of both dynamic equations are the same as before. Thus, the conditions for the stability of the model discussed in section 4 remain valid. Furthermore, the IS, EE, and DD curves all remain the same as in the baseline model (again, with the exception that productivity growth is now defined in hourly terms). The long-term equilibrium of the model is thus unchanged. It follows directly that a working time reduction has no long-term effect on growth, employment or distribution in our model.

The reason for this result is that the condition for a stable employment rate implies a balance between capital accumulation, labour supply growth and productivity growth. Since none of these three variables depend on the employment rate, the profit share has to adjust to balance their dynamics, as in the baseline model. Furthermore, the relationship between functional income distribution and employment defined by the wage bargaining process remains unchanged, since both variables are defined as before. The working time only plays a role for the relationship between the employment rate and capacity utilization, which has no implications for the long-term equilibrium.

Nevertheless, a reduction in the working time unbalances the dynamic system, since the isocline $\dot{\pi} = 0$ shifts downwards in the π-ζ-plane:

$$\bar{\zeta} = \frac{h}{u}\left[\frac{\mu_1\gamma_0 + (1-\mu_2)\tau\delta_0 - [\mu_1 + (1-\mu_2)\tau]\pi}{\mu_1\gamma_1} + \frac{+(1-\mu_3)[\phi_0 + \phi_1 g - \phi_2\pi]}{\mu_1\gamma_1}\right] \tag{20}$$

The intersection between this new isocline and the isocline $\dot{\zeta} = 0$, which remains unchanged, is thus at a lower value of ζ than before. Consequently, the system is out of equilibrium, since none of the other variables has changed so far. With a constant capital-effective labor supply ratio and a constant capacity utilization rate, the employment rate instantaneously increases due to the working time reduction. This triggers a dynamic adjustment process built into the differential equations of the system, until the (former) long-run equilibrium is re-reached. It is important to note that this dynamic process has effects on the *levels* of certain variables, i.e. the capital stock and output, even though the growth rate and the rate of capacity utilization return to their original values.

The dynamics of the system crucially depend on the demand and growth regime. The effect of a working time reduction on the level of output and the capital stock are the cumulative results of the temporary change in the growth rate and capacity utilization. Since the profit share temporarily falls due to the increase in the employment rate, the outcome of the adjustment process is different for wage-led and profit-led regimes.

Figure 5 illustrates the wage-led case. The working time reduction immediately raises the employment rate because the existing workload is redistributed more evenly. Therefore, the profit share declines because workers' bargaining position improves. Since the demand and growth regime are wage-led, both capacity utilization and the growth rate increase instantaneously.

The system is now out of equilibrium. Hence, a dynamic adjustment process sets in through which the profit share and the capital-effective labor supply ratio (and thus the employment rate) gradually readjust to their long-term equilibria.[22] Due to the temporary increase in the growth rate, the capital stock is higher in the new equilibrium than before. Since the ratio of output to the capital stock (i.e., the rate of capacity utilization) returns to its original value, the level of output is also higher in the new equilibrium. It is worth noting that the level of output increases sharply immediately after the working time reduction because of the upward jump in capacity utilization. During the dynamic process it gradually decreases to its new (higher) level due to the readjustment in the utilization rate. Obviously, in a profit-led regime, we would get the opposite result.

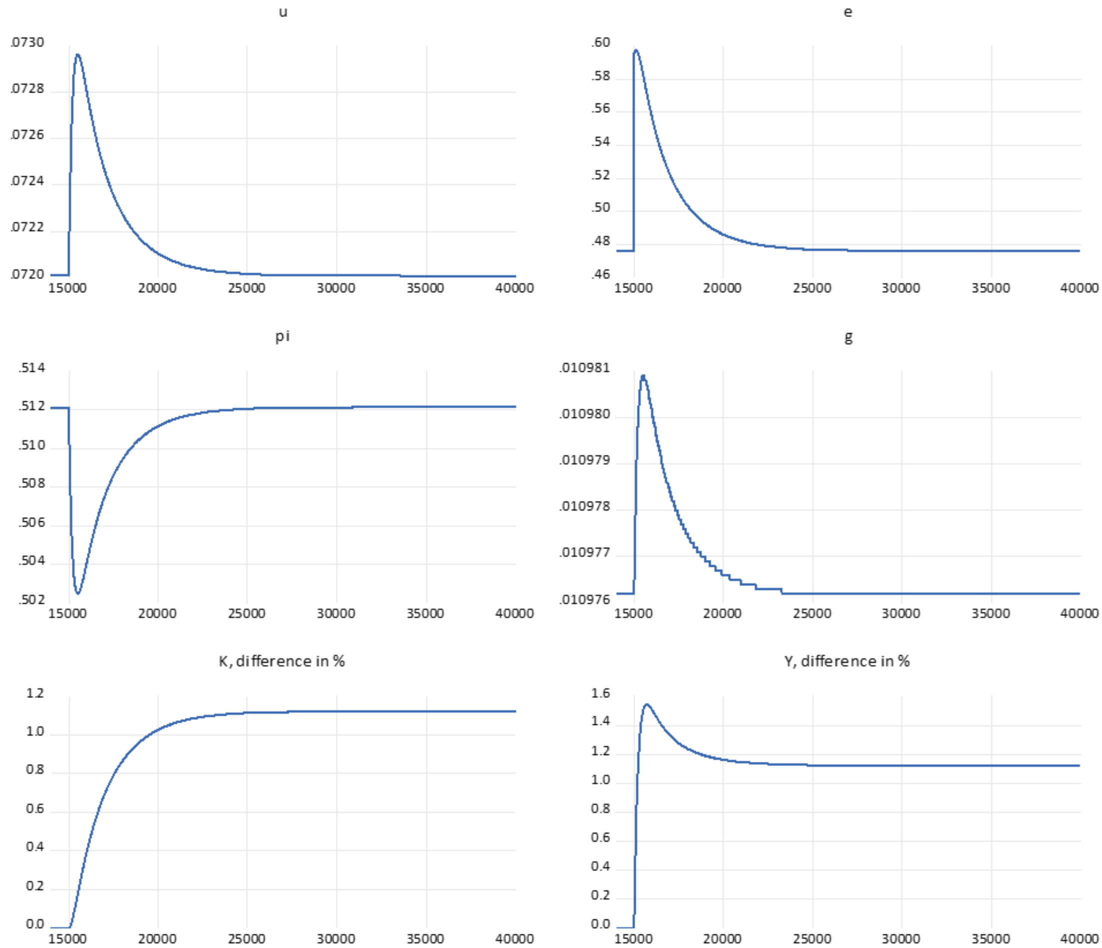

Figure 5: Working time reduction in a wage-led growth/demand regime.

A similar analysis can be conducted for any change in labour institutions, which is reflected by a shift in the wage bargaining parameters in our model. A better bargaining position of workers due to, say, an increase in unionization, could be reflected in a higher target wage share (γ_0), a higher elasticity of the wage share target with respect to the employment rate (γ_1), or in gaining a higher proportion of the difference between the target and the actual wage share (μ_1). Changes in the bargaining parameters have no

[22] The adjustment process can possibly follow a cyclical or a straight path, depending on the Eigenvalues of the differential equation system. See section 3.

impact on the functional income distribution and capacity utilization, but only modify the long-term equilibrium employment rate (see section 6). Since all parameters have similar effects, we focus on a change in the target wage share in what follows.[23]

An increase in the target wage share of workers immediately raises wage inflation and thus decreases the profit share (Figure 6). Since the long-term equilibrium remains unchanged, this initiates a temporary adjustment process. In a wage-led regime, the increase in the profit share raises capacity utilization and growth. Similar to above, both rates gradually decrease to their former values. The capital stock and the level of output at the end are however higher than before the shock. Even though a better bargaining position of workers does not increase the wage share and thus capacity utilization and growth in the long run, the economy ends up at a higher output. In contrast to the working time reduction, the long-term employment rate is lower than before, because the relationship between employment and distribution (i.e., the DD curve) has shifted.

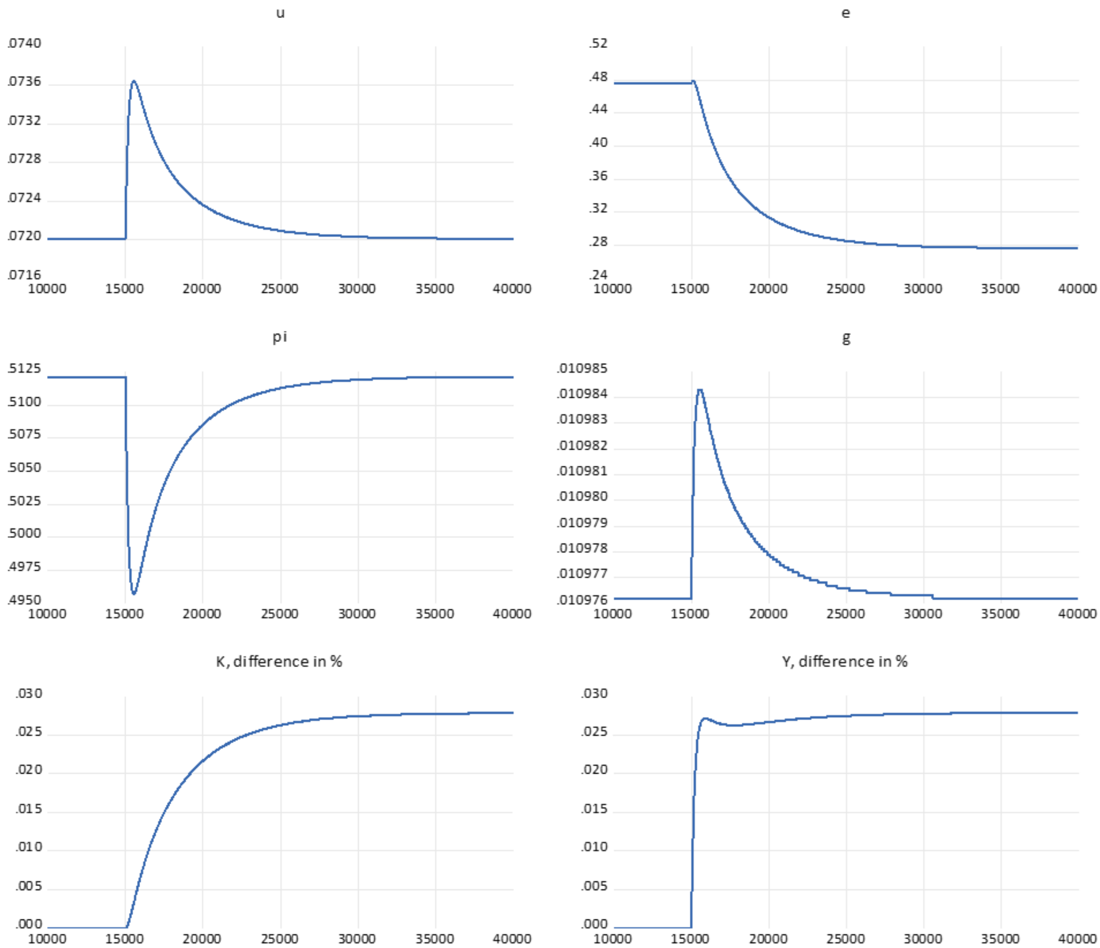

Figure 6: Increase in workers' bargaining position

Finally, it is worth noting how the inflation rate reacts to a demand shock when at the same time the wage bargaining position of workers erodes (Figure 7). Price inflation is

[23] Similar to above, we present the dynamics for a wage-led demand and growth regime. The outcome for a profit-led regime would be the opposite.

given by the deviation of the profit share from the target of firms (equation (9)). Since the latter is constant in the model, the inflation rate is determined by the former. A positive demand shock reduces the long-term equilibrium for the profit share, which thereby deviates further from firms' target. Consequently, prices increase, and inflation rises over time to its new long-term equilibrium. An erosion of workers' bargaining power on the other hand raises the employment rate but leaves all other variables unchanged. The long-term inflation rate is thus the same as before.[24] A combination of such a change with the above-mentioned positive demand shock would result in the same long-term equilibrium as just the latter alone, except for a higher employment rate.

Temporarily however, the erosion of workers' bargaining power increases the profit share and thus reduces inflation. Due to the demand shock, prices pick up momentum after some time, but inflation remains subdued during the entire adjustment process because of the negative bargaining power shock, even though in the end it reaches its new equilibrium. At the same time, the employment rate increases at a faster rate to a higher equilibrium. Both the demand shock and the bargaining power shock contribute to this rise. The erosion of workers' bargaining power might thus be a reason for the observed 'break-down of the Philips curve': an increase in demand and employment entails only a moderate rise of the inflation rate.

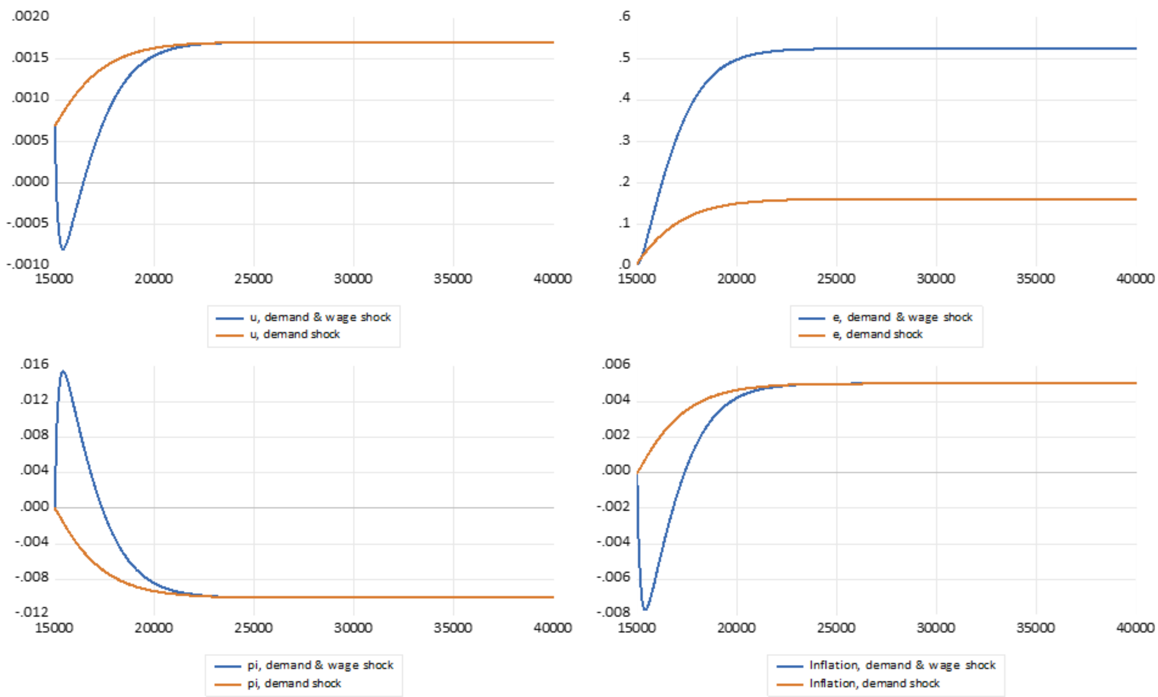

Figure 7: Effects of a demand shock with an erosion of labour power

[24] Note that this is different from a standard NAIRU model: the long-term inflation rate does not depend on the relative powers of workers and capitalists in the bargaining process, but only on the profit share, which is determined by the condition for a stable employment rate.

7 Conclusion

We contribute to a growing literature which aims at analysing labour market dynamics in a Post-Keynesian growth model. The dynamics of endogenous productivity growth emerge as the regulating factor in our model in stabilizing the employment rate and the relative wage share in the long run: technological change adjusts to mitigate class struggle by replenishing the reserve army and thereby keeping wage demands in check. This channel improves if increases in labour productivity are passed on to workers incompletely, as has been the case in many advanced economies over the past decades.

Our main findings are that a demand shock is likely to lower the profit share and increase the employment rate. A supply shock (i.e., higher labour supply growth or technological change) in contrast tends to have detrimental effects on employment and the income distribution, even though the growth rate potentially rises. Including an incomplete pass-through of productivity growth onto wages somewhat dilutes the unambiguous results of the baseline model but maintains the overall tendency of its outcomes.

Labour market institutions have no long-term effect on growth, distribution and inflation in the model, but impact the employment rate. Their effects on the capital stock and the level of output depend on the regime: If demand and growth are wage-led, an increase in workers' bargaining power leads to a temporary increase in the growth rate, so that the economy ends up at a higher output level than before. Furthermore, an erosion of labour market institutions dampens inflation (only) temporarily.

Reductions in working time have no effects on growth, employment and distribution in the long run, regardless of the demand and growth regime. They however have positive temporary effects on growth and lead to a higher output level and a higher capital stock in a wage-led regime. Proposals for reducing working time as an effective means of lowering income and environmental impacts are thus not supported by our analysis.

The outcomes of the model provide possible explanations for several current economic phenomena. 'Secular stagnation' is most likely caused by a lack of demand. Digitalisation and automatization increase the inequality between workers and capitalists, and possibly have negative effects on the employment rate even if they raise growth. Faster autonomous technological change can partially be offset by an endogenous slow-down of productivity growth due to the rising profit share. Finally, the erosion of labour market institutions is a possible cause for the 'break-down of the Philips curve' since it subdues inflation, even though an increase in demand raises growth and employment.

The above simulations show that the temporary effects of certain policy measures, such as a legal working time reduction or the strengthening of wage bargaining institutions depend on the demand and growth regime. Since adjustment to the long run equilibrium works via changes in productivity and therefore takes time, these temporary effects are obviously important. Determining empirically whether the regimes are wage-led or profit-led is thus still important for policy analysis. Furthermore, an empirical investigation into the extent of the Marx effect of income distribution on productivity growth is crucial to assess the speed of the adjustment process and thus the duration of the temporary effects.

A few caveats are worth mentioning: First, the distribution dynamic in our model follows a bargaining process which mediates the conflicting claims of workers and capitalists, and whose outcome is a negative relationship between employment and distribution. Yet there are good arguments in the Post-Keynesian literature why this relationship might be reversed. This would possibly entail significant consequences for the stability of the model and its long-term equilibrium. Second, we focus on the functional income distribution as conventional in Post-Keynesian models. A small but growing literature extends this kind of models by personal income distribution. This would allow to analyse the distributional consequences of technological change not only in terms of functional income distribution but also with regard to the distribution of labour income itself and would thereby better capture the spirit of the 'polarisation' debate. Third, other variables such as wealth accumulation and distribution, which are not considered in the model, might play a major role for its dynamic stability and the results. These extensions are beyond the scope of the present paper and are left for future research.

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Appendix A: Model extensions

The model can be extended by including other effects mentioned in the literature: First, following Lima (2004), we add the possibility of technology-induced investment. Technological change can place continuous pressure on firms to invest in order to remain competitive, whereas the process of innovation itself opens up new investment opportunities for firms. The extended investment equation amounts to

$$g = {}^{I}/_{K} = \beta_0 + \beta_1 u + \beta_2 \pi + \beta_3 \hat{a} \tag{A1}$$

Capacity utilization and the growth rate consequently depend on the rate of autonomous technological change. This increases the probability of wage-led demand, since a rise in the profit share ceteris paribus reduces productivity growth, which in turn dampens investment and thus capacity utilization. All of the above-analyzed effects but those of a rise in the rate of autonomous technological change however remain the same.

Faster autonomous technological change ceteris paribus increases investment and thus shifts the IS curve to the right. The effects on the EE and the DD curve qualitatively remain the same as in the baseline model. In the case of wage-led demand, capacity utilization and the profit share can now possibly also rise if the induced investment effect is strong. In the profit-led case, capacity utilization still unambiguously increases, as in the baseline model. The profit share however can now possibly also decrease. The effects of faster technological change on distribution and growth thus become completely ambiguous.

Shock	IS	EE	Wage-led				Profit-led			
			u	π	DD	e	u	π	DD	e
ϕ_0	→	↑	±	±	⇅	±	+	±	⇅	±

Table A1: Summary of the effect of an increase in the rate of exogenous technological change with technology-induced investment demand

Second, we allow for firms' profit share target to depend on capacity utilization. The economic logic is that firms increase their mark up when operating near full capacity. The price equation now amounts to

$$\hat{p} = \tau(\pi_{Tr} - \pi) = \tau(\delta_0 + \delta_1 u - \pi) \tag{A2}$$

The only change compared to the baseline model is in the DD curve, which now also depends on capacity utilization (independently of whether or not there is an incomplete pass-through). The direction of the shift of the DD curve due to a change in capacity utilization however is the same as that of the Verdoorn effect in the baseline model. Furthermore, since the IS and the EE curve remain unchanged, the effects on u and π are also the same. This effect thus adds nothing to the above-mentioned analysis.

A third and interesting extension is to include an (inverse) Okun effect. The Okun effect is usually specified as an elasticity of employment with respect to output of less than one. The result is that productivity changes pro-cyclically when output rises or falls. We include a capacity utilization term into the equation for productivity growth, i.e.

$$\hat{a} = \phi_0 + \phi_1 g - \phi_2 \pi + \phi_3 u, \tag{A3}$$

to represent this pro-cyclicality in productivity growth. The higher the parameter ϕ_3 (assuming that $0 \leq \phi_3 \leq 1$), the higher is the pro-cyclicality of productivity growth. We thus label ϕ_3 *inverse* Okun effect, which partially decouples output and employment growth.[25]

The inclusion of the inverse Okun effect does not change the properties of the IS and the DD curve. Interestingly however, it potentially makes the EE curve upward rising. With a strong inverse Okun effect (i.e., a strong pro-cyclicality of productivity growth), a higher capacity utilization ceteris paribus increases productivity growth, so that the profit share must rise to balance the employment rate via the Marx effect.

All effects but those of a rise in autonomous investment remain unchanged. The latter however now possibly increases the profit share. With wage-led demand, this somewhat dampens the positive effect on capacity utilization so that the employment effect becomes ambiguous.

Shock	IS	EE	Wage-led				Profit-led			
			u	π	DD	e	u	π	DD	e
β_0	→	↓	+	±	↑	±	±	±	⇅	±

Table A2: Effect of an increase in autonomous investment demand with the inverse Okun channel

[25] This is a way to partly decouple output and employment different to Palley (2012, 2014), who gives up the mutual dependency between those two variables entirely.