



Multiplicity and not necessarily heterogeneity: implications for the long-run degree of capacity utilization

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Abstract

The paper discusses the implications of disaggregation within the post-Keynesian debate on the long-run convergence of the degree of capacity utilization toward the normal one. The debate is related to the emergence of Harroddian instability inside multiplier–accelerator models and has been characterized by two “opposite” positions: the supermultiplier (SM) and the neo-Kaleckian approaches. These approaches solve the instability issue differently, but both share the postulate that an equilibrium position is such only if the desired state of firms is realized. In the long run, the economy converges toward a *fully adjusted position* where the realized degree of capacity utilization is equal to the normal/desired one. In this paper, we develop an Agent Based—Stock Flow Consistent version of the SM model showing that once multiplier–accelerator mechanisms are explicitly reproduced in a multi-firm economy, the accumulation process can be stable without requiring any convergence between the actual and normal rate. Conversely, the modeled economy displays two emergent properties: the fluctuations of the business cycle arise endogenously, and the long-run aggregate degree of capacity utilization persistently fluctuates around a level lower than the normal one. To this extent, the quasi-steady state corresponds to a situation where the desired state of agents is not realized and single elements are not in equilibrium, but the aggregate is. Finally, we compare outcomes produced from the model according to different scenarios on firms’ heterogeneity and network symmetries.

Keywords Out-of-equilibrium · Capacity utilization · Business cycle · Agent-based modeling · Stock-flow consistent models

JEL Classification B50 · E03 · E12 · E22 · E32

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1 Introduction

In recent years, the discussion on the long-run degree of capacity utilization has represented one of the main arguments of contention within the post-Keynesian family. The central question can be traced back to which is the adjusting variable between the realized and the normal degree of capacity utilization.

On the one hand, within the supermultiplier (SM) approach, the realized degree of capacity utilization adjusts to the normal one. On the other hand, the normal degree of capacity utilization adjusts to the realized one in the neo-Kaleckian model.

The issue of capacity utilization represents a crucial point for demand-led growth models for two main reasons. The first one refers to the possibility to extend the principle of effective demand to the long run. As originally stated by Harrod (1939), models integrating the accelerator and multiplier effect could present unstable or explosive dynamics. That is, if firms adjust productive capacity to maintain over time the desired degree of capacity utilization, they increase investments in response to a demand shock, as investments are a component of aggregate demand, this will furtherly expand aggregate demand. If aggregate demand proportionally reacts to variation in investments, the actual degree of capacity utilization will be persistently higher than normal, and the economy will move further and further away from a stable growth path. Such a phenomenon is commonly defined as Harroddian instability. Therefore, the possibility to define a mechanism of convergence to an equilibrium where the actual degree of capacity utilization is equal to the normal (or desired) represents a key point to avoid such instability. The second one refers to the relationship between functional income distribution and the output growth rate. If the normal degree of capacity utilization adjusts to the realized one, the growth rate of the economy is affected by income distribution. That is, the economy can be profit-led or wage-led, as in the neo-Kaleckian model (Marglin and Bhaduri 1990). If the normal degree of capacity utilization is exogenous, the distribution of income only has a level effect, and the growth rate of the economy ultimately depends on the growth rate of the autonomous component (Pariboni 2016a, b).

The initial formulation of the neo-Kaleckian model (Rowthorn 1981; Dutt 1984; Amadeo 1986) has been criticized as it fails to reconcile the actual and the normal rate (Committeri 1986, 1987; Cesaratto 2015; Skott 2012; Pariboni and Girardi 2016; Gahn 2021). According to many authors, this situation cannot be considered an “equilibrium position”; of course, a utilization rate different from the normal one would prompt firms to further revise their expectations and investment decisions (Palumbo and Trezzini 2003). In other words, the constant divergence between the realized and normal degree of capacity utilization would be inconsistent with the capacity adjustment principle (Shaikh 2009). At this point, as its proponents recognize (e.g., Hein et al. 2012), the main problem within the model would be that the attempt of firms to restore the desired degree via changes in accumulation would generate instability of the Harroddian type.

To avoid such instability, neo-Kaleckian authors have proposed a “closure” of the model where the normal degree of capacity utilization endogenously adapts to

the realized one. Amadeo (1986), Lavoie (1995, 1996, 2010), Lavoie et al. (2004) and Dutt (1997, 2010) suggest a mechanism that assumes that the normal rate of capacity is influenced by past values of the actual rate of utilization. The traditional explanation argues that, in conditions of uncertainty, firms follow conventional rules by adjusting the desired degree to previous realizations (Hein et al. 2012). Skott (2012) asserts that it seems reasonable to assume the presence of some conventional elements in the notion of normal capacity utilization rate, but he contends that not only does the neo-Kaleckian formulation requires some elements of adaptation in conventional behaviors, but it also needs a process that is both quantitatively fast and unbounded in order to guarantee the functioning of the stabilizing mechanism.¹

More recently, other authors have justified this assumption by means of a micro-economic model in which firms minimize costs under the condition of increasing returns to scale (Nikiforos 2013, 2016; Dávila-Fernández et al. 2017). This scheme shows the effect that the production level would have on the desired degree of capacity utilization.

However, these “reinterpretations” have also incurred in criticisms, both for an internal inconsistency and for the manner of the aggregation process from micro to macro. On the one hand, it is assumed that firms take prices as given when increasing returns should entail a certain degree of monopoly. On the other hand, it is assumed that the variation in the average output of singular firms depends on the discrepancy between the expected growth rate and the realized one while, when the growth rate of the economy is equal to the expected one, the variation in production for each firm is zero (see Pariboni and Girardi 2018). On the empirical side, Gahn (2021) and Gahn and González (2020) have shown that in most countries, after an output shock, capacity utilization returns to its previous level. This partially confutes the neo-Kaleckian argument according to which a permanent shock in aggregate demand should lead to a permanent increase in the degree of capacity utilization. However, these authors point out that nothing in their analysis points to a convergence toward equilibrium with normal capacity utilization.

Starting from the contribution of Serrano (1995), some Sraffian authors have developed the supermultiplier model (Freitas and Serrano 2015; Cesaratto et al. 2003; Pariboni and Girardi 2016; Deleidi and Mazzucato, 2019) where the normal degree of capacity utilization is exogenous and the actual rate is the adjusting variable: in the long run, the realized degree of capacity utilization converges to the normal one. The presence of the autonomous component leads to a not proportional relation between investments and aggregate demand generating a progressive variation in the share of investments on GDP. If the exogenous growth rate of the autonomous component remains constant for enough periods, such mechanisms engender the convergence of the expected and realized growth rate to that of the autonomous component and the degree of capacity utilization converges to the normal one.

¹ If the normal rate does not adjust quickly enough to the accelerator mechanisms, the model would still present Harrodian instability.

Nonetheless, also this model ran into some criticisms. On the one hand, Trezzini and Palumbo (2013, 2016) reject the analysis of growth through *steady-state* positions turning down the idea that the long-run degree of capacity utilization can equal the normal one, either continuously or on average. On the other hand, recent contributions claim that the exogenous trend of the autonomous components of demand should be considered a short- or medium-term phenomenon (Lavoie 2016; Skott 2017, 2019; Nikiforos 2018). In this regard, some authors have criticized the SM model for the incompatibility between the hypothesis of an exogenous trend of autonomous components of demand and long-term analysis. This hypothesis would not be consistent with the role played by these components, namely as stabilizers of the model in the long run (Lavoie 2016; Nikiforos 2018; Skott 2019).

In general terms, both Neo-Kaleckian and Sraffian approaches share the idea that an equilibrium position is such only if the desired state of firms is realized: in the long run the economy converges toward a *fully adjusted position* (Vianello 1989) where the realized degree of capacity utilization is equal to the normal (or desired) one. This circumstance turns out to be the only one compatible with a stable process of accumulation, defusing Harroddian instability.

In this paper, we confute both these positions pointing out that, once the interaction between the multiplier and accelerator is explicitly reproduced in an economy with a multitude of firms and households, the economic system converges to a stable process of accumulation where the degree of capacity utilization persistently differs from the normal one without causing Harroddian instability. At this point, the aggregate equilibrium does not necessarily have to correspond with the realization of the desired state of single agents. In the stationary state, single elements are not in equilibrium, but the aggregate is. As it will be shown, these kinds of “equilibrium” can arise when considering the economy as a complex system where the macroeconomic mechanisms characterizing aggregate models are reproduced in an economy populated by a multiplicity of interacting agents.

To this end, taking the SM as the reference model for the aggregate version, we develop an Agent Based—Stock Flow consistent model (Caiani et al. 2016, 2019, 2020; Botta et al. 2020, 2021; Dosi et al. 2019; Catullo et al. 2020) with an exogenously given normal rate, fully induced investments and one autonomous component of demand (public expenditure).

By comparing the aggregate and disaggregated versions of the model, we show that, in correspondence with the parameter setup for which the aggregate model determines a *fully adjusted* position, the AB version generates endogenously the fluctuation of the business cycle, while the long-run aggregate degree of capacity utilization fluctuates around a level lower than the normal one. This analysis goes in the direction of considering an economy as a complex system where the aggregate is not the sum of its component (Anderson 1972), but emerges from the interactions across the components themselves.

To this extent, the contribution of this work is twofold. Firstly, we show that a multi-firm economy based on the same features of the SM can produce a sort of (first version) neo-Kaleckian “equilibrium,” namely the normal degree of capacity can remain fixed without implying a process of gravitation toward it. Parallely, unlikely the neo-Kaleckian model, the constant attempt of firms to restore a normal

degree of capacity utilization does not generate instability: in the *quasi-steady state* firms keep trying to restore a normal degree of capacity utilization without succeeding in that, and assuming the endogeneity of the normal degree to the realized one is not necessary. The same attempt of single firms has a counterproductive effect: the feedback loop between firms' investment decisions and aggregate demand causes a "perverse" dynamic which does not allow the long-run convergence of the aggregate degree of capacity utilization to the desired one. In this respect, although the *fully adjusted position* is thought to be the only one compatible with a stable accumulation, we point out that a degree of capacity utilization persistently lower than the normal one can represent an "equilibrium position" characterized by undesired micro-realizations, without generating Harrodian instability.

Secondly, whereas post-Keynesian economics has generally represented the theoretical roots for macro-AB models (see Di Guilmi 2017 for a review), this paper highlights the theoretical insights that the AB approach can offer to the post-Keynesian approach. So far, in the literature, little space has been reserved to this stream of investigation (Bassi and Lang 2016; Seppecher et al. 2018; Teglio 2020; Bassi et al. 2022). In particular, Bassi and Lang (2016) show that genuine hysteresis can emerge within a post-Keynesian/Kaleckian growth model based on the AB approach. The authors argue that the presence of heterogeneous agents allows for the inclusion of remanence and selective memory in the model. These would be the precursors of the emerging properties and would be excluded by construction in a representative agent model. The paper of Teglio (2020) represents the closest attempt to our work in microfounding Keynesian models. The author develops an AB model of the traditional Keynesian cross diagram without investments, showing that the aggregate version can be a good approximation of an economy characterized by a multiplicity of interacting households and firms only in limited circumstances. In particular, the predictive performance of the representative agent model decreases as overall rationality in the economy decreases and its heterogeneity increases.

In this paper, we show that different theoretical conclusions emerge when the bottom-up approach is used within the traditional aggregative structure of the SM approach and, thus, the aggregate models' implicit assumption of centralized control over total productive capacity is removed by considering a multiplicity of firms that takes uncoordinated investment decisions. That is, more is different: as well recognized in the field of complex systems, there is no isomorphism between micro-behaviors and aggregate dynamics (Dosi and Roventini 2019).

In this sense, the possibility to have a sort of "undesired" equilibrium is a typical characteristic of complex systems where equilibrium does not require that every single element is in equilibrium, but rather that the statistical distributions describing aggregate phenomena are stable (Clementi et al. 2019).²

The rest of the paper is organized as follows. Section 2 discusses the theoretical background of the model and resumes briefly the traditional version of the SM, while the main features of the AB-SFC model are reported in Sect. 3. In Sect. 4, we

² The authors refer to "a state of macroscopic equilibrium maintained by a large number of transitions in opposite directions" (ibidem, p. 356).

present the empirical validation of the model. Section 5 discusses the main findings of the model, also according to the different assumptions on firm heterogeneity, and rigid or dynamic networks. Section 6 concludes. The paper results, including the empirical validation of the model, can be reproduced using codes and datasets published here: <https://github.com/LorenzoDiDomenico/-Multiplicity-and-not-necessarily-heterogeneity-implications-for-the-long-run-degree-of-capacity-utili.git>.

2 Theoretical background of the model

The AB-SFC model developed in this paper presents the same features as the SM model (Freitas and Serrano 2015; Cesaratto et al. 2003; Pariboni and Girardi, 2016; Deleidi and Mazzucato 2019): the capacity adjustment principle, the exogenously given normal rate, an autonomous component of demand and adaptive expectations.

The SM extends to the long-run principle of effective demand and combines the role of non-capacity creating autonomous components of demand with the accelerator mechanism. Firms try to adjust productive capacity to match the expected demand at the normal or desired degree of capacity utilization. The long-run output is the result of the interaction between the multiplier and the accelerator mechanisms, while savings adjust to investments through variations in the level of production and the corresponding production capacity. Such interaction is triggered by the exogenous injections of purchasing power into the system that are realized through the autonomous components (i.e., public spending, credit to consumption, residential investments, etc.). The main result of the model is that the output growth rate converges toward that of the autonomous component in the long run, while the degree of capacity utilization converges to the normal one.

The aggregate SM model can be described by the following system of difference equations:

$$\begin{cases} Y_t = C_t + G_t + I_t & (2.1) \\ C_t = (Y_{t-1} - K_{t-1}\delta)(1 - \theta)c & (2.2) \\ I_t = Y_t^e v^n - K_t(1 - \delta) & (2.3) \\ Y_t^e = Y_{t-1} & (2.4) \\ K_t = K_{t-1}(1 - \delta) + I_{t-1} & (2.5) \end{cases}$$

where I_t is the level of investments, C_t is the level of consumption, G_t is public spending, K_t is the capital stock, δ is the depreciation rate, v^n is the normal capital-to-output ratio, and c is the propensity to consume out-of-income. In this formulation, the disposable income of households is net of capital amortization, that is it corresponds to net domestic product (NDP). Traditional SM models implicitly assume that investments are fully financed by loans (there are no retained profits); thus, in a SFC framework, the amortization corresponds to the debt service of the private sector.³

³ It is worth noticing that not including amortization ($-K_{t-1}\delta$) in the equation of disposable income would stand for that firms do not repay the loan. On the other side, this would not be compatible with the assumption of no-retained profits.

The system can be rewritten as a fourth-order difference equation:

$$Y_t = Y_{t-1}[(1-\theta)c + v^n] - Y_{t-2}v(1-\delta) - Y_{t-3}v\delta(1-\theta)c + G_0(1+g_G)^{t-1} \quad (2.6)$$

By solving Eq. (2.6), it is possible to determine the value of GDP in each period:

$$Y_t = \mathbb{C}_1 x_1^t + \mathbb{C}_2 x_2^t + \mathbb{C}_3 x_3^t - G(1+g_G)^{t+2} \psi \quad (2.7)$$

where

$$x_1 = \frac{a}{3} - \frac{B}{3} \sqrt[3]{\frac{2}{C}} + \sqrt[3]{\frac{C}{32}}, \quad (2.8)$$

$$x_2 = \frac{D}{3} + \frac{(1+i\sqrt{3})B}{\sqrt[3]{32^2 C}} - \frac{(1-i\sqrt{3})\sqrt[3]{C}}{\sqrt[3]{62}}, \quad (2.9)$$

$$x_3 = \frac{D}{3} + \frac{(1-i\sqrt{3})B}{\sqrt[3]{32^2 C}} - \frac{(1+i\sqrt{3})\sqrt[3]{C}}{\sqrt[3]{62}} \quad (2.10)$$

See Appendix A for the expression of A, B, C, D and ψ .

Since $0 < c < 1, 0 < \delta < 1, 0 < \theta < 1$, the absolute values of $x_{1,2,3}$ are lower than one, the “endogenous” growth rate is zero and GDP converges to the growth rate of the autonomous component g_G .

If $g_G = 0$, the system reaches a stationary state where GDP is:

$$Y^* = \frac{\bar{G}}{1-c(1-\theta)(1-\delta v)-\delta v} \quad (2.11)$$

It is possible to verify that when GDP converges to a stationary state, the degree of capacity utilization converges to the normal one. The stationary value of the capital stock is:

$$K^* = Y_{t-2}v^n = Y^*v^n \quad (2.12)$$

The realized degree of capacity utilization is:

$$u_r = \frac{Y^*}{Y_{max}} = \frac{Y^*v^n u_n}{K^*} = u_n \quad (2.13)$$

Conversely, if $g_G > 0$, the GDP growth rate converges to the growth rate of public spending.

3 The model

The macroeconomy is populated by firms operating in the capital sector (K), firms producing the consumption good (C), households (H), Government (G), central bank (CB) and a commercial bank (B) interacting in four markets:

- Capital market;
- Consumption market;
- Labor market;
- Credit market

The economic system is described by the monetary flow diagram in Fig. 1.

The household sector consists of a multitude of workers and capitalists. Workers offer labor to firms and receive wages in return; each capitalist owns a single firm (the number of capitalists equals the number of firms) and receives dividends. Commercial bank profits are equally distributed across capitalists. Capitalists hold their savings in the form of deposits and public bonds, workers exclusively in the form of deposits.

In sector C, firms produce the consumption good by means of labor and capital, while the capital sector is an integrated sector in which firms produce using labor as only external input. Firms operating in sector C define the level of production for each period based on the expectations of future demand and the desired level of inventories. They adjust productive capacity to satisfy the expected demand at a normal degree of capacity utilization. Moreover, they pay wages and capital goods in advance, while K-firms produce on spot according to the orders received. They fix current production depending on the number of periods needed to produce a single capital good. The price of the goods is set according to the logic of production costs, and the markup is applied over normal—unitary costs.

The number of firms is fixed, while their size varies endogenously depending on the evolution of aggregate demand and its distribution. Firms, in their respective

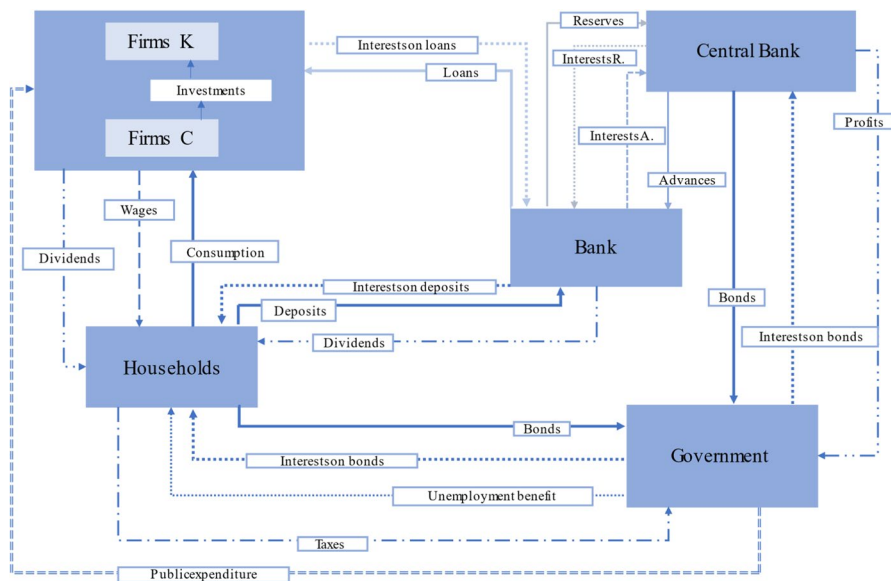


Fig. 1 Diagram of the economic system

sectors, have the same technical conditions (capital-to-output ratio, capital-to-labor ratio and normal degree of capacity utilization). Depending on the leverage target, firms finance production decisions through a mix of self-financing and loans. Firms with negative net wealth that are unable to repay debts go bankrupt. The bankrupt firm is replaced by a new firm with a lower expected quantity to be produced.

There is one commercial bank that provides credit to firms and collects household deposits. The interest rate on deposits and loans depends on the rate set by the monetary authority.

Finally, the Government issues public bonds to finance the deficit. The share of public bonds not acquired by households is held by CB which acts as a lender of last resort. The Government's direct public spending is distributed among C-firms proportionally to their productive capacity. Below are the behavioral and accounting equations of the agents in the various sectors. The balance sheet and the transaction matrixes are reported in Appendix A.

3.1 Consumer sector

C-firms employ labor and capital as inputs. They fix current production ($y_{t,i}^d$) based on expected demand ($q_{t,i}^e$). In addition, firms consider a store of inventories to address the discrepancies between expected demand and realized one. The expected demand ($q_{t,i}^e$) and the desired production ($y_{t,i}^d$) are defined as follows:

$$q_{t,i}^e = q_{t-1,i}^e + \beta_i (q_{t-1,i}^r - q_{t-1,i}^e) \quad (3.1)$$

$$y_{t,i}^d = \max \left\{ 0, q_{t,i}^e (1 + \sigma^T) - \text{inv}_{t-1,i} \right\}, \quad (3.2)$$

where β_i is the expectation parameter, $q_{t-1,i}^r$ is the amount of realized sales in the previous period, σ^T is the desired ratio of inventory on sales and $\text{inv}_{t-1,i}$ is the amount of inventories from the previous period. The degree of capacity utilization in correspondence of the planned production is:

$$\omega_{t,i}^e = \min \left\{ 1, \frac{y_{t,i}^d v_{t,i}^*}{k_{t,i}} \right\}, \quad (3.3)$$

where $v_{t,i}^*$ is the capital-to-output ratio at the full utilization of the productive capacity. Given the amount of capital needed to produce $y_{t,i}^d$ and the capital-to-labor ratio ($\alpha_{t,i}$), firms determine the labor demand:

$$L_{t,i}^d = \frac{\omega_{t,i}^e k_{t,i}}{\alpha_{t,i} h^m} = \frac{y_{t,i}^d l_c}{h^m}, \quad (3.4)$$

where h^m is the maximum amount of working hours⁴ that each worker can work in a period and l_c corresponds to the number of required working hours per unit of output.

The production function is characterized by fixed coefficients of production (Leontief technology). The feasible production is:

$$y_{t,i} = \min \left(\frac{L_{t,i} h^m}{l_{t,i}}; \frac{k_{t,i}}{v_{t,i}^*} \right) \quad (3.5)$$

C-firms adjust productive capacity in order to satisfy expected demand at the normal (desired) degree of capacity utilization (in the period in which the capital will be available, that is in $t + dk$):

$$I_{t,i} = \max \left\{ 0; q_{t+dk,i}^e (1 + \sigma^T) v_{t,i}^n - k_{t+dk,i} \right\} \quad (3.6)$$

⁵where $v_{t,i}^n$ is the normal capital-to-output ratio, $k_{t+dk,i}$ is the residual stock of capital in the period in which the ordered capital good would be installed if the investments were not made, $g_{t+1,i}^e$ is the expected growth rate of demand, and dk is the number of periods needed to produce one unit of the capital good. The expected demand (to fix current production) and the expected growth rate of demand (to fix investment plans) are defined as follows:

$$q_{t+dk,i}^e = q_{t,i}^e (1 + g_{t,i}^e), \quad (3.7)$$

$$g_{t,i}^e = g_{t-1,i}^e + \beta_i (g_{t-1,i}^r - g_{t-1,i}^e). \quad (3.8)$$

The capital stock in period t is composed of the residuals of capital goods installed in the previous $z + 1$ periods (vintage capital goods), with z representing the useful life of the capital good:

$$k_{t,i} = \sum_{j=t-z+1}^t k_{j,i}^{ins} \left(\frac{j+z-t}{z} \right), \quad (3.9)$$

where $k_{j,i}^{ins} = I_{t-dk,i}$ is the amount of capital installed in period j and corresponds to the gross investment carried out in dk previous periods. The absolute deterioration is

⁴ The inclusion of working hours is necessary since the worker is indivisible. Otherwise, because the number of hired workers is rounded up with respect to that actually necessary, firms would structurally be producing a higher quantity than desired or paying an higher wage bill compared to the one actually required for the needed amount of working hours.

⁵ It is worth noticing that the investment function in eq. 3.6 is a more general formulation of the investment function adopted in the SM, that is $I_t = v(\delta + g_t^e)Y_t$ (Cesaratto et al. 2003). In this respect, while the latest is valid only in the steady state, eq. 3.6 is also valid outside the equilibrium. It is possible to verify that only when the actual rate of capacity utilization is equal to the normal one, we can substitute $k_t = Y_t v^n$ and get the traditional SM investment function.

constant, and total deterioration ($\zeta_{t,i}$) in each period is composed of the sum of the deterioration of capital goods installed in the previous z periods (including the current one):

$$\zeta_{t,i} = \sum_{j=t-z+1}^t \frac{k_{j,i}^{ins}}{z}. \quad (3.10)$$

The amortization for computing unit cost includes both the cost of capital and the cost of debt service, considering the full leverage. The amortization for computing profits considers the realized leverage and is defined as follows:

$$\Lambda_{t,i} = \frac{1}{az} \sum_{j=t-z+1}^t p_{i,\text{index } K} k_j^{ins} (1 + r_j b l_j) (j + z - t) \quad (3.11)$$

where r_j e l_j represent, respectively, the interest rate in the period in which the debt was contracted and the *leverage* realized in purchasing the capital good.

$K_{j,i}^{ins}$ is the installed capital in period j from firm i , and $p_{i,\text{index } K}$ is its price (because z is the useful life of the capital good, 3.10 and 3.11 go back up to a maximum of z periods in the computation of amortization and depreciation). $a = \sum_{i=1}^z \frac{i}{z}$ e $b = \frac{1}{az} \sum_{i=1}^z \frac{i^2+i}{2}$ are the multiplying factors for the calculation, respectively, of the interest accrued on loan granted in a given period and of the (potential) cumulated production (in correspondence with the normal degree of capacity utilization) over the useful life of capital good. See Di Domenico (2020) for an explanation of amortization and unit cost computation.

3.2 Capital sector

The quantity that firm i wishes to produce and labor demand is

$$y_{t,i}^d = \sum_{j=t-dk}^t \frac{\text{orders}_{j,i}}{dk}, \quad (3.12)$$

$$L_{t,i}^d = \frac{y_{t,i}^d l_k}{h^m}. \quad (3.13)$$

where the sum corresponds to the number of capital goods ordered to firms i , from previous dk periods to period t . The value of dk strongly affects the magnitude of the interaction between multiplier and accelerator and, thus, the volatility and amplitude of the fluctuation of the business cycle.

3.3 Price setting

Prices are determined according to the historical normal cost of production (Andrews 1949; Andrews and Brunner 1975). The unit cost (which takes into

account the different ages of the capital goods) is defined in correspondence with the normal degree of capacity utilization, and amortization is computed by adopting the full-cost methodology.⁶ A markup is applied over the normal unit cost.

The unit cost of the capital good is:

$$c_{t,i}^k = w_{t,i} l_k. \quad (3.14)$$

The unit cost of C-firms is defined as follows:

$$c_{t,i} = \frac{\bar{w}_{t,i} * L_{nt,i}}{y_{t,i}^n} (1 + ra_s z_s) + \frac{\Lambda_{t,i}}{y_{t,i}^n} = \left[\bar{w}_{t,i} l_c (1 + ra_s z_s) + \frac{\frac{1}{az} \sum_{j=t-z+1}^t p_{kj} K_j^{ins} (1 + r_j b l_j) (j + z - t)}{\frac{a^n}{v_{t,i}^s} \sum_{j=t-z+1}^t K_j^{ins} \left(\frac{j+z-t}{z} \right)} \right], \quad (3.15)$$

where $L_{nt,i}$ is the amount of working hours corresponding to the normal degree of capacity utilization, $y_{nt,i}$ is the normal production, $\bar{w}_{t,i}$ is the nominal wage, $\Lambda_{t,i}$ is the amortization, p_{kj} is the price of the capital acquired in period j , a_s is the multiplicative factor to compute the total debt service, and z_s is the payback time of short loans (aimed at advancing wages). If p_{kj} , r_j and l_j are constant over time and $l_j = 1$ (full-cost pricing), the equation of unit cost is reduced to:

$$c_{t,i} = \bar{w}_{t,i} l_c (1 + ra_s z_s) + \frac{v^n p_k}{a} (1 + rb). \quad (3.16)$$

To keep the same structure as the supermultiplier model, markups are fixed and equal across all firms.

3.4 Labor market

The modeling of labor market is kept as simplest as possible; the nominal wage and labor skills are homogenous across firms and workers and constant over time. In each period, depending on labor demand, firms can fire or hire workers. In the labor market matching, firms randomly pick up an unemployed worker and hire him. Firms reiterate this operation until they have satisfied their labor demand.

There are no frictions in the labor market, meaning that each firm can fire or hire workers whenever it needs to and labor force is always higher than labor demand. Therefore, employment is always equal to labor demand.

3.5 Supplier selection and goods market matching

In the baseline model (Scenario A), the network is dynamic: households and firms choose their supplier randomly and buy from them. Both households and firms reiterate this sequence until they have satisfied their demand. In Scenario B, the network

⁶ In the full-cost methodology the leverage is equal to one. Therefore, according to the logic of opportunity cost (Pivetti 1985; 1991), the interest rate is applied to all the inputs of productions or all the anticipations independently from the actual leverage.

characterizing capital and the consumer market is rigid. In this scenario, buyers can only change suppliers if their own do not have enough inventories to satisfy their demand. In the initialization of both scenarios, firms and households are equally distributed across suppliers.

We consider two scenarios to show that the variance of the distribution of demand among firms cannot go to zero even in the scenario with a rigid network. This point is relevant since, as it will be shown, the magnitude of the emergent properties of the model depends on such variance.

3.6 Loan demand and debt service

In case C-firms have enough liquidity, they finance investments with the desired leverage; otherwise, they increase this proportion. If liquidity is scarce, priority is given to the payment of wages in the allocation between the financing of wages and investments and the corresponding leverage. Loan demand is defined as follows:

$$L_{t,i}^{d, \text{long}} = K_{t,i}^{df} l^T \quad (3.17)$$

$$\left\{ \begin{array}{l} \text{if } \text{cash}_{t,i} \geq WB_{t,i} + K_{t,i}^{df}(1 - l^T) : L_{t,i}^{d, \text{long}} = K_{t,i}^{df} l^T; l_{t,i}^w = 0; l_{t,i}^k = l^T \\ \text{else if } \text{cash}_{t,i} \geq WB_{t,i} : L_{t,i}^d = K_{t,i}^{df} l_{t,i}^k; l_{t,i}^w = 0; l_{t,i}^k = \frac{K_{t,i}^{df} - \text{cash}_{t,i} + WB_{t,i}}{K_{t,i}^{df}} \\ \text{else } L_{t,i}^{d, \text{short}} = wb_{t,i} l_{t,i}^w; L_{t,i}^{d, \text{long}} = K_{t,i}^{df} l_{t,i}^k; l_{t,i}^w = \frac{WB_{t,i} - \text{cash}_{t,i}}{WB_{t,i}}; l_{t,i}^k = 1 \end{array} \right. \quad (3.18)$$

$$L_{t,i}^d = L_{t,i}^{d, \text{short}} + L_{t,i}^{d, \text{long}} \quad (3.19)$$

where $L_{t,i}^{d, \text{long}}$ is the long-term loan to finance the purchase of the capital good, l^T is the leverage target, $l_{t,i}^k$ is the realized leverage to finance the purchase of capital good, $L_{t,i}^{d, \text{short}}$ is the short-term loan to finance the wage bill, $l_{t,i}^w$ is the relative realized leverage, $WB_{t,i}$ is the wage bill, and $\text{cash}_{t,i}$ is the amount of the firm's available cash.

Since the interest rate may vary across the periods in which debt is incurred, the payment of interest rates for each period is calculated using the historical composition of the residual debt stock. The evolution of debt installments is decreasing, and it is consistent with the path of capital amortization. Total debt service includes debt installments of short- and long-term loans, *rollover* loans and financial charges.

3.7 Households

The household sector is composed of a multitude of workers and capitalists. Consumption demand is a function of the income and wealth stock (Godley and Lavoie 2007). The consumption function of workers is:

$$c_{t,i}^{D,w} = YD_{t,i} c_{1,w} + V_{t-1,i} c_{2,w}, \quad (3.20)$$

where disposal income is defined as follows:

$$YD_{t,i} = \begin{cases} (w_{t,i}h_{t,i}^{\text{work}} + M_{t-1}r_{t-1}^m)(1 - \tau^{\text{work}}) & \text{if employed} \\ (w_{\text{gov}} + M_{t-1}r_{t-1}^m) & \text{otherwise} \end{cases} \quad (3.21)$$

where $h_{t,i}^{\text{work}}$ are the monthly worked hours, w_{gov} is the unemployment benefit, and τ^{work} is the tax rate on workers income. Workers hold all their wealth in the form of deposits: $V_{t,i} = M_{t,i}$.

The consumption function of capitalists is:

$$c_{i,t}^{D,\pi} = YD_{t-1,i}c_{1,\pi} + V_{t-1,i}c_{2,\pi} \quad (3.22)$$

The income of capitalists consists of dividends distributed by firms and the commercial bank, the interest accrued on deposits and public bonds:

$$YD_{t-1,i} = \left(\text{Div}_{t-1,i} + M_{t-1,i}r_{t-1}^m + B_{t,i}^h r_{t-1}^b \right) (1 - \tau^\pi), \quad (3.23)$$

$\text{Div}_{t-1,i}$ are dividends and τ^π is the tax rate on capitalists' income.

The stock of capitalist wealth is made up of deposits and government bonds:

$$V_{t,i} = M_{t,i} + B_{t,i}^h = V_{t-1,i} + YD_{t-1,i} - C_{t,i}. \quad (3.24)$$

The demand for government bonds is a function of the stock of wealth, disposable income and the interest rate (Tobin 1982):

$$\frac{B_{t,i}^d}{V_{t,i}} = \lambda_0 + \lambda_1 r_t^b + \lambda_2 \left(\frac{YD_{t,i}}{V_{t,i}} \right). \quad (3.25)$$

3.8 Commercial bank

The banking sector consists of one single commercial bank. It supplies credit to firms and collects household deposits. The bank applies a markup on the rate set by the central bank to fix the interest rate on loans; the interest rate on loans is higher than that on deposits. Since the commercial bank does not buy equities, stocks or public bonds, it holds the difference between loans and deposits at the CB in the form of reserves (reserves accrue at an interest rate equal to that of deposits). This allows the bank to balance assets and liabilities, making possible the payment of interest rate on deposits. The profits of the bank are:

$$F_{B_t} = r_t^h H_t + r_t L_t - r_t^m M_t - A_t r_t^d \quad (3.26)$$

where H_t is the amount of reserves held at the CB.

3.9 Government

The public sector has a direct and exogenous component of expenditure consisting of consumer goods demand and an endogenous component linked to unemployment benefits and debt service. Direct public expenditure is constant, while unemployment benefits and debt service are countercyclical:

$$G_{c,t} = G_{c,t-1}(1 + \pi)(1 + g_G), \quad (3.27)$$

$$G_t = G_{c,t} + U_t w_{G_t}, \quad (3.28)$$

where $G_{c,t}$ is direct public expenditure (demand for consumption goods), g_G is the real growth rate of direct public expenditure, π is the inflation rate, and U_t is the number of unemployed, G_t is primary public spending. The unemployment benefit (w_{G_t}) is a percentage of the expected average wage paid by the private sector.

The Government deficit is:

$$S_{t,g} = G_t - \sum_i^N y_i \tau_i + r_b B_{t-1} - F_t^{cb}, \quad (3.29)$$

where F_t^{cb} are distributed profits by CB, θ is the tax rate, B_t is the stock of public debt.

The supply of public bonds is:

$$B_t = B_{t-1} + S_{t,g}. \quad (3.30)$$

3.9.1 Central bank

The central bank acts as the lender of last resort in the public bonds market:

$$B_t^{cb} = B_t - \sum_i^{ncap} B_{t,i}^d, \quad (3.31)$$

where $\sum_i^{ncap} B_{t,i}^d$ is the amount of bonds held by capitalists.

Central bank profits depend on the interests earned on public bonds (B_{t-1}^{cb}), advances (A_{t-1}) and interests paid on reserves (H_{t-1}^{cb}).

$$F_t^{cb} = B_t^{cb} r_t^b - H_t^{cb} r_t^h + A_t r_t^a. \quad (3.32)$$

See Appendix A for all the equations regarding the stock-flow consistency, bankruptcy, accountancy and sequence of events.

4 Calibration and empirical validation

To analyze the properties of the model and the processes that characterize the co-evolution of the micro- and macrovariables, the model is solved through simulations. In order to eliminate the stochastic variability across these and test the robustness of the model, the following results correspond to the median values of the Monte Carlo analyses. In the initialization of the model, to minimize the variability of the output, monetary stocks are taken equal to zero. The initial capital stock is such as to allow to produce the quantity initially desired at the normal degree of capacity utilization. Initial monetary stocks, such as debts, bonds and deposits, are set to zero. Trivially, this type of initialization complies by construction with Copeland's principle of four entries (Copeland 1949, Godley and Lavoie, 2007) and, therefore, the economic system starts from a condition of stock-flow consistency.

As proposed by Grazzini and Richiardi (2015), Grazzini et al. (2012a,b), Gilli and Winker (2001, 2003), Chen et al. (2012), we adopt the method of simulated moments to calibrate and validate the model. The parameter calibration is performed by minimizing the distance between a set of statistical moments for the actual observations and the simulated series. Following Assenza et al. (2015) and Caiani et al. (2016), the moments are the autocorrelations and cross-correlations of GDP, consumption and investments. The selected vector is the one that minimizes the distance between the moments of the real and simulated time series, that is it minimizes the following objective function:

$$\arg \min \Gamma(X^r, X^s, \theta)$$

where X^r e X^s are, respectively, simulated and real time series. θ represents the set of vectors describing the entire space of possible combinations.⁷

The parameter space adopted by the multivariate analysis is generated by the combinations of parameters values presented in Table 1.

The macro-dynamic depicted by the AB version shows that the disaggregation and inclusion of local interaction are sufficient to generate a model able to reproduce main stylized facts.

In accordance with the Dickey-Fuller tests, the cyclical components of macrovariables such as GDP, consumption and investments, show a *unit root* and have the usual *roller-coaster* characteristics (Stock and Watson 1999; Napoletano et al. 2006) (Fig. 2).

⁷ As in Caiani et al. (2016), the results are compared with the US historical series of FRED from 1947-01-01 to 2019-10-01 (FRED codes: PCECC96, GPDIC96 and GDPC1). We use the squared values of the percentage deviation from the actual series in order to keep the same weight for different values of absolute deviations across different moments. This work was undertaken on ARC4, part of the High Performance Computing facilities at the University of Leeds, UK.

Table 1 Parameter space of the multivariate analysis

Description	Symbol	Initial value	Final value	Delta
Capital-to-output ratio	ν	0.01	4	0.01
Capital-to-labor ratio	α	0.01	4	0.01
Reciprocal of labor productivity in capital good sector	l_k	0.01	4	0.01
Capital good lifetime	z	10	50	1
Number of periods to produce the capital good	dk	1	10	1
Expectation parameter	β	0.1	0.8	0.1

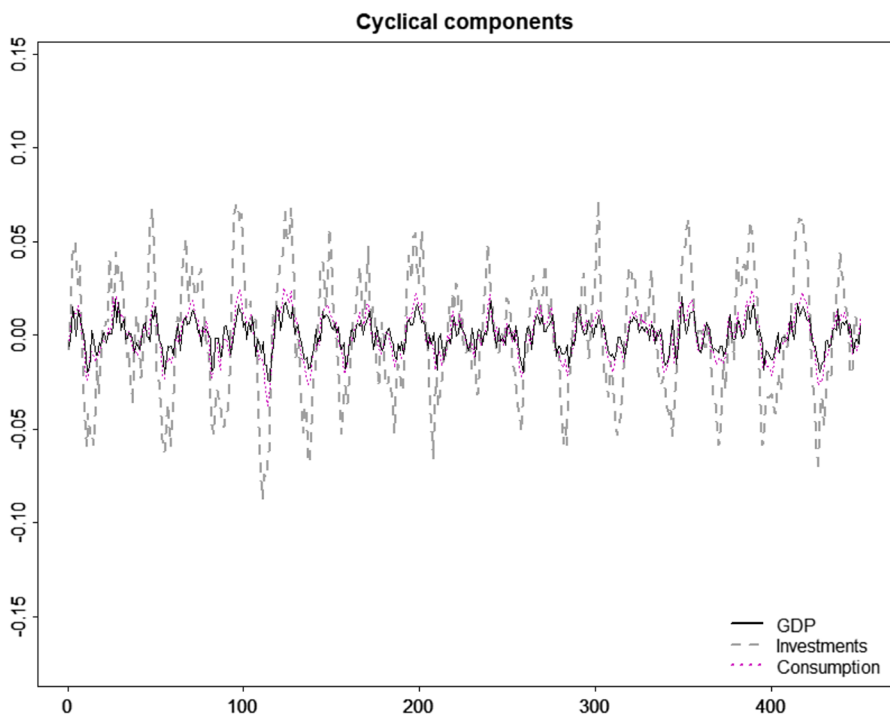


Fig. 2 Cyclical component of GDP, investments and consumption

Figures 3 and 4 report the real and artificial series of autocorrelations and cross-correlations (up to 20 and 10 lag, respectively), after having detrended the series with the Hodrick-Prescott filter. Investments, consumption, inventory changes and GDP are pro-cyclical with investments characterized by higher volatility. The unemployment rate and public debt service are counter-cyclical. In tune with the empirical evidence, firm size distributions are well approximated by power-law densities (Fig. 5).

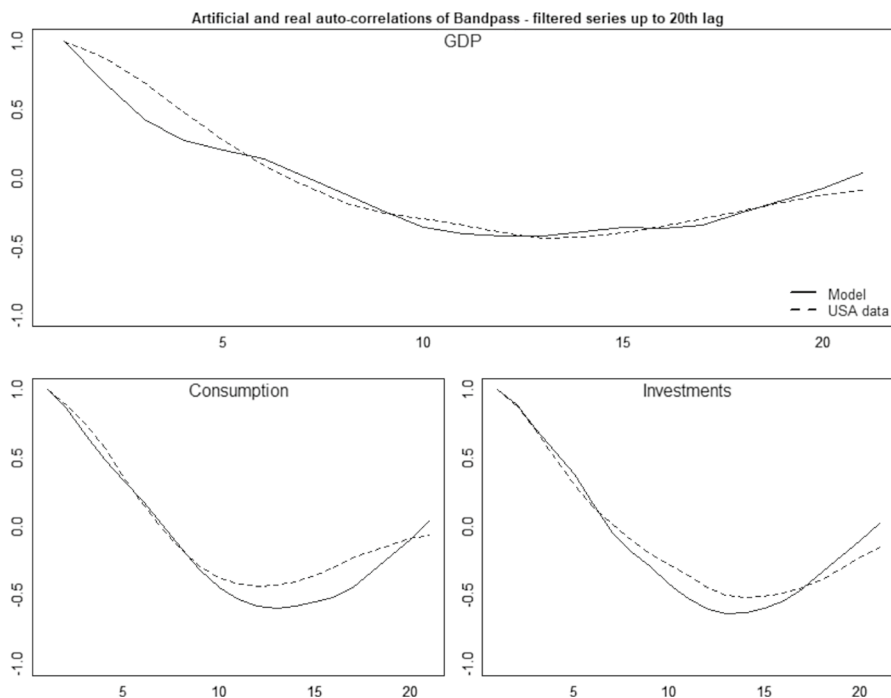


Fig. 3 Autocorrelation up to 20 lag of artificial and real time series (detrended)

Unlike the mainstream models based on the Walrasian general equilibrium, which have been criticized—among other things—for their inability to explain and reproduce the autocorrelation observed in real time series (Ascari et al. 2015; Roventini et al. 2016), in this system the autocorrelation in aggregate variables emerges from the micro-level without the need to introduce any exogenous shock.

Unlike standard macro-post-Keynesian models, this model can reproduce endogenous cycles and crises, providing a demand-side explanation of the nature of the business cycle. In particular, in this model, periods of crisis can be reproduced by considering only the real dimension: because of the evolution of the distribution of demand among firms, the downturns of the cycle can turn into crisis phases due to the domino effects of shocks realized at the micro-level. This phenomenon is mostly due to individual overproduction or, better, over-investment. The dynamic is the following: if the share of demand that 'flows back' to the single firm remains for a sufficient number of periods at a level below that of "historical" participation to cause bankruptcy,⁸ the isolate can trigger a contagion dynamic. On the one hand, the loss of the latter's contribution to the financing of aggregate demand increases the probability of bankruptcy for firms that were close in the distribution of differentials to the bankrupted firm. On the other hand, this dynamic undermines the revenues

⁸ If a single firm registers a degree of capacity utilization lower than the normal one for a prolonged period of time, it is not able to pay back the loan.

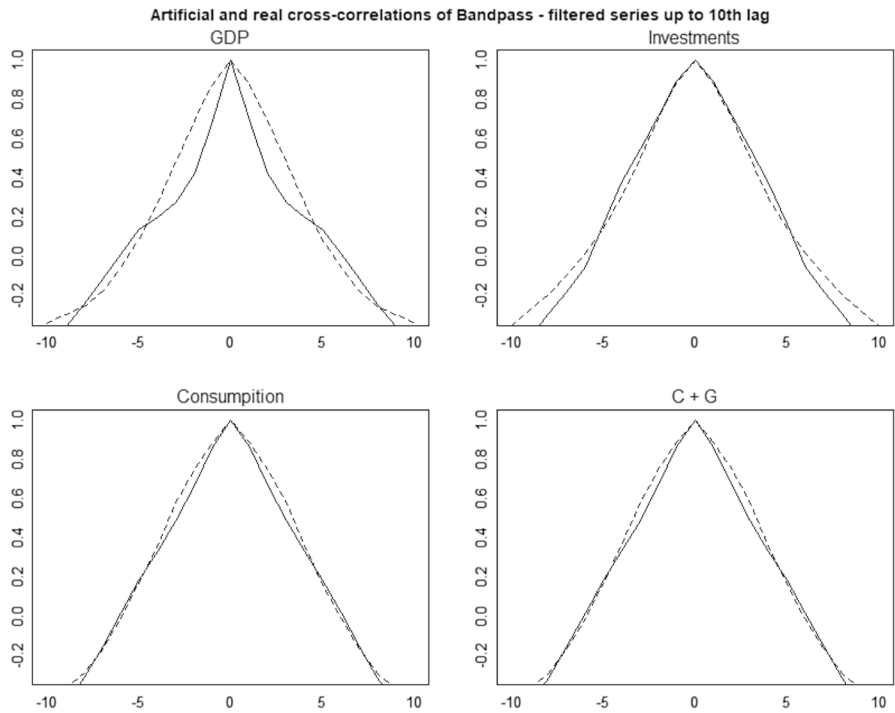


Fig. 4 Cross-correlations of artificial and real time series (detrended)

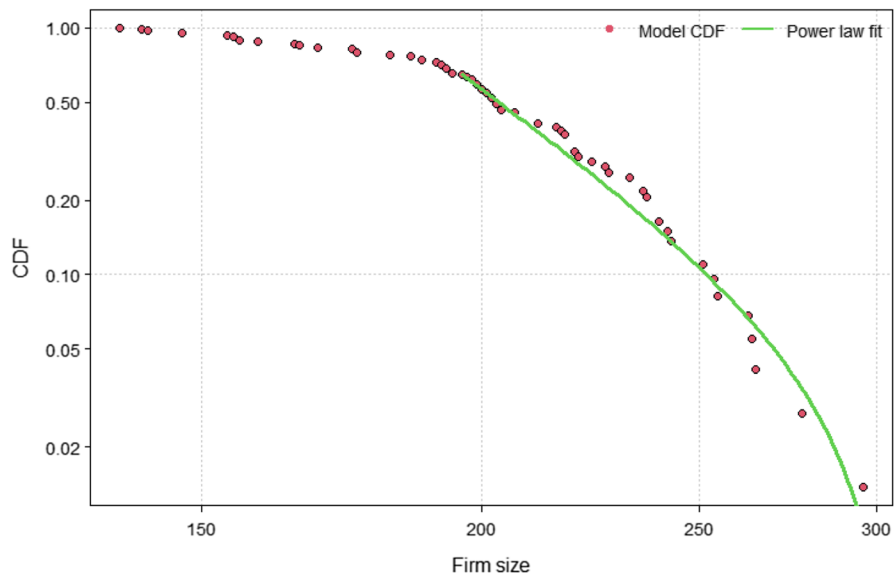


Fig. 5 Power-law fit and consumer firm (size) distribution

and debt sustainability of firms further to the right of the distribution, i.e., those that have benefited from a positive differential between the contribution share and the market share. Indeed, the larger size of these firms in terms of installed capacity is justified by this differential, i.e., by the fact that they manage to capture for a sufficient number of periods the demand previously generated by other firms (i.e., those that go bankrupt later). When the share of demand created by bankrupt firms disappears, revenue flows needed to pay back the debt installments (related to the installed capacity) also disappear, triggering a domino effects on the bankruptcy of other firms and initiating a phase of crisis.

5 Findings: the equilibrium can be “undesired”

In this section, we depict the different implications for the long-run trend of the degree of capacity utilization (and whether to study the long-term growth according to *steady-state* positions) deriving from an analysis based on disaggregated models. To keep all features as in the traditional SM, the propensity to consume out-of-wealth, interest rates, unemployment benefits are set to zero and prices are equal across firms (technology and markups are uniform and constant). In addition, as it is implicitly assumed in the SM, firms do not retain profits to finance investments, they are totally distributed to capitalists (the leverage to finance investments is equal to one). Public expenditure is the only autonomous non-capacity creating component.

Since the emergent proprieties of the model are due to level effects, we consider a zero-growth rate of primary public spending; thus, in the long run the model reaches a stationary state where GDP growth rate is equal to zero. This setup allows us to explain with a higher degree of clarity the mechanisms behind macroeconomic dynamics.⁹ In this regard, Appendix C shows that results do not differ when considering a positive growth rate of public spending. Appendix B, instead, reports the results of simulations when interest rate, propensity to consume out-of-wealth and unemployment subsidies are positive. Also in this case, the results regarding the emerging proprieties of the model do not change.

The following results refer to the baseline model with no heterogeneity across firms and, in tune with the traditional AB approach, with local interactions. The setup of the disaggregated version consists of equal redistribution of the initial aggregate productive capacity of the macro-model across a multitude of homogenous firms with the same technology and capital endowments. Furthermore, in the initialization, an equal number C-firms is assigned to each K-firm. All firms follow the same rules in investments, production and financing decisions and are characterized by the same parameters. These remain constant across all simulations and time periods.

Figure 6 reports the results of the traditional supermultiplier model (aggregate version) and AB model (the gray band is the range of standard deviation resulting from Monte Carlo simulations). Given the same setup of parameters¹⁰ which

⁹ In addition, a positive growth rate of public spending would require to include technical change or population growth rate in the model increasing complexity while not adding anything useful to the purpose of the discussion.

¹⁰ Table 1.5 in Appendix D reports parameters' values.

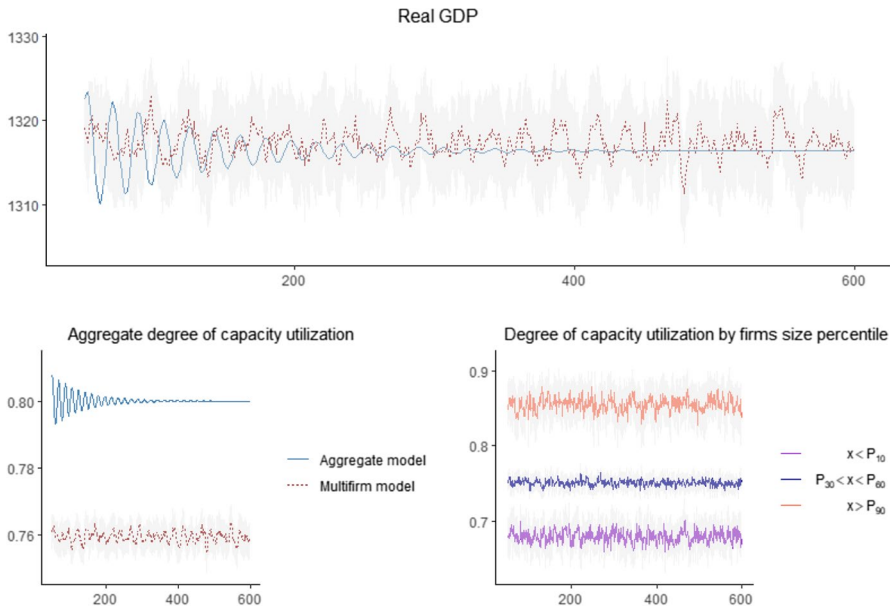


Fig. 6 Aggregate degree of capacity utilization and GDP in the two versions of the model. Averages for 50 MC runs in the period [200, 800]

generate a steady state with a normal degree of capacity utilization in the aggregate model, in the disaggregated version the fluctuations of the business cycle emerge, the level of GDP results slightly higher and the long-term (aggregate) degree of capacity utilization persistently fluctuates around a level lower than the normal one ($u_n = 0.8$). Parallely, the tenth percentile of firms has an average degree of capacity utilization much lower than normal, while the rate of the smaller ones (over the 90th percentile) is higher than normal.¹¹

The core of the difference in the mechanisms between the one-firm economy and AB version is the following: Since the control over the aggregate productive capacity is split across different agents that take uncoordinated decisions, the rigid *ping-pong* between investment decisions, changes in aggregate demand, and variations in the degree of capacity utilization characterizing the one-firm economy is lost. The lack of this feature implies that it is not possible to describe the convergence toward a *fully adjusted position*. This is the result of two properties that necessarily emerge when a number of firms higher than one is considered:

¹¹ This evidence only provides a snapshot of the degree of capacity utilization of each firm subgroup in each period. It does not mean that the same firm (small or large) persistently shows a lower or higher degree than normal. Conversely, along the intertemporal dynamic, the composition of the percentiles varies: the size of individual firms changes and each firm can move from a group to another. Firms above the 90 percentile present a lower degree of capacity utilization because a slight change in the distribution of demand strongly impacts the capacity utilization of small firms.

- (i) The dynamic instability of the differential between the share with which each firm contributes to the formation of the aggregate demand (as a result of its production) and the share of demand that "flows back" to the firm through sales.
- (ii) The interplay between the level of aggregate demand and the way it is distributed across firms. That is, given the same level of aggregate demand, a different distribution across firms produces different reactions in terms of investments and presents different changes in the aggregate demand itself.

Both features interact and affect aggregate dynamics through the investment channel. The first one is responsible for the persistence of fluctuations and the endogeneity of the business cycle, while the second one is for the lower level of the degree of capacity utilization around which the (aggregate) rate fluctuates.

Regarding the first issue, in each period, firms contribute differently to feed aggregate demand through the purchase of capital goods, payment of wages and distribution of dividends. At the same time, by means of sales realization, each firm benefits with a different share from the overall demand. While in the aggregate version each variation in investments and production decisions has a rigid and constant relationship with changes in demand collected by the same macro-firm that (partially) fuels it,¹² the disaggregation in the production sector implies a positive and unstable differential (ξ) between the share through which each firm contributes to the creation of aggregate demand and the share of it that "flows back" in terms of sales realization.¹³ This feature implies that the investment growth rate at the micro- and macrolevel never stabilizes. In this regard, the realization of a *steady state* with a normal degree of capacity utilization requires that, in the long run, during the inter-periodical process of revising expectations, ξ remains constant and equal to zero. Such condition is verified by construction in an aggregate model such as the SM (see Fig. 7).¹⁴

On the contrary, in the disaggregated model, through the matching mechanism and changes in the incomes of agents the differential between the two shares varies with the succession of periods and the fluctuations persist in the long term as well.

Regarding the second point, the emergence of an aggregate degree of capacity utilization lower than the normal one is due to the dispersed nature of investment decisions with respect to the aggregate productive capacity.

Since in each period each firm observes—with multiple degrees of differentiation—a higher or lower share of the demand than that generated by itself, each firm

¹² In the aggregate model, each production and investment decision is transformed into demand for the same macro-firm in sector C, through wages and dividends paid directly to its workers and capitalists and, indirectly, through the payment of dividends and wages when purchasing the capital goods. Such contribution is "partial" because the other fraction of demand consists of public spending.

¹³ Trivially, the wage bill paid by a firm in sector C can turn into demand, via the consumption of workers, for another firm in the same sector.

¹⁴ The disaggregated version shows the average of the differentials between C-firms. The equation of the

single differential is: $\xi_{t,i} = \varepsilon_{t,i} - \gamma_{t,i} = \frac{wb_{t,i} + \text{div}_{t-1,i} + \frac{\sum_{k=0}^{Kd} Kd}{d(1+q)} + \sum_{i=0}^{t-1} Kd \frac{q}{d(1+q)}}{Gf_i + C_i} - \frac{\text{sales}_{t,i}}{Gf_i + C_i}$

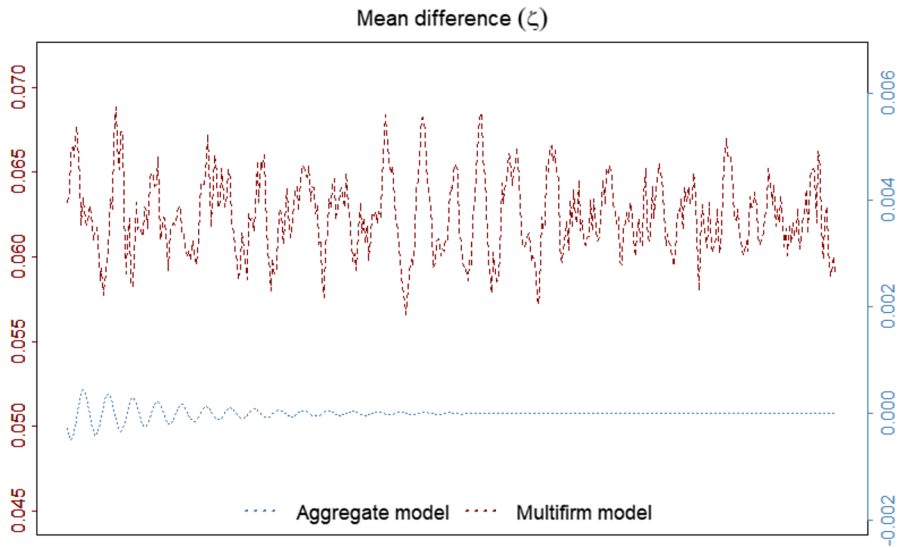


Fig. 7 Dynamic of ξ in the two versions of the model

can have a different degree of capacity utilization and, in particular, there can be firms with a degree of utilization lower than normal and others where it is higher. This entails a significant variability in the intensity of the reaction that the aggregate acceleration process has to variations in the effective demand: depending on the modalities of distribution across productive capacities, the same level of demand generates a different aggregate level of investments. Specifically, given the same level of aggregate demand, the decentralized control over the shares of aggregate productive capacity leads to a higher level of investments compared to the aggregate macro-firm. Figure 8 is useful to explain the intuition behind this mechanism.

Given the same values of aggregate productive capacity, effective demand and the same coefficients of production, in the one-firm economy the level of investment is zero (Case 1), while in the two-firm economy, through the channel of demand distribution, it results to be positive (Case 2—right side). In a more general sense, because of the nonlinearity of investments,¹⁵ in correspondence with the aggregate demand that produces a normal degree of capacity utilization and zero net investment in the one-firm economy, the multi-firm economy causes a higher level of investments for each possible combination in the distribution of demand across firms. The only special case in which the level of investments can remain unmodified is when the distribution of aggregate demand is kept constantly equal across firms and proportionally to each specific productive capacity (as shown in case 2—left side).

¹⁵ Net investments are non-negatives when the expected degree of capacity utilization is lower than desired one.

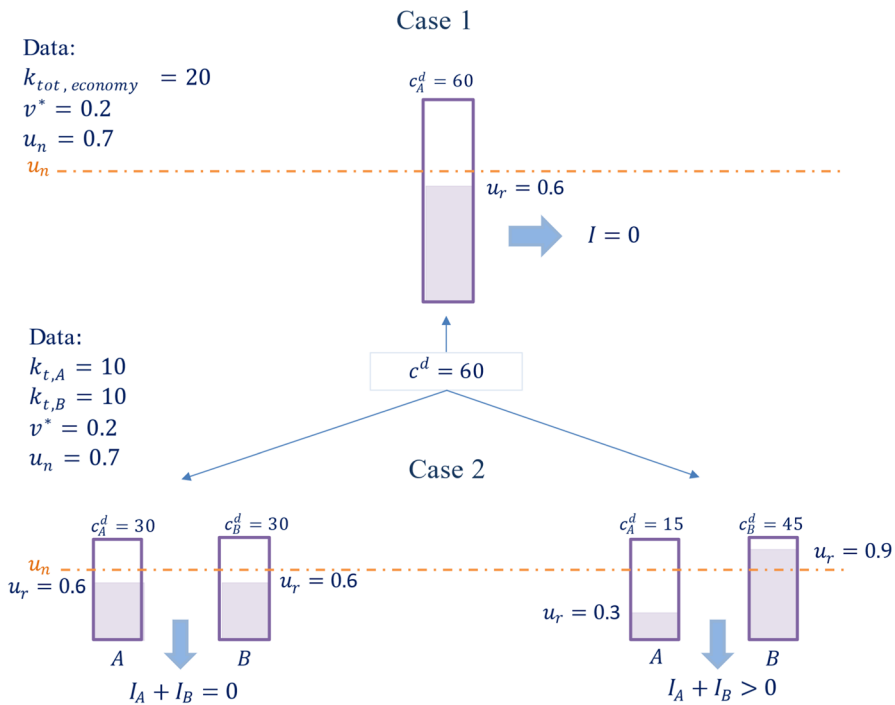


Fig. 8 Case 1: Aggregate model–Case 2: Aggregate productive capacity is equally split among two firms

As Fig. 9 shows, this dynamic is explained by a higher share of investments in aggregate demand in the disaggregated model (red lines) compared to the aggregate one (blue lines). Due to the presence of the autonomous component, the aggregate demand does not react proportionally to the changes in capital stock; hence, the equilibrium degree of capacity utilization results lower than the normal one.

Through the above-mentioned channels, the value of the difference in terms of GDP and long-run degree of capacity utilization between the aggregate and disaggregate model depends on the number of firms and on the value of the accelerator. Latter expresses the degree of responsiveness of firms with respect to the divergence in the degree of capacity utilization. The results of the simulations showing the effect of changes in the number of firms and the accelerator (β) are reported in Table 2. Phase diagrams are reported in Appendix B.

The higher the number of firms, the more the asymmetry in the concentration of demand across firms-specific productive capacity, and the effect of the interplay between aggregate demand and demand distribution will also be higher. For the same reason, the dimension of such effects is negatively correlated with the degree of market concentration: the higher the degree of monopoly in the economy, the closer the growth path will be to the aggregate model. Thus, the value of the (super) multiplier does not depend only on the propensity to consume, the tax rate, the capital intensity and the firm's propensity to invest, but also on the features that affect the variance of demand distribution across firms. The latter influences the accelerator mechanism.

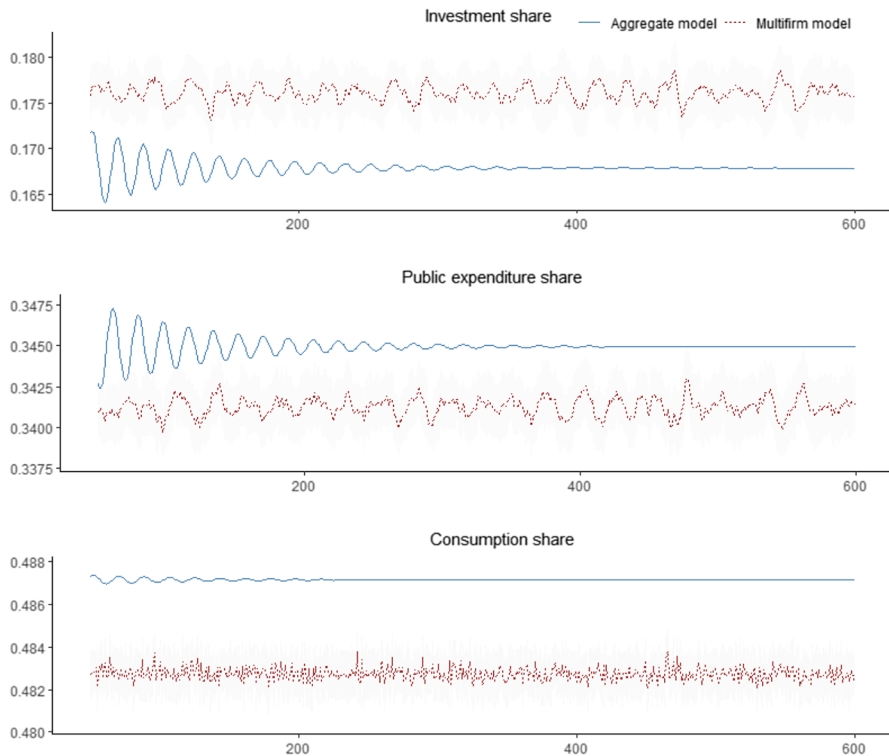


Fig. 9 Consumption, investments and public expenditure shares in the two versions of the model

Table 2 Comparison between different model setups: variation in the number of firms and the value of the accelerator (β). Averages for 50 MC runs in period [200, 800]

	Parameter	GDP	u_r	Investment share	u_r volatility
Number of Firms in each sector ($\beta = 0.6$)	1	369 (0)	0.8 (0)	7.8% (0)	0.00 (0)
	200	388 (0.0007)	0.756 (0.0015)	9.1% (0.0003)	0.023 (0.0005)
	400	391 (0.0006)	0.754 (0.0017)	9.2% (0.0004)	0.021 (0.0009)
	600	393 (0.0007)	0.754 (0.0016)	9.2% (0.0002)	0.02 (0.0012)
	800	398 (0.0005)	0.753 (0.0018)	9.3% (0.0005)	0.019 (0.0013)
β	0.4	378 (0.0006)	0.779 (0.0022)	8.8% (0.0003)	0.014 (0.0011)
	0.5	388 (0.0005)	0.768 (0.0019)	8.9% (0.0003)	0.018 (0.0010)
	0.6	393 (0.0009)	0.754 (0.0017)	9.2% (0.0007)	0.017 (0.0012)
	0.7	403 (0.0008)	0.748 (0.0016)	9.3% (0.0005)	0.019 (0.0014)

These results point out that multiple equilibria in the degree of capacity utilization are compatible with a stable accumulation. In contrast with the standard conclusion of the supermultiplier model, in the long run, the degree of capacity utilization

can be persistently different from the desired one as the economy reaches a steady state.

Although this outcome apparently evokes the results of the first versions of the neo-Kaleckian model, it is intrinsically different: in the quasi-steady state firms keep trying to restore the desired degree. On the contrary, in such a model, the persistency would imply Harrodian instability and it becomes necessary to hypothesize the normal degree as the adjusting variable (unless the autonomous non-capacity creating component is introduced in the model (Nah and Lavoie 2018)). In this regard, the long run is characterized by a fully adjusted position also in the neo-Kaleckian model, and firms achieve their realized target, as in the supermultiplier model. On the contrary, the results of the multi-firm economy show that long-run equilibrium can be characterized by undesired realizations and the aggregate degree of capacity utilization does not display any convergence toward the normal one. In detail, the aggregate degree of capacity utilization will differ from the normal one also on average.

To some extent, such aggregate models call to mind the reductionist approach of neoclassical models in which the functioning of the aggregate system is directly derived from the proprieties of single elements: the equilibrium needs to correspond to the realization of the desired state of agents. Conversely, the proposed analysis goes in the direction of considering an economy as a complex system where the aggregate is not the sum of its component (Anderson 1972), but emerges from the interactions across the components themselves. These systems are characterized by scale-invariant phenomena where the statistical equilibrium is spontaneously reached and, while the single elements are not in equilibrium, the aggregate is.

Finally, this depiction warns about the attempt to infer the normal rate from the time series on capacity utilization. In this sense, this demonstration goes in the direction of supporting the argument of authors such as Nikiforos (2016) who argues that a constant utilization over time in empirical data can be misinterpreted as constant normal utilization.¹⁶ At the same time, denying such an argument is not necessarily proof of the adaptation in conventional behavior. In this respect, some neo-Kaleckian contributions estimate the normal degree of capacity utilization using a moving average of the average capacity utilization (Bassi et al. 2020) or the Hodrick-Prescott filter (Lavoie 2004).¹⁷ Due to the mechanism we have shown, a similar exercise would lead to an incorrect estimate.

5.1 Rigid, dynamic network and heterogeneity

In order to trace the roots of the micro-phenomena that affect the macrodimension through the network channel, we compare the results of the model in different scenarios regarding the typology of the network and the heterogeneity of firms. Four

¹⁶ As we have shown, the degree of capacity utilization can persistently fluctuate around a constant value, although this value is not the normal one.

¹⁷ The same commentary applies to the methodology proposed by Botte (2019) who criticizes Lavoie (2004) and Bassi et al. (2020). The methodology proposed by the author consists of a weighted average of past values with exponentially decaying weight.

scenarios come out from the combination of a rigid or dynamic network with the cases of an economy with homogeneous or heterogeneous firms.

In the case of a rigid network, we are taking the extreme assumption of customers that never change suppliers in the long run. Therefore, we impose exogenously the supplier of each household and firm, and we keep it constant along with all the simulations.¹⁸ Customers can change suppliers only if theirs have exhausted inventories. In the initialization, households and C-firms are equally distributed across C-firms and K-firms, respectively.

The heterogeneity is referred to the formulation of expectations, that is the parameter β expressing the responsiveness of the accelerator process.¹⁹ In the dynamic network scenario households and firms select their supplier randomly (the related results refer to the baseline model previously presented). Table 3 shows the results.

When we exclude local interactions imposing an exogenous and constant network (namely, an extremely low variance characterizing the intertemporal concentration of demand across firms), the long-run fluctuations remain, while the emergence of a lower degree of capacity utilization is quite debased. This rigidity strongly lowers the interplay between aggregate demand and investments. Indeed, the volatility of single firm's demand depends on two mechanisms:

- Probability to lose or acquire new customers;
- Swing in individual consumption patterns (dependent on the employment status of workers and capitalists' dividends).

While both mechanisms characterize the dynamic network, only the second one is active in the rigid network. In this case, the persistence of the business cycle is due to the oscillations of individual consumption patterns which depend on the economic performances of associated firms (consumers are workers or owners of associated firms), and vice versa. In this sense, not only is the variance of the demand for each firm a function of the variability in the supplier selection, but it also depends on the evolution of the disposable income of existing customers. Indeed, in the aggregate model, the transition phase is also characterized by short-term fluctuations with consequent variations in the level of employment and distributed profits.²⁰ In the multi-firm economy, the interaction between individual income variations and singular firms' revenues modifies the status of every firm and prevents the gradual damping of short-term fluctuations until the convergence toward the fully adjusted position.

In the AB version, the distributional dimension linked to the short-run variation in the employment status and dividends of capitalists maintains the instability of the differential ξ and does not allow the transition phase to be as so. An example of the

¹⁸ In the first period, each firm has an equal number of customers.

¹⁹ The value of each β_i is randomly extracted from a normal distribution with mean equal to the value of the homogenous scenario and standard deviation equal to 0.05.

²⁰ The presence of the single macro-firm, not modifying the differential ξ , causes the expected growth rate of the demand to converge to that of the autonomous component and, therefore, the fluctuations to slowly dampen.

Table 3 Comparative results in four scenarios: homogeneous firms/rigid network, homogeneous firms/dynamic network, heterogeneous firms/rigid network and heterogeneous firms/dynamic network

	Homogeneous firms				Heterogeneous firms			
	log(GDP)	u_r volatility	Mean u_r	M*	log(GDP)	u_r volatility	Mean u_r	M*
Rigid network	8.41 (0.0001)	0.005 (0.0002)	0.774 (0.0001)	0.033 (0.0003)	8.41 (0.0001)	0.005 (0.0003)	0.773 (0.0002)	0.04 (0.0003)
Dynamic Network	8.43 (0.0012)	0.002 (0.0018)	0.735 (0.0021)	0.003 (0.0009)	8.43 (0.0008)	0.002 (0.0022)	0.733 (0.0028)	0.003 (0.0011)

*M: Market concentration

mechanism is as follows: a variation in the demand of a firm in sector K (K^a) changes the employment status of workers and the dividends distributed by K^a and, with it, the consumption pattern of these households. This change will also affect the revenues of the C-firms ($C^{a...c}$) which have these customers in their network, so the profits and wages paid by these firms also change. Subsequently, the revenues of firms $C^{f...j}$ that has the capitalists and workers of firms $C^{a...c}$ in their network will also change, reproducing the same cascade effect on the suppliers of their capitalists and workers. At the same time, also the $K^{b...d}$ suppliers of the capital goods for $C^{a...c}$, $C^{f...j}$ and of all other firms will register a change in their orders too; thus, the C-firms that have $K^{b...d}$ capitalists and workers in their network will also be subject to a variation in revenues.

Considering that not only does each of these effects produce a cascading impact on the other firms and ultimately on the firm itself, but that the same type of dynamics is simultaneously triggered by changes in the sales realized by the other firms, the combination of these mechanisms produces a positive variance in the distribution of demand across firms and prevents the realization of a *fully adjusted position*. The domino effect takes place contemporarily for all the firms of the economy, and their magnitude expands with the increase in the number of sectors and firms.

Finally, it is important to highlight that the aggregate degree of capacity utilization is positively correlated to the degree of monopoly: the higher market concentration lowers the differential ξ , and, through the investment channel, the magnitude of the interplay between aggregate demand and investments. Therefore, the increase in the degree of market concentration has the same effect as a decrease in the number of firms: in the most extreme case, the maximum degree of monopoly is reached by the single-firm economy, that is the aggregate model.

The rigid network scenario presents a higher capacity utilization mostly because of this feature. Indeed, being characterized by a higher market concentration, the second channel (the effect of the swing in the individual pattern of consumption) is strongly depowered, and, as a result, a low number of firms is responsible for the feeding of demand through investments and the realization of sales through its efflux. It is worth noticing that, in the rigid network scenario, despite starting from a situation of equal distribution of customers across suppliers, the market rapidly moves toward an oligopolistic configuration with a lower number of firms of a similar size (see Fig. 10). The firms that initially lose the demand following a change in the income of their

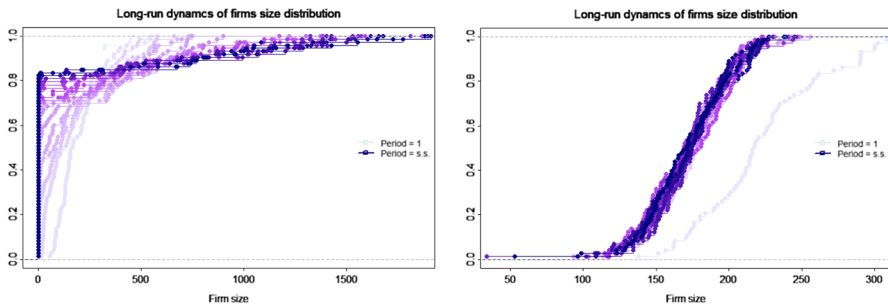


Fig. 10 Temporal evolution of the density function of firm size distribution in rigid (left side) and dynamic network (right side)

customers are no longer able to recover it. Demand is captured by larger firms that have been able to satisfy their demand.

The inclusion of heterogeneity across firms does not affect the results significantly. In particular, it does not change the results in the dynamic network scenario at all: given the same average β and an equal probability across firms to capture demand, the effect of heterogeneous firm decisions compensates each other on aggregate. In the scenario with the rigid network, it slightly modifies the results because it changes the weight of the β s with respect to the aggregate productive capacity: it increases the relevance of β s characterizing “oligopolistic” firms.

6 Conclusions

The concept of normal capacity utilization has held an important role in the debate within the analyses of demand-led growth, becoming the focus of a growing body of literature. In this regard, the demonstration of this paper contributes to the debate between neo-Kaleckian and SM positions. Both approaches share the idea that the degree of capacity utilization converges to the normal one. According to the SM approach, it is the realized degree of capacity utilization that adjusts to the normal; according to the neo-Kaleckian approach, it is normal that adjusts to the realized.

Traditionally, within both approaches, the stable solution corresponds to the realization of the desired state of firms. In this respect, the situation in which the degree of capacity utilization persistently differs from the normal one cannot be considered an “equilibrium” position since the reaction of firms would modify the investment growth rate inducing a change in the capacity utilization.

Conversely, we point out that once the interaction between the multiplier and the accelerator is explicitly reproduced in a multi-firm economy, a stable equilibrium or a steady-state position is characterized by singular non-equilibrium states, namely the aggregate dynamic can be stable, while agents are in non-equilibrium positions and keep trying to achieve the desired states. In particular, in the long run, the aggregate degree of capacity utilization does not display any tendency to converge toward the normal one; conversely, it fluctuates around a lower level. Parallely, this depiction

goes in the direction of providing a demand-side explanation of the business cycle without requiring the exogenous introduction of aggregate or idiosyncratic shocks.

We demonstrate that, within a demand-led growth model with non-capacity creating autonomous components of demand, the normal degree of capacity can be fixed without implying a process of gravitation toward it. So, differently from the traditional SM, the micro-founded dimension highlights how multiple equilibria of the actual degree of capacity utilization are compatible with a stable process of accumulation.

Unlike the neo-Kaleckian model, this is not the result of the realization of a conventional behavior at the firm level, but an emergent phenomenon. The equilibrium is not a *fully adjusted position* and does not correspond to the fulfillment of an endogenous adjustment in the desired degree of capacity utilization, neither continuously, nor on average. The possibility to have a sort of “undesired” equilibrium is a typical characteristic of complex systems where equilibrium does not require that every single element is in equilibrium, but rather that the statistical distributions describing aggregate phenomena are stable (Clementi et al. 2019).

In the considered economy, this outcome derives, precisely, from considering a multiplicity of firms rather than the aggregate macro-firm. Such feature necessarily brings along two mechanisms: (i) The dynamic instability of the differential between the share with which each firm contributes to the formation of the aggregate demand (as a result of its production decisions), and the share of demand that “flows back” to the firm itself through sales. Conversely, the single macro-firm or the representative firm of the macro-model takes all and creates all the induced demand (induced investments and consumption from associated income). As a consequence, the investment function of “aggregate” approaches reacts rigidly to self-induced changes in demand. To this extent, a necessary condition to achieve a steady state with a normal degree of capacity utilization, and verified by construction in an aggregate model, is this differential remaining constant during the inter-periodical process of revising expectations. (ii) The interplay, via investment channel, between the level of aggregate demand and how it is distributed across firms. That is, given the same level of aggregate demand, a different distribution across firms produces different reactions in terms of investments, with consequent different changes in the aggregate demand itself. In particular, given the normal level of aggregate demand where the aggregate model generates zero net investments, whatever distribution of such demand in the multi-firm economy produces a positive level of net investments. In short, the multiplicity causes over-investment with respect to the normal growth path and multiple degrees of capacity utilization result to be compatible with a stable accumulation.

The first is responsible for the endogeneity of the business cycle, while the second one is responsible for the emergence of a lower (aggregate) degree of capacity utilization. Being the control over the aggregate productive capacity split across different identities that take uncoordinated decisions, the share of investments on aggregate demand always results to be higher than the one determined in the case of the aggregate macro-firm. Due to the presence of the autonomous component, the aggregate demand does not react proportionally to the changes in capital stock; hence, the pattern of the degree of capacity utilization results lower than the normal one.

Appendix A

Coefficients of Eqs. 2.8–2.10

The coefficient (ψ) of the non-homogenous component of the difference equation is:

$$\psi = \left\{ (-1 + \delta)^2 v^2 + \frac{c^2(1-\theta)^2 \delta v(\delta v + 3y^2)}{y^2} - v y (-1 + \delta + 2y - \delta y + x_2^2 + g_G(-1 + \delta + y)) - \frac{c(1-\theta)(\delta^2 v^2 + y^3(1 + g_G + y) - \delta v(v + y + g_G y + 3vy))}{y} + y^2(y(1 + g_G) + 2y^2 + 6xz) \right\} / \left[(1 + g_G - x)(1 + g_G - y)(1 + g_G - z)(x - y)(y - z)((-1 + \delta)v + y^2 + 2xz) \right] \quad (\text{A.1})$$

where $x = x_1, y = x_2, z = x_3$

$$\begin{aligned} C &= 3\sqrt{3} \\ &\sqrt{- (c * (1 - \theta) + v)^2 (v(1 - \delta))^2 + 4(v(1 - \delta))^3 - 4(c * (1 - \theta) + v)^3 c \delta v(1 - \theta)} \\ &\sqrt{+ 18(c * (1 - \theta) + v)v(1 - \delta)c \delta v(1 - \theta) + 27(c \delta v(1 - \theta))^2} \\ &\quad + 2(c * (1 - \theta) + v)^3 - 9(c * (1 - \theta) + v)v(1 - \delta) - 27c \delta v(1 - \theta) \end{aligned} \quad (\text{A.2})$$

$$B = -(c * (1 - \theta) + v)^2 + 3v(1 - \delta) \quad (\text{A.3})$$

$$a = (c * (1 - \theta) + v) \quad (\text{A.4})$$

Accountancy, debt service and bankruptcy

Total debt service includes debt installments of short- and long-term loans and *roll-over* loans and financial charges:

$$\begin{aligned} SD_{t,i} &= \frac{1}{a} \frac{1}{z} \sum_{j=t-z}^{t-1} l_{ij} K_{ij}^d (1 + b^{long} r_j) (j + z - t) \\ &\quad + \frac{1}{z^{short}} \sum_{j=t-z^{short}}^{t-1} l_j WB_{j,i} (1 + a^{short} r_j) (j + z^{short} - t) \\ &\quad + \frac{1}{z^{ponzi}} \sum_{j=t-z^{ponzi}-1}^{t-2} L_{j,i}^{ponzi} (1 + a^{ponzi} r_j) (j + z^{ponzi} - t) \end{aligned} \quad (\text{A.5})$$

Financial charges are computed on the remaining stock of debt; thus, debt installments are decreasing over time. This is consistent with the evolution of amortization.

At the end of the period, firm cash is:

$$CF_{t,i} = CF_{t-1,i} + \text{revenues}_{t,i} + L_{t,i}^{d,\text{short}} + L_{t,i}^{d,\text{long}} + L_{t-1,i}^{\text{ponzi}} - WB_{t,i} - \sum p_{\text{index},t} k_{i,t}^D - SD_{\text{tot},i} \quad (\text{A.6})$$

where $CF_{t,i}$ is the cash available to the firm,, $L_{j,i}^{\text{ponzi}}$ is the loan granted to payback the outstanding debt, $WB_{t,i}$ is the wage bill, $\sum p_{\text{index},t} k_{i,t}^D$ is the expenditure to acquire the capital good, and $SD_{\text{tot},i}$ is the total debt service including financial charges.

If firms' cash net of the debt service is negative, firms can ask for an additional loan to pay the outstanding debt. This possibility is granted by the bank for a maximum number of periods \lim^{ponzi} within the same window of the debt repayment. If the net wealth is positive or the number of periods of (over) indebtedness is less than \lim^{ponzi} , the firm is granted a further loan; otherwise, it goes bankrupt. If capitalist deposits (relating to the bankrupt firm) are at least equal to the residual value of physical capital and inventories, the firm is "recapitalized" for that value and, therefore, the non-performing loan corresponds to the debt stock of firm net of the recapitalization. If deposits are lower, the non-performing loan is equal to the difference between the firm debt stock and the deposits of the capitalist (owner of the firm). The following expression defines the condition under which the *ponzi* loan is granted and the updating of financial variables in case of bankruptcy:

$$\text{if } CF_{t,i} < 0 \begin{cases} \text{if } NW_{t,i} > 0 \vee n_{t,i}^{\text{ponzi}} < \lim^{\text{ponzi}} : L_{j,i}^{\text{ponzi}} = -CF_{t,i}; n_{t,i}^{\text{ponzi}} = n_{t-1,i}^{\text{ponzi}} + 1 \\ \text{otherwise bankruptcy}_{t,i} = 1 \text{ and } \begin{cases} \text{if } (M_{t,\text{cap}_i} \geq Rv_{t,i} : NPV_{t,i} = D_{t,i} - Pdr_{t,i} - Rv_{t,i} \\ \text{else} : NPV_{t,i} = D_{t,i} - Pdr_{t,i} - M_{t,\text{cap}_i} \end{cases} \end{cases} \quad (\text{A.7})$$

where $NW_{t,i}$ is firm net wealth, $n_{t,i}^{\text{ponzi}}$ is the number of periods the firm has been granted with a *ponzi* loan, M_{t,cap_i} is the deposit amount of the owner of bankrupted firm, $D_{t,i}$ is the outstanding debt, $NPV_{t,i}$ is the non-performing loan, and $Pdr_{t,i}$ is the fraction of current stock of debt paid back by the bankrupted firm:

$$Pdr_{t,i} = CF_{t-1,i} + \text{revenues}_{t,i} + L_{t,i}^{d,\text{short}} + L_{t,i}^{d,\text{long}} + \text{Ponzidebt}_{t-1,i} - WB_{t,i} - \sum p_{\text{index},t} k_{i,t}^D \quad (\text{A.8})$$

The net wealth of firms is:

$$NW_{t,i} = am_{t,i}^{\text{residual}} + CF_{t,i} - D_{t,i} + \text{inv}_{t,i} uc_{t,i}^h \quad (\text{A.9})$$

$$Rv_{t,i} = \text{ResidualValue}_{t,i} = am_{t,i}^{\text{residual}} + \text{inv}_{t,i} uc_{t,i}^h \quad (\text{A.10})$$

Sequence of events

The sequence of events within each period is:

1. Updating of the capital stock;
2. Computing unit costs and fixing markups;
3. Firms C set desired production, labor and capital demand;

4. Matching in the capital market;
5. Firms K, based on the percentage of completion of semi-finished products and new orders, set the desired production and labor demand;
6. Matching in the labor market;
7. Production start:

Sector K:

$$\left\{ \begin{array}{l} \text{if } L_{t,i}^d = \text{employees}_{t,i} : y_{t,i} = y_{t,i}^d; h_{t,i}^{\text{work}} = \frac{L_{t,i}^d}{h_{\text{month}}} \\ \text{otherwise} : y_{t,i} = \frac{\text{employees}_{t,i} h_{\text{month}}}{l_c}; h_{t,i}^{\text{work}} = h_{\text{month}} \end{array} \right. \quad (\text{A.11})$$

If labor demand has been satisfied, the working hours are equally distributed among employees in such a way as to produce exactly the desired quantity. In case labor demand has remained unsatisfied, workers will work full time (h^m).
Sector C :

$$\left\{ \begin{array}{l} \text{if } L_{t,i}^d = \text{employees}_{t,i} : y_{t,i} = \min(y_{t,i}^d, \frac{k_{t,i}}{v_{t,i}}); h_{t,i}^{\text{work}} = \frac{L_{t,i}^d}{h^m} \\ \text{otherwise} : u_{t,i}^l = \frac{\text{employees}_{t,i} h^m \alpha}{k_{t,i}}; y_{t,i} = \min(u_{t,i}^l, \frac{k_{t,i}}{v_{t,i}}) h_{t,i}^{\text{work}} = h^m \end{array} \right. \quad (\text{A.12})$$

8. Based on the quantity produced in sector K in current and last dk periods, the (previous) capital goods demand is satisfied;
9. Credit demand, payment of capital goods and wages (unemployed workers receive government subsidies);
10. Matching in the consumer market;
11. Cash flows computation. Some firms, if necessary, can apply for additional financing, those that do not meet the requirements go bankrupt;
12. Profits computation and dividends payment;
13. CB profits computation and public bonds are sold.

Stock-flow consistency

The model considers two different exogenous injection of purchasing power financed through a correspondent variation in aggregate debts. These are public spending financed by CB and bank loan granted to finance investments.

Household savings are equal to the sum of public and private debt, while households' deposits are equal to the stock of public bonds held by CB and the stock of loans. The redundant equation is the following:

$$M_t = L_t + B_{cb,t}, \quad (\text{A.13})$$

where M_t is the stock of deposits, L_t is the stock of private debt, and $B_{cb,t}$ is the amount of public debt held by CB. Latter can be rewritten as:

$$M_t - L_t = B_{cb,t} = H_{cb,t} \quad (\text{A.14})$$

where $H_{cb,t}$ is the stock of reserves held by commercial bank at CB.

The redundant equation expresses the indirect relationship between public bonds purchased by CB and the stock of reserves held by commercial bank. The difference between total deposits and bank loans corresponds to the stock of public bonds held by CB that, in turn, are equal to the reserves held by the bank at the CB. The remaining part of public debt is held by capitalists.

Including advances, bankruptcy and non-performing loans, the check-consistency equation becomes:

$$M_t = L_t + B_{cb,t} + NPL_t + A_t \quad (\text{A.15})$$

where NPL_t are non-performing loans and A_t are the advances from CB to the commercial bank. Advances may be required when bank is not able to pay interest rates on deposits when it cumulates NPL. However, in model simulation they are never used and are always equal to zero.

The balance sheet and the transaction matrix describing the economy are reported in Tables 4 and 5.

Table 4 Aggregate balance sheet

Assets	Workers	Capitalists	Firms K	Firms C	Banks	Government	CB	Σ
Check deposits ^a		M_{cap}^c	M_k^c	M_c^c	$-M1$			0
Time deposits	$+M_w$	$+M_{cap}$			$-M2$			0
Reserves					$+H_b$		$-H$	0
Advances BC					$-A$		$+A$	0
Loans				$-L_c$	$+L$			0
Non-performing loan				$+NL_c$	$-NL$			0
Fixed capital				$+K_f$				$+K_f$
Inventories				$+INV_f$				$+INV_f$
Public bonds		$+B_{h, cap}$				$-B$	$+B_{cb}$	0
Net Wealth.	$-V_{h,w}$	$-V_{h, cap}$	$-V_k$	$-V_c$	0	$+V_G$	0	$-K_f$
Σ	0	0	0	0	0	0	0	0

^aThe distinction between check deposits and time deposits is required since the income distributed to capitalists at the end of the period (from which the demand for consumer goods in the following period is generated) does not represent savings. Time deposits, on the other hand, are the portion of saved income and held in the form of deposits. These, unlike deposit accounts, accrue interests in each period

Table 5 Aggregate transaction matrix

	Workers	Capitalists	Firms K	Firms C	Government	Bank		CB		Σ
						Current	Capital	Current	Capital	
Consumption	$-C_w$	$-C_{cap}$	$+I$	$+C$						0
Investments				$-I$						0
Public expenditure				$+G$	$-G$					0
Unemp. Benefit	$+U$				$-U$					0
Wages	$+W$		$-W_k$	$-W_c$						0
Tax	$-T_w$	$-T_{cap}$			$+T$					0
Dividends Firms		$+Div_F$	$-Div_k$	$-Div_c$						0
Dividends Bank		$+Div_B$				$-Div_B$				0
Profits CB					$+F_{cb}$			$-F_{cb}$		0
Recapitalization		$-K_r$		$+K_r$						0
Int. Deposits	$+r_m M2_{w,t-1}$	$+r_m M2_{c,t-1}$				$-r_m M2_{t-1}$				0
slnt. Loans			$-r_l L_{k,t-1}$	$-r_l L_{c,t-1}$		$+r_l L_{t-1}$				0
Int. Bond		$+i_{t-1} B_{h,t-1}$			$-i_{t-1} B_{t-1}$			$+i_t B_{bc,t-1}$		0
Int. Reserves						$+r_{t-1} H_{t-1}$		$-r_{t-1} H_{t-1}$		0
Int. Advances						$-r_{ad,t-1} A_{t-1}$		$+r_{ad,t-1} A_{t-1}$		0
Δ Time deposits		$-\Delta M_{cap}$	$-\Delta M_k$	$-\Delta M_c$			$+\Delta M^c$			0
Δ Check deposits		$-\Delta M_w^c$					$+\Delta M$			0
Δ Loans			$+\Delta L_k$	$+\Delta L_c$			$-\Delta L$			0
Δ Bond		$-\Delta B_h$			$+\Delta B$				$-\Delta B_{bc}$	0
Δ Non-performing loan				$-\Delta NL_c$			$+\Delta NL$			0
Δ Reserves							$-\Delta H$		$+\Delta H$	0
Δ Advances							$+\Delta A$		$-\Delta A$	0
Σ	0	0	0	0	0	0	0	0	0	0

Appendix B

See Figs. 11 and 12

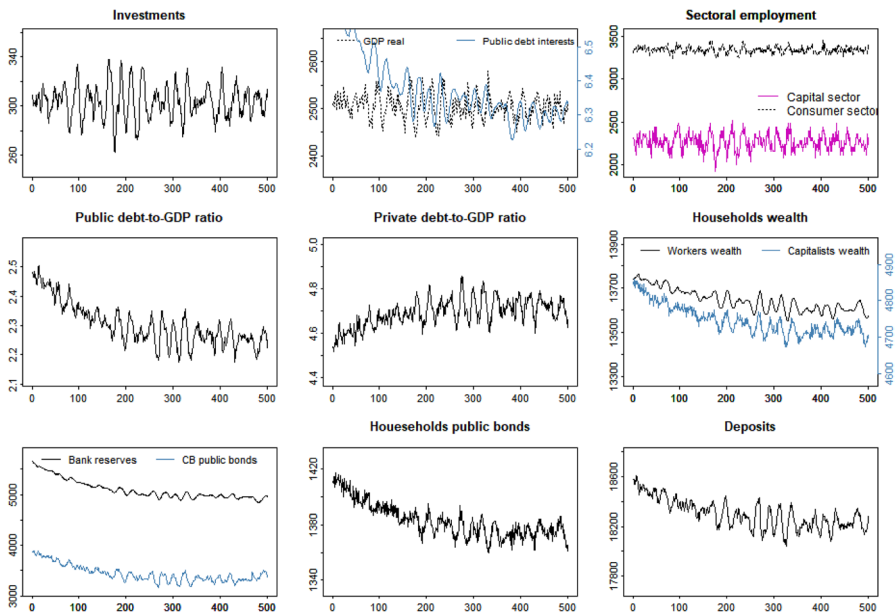


Fig. 11 Time series refers to a single simulation run (seed = 1, $c_2 > 0$)

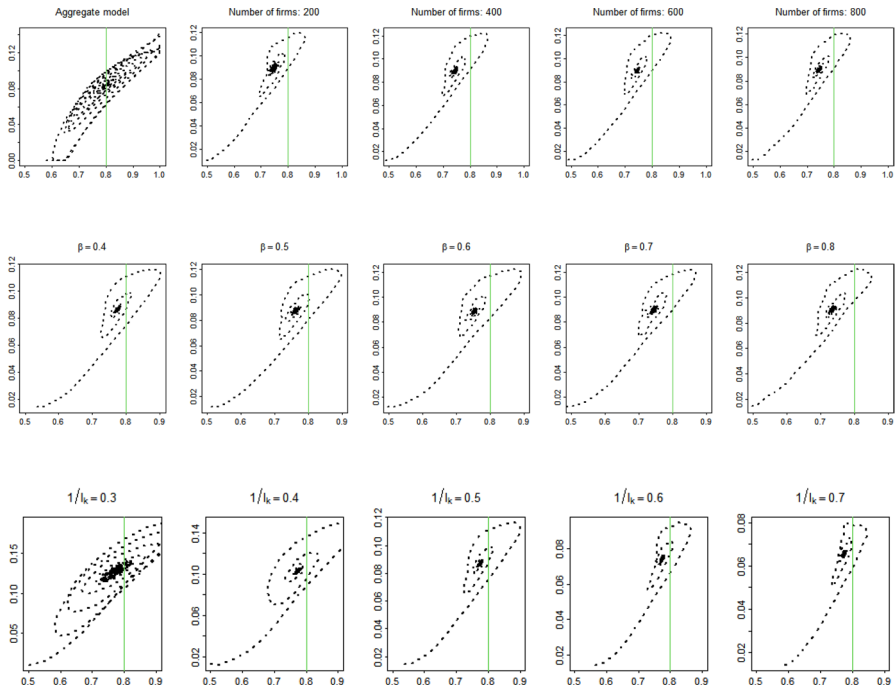


Fig. 12 Phase diagrams according to different values of the number of firms (a), the expectation parameter (b) and labor productivity in capital sector (c). The x-axis shows the utilization rate and y-axis shows the investment share

Appendix C

See Fig. 13

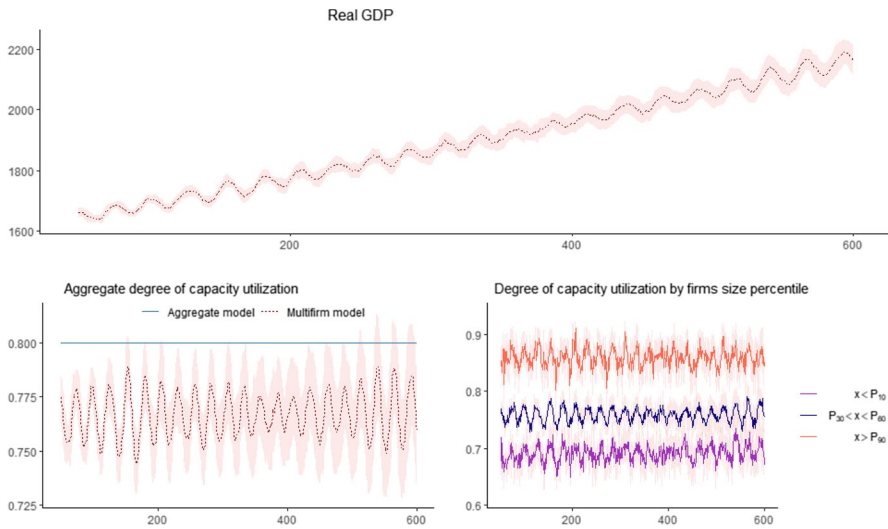


Fig. 13 Aggregate degree of capacity utilization and GDP in the two versions of the model with positive growth rate of the autonomous component of demand. Averages for 50 MC runs in the period [200, 800]

Appendix D

See Table 6

Table 6 Table of parameters in the baseline scenario.

Description	Symbol	Value
Monte Carlo replications	MC	50
Time sample	T	800
Number of firms in the capital good sector	F_k	70
Number of firms in the consumption good sector	F_c	300
Number of workers	N_w	5630
Number of capitalists	N_c	370
Capital good firms markup	φ_k	0.2
Consumption good firms markup	φ_c	0.2
Normal degree of capacity utilization	u_n	0.8
Capital-to-output ratio	v	0.85
Capital-to-labor ratio	α	0.9
Reciprocal of labor productivity in capital good sector	l_k	0.55
Capital good lifetime	z	50
Number of periods to produce the capital good	dk	6
Desired inventories-to-sales ratio	σ^T	0.02
Expectation parameter	β	0.6
Tax rate	θ	0.2
Unemployment subsidy rate	ρ	0 (0.4)
Fixed interest on loans	r_l	0 (0.03)
Fixed interest on public bonds	r_b	0 (0.04)
Interest on deposit	r_d	0 (0.01)
Interest on reserves	r_r	0 (0.01)
Interest on advances	r_a	0 (0.01)
Payback time of long-term loans	z_z	50
Payback time of short-term loans	z_s	10
Dividends distribution rate	ω	1
Desired leverage	l^T	1
Initial public expenditure rate	$\bar{\tau}$	0.1
Public expenditure growth rate	g_G	0
Propensity to consume out-of-income of workers	c_w^y	0.8
Propensity to consume out-of-wealth of workers	c_w^V	0 (0.03)
Propensity to consume out-of-income of capitalists	c_π^y	0.6
Propensity to consume out-of-wealth of capitalists	c_π^V	0 (0.03)

The scenario with aggregate model presents the same parameters except for the number of firms in capital and consumer sector where we consider $F_k = F_c = 1$. The values of the parameters used in the simulations in Appendix B are given in brackets

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References

- Amadeo EJ (1986) Notes on capacity utilisation, distribution and accumulation. *Contribut Political Econom* 5:83–94
- Anderson PW (1972) More is different. *Science* 177(4047):393–396
- Andrews PWS (1949) A reconsideration of the theory of the individual business. *Oxford Econom Papers* 1:54–89
- Andrews PWS, Brunner E (1975) *Studies in pricing*. Macmillan, London
- Ascari G, Fagiolo G, Roventini A (2015) Fat-Tail Distributions and business-cycle models. *Macroecon Dyn* 19(2015):465–476
- Assenza T, Delli Gatti D, Grazzini J (2015) Emergent dynamics of a macroeconomic agent based model with capital and credit. *J Econ Dyn Control* 50:5–28
- Bassi F, Lang D (2016) Investment hysteresis and potential output: a post-Keynesian-Kaleckian agent-based approach. *Econ Model* 52:35–49
- Bassi F (2020) Growth without Full Capacity Utilization And Full Capacity Utilization Without Growth. CEPN Working Papers 2020–02, Centre d'Economie de l'Université de Paris Nord.
- Bassi F, Bauermann T, Lang D, Setterfield M (2022) Is capacity utilization variable in the long run? An agent-based sectoral approach to modeling hysteresis in the normal rate of capacity utilization. *Struct Chang Econ Dyn* 63:196–212
- Botta A, Caverzasi E, Russo A, Gallegati M, Stiglitz JE (2021) Inequality and finance in a rent economy. *J Econom Behav Organiz Elsevier* 183:998–1029
- Botta A, Caverzasi E, Russo A (2020) When complexity meets finance: a contribution to the study of the macroeconomic effects of complex financial systems, *Research Policy*.
- Botte F (2020) Estimating normal rates of capacity utilisation and their tolerable ranges: a comment on mark setterfield. *Camb J Econ* 44(2):475–482
- Caiani A, Godin A, Caverzasi E, Gallegati M, Kinsella S, Stiglitz JE (2016) Agent based-stock flow consistent macroeconomics: towards a benchmark model. *J Econom Dynam Control, Elsevier* 69:375–408
- Caiani A, Russo A, Gallegati M (2019) Does inequality hamper innovation and growth? an ab-sfc analysis. *J Evol Econ* 29(1):177–228
- Caiani A, Russo A, Gallegati M (2020) Are higher wages good for business? An assessment under alternative innovation and investment scenarios. *Macroecon Dyn* 24(1):191–230
- Catullo E, Gallegati M, Russo A (2020) Forecasting in a complex environment: Machine learning sales expectations in a Stock Flow Consistent Agent-Based simulation model.
- Cesaratto S, Serrano F, Stirati A (2003) Technical change, effective demand and employment. *Rev Political Econom* 15(1):33–52
- Cesaratto S (2015) Neo-Kaleckian and Sraffian controversies on the theory of accumulation. *Rev Political Econom* 27(2):154–182
- Cesaratto S, Di Bucchianico S (2020) Endogenous money and the theory of long-period effective demand. *Bull Political Econom* 14(1):1–38
- Chen S, Chang C, Du Y (2012) Agent-based economic models and econometrics. *Knowl Eng Rev* 27(2):187–219

- Cincotti S, Raberto M, Teglio A (2010) Credit money and macroeconomic instability in the agent-based model and simulator Eurace, Economics - The Open-Access, Open-Assessment E-Journal (2007–2020), 4, issue, p. 1–32.
- Committeri M (1986) Some comments on recent contributions on capital accumulation, income distribution and capacity utilization. *Political Econom* 2(2):161–186
- Committeri M (1987) Capacity utilization, distribution and accumulation: a rejoinder to Amadeo. *Political Econom* 3(1):91–95
- Copeland MA (1949) Social accounting for moneyflows. *Account Rev* 24(3):254–264
- Dávila-Fernández MJ, Oreiro JL, Punzo LF (2017) Inconsistency and overdetermination in neo-Kaleckian growth models: A note. *Metroeconomica*.
- Deleidi M, Mazzucato M (2019) Putting austerity to bed: technical progress, aggregate demand and the supermultiplier. *Rev Political Econom* 31(3):315–335
- Di Bucchianico S (2020) Discussing secular stagnation: a case for freeing good ideas from theoretical constraints? *Struct Chang Econ Dyn* 55:288–297
- Di Bucchianico S (2021) Inequality, household debt, ageing and bubbles: A model of demand-side Secular Stagnation. IPE Working Papers 160/2021, Berlin School of Economics and Law, Institute for International Political Economy (IPE).
- Di Domenico L (2020) Business cycle and growth in a monetary economy of production: the impact of fiscal and monetary policies on long-run output and public finance, Doctoral Thesis. University of Roma Tre.
- Dosi G, Roventini A (2019) More is different ... and complex! the case for agent-based macroeconomics. *J Evol Econom*, Springer 29(1):1–37
- Dosi G, Pereira MC, Roventini A, Virgillito ME (2019) What if supply-side policies are not enough? The perverse interaction of flexibility and austerity. *J Econom Behav Organiz* 162:360–388
- Dutt AK (1984) Stagnation, income distribution and monopoly power. *Camb J Econ* 8(1):25–40
- Dutt AK (1990) Growth, distribution and uneven development. Cambridge University Press, Cambridge
- Fagiolo G, Roventini A (2017) Macroeconomic policy in DSGE and agent-based models redux: new developments and challenges ahead. *J Artificial Soc Soc Simulation* 20(1):1–1
- Freitas F, Serrano F (2015) Growth rate and level effects, the stability of the adjustment of capacity to demand and the Sraffian supermultiplier. *Rev Political Econom* 27(3):258–281
- Gaffeo E, Catalano M, Clementi F, Gatti DD, Gallegati M, Russo A (2007) Reflections on modern macroeconomics: can we travel along a safer road? *Physica A* 382(1):89–97
- Gahn SJ, González A (2020) On the ‘utilisation controversy’: a comment. *Camb J Econ* 44(3):703–707
- Gahn SJ (2021) On the adjustment of capacity utilisation to aggregate demand: revisiting an old Sraffian critique to the Neo-Kaleckian model. *Struct Chang Econ Dyn* 58:325–360
- Garegnani P (1992) Some notes for an analysis of accumulation. Beyond the steady – state: a revival of growth theory. Macmillan, Londra, pp 47–71
- Gilli M, Winker P (2003) A global optimization heuristic for estimating agent based models. *Comput. Stat. Data Anal.* 42(2):299–312
- Gilli M, Winker P (2008) Review of heuristic optimization methods in econometrics. Comisef Working Paper series
- Girardi D, Pariboni R (2016) Long-run effective demand in the US economy: an empirical test of the sraffian supermultiplier model. *Rev Political Econom*, Taylor & Francis J 28(4):523–544
- Girardi D, Pariboni R (2019) Normal utilization as the adjusting variable in Neo-Kaleckian growth models: a critique. *Metroeconomica*, Wiley Blackwell 70(2):341–358
- Godley W, Lavoie M (2006) Monetary economics: an integrated approach to credit, money, income, production and wealth. Springer, Berlin
- Graziani A (1990) The theory of the monetary circuit, *économies et sociétés. Série Monnaie Et Product* 24:6
- Grazzini J, Richiardi M, Sella L (2012a) Small sample bias in msm estimation of agent-based models. In: Andrea Teglio, Simone Alfarano, E. C.-C. M. G.-V.(Eds.), *Managing Market Complexity. The Approach of Artificial Economics. Lecture Notes in Economics and Mathematical Systems*. Springer, New York, USA.
- Grazzini J, Richiardi MG, Sella L (2012) Indirect estimation of agent-based models. An application to a simple diffusion model. *Complex Econ* 1(2):25–40
- Grazzini J, Richiardi M (2015) Estimation of ergodic agent-based models by simulated minimum distance. *J Econom Dynam Control* 51:148–165
- Harrod RF (1939) An essay in dynamic theory. *Econ J* 49(193):14–33

- Hein E, Lavoie M, Van Treeck T (2012) Harrodian instability and the normal rate of capacity utilization in Kaleckian models of distribution and growth – a survey. *Metroeconomica* 63(1):39–69
- Keynes JM (1933) A monetary theory of production. The Collected Writings of John Maynard Keynes 13:408–411
- Kindleberger C, Aliber R (2011) Manias, panics, and crashes: a history of financial crises. Wiley, Hoboken
- Lavoie M (1996) Traverse, hysteresis, and normal rates of capacity utilization in Kaleckian models of growth and distribution. *Rev Radical Political Econom* 28(4):113–147
- Lavoie M (2004) Circuit and coherent stock-flow accounting. In: Arena R, Salvadori N (eds) Money, credit and the role of the State. Ashgate, Aldershot, pp 134–149
- Lavoie M, Rodriguez G, Seccareccia M (2004) Similitudes and discrepancies in post-keynesian and marxist theories of investment: a theoretical and empirical investigation. *Int Rev Appl Econ* 18(2):127–149
- Lavoie M (2016) Convergence towards the normal rate of capacity utilization in neo-kaleckian models: the role of non-capacity creating autonomous expenditures. *Metroeconomica* 67(1):172–201
- Levero E (2013) Marx on absolute and relative wages and the modern theory of distribution. *Rev Political Econom* 25(1):91–116
- Marglin S, Bhaduri A (1990) Profit squeeze and Keynesian theory. In: Marglin S, Schor J (eds) The golden age of capitalism: reinterpreting the postwar experience. Clarendon, Oxford, pp 153–186
- Minsky H (1975) John maynard keynes. Columbia University Press, New York
- Nah WJ, Lavoie M (2019) The role of autonomous demand growth in a neo-Kaleckian conflicting-claims framework'. *Struct Chang Econ Dyn* 51:427–444
- Napoletano M, Roventini A, Sapio S (2006) Are business cycles all alike? A bandpass filter analysis of the italian and US cycles. *Rivista Italiana Degli Econom* 1:87–118
- Nikiforos M (2013) The (normal) rate of capacity utilization at the firm level. *Metroeconomica* 64(3):513–538
- Nikiforos M (2016) On the 'utilization controversy': a theoretical and empirical discussion of the Kaleckian model of growth and distribution. *Camb J Econ* 40(2):437–467
- Nikiforos M (2018) Some comments on the Sraffian Supermultiplier approach to growth and distribution. *J Post Keynesian Econom* 41(4):659–675
- Palumbo A, Trezzini A (2003) Growth without normal capacity utilization. *Eur J History of Econom Thought*, Taylor & Francis J 10(1):109–135
- Palumbo A, Trezzini A (2016) The theory of output in the modern classical approach: main principles and controversial issues. *Rev Keynesian Econom*, Edward Elgar Publish 4(4):503–522
- Parguez A, Seccareccia M (2000) The credit theory of money: the monetary circuit approach. In: Smithin J (ed) What is money? Routledge, London, pp 101–123
- Pariboni R (2016a) Household consumer debt, endogenous money and growth: a supermultiplier based analysis. *PSL Quarterly Rev* 69(278):211–233
- Pariboni R (2016b) Autonomous demand and the Marglin-Bhaduri model: a critical note. *Rev Keynes Econ* 4(4):409–428
- Pariboni R (2015) Autonomous demand and capital accumulation: three essays on heterodox growth theory. Doctoral dissertation.
- Passarella M (2012) A simplified stock-flow consistent dynamic model of the systemic financial fragility in the 'New Capitalism. *J Econom Behav Organiz* 83:570–582
- Pivetti M (1985) On the monetary explanation of distribution, with a reply to comments by L. Pasinetti e J. Steindl, in Bhadrarwaj, K. and Schefold, B. (eds), Essays on Piero Sraffa - Critical Perspectives on the Revival of Classical Theory, London, Unwim Hyman.
- Pivetti M (1991) An essay in money and distribution. Macmillan, London
- Serrano F (1995) Long period effective demand and the sraffian supermultiplier. *Contribut Political Econom* 14(67–90):24
- Seppacher P, Salle IL, Lavoie M (2018) What drives markups? Evolutionary pricing in an agent-based stock-flow consistent macroeconomic model. *Ind Corporate Change*, Oxford University Press 27(6):1045–1067
- Setterfield M (2017) Long-run variation in capacity utilization in the presence of a fixed normal rate. New School for Social Research Working Papers 1704.
- Setterfield M, Avritzer JD (2020) Hysteresis in the normal rate of capacity utilization: a behavioral explanation. *Metroeconomica*, Wiley Blackwell 71(4):898–919

- Shaikh A (2009) Economic policy in a growth context: a classical synthesis of Keynes and Harrod. *Metroeconomica* 60(3):455–494
- Skott P (2012) Theoretical and empirical shortcomings of the Kaleckian investment function. *Metroeconomica* 63(1):109–138
- Skott P (2017) Autonomous demand and the harrodian criticisms of the Kaleckian model. *Metroeconomica*, Wiley Blackwell 68(1):185–193
- Stirati A (1994) The theory of wages in classical economics: a study of Adam Smith, David Ricardo, and their contemporaries. Edward Elgar Publishing.
- Stock JH, Watson MW (1999) Business cycle fluctuations in US macroeconomic time series. *Handb Macroecon* 1:3–64
- Teglio A (2020) On the typicality of the representative agent. MPRA Paper 105407, University Library of Munich, Germany.
- Vianello F (1985) The pace of accumulation. *Political Econom I* 1:69–87

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