How Economic Policies Profile Industrial Cycles and Long-term Trends (an Application to the USA)

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Abstract. Under the endemic circular stagnation of the state-monopoly capitalism, the US financial capital and the State have been designing a revival policy, the essence of which has not been presented in detail publicly. This paper responds to this gap. An original economic-mathematical model of capitalist reproduction, maintained by the law of surplus value, is upgraded. This allows comparing impacts of economic policies on industrial cycles and on long-term trends in the US economy. Inertia scenario I and mobilizing scenario II anticipate regular repetition of over-production and paroxysms. In 2017, the crisis will probably start, opening the next industrial cycle ending in 2024 in scenario I or in 2025 in scenario II. Internationalized capitalism is moving to explosion of its contradictions and to sharpening of geopolitical tensions. This social mode of production is entering a new period of over-production when sound economic policy becomes even more critical.

Based on the US macroeconomic data mainly for 1979–2016, computer simulation runs for a later period (through 2031) exhibit how policy optimization in 2017 and afterwards could alleviate severity of the next crises and improve long-run performance of the US economy compared to the inertia evolution.

Key words: capital accumulation, industrial cycle, secular trend, economic policy, economic-mathematical modelling, prospective scenario

1. Introduction

This research addresses long-term tendencies in the US economy such as the declining countervailing power of labour, falling labour share in national income, lower industrial capacity utilisation and atrophy of net non-residential investment. It focuses on the courses of the industrial cycles in the USA especially on tendencies to relative and absolute capital over-accumulation abstracting from environmental issues treated in the other works of the same author.

This paper continues a research thread of a class conflict theory of macropolicy based upon the Marxian concept of cycle. The key assumptions are: first, the contradictions between social character of production and private property, between value and use-value of labour power (its ability to create surplus value) are fundamental factors of capitalist development (including the structural “great recession”); second, investment are the main trigger mechanism of industrial cycle, third, capital has been pursuing policies aimed at maximisation of profit that requires the industrial cycle, fourth, from capitalist point of view, “benefit” of a crisis is that it purges the excesses of the previous boom, leaving the economy in a healthier state.

Under the endemic circular stagnation of the state-monopoly capitalism, the US financial capital and the State have been designing a revival policy, the essence of which has not been presented in detail publicly. This paper responds to this gap armoured by system dynamics methodology and instruments (Sterman 2000). It supports, in particular, the view that short termism in corporate governance favours under investment as a factor of secular stagnation (cf. Summers 2017).

The presented models consider relations between classes of capitalists and workers at a rather high level of abstraction. The commodity market is *not* cleared á la vulgar Say's Law because of fundamental contradiction between *value* and *use-value* of commodity. Still an explicit treatment of disequilibria on good market is left for a future research. Capitalist class owns means of production and circulation; workers own their labour power that they sell to capitalists for a restricted period of time. Only one good is produced as net output in macro-economic setting. These models abstract from differences between product real labour compensation and purchasing power real labour compensation arising due to differences between price index of net output and that of workers' consumption bundle.

Strictly speaking prices exists in these models only for two commodities: labour power and workers' consumption good whereas there is no interest rate and no price of capital good, which is in entire possession of the collective capitalist. The collective capitalist does not sell surplus product on the good market explicitly. Therefore surplus product is not a visible commodity and has neither perceptible labour value nor observable price. It is assumed for simplicity that abstract labour embodied in surplus product does represent surplus value and that net output unit price is identically one whereas profit equals surplus product.

Time is viewed as a continuous variable. So the appropriate measure for the rate of change of a variable x is the derivative of x with respect to time ($\dot{x} = dx/dt$), while its growth rate is logarithmic derivative $\hat{x} = \ln(x)' = \dot{x}/x = dx/(xdt)$. The same convention is appropriate for all variables.

Table 1 lists the state and other variables of the hypothetic laws (HLs).

Table 1. The main variables of H-1 and H-2

Variable	Expression	Unit of measurement
Real net output	P	bln $ 2009 /year
Employment	L	thousand workers
Labour force	N	thousand workers
Output per worker	$a = P/L$	mln. $ 2009 /(year* worker)
Employment ratio	$v = L/N$	unit fraction
Fixed capital (net)	K	bln $ 2009
Worker's real labour compensation	w	mln. $ 2009 /(year* worker)
Unit value of labour power (relative labour compensation)	$u = w/a$	unit fraction
Capital-output ratio	$s = K/P$	year
Output-capital ratio	$m = 1/s$	1/ year
Profit, surplus product	$M = (1 - u)P$	bln $ 2009 /year
Surplus value	$S = (1 - u)L$	thousand workers
Capital accumulation rate	k	unit fraction
Net accumulation of fixed capital	$\dot{K} = kM = k(1 - u)P$	bln $ 2009 /year
Capital intensity	$K/L = sa$	mln $ 2009 / worker
Profit rate (profitability)	$M/K = (1 - u)/s$	1/year
Rate of surplus value	$S/(L–S) = (1 - u)/u$	unit fraction

Calculations of u and s are done with the nominators and denominators measured in current prices. The employment ratio v is for the civil labour force (without accounting the latent and stagnant unemployment). The net fixed capital K is a sum of private and governmental produced non-residential fixed assets (yet without intellectual property products in this paper).

The inverse of output per worker $1/a$ represents a total labour input embodied in a unit of net output, so it approximates a magnitude of labour value of this unit.[1] The value of a unit labour power is $u = w/a$, unit surplus value is $1 – u$; total surplus value is the labour value of surplus product, measured by surplus labour, $S = (1 – u)L = (1 – u)P/a$.

Total profit $M = Sa$ is the money form of surplus product. In hypothetical laws, net output unit price (1) is omitted below for simplicity.

The rest of this paper is organised in the following way.

Section 2 re-formulates the hypothetical law of capital accumulation for the modern US economy H-1 (denoted as HL-2 in Ryzhenkov 2010).[2] H-2 contains a modified partial non-linear dynamic law for accumulation rate that reflects a pro-cyclical character of this variable and its long-term movement towards a latent target magnitude. Besides two other modifications are added. The first extends the equation for a growth rate of labour force by the employment ratio as the factor of this growth rate. The second takes into account endogenous convulsive changes in production caused by the start or by the cessation of the second form of absolute over-accumulation of capital. A key parameter of the mechanization function from H-1 is transformed in a new variable in H-2. Its logical re-switching reminds us of a coupled flip-flop in electrical circuits. Consequently, absolute over-accumulation of capital causes spasmodic increase of growth rate of capital intensity together with abrupt decrease of growth rate of employment ratio.

Section 3 explores a historical fit of H-2 for the US Economy in 1979–2016 and offers other behaviour reproduction tests for these laws. Their non-observable parameters are identified through application of a simplified version of the extended Kalman filtering (EKF) to macroeconomic data over the base period 1979–2015 as a whole. The official US macroeconomic statistics provided by BEA, BLS and CEA, serve thereby as an empirical base (in particular, Economic Report of the President 2017).
Sections 4 and 5 investigate inertia scenario I based on unaltered H-2 as well as profit enhancing scenario II maintained by parametrically altered H-2, respectively. In the latter, capitalists maximise total profit over about four decades (2016–2057). Thus, scenario II implicitly assumes that the US state-monopoly capitalism has to overcome wide-spread (if not prevailing) short termism of "quarterly capitalism" as a prerequisite for sustainable development.

Revealing advantages of strategic refocusing capitalism on the long term value creation in scenario II compared to scenario I marked by short termism, this paper does not attempt to uncover the whole set of required institutional reforms in corporate governance for overcoming circular stagnation (cf. Shaikh 2017). This issue is complicated by ecological aspects, omitted in this paper.

Appendix A contains detailed information on movement of main economic indicators for phases of the next industrial cycle in scenario I as well as in scenario II.

Tables and Figures below relate wholly to the US economy and its system dynamics modelling. The decimal sign is dot in the text and Tables, it is comma in Figures.

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[1] Let Q is the total product, A is the direct material input per unit of total output, $l = L/Q$ is the direct labour input per unit of total output; $P = (1 – A)Q$ is the net output, while $Q = (1 – A)^{–1}P$. Then $L = lQ = l[(1 – A)^{–1}P] = P/a$ is the total labour input, and $1/a = l(1 – A)^{–1}$. The labour value of an output unit is approximated by the total labour embodied in this unit: $\omega = \omega A + l = l(1 – A)^{–1} = 1/a$.

[2] The estimates in this paper are different from estimates given in (Ryzhenkov 2010) mainly because that did not grasp deeply enough the endogenous recurrent impact of capital over-accumulation on industrial cycles.

2. An Extensive and Intensive Deterministic Forms of H-1

The advanced capital does not include variable capital since workers are paid at the end of each completed circulation process. Capital of circulation, natural capital and resource rent are not taken into explicit account; therefore magnitudes of general profit rate are biased. International relations are not presented explicitly.

Net national product (NNP) represents net output. As the US income receipts from the rest of the world exceed income payments to the rest of the world (including interest payments), NNP is bigger than net domestic product. Still a far greater part of surplus product is domestically produced. National income equals NNP less statistical discrepancy in the US national accounts statistics used in this paper.

Marx' notion of capitalist surplus product is the base for all three following definitions of (total) profit. They use BEA national income and product accounts.

The *first* definition grasps profit as a residual: NNP (gross national product less consumption of fixed capital) minus total labour compensation measured as pre-tax compensation of employees (including supplements) and minus imputed (by the author) labour compensation of self-employed persons as a part of proprietors' income.

In the *second* equivalent definition, profit consists of net domestic operating surplus of private enterprises, current surplus of government enterprises, less imputed (by the author) labour compensation of self-employed persons as a part of proprietors' income, plus taxes on production and import less subsidies, plus statistical discrepancy, plus income receipts from the rest of the world, less income payments to the rest of the world.

The *third* definition results from the second after adding details: total profit consists of remaining part of proprietors' income with inventory valuation and capital consumption adjustments, rental income of persons with capital consumption adjustments, corporate profits with inventory valuation and capital consumption adjustments, net interest and miscellaneous payments, taxes on production and imports less subsidies, business current net transfer payments, current surplus of government enterprises and statistical discrepancy (that is not included in national income but included in NNP).

For aggregate profit, the *first* definition is mostly relevant.

2.1. An Extensive Deterministic Form of H-1

For $t \geq 1979$, a deterministic model consists of the following equations:

$$P = K/s; \quad (1)$$

$$L = P/a; \quad (2)$$

$$u = w/a,\ 0 < u < 1; \quad (3)$$

$$\hat{a} = m_1 + m_2 \hat{K/L} + m_3 \psi_1(\hat{v}), \quad (4)$$

$$\psi_1(\hat{v}) = sgn(\hat{v})|\hat{v}|^j,\ m_1 > 0,\ 1 > m_2 > 0,\ m_3 > 0,\ 1 > j > 0;$$

$$\hat{K/L} = n_1 + n_2 u + n_3(v - v_c), \quad (5)$$

where $n_1 < 0,\ n_2 > 0,\ n_3 > 0,\ 1 > v_c > 0;$

$$v = L/N,\ 1 > v > 0; \quad (6)$$

$$n = n_a + p_1 e_2^{-M_2 (K/L - K_c/L_c)^{i_2}} \quad (7)$$

for $K/L \geq K_c/L_c,\ e_2 > 0,\ i_2 > 0,\ M_2 = 1,\ p_1 > 0,\ n_a \leq 0;$

$$\hat{w} = \hat{a} - d, \quad (8)$$

where $d = \begin{cases} d_1 > 0, v < V, \\ d_2 < 0,\ v \geq V. \end{cases}$

$$P = wL + M = Q + \dot{K} = wL + (1 - k)M + \dot{K}; \quad (9)$$
$$\dot{K} = k(1 - u)P = kM,\ 0 \le k \le 1; \quad (10)$$
$$\dot{k} = c_1\psi_2(\hat{s})k, \quad (11)$$

where $c_1 < 0$, $\psi_2(\hat{s}) = sgn(\hat{s})|\hat{s}|^{j_2}$, $1 \ge j_2 > 0$.

Equation (1) postulates a technical-economic relation connecting the net fixed capital *K*, net output *P* and capital-output ratio *s*. Equation (2) relates output per worker *a*, net output *P* and labour input, or employment *L*. Equation (3) describes the relative labour compensation *u*, or unit labour value, as the ratio of real labour compensation *w* to output per worker *a*.[3]

Equation (4) is an extended technical progress function. It includes: the rate of change of capital intensity, *K*/*L*, and direct positive scale effect, $m_3\psi_1(\hat{v})$; $|x| \ge 0$ is an absolute value of *x*; $sgn(x) = -1$ for $x < 0$, $sgn(x) = 1$ for $x \ge 0$.

The growth rate of output per worker changes stepwise at local maximums and minimums of the employment ratio mostly because of sudden movements of average working hours per labourer down and up, respectively. The non-linear continuous function $\psi_1(\hat{v})$ is analytical except at singular points with $\hat{v} = 0$ where its positive first derivative ($\psi_1'(\hat{v}) = j|\hat{v}|^{j-1} > 0$) becomes infinite. The derivatives of the function $\psi_1(\hat{v})$ of higher orders go to plus or minus infinity at the vicinity of $\hat{v} = 0$. This substantial singularity is suitable for reflecting the stepwise changes in growth rate of output per worker at local maximums and minimums of the employment ratio.

Equation (6) outlines the rate of employment *v* in result of the buying and selling of labour-power. Variable *v* plays a decisive role in determination of the rate of change of the real labour compensation *w*.

Due to prevalence of monopsonistic labour market, growth in real labour compensation is subordinated in (8) to growth of output per worker, except for periods when employment ratio *v* exceeds threshold $V \approx 0.95$. Equation (8) containing logical re-switching is an analogue of coupled flip-flop in electrical circuits.

Figure 1 exposes causality in (4) and (8) restricting this to three layers of parameters and variables in each case. Each causes tree is to be read from the left (factors) to the right (effects that become in turn factors for effects closer to a surface).

[3] The equity $u = 1$ is not compatible with capitalist production relations as the use value of labour power ceases to exist for capitalists when they get no surplus value at all. The equity $u = 0$ would exclude the specific premise of capitalist production relations, namely, market supply of labour force. Therefore $0 < u < 1$. The necessity of employment *and* unemployment for capital accumulation requires $0 < v < 1$. The socio-economic laws codetermine narrower bounds of both intervals that depend on economic policies as this paper demonstrates.

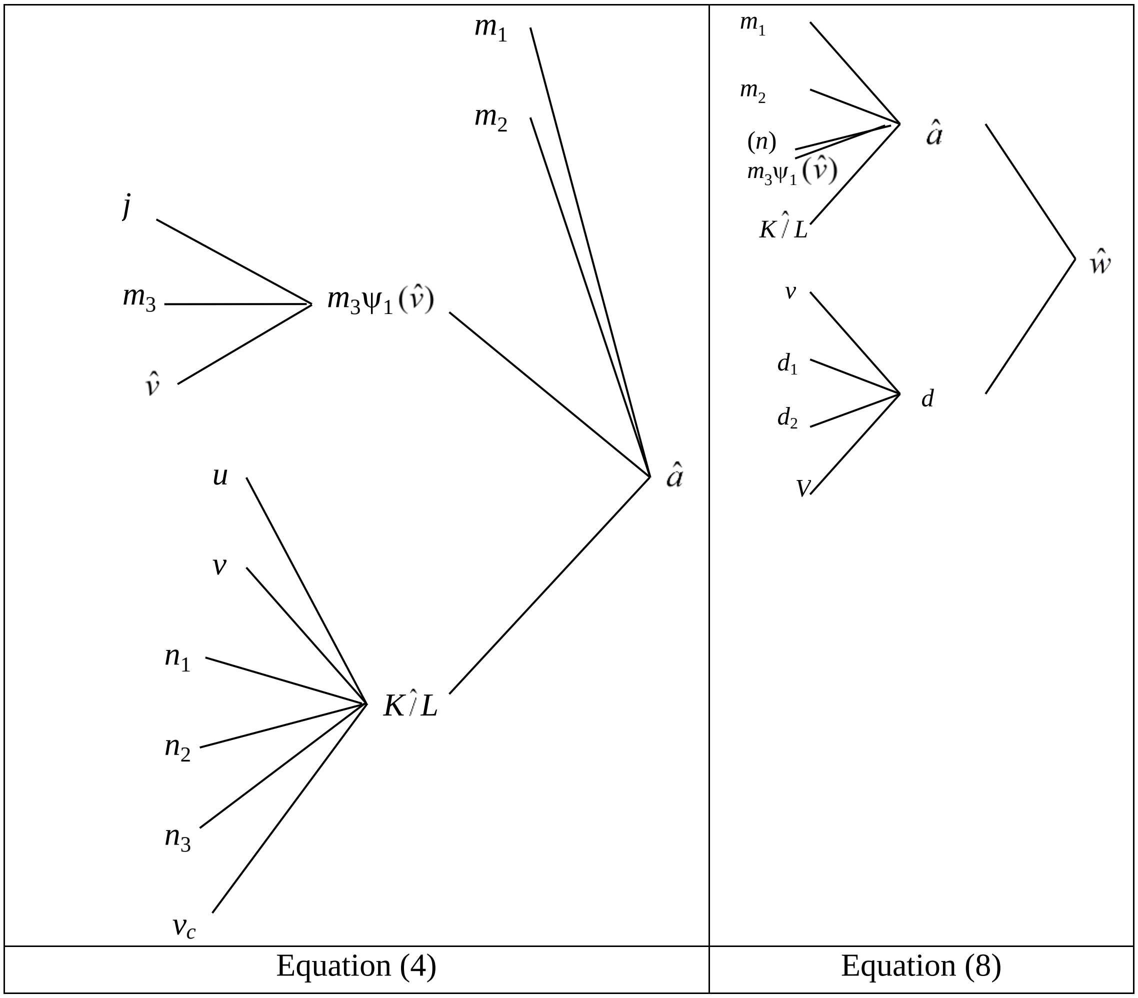

Figure 1. Causes trees of depth 2 for growth rate of output per worker $\hat{a}$ (4) and growth rate of labour compensation $\hat{w}$ (8) in H-1 and in H-2

Figure 2 presents the first order feedback loops of relative labour compensation (three positive, three negative and one of changing polarity) leaving loops of higher orders aside. Consider two of them (numbered 2 and 3). In both, in an infinitesimal time interval, an increment of relative labour compensation promotes increases in the growth rate of capital intensity that facilitates growth rate of output per worker, this either diminish the initial increment of relative labour compensation (loop 2) or facilitates growth rate of labour compensation that is favourable for further increment of relative labour compensation (loop 3). If $d > 0$ in (8), the loop 2 dominates over loop 3, and vice versa (if $d < 0$). More detailed Figure 3 displays the encompassing H-1 structure.[4]

[4] H-1 does not contain any feedback loop of P. This incompleteness is remedied in H-2 by explicit accounting for absolute over-accumulation of capital (Figure 8).

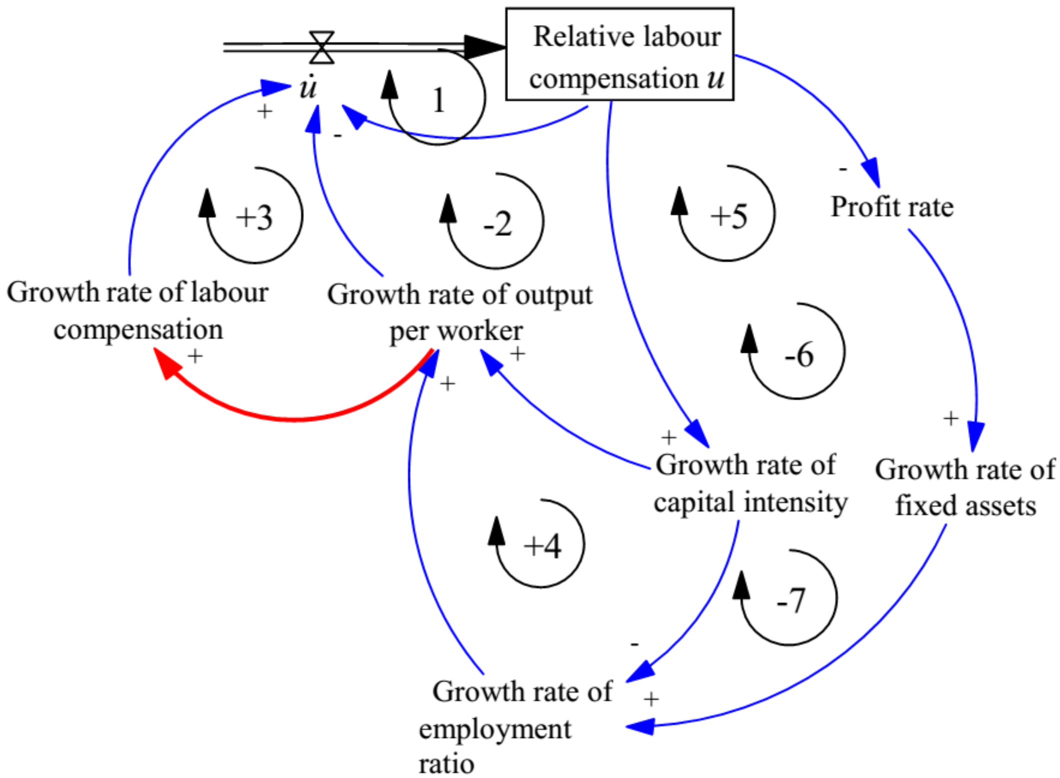

Figure 2. The first order feedback loops of relative labour compensation *u* in H-1

Mechanisation (automation) manifests itself in growing capital intensity. A high relative labour compensation and high employment ratio promote mechanization (automation) that shapes the labour supply. The growth rate of capital intensity *K*/*L* in (5) is a function of the relative labour compensation *u*, of the difference between the current employment ratio *v* and some base magnitude v_c. The latter is parameter in H-1 that becomes a new key variable in H-2.

Following reasoning stays behind a hypothetical partial law for the labour supply. Before reaching a critical magnitude, mechanisation (automation) pushes new demographic groups (children, women, aged, immigrants from less developed countries) into a labouring population (as far as qualification really or potentially satisfies technological requirements) thus chiefly accelerating the growth of supply of labour force. Afterwards mechanisation (automation) becomes mainly a decelerating factor for the growth of supply of labour force because a substantial part of working-age population does not possess adequate qualification for being hired or self-employed.

Accordingly, (7) determines the growth rate of supply of labour force *N* as a non-linear continuous function of capital intensity alone. Capital intensity, in turn, is a product of capital-output ratio and output per worker $(K/L = sa)$, it is implicitly applied in (18) below where $n = n(sa)$.

The growth rate of supply of labour force is monotonically increasing for $K/L \leq K_c/L_c$, reaching an absolute maximum $n_{\max} = n_a + p_1$ at the point $K/L = K_c/L_c$; this rate is monotonically decreasing for $K/L \geq K_c/L_c$. Time evolution of supply of labour force (*N*) is typically S-shaped. A magnitude of the constant n_a is not determined a priory.

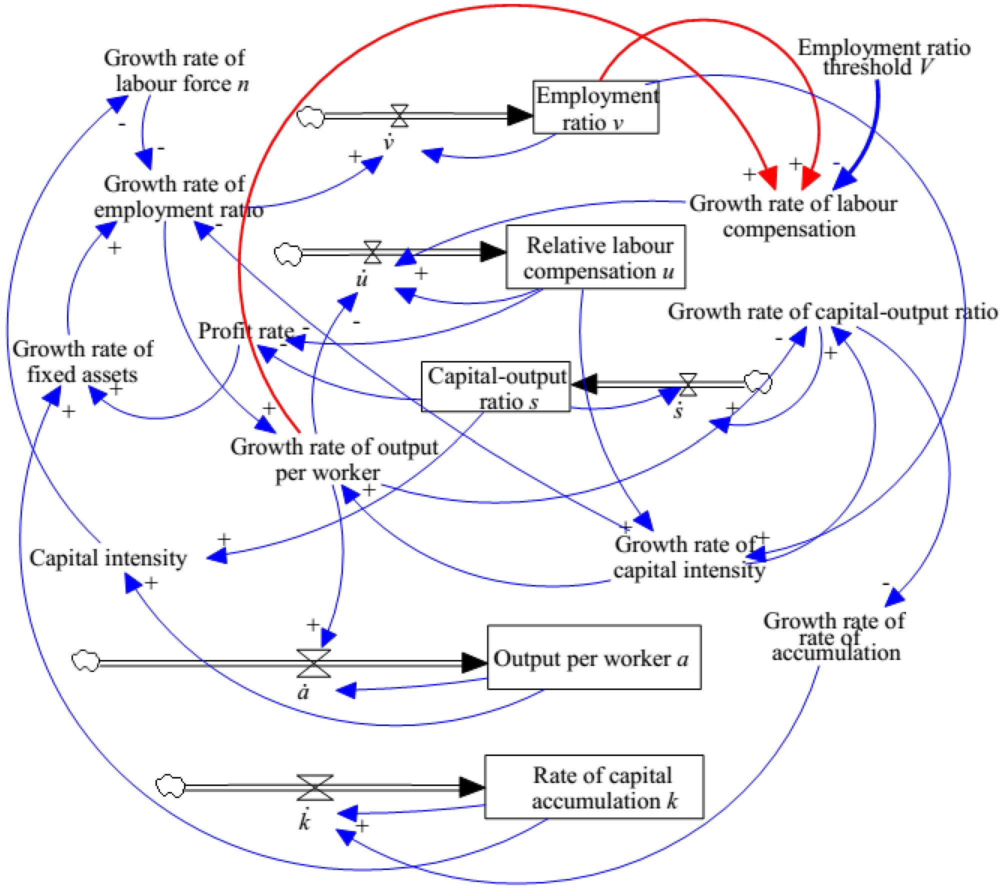

Figure 3. A condensed causal loop diagram of H-1

Consider (9). Net national output produced P is the sum of labour compensation wL and profit M. $\dot{K}$ denotes net formation of fixed capital; Q sums net export of goods and services E_1, net income receipts from the rest of the world E_2, net residential investment $\dot{R}$, net increment of inventories $\dot{I}$, final private C and public consumption expenditures G. In their turn, private consumption, net residential investment and public consumption consist of workers' and capitalists' parts (respectively, $C = C_w + C_c$, $\dot{R} = \dot{R}_w + \dot{R}_c$ and $G = G_w + G_c$). Notice that (9) satisfies requirement that produced net domestic product ($P - E_2$) equals net domestic product finally used ($\dot{K} + Q - E_2$). These details help clarify the common boundary of the hypothetic laws (HLs) in section 2.2.

Net non-residential investment, being a priority fraction of surplus product kM, covers net formation of fixed capital in (10) abstracting from delays. Equation (11) defines a derivative control over rate of capital accumulation k, whereby its growth rate depends strongly negatively (for $c_1 < 0$) and non-linearly (for $1 > j_2 > 0$) on a growth rate of capital-output ratio. For the chosen non-linear functional form (11) explicit analytical integration is not possible.

Following considerations support logically a working hypothesis on a pro-cyclical nature of rate of accumulation. In the economic literature, output-capital ratio $1/s$ represents typically a proxy of utilization of the productive capacity. The mathematical properties of function $\psi_2(\hat{s})$, in (11) in respect to the argument $\hat{s}$ are the same as the above properties of function $\psi_1(\hat{v})$ in (5) in respect to argument $\hat{v}$, although measurement units of these functions and of related parameters c_1 and m_3 differ. The chosen functional form (11) allows not only modelling abrupt and vigorous changes of rate of capital accumulation k near turning points of industrial cycles but its long term declining trend in the base period as well. This variable substantially neutralises the secular tendency of profit rate to fall.

In an infinitesimal time interval, an increment in accumulation rate facilitates growth of fixed capital and of employment ratio that, due to direct positive scale effect, fosters decline in capital-output ratio. The latter is, in turn, favourable for further extension of accumulation rate (Table 2, Figure 4). This positive feedback loop is an element of the greater structures of H-1 (Figure 3) and of H-2 (Figure 8).

Table 2. Feedback loops containing accumulation rate *k* in H-1 and H-2

No.	Order, sign	Loop and its economic interpretation
1	1, + or –	$k \xrightarrow{+} \dot{k}$ or $k \xrightarrow{-} \dot{k}$ Accumulation rate is positive or (negative) factor of its time derivative. If the growth rate of accumulation rate is zero, the impact of the accumulation rate on its derivative does not exist.
2	1, +	$k \rightarrow \hat{K} \rightarrow \hat{v} \rightarrow \hat{a} \xrightarrow{-} \hat{s} \xrightarrow{-} \dot{k}$ Increase of accumulation rate promotes the pace of capital formation; the increased growth rate of fixed capital accelerates employment rate growth that (thanks to the direct economies of scale) increases the growth rate of output per worker. The increased growth rate of output per worker reduces the growth rate of capital-output ratio. This decline, in turn, contributes to a further increase in accumulation rate.
3	2, –	$k \rightarrow \hat{K} \rightarrow \dot{v} \rightarrow v \rightarrow \widehat{K/L} \rightarrow \hat{s} \xrightarrow{-} \dot{k}$ Positive net change of accumulation rate facilitates the growth rate of fixed capital, the increased growth rate of fixed capital increases employment ratio. Increased employment ratio speeds up growth of capital intensity. This acceleration is a positive factor for the growth rate of capital-output ratio. A higher growth rate of capital-output ratio is unfavourable for net change of accumulation rate.
4	2, +	$k \rightarrow \hat{K} \rightarrow \dot{v} \rightarrow v \rightarrow \widehat{K/L} \rightarrow \hat{a} \xrightarrow{-} \hat{s} \xrightarrow{-} \dot{k}$ Positive net change of accumulation rate favours the growth of fixed capital and of employment ratio. Higher employment ratio increases the growth rate of capital intensity. Increased assets growth rate of capital intensity accelerates the growth of output per worker. The increased growth rate growth rate of output per worker slows net change of capital-output ratio. The slower growth of capital-output ratio pushes up the growth rate of accumulation rate.
5	3, – only for $v \rightarrow V$	$k \rightarrow \hat{K} \rightarrow \dot{v} \rightarrow v \rightarrow \dot{u} \rightarrow u \rightarrow \widehat{K/L} \rightarrow \hat{s} \xrightarrow{-} \dot{k}$ Positive net change of accumulation rate facilitates the growth of fixed capital and of employment ratio. If the employment ratio reaches threshold *V* and overcomes it, it increases the relative labour compensation gains. Increased relative labour compensation speeds up growth of capital intensity. The increased growth of capital intensity lifts growth rate of capital-output ratio. A higher growth rate of capital-output ratio is harmful for net change of accumulation rate.
6	3, + only for $v \rightarrow V$	$k \rightarrow \hat{K} \rightarrow \dot{v} \rightarrow v \rightarrow \dot{u} \rightarrow u \rightarrow \widehat{K/L} \rightarrow \hat{a} \xrightarrow{-} \hat{s} \xrightarrow{-} \dot{k}$ Positive net change of accumulation rate promotes the growth of fixed capital and of employment ratio. If the employment ratio reaches threshold *V* and overcomes it, it increases the relative labour compensation gains. Increased relative labour compensation speeds up growth of capital intensity. The increased growth of capital intensity facilitates growth rate of output per worker. This, in turn, inhibits growth rate of capital-output ratio. Decreased growth rate of capital-output ratio is beneficial for net change of accumulation rate.

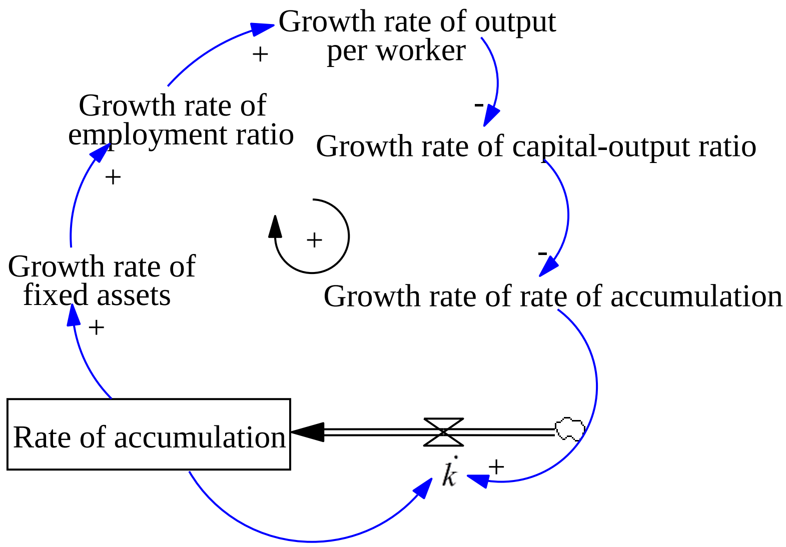

Figure 4. Endogenous accumulation rate *k* reinforcing economy of scale in H-1 and H-2

2.2. Looking at the H-1 boundary and beyond

A boundary of H-1 focused on the domestic economy (in a context of the world economy) is not shown explicitly yet. A specific approach to external socio-economic relations from (Ryzhenkov 2010) is helpful. This section abstracts from the environmental issues as the whole paper.

The starting point is (9) for relations of components of NNP produced with those of NNP used. Introduce a total E of net export E_1 and net income receipts from the rest of the world E_2:

$$E = E_1 + E_2, \tag{12}$$

where (for the US economy in the mean time) $E_1 < E < 0$ while $E_2 > 0$.

Assume that workers' labour compensation (before taxes!) equals their private and public consumption plus net residential investment

$$wL = uP = C_w + G_w + \dot{R}_w. \tag{13}$$

Then according to (9), (12) and (13)

$$P = wL + M = \dot{K} + Q = \dot{K} + C_w + C_c + \dot{R}_w + \dot{R}_c + \dot{I} + G_w + G_c + E_1 + E_2. \tag{14}$$

Re-grouping of terms in (14) leads to

$$\dot{K} + C_c + G_c + \dot{R}_c + \dot{I} = M - E_1 - E_2. \tag{15}$$

In (15), a sum (on the left) of domestic non-residential investment, capitalists' private and public consumption, their net residential investment, net increment of inventories equals profit (before taxes!) plus net import ($-E_1$) and net income payments to the rest of the world ($-E_2$). The uses (on the left) *in toto* exceed surplus product ($M - E_2$) domestically produced by quantity of net import ($-E_1$), whereas domestic surplus product is typically much higher than net increment of fixed capital ($M - E_2 >> \dot{K}$). The net foreign expenses ($-E > 0$) are covered by net foreign borrowing (not explicit in H-1).

Notice that in a special abstract (limit) case without net accumulation of fixed capital ($k = 0$) and without a change of inventory ($\dot{I} = 0$), (15) is simplified to $C_c + G_c + \dot{R}_c = M - E_1 - E_2$. A sum of capitalists' private and public (including military) consumption, net residential investment exceeds domestic profit by net export. The net foreign expenses are covered by net foreign borrowing again.

Although in our time the US income receipts from the rest of the world exceed income payments to the rest of the world, current account is negative due (arithmetically!) to, first, negative net export and, second, positive net current taxes and transfer payments to the rest of the world (given in foreign transaction current account). Negative current account less minor net capital account transaction equals net negative lending (given in foreign transaction capital account). Lavishness and military expenditures may foster accumulation of foreign debt especially during the protracted wars.

According to domestic capital account, a sum of positive net investment, minor net capital account transactions and negative net lending equals a sum of negative net national (private and government) saving and statistical discrepancy. This is a concretization for the USA of well-known identity: net domestic investment (including net change of inventories) ≡ net national saving + net foreign borrowing + statistical discrepancy.

This paper explores and validates the model that generate circular trends and industrial cycles and, particularly, fluctuations in the rate of unemployment being in congruence with Marx' theory and mostly supported by statistical data. These HLs imply that, first, net fixed capital formation is determined in the US economy by mostly domestic and partially foreign surplus labour embodied in surplus product and, second, that surplus labour and surplus product, in their turn, depend on net domestic fixed capital formation.

Foreign states and private investors, often seeking out safety, accumulate fictitious capital as claims for a part of surplus value (flow) created by American labourers. Net additional claims are reflected as a financial account excess (flow) that equals a current account deficit (flow) with its sign reversed if capital account and statistical discrepancy are left aside. Negative net lending (positive net borrowing) as a flow facilitates foreign indebtedness (a stock) and thus it promotes income payments to the rest of the world (a flow); in turn, net increment of foreign indebtedness (a flow) lessens net US-owned assets abroad (a stock) and worsens the US net international investment position (a stock) although assets revaluation may have an opposite effect on this position.[5]

2.3. An Intensive Deterministic Form of H-1

An intensive deterministic form of H-1, derived from (1)–(7), (8), (9) – (11), consists of five non-linear ODEs (11), (16) – (19):

$$\dot{a} = \{m_1 + m_2\,[n_1 + n_2 u + n_3(v - v_c)] + m_3\psi_1(\hat{v})\}a, \qquad (16)$$

$$\dot{s} = \{-m_1 + (1 - m_2)[n_1 + n_2 u + n_3(v - v_c)] - m_3\psi_1(\hat{v})\}s, \qquad (17)$$

$$\dot{v} = \left[k\frac{1-u}{s} - n_1 - n_2 u - n_3(v - v_c) - n\right]v, \qquad (18)$$

$$\dot{u} = -\,du, \qquad (19)$$

where, as in (8), $d = d_1 > 0$ if $v < V$, or $d = d_2 < 0$ if $v \geq V$.

The trajectory of $u(t)$ consists of growing and declining exponential parts connected in piece-wise manner. Local maximums and minimums of u correspond to occurrences of $v = V$ when variable d changes abruptly in (8) and (19).

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[5] International transaction accounts (ITAs) and international investment position accounts (IIPAs) reflect these processes statistically (BEA 2010). Changes attributable to valuation adjustments in IIPAs are connected with changes of stock market and real estate prices, changes in exchange rates, etc. ITAs abstract from them.

Formally, properties of a system of non-linear ODEs can be examined with the help of the Lie derivative or divergence defined in the present case for the vector-function $f\,(a, k, s, v, u)$ as

$$\mathrm{div}(f) = \frac{\partial \dot{a}}{\partial a} + \frac{\partial \dot{k}}{\partial k} + \frac{\partial \dot{s}}{\partial s} + \frac{\partial \dot{v}}{\partial v} + \frac{\partial \dot{u}}{\partial u}. \qquad (20)$$

For the H-1 intensive form (11), (16) – (19), where $\hat{a} + \hat{s} + \hat{v} = \frac{k(1-u)}{s} - n$, the Lie derivative is calculated as follows:

$$\mathrm{div}(f) = \frac{k(1-u)}{s} - n \; - n_3 v + c_1\psi_2(\hat{s}) + m_3\psi_1'(\hat{v})\frac{k(1-u)}{s}[1 - c_1\psi_2'(\hat{s})] - d. \qquad (21)$$

In vicinity of critical (singular) points where $\psi_1'(\hat{v}) \to +\infty$ for $\hat{v} \to 0$ and $\psi_2'(\hat{s}) \to +\infty$ for $\hat{s} \to 0$, the Lie derivative (21) moves for $k > 0$ to positive infinity since the compound element $m_3\psi_1'(\hat{v})\frac{k(1-u)}{s}[1 - c_1\psi_2'(\hat{s})]$ goes to positive infinity as $c_1 < 0$, $m_3 > 0$ and $\frac{k(1-u)}{s} > 0$. So induced technical progress, economy of scale and pro-cyclical character of profit investment share are at least locally destabilising in vicinity of such critical points in H-1.

A non-trivial stationary state with positive relative labour compensation in H-1 does not exist for $d \neq 0$ in (8). The existence of limit cycle is not yet proven analytically. Still multiple computer simulations with different integration techniques demonstrate that transient to very close vicinity of limit cycle endures centuries and millenniums. Although full transition to limit cycle and limit cycle itself cancannot be simulated precisely, simulations depict them with sufficient accuracy.

3. An Extensive Deterministic Form of H-2

The upgraded model contains additional elements. At first, proportional control over capital accumulation rate k is added to derivative control already present in (11). It utilizes a latent target magnitude of the capital accumulation rate k_b. A modified (11) is written as

$$\dot{k} = c_1\psi_2(\hat{s})k + c_2(k_b - k), \qquad (22)$$

where $c_1 < 0$, $c_2 = \begin{cases} c_{21} = 0, 1979 \le t < 2008, \\ c_{22} > 0, t \ge 2008, \end{cases}$

$0 < k_b \le 1$, $\psi_2(\hat{s}) = sgn(\hat{s})|\hat{s}|^{j_2}$, $1 > j_2 > 0$.

Figure 5 presents causes tree for net change $\dot{k}$ of capital accumulation rate with the initial structure (below) and added superstructure (at the top). Figure 5 contains five layers unlike Figure 1 with three ones.

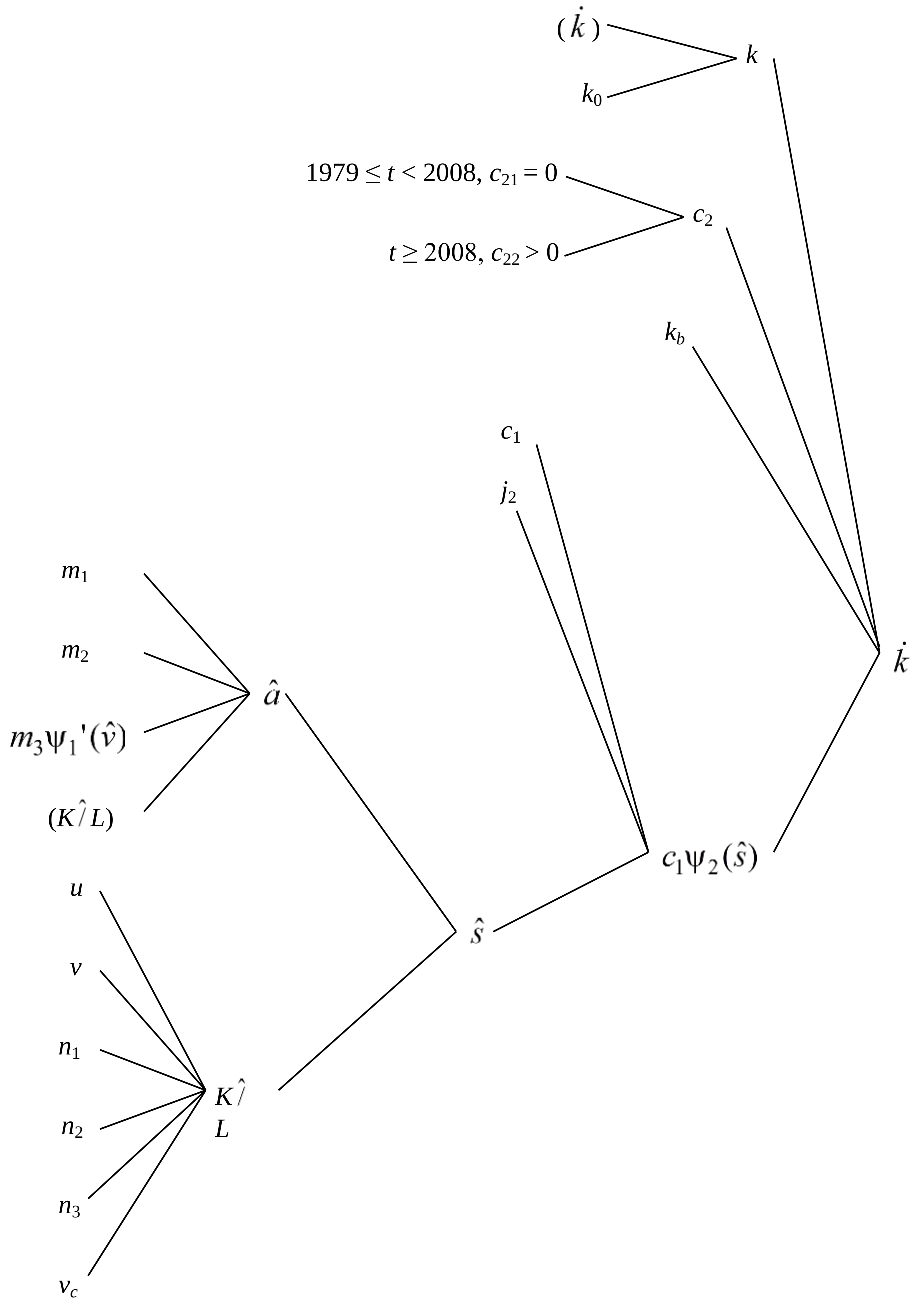


Figure 5. Causes tree of depth 4 in H-2 for net change $\dot{k}$ of capital accumulation rate

The second addition reflects the positive impact of employment ratio v on the growth rate of the labour force written as $n_5 v$ in

$$n = n_a + p_1 e_2^{-M_2(K/L - K_c/L_c)^{i_2}} + n_5 v \tag{23}$$

for $K/L \ge K_c/L_c$, $e_2 > 0$, $M_2 = 1$, $p_1 > 0$, $n_a < 0$, $n_5 > 0$.

In the absence of this cyclic component, the absolute maximum of n that is $n_{\max} = n_a + p_1$ is achieved at $K/L = K_c/L_c$, there is a monotonic decay of n further for $K/L > K_c/L_c$.

K. Marx distinguished two forms of absolute abundance (over-accumulation) of capital:

1) if increased capital produced the same or even less profit than before its increase (form I): $M_t \le M_{t-1}$ for $K_t > K_{t-1}$;
2) if increased capital produced the same or even less surplus value than before its increase (form II): $S_t \le S_{t-1}$ for $K_t > K_{t-1}$.

The third addition is the most principal alteration based on the law of surplus value. The second form of absolute over-accumulation of capital causes spasmodic increased rate of growth of capital intensity and a sharp decline in the rate of growth of employment ratio, in particular. It is achieved by transforming former parameter v_c into the new discrete variable

$$v_c = \begin{cases} v_c^{\max}, \text{ if } (1-u_t)\dfrac{P_t}{a_t} > (1-u_{t-1})\dfrac{P_{t-1}}{a_{t-1}}, \\ v_c^{\min}, \text{ if } (1-u_t)\dfrac{P_t}{a_t} \le (1-u_{t-1})\dfrac{P_{t-1}}{a_{t-1}}, \end{cases} \qquad (24)$$

where $L_{t-1} = \dfrac{P_{t-1}}{a_{t-1}}$ and $L_t = \dfrac{P_t}{a_t}$.[6] The causes and users trees of this variable are displayed on Figure 6 and Figure 7, respectively.

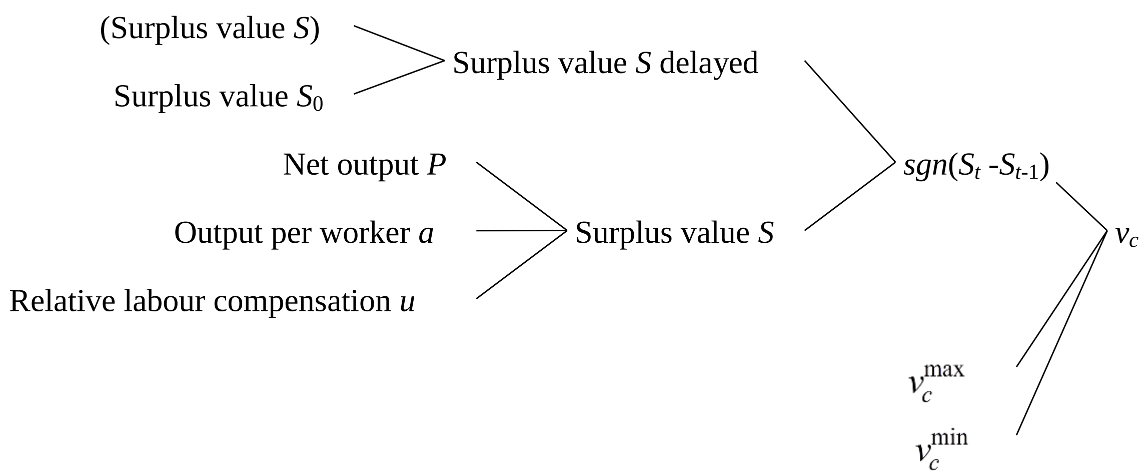


Figure 6. Causes tree of depth 3 in H-2 for v_c in (24)

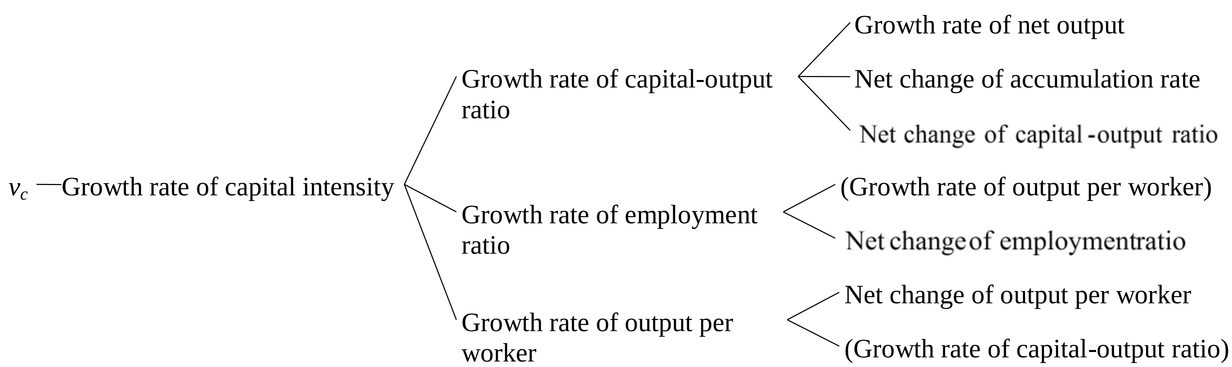


Figure 7. Users tree of depth 3 in H-2 for v_c in (24)

[6] Equation (24) containing logical re-switching is again an analogue of coupled flip-flop in electrical circuits like (8).

The condensed causal-loop structure of H-2 on Figure 8 reflects these three modifications. Two key re-switching, marked by red colour, create impulses that keep industrial cycles alive without exogenous shocks in contrast to so-called real business cycles preferred by "neoclassical" school.

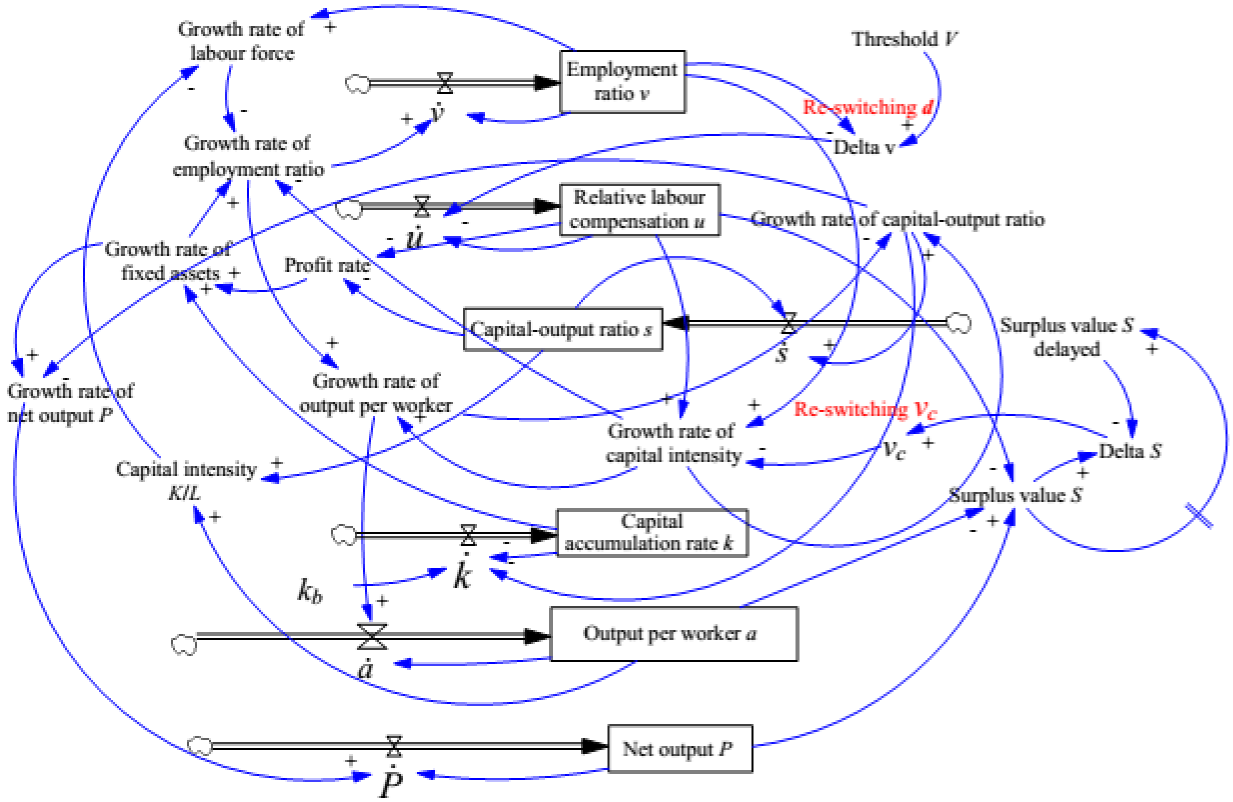


Figure 8. A condensed causal loop structure of H-2

Consider additional 1st order feedback loops for relative labour compensation with a help of Figure 9. These three new 1st order feedback loops are due to re-switching v_c in (24). Table 3 interprets them economically.

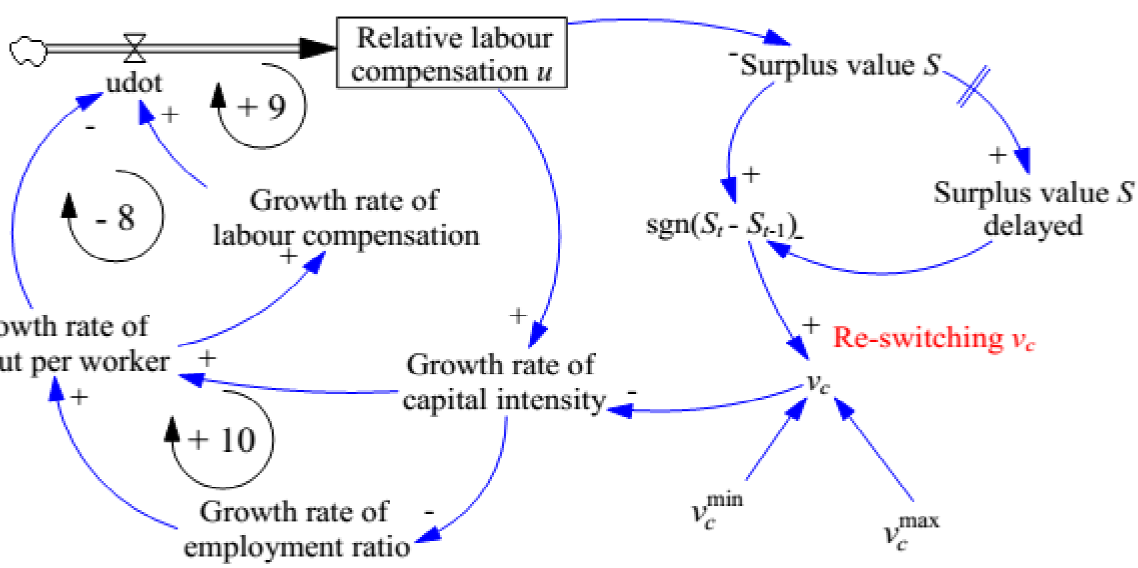


Figure 9. The three additional 1st order feedback loops containing u in H-2

Table 3. The three additional 1st order feedback loops for u in H-2 due to re-switching in v_c in (24)

No	Polarity	Feedback loop
8	-	$u \xrightarrow{-} S \to \delta(S) \to v_c \xrightarrow{-} \widehat{K/L} \to \hat{a} \xrightarrow{-} \hat{u} \to \dot{u}$ Absolute over-accumulation of capital speeds up growth of capital intensity and of output per worker that suppresses a growth rate of relative labour compensation that counter-acts over-accumulation. Opposite processes take place when absolute over-accumulation is over.
9	+	$u \xrightarrow{-} S \to \delta(S) \to v_c \xrightarrow{-} \widehat{K/L} \to \hat{a} \to \hat{w} \to \hat{u} \to \dot{u}$ Absolute over-accumulation of capital speeds up growth of capital intensity and of output per worker that facilitates growth rates of labour compensation and of relative labour compensation strengthening over-accumulation. Opposite processes take place when absolute over-accumulation is over.
10	+	$u \xrightarrow{-} S \to \delta(S) \to v_c \xrightarrow{-} \widehat{K/L} \xrightarrow{-} \hat{v} \to \hat{a} \xrightarrow{-} \hat{u} \to \dot{u}$ Absolute over-accumulation of capital speeds up growth of capital intensity detrimental for growth rate of employment ratio and via that rate – for growth of output per worker that facilitates growth of relative labour compensation strengthening over-accumulation. Opposite processes take place when absolute over-accumulation is over.

The above three modifications generated a great number of additional feedback loops for main variables. Table 4 demonstrates that, thanks to re-switching in v_c in (24), four additional 2nd order feedback loops containing accumulation rate k are created, in particular.

Table 4. The new four 2nd order feedback loops containing accumulation rate k in H-2

No.	Order, polarity	Loop
7	2, +	$k \to \hat{K} \to \hat{P} \to \dot{P} \to P \to S \to \delta(S) \to v_c \xrightarrow{-} \widehat{K/L} \to \hat{s} \xrightarrow{-} \dot{k}$ Absolute over-accumulation of capital fosters growth rates of capital intensity and of capital-output ratio that suppresses net change of accumulation rate and inhibits capital accumulation, so economic growth decelerates thus surplus value plunges and absolute over-accumulation is further worsening. Opposite processes take place when absolute over-accumulation is over.
8	2, -	$k \to \hat{K} \to \hat{P} \to \dot{P} \to P \to S \to \delta(S) \to v_c \xrightarrow{-} \widehat{K/L} \to \hat{a} \xrightarrow{-} \hat{s} \xrightarrow{-} \dot{k}$ Absolute over-accumulation of capital facilitates growth rates of capital intensity and of output per worker that is favourable for output-capital ratio and net change of rate of accumulation. Gain in net change of accumulation rate promotes growth rate of fixed capital and growth rate of net output. The higher growth rate of net output facilitates surplus value that contributes to overcoming of absolute over-accumulation. Opposite processes take place when absolute over-accumulation is over.

Table 4 (continued). The new four 2nd order feedback loops containing accumulation rate k in H-2

9	2, -	$k \to \hat{K} \to \hat{v} \to \hat{a} \to \dot{a} \to a \xrightarrow{-} S \to \delta(S) \to v_c \xrightarrow{-} \widehat{K/L} \to \hat{s} \xrightarrow{-} \dot{k}$ Absolute over-accumulation of capital promotes growth rate of capital intensity and of capital-output ratio that suppresses net change of accumulation rate and inhibits capital accumulation, so growth of employment ratio and of output per worker decelerates thus surplus value increases and absolute over-accumulation is less acute. Opposite processes take place when absolute over-accumulation is over.
10	2, +	$k \to \hat{K} \to \hat{P} \to \dot{P} \to P \to S \to \delta(S) \to v_c \xrightarrow{-} \widehat{K/L} \xrightarrow{-} \hat{v} \to \hat{a} \xrightarrow{-} \hat{s} \xrightarrow{-} \dot{k}$ Absolute over-accumulation of capital strengthens growth rate of capital intensity and accelerates lay-offs of workers, consequently growth rate of output per worker suffers that is favourable for increases in capital-output ratio detrimental for net change of rate of accumulation. Lower net change of accumulation rate inhibits growth rate of fixed capital and growth rate of net output. The lower growth rate of net output becomes negative, production decreases; surplus value falls further that worsens absolute over-accumulation. Opposite processes take place when absolute over-accumulation is over.

4. A Historical Fit of H-2 for the US Economy in 1979–2016

4.1. Probabilistic Form of H-2

For estimating probable states of the economy and for identifying unobserved parameters in the base period the deterministic model H-2 has been transformed in a stochastic model, taking into account measurement errors and an impact of factors neglected in the model assumptions.[7] This makes implicit allowances for short-term economic fluctuations by specification of the random components. The latter models include state equations and measurement equations for discrete moments of time

$$\mathbf{x}(\tau) = \mathbf{f}_t[\mathbf{x}(\tau - 1)] + \mathbf{w}(\tau),$$

$$\mathbf{z}(\tau) = \mathbf{H}\mathbf{x}(\tau) + \mathbf{v}(\tau),$$

where $\tau = 1980,\ldots, 2016$ is an index of data samples, $\mathbf{x}(1979)$ – a vector of an initial state of the system, $\mathbf{w}(\tau)$ – a vector of equations errors (driving noise), $\mathbf{v}(\tau)$ – a vector of measurement errors. The deterministic part $\mathbf{x}(\tau) = \mathbf{f}\,[\mathbf{x}(\tau - 1)]$ corresponds to the system (1) – (6), (8) – (10) and (22) – (24). The symbol $\mathbf{H}$ is for a square matrix. The residuals are not due entirely, or largely, to pure random influences. On the contrary, these residuals contain highly systematic, non-random components.

A simplified version of an extended Kalman filtering (EKF), realised in the Vensim software developed by Ventana Systems, Inc., has been applied. This software enables to estimate the unobservable components of the system by a procedure of maximum likelihood.

Simulation runs have used the observed magnitudes for the initial year (1979) posted in Table 5 (additionally $a_0 \approx 0.05956$ mln \$ 2009 per worker a year, $N_0 \approx 104961$ thousands persons, $P_0 \approx 5885.8$ bln \$ 2009/year). They calculated the most probable (still sub-optimal) magnitudes of state variables in the subsequent years.

[7] It is not possible to check whether the given deterministic model is able to replicate behaviour and create understanding of the observable economic behaviour without estimating parameters that usually requires construction of a stochastic model. A direct measurement of parameters' values, rarely achievable in macroeconomic modelling, is not for this particular study.

Table 5. Initial and average observable magnitudes for US economic development in 1979–2015

	Accumulation rate *k*	Capital-output ratio *s*	Employment ratio *v*	Relative labour compensation *u*	Profit rate $(1 – u)/s$
Initial 1979	0.247	2.008	0.942	0.704	0.147
Average 1979–2015	0.141	1.933	0.936	0.698	0.157

4.2. Behaviour reproduction tests of H-2

The H-2 probabilistic form has to pass behaviour reproduction tests. In particular, the Theil inequality statistics are used for estimating historical fit (Theil 1966).

Rather small root-mean-square errors as the percentage of the means (RMSE as percentage of the mean) and prevailing non-systematic errors of incomplete co-variation (U^C) over bias (U^M) and over difference in variation (U^S) show that these probabilistic forms track observations of the major variables in the base period agreeably (Table 6). Figures 9 and 10, demonstrating a certain likeness between simulated and realised (observed) magnitudes in the base period 1979–2016, support this conclusion.

Table 6. Decomposition of errors of the retrospective forecast for 1979–2016 (3 Q)

Variable	Period	$\sqrt{MSE}$ (units)	U^M	U^S	U^C	$\frac{\sqrt{MSE}}{mean}$, per cent
a	1979–2016 (3 Q)	0.0000	0.000	0.016	0.984	0.005
s	1979–2015	0.004	0.009	0.057	0.934	0.220
v	1979–2016 (3 Q)	0.0000	0.056	0.104	0.840	0.183
u	1979–2016 (3 Q)	0.0000	0.049	0.099	0.852	0.502
k	1979–2015	0.010	0.003	0.010	0.987	7.217
$(1 – u)/s$	1979–2015	0.0000	0.022	0.107	0.871	1.209
N	1979–2016 (3 Q)	1700	0.002	0.011	0.987	1.254
L	1979–2016 (3 Q)	1644	0.006	0.009	0.985	1.294
P	1979–2016 (3 Q)	126	0.010	0.010	0.981	1.284
S	1979–2016 (3 Q)	797	0.003	0.034	0.963	2.064
M	1979–2016 (3 Q)	62	0.000	0.019	0.981	2.059

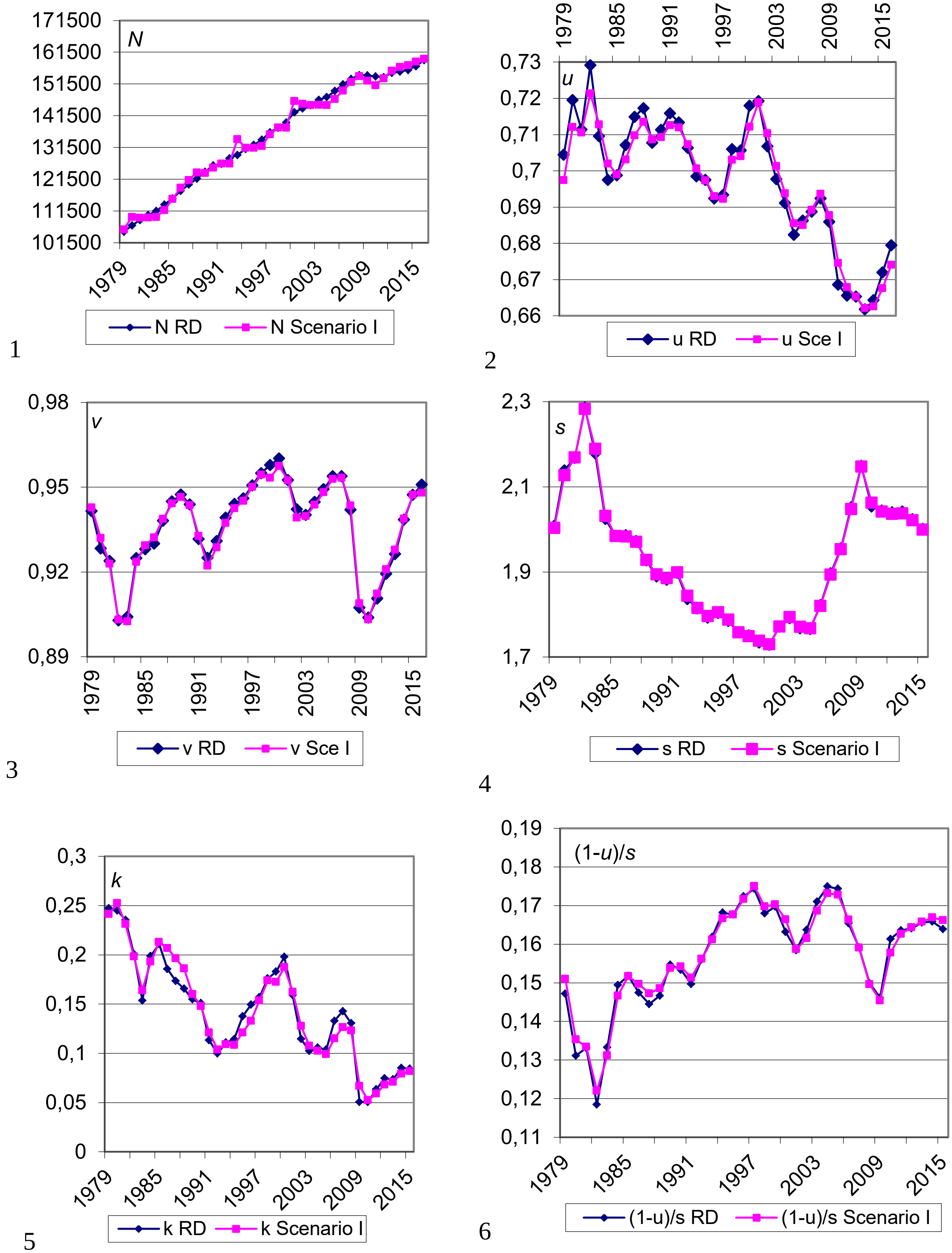


Figure 9. The observed (diamond) 1948–2016 (3 Q) and simulated (square) magnitudes 1979–2016: 1 – civil labour force *N*, 2 – relative labour compensation *u*, 3 – employment ratio *v*, 4 – capital-output ratio *s*, 5 – accumulation rate *k*, 6 – profit rate (1– *u*)/*s*

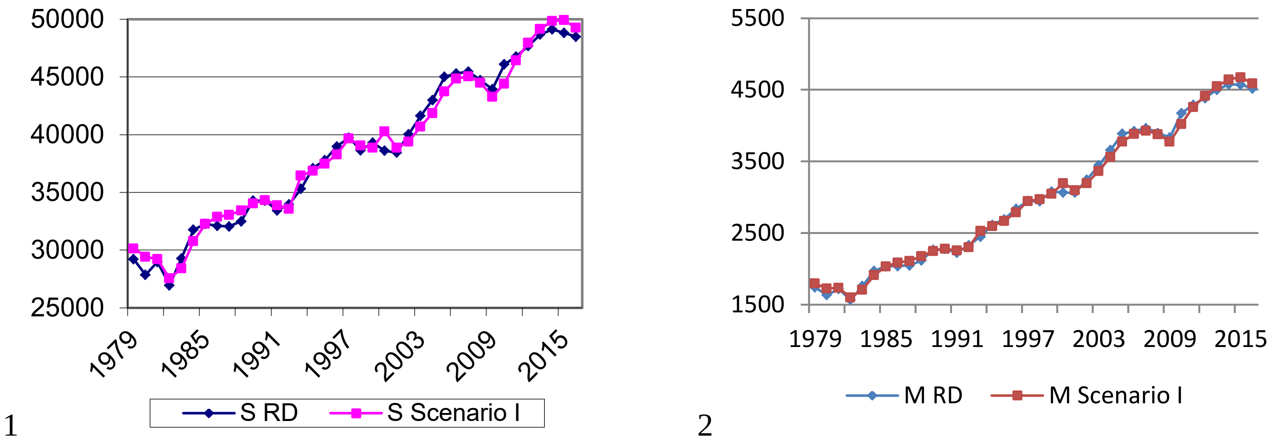


Figure 10. The observed (diamond) 1979–2016 (3 Q) and simulated (square) magnitudes 1979–2016: surplus value *S* (panel 1) and profit *M* (panel 2)

5. Prospective scenarios of US Economic Development

The scenarios I and II are based on the unaltered H-2 and on parametrically altered H-2, respectively. Table 7 contains magnitudes of main variables in these scenarios of US economic development for the scenarios' initial years 2015–2016. Selected parameters values are given in Table 9.

Table 7. Magnitudes of main variables in the scenarios and their observed magnitudes for 2015–2016

Data specification	Rate of accumulation k	Capital-output ratio s	Relative labour compensation u	Employment ratio v	Profit rate $(1 - u)/s$
Observed in 2015	0.085	2.001	0.672	0.947	0.164
Scenario I in 2015	0.082	2	0.668	0.947	0.166
Observed in 2016	…	…	0.678	0.951	…
Scenarios I and II in 2016	0.070	2.024	0.674	0.948	0.161

5.1. Inertia Scenario I

A computer-supported mental experiment roughly reproduces conditions with information up to 2016 (3 Q) available in the beginning of 2017. The model based on probabilistic and deterministic forms of H-2 was simulated with parameters values identified with Kalman filtering applying observations up 2015, extrapolated further with Kalman filtering for 2016 and without it afterwards.

An extrapolation of the retrospective forecast for the year 2017 and beyond, based on the unaltered deterministic model H-2 is called the inertia scenario I. Figures 11 and 12 visualise this and the other scenario generated in result of policy optimization. The first distinguished complete industrial cycle encompasses 2017–2024.

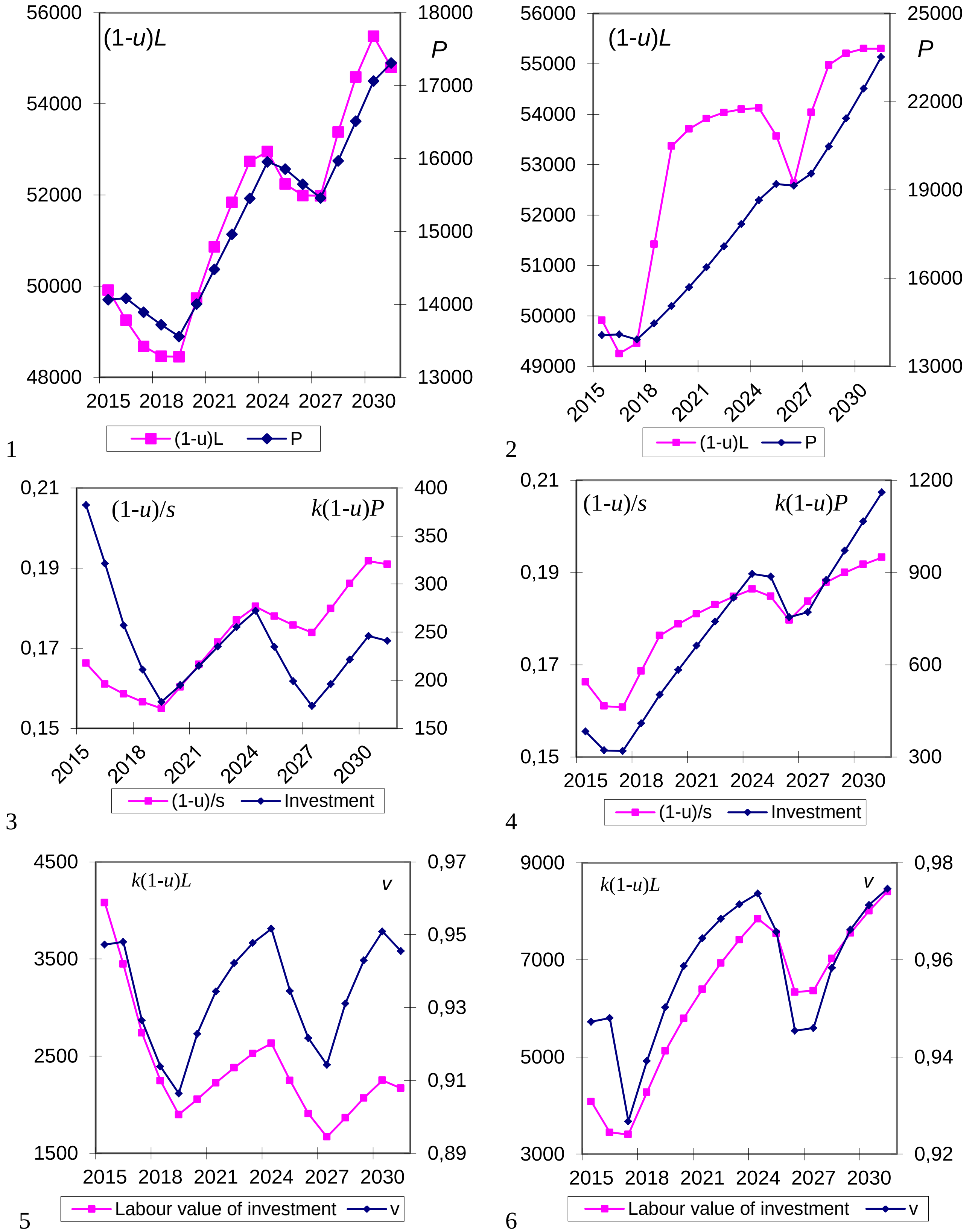


Figure 11. Evolution in scenarios I (on the left) and II (on the right), 2015–2031: surplus value S and net output P (panels 1, 2), profit rate $(1 - u)/s$ and investment $k(1-u)P$ (panels 3, 4), labour value of investment $k(1-u)L$ and employment ratio v (panels 5, 6)

Profitability tends upwards unlike investment (Figure 11, panels 3 and 5). The reader sees that H-2 explains why profit and investment do not move together and reproduces their apparently puzzling behavioural patterns (cf. Baker, Dew 2017).

The outlook of this paper: in aftermath of the crisis of 2017, recovery begins after achieving bottom line of net output P in inertia scenario I – in 2021, in profit enhancing scenario II – in 2018 (Table 8).

Table 8. Projecting the first match with 2009–2016 maximal economic indicators in the scenarios

Economic indicator	Year of local maximum in the base period	Year of the 1st exceeding previous local maximum in scenario	
		I	II
Net output P	2016	2021	2018
Profit $(1 – u)P$	2015	2020	2018
Surplus value $(1 – u)L$	2015	2021	2018
Rate of surplus value $(1 – u)/u$	2013	2021	2018
Profit rate $(1 – u)/s$	2014	2022	2018
Employment L	2016	2022	2019
Employment ratio v	2016	2024	2019
Relative labour compensation u	2016	outside reach	2031
Unit labour compensation w	2016	2020	2018
Total labour compensation wL	2016	2021	2018
Capital-output ratio s	2009	2019	outside reach
Capital accumulation rate k	2015	outside reach	2018
Investment $\dot{K}$	2015	outside reach	2018
Labour value of investment $\dot{K}/a$	2015	outside reach	2018

Anticipated dynamics of net output and profit rate in the inertia scenario I, unsatisfactory for capital, requires at least parametrical alteration of H-2. We will see that parametrical alteration of H-2, first of all, in capital interests maintains policy optimization. Mostly likely, intentional parametrical alteration of H-2 (for improving long-term profitability and for elevating total profit) could turn the approaching protracted crisis in scenario I into a milder recession in scenario II.

5.2. Profit Enhancing Scenario II

Scenario II is focused on long term value creation contrary to short termism in scenario I. The integral profit 2016–2057 is now maximised subject to (1)–(6), (8), (9), (10), (22)–(24) as well as to initial conditions of 2015–2016 (3 Q). This payoff takes the magnitude of profit net of punishment for excessively high employment ratio that surpasses 0.975. The focus of the current optimisation procedure is on five parameters that determine secular profitability trends and shape transients to regular cycles: parameters d_1 and d_2 from (8), c_{21} and k_b from (22), as well as n_a from (23).

We find optimal parameters' magnitudes (Table 9) for scenario II by maximising total profit for a selected time horizon under certain restrictions:

$$Maximise\left[\int_{2016}^{2057}(1-u)P\,dt - \text{Fine for excessive } v\right] \qquad (25)$$

subject to $\dot{x} = f_{H-2}[x(t), c_{21}, d_1, d_2, k_b, n_a]$, $x_0 = [a_0, k_0, P_0, s_0, v_0, u_0]$,

$0 \le c_{21} \le 0.4$, $0.002 \le d_1 \le 0.012$, $-0.01 \le d_2 \le -0.0049$, $0.02 \le k_b \le 0.3$, $-0.0980 \le n_a \le -0.0948$.

Table 9. Parameters of H-2 in base period and in the scenarios for 2016 and beyond

No. of Eq.	Parameter	Base period and scenario I	Scenario II
8	d_1	0.004	0.0109
8	d_2	–0.0085	–0.0049
22	c_{21}	0 ($1979 \leq t \leq 2007$) or 0.2 ($t \geq 2008$)	0.2
22	k_b	0.03	0.1032
23	n_a	–0.0965	–0.0948

Computer simulations reveal secular movements as well as middle-term fluctuations of phase variables (k, s, v, u), profit rate, growth rates of output per worker and real labour compensation with a period typical for industrial cycles in a range of (6–9 years). These fluctuations are anharmonic. Each of them represents proper industrial cycle as net output does decrease in its crisis.

Amplitude of fluctuations over a certain period is measured as a difference between maximal and minimal magnitudes of the respective variable. In inertia scenario II, profitability experiences middle-term fluctuations with smaller amplitude than in scenario I.

The analysis of scenario II gives support to the important conclusion made more than four decades ago: "We conclude on the basis of an examination of the data that the political-economic function of macropolicy in the short-run is not to pursue sustained full employment nor a steady, relaxed economy with a stable reserve army. Rather its function is to ensure that the alternating pressures for expansion and contraction emanating from the private sector result in that cyclical pattern most conducive to long-run profit maximization. The goal of macropolicy is not to eliminate the cycle but to guide it in the interests of the capitalist class" (Boddy and Crotty: 10).

The outlooks through 2031 in scenarios I and II

Longer projections confirm that the aggressive profit enhancing scenario II (Tables 8, 10–15, Figures 11 and 12) is best for capital. Scenario I requires a dramatic plunge of labourers' living standard for a protracted period with returning to the level of labour compensation w of 2016 only in 2020, whereas total labour compensation wL will not match the 2016 level until 2021, the previous local maximum of the employment ratio of 2016 will be outside reach until 2024. Scenarios I and II substantially differ from those of (CBO January 2017: 39, 44, 47): "CBO expects business investment to strengthen, helping to raise the growth of output to 2.3 percent this year and 1.9 percent in 2018. From 2017 to 2027, CBO estimates that real output will expand at an average rate of 1.9 percent per year…Unlike the projections for 2017 and 2018, CBO's projections for the subsequent years do not reflect expected cyclical developments in the economy. Rather, they serve as transitions to the values that CBO projects for the 2021–2027 period—which are based on anticipated longer-term economic trends, rather than on predictions of business-cycle fluctuations… Business investment will grow strongly in 2017…"

Table 10. Summary statistics of main labour variables in the scenarios for 2017–2031

Scenario	Mean			Normalised standard deviation		
	Employment ratio v	Relative labour compensation u	Rate of surplus value $(1–u)/u$	Employment ratio v	Relative labour compensation u	Rate of surplus value $(1–u)/u$
II	0.959	0.666	0.503	0.014	0.009	0.028
I	0.932	0.657	0.523	0.015	0.012	0.035
(II-I)/I %	2.9	1.4	-3.8	-6.7	-25.0	-20.0

Table 11. Additional summary statistics of main labour variables in the scenarios for 2017–2031

Scenar-io	Mean			Range		
	Labour com-pensation *w*	Total labour compensa-tion *wL*	Consump-tion per worker *vw*	Labour com-pensation *w*	Total labour compensa-tion *wL*	Consump-tion per worker *vw*
II	0.076	12208	0.073	0.031	6606	0.033
I	0.067	10054	0.062	0.010	2191	0.012
(II-I)/I %	13.4	21.4	17.7	210.0	201.5	175.0

Table 12. Summary statistics of the main capital variables in the scenarios for 2017–2031

Scenario	Mean			Normalised standard deviation		
	Capital-output ratio *s*	Capital accumulation rate *k*	Profit rate (1 – *u*)/*s*	Capital-output ratio *s*	Capital accumulation rate *k*	Profit rate (1 – *u*)/*s*
II	1.841	0.122	0.182	0.059	0.191	0.046
I	1.985	0.042	0.173	0.047	0.142	0.067
(II-I)/I %	-7.3	190.5	5.2	25.5	34.5	-31.3

Table 13. Additional summary statistics of the main capital variables in the scenarios for 2017–2031

Scenario	Mean			Range		
	Surplus value (1 – *u*)*L*	Profit (1 – *u*)*P*	Capital intensity *K*/*L*	Surplus value (1 – *u*)*L*	Profit (1 – *u*)*P*	Capital intensity *K*/*L*
II	53678	6115	0.208	5846	2999	0.039
I	51880	5268	0.201	7031	1558	0.014
(II-I)/I %	3.5	16.1	3.5	-16.9	92.5	178.6

Table 14. Average geometric growth rates in the scenarios for 2017–2031

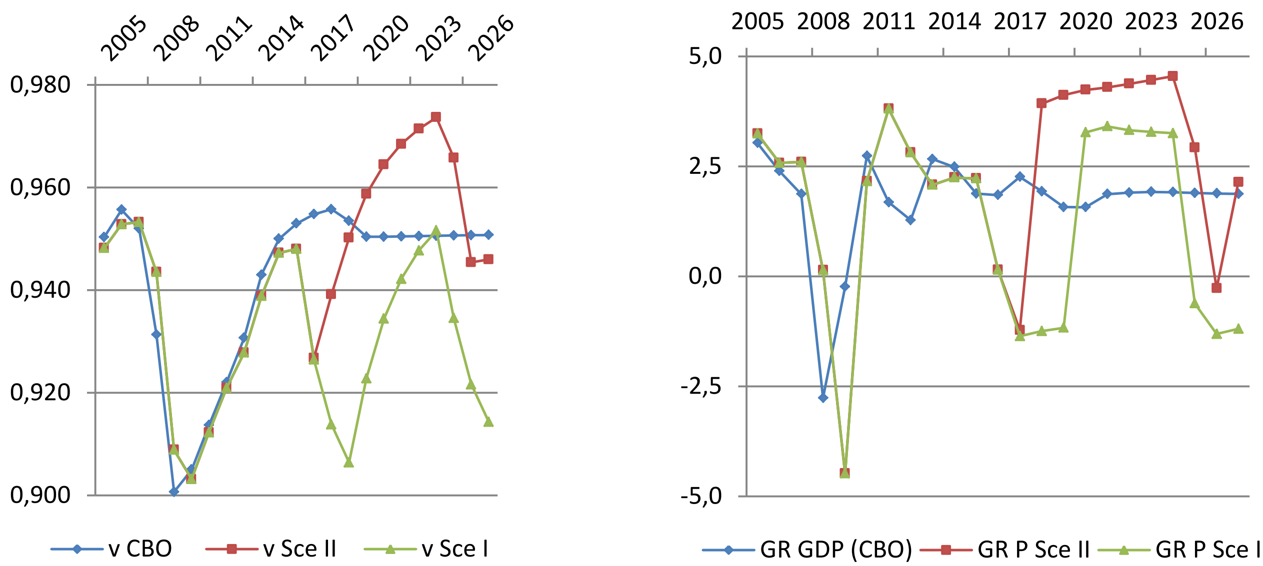
Economic indicator	Scenario I			Scenario II		
	cycle 2017–2024	cycle 2025–2031	2 cycles 2017–2031	cycle 2017–2025	cycle 2026–2031	2 cycles 2017–2031
Wage *w*	0.010	0.008	0.009	0.026	0.028	0.027
Consumption a head *vw*	0.010	0.007	0.009	0.028	0.030	0.029
Output per worker *a*	0.013	0.010	0.012	0.026	0.027	0.027
Employment *L*	0.003	0.001	0.002	0.009	0.007	0.008
Labour force *N*	0.002	0.002	0.002	0.007	0.005	0.006
Net output *P*	0.016	0.012	0.014	0.035♠	0.034	0.035
Surplus value *S*	0.009	0.005	0.007	0.009	0.005	0.008
Profit *M*	0.022	0.015	0.019	0.036	0.033	0.035
Capital-output ratio *s*	-0.008	-0.005	-0.006	-0.015	-0.009	-0.012
Capital intensity *K*/*L*	0.005	0.006	0.005	0.011	0.018	0.014
Total labour compensation *wL*	0.012	0.010	0.011	0.035	0.035	0.035
Investment *k*(1-*u*)*P*	-0.021	-0.017	-0.019	0.119	0.046	0.089
Labour value of investment *k*(1-*u*)*L*	-0.033	-0.027	-0.030	0.091	0.018	0.061
Accumulation rate *k*	-0.042	-0.032	-0.037	0.081	0.013	0.053

♠ Cf. the candidate's pledge on 9/15 2016 before his winning of the presidential election.

Table 15. Economic indicators in the scenarios and in CBO (2017) projection for 2017–2027

Scenario	Unemployment rate	Average growth rate %/year 2017–2027						
	$1-v$, %,	Output per worker *a*	Labour compensation *w*	Total labour compensation *wL*	Net output *P*	Labour force *N*	Fixed capital *K*	Employment *L*
I	7.1	1.0	0.7	0.6	1.0	0.2	0.8	-0.1
II	4.5	2.4	2.3	2.9	2.4	0.6	2.0	0.6
CBO	4.8	1.3	1.4[1]	1.9[4]	1.9[2]	0.6	2.1[3]	0.6

[1] GDP price deflator is applied. [2] GDP. [3] CBO considers capital services (including those of intellectual property products) in nonfarm business sector. [4] GDP price deflator is applied.



1 2

Figure 12. Evolution of the employment ratio *v* (fraction) on panel 1 and of growth rate (GR) of net output $\hat{P}$ (%/year) on panel 2 in the scenarios compared with CBO's projections over 2017–2027 (diamond – CBO (2017), triangle – I, square – II)

K. Marx wrote ironically in the 3rd volume of "Capital": "Business is always thoroughly sound and the campaign in full swing, until suddenly the debacle takes place". Net product *P* reaches its local maximum on the completion of the boom with the onset of the crisis. Ending the fall of net product *P* expresses completion of crisis, whereas achieving pre-crisis peak completes recovery. Depression is defined as phase starting at the end of the crisis and ending before recovery, when capital-output ratio *s* is (locally) maximal. In the modelled dynamics that abstracts from orders and inventories, phases of crisis and depression are not separated (they overlap).

Moreover, recent data (BEA 2017) shed more light on absolute over-accumulation of capital and fragile safety of the markets: "profits from current production decreased $48.4 billion, or 2.3 percent (quarterly rate), in the first quarter [of 2017]. Domestic profits of financial corporations decreased $27.9 billion, domestic profits of nonfinancial corporations decreased $11.1 billion, and rest-of-the-world profits decreased $9.4 billion." CBO has not sufficiently taken into account this continued over-accumulation of capital in its rosy outlook updated in June 2017.

Tables 18–21 in Appendix A contain additional detailed information on the current and next industrial cycles in scenario I as well as in scenario II. The suggested chronological positioning is mostly plausible, in the author's opinion, based on the available incomplete information at the end of 2016 and beginning of 2017.

Outlooks in scenarios I and II through 2335

The exposition turns to behavioural reproduction tests. They have revealed very strong sensitivity of projected dynamics to initial conditions and to parameters' magnitudes mostly because of re-switching in d in (8) and especially in v_c in (24). The surmised limit cycles in H-1 are substituted by more or less regular cycles in H-2 that are never quite identical in simulations runs even in remote time segments.

A period of industrial cycle declines along increasing time. A period of very remote prospective industrial cycle is 4–5 years in scenario I and 5–6 years in scenario II (Figure 13, Tables 16–17).

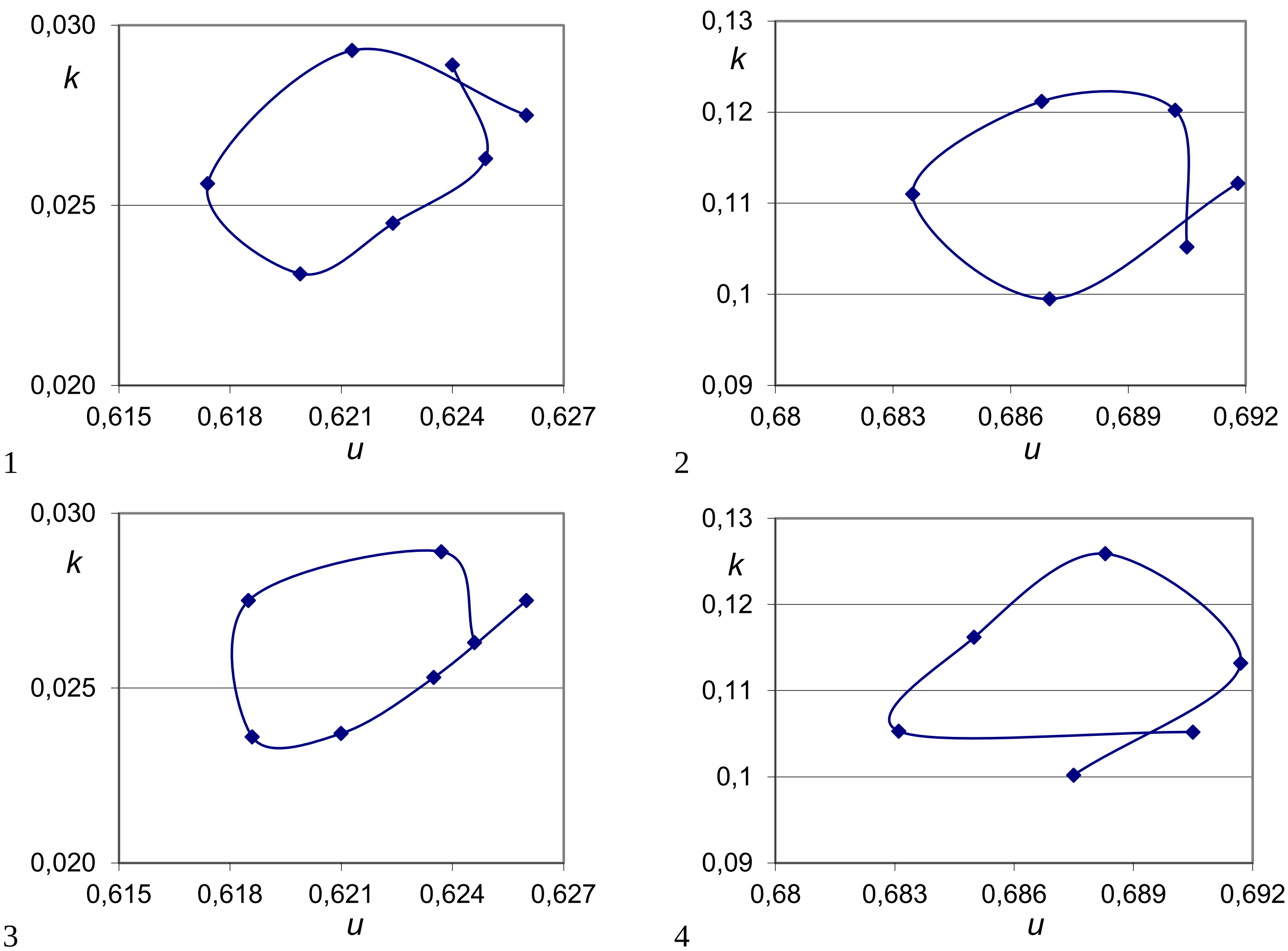


Figure 13. Clockwise evolution of relative labour compensation *u* vs. accumulation rate *k* in two adjacent industrial cycles on scatter graphs in scenario I (panel 1 – 2313–2319, panel 3 – 2319–2325) and in scenario II (panel 2 – 2317–2322, panel 4 – 2322–2327)

Table 16. Two pairs of two adjacent regular cycles generated by H-2

Property	Scenario I		Scenario II	
Time segment of 2 cycles approximation from peak to peak	2313–2318–2324	2324–2329–2335	2317–2321–2326	2326–2330–2335
Approximate period of each cycle from peak to peak	5 and 6	5 and 6	4 and 5	4 and 5

Table 17. Average magnitudes for approximations of two adjacent regular cycles

Economic indicator	Scenario I		Scenario II	
	2313–2324	2324–2335	2317–2326	2326–2335
Employment ratio *v*	0.945	0.945	0.956	0.956
Relative labour compensation *u*	0.622	0.622	0.688	0.688
Capital-output ratio *s*	2.571	2.643	1.253	1.250
Capital accumulation rate *k*	0.026	0.026	0.113	0.113
Rate of surplus value $(1 - u)/u$	0.608	0.609	0.454	0.453
Profit rate $(1 - u)/s$	0.147	0.143	0.249	0.249
Surplus value *S* (thousand workers)	47596	46572	71304	71808
Investment $\dot{K}$ (bln $ 2009/y)	583	592	(10^6)*2.55	(10^6)*3.30
Labour value of investment $\dot{K}/a$	1249	1223	8065	8128

Conclusion

This paper substantiates the *Guardian* (Business leader) view: "…the US has already enjoyed one of the longest periods of economic expansion on record... A recession is looming – and a recession delayed is only worse. Let's hope it's not a full-blown crash." Still besides such a plain hope this paper offers considerably more.

This paper tests the deterministic and probabilistic form of hypothetical law of capital accumulation (H-2) statistically for base period of the US economic evolution, 1979–2016 (3 Q). H-2 subordinates growth of labour compensation to growth of output per worker. As a result the achieved levels of profit rate in 1997–1999, 2004 and in 2014 (just before the onset of relative capital over-accumulation) were only to some extent lower than the maximal post-war profit rate observed in 1966 (0.180). On the decline of the industrial cycle, relative over-accumulation of capital continues after 2014, and absolute in both forms – since 2015. Consequently, internationalized capitalism is moving to explosion of its contradictions and to sharpening of geopolitical tensions.

Computer simulations reveal that phase variables (*k, s, v, u*), profit rate, growth rates of output per worker and real labour compensation as well as some other variables fluctuate coherently. These middle-term fluctuations are anharmonic and sensitively bounded. H-2 generates next industrial cycles with a period of about 7–9 years; regular cycles are simulated with a period of fluctuations of about 4–6 years in XXIII century in the extreme condition tests.

The dynamics of the base period are extrapolated in inertia scenario I; total profit over 2016–2057 is maximized by capitalists in mobilizing scenario II. In result of policy optimization, best on this criterion, the magnitudes of the five parameters are found. These essentially define the long-term profitability, transitions to regular cycles and regular cycles themselves that are rather sensitive to alterations in initial conditions and in parameters' changes.

The fundamental contradictions between social character of production and private property on means of production, between *value* and *use-value* of commodity (especially of *labour power* as commodity) are the most essential. A strive of capital dominated by its relentless financial arm to higher profit and higher profitability hides behind the *explosive and implosive nature* of capitalist reproduction in scenarios I and II based on unaltered and altered H-2, respectively. The apparently sudden crisis of over-production will soon follow from this law. Capital strives already to create for itself a favourable long-term macroeconomic environment in its aftermath.

The recovery from the next crisis of industrial cycle will last until 2018–2021 when the pre-crisis maximum of net output of 2016 is restored and until 2019–2022 when the pre-crisis maximum of employment of 2016 is reached again. The industrial cycle will run until 2024 in scenario I or up to 2025 in scenario II. The subsequent industrial cycles in both scenarios will be completed in 2031.

Scenario II substantially overcomes wide-spread (if not prevailing) short termism of "quarterly capitalism" in scenario I. An implementation of mobilizing scenario II, strategically focused on long term, would require against inertia scenario I the substantially increased accumulation rate and raised capital investment, reduced floating, latent and stagnant relative overpopulation (redundant labour force), as well as more deliberately controlled labour compensation. Consequently, performance indicators of capitalist production (employment ratio, output-capital ratio, profitability, profit and surplus value) could be increased as well as positive changes could occur in the workers' living standards.

Inertia scenario I and mobilizing scenario II anticipate typical (for capitalism in general and for state-monopoly capitalism in particular) recurrence of over-production and paroxysms. In scenario I, more likely than in scenario II, the coming American crisis will escalate into a global crisis. The latter will strengthen the former through multiple positive feedback loops. Beggar-my-neighbour policies, seductive for voters in one country or another, could promote a global slump that is not considered in this paper explicitly. A larger set of scenarios of next industrial cycles can be built around richer collection of possible national strategies and economic policies.

Policy resistance, particularly relevant for scenario II, is to be investigated in depth in future research before grasping other facets of circular stagnation of the state-monopoly capitalism.

References

Baker D, Dew B. 2017 (June). Corporate profits and investment: not moving together / *CEPR Blog*. URL: http://cepr.net/blogs/cepr-blog/corporate-profits-and-investment-not-moving-together

BEA. 2010. *A Guide to the U.S. International Transaction Accounts and the U.S. International Position Accounts* / BEA Briefing // Bureau of Economic Analysis.

BEA. 2017 (June). Technical note. Gross domestic product. First quarter of 2017 (Third Estimate). URL: https://www.bea.gov/newsreleases/national/gdp/2017/tech1q17_3rd.htm

Boddy R., Crotty J. 1975. Class conflict and macro-policy: the political business cycle / *Review of Radical Political Economics* 7 (1): 1–19.

Business leader. 2017 (March 12). Trump is set to win the battle on interest rates, but US economy will pay the price / *The Guardian*. URL: https://www.theguardian.com/business/2017/mar/12/victory-interest-rate-rise-donald-trump-us-economy-will-pay CBO.

CBO. 2017 (January). *The Budget and Economic Outlook: Fiscal Years 2017 to 2027*. / The Congress of the United States // Congressional Budget Office. URL: https://www.cbo.gov/publication/52370

CBO. 2017 (June). *An Update to the Budget and Economic Outlook: 2017 to 2027* / The Congress of the United States // Congressional Budget Office. URL: https://www.cbo.gov/publication/52801

Economic Report of the President 2017. 2016 (December). Washington, D.C. GPO.

Ryzhenkov A. V. 2010. The structural crisis of capital accumulation in the USA and its *causa prima // Proceedings of the 28th International Conference,* July 25 – 29, 2010, Seoul, Korea. The System Dynamics Society. Ed.by Tae-Hoon Moon.
URL: http://www.systemdynamics.org/conferences/2010/proceed/papers/P1353.pdf
http://www.systemdynamics.org/conferences/2010/proceed/supp/S1353.pdf

Shaikh N. The financial industry needs to start planning for the next 50 years, not the next five / *Harvard Business Review* // Digital article. URL: https://hbr.org/2017/07/the-financial-industry-needs-to-start-planning-for-the-next-50-years-not-the-next-five

Sterman J. 2000. *Business Dynamics*. Boston a.o.: Irwin, McGraw-Hill.

Summers L.H. 2017 (February 16). Is corporate short-termism really a problem? The jury's still out / *Harvard Business Review* // Digital article. URL: https://hbr.org/2017/02/is-corporate-short-termism-really-a-problem-the-jurys-still-out

Theil H. 1966. *Applied Economic Forecasting*. Amsterdam: North-Holland Publishing Company.

Appendix A
The Phases of Next Industrial Cycles

This paper supports and elaborates the author’s research conclusion in the middle of November 2016 on the US heading toward a crisis in 2017. Although the filtered signals from business press below point in the same direction, it seems at the very early days of July 2017 that this paper is possibly not completely free from some bearish bias in projecting cyclic inflexions. The length of critical material and information delays in processes that result from relative and absolute capital over-accumulation could be underestimated in H-2. Consequently, the crisis may start in simulations maintained by this model earlier than in reality. The experience of H-2 applications will help in its subsequent perfecting.

Table 18. The phases of next industrial cycles in inertia scenario I, 2014–2027

Economic indicator	Boom			Crisis		Recovery and boom		Crisis	
	2014	2015	2016	2017	2019	2023	2024	2025	2027
NNP *P*			max		min		max		min
Investment $\dot{K}$		max			min		max		min
Employment ratio *v*			max		min		max		min
Capital intensity *K*/*L*					max	min			max
Capital-output ratio *s*		min			max		min		max
Relative labour compensation *u*			max			min	max		
Profit rate *R*	max				min		max		min
Surplus value *S*		max			min		max		min
Profit *M*		max			min		max		min
Labour compensation *w*				max	min			max	
Output per worker *a*		max	min	max	min			max	
Total labour compensation *wl*			max		min		max		min
Consumption per head *vw*			max		min		max		min
Capital accumulation rate *k*		max			min		max		min
Labour value of investment $\dot{K}/a$		max			min		max		min
Employment *L*			max		min		max		min

Table 19. The phases of next industrial cycle in scenario I

Phase of industrial cycle	Phase period	Quantity of years
Crisis and depression	2017–2019	3
Recovery	2020	1
Boom	2021–2024	4
Complete cycle	2017–2024	8

For the crisis 2017–2019 in the industrial cycle up to 2024, *R* (maximum in 2014), $\dot{K}$, $m = 1/s$, *S*, *M*, *a*, *c*, $\dot{K}/a$ (maximum in 2015) are leading indicators; *P*, *v*, *u*, *vw*, *wL*, *L* are coinciding indicators; *w*, *a* (maximum in 2017), *s* and *K/L* (maximum in 2019) are lagging indicators. For the crisis of 2025–2027 in the industrial cycle up to 2031 coinciding indicators include *P*, *R*, $\dot{K}$, *u*, *v*, *m*, *S*, *M*, *vw*, *wL*, *L*, *k* and $\dot{K}/a$ (maximum in 2024); on the other hand, *w*, *a* (maximum in 2025), *s* and *K/L* (maximum in 2027) are lagging indicators.

Table 20. The phases of next industrial cycles in scenario II, 2014–2027

Economic indicator	Boom			Crisis	Recovery and boom			Crisis	Recovery
	2014	2015	2016	2017	2019	2024	2025	2026	2027
NNP *P*			max	min			max		
Investment $\dot{K}$		max		min		max		min	
Employment ratio *v*			max	min		max		min	
Capital intensity *K*/*L*				max	min				
Capital-output ratio *s*		min		max			min	max	
Relative labour compensation *u*			max		min			max	
Profit rate *R*	max			min		max		min	
Surplus value *S*		max	min			max		min	
Profit *M*		max	min				max	min	
Labour compensation *w*		max		min					
Output per worker *a*		max	min						
Total labour compensation *wl*			max				max	min	
Consumption per head *vw*			max				max	min	
Capital accumulation rate *k*		max		min			max		min
Labour value of investment $\dot{K}/a$		max		min			max	min	
Employment *L*			max	min			max	min	

Table 21. The phases of next industrial cycle in scenario II, 2017–2025

Phase of industrial cycle	Phase period	Quantity of years
Crisis	2017	1
Recovery and boom	2018–2025	8
Complete cycle	2017–2025	9

For the crisis in 2017 in industrial cycle up to 2025 *R*, $\dot{K}$, *m* =1/*s*, *S*, *M*, *w*, *a*, *c* and $\dot{k}/a$ are leading indicators; *P*, *v*, *u*, *vw*, *L* and *wL* are coinciding indicators; *K/L* and *s* are lagging indicator. For the crisis in 2026 in the industrial cycle up to 2031 leading indicators include $\dot{K}$, *v*, *R*, *S*, coinciding indicators contain *P*, *m* =1/*s*, *M*, *vw*, *wL*, *L*, *k* and $\dot{k}/a$, lagging indicators contain *u*.

Additional information on the economy heading to recession

Objective evidence accumulates that the US economy has been heading toward the crisis indeed (domestic production and sales of autos have dropped, retail stores have been closed in masse, the US equity market capitalization to GDP ratio is close to a past peak before "great recession" of 2007–2009, stock markets are feeding themselves, etc.). Abridged sources of these signals – that point to a crisis next after "great recession" – follow:

Bain M. 2017 (April). US retailers are on pace to close more stores in 2017 than in the 2008 Great Recession / Reuters. URL: https://qz.com/967055/us-retailers-are-on-pace-to-close-more-stores-in-2017-than-in-the-2008-great-recession-m-bebe

Carey N. 2017 (July) U.S. auto sales fall for fourth straight month in June / Reuters. URL: https://www.reuters.com/article/us-autos-sales-usa-idUSKBN19O1PJ

Huebscher R. 2017 (June). Are US equities entering the death zone? / MarketViews™. URL: http://www.marketviews.com/rmg/are-us-equities-entering-the-death-zone