

Analysis

Consistency and stability analysis of models of a monetary growth imperative

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ABSTRACT

Is fostering economic growth ‘only’ a question of political will or ‘unavoidable’ to maintain economic stability? It is disputed whether such a ‘growth imperative’ is located within the current monetary system, creating conflicts with sustainability. To examine the claim that compound interest compels economies to grow, we present five post-Keynesian models and show how to perform a stability analysis in the parameter space. A stationary state with zero net saving and investment can be reached with positive interest rates, if the parameter ‘consumption out of wealth’ is above a threshold that rises with the interest rate. The other claim that retained profits from the interest revenues of banks create an imperative is based on circuitist models that we consider refutable. Their accounting is inconsistent, and a modeling assumption central for a growth imperative is not underpinned theoretically: Bank’s equity capital has to increase even if debt does not. This is a discrepancy between the authors’ intentions in their texts and their actual models. We conclude that a monetary system based on interest-bearing debt–money with private banks does not lead to an ‘inherent’ growth imperative. If the stationary state is unstable, it is caused by agents’ decisions, not by structural inevitableness.

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1. Introduction

The debate about ecological limits and ‘planetary boundaries’ (Rockström et al., 2009; Steffen et al., 2015) has propelled forward the debate whether the economy will reach a non-growing, stationary state (D’Alisa et al., 2014; Jackson, 2009; Schmelzer, 2015; Steurer, 2002). This is in conflict with the ‘credo of unlimited growth’ (Schmelzer, 2015, pp. 262–70) that was based on the notion of the economic circuit as a self-contained, ‘perpetual’ flow of exchange value, while the inevitable ‘physical flow of matter–energy which is not circular’ was neglected (Daly, 1985, pp. 279–81). Gordon and Rosenthal (2003, p. 26) argued that in neoclassical theory, ‘growth is a matter of taste’, ‘no more than preference between present and future consumption’, and Robert Solow as a founder of neoclassical growth theory summed it up by saying that there is ‘nothing intrinsic in the system that says it cannot exist happily in a stationary state’

(Stoll, 2008, p. 92). But some authors have argued that for structural or systemic reasons only a growing economy is compatible with economic stability. The lack of any viable alternative to growth seems to create a ‘growth imperative’, creating a conflict with sustainability. Beltrani (1999, p. 123) claimed that immanent systemic mechanisms exist that the economy has to grow to maintain economic stability, *independent of the will* of the economic agents. Discussing cultural and societal influences in relation to economic growth, Richters and Siemoneit (2017a) provide a more detailed discussion on terminology. A (weaker) ‘constant incentive for growth’ caused by voluntary decisions of economic agents is called ‘growth impetus’ (Binswanger, 2013, p. 116) or ‘driver’ (Jackson and Victor, 2015, p. 39).

Beltrani (1999), Binswanger (2013), Binswanger (2009), Douthwaite (2000), Farley et al. (2013), and Lietaer et al. (2012) locate a growth imperative within the monetary system, while Berg et al. (2015), Cahen-Fourot et al. (2016), Jackson and Victor (2015), Strunz et al. (2017), and Wenzlaff et al. (2014) dispute this claim. The political relevance of this controversy is emphasized by some members of the Study Commission on ‘Growth, Wellbeing and Quality of Life’ by the German parliament: They suggest to study the different positions

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on the relation of growth, money, and credit to improve the basis for decision-making (Deutscher Bundestag, 2013, p. 794). This paper adds insights to the question of whether a stationary state (with non-growing GDP, Gross Domestic Product) is feasible in monetary models driven by effective demand. The study can be considered as part of the emerging field of ecological macroeconomics at the frontier of ecological and post-Keynesian ideas (Berg et al., 2015; Fontana and Sawyer, 2016; Holt et al., 2009; Jackson et al., 2014; Kronenberg, 2010; Rezai and Stagl, 2016).

In the following, we review two different lines of argument and corresponding mathematical models from the literature. The central aim is to clarify *why* certain modeling approaches lead to a growth imperative and others do not. Section 2 analyzes the arguments for a monetary growth imperative stemming from the existence of credit money and compound interest. This claim is examined with five post-Keynesian models of a monetary economy from the literature, some of which were explicitly designed to investigate this argument. The stability analyses reveal that the interplay of consumption decisions and interest income determines whether a stable stationary state exists. Section 3 critically reviews models locating the growth imperative within retained profits of private banks. Our analysis shows that they are based on inconsistencies and a discrepancy between the authors' intention in their texts and their actual models. Section 4 presents results and conclusions, trying to help to resolve the controversy of whether a monetary growth imperative exists.

Note that two definitions for profit are used parallel in economic literature (Mankiw and Taylor, 2011, ch. 13). *Accounting profit* (as used in all models) is the increase of a firm's equity capital *before profit appropriation*, i. e., the surplus of revenues over costs. For *economic profit* revenues not only have to compensate for the explicit costs of accounting, but for all costs required to keep factor inputs in their current use. This includes an appropriate estimation of the owners for the value of their working time, but also the losses of income due to the renunciation of better job or investment alternatives (opportunity costs). Thus, firms with an economic profit of zero can be 'profitable' and provide a living for their owners, realizing accounting profits which are fully distributed.

2. The Interplay of Consumption Decisions, Credit Money and Compound Interest

Several authors locate a growth imperative within the monetary system, particularly within interest bearing debt. For an overview on arguments and theoretical foundations, see Strunz et al. (2017) and Wenzlaff et al. (2014). One of the arguments is that credit and interest can only be paid back if 'new' money enters the system, increasing the money supply: 'Debt grows exponentially, obeying the abstract laws of mathematics' (Farley et al., 2013, p. 2809) because of 'compounded interest' or 'interest on interest' (Lietaer et al., 2012, pp. 100–1). This would imply that 'the economy must grow continuously if it is not to collapse' (Douthwaite, 2000, p. 6). The central argument along these lines is that debt claims increase exponentially because of interest dues, and therefore liabilities have to increase in lockstep. The looming debt overload could only be neutralized by defaults and crisis, or mitigated by steady economic growth. Farley et al. (2013, p. 2811) concluded that in a stable non-growing economy, 'money creation ... cannot be debt-based and interest-bearing.' Dittmer (2015) has critically discussed non debt-based money extensively, thus we focus on investigating whether a stationary state is compatible with positive interest rates.

Do positive interest rates on money necessarily lead to accumulation of financial assets? If creditors spend their interest income for investments or consumption, money flows back into circulation and is available for repayment, so exponential growth of debt and

deposits does not happen (Berg et al., 2015). This possibility is omitted by those cited above arguing that positive interest rates are incompatible with zero growth for systemic reasons. Glötzl (1999, 2009) objected that it is unrealistic that creditors decide to fully spend their interest income, which is why credit claims increase and the collective of debtors is powerless to repay the debt. But note that this is not 'independent of the will of agents', but dependent on consumption decisions of those who achieve income. Only if agents decide to increase their money stocks permanently and boundlessly, no stationary state can be obtained. The conclusion is that the relevant condition for a stationary state is not interest rates, but the aggregate net saving ratio and net investment to be zero, i. e., the proportion of income which is saved and invested on top of replacement investment. The relation between income (from wages or interest) and consumption can be studied in post-Keynesian models.

2.1. Insights from Post-Keynesian Models

Models describing a monetary economy were used to investigate whether a monetary growth imperative exists. The theoretical foundation of these models driven by effective demand is the 'Monetary Theory of Production' (Fontana and Realforzo, 2005; Godley and Lavoie, 2012) in the tradition of Keynes (1936, 1973).

Jackson and Victor (2015, p. 44) 'found no evidence of a growth imperative arising from the existence of a debt-based money system' in their model, because simulations converged to a stationary state. Cahen-Fourot et al. (2016) came to the same conclusion, emphasizing that it is necessary to include consumption out of wealth to reach a stationary state, because saving out of profit has to be compensated. The parameter 'consumption out of wealth' c_v indicates the percentage of the stock of wealth of households at the end of one period that they spend during the next period. Both papers concluded that positive interest rates and debt-money are compatible with a stationary economy.

Berg et al. (2015) provided a more nuanced view based on a systematic approach, further explained in Richters (2015): The stability analysis of their model showed that the question of whether a stationary state is stable depends on the interplay of interest rates and consumption parameters. If the interest rate is high and 'consumption out of wealth' c_v low, a stable, non-growing economy is impossible.

We will show in the following that this result can be generalized to other models, because they are based on similar assumptions about consumption and investment decisions (Section 2.2). Sections 2.3.1–6 explain the methodology and provide five stability analyses of the papers by Berg et al. (2015), Cahen-Fourot et al. (2016), Jackson and Victor (2015), and, for comparison, chapters 4 and 10 of the textbook 'Monetary Economics' (Godley and Lavoie, 2012). The results are jointly discussed in Section 2.4.

2.2. Introductory Thoughts on Consumption and Investment Decisions

In all the dynamical models of this chapter, consumption C is composed of not more than three components, the first being a fixed autonomous spending c_0 (sometimes set to 0), the second being proportional to disposable income Y_d ($c_y Y_d$) or disposable wage income W_d ($c_w W_d$), and the third being proportional to the net wealth of households of the previous period $V_{(t-1)}$ (with parameter 'consumption out of wealth' c_v):

$$C_{(t)} = c_0 + c_y Y_{d(t)} (\text{resp. } c_w W_{d(t)}) + c_v V_{(t-1)}. \quad (1)$$

The papers may use different notations (α_2 for c_y ; α_1 for c_y or c_w), but we harmonized them for increased readability. The old Keynesian

argument that people ‘increase their consumption as their income increases, but not by as much as the increase in their income’ (Keynes, 1936, p. 96) is respected as $c_y < 1$. On the other hand, Keynes argued that the ‘marginal propensity to consume is not constant for all levels of employment, and it is probable that there will be, as a rule, a tendency for it to diminish as employment increases’ (p. 120). This is not reflected in this type of consumption function: if consumption out of wealth or income is proportional to wealth or income, then average and marginal propensity to consume are identical.

If we look at the situation in Germany in 2003, we see that the saving rate out of national income indeed rises with income, from –10% for the decile with the lowest income to more than 35% for the decile with the highest income (Klär and Slacalek, 2006). According to polls, the quartile with the highest income had a saving ratio out of disposable income between 13 and 16% with a rising trend between 1995 and 2007 in Germany, while saving ratio of the poorest quartile went down from above 7% to 4% (Stein, 2009, p. 12). At the same time, marginal propensity to consume was estimated to be significantly higher for wages compared to profit income in the G10 in the years 1960–2007 (Onaran and Galanis, 2012) and the OECD in the years 1970–2011 (Hartwig, 2014). Distribution of income therefore has an effect on the saving ratio. This raises some doubt about consumption functions where the saving ratio is assumed to be homogeneous and independent on the type of income.

Panel regression by Hartwig (2014) on a specific growth model yielded average saving out of wages (resp. profits) to be 0.202 (resp. 0.317).¹ Both are higher than today’s net saving ratios in the OECD (OECD, 2015, Table 6.1), but given Eq. (1), consumption out of wealth and autonomous consumption reduce net saving: dependent on these consumption parameters, one may even reach zero net saving in the stationary state. In the following, we will therefore assume that households consume 80% of their wage income and 68% of profits, if possible: Some models assume a priori that consumption out of profits is zero while consumption out of wages is unity, or that a uniform consumption out of income c_y exists. In the latter case, we assume that $c_y = 0.8$. Note that in the models, profits are always distributed to households, and increases in capital stock (if modeled) are financed with loans or emission of equity. If modeled differently, retained profits could contribute significantly to saving out of profits.

In post-Keynesian theory, investments can be made without prior saving, a usual assumption in the presence of credit money (Godley and Lavoie, 2012; Graziani, 2003). Having said that, in all the models investment by firms is determined by their sales: either directly (Godley and Lavoie, 2012, ch. 4) or indirectly via sales expectations (Berg et al., 2015; Godley and Lavoie, 2012, ch. 10; Jackson and Victor, 2015). There is no autonomous investment. As government expenditures are assumed to be fixed, sales and investment (and the stationary state of zero saving and investment) are ultimately determined by consumption decisions by households.

2.3. Stability Analyses of Five Models

In the following five Sections 2.3.2–6, we perform a stability analysis for each of the models. Before, we describe the mathematical foundations in Section 2.3.1 and provide a rather detailed description of the process for one model in Section 2.3.2. This is required for understanding the analysis of the following models, which are treated more briefly. Section 2.4 will provide a comprehensible summary of the results, focusing on the economic interpretation.

2.3.1. Methodology: Dynamical Systems and Stability Analysis

With the exception of the static model by Cahen-Fourot et al. (2016), all the models studied in this chapter are Stock-Flow Consistent models (SFC)². They are examples of discrete dynamical systems, because variables change in each time step, indicated with the subscript t (see e. g., Kuznetsov, 2004). An iteration means calculating the value of the variables in the vector $\vec{x}_{(t)}$ based on the values of the previous period $\vec{x}_{(t-1)}$, with f being a function or map:

$$\vec{x}_{(t)} = f(\vec{x}_{(t-1)}). \quad (2)$$

The stationary states can be determined by finding the fixed points of the dynamical system. A fixed point \vec{x}^* is a point in the phase space where the iteration does not change the values of the variables:

$$\vec{x}^* = f(\vec{x}^*). \quad (3)$$

If a model converges to a well-defined stationary state, the existence of a growth imperative in this model can be rejected. In SFC models, a stationary state is reached ‘if all stocks and all flows remain constant over time, and therefore inflows equal outflows’ for all agents in the system (Berg et al., 2015, p. 13). As an example, household’s ‘consumption must be equal to disposable income’ (Godley and Lavoie, 2012, p. 73).

It is known from dynamical systems theory that a fixed point can be stable or unstable (Abraham et al., 1997, pp. 23–7). A stable fixed point means that after a small perturbation in one variable, the model economy will be pushed back to the stationary state then called ‘attractor’. In the case of an unstable fixed point, the economy will be pushed away from this state (‘repeller’) – which means that an economy initialized aside this point can never reach this stationary state. Note that an unstable fixed point (repeller) does not necessarily indicate any economic instability – it may also mean steady economic growth. In the following we will use *attracting* and *repellent* to avoid confusion with economic instability. To determine the stability properties of a fixed point, one has to consider the dynamic evolution of the system. In Section 2.3.2, we will explicate the stability analysis for SFC models as described in Berg et al. (2015) and Richters (2015) using a simple portfolio choice model.

The stability analysis will reveal that each of these model economies has one single fixed point that can be attracting (economy reaches a stationary state) or repellent (economy never reaches a stationary state), depending on the chosen set of parameters. If a certain parameter is increased and the fixed point changes its stability and the system undergoes a sudden change in dynamics, this is called a *bifurcation*. The *bifurcation threshold* separates the attracting and the repellent region of the parameter space. The threshold can be calculated analytically for all the models analyzed in this paper, while more complex models may require to numerically sweep through the parameter space and determine for each set of parameters separately whether a stationary state will be reached.

In economic models it is further relevant whether a fixed point is meaningful: For example, GDP Y in the stationary state should not be negative. If the stationary state is meaningless but attracting, this generally indicates that the model is not properly defined. Fig. 2 will help to clarify the steps of determining whether the mathematically determined fixed point of Section 2.3.2 corresponds to a stable stationary state that is also economically meaningful.

¹ Note that Onaran and Galanis (2012) found an even higher discrepancy between the two rates.

² SFC models are a class of structural macroeconomic models based on a detailed and careful articulation of balance sheets and accounting relationships. For a review on these models, see Caverzasi and Godin (2015) and the textbook by Godley and Lavoie (2012).

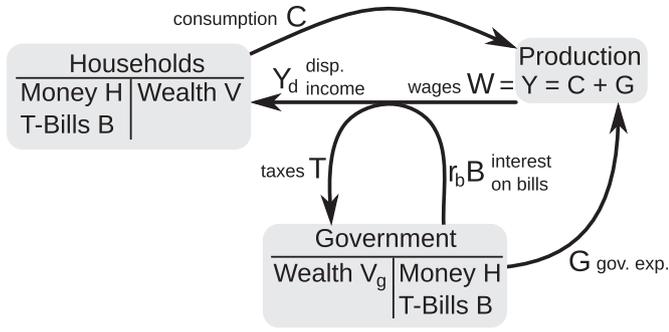


Fig. 1. Stocks and flows of the model in Section 2.3.2. The T-accounts display the balance sheets of the agents, while flows are depicted with arrows. Note that accounting identities guarantee that $V = V_g$. Taxes T are levied as a constant fraction θ on income $r_b B + W$. The consumption function is given by $C_{(t)} = c_y Y_{d(t)} + c_v V_{(t-1)}$.

2.3.2. Simple Portfolio Choice Model by Godley & Lavoie 2012, ch. 4

The first model, namely the simple portfolio choice model provided in chapter 4 of the textbook ‘Monetary Economics’ (Godley and Lavoie, 2012), consists of three sectors: households, government, and firms. For the structure of stocks and flows, see Fig. 1. Firms are modeled as passive agents that produce output in a pure service economy without any capital goods. Households can choose to consume their income or save it in the form of money or treasury bills³, the latter with a positive interest rate r_b .

The consumption function is a variation of Eq. (1) with autonomous consumption $c_0 = 0$:

$$C_{(t)} = c_y Y_{d(t)} + c_v V_{(t-1)}, \tag{4}$$

with C consumption, Y_d disposable income (thus after taxes), $V_{(t-1)}$ the wealth of the previous period. c_y is consumption out of income, while c_v is consumption out of wealth, two parameters between 0 and 1. Wealth $V_{(t)}$ is allocated to money $H_{(t)}$ and bills $B_{(t)}$. In the book, wealth allocation is adjusted dynamically dependent on interest rate and income, but to improve readability, we assume that portfolio choice is given by fixed proportions: $B_{(t)} = bV_{(t)}$, $H_{(t)} = (1 - b)V_{(t)}$, with $0 < b < 1$. The average interest rate paid on government liabilities is given by $r = r_b b$. The government taxes income with a tax rate of θ and has constant government expenditures G in each period. Disposable income $Y_{d(t)} = (1 - \theta)(Y_{(t)} + r_b b V_{(t-1)})$ consists of interest income $r_b B_{(t-1)}$ plus national income Y (determined by consumption C plus government expenditures G), minus taxes, levied as a fraction θ on income. Therefore, the equation for Y is given by:

$$Y_{(t)} = G + C_{(t)} = G + c_y(1 - \theta)(Y_{(t)} + r_b b V_{(t-1)}) + c_v V_{(t-1)}, \tag{5}$$

which can be solved for $Y_{(t)}$ to be:

$$Y_{(t)} = \frac{G + (c_y(1 - \theta)r_b b + c_v) V_{(t-1)}}{1 - c_y(1 - \theta)}. \tag{6}$$

Wealth $V_{(t)}$ can be calculated as $V_{(t-1)} + Y_{d(t)} - C_{(t)}$ which yields:

$$V_{(t)} = \left[1 - \frac{\theta c_v - (1 - \theta)(1 - c_y)r_b b}{1 - c_y(1 - \theta)} \right] V_{(t-1)} + \frac{(1 - \theta)(1 - c_y)}{1 - c_y(1 - \theta)} G. \tag{7}$$

³ Government debt instruments that mature in less than one year, here: mature in one period.

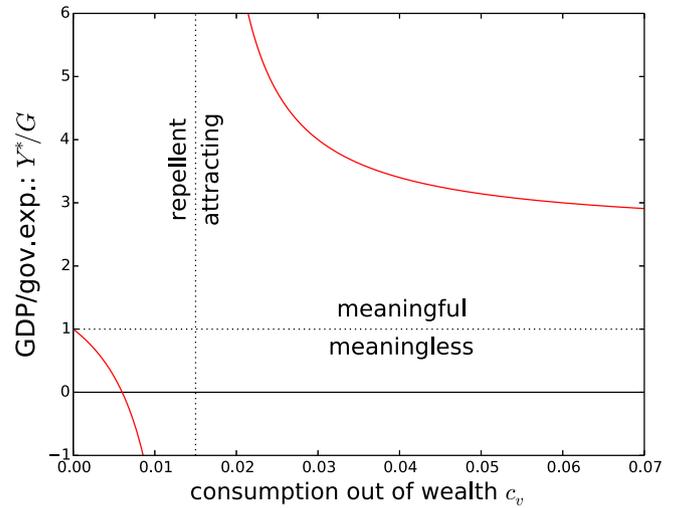


Fig. 2. Relation between consumption out of wealth c_v and GDP Y^* in the stationary state (expressed as a multiple of government expenditures G) according to Eq. (10) for the model by Godley and Lavoie (2012, ch. 4), see Section 2.3.2. The calculations were performed with $c_y = 0.8, \theta = 0.4, r = 0.05$. Eq. (11) provides the bifurcation threshold $c_v = 0.015$ depicted as vertical dotted line, thus the change from repellent to attracting, see also Fig. 3. If c_v is below this threshold, the stationary state is repellent, and GDP in the stationary state is below government expenditures G , which is economically not meaningful. If c_v is above, the stationary state is attracting and meaningful, and the economy converges to the stationary state. Note that the model structure guarantees that no attracting, but meaningless fixed points exist.

This way, the dynamics of the system can be boiled down to a linear map of the form

$$V_{(t)} = mV_{(t-1)} + n, \tag{8}$$

with m and n constant, depending on parameters (including government expenditure G). All other variables can be derived from this equation. V^* is a fixed point following Eq. (3) with $\vec{x}_{(t)} = (V_{(t)})$ if and only if

$$V^* = n/(1 - m) = \frac{G(1 - \theta)(1 - c_y)}{\theta c_v - (1 - \theta)(1 - c_y)r_b b}. \tag{9}$$

This fixed point is attracting if and only if $|m| < 1$ (Kuznetsov, 2004). If $|m| > 1$, V^* still is a fixed point of the system, but is repellent. GDP Y^* in the stationary state can be calculated by Eqs. (6) and (9) to be:

$$Y^* = G \frac{c_v - (1 - c_y)(1 - \theta)r}{\theta c_v - (1 - c_y)(1 - \theta)r}, \tag{10}$$

which is consistent with Godley and Lavoie (2012, eq. 4.25). Because of the subtraction in the denominator, Y^* can be undefined or negative as depicted in Fig. 2, thus economically meaningless. However, by design, the model economy does not evolve to a state that is not meaningful. This paradox is explained by the fact that if $Y^* < 0$, the fixed point is repellent and ‘pushes’ the model economy away from it, which means that this stationary state can be calculated, but never be reached by iterating the model. If the model is initialized at any meaningful state with $V > 0$, government debt and

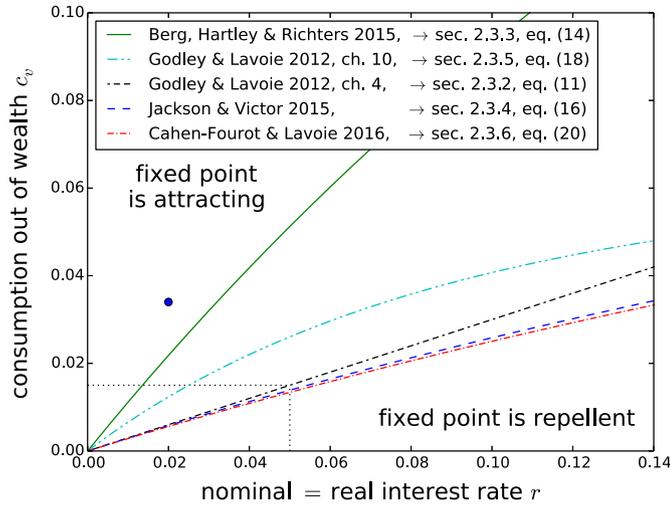


Fig. 3. Stability map of interest rates r and consumption out of wealth (c_v): If the parameter for ‘consumption out of wealth’ is above the line for a given interest rate, the stationary state (a fixed point of the dynamical system) is attracting. Consumption out of wealth can then balance interest income. The plot summarizes the stability frontiers of five models according to own calculations and parameter values provided in Sections 2.3.2–6. Dotted vertical and horizontal lines correspond to the numerical example used in Fig. 2 and discussed below Eq. (11). The parameters used by Jackson and Victor (2015) in their paper are indicated by the blue dot, explaining why they find a stable system.

interest dues grow unboundedly. Then the share of interest payments in total government spending approaches 1, not indicating a robust economic system.

What are the conditions for a meaningful and attracting stationary state? Y^* is bigger than G , V^* is positive, $|m| < 1$, and the fixed point is attracting if and only if consumption out of wealth c_v is bigger than a certain threshold:

$$c_v > \frac{(1 - c_y)(1 - \theta)r}{\theta} \tag{11}$$

If c_v is below the threshold, $Y^* < G$, which is economically meaningless, and the fixed point is repellent. The threshold defined by Eq. (11) corresponds to a change of stability, called bifurcation. It separates the stable and unstable region in the parameter space of c_v and average interest on government liabilities r as depicted in Fig. 3 with tax rate $\theta = 0.4$; consumption out of income $c_y = 0.8$.

A numerical example for Eq. (11) may help to give an intuition for this threshold. If yearly interest on government bills is $r_b = 5\%$ and tax rate on income is $\theta = 40\%$, a household owning bills worth \$100 will receive a yearly non-taxed interest income of \$3. It consumes $c_y = 80\%$ of this income, then \$0.60 non-taxed, non-consumed interest income is left. This means that consumption out of wealth c_v has to be at least 0.6% per year to compensate the interest income. In fact, as a fraction $(1 - \theta)$ of the consumption expenditures comes back as factor income to the households, these 0.6% have to be increased to $c_v = 0.6\%/\theta = 1.5\%$ to compensate this income stream, as indicated with dotted lines in Figs. 2 and 3.

Why does the minimum value for c_v according to Eq. (11) drops to zero for $r \rightarrow 0$? Non-taxed, non-consumed wage income could have the same effect as interest income and requires a rate of consumption out of wealth above a certain threshold, but $c_v > 0$ is sufficient: By saving, net worth V is increased, while in parallel, $c_v V$ as a component of the consumption function grows until it is high enough to compensate wage (and in later models profit) income, and a stationary state will be reached. In contrast to profits or wages, interest income

also rises proportionally with wealth – and if it rises more quickly than consumption, households’ wealth stock will increase over time without bound.⁴ Therefore, in the presence of a positive interest rate, c_v has to be not only bigger than zero, but above a positive threshold according to Eq. (11) for the stationary state to be attracting. This threshold increases with the interest rate.

2.3.3. Stock-Flow Consistent Input–Output Model by Berg et al. 2015

Berg et al. (2015) presented a Stock-Flow Consistent Input–Output model with households, multiple production sectors, and a joint sector including banks, central bank, and government. Households own firms and interest charging deposits, but no other financial assets. The consumption function is given by

$$C_{(t)} = c_w(1 - \theta)W_{(t)} + c_vV_{(t-1)}, \tag{12}$$

which means that in their model, consumption out of profit and interest income is zero, because only a fraction c_w of wage income $W_{(t)}$ is consumed within the period. Both add to the stock of wealth that may finance later consumption. Berg et al. (2015, p. 19) could transform their model into a non-homogeneous first-order matrix difference equation:

$$\vec{x}_{(t)} = \mathcal{M}\vec{x}_{(t-1)} + \vec{n}. \tag{13}$$

Note that $\vec{x}_{(t)}$ and \vec{n} are vectors and \mathcal{M} is a matrix here, different to the scalar form in Eq. (8). If the absolute values of all the eigenvalues of the matrix \mathcal{M} are smaller than one, the fixed point is stable (Kuznetsov, 2004). The eigenvalue calculation was performed numerically and showed that the parameter ‘consumption out of wealth’ has to be above a certain threshold to obtain an attracting stationary state as in Eq. (11), but they did not calculate the threshold analytically. This was done in Richters (2015, eq. 59) and yielded the following for the special case of all sectors being identical:

$$c_v > r_M(1 - \theta) \frac{\phi + \omega\lambda(1 + \phi)(1 - c_w(1 - \theta))}{\theta(\phi + \omega\lambda(1 + \phi)) + \sigma^T r_L(1 - \theta)}. \tag{14}$$

The dependence of c_v on interest on deposits r is presented in Fig. 3, using the following parameters: wages per output unit $\omega\lambda = 0.25$; markup $\phi = 1/3$; thus intermediate sales per output unit $1/(1 + \phi) - \omega\lambda = 0.5$; interest on loans and deposits $r = r_L = r_M$; targeted inventory to expected sales ratio $\sigma^T = 1$; consumption out of wages $c_w = 0.8$; tax rate $\theta = 0.4$.

As Richters (2015) showed, the stationary state may be repellent even if meaningful: The interaction of sales expectations and inventory targets can lead to ‘inventory oscillations’. This may not happen in the model discussed in Section 2.3.2, but we cannot rule out this case in the following sections. We restrict our analysis to the instability related to positive interest rates, which is equivalent to asking whether the stationary state is meaningful. While this may not be a sufficient condition for a stable stationary state to exist, it clearly is a necessary condition, and the one related to positive interest rates and a monetary growth imperative.

2.3.4. Stock-Flow Consistent Model with Banks by Jackson & Victor 2015

Jackson and Victor (2015) provided a SFC model including banks, central banks, and government as explicit sectors. Banks provide

⁴ This is also the reason why a consumption function of the type $c_0 + c_y Y_d$ (with $c_0, c_y > 0$, see Godley and Lavoie, 2012, 78) is not sufficient to guarantee the existence of a stationary state.

loans to firms, receive deposits by households (but can provide loans without holding deposits, which enables the creation of credit money), and hold government bonds and central bank reserves to maintain adequate levels of capital and liquidity (p. 35). Banks calculate equity requirements for desired net lending and distribute any additional profits. The authors intended to explicitly model statutory provisions such as equity and reserve requirements to show that there is no obstacle to reaching a stationary state.

The consumption function is given by Eq. (4), except that disposable income is replaced by a simple extrapolation of the trend over the previous period, which is not relevant in the stationary state. Jackson and Victor (2015) did not calculate GDP in the stationary state of their discrete dynamical model analytically, but we show in Appendix A that this can be done, yielding:

$$GDP = \frac{G}{1 - r_\delta \kappa} \cdot \frac{c_v - (1 - c_y)(1 - \theta)r_B}{\theta c_v - r_B(1 - \theta) \left(1 - c_y - \frac{c_v \kappa}{1 - r_\delta \kappa}\right)}. \quad (15)$$

For this to be bigger than G as a necessary condition for a reasonable stationary state, a minimal rate of consumption out of wealth c_v exists:

$$c_v > \frac{(1 - \theta)(1 - c_y)r_B}{\theta + (1 - \theta)\kappa r_B / (1 - r_\delta \kappa)}. \quad (16)$$

The parameters used for Fig. 3 are: interest on bonds $r_B = r$; tax rate $\theta = 0.4$; consumption out of income $c_y = 0.8$; capital to output ratio $\kappa = 1$; depreciation rate $r_\delta = 0.0667$. For $\kappa = 0$, the result is identical to Eq. (11).

2.3.5. Model with Inside and Outside Money by Godley & Lavoie 2012, ch. 10

In chapter 10 of ‘Monetary Economics’, Godley and Lavoie (2012) present a model of a ‘whole monetary economy’ in which ‘active’ commercial banks ‘take decisions of their own’, but are limited by the central bank’s own policy attempts to exercise control over the commercial banks (p. 314). The model includes cash, checking accounts, and deposit accounts in addition to bills and bonds (p. 315), while integrating ‘compulsory reserve requirements’ (p. 333), minimum targets on the bank liquidity ratio (p. 339), and banks’ profits (p. 340). Banks’ profits are distributed as dividends, so banks do not build up equity. The consumption function is again given by Eq. (4) including a simple extrapolation of the trend as in the previous section. Thereby, the model economy reaches ‘such a high degree of dynamic interdependence that its exposition in words presents considerable difficulties’ (p. 318). As this is valid a fortiori for this paper, we refer to the book for a detailed description, and abstract from inflation here. GDP Y^* in the stationary can be calculated following Eq. (B.3) in Appendix B to be:

$$Y^* = G \frac{1 - r(1 - c_y)/c_v}{\theta/(1 + \theta) + r[(1 + \theta)(1 + \phi)(1 + r_l \sigma^T) - (1 - c_y)/c_v]}. \quad (17)$$

For this to be bigger than government expenditures G as a necessary condition for a reasonable stationary state, a minimal rate of consumption out of wealth c_v exists:

$$c_v > \frac{(1 - c_y)r}{\theta/(1 + \theta) + r \sigma^T (1 + \theta)(1 + \phi)(1 + r_l \sigma^T)}. \quad (18)$$

The parameters used for Fig. 3 are: average nominal interest rate on government liabilities r ; interest on loans for firms $r_l = r$ for simplicity; targeted inventory to expected sales ratio $\sigma^T = 1$; tax rate $\theta = 0.4$; consumption out of income $c_y = 0.8$.

2.3.6. Static Model revisiting Cambridge and Kalecki equations by Cahen-Fourot & Lavoie 2016

The model presented by Cahen-Fourot et al. (2016) is not a dynamical model, but simply a collection of static equations used to determine the stationary state, based on the Cambridge and Kalecki equations. It is assumed that after taxes are paid as a fraction θ of income, all remaining wage income is consumed, while a fraction s_p of profit income $(1 - \theta)\pi Y$ (π : profit share) and interest payments on government bonds B held by households is saved. At the same time, a fraction c_v (consumption out of wealth) of net worth V of households consisting of capital stock kY and bonds B is consumed.

Cahen-Fourot et al. (2016, Eq. 16) solve for GDP Y^* in the stationary state:

$$Y^* = G \frac{c_v - s_p(1 - \theta)r}{c_v(k(1 - \theta)r + \theta) - s_p r(1 - \theta)(\theta - \pi(1 - \theta))}. \quad (19)$$

They argued that this proves that a stationary state is compatible with positive interest rates. They acknowledged that ‘restrictions on parameter values’ (p. 167) are necessary, but did not state them. We can make these restrictions explicit, because Y^* is bigger than G only if

$$c_v > \frac{(1 - \theta)r s_p (\theta + \pi(1 - \theta))}{\theta + (1 - \theta)rk}. \quad (20)$$

If c_v is smaller, the model has no meaningful stationary state. As no dynamical model is provided, we cannot say anything about what would happen in this case. The relation is depicted in Fig. 3 with the following parameters: interest rate r ; tax rate $\theta = 0.4$; capital coefficient $k = K/Y = 1$; saving out of profits $s_p = 0.32$; profit rate $\pi = 1/3$.

2.4. Discussion

In each of the models in Section 2.3.2–6, a lower limit for consumption out of wealth c_v was calculated, always dependent on the interest rate. For an attracting stationary state to exist, consumption out of wealth has to be above a threshold that increases with the interest rate in all the models, if tax rate and consumption out of income are kept constant. These stability thresholds are jointly displayed in Fig. 3. They do not depend on parameters describing reserve, equity or liquidity requirements, thus these parameters do not influence the stability of the stationary state. In every model where firms and profits are modeled, profits are strictly positive in the stationary state: In Berg et al. (2015) and Godley and Lavoie (2012, ch. 10), firms set prices with a markup on costs, thus guaranteeing positive profits. Jackson and Victor (2015) assume that profit is a residual that accounts to one eighth of GDP given the parameters chosen, and Cahen-Fourot et al. (2016) set profits as a constant fraction of GDP. These accounting profits are fully distributed to the owners.

The gradients of the bifurcation thresholds in Fig. 3 differ between the models. The most important reason is that Berg et al. (2015) assumed no immediate consumption out of interest and profit income at all, Cahen-Fourot et al. (2016) argued that wages are fully consumed, while the other three models assumed equal consumption propensities for all types of income. Obviously, higher consumption out of income reduces the need for consumption out of wealth in the stationary state. The second reason are capital goods (fixed or inventories): In Jackson and Victor (2015), households consume out of equity, so if capital requirements are higher, consumption out of wealth is increased. Thus, a smaller propensity of consumption out of wealth is sufficient to reach a stationary state. In contrast, equity of firms does not lead to higher consumption in Berg et al. (2015). In the case of Godley and Lavoie (2012, ch. 10), firms are financed

only by bank loans. Higher capital requirements lead to higher interest payments to banks, higher bank profits, and ultimately higher household income. However, household consumption out of wealth does not increase in this case. Therefore, higher capital requirements push up the minimal rate of consumption out of wealth to maintain stability. The thresholds of Godley and Lavoie (2012, ch. 4, 10) and Jackson and Victor (2015) are identical if capital to output ratio and inventory to sales ratio targets are set to zero. These findings may provide an intuition why the bifurcation thresholds of the five models differ.

The stability analysis reveals that a change in parameters may render the model unstable. In their numerical simulations, Jackson and Victor (2015, Eq. 50) sidestep this insight by adjusting the tax rate to higher values if consumption out of wealth drops. With this specification, the model is always stable. The crucial dependence on consumption out of wealth for a stable stationary state has been recognized by Godley and Lavoie (2012, p. 77), because without it, 'in models without growth, [...] renders the model unstable', and Cahen-Fourot et al. (2016, p. 167) agree. This suggests that consumption out of wealth has to be above zero for a stable stationary state. The bifurcation diagram in Fig. 3 specifies precisely the parameter space corresponding to a stable stationary state, indicating that consumption out of wealth has to be above a positive threshold. Specific simulations may lead to conclusions that are not true in general, which underlines that the stability analysis adds additional insights to numerical simulations of the dynamics.

For the question of a monetary growth imperative, the results for the five post-Keynesian models are quite similar: It is neither true that a stationary state is impossible, nor that it can always be attained while interest rates are irrelevant. Positive interest rates do not systematically lead to exponentially growing deposits, because taxation and consumption out of wealth and income can dampen the positive feedback loop of compound interest. However, a stable non-growing economy can be attained only for certain combinations of parameters: The stability therefore depends on consumption decisions of both the creditors and recipients of income reflected by consumption parameters. If the fixed point of the dynamical system is repellent and no stationary state can be reached, the models show continued economic growth. Along the growth path, government consumption expenditures G as a fraction of GDP or total government spending (including interest payments) drop to zero, not indicating a robust economic system. As all the models neglect technical change, analyzing growth processes is beyond the scope of the models.

In the stationary state, saving and investment net of depreciation have to drop to zero. In most OECD countries, average net saving rate and net investment in the last decade were above zero and a stationary state was (obviously) not attained (OECD, 2015). The stability analysis reveals that consumption out of wealth is relevant for the stability of the stationary state. Unfortunately, Cooper and Dynan (2016, p. 50) argued that 'macroeconomic data have offered limited insight into the relationship between household net worth and consumption.' They summarized empirical research that the marginal propensity to consume (MPC) out of wealth (thus for the last unit of wealth) is between 3 and 10 %, while Slacalek (2009, p. 26) found that 'marginal propensities to consume out of wealth typically range between 1 and 5 cents' per dollar of additional wealth in the 16 industrialized countries studied.

Just for the sake of argument, let us assume that the empirically determined marginal propensity to consume (thus for the last unit of wealth) is equal to average propensity to consume out of wealth, as it is done in all these models. If consumption out of wealth was 1% per year, an attracting stationary state can be reached if the interest rate is smaller than the model-dependent threshold that lies between 1% and 5%, as derived from Fig. 3. A reasonable parametrization can lead to a model without a stable stationary

state. Note that the model by Berg et al. (2015) yielding 1% is the one without any immediate consumption out of interest and profits, which is not supported empirically (Hartwig, 2014). If consumption out of wealth is higher than 1% as in other countries, the interest rate admissible for a stable stationary state rises more or less proportionally.

The models may nevertheless exclude factors that are possibly important: First, interaction between banks or distributional effects among households are neglected. Second, all the models assume that consumption out of wealth is proportional to wealth, which means that average and marginal propensity to consume are identical, which is disputable, see Section 2.2. We have shown that this is a central assumption for reaching stationary states in the models, and consumption rising less than proportionally could invalidate the related arguments. Third, the models by Jackson and Victor (2015) and Godley and Lavoie (2012, ch. 10) are the only ones which actually include banks, but their analysis showed that integrating minimum bank liquidity ratios, reserve and equity requirements or banks profits do not change the big picture, as GDP in the stationary state is independent of the corresponding parameters. In the stationary state, banks distribute all their profits to the households and do not build up equity. This may exclude behavior relevant for establishing a monetary growth imperative, an idea addressed in Section 3.

3. Retained Profits of the Banking Sector

Some authors going back to Binswanger (1991, 1996) locate the growth imperative not within decisions of consumers or firms, but in the fundamental connection between investment, credit creation, and profits: The explanation why economic growth is no side effect but requirement of a monetary economy, relies on three simple, independent statements: Businesses have to generate positive profits, investments are funded by credit, and interest is charged on credit. A positive rate of economic growth is necessary, because zero growth would lead to losses of businesses in the aggregate, and therefore to a downward spiral. The different circular flow models by Beltrani (1999), Binswanger and Beltrani (2009, 2013), Binswanger (2009, 2015), Gilányi (2015), and Johnson (2015) seem to confirm this reasoning.

All models discussed here are formulated in discrete time with representative agents. Production and sales are assumed to fall into different periods, and therefore enterprises have to pre-finance production via credit. In every period, consumers spend all they receive. As we will show, a growth imperative exists in these models because of the assumption that private banks distribute only a fraction < 1 of their profits even if their liabilities do not increase. We will present the different modeling approaches first, using r to denote the interest rate, and discuss them jointly in Section 3.4.

3.1. The Model by Beltrani 1999

The dissertation of Beltrani (1999) is probably the first explicit model of a monetary growth imperative. The role of the banking sector can be summarized as follows: δ denotes variable costs in the financial sector and r the interest rate, while $r - \delta$ is profit per unit of credit (p. 139). For the financial sector to be profitable, this has to be bigger than zero (p. 140). The resulting profit has to be retained, because equity capital and reserves of banks have to rise according to statutory provisions (p. 132) such as minimum reserves and equity capital regulations (p. 177). The profit will be kept as hoarded money (p. 139, 165) because other investments are ruled out (p. 181), resulting in money vanishing from circulation (p. 132). The latter is stated to be responsible for the growth imperative (p. 165). In the simple model (pp. 113–170), the minimal growth rate w of a stable growth path is calculated to be $w > r - \delta$ (p. 158, with $b \geq 0$ according to

p. 138). As long as $r > \delta$, the financial sector is profitable, increases its hoarding of money, and a growth imperative persists (p. 165). The more general model (pp. 171–300) is much more complex, but the relevant relations remain unchanged, and the minimal growth rate w again drops to zero if and only if $r = \delta$ (p. 260, Eq. 6.66–67).

3.2. The Model by H. C. Binswanger and Beltrani 2009, 2013

The model presented by Binswanger and Beltrani (2009, 2013) can be summarized as follows: The only capital stock are inventories valued at production costs of the previous period. In each period, firms sell inventories of value $C_t = K_{t-1}$. Capital stock K_t is financed by borrowed capital (K_t^B) and equity (K_t^E). Investment $I_t = K_t - K_{t-1}$ can also be differentiated into equity funded I_t^E and borrowed I_t^B . In every period, the firms pay interest on borrowed capital rK_{t-1}^B to the banks, dividends D_t (consisting of net profit G_t minus equity increase I_t^E) and production costs $K_t = K_{t-1} + I_t$ to the households. The production costs are equal to the new value of inventories C_t . The banks receive interest payments by the businesses (interest rate r on borrowed capital K_{t-1}^B) and distribute it partially as dividends and wages to households. The remaining earnings are retained by 'a transfer of funds from sight [or checking] deposits, which represent money, to the equity capital which does not represent money' (2013, 131). Therefore, 'a portion of money is constantly removed from circulation' (2013, 131). The payout fraction of the banks is denoted with b , the share of money leakage to banks' capital accordingly $1 - b$. As 'banks must make a profit in order to stay in business' (2013, 139), they distribute only a fraction $b < 1$ of profits to households. This formulation does not distinguish clearly between accounting profit and economic profit. Full distribution $b = 1$ is compatible with positive accounting profit, but means zero economic profit. The households consume all they receive, namely $K_t + brK_{t-1}^B + D_t$ in exchange for inventories C_t . Firms therefore receive $K_t + brK_{t-1}^B + D_t$ but spend $K_t + rK_{t-1}^B + D_t$ which is higher if $b < 1$ because banks retain earnings. Finally, the stock of inventories of firms is increased by $I_t = K_t - K_{t-1}$, while their stock of money is reduced by $(1 - b)rK_{t-1}^B$. The balance of the firm is positive only if $I_t > (1 - b)rK_{t-1}^B$, an equation not explicitly stated in the book. If $r > 0$ and $(1 - b) > 0$, this is only possible by (exponential) growth of the capital stock, and because inventories are sold completely by assumption in the next period, the economy has to grow. This equation proves that the removal of money through retained profits is crucial for establishing the growth imperative as stated explicitly only in the German edition (2009, 331): The leakage of money to banks' capital has to be compensated by credit increase via investment.

3.3. Models in the Tradition of M. Binswanger 2009

The paper by Binswanger (2009) was recently discussed by Binswanger (2015), Gilányi (2015), and Johnson (2015). The model was assigned by Johnson (2015, p. 602) to the tradition of the Theory of the Monetary Circuit (TMC) Graziani (1989, 1994). TMC addresses explicitly the following questions: 'Where is all the money going? Where do all the money come from?' (Chesnutt, 2012, p. 1). It 'involves a temporal perspective', 'step by step, after money creation, economic activity appears in the circuit and makes possible relationships between macroeconomic agents' (Accoce et al., 2007, p. 68).

In the model of Binswanger (2009, p. 711), the 'economy is modeled from a circular flow perspective, and, except for real capital (a stock), it includes only flow variables'. In every period, firms pay out dividends to households as a fraction $(1 - \rho)$ of the profits Π_{t-1} of the previous period, while the rest $\rho\Pi_{t-1}$ is retained earnings that are fully reinvested. Similarly, banks pay out brL_{t-1} with L_{t-1} credit volume, r interest rate and b payout ratio. Firms realize depreciation

dK_{t-1} , get new credit L_t that is used together with retained earnings to fund investment and wages that both end up as wage income of households. Households spend all their income $L_t + \Pi_{t-1} + brL_{t-1}$ for consumption which constitutes the only income of firms. Firms receive $L_t + \Pi_{t-1} + brL_{t-1}$ while they spend $\Pi_{t-1} + L_t + rL_{t-1}$ which is higher because banks retain earnings ($b < 1$).

The model is defined such that 'all loans are paid back at the end of the period and, therefore, all money is destroyed again' (Binswanger, 2015, p. 654). To repay the debt, firms have to obtain all the liquidity that was created during the period by the banks. But the retained earnings to increase bank equity lead to a 'net removal' of money from circulation, one of the joint foundations of all four papers (Binswanger, 2015, p. 658): 'Banks have to increase their capital on the liability side of their balance sheet (equity and reserves) along with the increase in loans, as a certain fraction of loans (a risky asset) must be covered by owners' capital. Therefore, a portion of banks' income is not put back into circulation but is used to increase banks' capital, which does not represent money.' By tracking the flows of money through the economic circuit, Gilányi (2015, p. 594) showed that in a non-growing economy, the money that is removed from circulation by banks is not compensated by ever increasing borrowing to finance ever more production. Profits of firms in the stationary state are therefore negative. This is why the net removal of money by banks is 'crucial for establishing the growth imperative' (Binswanger, 2009, p. 713).

Commenting on Binswanger (2009), Cahen-Fourot et al. (2016, p. 163) argue that 'if one sector is accumulating net wealth (as the bank sector does when it is adding retained earnings to its equity funds), then the other sectors must be running a deficit and accumulating debt while their flow of income remains constant.' In the model, the accumulation of debt is not studied because of the a priori assumption that all loans are paid back at the end of each period. Also Johnson (2015, p. 601) insists that loans have to be treated as a stock that may grow over time, not as a flow, which lead to a not-yet-resolved controversy with Binswanger (2015, p. 659). Surprisingly, a stock not modeled in any of the formulations of Binswanger (2009, 2015), Gilányi (2015), and Johnson (2015) is the equity capital of banks, despite its accented relevance.

3.4. Discussion

In the papers studied in Section 3, the results of Section 2 on households saving are irrelevant because households consume all they receive. The decisive reason for a growth imperative are retained profits of the banking sector. In these models, 'all money is bank money' (Binswanger and Beltrani, 2013, p. 131), and Binswanger (2009, p. 717) speaks of a 'pure credit money economy.' Therefore, banks do not hold other assets than credit claims. Dittmer (2015, p. 14) argued that Binswanger (2009) misunderstands bank capital treating it as 'cash that sits idly in the bank's tills without being put to work in the economy' (Admati and Hellwig, 2013, p. 6). This critique misses the point because in a pure credit economy, 'cash' does not even exist. Credit money is a liability of the bank, and increasing bank capital in these models is only possible if debt claims to businesses persist, which follows from a balance sheet perspective (Wenzlaff et al., 2014, pp. 23–4). Therefore, the increase in bank equity by hoarding credit money emitted by themselves (Beltrani, 1999, p. 165) and the 'transfer of funds from sight deposits, which represent money, to the equity capital which does not represent money' (Binswanger and Beltrani, 2013, p. 131) obscures the matter.

All the models in this section assume that money is removed from circulation to increase bank's capital, and therefore require 'positive net inflows of money into the economy'. If the net removal of money to increase bank's equity capital plays such a decisive role for deriving a growth imperative, it is imperative to integrate this variable into the model. Its omission corresponds to 'black holes'

(Godley, 1996, p. 7) of accounting inconsistency to be avoided in models of a monetary circuit.

Not modeling the stock of equity of banks and the related flow of interest payments is a drawback common in the Theory of the Monetary Circuit (TMC): 'As the accounting is analyzed, it appears that several, if not all, contributors to the TMC fail to take properly into account how banks' profits can be spent in the goods or the financial markets. In several models, interest payments on loans made from firms to banks are not accounted for as part of national income, and simply disappear, instead of being treated as a possible source of demand for goods and/or financial assets' (Zezza, 2012, pp. 155–6). In our case, only a fraction of these interest payments disappears, but this does not invalidate Zezza's critique. He continued: 'By ignoring the accounting and behavioural implications of interest payments, TMC models are usually characterized by a 'paradox of profits'.' The negative profits realized in the TMC models on a monetary growth imperative are representatives of this paradox, as also stated by Johnson (2015, p. 602).

The distinct sequence of events is a feature of many TMC models (Rochon, 2005, p. 126), and Beltrani (1999, pp. 124–5) considered this to be necessary for establishing a growth imperative. At the same time, stocks that may act as buffers to be used in the following period are very limited in all the models. It is methodologically questionable that such general and far-reaching results depend on a very specific model structure.

Apart from the problematic modeling, what about the theoretical foundation of a growth imperative? In all the models, the imperative stems from the net removal of money due to the fact that 'banks have to increase their capital on the liability side of their balance sheet (equity and reserves) along with the increase in loans' (Binswanger, 2009, 2015). Similarly, Binswanger and Beltrani (2013, p. 131) argued that 'equity capital of the banks must to a certain extent keep pace with the increase in debt,' and Beltrani (1999, p. 177) cited statutory provisions such as equity and reserve requirements. But all authors construct their models such that bank's equity capital has to increase *even if debt does not*, which is a discrepancy between the authors' intention in their text and their actual model.

If equity of banks was included as difference between their assets and their liabilities, one would realize that banks' equity capital can increase only if liabilities of firms towards banks rise (accounted on the asset side of banks' balance sheet), if no other assets exist in the model. If *any* sector continues to accumulate credit claims, this will always avoid the convergence to a stable stationary state (Cahen-Fourot et al., 2016, p. 163). If liabilities of firms rise, their equity remains positive only if production grows. Rosenbaum (2015, p. 644) argued that in a non-growing economy, 'banks do not have to increase their equity' and hence the 'Binswanger model allows stable zero growth,' a conclusion valid for all models discussed in this section. This explains why the models by Jackson and Victor (2015) and Godley and Lavoie (2012, ch. 10) (see Sections 2.3.4 and 2.3.5) that explicitly include reserve or equity requirements show no inherent growth imperative, because they assume that reserves or equity remain constant if liabilities do. If it is assumed that banks constantly retain earnings, this must be underpinned theoretically as the main reason for a growth imperative – which is (as we have shown) not done in these papers, because of a discrepancy between intention and model.

4. Results and Conclusions

To summarize, analyzing the different modeling approaches shows that no 'immanent' or 'systemic' growth imperative can be found within a monetary economy relying on credit money and positive interest rates.

Decisive for ongoing growth of the economy are saving and investment *decisions* of those receiving income, be it from interest

or other sources. Therefore, the existence of positive interest rates alone cannot be responsible for a growth imperative. In general, if *any* model assumes permanent positive net saving or investment for certain agents, this necessarily renders a stationary state impossible. Monetary saving has to lead to debt accumulation elsewhere because the sum over monetary assets and liabilities has to be zero. Money may not be neutral, but the structure of the monetary system alone does not seem to cause a growth imperative, which would have been a very strong non-neutrality.

The stability analysis of five post-Keynesian models (Section 2) yielded the following results: Depending on parameter values, the stationary state can be stable or not. If the model economy does not reach a stationary state, this is caused by a net saving ratio (and therefore net investment, see Section 2.2) permanently above zero caused by saving decisions, not by a systematic, inescapable necessity. Aggregated accounting profits of firms can be positive without growth, if they are completely distributed. A possible need to reinvest profits could arise from competition and innovation (Marx, 1906, p. 649; Schumpeter, 1942, pp. 30–3; see also Richters and Siemoneit, 2017b), which is not discussed by the proponents of a monetary growth imperative. Net saving can drop to zero in a non-growing economy either by complete spending of income or (more plausibly) through parallel saving and dissaving. The higher the interest rate, the higher 'consumption out of wealth' has to be for compensating interest income that indeed plays an exceptional role, as it rises with wealth. If consumption out of wealth is as low as 1% as in some specific countries, the stability analysis shows that real interest rates between 1 and 5% may be high enough to prohibit convergence to a stationary state. Note that this numerical result is based on rough estimates and rather simple models.

The models in the tradition of Beltrani and Binswanger locating the growth imperative within retained profits of banks (Section 3) have inconsistencies in their modeling of banks' capital. Additionally, they claim that banks' capital has to keep pace with the increase in debt, but construct their models such that capital has to increase even if debt is constant. As both are critical assumptions for deriving the growth imperative, we claim that the models are refutable and should be revised.

The controversy whether positive interest rates are compatible with a stable stationary state therefore boils down to different assumptions about the consumption behavior of households and the distribution of profits by banks: If agents decide to steadily save part of their income, no stable stationary state can be reached. This is in line with proponents of the 'Monetary Circuit' arguing that 'the fundamental structural properties of economic equilibrium – such as income distribution, the rate of accumulation, the rate of growth – are determined ... by decisions of those agents who enjoy command over money' (Graziani 1994, p. 274). Based on this analysis, the term 'imperative' in the sense of *no room for maneuver* does not seem to be justified: Investment or consumption parameters in the models reflect economic decisions and are not 'independent of the will' of the agents.

For future research, it is important to note that all these models do not investigate whether the monetary stationary state corresponds to an ecologically viable scale or socially favorable situation. Therefore, effects of distribution should be studied. Second, Rosenbaum (2015, p. 630) emphasized that in a Kaleckian growth model, 'zero growth can only be maintained if depreciation is added to the model' which allows for positive gross investment. Most of the models we studied did not include depreciation and nevertheless reached a stationary state, but this is due to the fact that investment was determined by sales (expectations), see Section 2.2. If autonomous investment was added, this may change. Third, most models in Sections 2 and 3 consider inflation to be negligible, which is questionable because a nominal growth imperative could be compatible with zero real growth. Fourth, the role of banks, their equity, and

possible retained earnings need further investigation, but it has to be specified explicitly what banks do with these earnings, and why equity would have to be increased independent of the will of the owners of the banks. Fifth, the remarks on the empirical plausibility of consumption functions and the numerical estimation of bifurcation thresholds undoubtedly could be refined. All this could provide additional insights into the relation between economic growth and the monetary system.

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Appendix A. Derivation of GDP in the Stationary State for Jackson & Victor 2015

Jackson and Victor (2015) do not analyze their Stock-Flow Consistent model analytically, but the stationary solution can be obtained this way. The second equation in their paper is denoted with (J2).

We start from their definition of GDP (Eq. J1) and of income Y^h of households in Eq. (J2) (with C : consumption, G : government expenditures, I : investments, W : wage bill, P^f : profits of firms, i_f : net interest paid out by firms, $\delta = r_\delta K_{-1}$: depreciation, K_{-1} : capital stock of firms, P^{fd}, P^{bd} : profit distributed by firms and banks, i_{bh} : interest on deposits of households, i_{bh} : interest on bonds held by households, $i_B = r_B B$: interest paid by government on bonds to households, banks and firms). For simplicity, $L^h = D^f = 0$ is assumed as suggested by the authors.

$$GDP = C + G + I = W + P^f + i_f + \delta. \tag{A.1}$$

Inserting all the definitions they provide into Eq. (J2) to calculate the income of households Y^h , and assuming that the economy is in stock-flow equilibrium where stocks and flows do not change over time (hence $K = \kappa GDP$ and $I = \delta = r_\delta \kappa K$), yields:

$$Y^h = GDP - \delta + i_B. \tag{A.2}$$

The disposable income Y^{hd} is defined with θ as tax rate by Eq. (J3) as:

$$Y^{hd} = (1 - \theta)(GDP - \delta + i_B). \tag{A.3}$$

Eq. (J47) for the government balance is:

$$G = \theta Y^{hd} - i_B = \theta(GDP - \delta) - (1 - \theta)i_B. \tag{A.4}$$

Therefore, GDP in equilibrium can be calculated to be:

$$GDP = \frac{G + (1 - \theta)i_B}{(1 - r_\delta \kappa)\theta}. \tag{A.5}$$

Net worth NW^h of households is given by

$$NW^h = D^h + B^h + E, \tag{A.6}$$

with D^h households' deposits, B^h bonds held by households, $E = E^f + E^b$ total equity with equity of firms E^f and banks E^b . Loans of firms are $L^f = cE^f$; capital of firms $K = L^f + E^f = L^f(1 + 1/\epsilon)$. The reserves R held by the banks are $R = \psi D^h$ and the bonds $B^b = D^h(1 - \psi) - L^f(1 - \phi)$, while the equity of banks is $E^b = \phi L^f$. The total equity can be calculated to be $E = L^f(\phi + 1/\epsilon)$. The bonds held by the central bank are $B^{cb} = \psi D^h$. Inserting these definitions into Eq. (A.6) yields:

$$NW^h = D^h + B - B^{cb} - B^b + E = B + K. \tag{A.7}$$

Inserting these results in the consumption function of households given by Eq. (J4) ($C = c_y Y^{hd} + c_v NW^h$) yields (note that c_y corresponds to α_1 and c_v to α_2 in the original paper):

$$C = c_y \frac{1 - \theta}{\theta}(G + i_B) + c_v(B + K). \tag{A.8}$$

In equilibrium, $Y^{hd} = C$. This yields the following equilibrium condition:

$$\frac{1 - c_y}{c_v} \frac{1 - \theta}{\theta} [G + r_B B] = B + \kappa \frac{G + (1 - \theta)r_B B}{(1 - r_\delta \kappa)\theta}. \tag{A.9}$$

Now solve for B which are all the bonds not held by the central bank, and put the result into Eq. (A.5) to get the level of GDP in the stationary state in Eq. (A.11):

$$B = G \frac{\frac{c_y \kappa}{1 - r_\delta \kappa} - (1 - c_y)(1 - \theta)}{(1 - c_y)(1 - \theta)r_B - c_v \frac{(1 - \theta)\kappa}{1 - r_\delta \kappa} r_B - \theta c_v}, \tag{A.10}$$

$$GDP = \frac{G}{1 - r_\delta \kappa} \cdot \frac{(1 - c_y)(1 - \theta)r_B - c_v}{r_B(1 - \theta) \left(1 - c_y - \frac{c_y \kappa}{1 - r_\delta \kappa}\right) - \theta c_v}. \tag{A.11}$$

We use this formula for the stability analysis in Section 2.3.4.

Appendix B. Derivation of GDP in the Stationary State for Godley & Lavoie 2012, ch. 10

Godley and Lavoie (2012, eq. 10.98, p. 414) offer a solution for the GDP in the stationary state of the rather complex model of chapter 10 to be:

$$Y = \frac{G - (i - \Psi)(1 - c_y)/c_v}{\theta/(1 + \theta) - [(1 - c_y)/c_v - \sigma^\top UC/p](i - \Psi)} \tag{B.1}$$

with i nominal interest rate, Ψ inflation, c_y, c_v consumption parameters, θ tax rate, σ^\top targeted inventory to sales ratio, UC unit cost, p price, G government expenditures.

Unfortunately, in the numerator we find a monetary value (government expenditures G) summed up with a relative number (interest rate, consumption factors). This is an error because consumption C in the numerator was accidentally omitted in the derivation. The correct equation would be:

$$Y = \frac{G - (i - \Psi)(1 - c_y)/c_v \cdot C}{\theta/(1 + \theta) - [(1 - c_y)/c_v - \sigma^\top UC/p](i - \Psi)}. \tag{B.2}$$

As consumption is determined by several factors such as income or wealth, it is not an exogenous variable such as government expenditure G , thus this equation is not very helpful. But as we know that in the stationary state, $Y = G + C$ (eq. 10.13, p. 369), one can replace C by $Y - G$ and solve for Y to get, while at the same time replacing

$i - \Psi$ by the real interest rate r and UC and p by using their definitions (Eq. 10.10–11, p. 319):

$$Y = G \frac{1 - r(1 - c_y)/c_v}{\theta/(1 + \theta) + r[(1 + \theta)(1 + \phi)(1 + r_1\sigma^T) - (1 - c_y)/c_v]}. \quad (\text{B.3})$$

Here, r_1 is the interest rate for loans by firms. We use this corrected formula for the stability analysis in Section 2.3.5.

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