Income distribution, technical change, and economic growth: A two-sector Kalecki–Kaldor approach

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Income distribution, technical change, and economic growth: A two-sector Kalecki–Kaldor approach

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Abstract

This paper presents a two-sector Kalecki–Kaldor model of income distribution, technical change, and economic growth. The model is Kaleckian in the sense that it incorporates mark-up pricing, investment independent of saving, and excess capacity. It is also Kaldorian in that labour productivity growth is led by Kaldor's technical progress function. In other words, productivity growth is endogenously realised through the technology embodied in new capital stock, which differentiates our model from previous two-sector models. Our extension drastically changes the standard Kaleckian implications. We find that although the economic activity levels in the short run are led by the demand and income distribution parameters, economic growth in the long run is realised by supply-side (i.e. technical change and the associated productivity and wage growth) parameters. The important implication of our findings is that a two-sector economy faces a trade-off between a high economic growth rate and the local stability of the steady state.

Keywords: Two-sector model, Economic growth, Endogenous productivity growth, Technical change, Income distribution

JEL Classification: D33, E12, O41

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1 Introduction

This study analyses the short- and long-run macroeconomic performance of income distribution, technical change, and economic growth in a two-sector economy in which sector 1 is a capital goods production industry and sector 2 is a consumption goods production industry. The model is built from a Kaleckian perspective of income distribution and economic growth. It also explicitly incorporates technical progress and the associated productivity growth from the Kaldorian perspective.

Kaleckian models have analysed the relationship between functional income distribution and economic growth. The analysis of the existence and stability of wage-led demand (WLD) and profit-led demand (PLD) regimes has attracted much research interest (Lavoie and Stockhammer (2013); Setterfield (2016); Nishi and Stockhammer (2020a,b)). Since effective demand is the driving force of the economic growth in these models, they are characterised as demand-led growth models (Blecker and Setterfield (2019)). Over time, demand-led growth models have been extended in various ways, with endogenous change in labour productivity, in particular, being recently introduced (Storm and Naastepad (2017); Tavani and Zamparelli (2017); Fazzari et al. (2020)). As these models are mostly built in an aggregate style, as shown by Tavani and Zamparelli (2017), they do not consider the dynamics of production and expenditure specific to each industry or the associated feedback between sectors.

Indeed, recent empirical studies have found that macroeconomic performance measures such as income distribution, economic growth, and productivity dynamics are heterogeneously affected by different industries. For instance, De Serres et al. (2002) show that the decline in the aggregate wage share over much of the 1980s and 1990s in European countries and the United States partly reflects changes in the sectoral composition of the economy. Timmer et al. (2013) empirically find that the industry sources of Europe's economic growth slowdown differ from those of the United States. In analysing Baumol's growth disease, Nishi (2019) reveals that manufacturing and non-manufacturing sectors in Japan present different productivity growth rates. These empirical studies highlight that the roles of different industries are crucial to understanding long-run macroeconomic performance. However, an aggregate macroeconomic model cannot analyse such heterogeneous industrial dynamics.

To shed light on some of these dynamics, a disaggregated approach has gradually developed in Kaleckian studies and the two-sector model is the most dominant platform. Recent studies featuring Kaleckian (or post-Keynesian) two-sector models have tended to follow three threads: (i) the effect of income distribution and savings (Fujita (2019a,b); Beqiraj et al. (2019)), (ii) the possibility of business cycles (Murakami (2017); Murakami and Zimka (2020)), and (iii) endogenous change in productivity growth (Bassi and Lang (2016); Nishi (2020)).

First, Fujita (2019a,b) finds the existence of a hybrid demand regime in different sectors. A hybrid demand regime means that the demand regime (i.e. WLD/PLD) differs between two sectors. Beqiraj et al. (2019) show a structural change towards tertiarisation advances through changes in consumers' preference or the saving rate. These phenomena are particular to the multisector model, but none of these models suppose an endogenous change in productivity growth. Second, Murakami (2017) finds the existence of limit cycles, and Murakami and Zimka (2020) further identify their stability in a two-sector model. Interestingly, they reveal that investment goods production leads consumption goods production in business cycles. However, income distribution and technical change are excluded from these models. Third, Bassi and Lang (2016) present an agent-based model with endogenous productivity growth to explain hysteretic output dynamics. Nishi (2020) formalises endogenous labour productivity changes and also finds the existence of a hybrid demand regime. These studies are important because two-sector models have paid less attention to labour productivity dynamics. Nonetheless, Bassi and Lang (2016) *a priori* suppose a WLD regime only, whereas the mechanism of the technical change is ambiguous in Nishi (2020).

The causes and effects of income distribution, labour productivity dynamics, and growth cycles have thus been important research topics in the two-sector Kaleckian (or post-Keynesian) studies. However, previous models have focused on only one or two of these aspects despite increasing research interest and the empirical relevance of the multisectoral perspective. Consequently, the linkage and feedback mechanism between income distribution, labour productivity dynamics, and economic growth have not been comprehensively understood in Kaleckian two-sector models.

How do income distribution, technical change, and effective demand dynamics interact to generate the sectoral and macroeconomic outcomes in a multisector framework? The present study contributes to answering this fundamental question by comprehensively analysing the linkage or feedback mechanism among them. Essentially, we adopt a Kaleckian approach, as we set an investment function independent of savings and mark-up pricing in oligopolistic goods markets characterised by excess capacity. Moreover, the presented model is also Kaldorian in the sense that labour productivity growth is endogenously determined by the technical change embodied in capital accumulation. Hence, we call our approach a two-sector Kalecki–Kaldor (TKK) approach.[1]

Following previous studies, we examine the short- and long-run dynamics of a two-sector economy. In the short run, a change in the exogenous variables is accommodated by the variation in the capacity utilisation rates. In the long run, while the capacity utilisation rates continuously vary, the dynamics of capital accumulation and technical change also proceed.

Our model departs from those of previous studies in two ways. First, we introduce technical change and the associated productivity and wage growth dynamics as the supply-side effects. Following Foley et al. (2019) Chapter 3, the production technique in a sector is defined by its labour productivity and the output–capital ratio, and the pattern of technical change is identified by its growth rates. This extension, thus, differentiates our study from the first and second threads of previous studies discussed above, which do not incorporate these effects.[2] Second, unlike Bassi and Lang (2016), we do not suppose an *a priori* WLD regime only, and differently from Nishi (2020), technical change is explicitly formalised through the Kaldorian technical progress mechanism as a long-run phenomenon.[3] By doing so, this study comprehensively addresses the

[1]This study is a theoretical analysis, but the approach also has empirical relevance. For instance, the Kaleckian model has been applied to estimate the relationships among income distribution, aggregate demand, and economic growth in many countries, and WLD and PLD regimes have been identified (Lavoie and Stockhammer (2013) and Stockhammer (2017)). Meanwhile, although Kaldor (1957)'s model is dated, the empirical validity of its technical progress function is still econometrically confirmed. Fabrizio et al. (2020) empirically show that both the output growth rate and the process of capital intensification exert positive effects on labour productivity growth. Marquetti et al. (2020) also confirm that higher capital accumulation is associated with a higher and positive labour productivity growth rate.

[2]This study regards technical change and the associated productivity and wage growth as a supply-side effect because they principally determine how efficiently an economy can produce goods and generate income using different production techniques. This effect is also affected by the changes in effective demand dynamics in the following dynamic modelling.

[3]Nishi (2020) is the closest to the present study, but it has two deficiencies in reality. The first is that the endogenous change in productivity growth proceeds before capital accumulation in his model, which does not fit with the historical fact that technical change is embodied in new capital stock (Duménil and Lévy (2010); Campbell and Tavani (2019)). The second is that capitalists do not consume at all, saving all that they earn. This behaviour is probably assumed for simplicity to analyse the model. However, it means that capitalists cannot survive because they do not consume, which is unrealistic. Our TKK approach also addresses these deficiencies.

remaining gaps in the body of knowledge on this topic.

Our TKK approach offers similar short-run implications for standard Kaleckian models, but this drastically changes in the long run. First, the two-sector economy's activity levels in the short run are led by demand and income distribution. The hybrid demand regime can also be observed in our model, where the two sectors respond differently to the same distribution shock. Second, in the long run, the growth rates of output and labour productivity are exclusively realised by the supply-side effects. These effects also determine the persistent disparity in the growth rates of productivity and wages between the two sectors. Lastly, the so-called paradoxes of cost and thrift do not work in this period.[4] Thus, the model is Kaleckian in the short run but Kaldorian in the long run. In summary, the novelty of the present study is that these long-run implications have not been revealed by previous two-sector models.

The remainder of this paper is organised as follows. Section 2 describes the basic framework of our model. Section 3 presents a short-run analysis that considers the extent to which changes in income distribution and the saving rate affect the capacity utilisation rates. Section 4 investigates the long-run dynamics under which capital accumulation and the associated change in labour productivity growth are also realised. Identifying the stability conditions for the long-run steady state, it also sheds light on how macroeconomic performance differs from industrial performance with regard to changes in the relevant parameters. Finally, Section 5 concludes. The Appendix provides the mathematical explanations for the comparative statics analysis.

2 Model

This section describes the TKK model, which consists of the dynamics of the capacity utilisation rates, the relative ratio of the unit labour cost, and capital stock between the two sectors. We use the following notations to set up the model: X_{it}: output level, D_{it}: effective demand, L_{it}: labour employment, K_{it}: capital stock, C_{it}: consumption, I_{it}: investment, w_{it}: nominal wage rate, r_{it}: profit rate, p_{it}: price level, μ_{it}: mark-up rate, a_{it}: labour productivity level, g_{it}: capital accumulation rate, m_{it}: profit share, u_{it}: capacity utilisation rate, k_t: relative capital ratio (hereafter

[4]The paradox of costs means that lowering the wage share (or real wages) leads to lower output and higher employment. The paradox of thrift implies that a rise in the saving rate actually lowers aggregate demand. Both paradoxes arise because of a fall in consumption demand, causing the profit rate or output growth rate to decline consequently.

capital ratio), z_{it}: relative unit labour cost ratio (hereafter unit cost ratio), i: sector $i = 1, 2$, and t: time. The variables with t change over time, but we do not explicitly denote it below for parsimony.

A closed economy with no government sector is supposed. It is composed of two sectors: sector 1 produces capital goods and sector 2 produces consumption goods. Each sector specialises in its original goods using capital stock and labour. In each sector, workers supply labour to firms managed by capitalists. The former receive a wage bill and the latter receive a profit income. The model does not suppose the depreciation of capital stock or intermediate goods for simplicity.

Firms in the economy operate with the following Leontief-type fixed coefficient production function using capital stock and labour:

$$X_1 = \min(u_1 K_1, a_1 L_1), \tag{1}$$

$$X_2 = \min(u_2 K_2, a_2 L_2). \tag{2}$$

We suppose that the potential output–capital ratio is constant and normalised to unity. Then, the output–capital ratio can be considered to be the capacity utilisation rate (i.e. $u_i = X_i/K_i$).[5] When this rate is constant at a steady state in the long run, the growth rates of capital stock and actual and potential output levels are the same.

The income generated by production and selling is distributed to the workers and capitalists in each sector:

$$p_1 X_1 = w_1 L_1 + p_1 r_1 K_1, \tag{3}$$

$$p_2 X_2 = w_2 L_2 + p_1 r_2 K_2, \tag{4}$$

where $p_i X_i$ is total income, $w_i L_i$ is the wage bill, and $p_1 r_i K_i$ is the total profit in sector i.

Each sector is under monopolistic competition, and the capitalists set the price level based on mark-up pricing:

$$p_1 = (1 + \mu_1)\frac{w_1}{a_1}, \tag{5}$$

$$p_2 = (1 + \mu_2)\frac{w_2}{a_2}. \tag{6}$$

[5]The output–capital ratio can be decomposed into $u_i = \frac{X_i}{\bar{X}_i} \cdot \frac{\bar{X}_i}{K_i}$, where $\bar{X}_i$ denotes the potential output of sector i. As the capital stock to potential output ratio is set to unity, the movement of the output–capital ratio is proportional to the ratio of actual output to potential output. Accordingly, the output–capital ratio is a proxy of the capacity utilisation rate.

The mark-up rate μ_i is set over the unit labour cost. The present model assumes that the nominal wage rates are different and considers an endogenous change in wage growth at a different pace in the long run.[6]

Based on eqs. (3)–(6), the profit share of each sector is

$$m_1 = 1 - \frac{w_1 L_1}{p_1 X_1} = \frac{\mu_1}{1+\mu_1}, \tag{7}$$

$$m_2 = 1 - \frac{w_2 L_2}{p_2 X_2} = \frac{\mu_2}{1+\mu_2}. \tag{8}$$

Thus, there is a one-to-one relationship between the profit share and mark-up rate. A rise in the latter obviously increases the former. If the mark-up rate is constant, we can regard the profit share as an exogenous variable. Below, we employ the profit share as such and clarify its impact on the capacity utilisation rates and output growth.

Replacing the mark-up rate with the profit share in eqs. (5) and (6), we define the relative price ratio between the two sectors as follows:

$$p \equiv \frac{p_1}{p_2} = \left(\frac{1-m_2}{1-m_1}\right) z, \tag{9}$$

where $z \equiv \dfrac{w_1 a_2}{w_2 a_1}$ is the unit cost ratio, which is supposed to be constant in the short run.

Next, we define demand for (expenditure on) the goods produced in each industry. Demand for the capital goods produced in sector 1 consists of the expenditure by firms in both sectors. In the nominal term, their demand is

$$p_1 D_1 = p_1(I_1 + I_2). \tag{10}$$

Then, we introduce a linearised version of the investment function *à la* Bhaduri and Marglin (1990) that also determines the capital accumulation rate in the long run:

$$\frac{I_1}{K_1} = g_1 = \alpha_1 + \beta_1 m_1 + \gamma_1 u_1, \tag{11}$$

$$\frac{I_2}{K_2} = g_2 = \alpha_2 + \beta_2 m_2 + \gamma_2 u_2, \tag{12}$$

where α_i is a positive constant term and β_i and γ_i are positive coefficients that measure the profit effect and accelerator effect of the investment demand, respectively. In a multisector model,

[6] Sraffian questions Kaleckian that a change in the mark-up rate in one sector affects the mark-up rate and price level in another sector (Steedman (1992)). If one introduces intermediate goods into a two-sector model, this may happen as Fujita (2019a,b) shows. However, this study exclusively examines the interactions of income distribution, technical change, and effective demand dynamics of two sectors, without using Sraffian price determination.

these parameters may differ across sectors, meaning that the effect of each variable on sectoral investment is heterogeneous.

Substituting eqs. (11) and (12) into (10) and representing demand for capital goods by the capacity utilisation rate, we obtain the following equation:

$$\frac{D_1}{K_1} = \alpha_1 + \beta_1 m_1 + \gamma_1 u_1 + (\alpha_2 + \beta_2 m_2 + \gamma_2 u_2)k, \tag{13}$$

where $k \equiv \dfrac{K_2}{K_1}$ is the capital ratio between the two sectors, which is supposed to be constant in the short run.

Demand for the consumption goods produced in sector 2 consists of the expenditure by the workers and capitalists in both sectors. Assuming a classical consumption hypothesis, the workers spend all their wage income, whereas the capitalists spend a proportion of their profit income. We simply assume that the saving rate of the capitalists is unique across the sectors, which is denoted by $s \in (0, 1)$. Demand for consumption goods presented in the nominal term is

$$p_2 D_2 = p_2(C_1 + C_2) = (w_1 L_1 + w_2 L_2) + (1 - s)(p_1 r_1 K_1 + p_1 r_2 K_2), \tag{14}$$

where the first and second terms on the right-hand side represent consumption by all the workers and that by all the capitalists, respectively. Normalising with sector 2's nominal capital stock, demand for consumption goods is written as follows:

$$\frac{D_2}{K_2} = \frac{z(1 - sm_1)(1 - m_2)u_1}{k(1 - m_1)} + (1 - sm_2)u_2. \tag{15}$$

The propensity to consume is higher for the workers than for the capitalists. Then, a rise in the saving rate by the capitalists (s) reduces demand for consumption goods.

Further, a rise in the profit share in sector 1 (m_1) increases demand for consumption goods for the following reasons. First, it decreases demand for consumption goods through the redistribution of income from the workers to the capitalists. Second, by contrast, a rise in sector 1's profit share lowers the price of consumption goods towards that of capital goods (i.e. a higher p), increasing the purchasing power of both the capitalists and the workers in sector 1 for consumption goods. If the saving rate of the capitalists is below unity, the second effect works stronger than the first effect.[7]

[7] In eq. (15), a rise in the profit share reduces consumption demand by $-sp\frac{u_1}{k}$, which is the first effect. It simultaneously increases that demand by $(1 - sm_1)\frac{u_1}{k}\frac{\partial p}{\partial m_1}$ through the change in the relative price ratio, which is the

Moreover, a rise in sector 2's profit share (m_2) decreases demand for consumption goods because it redistributes income from the workers to the capitalists. Additionally, it raises the price of consumption goods towards that of capital goods (i.e. a lower p), also decreasing the purchasing power of both the capitalists and the workers in sector 1 for consumption goods.

Finally, a change in the unit cost ratio (z) alters the relative price ratio, affecting the purchasing power of the workers and capitalists in sector 1. If the unit labour cost falls faster in sector 2 than in sector 1, the unit cost ratio rises. Then, sector 2's price level becomes cheaper (i.e. a higher p), increasing the purchasing power of the workers and capitalists in sector 1 for consumption goods.

3 Analysis of the short-run dynamics

3.1 Dynamic system, steady state, and stability

In the short run, the quantity adjustment is dominant given the technique of production in a sector. In other words, the state variables are the sectoral capacity utilisation rates u_i given the capital ratio k and unit cost ratio z.[8]

The dynamic system consists of the quantity adjustment process for excess demand or supply for capital and consumption goods:

$$\dot{u}_1 = \phi_1 \left(\frac{D_1}{K_1} - u_1 \right) = \phi_1 (g_1 + g_2 k - u_1), \tag{16}$$

$$\dot{u}_2 = \phi_2 \left(\frac{D_2}{K_2} - u_2 \right) = \phi_2 \left(\frac{z(1 - s m_1)(1 - m_2) u_1}{k(1 - m_1)} - s m_2 u_2 \right), \tag{17}$$

where the dot over the variable represents its time derivative (i.e. $\dot{u}_i \equiv du_i/dt$). ϕ_1 and ϕ_2 are positive parameters representing the adjustment speed of the quantity in sectors 1 and 2, respectively, and g_1 and g_2 follow eqs. (11) and (12), respectively.

second effect. Therefore, the total effect is

$$\frac{\partial D_2/k_2}{\partial m_1} = \frac{(1-s)u_1 p}{(1-m_1)k},$$

which is positive if the saving rate of the capitalists is below unity.

[8]We conventionally divide the entire period into the short and long run, but actually the long-run trend is only a slowly changing component of a chain of short-run situations, as Kalecki (1971) states (p. 165). Put differently, in this time process, the capacity utilisation rates are fast variables, which vary faster than the slow ones. The slow variables are capital stock and labour productivity, which are fixed in the short run.

The steady state is given by the capacity utilisation rates (u_1^*, u_2^*) satisfying $\dot{u}_1 = \dot{u}_2 = 0$. We can find a unique value of the short-run steady state as follows:

$$u_1^* = \frac{(1-m_1)\,m_2 s(G_1+G_2k)}{sm_2\,(1-\gamma_1)\,(1-m_1)-\gamma_2(1-m_2)(1-sm_1)z}, \tag{18}$$

$$u_2^* = \frac{(1-m_2)\,(1-sm_1)\,z(G_1+G_2k)}{k[sm_2\,(1-\gamma_1)\,(1-m_1)-\gamma_2(1-m_2)(1-sm_1)z]}, \tag{19}$$

where we denote $G_1 \equiv \alpha_1+\beta_1 m_1 > 0$ and $G_2 \equiv \alpha_2+\beta_2 m_2 > 0$. As we show below, the steady-state values of the capacity utilisation rates are positive if their local stability conditions are ensured.

We then investigate the local asymptotic stability of the steady state by linearising the system of differential eqs. (16) and (17). Let $\boldsymbol{J}^*$ denote the Jacobian matrix for the short-run dynamic system; its elements are given as follows:

$$j_{11} \equiv \frac{\partial \dot{u}_1}{\partial u_1} = -\phi_1(1-\gamma_1), \tag{20}$$

$$j_{12} \equiv \frac{\partial \dot{u}_1}{\partial u_2} = \phi_1\gamma_2 k, \tag{21}$$

$$j_{21} \equiv \frac{\partial \dot{u}_2}{\partial u_1} = \frac{\phi_2(1-sm_1)(1-m_2)z}{k(1-m_1)}, \tag{22}$$

$$j_{22} \equiv \frac{\partial \dot{u}_2}{\partial u_2} = -\phi_2 sm_2, \tag{23}$$

where all the elements are evaluated at the steady state. The necessary and sufficient conditions for the stability of the short-run steady state are

$$\mathrm{Tr}\,\boldsymbol{J}^* = -\phi_1(1-\gamma_1) - sm_2\phi_2 < 0, \tag{24}$$

$$\det \boldsymbol{J}^* = \frac{\phi_1\phi_2}{1-m_1}\,(sm_2(1-\gamma_1)(1-m_1)-\gamma_2(1-m_2)(1-sm_1)z) > 0, \tag{25}$$

where $\mathrm{Tr}\,\boldsymbol{J}^*$ and $\det \boldsymbol{J}^*$ are the trace and determinant of the Jacobian matrix, respectively.

The necessary and sufficient conditions are satisfied if $1 > \gamma_1$ and $sm_2\,(1-\gamma_1)\,(1-m_1) > \gamma_2(1-m_2)(1-sm_1)z$. The economic meaning of these conditions is as follows. The first inequality represents the Keynesian stability condition for sector 1's quantity adjustment, which ensures a self-stable capacity utilisation rate in this sector. The second inequality excludes the extreme case in which the positive feedback between the capacity utilisation rates of the two sectors is very strong. If this is the case, the short-run steady-state values of the capacity utilisation rates are also positive, as in eqs. (18) and (19).

Therefore, the short-run stability conditions can be summarised in the following proposition.

Proposition 1. *The short-run steady state is locally and asymptotically stable if the Keynesian stability condition for sector 1's quantity adjustment is ensured and if the positive feedback of the capacity utilisation rates between the two sectors is weak.*

In the following, we advance our argument as Proposition 1 holds.

3.2 Comparative statics analysis

We graphically present the impacts of a change in the income distribution and saving rate of the capitalists on the capacity utilisation rates. Tracing the change in the short-run steady-state loci in a figure helps us explain their effects on the capacity utilisation rates.[9]

The $\dot{u}_1 = 0$ and $\dot{u}_2 = 0$ loci can be given by eqs. (16) and (17), respectively:

$$u_1|_{\dot{u}_1=0} = \frac{G_1 + G_2 k + \gamma_2 k u_2}{1-\gamma_1}, \tag{26}$$

$$u_1|_{\dot{u}_2=0} = \frac{sk(1-m_1)m_2}{z(1-m_2)(1-sm_1)} u_2. \tag{27}$$

We plot the capacity utilisation rate of sector 2 on the x axis and that of sector 1 on the y axis. Then, $\dot{u}_1 = 0$ is a straight line with a positive slope and intercept, and $\dot{u}_2 = 0$ is also a straight line starting from the origin. When the short-run stability conditions are satisfied, the slope of the $\dot{u}_2 = 0$ line is steeper than that of the $\dot{u}_1 = 0$ line, and we can obtain the positive steady-state values for the capacity utilisation rates.

The original steady-state locus is presented with a dashed line and the steady state of the system is shown by E^* in Figures 1, 2, and 3. Compared with the original state, if the new steady state shifts to the top right, then the capacity utilisation rates in both sectors increase, whereas if it shifts to the bottom left, they decrease. Hence, a sector has a PLD (WLD) regime when a rise in the profit share in one sector increases (decreases) its capacity utilisation rate. In addition, the two-sector economy has a hybrid demand regime when the capacity utilisation rate in one sector increases whereas that in the other sector decreases. This regime can be observed when the new steady state shifts to the top left.

First, the impacts of a change in sector 1's profit share on the $\dot{u}_1 = 0$ and $\dot{u}_2 = 0$ lines are

[9] Although these impacts can be obtained by directly differentiating eqs. (18) and (19) with respect to m_1, m_2, and s, this yields complicated results. A graphical explanation instead allows us to understand the changes in demand following these shocks.

given as follows:

$$\frac{\partial u_1}{\partial m_1}|_{\dot{u}_1=0} = \frac{\beta_1}{1-\gamma_1} > 0, \tag{28}$$

$$\frac{\partial u_1}{\partial m_1}|_{\dot{u}_2=0} = -\frac{sk(1-s)m_2}{z(1-m_2)(1-sm_1)^2}u_2 < 0. \tag{29}$$

Eq. (28) shows that the intercept of $\dot{u}_1 = 0$ line shifts upwards, whereas eq. (29) shows that the slope of the $\dot{u}_2 = 0$ line flattens.

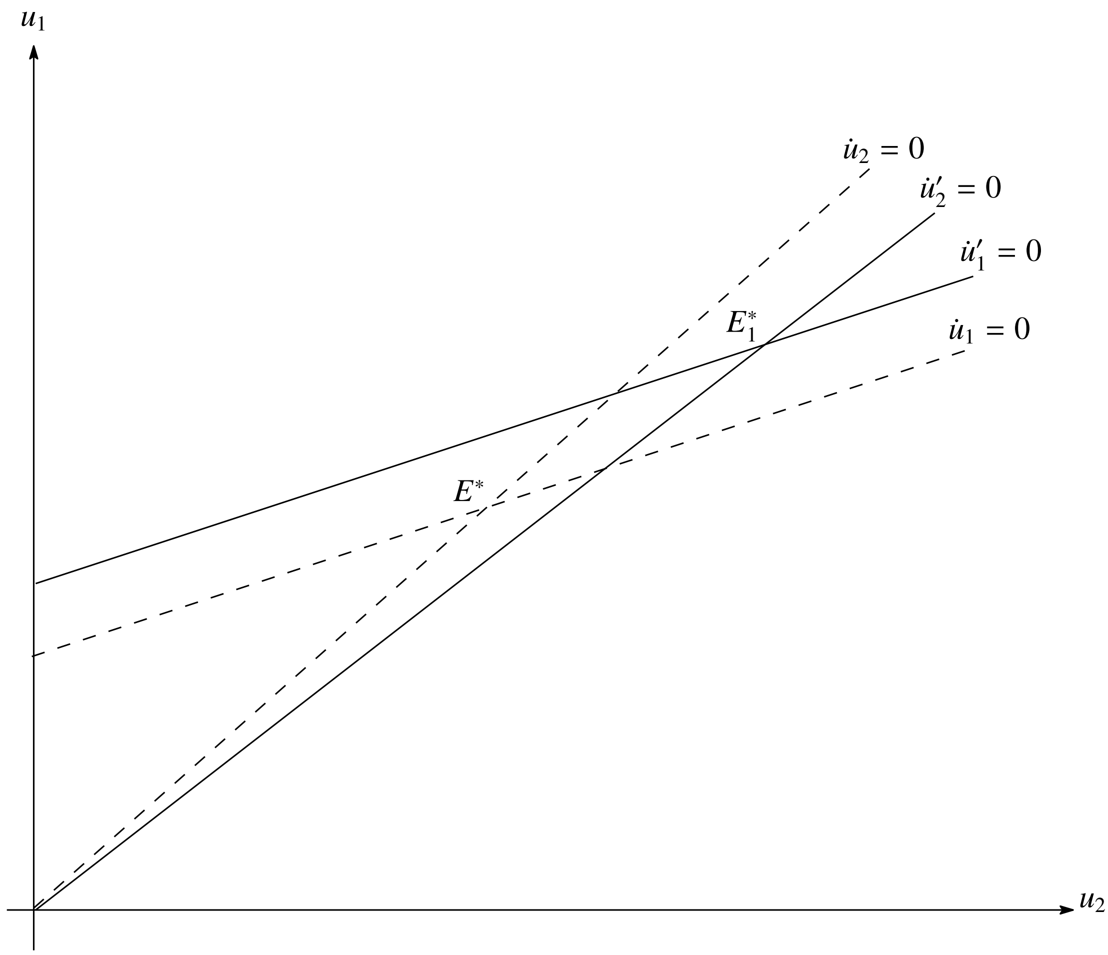


Figure 1: The effect of a rise in sector 1's profit share

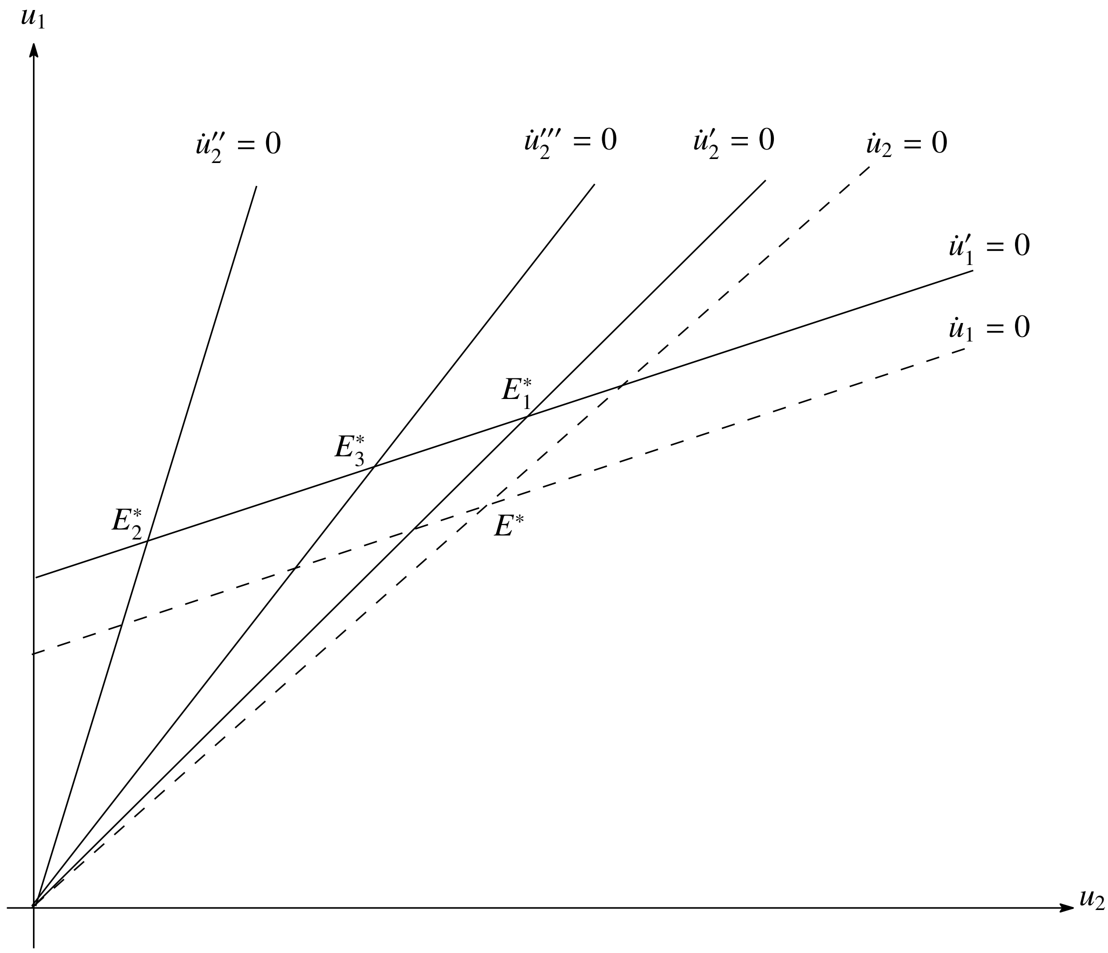
Figure 1 illustrates this case, where the new steady-state lines are denoted by $\dot{u}_1' = 0$ and $\dot{u}_2' = 0$ with solid ones. The PLD regime is established in both sectors because of the rise in sector 1's profit share. The steady state moves from E^* to E_1^* by the following mechanisms. First, a rise in sector 1's profit share accelerates investment demand through the profit effect, increasing the capacity utilisation rate in sector 1. Second, the rise in sector 1's profit share also increases demand for consumption goods through the relative price effect, raising sector 2's capacity utilisation rate. The positive and stable feedback between the capacity utilisation rates of both sectors leads the economy to the new steady state E_1^*, where the sectoral capacity utilisation rates are higher than before.

Second, the impacts of a change in sector 2's profit share on these lines are given as follows:

$$\frac{\partial u_1}{\partial m_2}|_{\dot{u}_1=0} = \frac{\beta_2 k}{1-\gamma_1} > 0, \tag{30}$$

$$\frac{\partial u_1}{\partial m_2}|_{\dot{u}_2=0} = \frac{sk(1-m_1)}{z(1-m_2)^2(1-sm_1)} u_2 > 0. \tag{31}$$

The intercept of the $\dot{u}_1 = 0$ line shifts upwards, whereas the slope of the $\dot{u}_2 = 0$ line becomes steeper. The former is driven by the profit effect on sector 2's investment demand and the latter is brought about by the negative effects of the relative price ratio and income redistribution. Figure 2 illustrates three possible scenarios due to a rise in sector 2's profit share. Given a constant upwards shift of the $\dot{u}_1 = 0$ line, the effects depend on the degree of the shifts of the $\dot{u}_2 = 0$ line.[10]



[10]The shift of the $\dot{u}_1 = 0$ line in Figure 2 is shown as constant to simply explain the underlining mechanisms in each scenario. However, the degree of the shift of both the $\dot{u}_1 = 0$ and the $\dot{u}_2 = 0$ lines determines the three possible scenarios.

Figure 2: The effect of a rise in sector 2's profit share

The first scenario is the shift to E_1^*, where the capacity utilisation rates in both sectors increase. Investment demand in sector 2 is stimulated by the rise in the profit share, inducing an upwards shift of the $\dot{u}_1 = 0$ line. Meanwhile, demand for consumption goods decreases due to the shock, rotating the $\dot{u}_2 = 0$ line anticlockwise. Because the reduction in sector 2's capacity utilisation rate is small in this scenario, the negative feedback on sector 1's capacity utilisation rate is limited. Sustained by the initially high rise in sector 1's capacity utilisation rate, the capacity utilisation rates in both sectors are higher than before. This scenario is observed when β_2 and γ_1 take high values and the $\dot{u}_1 = 0$ line shifts greatly. In addition, when z takes a high value but s and m_2 take low ones, the anticlockwise rotation of the $\dot{u}_2 = 0$ line is marginal.

The second scenario is the shift to E_2^*, where the capacity utilisation rates in both sectors decrease. When the negative impact on demand for consumption goods is strong, the $\dot{u}_2 = 0$ line greatly rotates anticlockwise ($\dot{u}_2'' = 0$), largely decreasing the capacity utilisation rate in sector 2. It further decreases sector 2's investment demand, reducing sector 1's capacity utilisation rate. Consequently, sector 1's total income decreases, causing a vicious circle between the sectoral capacity utilisation rates. The economy eventually reaches the new steady state E_2^*, where the capacity utilisation rates of both sectors are lower than before. This scenario is observed when β_2 and γ_1 take low values as well as when z takes a low value but s and m_2 take high ones. The former conditions hardly shift the $\dot{u}_1 = 0$ line, whereas the latter conditions substantially rotate the $\dot{u}_2 = 0$ line anticlockwise.

An interesting scenario is the shift to E_3^*, where the capacity utilisation rate of sector 1 is higher than before, whereas that of sector 2 is lower. As we have seen, a rise in sector 2's profit share initially raises the capacity utilisation rate of sector 1 but lowers that of sector 2. In the feedback process, the fall in sector 2's capacity utilisation rate negatively affects sector 1's capacity utilisation rate. However, when the anticlockwise rotation of the $\dot{u}_2 = 0$ line is moderate ($\dot{u}_2''' = 0$), the negative impact on sector 1's capacity utilisation rate is modest. Accordingly, the initial rise in sector 1's capacity utilisation rate is sustained in the short run, preventing a large decrease in sector 2's capacity utilisation rate as in the second scenario. This two-sector economy realises a hybrid demand regime in which sectors 1 and 2 experience PLD and WLD regimes, respectively. This scenario is more likely when the relevant parameters take moderate values, so that the shifts of the $\dot{u}_1 = 0$ and $\dot{u}_2 = 0$ lines are also intermediate.

Finally, the impact of a change in the saving rate on the $\dot{u}_1 = 0$ line is zero, whereas that on the $\dot{u}_2 = 0$ line is

$$\frac{\partial u_1}{\partial s}\Big|_{\dot{u}_2=0} = \frac{k(1-m_1)m_2}{z(1-m_2)(1-sm_1)^2}u_2 > 0, \tag{32}$$

which shows that the slope of the $\dot{u}_2 = 0$ line becomes steeper.

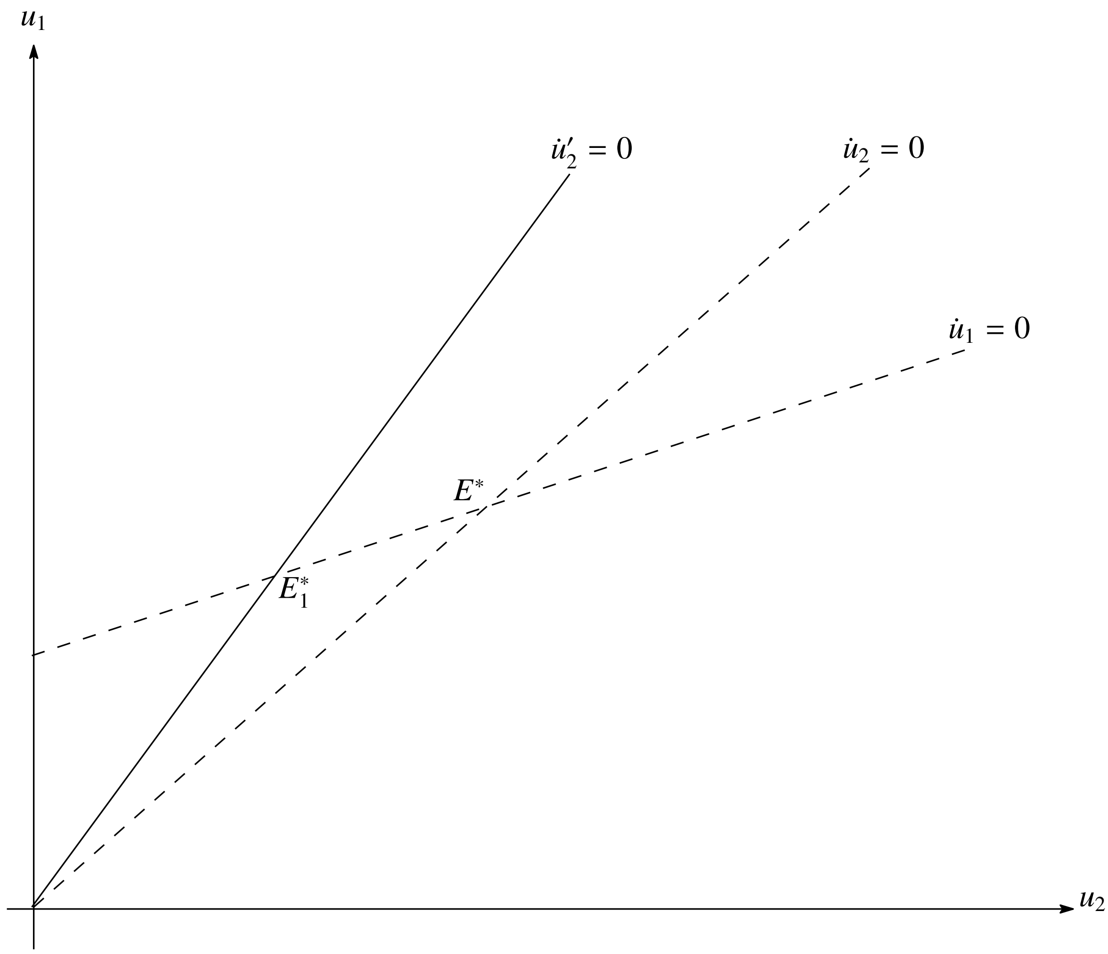


Figure 3: The effect of a rise in the capitalists' saving rate

Figure 3 illustrates the case in which the new steady-state line for sector 2 is given by $\dot{u}_2' = 0$ with a solid one. Combined with the original $\dot{u}_1 = 0$ line being unaffected, the steady state moves from E^* to E_1^*, where the capacity utilisation rates are lower than before. The so-called paradox of thrift prevails in the short run. A rise in the saving rate of the capitalists simply means a reduction in their consumption expenditure. Hence, it decreases sector 2's capacity utilisation rates and investment demand. Consequently, sector 1's capacity utilisation rate is also negatively affected.

Table 1: Short run effects of a rise in profit share and saving rate

	u_1^*	u_2^*	Changes in capacity utilisation rates and conditions
m_1	+	+	Always PLD regime
	+	+	(1) PLD regime, if β_2, γ_1, and z are large, or s and m_2 is small
m_2	−	−	(2) WLD redime, if β_2, γ_1, and z are small, or s and m_2 is large
	+	−	(3) Hybrid demand regime, if they are intermediate
s	−	−	Paradox of thrift holds (demand-led)

Table 1 summarises the main results of the comparative statics analysis. A rise in sector 1's profit share increases the rates of capacity utilisation, always establishing the PLD regime in both sectors. Depending on the values of the relevant parameters, a rise in sector 2's profit share generates (1) the PLD regime in both sectors, (2) the WLD regime in both sectors, or (3) the hybrid demand regime. Finally, a rise in the capitalists' saving rate decreases the rates of capacity utilisation and the paradox of thrift holds in both sectors. Further, we can easily confirm that a rise in the parameters of investment demand (i.e. G_1 and G_2) also increases the rates of capacity utilisation in both sectors, as eqs. (18) and (19) show. Thus, the short-run capacity utilisation rates are demand- and distribution-led ones.

4 Analysis of the long-run dynamics

4.1 Dynamic system and steady state

In the long-run period, the investment realises new capital stock, whereas the capacity utilisation rates continuously change according to the short-run steady state. Therefore, $\dot{K}_1 = I_1$ and $\dot{K}_2 = I_2$ are newly effective, and accordingly, we have to analyse the dynamics of the capital ratio $k \equiv \frac{K_2}{K_1}$.

We extend the short-run model in two ways. First, we consider the Kaldorian effects of technical change. The production technique in a sector is measured by its labour productivity a_i and the output–capital ratio u_i. Both variables change due to capital accumulation, whereas the output–capital ratio also varies according to the short-run steady state. Second, we allow for an endogenous change in the nominal wage rate associated with the labour productivity growth dynamics across industries. Because both wages and labour productivity simultaneously change, the unit cost ratio $z \equiv \dfrac{w_1 a_2}{w_2 a_1}$ varies over time.

First, we formalise the endogenous growth in labour productivity using Kaldor (1957)'s technical progress function. The labour productivity growth rate in each sector is given by

$$\hat{a}_1 = \theta_{10} + \theta_{11} g_1, \tag{33}$$

$$\hat{a}_2 = \theta_{20} + \theta_{21} g_2, \tag{34}$$

where g_i is realised by eqs. (33) and (34), meaning that the technical change is embodied in newly installed capital stock. According to Kaldor (1957), the labour productivity growth rate principally depends on two factors (pp. 595–6). The first is the degree of 'technical dynamism', which is the ability to invent, absorb, and introduce new production techniques, as summarised by $\theta_{i0} > 0$. The second is the effect of capital accumulation, with the labour productivity growth associated with the capital stock expansion changing in a cumulative manner. We present the degree of this effect by $\theta_{i1} > 0$, which is conventionally called the Kaldor–Verdoon coefficient.

Second, following empirical evidence (Marquetti (2004); Mallick and Sousa (2017)), we consider that higher productivity leads to higher wage growth.[11] Nominal wages endogenously change in the two sectors according to the differences in labour productivity growth. Then, the growth rate of the nominal wage rate in each sector is

$$\hat{w}_1 = (1 - \chi_1)\hat{a}_1, \tag{35}$$

$$\hat{w}_2 = (1 - \chi_2)\hat{a}_2. \tag{36}$$

In this linkage, we suppose that the workers want to prevent their living standard or wage rate from decreasing by claiming a certain proportion $(1 - \chi_i)$ of the labour productivity gain. The degree is exogenous but would be affected by, for example, the bargaining power of labour unions. A rise in their bargaining power (i.e. a fall in χ_i) would realise a higher wage rate as a result of higher productivity growth, and vice versa. The gap between the wage and labour productivity growth rates is reflected in the change in inflation. Therefore, the real wage rate changes according to productivity growth.

[11] Marquetti (2004) shows a link between real wages and labour productivity in the long run in the U.S. economy; here, technical change is basically a labour-saving and capital-using one, which is called Marx-based technical change. Mallick and Sousa (2017) find that technology has a positive and significant relationship with workers' wage rate in the United States and that the accumulation of knowledge capital also contributes to the endogenous growth process.

The dynamic system consists of the changes in the unit cost ratio and capital ratio, where the capacity utilisation rates immediately accommodate the changes in these ratios along the short-run steady state.[12] Observing eqs. (33)–(36), the system is defined as follows:

$$\begin{aligned}\dot{z} &= z(\hat{w}_1 - \hat{a}_1 - (\hat{w}_2 - \hat{a}_2))\\ &= z\{\chi_2[\theta_{20} + \theta_{21}(G_2 + \gamma_2 u_2^*)] - \chi_1[\theta_{10} + \theta_{11}(G_1 + \gamma_1 u_1^*)]\}, \quad (37)\\ \dot{k} &= k(g_2 - g_1)\\ &= k\{G_2 + \gamma_2 u_2^* - (G_1 + \gamma_1 u_1^*)\}, \quad (38)\end{aligned}$$

where u_1^* and u_2^* are the functions of the unit cost ratio and capital ratio determined in eqs. (18) and (19).

The long-run steady state of the two-sector economy is given by $(u_{1L}^*, u_{2L}^*, k_L^*, z_L^*)$, which all satisfy $\dot{u}_1 = \dot{u}_2 = \dot{k} = \dot{z} = 0$. Excluding the non-trivial values, the long-run steady state is given by the following equations:

$$u_{1L}^* = \frac{(\theta_{20}\chi_2 - \theta_{10}\chi_1) - G_1(\theta_{11}\chi_1 - \theta_{21}\chi_2)}{\gamma_1(\theta_{11}\chi_1 - \theta_{21}\chi_2)}, \quad (39)$$

$$u_{2L}^* = \frac{(\theta_{20}\chi_2 - \theta_{10}\chi_1) - G_2(\theta_{11}\chi_1 - \theta_{21}\chi_2)}{\gamma_2(\theta_{11}\chi_1 - \theta_{21}\chi_2)}, \quad (40)$$

$$k_L^* = \frac{(1-\gamma_1)(\theta_{20}\chi_2 - \theta_{10}\chi_1) - G_1(\theta_{11}\chi_1 - \theta_{21}\chi_2)}{\gamma_1(\theta_{20}\chi_2 - \theta_{10}\chi_1)}, \quad (41)$$

$$\begin{aligned}z_L^* &= \frac{(1-m_1)sm_2}{\gamma_2(1-m_2)(1-sm_1)}\left(\frac{(\theta_{20}\chi_2 - \theta_{10}\chi_1) - G_2(\theta_{11}\chi_1 - \theta_{21}\chi_2)}{(\theta_{20}\chi_2 - \theta_{10}\chi_1) - G_1(\theta_{11}\chi_1 - \theta_{21}\chi_2)}\right)\\ &\times\left(\frac{(1-\gamma_1)(\theta_{20}\chi_2 - \theta_{10}\chi_1) - G_1(\theta_{11}\chi_1 - \theta_{21}\chi_2)}{\theta_{20}\chi_2 - \theta_{10}\chi_1}\right) \equiv \frac{(1-m_1)sm_2 u_{2L}^* k_L^*}{(1-m_2)(1-sm_1)u_{1L}^*}. \quad (42)\end{aligned}$$

As we have all the endogenous variables, we can define the aggregate output growth rate (g_{AL}^*), profit share (m_{AL}^*), capacity utilisation rate (u_{AL}^*), and profit rate (r_{AL}^*).

Under the fixed production function, the growth rate of output is the same as that of capital stock. From eqs. (39), (40), and (11) or (12), the long-run economic growth rate is given by

$$g_{AL}^* = g_{1L}^* = g_{2L}^* = \frac{\theta_{20}\chi_2 - \theta_{10}\chi_1}{\theta_{11}\chi_1 - \theta_{21}\chi_2}. \quad (43)$$

Because the sectoral output growth rates are equalised at the steady state, the aggregate output growth rate is also the same as the sectoral ones regardless of the weight of the aggregation.

[12] As the growth rates of wages and labour productivity endogenously change in each sector, the unit cost ratio also varies. Unless this ratio becomes constant, demand for consumption goods keeps changing over time, and sector 2's capacity utilisation rate diverges, as eq. (17) indicates.

The aggregate profit share is given by the weighted average of the sectoral profit shares, which is as follows:

$$m^*_{AL} = \frac{p_1(r_1K_1 + r_2K_2)}{p_1X_1 + p_2X_2} = \frac{p^*_L u^*_{1L} m_1 + k^*_L u^*_{2L} m_2}{p^*_L u^*_{1L} + k^*_L u^*_{2L}} = \frac{m_2}{1 - s(m_1 - m_2)}. \tag{44}$$

The capitalists' saving rate affects the unit cost ratio (eq. (42)) and relative price ratio.

Finally, the aggregate capacity utilisation rate is given by[13]

$$u^*_{AL} = \frac{p_1X_1 + p_2X_2}{p_1(K_1 + K_2)} = \frac{p^*_L u^*_{1L} + k^*_L u^*_{2L}}{p^*_L(1 + k^*_L)} \equiv \frac{1 - s(m_1 - m_2)}{sm_2} g^*_{AL}. \tag{45}$$

This shows that the aggregate capacity utilisation rate is proportional to the economic growth rate.

Combining eqs. (44) and (45), the aggregate profit rate is

$$r^*_{AL} = u^*_{AL} m^*_{AL} = \frac{g^*_{AL}}{s}, \tag{46}$$

which means that the Cambridge equation (Kaldor (1955-6); Pasinetti (1961); Marglin (1984)) is exactly established at the macroeconomic level. By contrast, it follows from eqs. (39), (40), and (43) that $su^*_{iL} m_i = g^*_{iL}$ is not always guaranteed at the sectoral level.

Having identified the existence of the long-run steady state, we impose the following assumption so that the steady-state values are positive and economically meaningful:

Assumption 1.

$$(1 - \gamma_1)(\theta_{20}\chi_2 - \theta_{10}\chi_1) > G_1(\theta_{11}\chi_1 - \theta_{21}\chi_2) > 0, \tag{47}$$

$$(\theta_{20}\chi_2 - \theta_{10}\chi_1) > G_2(\theta_{11}\chi_1 - \theta_{21}\chi_2) > 0. \tag{48}$$

The first condition ensures positive values for sector 1's capacity utilisation rate (eq. (39)) and the capital ratio (eq. (41)). The second condition ensures the positive values for sector 2's capacity utilisation rate (eq. (40)). Accordingly, the unit cost ratio (eq. (42)) also takes a positive value. Moreover, the aggregate output growth rate, capacity utilisation rate, and profit rate are all positive.

[13] As different capital goods cannot be summed physically, we need to evaluate the value using their own prices. To calculate the aggregate capacity utilisation rate in eq. (45), we evaluate the value of capital and goods using the relative price ratio given by the steady state. By contrast, the aggregate output growth rate in eq. (43) is independent of such a weight because the output growth rates of both sectors are always the same.

Although the comparative statics analysis below considers the impact of functional income distribution on sectoral and macroeconomic performance, the patterns of the technical change as well as the wage and labour productivity growth differentials are worth mentioning.

Substituting the long-run growth rate into eqs. (33) and (34), we obtain the steady-state labour productivity growth rate in each sector:

$$\hat{a}_1^* = \left(\frac{\theta_{11}\theta_{20} - \theta_{10}\theta_{21}}{\theta_{11}\chi_1 - \theta_{21}\chi_2} \right) \chi_2, \tag{49}$$

$$\hat{a}_2^* = \left(\frac{\theta_{11}\theta_{20} - \theta_{10}\theta_{21}}{\theta_{11}\chi_1 - \theta_{21}\chi_2} \right) \chi_1. \tag{50}$$

The long-run labour productivity growth rate is either positive or negative depending on the relative magnitude of the technological parameters. If the ratio of the Verdoon coefficient to the degree of technical dynamism is larger in sector 1 than in sector 2 (i.e. $\theta_{11}/\theta_{10} > \theta_{21}/\theta_{20}$), the labour productivity growth rate is positive. In the opposite case, it is negative. As the capacity utilisation rate is constant in the long-run steady state, its rate of change is zero. Therefore, the long-run patterns of technical change are Harrod natural or labour-saving/using technical change (Villanueva and Jiang (2018); Foley et al. (2019)). In the former case, labour productivity increases, whereas capital productivity remains constant over time. In the latter case, labour productivity decreases, whereas capital productivity remains constant over time. Thus, the patterns of technical change are endogenously determined in our model.[14]

Moreover, eqs. (33)–(36) lead to

$$\frac{\hat{a}_1^*}{\hat{a}_2^*} = \frac{\chi_2}{\chi_1}, \tag{51}$$

$$\frac{\hat{w}_1^*}{\hat{w}_2^*} = \frac{(1-\chi_1)\chi_2}{(1-\chi_2)\chi_1}. \tag{52}$$

[14]We call our model TKK because technical change is formalised from Kaldor's idea. Therefore, the models are similar in that the long-run productivity growth rate is determined by the technical progress function (Kaldor (1957), p. 616). Nonetheless, there are differences between Kaldor's model and the TKK. First, the output and productivity growth rates are also determined by the wage productivity indexation in our TKK model. Second, Kaldor assumes full employment (Kaldor (1957), pp. 593–5), whereas we do not and the employment rate is endogenously determined by the difference between the output and labour productivity growth rates. Third, the price in relation to wages and the profit share accommodate the gap between saving and investment under full employment (Kaldor (1957), pp.606-8), whereas in our model wages and prices are associated with labour productivity growth and the profit share is determined by the mark-up. The third and fourth points come from the Kaleckian ideas built into the TKK model.

Interestingly, endogenous technical change and the associated wage dynamics explain the persistent disparity in the wage and productivity growth rates between the two sectors. The sectoral productivity and nominal wage growth rates never equate unless by chance (i.e. $\chi_1 = \chi_2$). For instance, a lower χ_i brings about relatively high growth in productivity and nominal wages in that sector. Given the other sector's unit labour cost remains constant, if there is a rise in wage growth in one sector because of a lower χ_i, a rise in labour productivity growth (and a change in the capacity utilisation rate) in that sector is required to keep the unit cost ratio constant.

4.2 Stability analysis

The previous section identified the existence of the long-run steady state. This section reveals its stability conditions. Let $\boldsymbol{J}_L^*$ be the Jacobian matrix for eqs. (37) and (38); then, its non-zero elements are given as follows:

$$j_{11}^L \equiv \frac{\partial \dot{z}}{\partial z} = z_L^* \left(\chi_2 \theta_{21} \gamma_2 \frac{\partial u_2^*}{\partial z} - \chi_1 \theta_{11} \gamma_1 \frac{\partial u_1^*}{\partial z} \right), \tag{53}$$

$$j_{12}^L \equiv \frac{\partial \dot{z}}{\partial k} = z_L^* \left(\chi_2 \theta_{21} \gamma_2 \frac{\partial u_2^*}{\partial k} - \chi_1 \theta_{11} \gamma_1 \frac{\partial u_1^*}{\partial k} \right), \tag{54}$$

$$j_{21}^L \equiv \frac{\partial \dot{k}}{\partial z} = k_L^* \left(\gamma_2 \frac{\partial u_2^*}{\partial z} - \gamma_1 \frac{\partial u_1^*}{\partial z} \right), \tag{55}$$

$$j_{22}^L \equiv \frac{\partial \dot{k}}{\partial k} = k_L^* \left(\gamma_2 \frac{\partial u_2^*}{\partial k} - \gamma_1 \frac{\partial u_1^*}{\partial k} \right), \tag{56}$$

where all the elements are evaluated at the long-run steady state. The sign of the impact of a change in the capital ratio and unit labour cost on the capacity utilisation rates plays an important role in local stability. Their signs are as follows:

$$\frac{\partial u_1^*}{\partial z} = \frac{\Lambda \gamma_2}{\Theta^2} > 0, \tag{57}$$

$$\frac{\partial u_2^*}{\partial z} = \frac{\Lambda (1 - \gamma_1)}{k_L^* \Theta^2} > 0, \tag{58}$$

$$\frac{\partial u_1^*}{\partial k} = \frac{s(1 - m_1) m_2 G_2}{\Theta} > 0, \tag{59}$$

$$\frac{\partial u_2^*}{\partial k} = -\frac{(1 - s m_1)(1 - m_2) G_1 z_L^*}{k_L^{*2} \Theta} < 0, \tag{60}$$

where

$$\Theta \equiv s m_2 (1 - \gamma_1)(1 - m_1) - \gamma_2 (1 - m_2)(1 - s m_1) z_L^* > 0, \tag{61}$$

$$\Lambda \equiv s(1 - m_1)(1 - s m_1)(1 - m_2) m_2 (G_1 + G_2 k_L^*) > 0. \tag{62}$$

We have $\Theta > 0$ because the long-run steady state is realised on the basis of the short-run steady state. $\Lambda > 0$ is also true because the profit share and the saving rate of the capitalists are principally between zero and unity.

The necessary and sufficient conditions for the stability of the long-run steady state are Tr $\boldsymbol{J}^*{}_L = j^L_{11} + j^L_{22} < 0$ and det $\boldsymbol{J}^*{}_L = j^L_{11}j^L_{22} - j^L_{12}j^L_{21} > 0$. The trace of the Jacobian matrix $\boldsymbol{J}^*_L$ can be developed as follows:

$$\text{Tr } \boldsymbol{J}^*{}_L = \underbrace{z^*_L\left(\chi_2\theta_{21}\gamma_2\frac{\partial u^*_2}{\partial z} - \chi_1\theta_{11}\gamma_1\frac{\partial u^*_1}{\partial z}\right)}_{j^L_{11}=?} + \underbrace{k^*_L\left(\gamma_2\frac{\partial u^*_2}{\partial k} - \gamma_1\frac{\partial u^*_1}{\partial k}\right)}_{j^L_{22}=-} < 0, \tag{63}$$

where the sign in the second term is negative from eqs. (59) and (60). A negative j^L_{11} is sufficient for the sign of the trace to be negative. Substituting eqs. (57) and (58), we can obtain

$$j^L_{11} = -\frac{z^*_L\Lambda\gamma_2}{k^*_L\Theta^2}\left(\frac{\theta_{11}\chi_1 - \theta_{21}\chi_2}{\theta_{20}\chi_2 - \theta_{10}\chi_1}\right)\left[(1-\gamma_1)(\theta_{20}\chi_2 - \theta_{10}\chi_1) - G_1\theta_{11}\chi_1\right]. \tag{64}$$

A negative value of j^L_{11} is obtained if the following conditions are satisfied:

$$(1-\gamma_1)(\theta_{20}\chi_2 - \theta_{10}\chi_1) - G_1\theta_{11}\chi_1 > 0, \tag{65}$$

which is a stronger condition than eq. (47) in Assumption 1.[15] If this holds, the sign of j^L_{11} is negative, and accordingly, the sign of the trace is negative. Economically, this means that a rise in the unit cost ratio reduces the unit labour cost in sector 1 more than in sector 2. Thus, both the unit cost ratio and the capital ratio have negative self-feedback dynamics.

Meanwhile, the determinant of the Jacobian matrix is developed as follows:

$$\det\ \boldsymbol{J}^*{}_L = k^*_L z^*_L\gamma_1\gamma_2(\theta_{21}\chi_2 - \theta_{11}\chi_1)\underbrace{\left(\frac{\partial u^*_2}{\partial k}\frac{\partial u^*_1}{\partial z} - \frac{\partial u^*_1}{\partial k}\frac{\partial u^*_2}{\partial z}\right)}_{-}, \tag{66}$$

where the sign in the second parentheses is determined by eqs. (57)–(60). Therefore, for this to be positive, we need

$$\theta_{11}\chi_1 > \theta_{21}\chi_2, \tag{67}$$

which is naturally satisfied under Assumption 1. This inequality means that the chain effect of a change in the capital accumulation rate on the change in the unit labour cost is stronger in sector 1 than in sector 2.

[15] Assumption 1 does not ensure this condition. To be more precise, eq. (65) is a sufficient condition for eq. (47) but not a necessary one.

The long-run steady state is locally and asymptotically stable if eqs. (65) and (67) hold. Since they are partially independent of Assumption 1, it is important to precisely specify the range within which the stabilisation conditions hold. These are summarised in the following simultaneous inequalities:

$$\theta_{11} < \frac{(1-\gamma_1)(\theta_{20}\chi_2 - \theta_{10}\chi_1)}{G_1\chi_1}, \tag{68}$$

$$\theta_{11} > \frac{\chi_2}{\chi_1}\theta_{21}. \tag{69}$$

Eq. (68) represents the negative trace of the Jacobian matrix, whereas eq. (69) ensures a positive determinant. Based on these, we have the following proposition on the stability of the long-run steady state.

Proposition 2. *Assume that the other parameters are constant under Assumption 1. (i) Given a constant value of* θ_{11}*, the long-run steady state is locally asymptotically stable as the value of* θ_{21} *is low, whereas it is unstable as the value of* θ_{21} *is high. (ii) Given a constant value of* θ_{21}*, the long-run steady state is locally asymptotically stable as the value of* θ_{11} *is moderate, ranging from* $\frac{\chi_2}{\chi_1}\theta_{21} < \theta_{11} < \frac{(1-\gamma_1)(\theta_{20}\chi_2 - \theta_{10}\chi_1)}{G_1\chi_1}$.

A graphical representation helps explain the properties of the long-run stability conditions. Taking θ_{21} and θ_{11} on the x and y axes, respectively, Figures 4 (case 1) and 5 (case 2) distinguish the stable and unstable areas. The stable area is drawn in the shadow formed by eqs. (68) and (69) and the unstable area is in plain shading including the solid lines themselves. Assumption 1, which guarantees positive steady-state values, is effective in the areas between the parallel solid lines based on eqs. (68) and (47) or (48). Depending on the values of γ_1, G_1, and G_2, the height of the intercept for eqs. (47) and (48) differs. Figure 4 (case 1) shows that the intercept for eq. (47) is higher, whereas Figure 5 (case 1) shows that the intercept for eq. (48) is higher, where the lower intercept is shown as the dashed line.[16]

[16] Precisely, the difference between the two intercepts is

$$\frac{(\theta_{20}\chi_2 - \theta_{10}\chi_1)}{G_2\chi_1} - \frac{(1-\gamma_1)(\theta_{20}\chi_2 - \theta_{10}\chi_1)}{G_1\chi_1} = \frac{(\theta_{20}\chi_2 - \theta_{10}\chi_1)}{\chi_1 G_1 G_2}[G_1 - (1-\gamma_1)G_2],$$

meaning that as G_2 is smaller and γ_1 and G_1 are larger, the intercept for eq. (48) is more likely to be higher than that for eq. (47). When γ_1 and G_1 are large, the lines for eqs. (47) and (68) shift downwards, narrowing the stable areas in the figures.

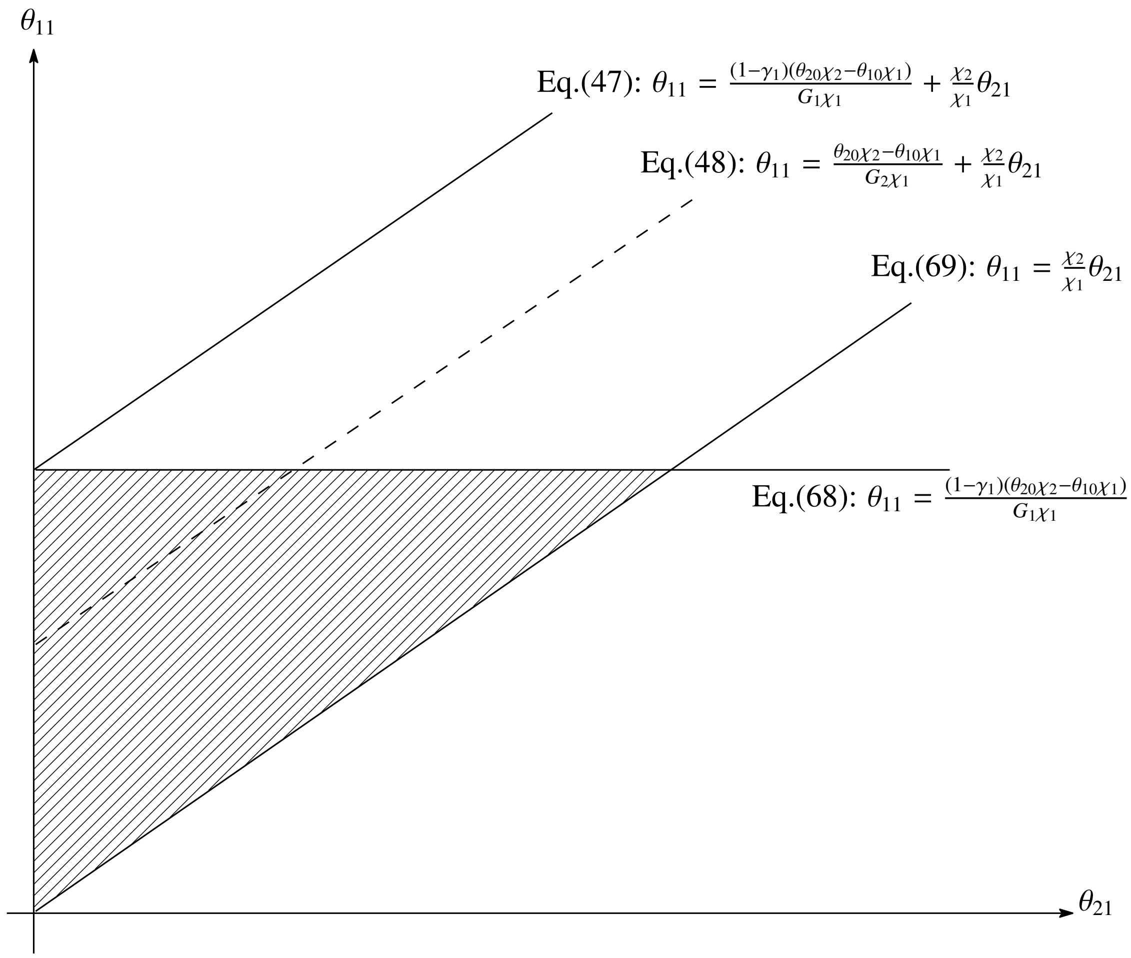


Figure 4: Stable (shadowed) and unstable (plain) areas: case 1

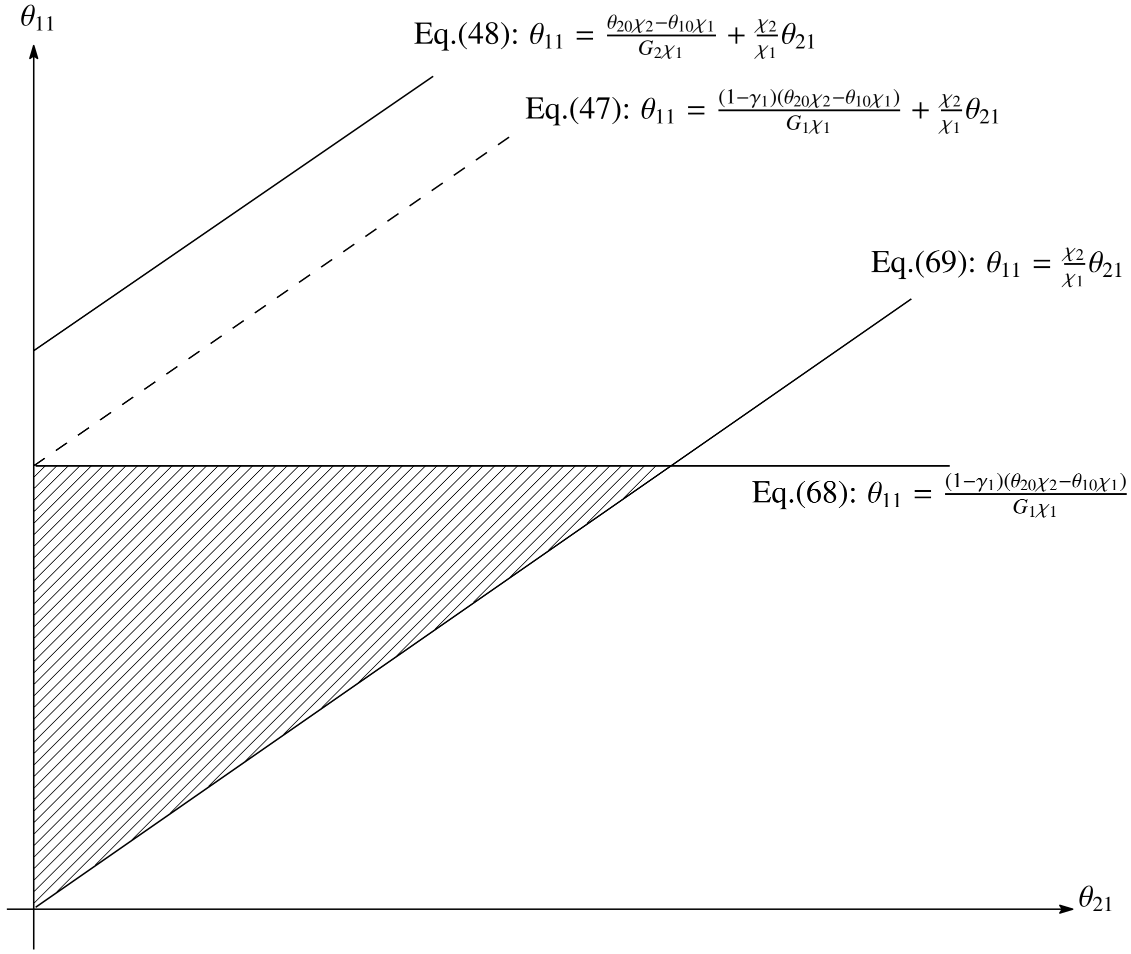


Figure 5: Stable (shadowed) and unstable (plain) areas: case 2

Proposition 2 suggests that given the other parameters, the Verdoon coefficients θ_{11} and θ_{21} must take a certain value to realise the stability of the long-run steady state. For instance, we can illustrate a destabilising process when θ_{21} takes a high value given a small θ_{11}, rejecting that $\det \boldsymbol{J^*}_L$ has to be positive. In this case, once a positive shock to z occurs in an original steady state, it lowers the capital ratio (eq. (55)) by largely stimulating sector 1's capacity utilisation rate. The lower capital ratio raises the unit cost ratio markedly (eq. (54)). Regardless of the unit cost ratio's self-feedback, when these interactions are sufficiently strong, the two-sector economy experiences saddle-path unstable dynamics.

We can conclude from this result that the long-run stability conditions are mostly determined by technical change and the associated productivity and wage growth parameters. By contrast, only γ_1 and G_1 concern these conditions from the demand side.

4.3 Comparative statics analysis

This section considers the impacts of income distribution, the saving rate, and technical changes on the *sectoral* capacity utilisation rates and profit rates based on eqs. (39) and (40) in the long-run steady state. We also compare their impacts on the *aggregate* output growth rate (eq. (43)), profit share (eq. (44)), capacity utilisation rate (eq. (45)), and profit rate (eq. (46)) to shed light on how macroeconomic performance differs from industrial performance.[17] Table 2 shows the results and the Appendix details the calculation.

Table 2: Long run effects of a rise in relevant parameters

	u^*_{1L}	u^*_{2L}	r^*_{1L}	r^*_{2L}	u^*_{AL}	m^*_{AL}	g^*_{AL}	r^*_{AL}
m_1	−	0	±	0	−	+	0	0
m_2	0	−	0	±	−	+	0	0
s	0	0	0	0	−	±	0	−
$\theta_{10},\ \theta_{11}$	−	−	−	−	−	0	−	−
$\theta_{20},\ \theta_{21}$	+	+	+	+	+	0	+	+

A positive shock to sector 1's profit share (the first row) has a negative impact on its capacity utilisation rate without affecting the other sector's performance. In other words, sector 1 presents a WLD regime in response to this shock. The rise in sector 1's profit share either raises or lowers its profit rate depending on the relative magnitude of such a rise and the fall in the capacity utilisation rate. It also increases the aggregate profit share, and the aggregate capacity utilisation rate follows a WLD expansion. However, sector 1's profit share has no effect on the long-run economic growth rate or profit rate at the aggregate level.[18]

[17]Although we could also analyse the impacts on the capital ratio and unit cost ratio, we do not consider these variables because they do not directly represent the sectoral or macroeconomic activity levels.

[18]The underlying mechanisms for these outcomes are as follows. The long-run output growth rate is determined exclusively by the parameters that affect the unit labour cost (eq. (43)). Then, the capacity utilisation rate of each sector is determined to accommodate these conditions (eqs. (39) and (40)) as $u^*_{iL} = (g^*_{AL} - G_i)/\gamma_i$, which only includes the income distribution share of that sector. Therefore, a rise in the profit share of each sector only affects that sector.

A rise in sector 2's profit share (the second row) has no impact on the capacity utilisation rate of sector 1. By contrast, that of sector 2 presents a WLD regime in response to this shock. Sector 2's profit rate either rises or falls depending on the relative magnitude of such a rise and subsequent fall in the capacity utilisation rate. It also increases the aggregate profit share, and the aggregate capacity utilisation rate follows a WLD expansion. However, the output growth rate is also independent of sector 2's profit share. It has no effect on the long-run aggregate profit rate either.

A change in the saving rate (the third row) does not affect the capacity utilisation and profit rates. In other words, the paradox of thrift does not occur at the sectoral level. Meanwhile, the aggregate capacity utilisation rate and profit rate decrease, whereas the change in the profit share depends on the magnitude of the relationship between the sectoral profit shares. When $m_1 > m_2$, the aggregate profit share rises, and the aggregate capacity utilisation rate moves like a WLD regime. In the opposite case, the aggregate profit share falls, and it moves like a PLD regime. This co-movement does not reflect the change in the sectoral profit share or capacity utilisation rate, but is induced by the saving rate and the associated change in nominal values.[19]

Importantly, the economic growth rates are determined by the supply-side parameters that affect the unit cost ratio (the fourth and fifth rows). If the rate of exogenous labour productivity growth in sector 2 (i.e. a rise in θ_{20}) accelerates compared with that in sector 1 (θ_{10}), the long-run economic growth rate rises. Although we do not report the details to save space, when the wage productivity growth indexation weakens in sector 2 (i.e. a rise in χ_2), the economic growth rate also rises. When this happens in sector 1 (i.e. a rise in χ_1), the economic growth rate falls.

Simultaneously, there is a trade-off between a high economic growth rate and the stability of the steady state. The long-run economic growth rate accelerates, as the gap between sector 2 and sector 1 is smaller for the chain effect of capital accumulation on the unit labour cost (i.e. $\theta_{11}\chi_1 - \theta_{21}\chi_2$ is positive but small in eq. (43)). By contrast, this chain effect must be stronger in sector 1 than in sector 2 for long-run steady-state local stability (i.e. $\theta_{11}\chi_1 - \theta_{21}\chi_2$ is positive

[19]These effects arise through the changes in nominal value weights to calculate the aggregate variables. The sectoral capacity utilisation rates and capital ratio are independent of the saving rate (eqs. (39)–(41)), but they raise the unit cost ratio and relative price ratio (eq. (42)). Decreasing the weight of sector 2's share, the rise in the relative price ratio reduces the aggregate capacity utilisation rate in eq. (45). Meanwhile, it equally increases and decreases the weight of the shares of sectors 1 and 2 in eq. (44), respectively. Depending on the magnitude of the relationship between the two sectors' profit shares, the aggregate profit share rises or falls.

and large in eq. (67)). If this gap is large, it contributes to local stability, whereas the long-run economic growth rate declines.

Our model offers implications for long-run economic performance that differ from those of existing Kaleckian two-sector models. Previous two-sector Kaleckian models have shown that a rise in the profit share or saving rate has a positive or negative effect on the economic growth rate, even in the long run (Beqiraj et al. (2019); Fujita (2019a,b); Nishi (2020)). By contrast, the presented TKK model reveals that income distribution has no impact on economic growth and that even the paradox of thrift does not hold.[20] Moreover, although a rise in the profit share of one sector accompanies a rise in the profit share and a fall in capacity utilisation rates at the aggregate level, it does not change the capacity utilisation rate of the other sector. Thus, macroeconomic performance does not necessarily reflect uniform changes in industrial performance.

In summary, the effect of income distribution and effective demand on economic growth in the present model is limited compared with in the conventional model. Unlike previous studies, the driving force for long-run economic growth is the parameters that regulate technical change and the associated wage dynamics. In brief, our model clearly shows that the short-run steady state has a Kaleckian character, whereas the long-run economic growth mechanism has a Kaldorian character.

5 Conclusion

We built a TKK model in which investment goods and consumer goods are produced, and analysed the short- and long-run effects of income distribution, technical change, and economic growth in terms of sectoral and macroeconomic performance. The main results can be summarised in the following eight points.

The stability analysis for the short-run steady state shows that (1) it is stable when the Keynesian stability condition for sector 1's quantity adjustment is effective and the positive feedback between the two sectors' capacity utilisation rates is weak. Our comparative statics analysis

[20] Duménil and Lévy (1999) present a two-good model, showing that the post-Keynesian implication holds in the short run, whereas the classical one holds in the long run. Their model also undermines Kaleckian implications such as the paradoxes of thrift and cost; however, its underlying mechanism is the role of monetary policy and its impact on capital accumulation. Our TKK model is different from theirs in that even if we do not suppose monetary policy, the long-run economy behaves unlike Kaleckian (or post-Keynesian) implications.

shows that the capacity utilisation rates of the two sectors (2) increase following a rise in sector 1's profit share; (3) decrease following a rise in the capitalists' saving rate; and (4) not only increase or decrease simultaneously, but also respond differently to a rise in sector 2's profit share. In contrast to aggregate Kaleckian models, result (4) is novel, confirming that a two-sector economy may experience a hybrid demand expansion, where sector 1 expands in a PLD manner, whereas sector 2 stagnates in a WLD manner. Thus, the benefit of changing sector 2's profit share is conflictive between the two sectors in the short run.

The stability analysis for the long-run steady state shows that (5) the conditions are mostly determined by the supply-side (i.e. technical change and the associated productivity and wage growth) parameters. Our comparative statics analysis shows that (6) a rise in the profit share of each sector lowers that sector's capacity utilisation rate and consequently, the aggregate capacity utilisation rate; (7) a rise in the capitalists' saving rate does not change the sectoral capacity utilisation rates or the aggregate output growth rate, but decreases the aggregate capacity utilisation rate and profit rate; and (8) a rise in the technological parameters in sector 2 raises the capacity utilisation and output growth rates at both the sectoral and the macroeconomic levels, whereas such a rise in sector 1 restrains these rates.

Thus, the short-run steady state is characterised as Kaleckian, where demand and income distribution matter, whereas long-run economic growth is more Kaldorian, where technical change matters. As the determinants of the long-run demand regime and economic growth rate are different from those not only in the short run but also in previous two-sector Kaleckian models, they should also be highlighted.

In our TKK model, the demand and distribution parameters have limited effects, whereas the supply-side parameters have broader effects on sectoral and aggregate macroeconomic performance and its stability. As result (6) shows, the capacity utilisation rates change in a WLD manner in response to a change in income distribution in that sector only. Thus, the benefit of the change in income distribution is not uniform between the two sectors in the long run. Surprisingly, from a Kaleckian standpoint, result (7) means that the paradox of thrift does not hold in the long run either. Result (8) reveals that the economic growth rates of both sectors are completely determined by technical change and the associated productivity and wage growth. Moreover, there is a persistent disparity in the wage and productivity growth rates between the two sectors. In this process, as the chain effects of a change in the capital accumulation rate on the change in the unit labour cost work more strongly in sector 2 than in sector 1, the long-run economic growth rate rises. However, in light of result (5), this effect is more likely to violate the long-run stability condition simultaneously. Hence, we find the important implication that a two-sector economy faces a trade-off between a high economic growth rate and the local stability of the steady state.

Appendix

This Appendix describes the calculation of the comparative statics in the long run presented in Table 2, showing that the effects of the relevant parameters are not zero. The impacts of the changes in the profit distribution shares of sectors 1 (the first row) on the long-run steady-state values are as follows:

$$\frac{\partial u_{1L}^*}{\partial m_1} = -\frac{\beta_1}{\gamma_1} < 0$$

$$\frac{\partial r_{1L}^*}{\partial m_1} = \frac{(\theta_{20}\chi_2 - \theta_{10}\chi_1) - (G_1 + \beta_1 m_1)(\theta_{11}\chi_1 - \theta_{21}\chi_2)}{\gamma_1(\theta_{11}\chi_1 - \theta_{21}\chi_2)} \lesseqgtr 0$$

$$\frac{\partial u_{AL}^*}{\partial m_1} = -\frac{(\theta_{20}\chi_2 - \theta_{10}\chi_1)}{m_1(\theta_{11}\chi_1 - \theta_{20}\chi_2)} < 0$$

$$\frac{\partial m_{AL}^*}{\partial m_1} = \frac{sm_2}{(1 - sm_1 + sm_2)^2} > 0$$

The effect on sector 1's profit rate is negative when the parameters $G_1 + \beta_1 m_1$ are large, whereas it is positive when they are small.

The impacts of changes in the profit distribution shares of sector 2 (the second row) on the long-run steady-state values are as follows:

$$\frac{\partial u_{2L}^*}{\partial m_2} = -\frac{\beta_2}{\gamma_2} < 0$$

$$\frac{\partial r_{2L}^*}{\partial m_2} = \frac{(\theta_{20}\chi_2 - \theta_{10}\chi_1) - (G_2 + \beta_2 m_2)(\theta_{11}\chi_1 - \theta_{21}\chi_2)}{\gamma_2(\theta_{11}\chi_1 - \theta_{21}\chi_2)} \lesseqgtr 0$$

$$\frac{\partial u_{AL}^*}{\partial m_2} = -\frac{(1 - sm_1)(\theta_{20}\chi_2 - \theta_{10}\chi_1)}{sm_2^2(\theta_{11}\chi_1 - \theta_{20}\chi_2)} < 0$$

$$\frac{\partial m_{AL}^*}{\partial m_2} = \frac{1 - sm_1}{(1 - sm_1 + sm_2)^2} > 0$$

The effect on sector 2's profit rate is negative when the parameters $G_2 + \beta_2 m_2$ are large, whereas it is positive when they are small.

The impacts of changes in the capitalists' saving rate (the third row) on the long-run steady-state values are as follows:

$$\frac{\partial u_{AL}^*}{\partial m_2} = -\frac{(\theta_{20}\chi_2 - \theta_{10}\chi_1)}{s^2 m_2(\theta_{11}\chi_1 - \theta_{20}\chi_2)} < 0$$

$$\frac{\partial m_{AL}^*}{\partial m_2} = \frac{(m_1 - m_2)m_2}{(1 - sm_1 + sm_2)^2} \lesseqgtr 0$$

$$\frac{\partial r_{AL}^*}{\partial m_2} = -\frac{(\theta_{20}\chi_2 - \theta_{10}\chi_1)}{(\theta_{11}\chi_1 - \theta_{21}\chi_2)} < 0$$

Hence, when $m_1 < m_2$, the aggregate profit share falls in response to a rise in the saving rate, whereas it rises when $m_1 > m_2$.

The impacts of changes in the technical progress function of sector 1 (the fourth row) on the long-run steady-state values are as follows (the results are shown in a compact manner to save space):

$$\frac{\partial u_{1L}^*}{\partial \theta_{10}} = \frac{1}{g_{AL}^*} \cdot \frac{\partial u_{1L}^*}{\partial \theta_{11}} = -\frac{\chi_1}{\gamma_1(\theta_{11}\chi_1 - \theta_{20}\chi_2)} < 0$$

$$\frac{\partial u_{2L}^*}{\partial \theta_{10}} = \frac{1}{g_{AL}^*} \cdot \frac{\partial u_{2L}^*}{\partial \theta_{11}} = -\frac{\chi_1}{\gamma_2(\theta_{11}\chi_1 - \theta_{20}\chi_2)} < 0$$

$$\frac{\partial r_{1L}^*}{\partial \theta_{10}} = \frac{1}{g_{AL}^*} \cdot \frac{\partial r_{1L}^*}{\partial \theta_{11}} = -\frac{m_1\chi_1}{\gamma_1(\theta_{11}\chi_1 - \theta_{20}\chi_2)} < 0$$

$$\frac{\partial r_{2L}^*}{\partial \theta_{10}} = \frac{1}{g_{AL}^*} \cdot \frac{\partial r_{2L}^*}{\partial \theta_{11}} = -\frac{m_2\chi_1}{\gamma_2(\theta_{11}\chi_1 - \theta_{20}\chi_2)} < 0$$

$$\frac{\partial u_{AL}^*}{\partial \theta_{10}} = \frac{1}{g_{AL}^*} \cdot \frac{\partial u_{AL}^*}{\partial \theta_{11}} = -\frac{\chi_1(1 - s_1 m_1 + sm_2)}{sm_2(\theta_{11}\chi_1 - \theta_{20}\chi_2)} < 0$$

$$\frac{\partial g_{AL}^*}{\partial \theta_{10}} = \frac{1}{g_{AL}^*} \cdot \frac{\partial g_{AL}^*}{\partial \theta_{11}} = -\frac{\chi_1}{(\theta_{11}\chi_1 - \theta_{20}\chi_2)} < 0$$

$$\frac{\partial r_{AL}^*}{\partial \theta_{10}} = \frac{1}{g_{AL}^*} \cdot \frac{\partial r_{AL}^*}{\partial \theta_{11}} = -\frac{\chi_1}{s(\theta_{11}\chi_1 - \theta_{20}\chi_2)} < 0$$

The impacts of changes in the technical progress function of sector 2 (the fifth row) on the long-run steady-state values are as follows:

$$\frac{\partial u_{1L}^*}{\partial \theta_{20}} = \frac{1}{g_{AL}^*} \cdot \frac{\partial u_{1L}^*}{\partial \theta_{21}} = \frac{\chi_2}{\gamma_1(\theta_{11}\chi_1 - \theta_{20}\chi_2)} > 0$$

$$\frac{\partial u_{2L}^*}{\partial \theta_{20}} = \frac{1}{g_{AL}^*} \cdot \frac{\partial u_{2L}^*}{\partial \theta_{21}} = \frac{\chi_2}{\gamma_2(\theta_{11}\chi_1 - \theta_{20}\chi_2)} > 0$$

$$\frac{\partial r_{1L}^*}{\partial \theta_{20}} = \frac{1}{g_{AL}^*} \cdot \frac{\partial r_{1L}^*}{\partial \theta_{21}} = \frac{m_1\chi_2}{\gamma_1(\theta_{11}\chi_1 - \theta_{20}\chi_2)} > 0$$

$$\frac{\partial r_{2L}^*}{\partial \theta_{20}} = \frac{1}{g_{AL}^*} \cdot \frac{\partial r_{2L}^*}{\partial \theta_{21}} = \frac{m_2\chi_2}{\gamma_2(\theta_{11}\chi_1 - \theta_{20}\chi_2)} > 0$$

$$\frac{\partial u_{AL}^*}{\partial \theta_{20}} = \frac{1}{g_{AL}^*} \cdot \frac{\partial u_{AL}^*}{\partial \theta_{21}} = \frac{\chi_2(1 - s_1 m_1 + s m_2)}{s m_2(\theta_{11}\chi_1 - \theta_{20}\chi_2)} > 0$$

$$\frac{\partial g_{AL}^*}{\partial \theta_{20}} = \frac{1}{g_{AL}^*} \cdot \frac{\partial g_{AL}^*}{\partial \theta_{21}} = \frac{\chi_2}{(\theta_{11}\chi_1 - \theta_{20}\chi_2)} > 0$$

$$\frac{\partial r_{AL}^*}{\partial \theta_{20}} = \frac{1}{g_{AL}^*} \cdot \frac{\partial r_{AL}^*}{\partial \theta_{21}} = \frac{\chi_2}{s(\theta_{11}\chi_1 - \theta_{20}\chi_2)} > 0$$

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