



A value-theoretic approach to economic dynamics and evolution—synthesizing different Marxian modules in a simulation model

Part II: simulation experiments

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Abstract

This part is devoted to simulation experiments based on the simulation model developed in part I from the value-theoretic reconstruction of the main parts of Marx's critique of Political Economy. After introducing the main parameters and the range of their variation (Section 1), a singular run as well as a sensitivity analysis for the chosen standard configuration ('moderation regime') is presented in Section 2. This is accomplished by configurations depicting characteristics of the capitalist development emphasized by Marx, i.e. the social conflict regime (Section 3) and the crisis regime (Section 4). Finally, an assessment of the simulation results (Section 4) is given, and conclusions as well as research requirements are discussed (Section 5).

Keywords Marx · Theory of value · Evolution · Social exploitation · Class antagonism · Accumulation · Reproduction · Profit rate · Crisis · Simulation

JEL classification B14 · B15 · B51 · B52 · C63 · E11 · P10

1 Introduction

The emphasis of this analysis is generally on the development of the structural terms, i.e. relations of magnitudes rather than the magnitudes themselves. This not only is a consequence of the arbitrariness of the numerical calibration but also reflects insights from the literature on capitalist development, which reveal that the structural terms are in fact the main explanatory factors. Nevertheless, numerical calibrations and

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simulations are necessary for demonstrating the role of the structural terms (such as organic composition of capital, rate of surplus value and rate of profit) in the course of time.

Hence, in the different simulation runs, the dynamic interdependence between the value-theoretic elements characterizing the different Marxian modules will be explained. These interdependencies are not wholly accessible by means of a (textual) conceptual analysis, which is implicitly confined either to a static assessment or to a rough and incomplete portrayal of the dynamic relations between the variables at stake. For all levels under consideration—production process, circulation and reproduction as well as the process as a whole—the model is not closed, i.e. there are elements that are relevant which are not explained by the model itself. The reasons for this openness are either pragmatic (avoiding over-complexity) or methodological (influence of historical contingencies). These elements are depicted as parameters; their influence is checked by sensitivity analysis. Regarding the mathematical basis (cf. part I, Section 4.2), the following parameters are relevant:

- For the production process: the rate of growth for the available labour population (δ), the power of wage labour (α), the factor for the surplus value dynamics (γ), the influence of the power of wage labour on the accumulation (β) and finally the incentive for safeguarding a ‘reserve army’ of wage labour (ρ)
- For the process of circulation and reproduction: the threshold for departmental disproportion triggering stagnation (λ_1), the shrinking factor in case of a stagnation (λ_2), the impact of circulation costs (λ_3) and the costs of additional money (φ)
- For the process as a whole: the degree of departmental competition (ξ)¹

Some of these parameters can be calibrated and combined in such a way that the interdependencies of the capitalist core process exhibit features that narrow the gap between abstract analysis and observable varieties of capitalism. Hence, a self-evident access to specify ‘regime’ or ‘modes’ of the interacting core variables is given. The basis for the simulation runs is a standard configuration of these parameters depicting a rather smooth regime of accumulation in that the level of social conflict is moderate, and the frictions for reproduction and allocation are low (*moderation regime*; cf. section 2). The sensitivity analysis for the main parameters in such a configuration is the background for distinguishing other regimes on an exemplary basis and for analysing their outcomes: the *social conflict regime* (cf. section 3) and the *crisis regime* being differentiated according to the different types of crisis (cf. section 4). The numerical specification of the parameters in these regimes is summarized in Table 1.²

¹ When the possibility to explain crisis is taken into account (cf. section 5.3 below), some additional parameters such as the minimum rate of profit (r^*) and—in the case of over-accumulation—the weight of precautionary hoarding (τ), the level of accumulation (η) and finally the level of investment from hoarding (ϵ) will be introduced.

² The model explained in part I, section 4.1 and 4.2, has been implemented in the Mathematica® 10.4. Due to the long-term perspective of the model, 1000 time steps have been taken into account. According to the operations happening in one time step, it seems plausible to equate one time step with about one month. Hence, the depicted time span is about 80 years.

Table 1 Parameters und their numerical specification for different regimes. Numbers in square brackets: minimum number, maximum number and numerical steps of sensitivity simulation

Parameters	Significance	Moderation (standard)	Sensitivity analysis	Social conflict	Repro-crisis	Accu-crisis
δ	Growth rate population	0.0025	-	0.0025	0.0025	0.0025
α	Degree of wl-power	1	[0.3, 1, 0.1]	0.3	1	1
γ	Surplus value dynamics	0.6	[0.3, 0.6, 0.1]	0.3	0.6	0.6
β	Influence of wl-power	1	[0.5, 1, 0.1]	1	1	1
ρ	Incentive reserve army	0.3	[0.3, 1, 0.1]	1	0.3	0.3
λ_1	Threshold for stagnation	1	-	1	[1, 10, 1]	1
λ_2	Shrinking in stagnation	0.998	-	0.998	0.998	0.998
λ_3	Circulation cost impact	0.3	[0.3, 1, 0.1]	0.3	2	[0.1, 0.4, 0.1] 0.3
φ	Money cost impact	0.0005	0.0005	0.0005	0	0
ξ	Degree of competition	1	[0, 1, 0.1]	0.1	1	1
ε (r^*)	Minimum profit rate	-	-	-	-	0.1
τ	Precaution hoarding	-	-	-	-	0.15
	Investment from hoarding	-	-	-	-	0.5
η	Accumulation in crisis	-	-	-	-	0

2 Moderation regime (standard configuration)

2.1 Singular run

As regards the *production process* in this regime, it is assumed that the organizing power of the wage labour is at the lowest level ($\alpha = 1$). Correspondingly, the resistance against the increase of surplus value by means of the methods mentioned in part I, section 3.2, is also low, allowing for a rather high γ . Whereas the propensity to substitute labour as an element of production is at the Marxian standard level ($\beta = 1$), the incentive to maintain a disposable part of wage labourers by capitalists is moderate due to the weak organizational capacities of the wage labourers ($\rho = 0.3$). This configuration leads to a high level of employment and a slightly fluctuating power of wage labour but—due to an undisturbed moderate growth of variable capital—to an increase in (per capita) wage related to performance. In terms of the value structure, this moderation regime brings about a slight increase in the rate of surplus value (after an initial declining phase) accompanied by an increase in the organic composition of capital—the constellation Marx had in mind as the general case of capitalist development (cf. part I, section 3.2) (cf. Fig. 1).

As regards the *circulation and reproduction* conditions, value adaptation (v-adapt, part I, section 4.2: Eqs. [15] and [16]) as well as allocative adaptation (a-adapt, part I, section 4.2: Eq. [28]) have to be taken into account. Furthermore, the loss of capital due to the negative impact of disproportionality between value components of different departments on growth is an important feature of capital's circulation and reproduction.

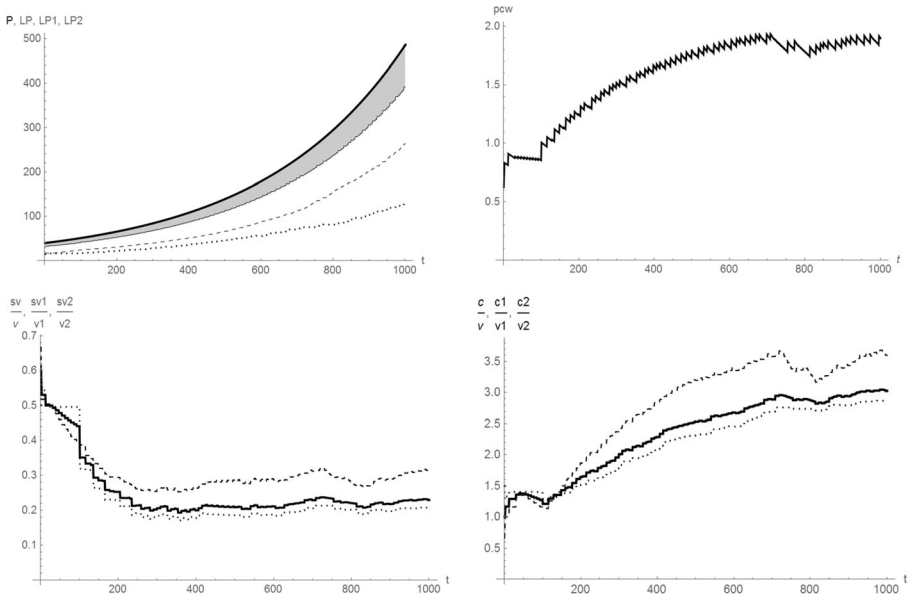


Fig. 1 Standard configuration. Production process, population (thick line), overall employment (thin line) and employment in both departments (dept. 1, dotted line and dept. 2, dashed line) vs time (first row, left); per capita performance wage vs time (first row, right); departmental (dotted line, dept. 1; dashed line, dept. 2) and general (thick line) rate of surplus value vs time (second row, left) and departmental (dotted line, dept. 1; dashed line, dept. 2) and general (thick line) organic composition vs time (second row, right)

This loss amounts to

$$KLoss_i(t) = (1-stag(t))K_i; i = 1, 2 \tag{1}$$

with

$$stag(t) = \begin{cases} \lambda_2, & \text{if } dp(t) > \lambda_1, \\ 1 & \text{else.} \end{cases} \tag{2}$$

The parameter for circulation costs and for money costs are set at a moderate level ($\lambda_3 = 0.3, \varphi = 0.005$). The same is true for the stagnation effect of disproportionality ($\lambda_2 = 0.998$). In accordance with the ongoing switch from phases with constant to changing value structures in both departments, the magnitude as well as the fluctuation of value adaptation is increasing in both departments (proportional to their relative size). For most of the time span on the one hand, the value adaption is in favour of department 2, i.e. it is tantamount to a revaluation of the *c*-components in department 2 and a devaluation of the *v*-components in department 1. On the other hand, the allocative adaptation runs the other way round: the remaining higher rate of profit in department 2 triggers a contraction (expansion) of the profit in department 2 (department 1) because the allocative adaptation in terms of equalizing the departmental profit rate is parametrized on a high level ($\xi = 1$). Due to the higher profit rate in department 2, there is an allocative tribute in favour of department 1 generating a higher rate of growth for department 1. Additionally, for most of the time for both departments, a

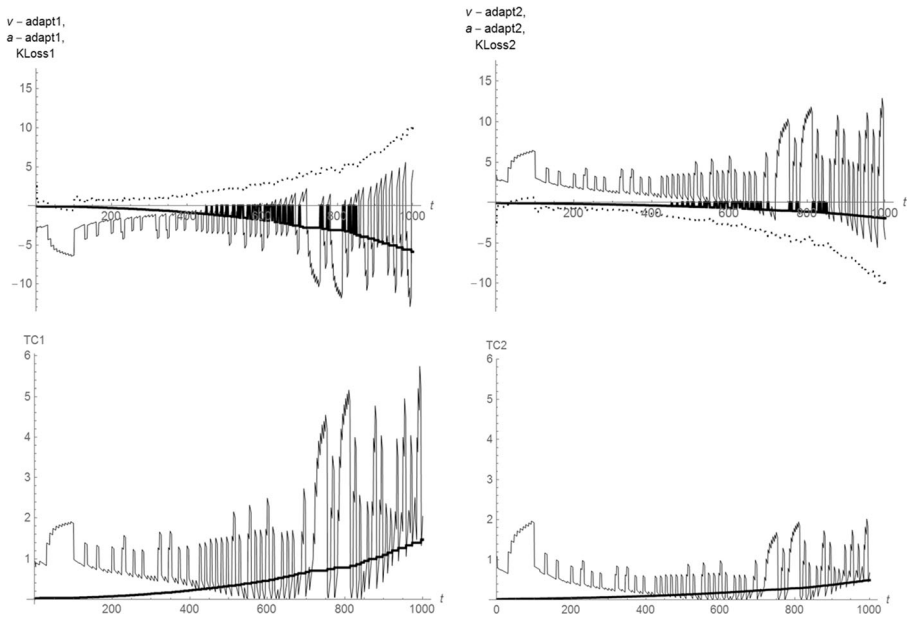


Fig. 2 Standard configuration. Reproduction process, value adaptation (thin line), allocative adaptation (dotted line) and capital loss (thick line) in department 1 vs time (upper row, left, positive numbers indicate revaluation, negative numbers indicate devaluation); value adaptation (thin line), allocative adaptation (dotted line) and capital loss in department 2 vs time (upper row, right, positive numbers indicate revaluation, negative numbers indicate devaluation); circulation costs (thin line) and money cost (thick line) in department 1 vs time (lower row, left); circulation costs (thin line) and money cost (thick line) in department 2 vs time (lower row, right)

capital loss occurs due to an amount of disproportionality overshooting the threshold (cf. Eqs. [1] and [2] above); this capital loss differs between departments according to their size. This disproportionality dynamic is also the driver for the commodity-related circulation costs (tcc) which vary in proportion to this disproportionality (dp). Contrary to that, the money-related circulation costs (tcm) are proportional to the growth of the aggregated departmental values (K) (cf. Fig. 2).

Looking finally at the *whole process*, the most important result is the falling rate of profit in both departments (being the result of quite different balancing procedures) and consequently for the economy as a whole. According to the assumed complete and symmetrical competition, the departmental profit rates are converging.³ Although for a large part of the time span, the overall results are in conformity with the Marxian hypothesis (increasing rsv, increasing oc and falling tendency of r), it can be shown that these conditions are rarely given in a single time step if the respective growth rates are taken into account.⁴ Rather, this impression of ‘Marx-conformity’ is an overall result of quite different successive constellations indicating a kind of cycle between constant and variable value structures (cf. part I, section 3.2). The dominance of the capitalist mode

³ The departmental profit rates do not coincide perfectly because it is assumed that the gross profit is the reference for competition excluding departmental circulation and money costs.

⁴ The growth rate for organic composition (oc), rate of surplus value (rsv) and profit rate (r) are defined as $\Delta oc(t) = \frac{oc(t+1) - oc(t)}{oc(t)}$, $\Delta rsv(t) = \frac{rsv(t+1) - rsv(t)}{rsv(t)}$, $\Delta r(t) = \frac{r(t+1) - r(t)}{r(t)}$, respectively.

of production, which can nevertheless be derived from this is an indicator of the social antagonism between wage labour and capital. This antagonism is directly visible when the trajectory of the performance wage-profit rate combinations is in focus: it manifests the inverse relationship between these two variables.⁵ A consequence of this capitalist mode of economic development is that the share of department I is increasing, and the growth of the gross value is high despite the limiting role of available population (cf. Fig. 3).

2.2 Sensitivity analysis

The main target variables for the sensitivity analysis selected here are the size of capital (K) and the profit rate (r), both of which summarize the overall process. The parameters taken into account from the production process (α , γ , β , ρ), from the reproduction process (λ_3) and from the overall allocation process (ξ) are affecting the *growth of capital* (K) in a different manner. An increase of α is c.p. tantamount to a decreasing $w(t)$ (cf. part I, section 4.2; Eq. [9] and Fig. 1), which favours a capital structure with a higher relative importance of wage labourers for accumulation. Although the barrier of available wage labourers has an increasing effect on accumulation and limits the growth of capital, for higher levels of α this is overcompensated by its positive effect on the growth of surplus value, a large part of which is invested in additional constant capital resulting in an overall higher growth (cf. Fig. 4, upper row, left). The same positive effect on capital's growth can be observed if γ is increasing (cf. Fig. 4, upper row, middle). Increasing β means increasing the relative importance of (additional) constant capital and c.p. postponing the labour power restriction for accumulation. Hence, a higher level of accumulation is possible (cf. Fig. 4, upper row, right). The influence of a higher ρ is also straightforward: the increased bias in favour of a buffer of available wage labourers (ρ) fosters the negative impact of the available population of wage labourers on accumulation and capital's growth directly (cf. Fig. 4, lower row, left). Contrary to that, the growth of allocative value adaptation (ξ) due to an assumed increase of competition between industrial departments seems to be almost neutral with respect to K . This can be explained by the inversely related impact on accumulation by reproductive adaptation on the one hand and allocative adaptation on the other hand. For low ξ , reproductive adaptation is high, while allocative adaptation is low; and for high ξ , it is just the other way around (cf. Fig. 4, lower row, middle). Finally, λ_3 is a direct restriction of accumulation; the higher it is, the lower the K (cf. Fig. 4, lower row, right).

Corresponding to the influence on accumulation and growth is the influence of the chosen parameters on the *profit rate* (r). An increase of α lowers the power of wage labour ($w(t)$) and therefore the incentive to substitute labour power as an element of production. Hence, the level of the profit rate is increasing and its tendency to fall is lessened with higher α (cf. Fig. 5, upper row, left). The same is true for an increase of γ , because it is positively related to the growth of surplus value (cf. Fig. 5, upper row, middle). Contrary to that, the level of β is negatively related to r , because it weights the

⁵ It should be noted that there is an essential difference to a neo-Ricardian w - r relation: the relation at stake here is a function of time that can include quite different phases, not all of which have the property of an inverse relationship.

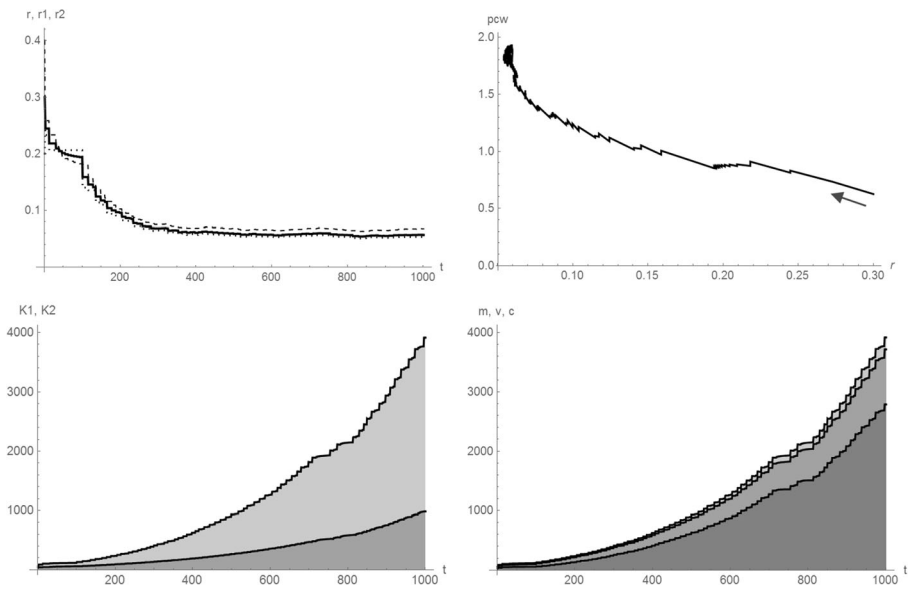


Fig. 3 Standard configuration. Overall process, departmental (dashed line, dept. 2; dotted line, dept. 1) and general (thick line) profit rate vs time (first row, left); trajectory for performance wage vs profit rate (first row, right); cumulative diagram of industrial departments over time (lower row, left) and cumulative diagram of value components over time (lower row, right)

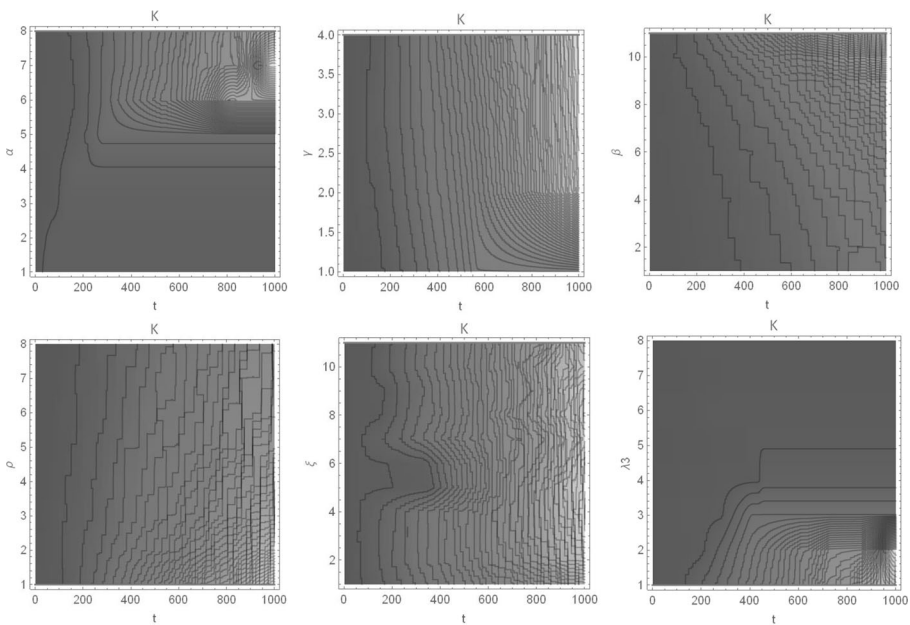


Fig. 4 Contour diagram of total capital over time for varying α , γ and β (upper row) and ρ , ξ and λ_3 (lower row). The lighter the colour, the higher the magnitude. For the range of parameter variation, cf. second column of Table 1

influence of the power of wage labour on accumulation. If accumulation is high, the incentive to increase the share of constant capital is increasing and r will c.p. fall (cf. Fig. 5, upper row, right). Inversely to that, an increase of ρ increasingly limits the power of wage labour and through this blocks the main driver for pursuing the capitalist mode of production, which lets the profit rate increase and weakens its fall (cf. Fig. 5, lower row, left). If the influence of departmental competition on realized profits (i.e. ξ) is higher, this is tantamount to a growing importance of the revaluation in favour of the department with higher organic composition (and a lower rate of surplus value). That means that the capital structures generating a falling rate of profit are strengthened (cf. Fig. 5, lower row, middle).⁶ Finally, the weight for the cost of reproductive adaptation (λ_3) generally has a negative influence on r , although the time span in which this becomes effective may vary for different levels of this parameter (cf. Fig. 5, lower row, right). For all these parameters, their increase brings about an increasing volatility in the profit rate path. The tendential decline of profit rate is interrupted by smaller time spans during which it increases slightly, indicating a rudimentary form of an industrial cycle. This cycle is due to longer periods of reproduction without accumulation imposed by the labour power constraint (corresponding to the characterization of the accumulation process Marx presented in vol. I of ‘Das Kapital’; cf. MEGA II/6, p. 561).

3 Social conflict regime

One of the essential features of this Marxian approach is the role of the relation between different classes, i.e. the social group that is able to dispose of the means of production (as well as money) vs the social group that is constrained to find an employer and to perform according to the obligations defined by these employers. This relation is conflict-laden and can unfold in different ways in the course of time. When this conflict becomes manifest, the dynamics of the monetary value aggregates will be influenced by a parameter constellation, which depicts such a situation at least to some degree. First of all, it is assumed that the power of wage labour is high due to strong organizational ties (high α). This corresponds to a more limited possibility for the capitalists to organize the work performance in such a way that the increase of surplus value is high (low γ). On the other side, the capitalists are averse to employing additional wage labourers and thus exhaust all options for substituting ‘non-living’ means of production for labourers as long as the power of wage labour ($w(t)$) remains high. Furthermore, for investment, the proviso exists to maintain a high disposable mass of unemployed labourers (high ρ). Finally, the dominance of the social antagonism in each industrial department relativizes the interdepartmental competition for an equalized profit rate (low ξ).

In such a regime, two phases can be distinguished (cf. Fig. 6): in the *first* phase, the limitations for increasing the surplus value in combination with the strategic filter against increasing employment leads to a contraction of surplus value, because a larger part of it is absorbed by the costs of reproductive value adaptation. This

⁶ The degree of competition (as expressed by ξ) is not crucial for the tendency of the rate of profit to fall as such but rather for the degree to which this occurs. This is a result that is essentially different from that reported by Shaikh (2016, p. 261).

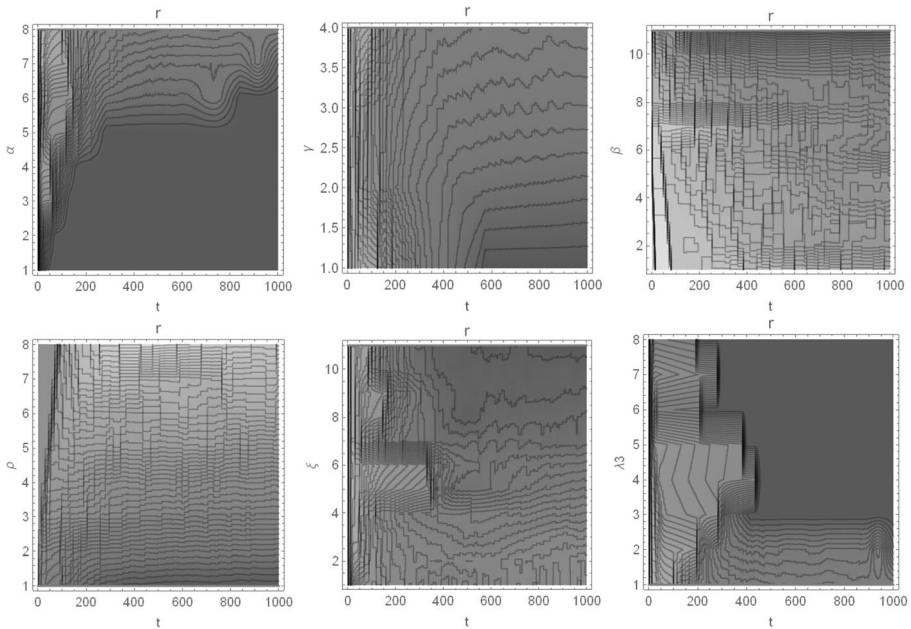


Fig. 5 Contour diagram of profit rate over time for varying α , γ and β (upper row) and ρ , ξ and λ_3 (lower row). The lighter the colour, the higher the magnitude. For the range of parameter variation, cf. second column of Table 2

dampens economic growth and generates a rapid fall of the profit rates, although these profit rates are initially higher than in the standard case due to the absence of allocative revaluation (cf. Section 2). In the *second* phase, the surplus value (and therefore the profit rate) is zero. Hence, there is no growth anymore and the value structure remains constant. Now unemployment is increasing exponentially. This runs counter to the initially assumed high organizational power of the wage labour class and erodes its ability to receive a higher performance wage. In this second phase, the trade-off of performance wage and profit rate is situated lower than in the standard case. Such stagnation would continue as long as the assumed parameter constellation persists.⁷ It can be concluded that an attempt to increase the control of wage labourers in production and to increase their income share is in the long run successful only under the constraint that the surplus value as well as the profit rate are diminishing. If they are zero, unemployment is increasing rapidly and the power of wage labour erodes. Hence, opportunities to improve the relative position of wage labourers in an antagonistic fashion are rather limited under the given systemic condition.⁸

⁷ It seems reasonable to assume that the increasing unemployment will undermine the strong organizational capacities of the wage labourers (α should rise), opening up new possibilities of profitable production.

⁸ Of course, this rather pessimistic vision has to be relativised if the high level of organizational capacity (high α) is not coupled to a capability to limit the production of surplus value (high instead of low level of γ). This may be the outcome of an institutional element in wage determination.

4 Crisis regime

Different views on crisis can be found in the manuscripts of Marx. Their common denominator is to understand ‘crisis’ as a dramatic form of the lower turning point or time span of the industrial cycle that is normally composed of phases with steady state stagnation and growth with structural change.⁹ Marx mainly linked three features of the capitalist mode of production with the occurrence of such a crisis and of the industrial cycle: (i) the ‘overaccumulation’ in which the experienced profit rate is too low for continuing the accumulation (cf. e.g. MEGA II/4.2, p. 325), (ii) the ‘disproportion’ between the value components of the leading industries (cf. e.g. MEGA II/4.2, p. 331) and (iii) the ‘underconsumption’ in terms of an erosion of demand derived from income not destined for accumulation of capital (mainly the wages) (cf. e.g. MEGA II/4.2, p. 540).¹⁰ Due to the unfinished nature of the Marx’s manuscripts, none of these links has been elaborated in depth (let alone formulated in quantitative terms) by him. In contrast to that, in the present attempt to synthesize and to reformulate the essentials of capitalist production and circulation, at least some of the ideas of Marx about crisis and industrial cycle can be specified (and quantified).¹¹

The core idea behind ‘overaccumulation’ is that a general or departmental minimum rate of profit (r^*) can be determined below which accumulation comes to a halt (or at least is drastically reduced):

$$\text{adc}_i(t) = \begin{cases} 0, & \text{if } r_i(t) \leq r^*(t) \\ \text{adc}_i(t) & \text{else,} \end{cases} \quad (3)$$

$$\text{adv}_i(t) = \begin{cases} 0, & \text{if } r_i(t) \leq r^*(t) \\ \text{adv}_i(t) & \text{else} \end{cases} \quad (4)$$

Furthermore, in the case of $r \leq r^*$, a part τ of the surplus value will be hoarded (i.e. kept in ‘liquid’ money form) either for cautionary or speculative reasons (cf. similar ideas of Keynes 1974/1936). Beyond a minimum of cash required for transactions (h^*), this hoarded money will be invested at rate r in later time steps where $r > r^*$ will hold again. Equations [3] and [4] are modified accordingly.

$$h_i(t) = \begin{cases} \tau \text{sv}_i(t), & \text{if } r_i(t) > r^*(t) \wedge \text{if } h_i(t) > h_i^*(t); 0 < \tau < 1 \\ 0 & \text{else,} \end{cases} \quad (5)$$

⁹ Even if—according to Marx—the crisis is a possibility or potential on all levels of his conceptual elaboration (cf. Clarke 1994), its acute manifestation seems to be bound to specific trigger conditions. Therefore, crisis in that sense is dealt with here as a specific regime.

¹⁰ In a way, the social conflict regime (cf. section 5.2) is another variant of crisis, the socio-politically induced ‘profit squeeze’ (cf. Glyn and Sutcliffe, 1972). To analyse the role of the financial sector as an originator and promoter of crisis and industrial cycles is beyond the scope of this elaboration.

¹¹ The case of ‘under-consumption’ requires a ‘deeper analysis of demand and supply’ (MEGA II/4.2, p. 269), especially of the reproduction of wage labourers and secondary income earners, which is beyond the scope of Marx’s analysis (and of this elaboration).

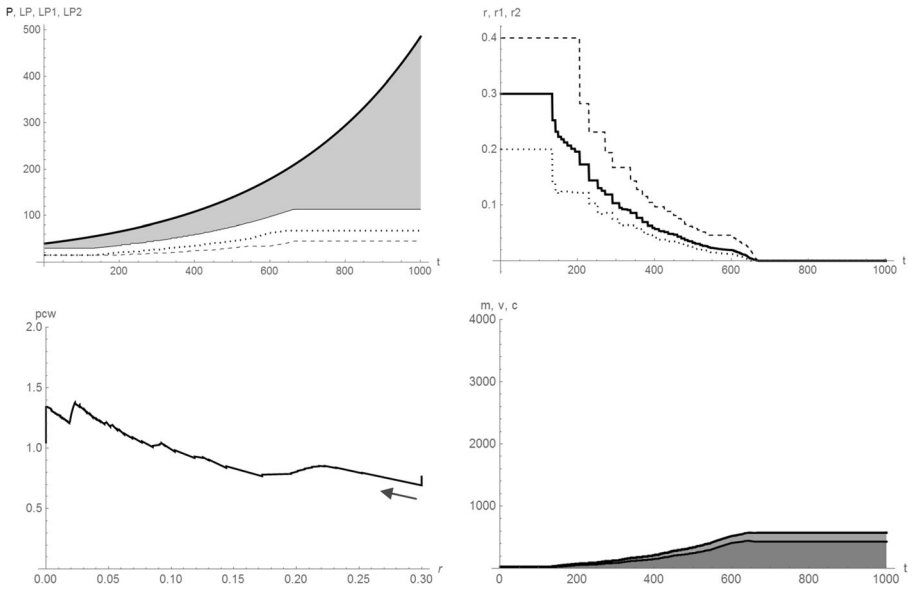


Fig. 6 Conflict regime. Population (thick line) and employed labourers (dotted line, dept. 1; dashed line, dept. 2) vs time with shaded unemployment area (first row, left), departmental (dotted line, dept. 1; dashed line, dept. 2) and general (thick line) profit rates vs time (first row, right), performance wage vs profit rate trajectory (second row, left) and cumulated diagram for growth of value component vs time (second row, right)

$$\text{adv}_i(t) = \begin{cases} 0, & \text{if } r_i(t) \leq r^*(t) \\ w(t) \left(m_i(t) + \Delta m_i(t) + (h_i(t) - h_i^*(t)); 0 \leq \theta \leq 1 \right) & \text{else,} \end{cases} \tag{6}$$

$$\text{adv}_i(t) = \begin{cases} 0, & \text{if } r_i(t) \leq r^*(t) \\ (1-w(t)) \left(m_i(t) + \Delta m_i(t) + (h_i(t) - h_i^*(t)); 0 \leq \theta \leq 1 \right) & \text{else.} \end{cases} \tag{7}$$

From this, it is obvious that the depressing effect of overaccumulation increases as r^* and τ increase. Furthermore, it has to be taken into account to what degree r_1 and r_2 are aligned (determined by the parameter ξ); if these departmental profit rates differ significantly, a general minimal rate is not directly effective for the whole economy. In any case, the chain of effects is straight forward: in the time step following the realization of the $r^* < r_i$ condition, on the one hand a stepwise reduction of sv_i occurs (due to the interruption of accumulation and the consequential hoarding), and on the other hand, Δsv is reduced due to the decline of the surplus value. This is a constraint for the devaluation of both c and v (cf. Eqs. [6] and [7]). Hence, although accumulation has stopped, the value of these capital elements increases in the first phase of the crisis.

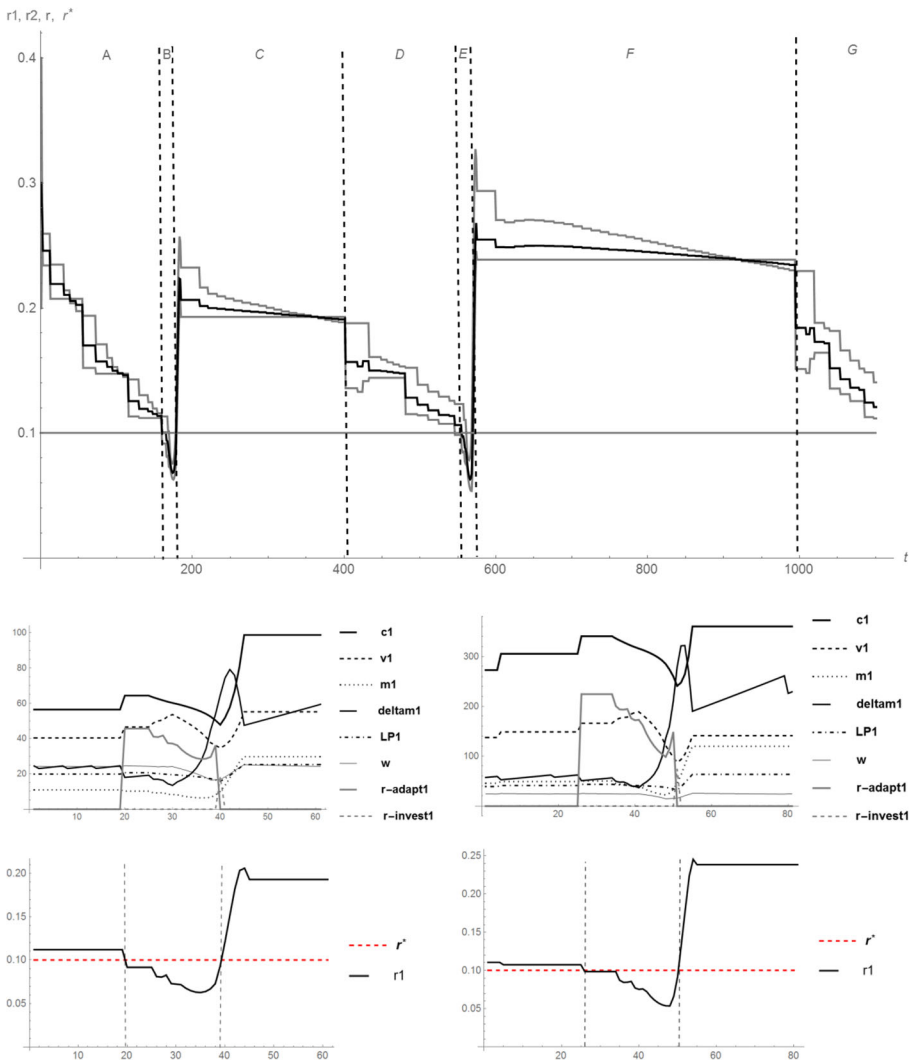


Fig. 7 Profit rate cycle vs time in the case of overaccumulation ($r^* = 0.1$): depression (A), crisis (B), prosperity (C), depression (D), crisis (E), prosperity (F), depression (G) (first row, black line, general profit rate; lower grey line, dept. 1; upper grey line, dept. 2); detail analysis of overaccumulation crisis B ($160 < t < 180$) and E ($545 < t < 570$) in department I for selected variables (w , $\Delta sv1$, $r\text{-adapt}1$, $r\text{-invest}1$ being multiplied by factor 30 for visibility reasons) vs time (second row) and resulting profit rate vs time (third row)

This is overcompensated in the second phase when Δsv (and with a time lag also sv) is increasing due to a reduction in w and the absence of accumulation is accompanied by higher devaluation of c and v . The overall effect then is a recovery of the profit rate. If it passes the minimum rate from below, the high level of Δsv , the curtailment of hoarding ($r\text{-adapt}$: $h(t)$) and its partial transformation into additional investment ($r\text{-invest}$: $(h(t) - h^*(t))$) collectively foster a jump of all crucial variables (c , v , sv , LP), establishing a phase of prosperity with almost constant profit rates before its decline occurs again (cf. Fig. 7 exemplarily for industrial department I).

The core idea behind ‘disproportion’ is a violation of inter-industrial reproduction requirements that has drastic negative spill-over effects for the whole economy. In the stylized representation of inter-industrial dependencies in terms of two industrial departments, this disproportion can be specified as the generation of a large divergence between the aggregated value components whose congruence is necessary for reproducing the value structure as a whole.¹² Two issues are involved in such an explanation, i.e. firstly, the value components and their possible divergence and secondly, the spill-over effect for the economy as a whole. The first part of this explanation has already been dealt with in section 4.2 of part I (cf. Eqs. [15], [16] and [17]) and boils down to a depiction of the possible divergence of the relevant value components in absolute terms over time. Due to the lack of further specification of inter-industrial relations, the second part of the explanation—the amount of spill-over of possible disproportions—is depicted as an additional circulation cost¹³ to be subtracted from the surplus value in both departments (cf. Eqs. [20] and [26] in section 4.2 of part I).

This disproportionality effect increases, the higher λ_3 , the higher the share of the department under consideration, and the higher dp happen to be, given the amount of surplus value (cf. Eq. [17] in section 4.2 of part I). For a high level of λ_3 , the surplus value and therefore the profit rate are instantly decreasing to almost zero for a long time span (depression phase) until the surplus value is slightly increasing due to a growing Δsv (with all its elements, $\frac{1-w}{w}$, $\frac{m}{v}$ and $LP1$ increasing) (prosperity phase). The turning point (beginning of crisis) is given when increased employment lessens $\frac{1-w}{w}$ as well as $\frac{m}{v}$. The resulting decrease in Δsv is accompanied by an increase in repro-adapt (i.e. the circulation costs induced by the disproportion: tcc ; cf. Eq. [26] in section 4.2 of part I) due to a rise of the organic composition of capital. Hence, the surplus value is absorbed by larger circulation costs and falls to almost zero again.¹⁴ The same is true for the profit rate (decline of sv and increasing organic composition of capital). Then, the phase of depression is starting again (cf. Fig. 8 exemplarily for industrial department I).

Given these idealized cases for crisis, it can be shown how they unfold over time in a different manner and in what sense these cases are different to the moderation scenario (cf. Fig. 9 exemplarily for the $w-r$ trajectory). With this analysis, it is demonstrated that the features Marx mentioned as possible triggers of crisis can indeed be specified in such a way that the normal mode of capitalist development (consisting of a sequence of phases with and without structural change in upward and downward direction) is transformed into a cyclical movement repeated in a more or less similar manner.¹⁵

¹² Possible physical constraints for the economic reproduction are beyond the scope of the value analysis presented here.

¹³ This circulation cost may be the result of a longer duration of circulation, of increasing inventories and of additional money holdings.

¹⁴ The relationship between circulation costs induced by industrial disproportion at this magnitude and surplus value seems to be similar to a predator/prey relationship. Considering the wage-profit rate relationship (cf. Fig. 9) as well as the employment rate-wage rate relationship, this is in conformity with Goodwin’s model of the growth cycle (cf. Goodwin 1973; Laibman 1987/1988), although the simulation model presented here is much more differentiated.

¹⁵ This repetition is not emphatically true because the long-term tendencies of capitalist production and circulation are overlapping these mid-term patterns.

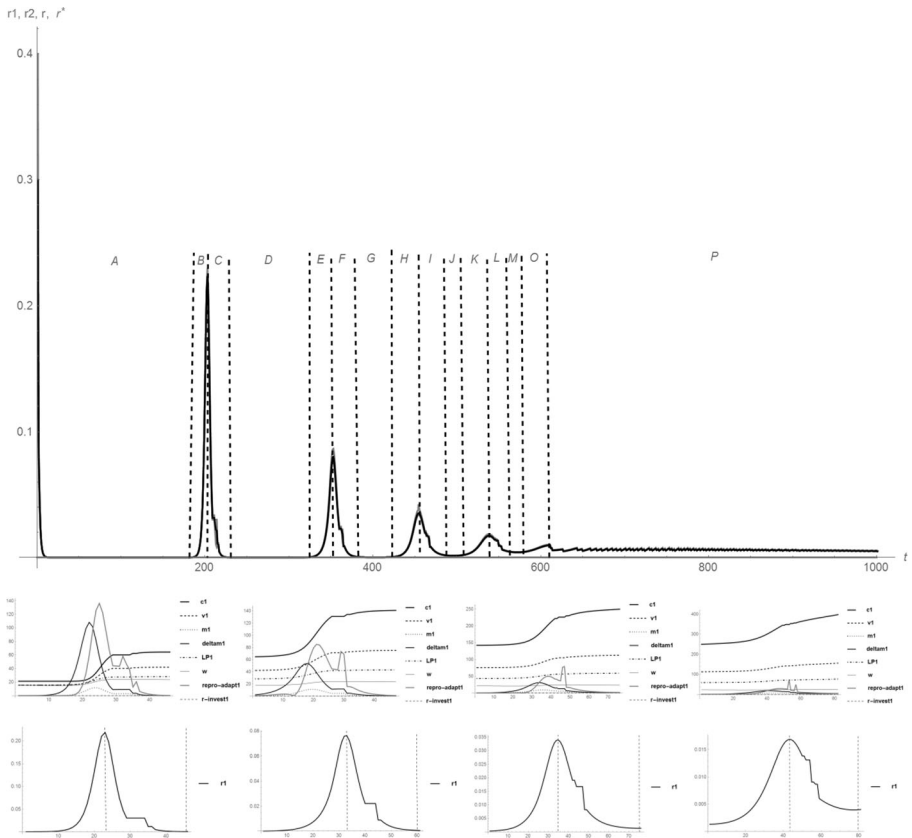


Fig. 8 Profit rate cycle over time in the case of disproportion: depression (A), prosperity (B), crisis (C), depression (D), prosperity (E), crisis (F), depression (G), prosperity (H), crisis (I), depression (J), prosperity (K), crisis (L) depression (M), prosperity (O) (first row); detail analysis of disproportion crisis C (180 < t < 245), F (320 < t < 380), I (420 < t < 495) and L (496 < t < 577) in department I for selected variables (w, Δm1, repro-adapt1 being multiplied by factor 30 for visibility reasons) vs time and resulting profit rate vs time (second and third row)

Due to the level of abstraction of this elaboration, this can be done only in a rather ‘mechanical’ (i.e. parametrized) fashion without explaining how the constellations depicted in terms of critical parameter values are generated by interacting economic agents. Hence, how these triggers for crisis occur in the course of time (in an isolated or combined fashion) requires a more disaggregated or even historical analysis.

5 Insights from the simulation model

The simulations show that the concepts put forward by Marx in his different manuscripts can at least partly be conceptually synthesized in such a way that the basic features of capitalist development are amenable for quantitative analysis. This implies a disaggregation into the main industrial departments. Their proportion is non-linear in the long run and fluctuating in the short run (even if the profit rates are assumed to

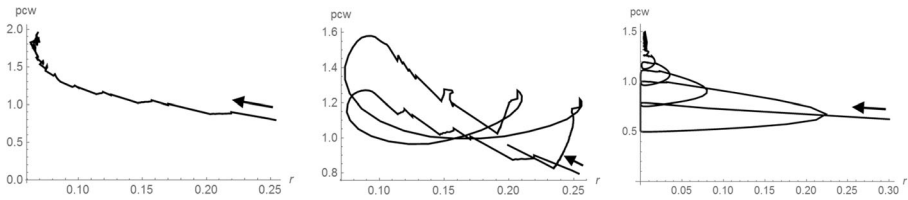


Fig. 9 Performance wage vs profit rate trajectory: moderation (left), overaccumulation crisis (middle), disproportion crisis (right)

converge). This development is determined by the interplay of labour population dynamics and a change of value structure in production as well as of circulation cost. In each of the industrial departments, it results in a succession of simple and expanded reproduction. Furthermore, depending on the calibration of externally determined parameters, different paths of economic development can be distinguished, and by linking these parameters, the state space for the variables can be further reduced to portray historical specificities in terms of regime. Hence, the different paths of endogenously determined $\frac{occ_1}{occ_2}$, $\frac{rsv_1}{rsv_2}$, $\frac{r_1}{r_2}$ and $\frac{K_1}{K_2}$ as well as occ , rsv , r and K can be classified as emergent properties because they cannot be derived from the initial conditions and the transformation rules in an analytical fashion.¹⁶

On the level of the economy as a whole, ‘unbalanced growth’ rather than ‘balanced growth’ is the rule in that the relation of industrial departments is changing over time.¹⁷ This is due to differences in organic composition, rate of surplus value and rate of profit, which do not compensate each other as regards the relative growth of departments. Apart from that, the rate of growth in each department is not the same as the rate of profit, although it is assumed that all surplus value is accumulated. The reasons for that are (i) the accumulation is conditional on the availability of additional labourers (as long as $w < 1$) and (ii) the notional difference between $r = \frac{\Delta c + \Delta v}{c + v}$ and $g = \frac{\Delta c + \Delta v}{c + v + m}$. Hence, the dynamic trade-off between profit rate and growth rate is different from the post-Keynesian static vision about the ‘expansion frontier’ (cf. e.g. Lavoie 2014, p. 141): generally a lot of jumps occur in growth (upwards and downwards) and the tendency is towards a simultaneous decline in profit rate and growth rate (cf. Fig. 10).

Furthermore, the assertions Marx made about the features of long run economic development can be confirmed to a certain degree. In a strict sense, this confirmation is bound to a specific—but reasonable—parameter constellation (i.e. the moderation regime; cf. section 2), and it has to be taken into account that this long run verification is a result of quite different successive singular situations. For a much wider range of parameter constellations, a part of the Marxian assertions can be supported in such a way that development paths can be generated in which the overall result conforms to Marx’s prognosis but the interdependencies of variables is more intricate and therefore different from what Marx had in mind.

¹⁶ Such a kind of modelling is markedly different from the usual conceptualization of macro-dynamics (cf. Okishio 1992 for an overview).

¹⁷ Balanced growth is endogenously generated if in both departments accumulation is blocked by insufficient supply of labourers.

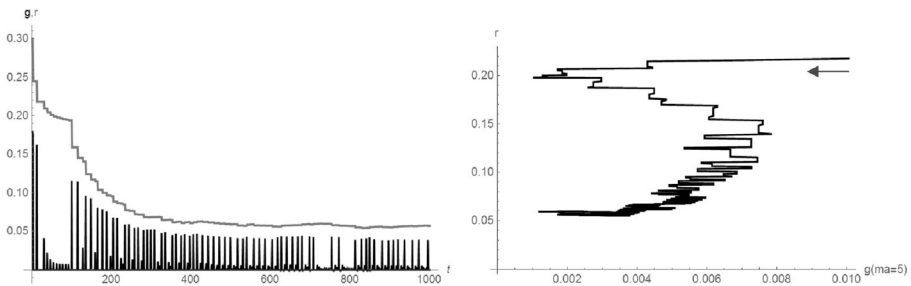


Fig. 10 Profit rate (grey line) and growth rate (black line) in the moderate regime vs time (left) trajectory depicting their dynamic trade-off for a moving average over 5 time steps (right)

Asserting a tendency of the profit rate to fall is reasonable for most cases. Due to the limiting influence of the available labour population on capital's accumulation, the main driver for this declining tendency of the profit rate is the 'capitalist mode of production' in connection with the rising organic composition of capital. But taking the proposed systemic interdependencies into account, this is not sufficient for increasing the rate of surplus value as Marx seems to suppose. Not only the relative growth of capital and of the labour population is of importance here, but also the conditions of reproduction and allocation, which may have a counteracting influence. Hence, the organic composition of capital and the rate of surplus value are linked in a complicated fashion and the outcome of this systemic process over time often diverges from the constellation Marx had in mind.

Nevertheless, the simulations show how the divergence between accumulation requirements and growth of the labour population gives the capitalist mode of production a central importance in realizing a growth in capital that is as high as possible, as well as moderating the class conflict, derived from this and other circumstances (such as the organizational power of the wage labourers).

Finally, the parametric openness of the suggested system configuration allows for figuring out different regimes of capitalist development. The stylized separation of different regimes is only a first step for classifying historical contingencies. A subsequent step (which is beyond the scope of this elaboration) would be a combination of regimes as might occur in different countries at the same time as well as their succession (regime switch) in a given country. This is another dimension of the evolutionary nature of capitalist development. In such a context, a change of parameter constellations can be related to the emergence of institutions: (i) The correlation between α and γ can be weakened (or even abolished) by social policy which can be derived from the precarious nature of wage labour. Such a policy allows for a high level of organization (low α) and a rather undisturbed generation of surplus value (high γ) at the same time. (ii) If the modern organization of monetary activities (by banks and financial institutions) is taken into account, the relevance of λ_i and φ may vary in a time-dependent fashion (according to the credit cycle and financial bubbles). (iii) Finally, ξ may diverge in different countries according to different historical conditions and market policy orientations.

6 Conclusions and further research requirements

Against the background of the deficits of the Marxian project in delivering a comprehensive theoretical explanation of the core features of the capitalist process (which have become especially evident with the new MEGA publications), the aim of this paper has been to show that a ‘modern’ reconstruction does not necessarily have to compromise its distinction from mainstream concepts. Beyond Marxist dogmatism (seeing no need for any revision of the Marxian assertions) on the one hand and mainstream-oriented constructivism (revising all Marxian assertions from the perspective of a preferred and imposed modern model construction) on the other hand, an attempt has been made to reformulate the concept of value, in such a way that the core features of the capitalist process (like thingification and reification of social relations, social exploitation, growth driving accumulation, out-of-equilibrium reproduction and market-form-based profit allocation) can be dealt with and synthesized to a specific view of economic evolution.

Compared with the Marxian concept (however unfinished this may be), two major revisions are implied in such an attempt¹⁸: Firstly, there is no need for a labour (embodied) theory of value—not because there is this phantasmagoria known as the ‘transformation problem’, but because such a theory contradicts the recursive nature of value (rudimentarily proposed by Marx himself) and blocks the possibility of explaining conflict-laden elements like wage and money. Secondly, the present effort abstains from hypostatizing an over-historic (universal) system of used values against which values can be contrasted as the specific historical dimension. The reason for this is that such a ‘universal’ system is itself shaped and changed by the value structures (which Marx himself concedes) and that it is not accessible from the aggregated value perspective due to its inherent heterogeneity.¹⁹ Both revisions stress the social science nature of the targeted value concept and hopefully disentangle it from any natural science flavour (suggesting some kind of ‘materialist’ or even physical objectivity). Hence, neither a total refutation of Marxian value theory nor its total corroboration is intended.

Picking up the initial remark on the peculiarities of the modern discourse in economics and its domination by mainstream concepts and model constructions, there may be a twofold importance of such a ‘modernized’ Marxian economics for the heterodox side streams, i.e. to enhance and reshape both heterodox macroeconomics and evolutionary economics.

In (heterodox) macroeconomics, Marx’s economic writings have up to now not really been assessed as regards their possible contribution and have played only a minor role in figuring out a more heterodox macroeconomics (cf. e.g. Lavoie 2014, Colander 2006, Dow 1996, Snowden et al. 1994 and Shaikh 2016 as exceptions). Apart from the fragmented form in which the original writings of Marx nowadays exist, the main reason may be that Marx’s approach runs counter to the usual way of (old) macroeconomic thinking, in that it does not

¹⁸ Minor revisions are the explicit account for the power of wage labour and reproductive as well as allocative value adaptation.

¹⁹ Therefore, notions like ‘technical composition of capital’, ‘real wage’ and ‘productivity’ can be operationalised only under very restrictive conditions.

superimpose equilibrium (i.e. social coherence) conditions upon economic activities ‘from above’ and does not define *ex ante* conditions for this equilibrium.²⁰ Instead, Marx tries to show that these aggregates are indeed regulating individual behaviour. In that sense, this kind of macroeconomics is less prone to be lacking a micro-foundation.²¹ From Marx’s perspective, macroeconomic aggregates should not be read as fictitious abstractions (serving as a playground for algebraic manipulation) but rather as ontological entities that are the result of a specific historical form of economic interaction. Correspondingly, the contribution of a modernized Marxian concept is mainly orientated to the ‘supply side’ but nonetheless is endogenously dynamic and not confined only to explaining income and its decomposition. Furthermore, adaptation as a procedure to tackle out-of-equilibrium situations is an integral part of this type of supply side analysis. Considering the other way around, this is tantamount to a lack of demand analysis in Marx. How reproduction requirements are transformed into market processes and in which way money in its different roles can intervene here on the side of firms and private consumers (which is the perspective of Keynes (1974/1936) is beyond the scope of his analysis. Nevertheless, the strategic research option to link production and reproduction dynamics with market dynamics (cf. Benetti et al. 2014, 2015) seems to be accessible.

According to the perspective sketched in part I, section 2.2, the other main contribution of a ‘modernized’ Marxian approach can be expected for evolutionary economics. The combination of deterministic and contingent elements in modernized Marxian explanations as well as the multi-level property for distinguishing macro (the economy as a whole), meso (departments and branches of the economy) and micro (single firms) phenomena found in this approach are in agreement with the approach of evolutionary economics. Core features of a mode of production, its varieties and changing institutional boundary conditions are all of central importance.²² This determinacy vs contingency distinction can be approached by stylizing different regimes (and a switching process between them) for the operative core features. Apart from this theoretical architecture, the difference (and hence possible enrichment) for evolutionary economics is provided by assuming that on each of these levels,

²⁰ Keynes as an exception is vulgarised, reintegrated and overcome in the course of time.

²¹ Accordingly, there is an essential methodological difference between conceptualizing agents as a personification of social conditions being complementary to their reification (cf. MEGA II/6, pp. 67, 114, 138, 171, 179, 239, 543, 839, 847, 897; Rubin 2008, pp. 22, 25, 59) on the one hand and stylizing representative agents in modern macroeconomics on the other hand. Apart from that, firms as important microeconomic entities are dealt with as exploring and routinizing organization strategies for surplus generation.

²² ‘Thus, through a chain of reciprocal relations of cause and effect, the social and technological stimuli that sustain long-term economic motion appear themselves as the product of economic growth, and an all-inclusive theory of socioeconomic evolution emerges...’ (Lowe 1976, p. 9). Lowe contrasts this (deterministic) all inclusive nature that is attributed to the theory of Marx with the indeterminateness resulting from using elements which cannot be produced within the depicted system, such as natural resources (ibid. p. 224). The present elaboration should have shown that this is not entirely correct: labour is linked to an external restriction in terms of available labourers (which cannot be produced by commodities), and as such it is a source of social tension and conflict due to the surplus generating role of labour and its boundedness to human individuals. Hence, it can be taken as a *pars pro toto* for the open nature of the theoretical system under consideration. How the resulting conflict between commodification and regulation of the quasi-commodities (like ‘labour power’ but also money) shapes the evolution in terms of a developing ‘social policy’ or ‘money policy’ is beyond the scope of this elaboration.

social contradictions are the drivers for dynamic developments (indicated on the macro level by the tendential fall of the profit rate, on the meso level by departmental disproportionalities and contested income allocation, and finally on the micro level by the influence of the power of wage labourers within the firm). These contradictions are moderated (not solved) in different fashions (depending on historical specificities). Correspondingly, the focus is not on the figure of the individual curious entrepreneur and his or her impact on the meso and macro level of the economy. Rather, the social embeddedness of this activity in class relations and competition rivalry is emphasized, thus opening the perspective towards explaining an economic growth ‘machine’. In that context, ‘technical change’ is mainly understood as a way for capitalist firms to tackle the class conflict by implementing a specific mode of production and organizing surplus value generating synergies. Conventional calculation devices function as a reification and subordination procedure for economic activities guiding the search for profit rate differentials and arbitrage opportunities. In that sense, the transformation of the economy as a whole (on its different interdependent levels) becomes the centrepiece of such a non-Darwinian explanation of evolution rather than isolated instances of novelty creation.

The approach suggested here is an attempt to link quantitative analysis with the sensitivity for social form aspects that is found in value theory (originated in the work of Rubin (2008) and Petry (1916) and promoted in the post-68 reading of Marx’s ‘Das Kapital’ especially in West-Germany; cf. Reichelt (1970); Backhaus (2011)). The preliminary nature of this endeavour can best be documented by referring to its limits and the corresponding further research requirements. These limits are twofold, i.e. limits in depth and limits in scope.²³

The in-depth specification of the simulation model can be improved firstly as regards the activated portfolio of surplus generating procedures (cf. section 3.1 and section 4.2, Eq. [1]); this may include a relativisation of the inverse proportional relationship between a change of v and sv , respectively. Against this background, it may be possible to depict the influence of the power of the wage labourers on the extracting procedures of surplus value more precisely. Secondly, fixed capital should be integrated in the model which implies a modification of the department structure in such a way that there are sub-departments for the elements of fixed capital and for the elements of circulating capital. This does not necessarily entail following the von Neumann path in the model setting (as e.g. Morishima (1973, 166) proposes and ending up with a neoclassical optimization procedure for a centralized planner (ibid., p. 184)). This modelling of fixed capital not only contradicts the usual calculation rules of capitalist firms, the social subordination role of the fixed capital within production (being of central importance, e.g. for intensifying the labour performance) can also not be dealt with if it is calculated as an output commodity.²⁴ Thirdly, an in-depth improvement would involve taking the different forms of

²³ Only limits of the simulation model will be discussed in the following. Elaborating the pros and cons of the textual interpretation is beyond the scope of the present article.

²⁴ Apart from that, it can be asked why is not ‘labour’ treated in the same fashion. The labourer is not simply a commodity bundle but is entering and leaving the production process as a person (though in different quality). For a criticism of this von Neumann vision cf. Mirowski (1988, p. 181) and Cutler et al. (1978, p. 225).

capital that occur in its circulation explicitly into account. Linked to that is the need to specify the time structure of the model and to take into account a possible role for additional demand from outside (picking up the Luxemburg-problem) (cf. Foley 1982, Basu 2014 and Duménil and Lévy 2012 for attempts in this direction). Combined with the integration of fixed capital, this necessitates the specifications of stocks and flows in terms of commodity capital, money capital and inventories. Finally, fourthly, the problem of assuming a given maximal rate of accumulation ($\frac{\Delta c + \Delta v}{sv} = 1$) is at stake here: can it be reasonably determined more precisely on an aggregated level?²⁵ It seems plausible to assume that the most important determinants for the rate of accumulation such as firm strategies, market situation, equipment modernization, equity accounting and financial opportunity costs require a more disaggregated level of analysis. On the aggregated level, only the conditions of the ‘market’ for wage labour seems to be of primary importance.

The limits of scope inherent in the proposed simulation model can be characterized in (at least) four directions. The *first direction* is to take into account the monetary and financial elements of the capitalist process. According to the stepwise recursive nature of explanation within value theory as proposed here, only elementary monetary features (money as a quasi-commodity) have been part of the analysis. Hence, there is a need to specify the working of this elementary monetary system as a whole. Based on that, advanced monetary systems with credit relations (within industrial capitalists and between capitalists and banks) have to be integrated (cf. MEGA II/4.2, p. 411, MEGA II/14, p. 230).²⁶ Finally, the modern financial sector with its new institutions and types of activities is targeted by this direction for enhancing the scope of research. The *second direction* is to analyse the use of non-reproducible elements in production, and the way they modify the sphere where commodities are produced by means of commodities. This study has shown that labour is such an element. Marx’s own research in this direction is mainly focussed on the economic use of land (being the background for his classification of ground rent as the most important type of income besides wage and profit) (cf. MEGA II/4.2, p. 667). But Marx was already aware that there are larger ecosystems whose survival is at stake here (cf. e.g. MEGA II/6, p. 477). Linked to these limits of commodified self-reproduction is the *third direction* for future research: based on the insights which can be gained from a closer analysis of the reproduction of wage labourers and of money regulation, the role of institutions and their relationships as part of capitalist reproduction is a possible focus here.²⁷

Finally, a fourth direction of a more methodological nature has to be mentioned, the problem of a deeper agent-based micro-foundation. On the one hand, the independence of individual agents, reification and thingification of social interaction (let alone class attributes)

²⁵ cf. Keynes referring to disaggregated expectation dynamics as part of his explanation in terms of a ‘marginal efficiency of capital’ (Keynes 1974/1936) and circular ex post explanations in a post-Keynesian framework like the acceleration principle (Kaldor) or yield anticipation (Kalecki); cf. Harris (1978, p. 186).

²⁶ This is different from the method of a ‘monetary reading’ of the labour theory of value in which these levels of analysis are not clearly specified and therefore mixed (e.g. Hein 2006, pp. 116, 125)

²⁷ This includes the role of institutional regulation, e.g. for the reproduction of wage labourer as emphasised by the regulation school (‘Fordism’ vs ‘post-Fordism’).

are forcing agents to conform (making a free choice illusory).²⁸ Hence, starting such an analysis in structural terms by focussing on the subordinating calculation structure is self-evident. But to derive from this that a deeper agent-based microanalysis is redundant seems to be premature.²⁹ It cannot be denied a priori, for example, that the activation of strategies on the firm level for enhancing the surplus value or the market-related behaviour of firms is important for aggregation in that the corresponding heterogeneities are not regulated away and remain important for the features of accumulation and reproduction on the aggregated level of values (cf. Jiang 2015).³⁰ Disaggregation, specifying institutional conditions as well as income expenditure can be considered as a background for integrating market dynamics, the ‘deeper analysis of supply and demand’ (MEGA II/4.2, p. 269) by taking into account a heterogeneous population of suppliers as well as consumers and their (exploring, exploiting and allocating) market activities. Hence, aggregated value analysis can be accomplished by a disaggregated simulation of an emergent production and market structure in terms of quantities, qualities, prices and market shares.

Taking these perspectives and various to-dos into account, a general conclusion is that overcoming the confusing work-in-progress nature of the various Marxian manuscripts of ‘Das Kapital’ without slavishly following its castration by modern model constructions (but rather being sensitized by them) is a promising research path in the direction of a unique non-mainstream Marxist tradition in economics.

²⁸ This may be accomplished by the necessary processes of cognitive economizing in terms of routines (cf. MEGA II/2, p. 114; Anderson 1993) and, not least, by conscious manipulation in terms of selective and suggestive information procedures.

²⁹ Cf. King (2012, pp 9) hinting at the ‘fallacy of composition’ and at ‘downward causation’ and Shaikh (2016, p. 75) discussing the ambiguous relation between micro foundation and macro pattern. These considerations do not capture the case of explaining emergent macro properties by a theoretically and empirically plausible modelling of interacting agents beyond the usual neoclassical ‘micro foundation’ ritual.

³⁰ Starting with m different producers on a disaggregated level (e.g. for $i, j = 1..n$ branches) and denoting a as the input quantities, b as the output quantities, mw as the (identical) money wage and s as the surplus (markup), prices can be determined according to: $a_{ij}^m(t)p_j^m(t) + mw_j(t) + s_j^m(t) = b_j^m(t + 1)p_j^m(t + 1)$. Given that there is a process (i) of specifying a (socially shaped) ruling technology out of m singular technologies (1 being the amount of labour) within a branch j ($\{a_{ij}^m, l_j^m\} \Rightarrow b_j^m$ to $\{a_{ij}^*, l_j^*\} \Rightarrow b_j^*$), (ii) of specifying a ruling price out of m singular prices within a branch j ($p_j^m \Rightarrow p_j^*$) and finally (iii) of specifying a ruling makeup ($s_j^m \Rightarrow s_j^*$), the price equation transformed to $a_{ij}^*(t)p_j^*(t) + mw_j(t) + s_j^*(t) = b_j^*(t + 1)p_j^*(t + 1)$. The social shaping takes place according to the influence of the power of wage labourers on the use of $s_i^*(t)$ for additional inputs and labourers in the next period (cf. part I, section 4.2, Eqs. [4] and [5]) and the way labour is activated for surplus production (cf. part I, section 4.2, Eq. [1]). If on this disaggregated level, values are defined as $b_j^*(t)p_j^*(t) \equiv K_j(t)$, $\sum_{i=1}^n a_{ij}^*p_j^* \equiv c_j(t)$, $mw_j(t) \equiv v_j(t)$ and $s_j(t) \equiv sv_j(t)$, it is obvious that these disaggregated value terms hide away the m producer’s differentials in terms of technology, price and mark up as well as their role for shaping specific paths of economic development. Capturing these differentials on the disaggregated level is a good reason for taking into account probabilistic methods suggested, e.g. by Farjoun and Machover (1983) and Cockshott and Cottrell (1998) as well as complexity methods suggested, e.g. by Arthur (2015).

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Compliance with ethical standards

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