Controlling Employment, Profitability and Proved Non-Renewable Reserves in a Theoretical Model of the U.S. Economy

Alexander V. RYZHENKOV

Institute for Economics & Industrial Engineering
Siberian Branch of Russian Academy of Sciences
17 Academician Lavrentiev Avenue
Novosibirsk, 630090, Russia
Fax: +007 383 330 25 80
E-mail: ryzhenko@ieie.nsc.ru

Abstract

This paper elaborates the original theoretical law of capital accumulation that (in its initial or transformed form) gives birth to scenarios of macroeconomic evolution. The state variables are relative labour compensation, employment ratio, gross unit rent, produced capital-output ratio, proved non-renewable reserves-output ratio, desired proved non-renewable reserves-output ratio, and depletion of non-renewable reserves per unit of net output. This law was presented in the author's earlier books and papers.

Worsening profitability and declining employment ratio over the long term characterise the inertia scenario for the U.S. economy over 1991–2107. Excessive depletion of proved non-renewable reserves contributes to these disadvantageous tendencies.

This paper demonstrates how a forward-looking investment policy based on proportional and derivative control over proved non-renewable reserves brings about their extension, raises profitability and employment over the long term in the first normative scenario in comparison with the inertia scenario.

Long waves with ups and downs of substantial amplitude in profitability, in employment ratio and in other indicators represent the shortcomings of this normative scenario. These shortcomings necessitate elaboration of closed-loop control over total profit and employment ratio in addition to closed-loop control over proved non-renewable reserves.

The initial theoretical law is transformed into control law of capital accumulation. The present operational application of this control law to the U.S. economy reveals and explains substantial lasting improvements in profitability, employment ratio, labour productivity and real labour compensation in the second normative scenario compared with the first normative scenario that are achieved together with extending proved non-renewable reserves.

Keywords: Capital accumulation, proved reserves, long wave, closed-loop control, excess income levy, the U.S. economy

Introduction

Strengthening the system dynamics paradigm necessitates building its solid core (Forrester, 1983). Adherence to this core building motivated the earlier books and papers that introduced and refined a first hypothetical Law (HL1) of capital accumulation constrained by natural capital (Ryzhenkov 2000, 2001, 2002, 2003). Its state variables are the relative labour compensation, employment ratio, gross unit rent, produced capital-output ratio, natural capital-output ratio, indicated natural capital-output ratio, and expense of the natural capital per unit of net output.

An application of HL1 in its probabilistic form together with extended Kalman filtering to the U.S. macroeconomic data 1958–1991 identified unobservable components of this law. In this empirical application the notion of natural capital was narrowed to proved mineral reserves since the available statistical sources did not provide consistent data on other kinds of natural capital.[1] Despite these limitations, it was shown that long wave was a dominant non-equilibrium quasi-periodic behavioural pattern of the U.S. capital accumulation dependent on investment policy in proved non-renewable reserves.

The previous paper (Ryzhenkov 2005) has unveiled and explained the paradox that profit is the decisive factor of long waves under capitalism and could be the key for smoothing them. That paper has demonstrated that a more efficient social control over the oscillatory macroeconomic system requires a substantial reshaping of primary income distribution that takes into explicit account this dual characteristic of profit. The present paper elaborates this duality by introducing excess labour compensation levy and subsidy on pre-levy primary profit.

The above mentioned previous paper has defined a second hypothetical Law (HL2) of capital abstracting from explicit constraints of natural resources. The main state variables are the labour productivity, relative labour compensation, employment ratio, and capital-output ratio; a comprehensive Phillips equation governs a rate of growth of real labour compensation. An application of HL2 in its probabilistic form together with an

[1] The terms reserve(s), proved reserve(s), total resource(s) are in agreement with the UN Framework Classification for mineral reserves/resources. See ENERGY/WP.1/R.70 ECE-UN document [17 February 1997]: United Nations International Framework Classification for Reserves/Resources – Solid Fuels and Mineral Commodities: Geneva.

extended Kalman filtering to the U.S. macroeconomic data covering 1969–2002 and computer simulation runs have shown that long wave resulted from the socio-economic relations was a viable pattern of capital accumulation. HL2, unlike HL1, includes a hypothetical partial law for the labour supply as a non-linear function of capital intensity. Although this partial law is not a necessary condition for long waves, it helps to portray them more accurately.

The characteristic of the inertia scenario based on HL2 in its deterministic form is a strengthening of the secular tendency of the general profit rate to fall. This is not accepted by the U.S. state and business leadership pursuing a pro-growth stabilization policy at least since 2001.

This previous paper (Ryzhenkov 2005) has uncovered long-term advantages of the overt closed-loop control over total profit depending on the difference between desired and current employment ratios. Based on examination of causal linkages, the supposed control law (CL) of primary distribution of income is derived as a modification of the non-probabilistic form of HL2. The new equation, representing feed-forward control, substitutes the comprehensive Phillips equation for real labour compensation of the initial HL2. A controlled transition to a non-trivial stationary state defined explicitly alleviates the tendency of general profit rate to fall, maintains deliberately high employment ratio and upholds total profit.

The comparison of the basal scenario (based on CL) to the inertia scenario (based on HL2) has demonstrated that the supposed closed-loop control *could bring about*, *each year*, *additionally* 1 trillion 1996 dollars of profit and 5 million of jobs in the U.S. (on the average for 2001–2057). This earlier paper has shown robustness of the proposed CL as well.

The purpose of the current paper is a synthesis of the CL and HL1 based on their deterministic forms. The focus is again on pro-growth stabilization policy that brings about shifts in distribution of net value output between the two main social classes under an explicit constraint of proved mineral reserves. The restricted presentation of U.S. natural capital by proved mineral reserves up to the year 1991 only is due to well-known limitations of the BEA statistics (*Survey of Current Business*, April 1994).[2] Although these data are somehow aged in the mean time, their current usage is acceptable for achieving exclusively methodological purposes of this paper.

[2] The BEA estimated value of resource reserves and changes in reserves for the period 1958–91 for major mineral resources. The minerals valued include the fuels (petroleum, natural gas, coal, and uranium), the metals (iron ore, copper, lead, zinc, gold, silver, and molybdenum), and other minerals (phosphate rock, sulfur, boron, diatomite, gypsum, and potash). Petroleum and gas account for the lion's share of mineral production in the USA.

The present author agrees with other experts that informed planning and decisions concerning sustainability and resource development require a long-term perspective and an integrated approach to land-use, resource, and environmental management worldwide. This paper offers important generic building blocks for implementing this integrated approach that can be realized by international co-operative efforts.

1. The main model assumptions

This paper considers the American economy as restricted to a certain degree by proved mineral reserves while total (non-renewable) mineral resources are not explicit constraints. Import from the rest of the world can substitute extracting non-renewable resources in the USA at least partially. It is assumed in this paper additionally that renewable and environmental resources do not constrain production explicitly.

Produced capital (fixed assets) and proved mineral reserves are essentially complementary to each other and are also substitutes to some degree depending on the factors distributive shares and employment ratio. These two different kinds of use values are measured in the same monetary units as the net output (in constant U.S. 1996 dollars).

The other important premises are such:

(1) two social classes (capitalists and labourers); the state enforces property rights, yet the cost of such an enforcement is not treated explicitly;

(2) three factors of production – labour force, produced capital (fixed assets), proved mineral reserves – are homogenous and non-specific;

(3) only one aggregated good is produced for consumption, investment and circulation, its price is identically one;

(4) production (supply) equals effective demand;

(5) all labour compensation consumed; the gross mineral rent and a part of profit saved and invested;

(6) steady growth in the labour force that is necessarily not fully employed;

(7) a growth rate of real labour compensation rises in the neighbourhood of full employment;

(8) a change in capital intensity and technical progress are not separable due to a flow of invention and innovation over time;

(9) a qualification of the labour force corresponds to technological requirements.

The model abstracts from over-production of commodities inherent in over-production of capital during certain phases of industrial cycles. The assumption (5) corresponds to the immediate aim of capitalist production. It may be a key to explanation of the fact that the rate of profit on capital of order of 12 or 15 per cent per annum is compatible with a rate of economic growth of two or three and half per cent per annum.

The assumption (6) means that the labour force grows exponentially over time. This assumption may be substituted by an assumption of an asymptotic growth or by another hypothesis (Ryzhenkov 2005).

The focus of research is on pro-growth stabilization policy that brings about shifts in primary income distribution between two main social classes.[3] This research envisages in particular reshaping of primary distribution of income that may enhance sustainable development.

2. The detailed assumptions and model equations

The model is formulated in continuous time. Time derivatives are denoted by a dot, while growth rates will be indicated by a hat. The model of the (implicitly open) U.S. economy consists of the following equations:

$$P = K/s; \tag{1}$$

$$a = P/L; \tag{2}$$

$$u = w/a; \tag{3}$$

$$\hat{a} = m_1 + m_2 \hat{K/L} + m_3 \psi(\hat{v}) + m_5 \hat{F/L}, \tag{4}$$

where $\psi(\hat{v}) = \text{sign}(\hat{v}) |\hat{v}|^j$, $m_1 \geq 0$, $1 \geq m_2 \geq 0$, $m_3 \geq 0$, $m_5 \geq 0$, $0 < j$;

$$\hat{K/L} = n_1 + n_2 u + n_3 (v - v_c) + n_5 Z/P, \tag{5}$$

where $n_2 \geq 0$, $n_3 \geq 0$, $n_5 \geq 0$, $1 > v_c > 0$;

$$v = L/N; \tag{6}$$

$$N = N_0 e^{nt}, \; n = const \geq 0, \; N_0 > 0; \tag{7}$$

$$\hat{w} = -g + rv + b\hat{K/L} + q\hat{F/L}, \; g \geq 0, \; r > 0; \tag{8}$$

$$P = C + \dot{K} + Y = wL + (1 - k)M + \dot{K} + Y; \tag{9}$$

$$\dot{F} = Y - Z; \tag{10}$$

[3] Different types of property income payable out of the value added created by production (profit before taxes, interest, resource rent) belong to primary income of owners of capital (capitalists). Primary income of labour consists mainly of wages and salaries of employees, employers' social contribution and imputed labour income of self-employed. See for details (Commission of the European Communities – Eurostat et al., 1993: 157–182).

Only net value added created by production is considered in this paper. The primary income of government is not treated separately, having been included in property income on this stage of research.

$$Z = eP,\ 0 < e < 1; \tag{11}$$

$$\dot{y} = [o_1(c - f) + o_2\hat{f}]y,\ \ y = Y/P \geq 0; \tag{12}$$

$$\hat{X} = i; \tag{13}$$

$$f = F/P,\ f > 0; \tag{14}$$

$$c = X/P,\ c > 0; \tag{15}$$

$$\hat{e} = \hat{P}(e_1/e - 1),\ \ e > e_1 \geq 0; \tag{16}$$

$$\dot{K} = kM = k[(1 - w/a)P - Y] = k[(1 - u)P - Y], \tag{17}$$

where $0 < k \leq 1$.

Equation (1) postulates a technical relation between the produced capital stock (K) and net output (P). The (produced) capital-output ratio is denoted by s. Equation (2) relates labour productivity (a), net output (P) and labour input or employment (L). Equation (3) describes the labour compensation share in net output or relative labour compensation (u).[4]

Equation (4) is an extended technical progress function. The rate of change of produced capital intensity, K/L, the direct scale effect, $m_3\psi(\hat{v})$, and the rate of change of natural capital intensity, F/L, are factors determining the rate of change of labour productivity.

Equation (6) defines the employment ratio (v) as a result of the buying and selling of labour-power. Labour force grows exponentially in (7). In the equation (8), the rate of change of the labour compensation rate (w) depends on the employment ratio (v), as in the usual Phillips relation, and on the rates of change of produced

[4] The reader may be well informed that payroll taxes belong to other taxes on production and imports; they do not include compulsory social security contributions paid by employers or any taxes paid by the employees themselves out of their wages or salaries (Commission of the European Communities – Eurostat et al., 1993: 172). Among other subsidies on production there are subsidies on payroll or workforce, these may consist of subsidies payable on the total wage or salary bill (Ibid.: 174). Net receipts from taxes on production and imports are treated as primary incomes of governments (Ibid.: 157). Economists generally believe the employer tax is ultimately paid by labourers in the form of relatively lower wages (Economic Report of the President, 2007: 90).

A part of payroll taxes may be used for providing health services (for example, Medicare spending in the USA is financed by a combination of payroll taxes, general revenue, and premiums paid by beneficiaries). These and similar processes that do not belong to primary distribution of income are not treated explicitly in this paper.

capital intensity (K/L) and of natural capital intensity (F/L), additionally. The produced capital intensity (K/L) is a proxy for qualification of the labourers.

In the equation (9), final private and public consumption is $C = P[u + (1– k)(1 – u – y)]$. The net formation of produced fixed capital is $\dot{K} = kM$, where K is produced fixed assets.

The gross accumulation of proved mineral reserves Y equals the gross mineral resource rent measured in net output units.[5] The letter y stands for the gross mineral unit rent.

There is a potential threat of complete depletion of remaining mineral resource (a sum of proven reserves and undiscovered resource, in Sterman's paper terminology).[6] With attentiveness to this caveat, this paper assumes that in next hundred years the remaining aggregated mineral resource in the USA (and in the world) will not be depleted wholly and that it will not become uneconomical. The equation (12) requires, in other words, non-zero remaining mineral resources that are of economic interest or potentially economic.

Profit is defined as a residual ($M = (1 – u – y)P$). Equations (9) and (17) show that profit and incremental produced capital ($\dot{K}$) are not equal in monetary terms if the investment share $k < 1$. Considering the latter as a variable and reflecting the labourers saving is left for a future research.

In the equation (10), $\dot{F}$ is a net accumulation (loss) of the proved mineral reserves (F). In this equation, Z is the depletion of proved mineral reserves – the decline in the stock (F) associated with extraction in the current period. This outflow is mitigated by inflow Y that represents additions to the proved mineral reserves due to improvements in recovery techniques, as well as owing to investment in resource exploration and development in the current period.

---

[5] Constant 1996 U.S. dollars are used to measure ratios of extraction from and addition to proved reserves to net output for each year. These ratios are e and y respectively.

[6] According to that paper (Sterman, 2002: 514): "As exploration adds to the stock of proven reserves, the stock of undiscovered resource falls. *Ceteris paribus*, the smaller the stock of resources remaining to be discovered, the lower the productivity of exploration activity must be (on average), and the smaller the rate of addition to proven reserves will be for any investment rate. In the limit, if the stock of undiscovered resource fell to zero, the rate of additions to proven reserves would necessarily fall to zero…How large the resource base is, what the costs of backstop technologies are, and whether a backstop technology can be developed before depletion constrains extraction and reduces economic welfare are empirical questions, not matters of faith. The very possibility that depletion might matter cannot be assumed away, to be made untestable with models in which resources are assumed infinite, the price system always functions perfectly, delays are short and technology provides backstops at low cost."

The rate of change of the capital intensity (K/L) in the equation (5) is a function of the following factors: relative labour compensation (u), the difference between real employment ratio and some base magnitude ($v - v_c$), depletion of proved reserves in relation to net output (Z/P). The rate of growth of produced capital intensity depends positively on the relative depletion of proved mineral reserves (an application of the principle 'a pollution prevention pays'), in particular.[7] A high labour compensation share and high employment ratio foster mechanisation (automation) as well.

The desired proved mineral reserves (X) may remain constant, decrease or increase exponentially in the equation (13). The equation (12) defines an investment policy that is aimed to develop the proved mineral reserves in accordance with the desired proved mineral reserves. The proved mineral reserves-output ratios – real (f) and desired (c) – belong to the state variables in the equations (14) and (15). A combination of proportional and derivative control over this form of natural capital is attainable hereby if the first parameter is positive ($o_1 > 0$), whereas the second parameter in this equation is negative ($o_2 < 0$). It is likely that this a priory expected combination has been absent in the reality on the macro scale (see section 4 below) possibly due to bounded rationality of economic subjects and (or) for another reason.

I assume that the relative depletion of aggregated proved mineral reserves (e) asymptotically declines to the minimal level ($e_1 = const \geq 0$) due to substitution and structural change according to the equation (16) where $\hat{e} < 0$ for $\hat{P} > 0$. Obviously, the higher the rate of economic growth and the lower the minimal depletion of proved mineral reserves per unit of net output attainable in the USA, the faster proved mineral reserves are relative depleted. In practice, for particular natural resources (for example crude oil) the relation $|\hat{e}| > \hat{P}$ is possible, still it is assumed that for the aggregated proved mineral reserves the relation $|\hat{e}| \leq \hat{P}$ is valid.

The equation (16) is a better approximation than $e = \text{const} \geq 0$. Another approximation could be easily implemented. A tendency to greater substitution of mineral extraction by import is modelled in extreme condition tests for the U.S. economy (see section 4 below again).

Three profit rates are defined for this economy. The first is the *average* rate of return on produced capital $(1 - u - y)/s$. The second is the *general* one; it measures a ratio of the economic surplus to the sum of produced capital and natural capital in the form of proved mineral reserves $(1 - u - e)/(s + f)$. The third is a *biased* profit rate $(1 - u)/s$ that is more easily calculated based on commonly available statistics.

[7] Extraction of minerals brings about directly or indirectly environmental damage of different kinds that is still not modeled explicitly. The relative depletion of proved mineral reserves (e) is the quantity of depleted proved mineral reserves per unit of net output.

The rate of net mineral rent is $(y - e)/f$. The general rate of profit is a weighted average of the rate of return on produced capital and the rate of net mineral rent: $(1 - u - e)/(s + f) = [s/(s + f)](1 - u - y)/s + [f/(s + f)](y - e)/f$.

3. The first hypothetic law in a compact form (HL1)

In a compact form, the model consists of the seven non-linear ordinary differential equations (18)–(24) that define the *hypothetical Law of capital accumulation* (HL1):

$$\dot{s} = -\frac{1}{1-m_5}\{m_1 + (m_2 + m_5 - 1)[n_1 + n_2 u + n_3(v - v_c) + n_5 e] + m_3\psi(\hat{v}) + m_5\hat{f}\}s, \tag{18}$$

$$\dot{v} = \{k\frac{1-u-y}{s} - [n_1 + n_2 u + n_3(v - v_c) + n_5 e] - n\}v, \tag{19}$$

$$\dot{u} = \{-g + rv - m_1 + (b + q - m_2 - m_5)[n_1 + n_2 u + n_3(v - v_c) + n_5 e] - m_3\psi(\hat{v}) + (q - m_5)(\hat{f} - \hat{s})\}u, \tag{20}$$

$$\dot{f} = \{(1 - m_5)\frac{y-e}{f} - m_1 - m_2[n_1 + n_2 u + n_3(v - v_c) + n_5 e] - m_3\psi(\hat{v}) - (1 - m_5)(\hat{v} + n)\}f, \tag{21}$$

$$\dot{c} = (i - k\frac{1-u-y}{s} + \hat{s})c, \tag{22}$$

$$\dot{y} = [o_1(c - f) + o_2\hat{f}]y, \tag{23}$$

$$\dot{e} = \{k\frac{1-u-y}{s} + m_1 + (m_2 + m_5 - 1)[n_1 + n_2 u + n_3(v - v_c) + n_5 e] + m_3\psi(\hat{v}) + m_5(\hat{f} - \hat{s})\}(e_1 - e), \tag{24}$$

where $s > 0$, $1 \geq v > 0$, $1 \geq u > 0$, $f > 0$, $c > 0$, $1 > y \geq 0$, $1 > e \geq 0$.[8] The requirement for denominators to be positive is skipped. If $\dot{K} > 0, \dot{F} > 0$ for an every instant of time, the system (18)–(24) defines a *strongly sustainable development*.

There is a continuum of the non-trivial stationary states in this model with the same positive relative labour compensation, employment ratio and relative depletion of proved reserves. A particular stationary state is defined as

[8] For details see (Ryzhenkov 2003).

$$E_a = (s_a, v_a, u_a, f_a, c_a, y_a, e_a), \quad (25)$$

where

$s_a = s_0$,

$v_a = [g + (1 - b - q)(d - n)]/r$,

$u_a = [d - n - n_1 - n_3(v_a - v_c) - e_a n_5]/n_2$,

$f_a = (1 - u_a - e_a)/d - s_a/k$,

$c_a = f_a$,

$y_a = e_a + d f_a$,

$e_a = e_1$,

$i = d$.

The produced capital stock, proved mineral reserves and net output increase thereby at the rate

$\hat{K}_a = \hat{F}_a = \hat{X}_a = \hat{P}_a = d$

that is equal to the net mineral rent rate and less than (for $k < 1$) or equal to the average profit rate (for $k = 1$). The stationary average profit rate equals $(1 - u_a - y_a)/s_a = d/k$. The both quantities ($d$ and d/k) are used as benchmarks below. The stationary produced-capital output ratio $s_a > 0$ in the equation (25) is chosen from an infinite number of possible positive magnitudes, such that stationary proved reserves-output ratio remains also positive ($f_a > 0$).

An extended Kalman filtering

The Kalman filter is a particular powerful tool for estimating unobservable part of a model (parameters and meta–parameters like variances) in one operation. Although the Kalman filter itself does not estimate the unknown parameters of the model, it provides a one-step-ahead prediction error with its covariance matrix. The prediction error decomposition of the likelihood function utilises this information. The *Vensim* professional soft-ware has served for performing such an extended Kalman filtering (EKF) in previous papers (Ryzhenkov 2001, 2002, 2005) that report about quasi-optimal estimates obtained.

The data from the official U.S. sources fed the model (1)–(17) for the period 1958–1991. The information on natural capital relates to a significant part of natural capital, namely the proved mineral reserves.

EKF realised in the VENSIM software has enabled to estimate the unobservable components of HL1. The magnitudes of the identified parameters and components of the state vector for the year 1991 follow:

$b = 0.621$, $d = 0.0384$, $e_1 = 0.0054$, $g = 0.0532$, $i = 0.0374$, $j = 0.211$, $k = 0.267$, $m_1 = 0.0145$, $m_2 = 0.100$, $m_3 = 0.011$, $m_5 = 0.089$, $n = 0.020$, $n_1 = -0.242$, $n_2 = 0.353$, $n_3 = 0.5$, $n_5 = 0.011$, $o_1 = -0.030$,

o_2 = –9.934, q = –0.008, r = 0.061, v_c = 0.925; $a_0 \approx 0.0512$, $s_0 \approx 2.052$, $c_0 \approx 13.98$, $f_0 \approx 0.1091$, $e_0 \approx 0.0087$, $y_0 \approx 0.0083$, $v_0 \approx 0.9475$, $u_0 \approx 0.6948$.

The stationary state E_a defined by the equation (25) with almost full employment in a literal sense ($v_a \approx 0.991$) is not stable, unlike a full employment stationary state in the well-known Solow neoclassical model.

The simulation run based on the HL1 produces an inertia scenario. The magnitudes of the parameters and components of the state vector are taken in this run as presented above with only two exceptions; the new exogenous growth rate of labour force is the observed average for 1990–2004: $n \approx 0.011$ (Board of Trustees 2006), the new exogenous growth rate of desired proved mineral reserves is set equal to the new stationary growth rate of net output ($i = d \approx 0.0295$) that is lower than before.[9]

This scenario projects the internal tendencies of capital accumulations into the XXI century. It is exploratory rather than normative.

4. The inertia scenario based on HL1: a falling rate of capital accumulation

Capitalists accumulate profit and expand output. New more advanced machinery is a main source of increased labour productivity. The economic growth is punctuated by recurrent slowdowns. A quasi–period of fluctuations is about 37 years. The rate of produced capital accumulation is repeatedly slowed down by the relative shortage of labour. Accelerated introduction of the living labour-saving machinery, shedding of labour enables to overcome these temporally hindrances.

A long term decline in e and f reflects several factors, including the economy's increased reliance on foreign resources and the increased efficiency in the use of fuels and other minerals. Still there is a visible secular tendency of the average profit rate (Figures 1 and 3) and employment ratio to fall (Figure 4) accompanied by a similar tendency of growth rate of labour productivity (Figure 2). The net mineral rent rate is negative over the long term (Figure 1). The rate of net mineral rent falls from zero to –0.079, that is substantially lower then the positive benchmark (d). This and all other Figures in this paper relate exclusively to the U.S. economy.

[9] Under the familiar (intermediate) assumptions, the labor force is projected to increase in the U.S. by about 0.9 percent per year, on average, 2005 through 2015. Thereafter, the labor force is projected to increase much more slowly, averaging 0.5 percent over the 2015 to 2020 period, and 0.3 percent over the remainder of the 75-year projection period up to 2080 (Board of Trustees 2006). A subsequent work could easily apply these estimations in modified scenarios.

Worsening profitability obstructs the growth in productivity that inhibits profitability, in turn. The both profit rates $(1 - u - e)/(s + f)$ and $(1 - u - y)/s$ tend to be lower and lower than the benchmark $d/k \approx 0.1103$; the growth rate of net output deviates from the benchmark ($d \approx 0.0295$) downward while the growth rate of labour productivity drops below its benchmark ($d - n \approx 0.0185$).

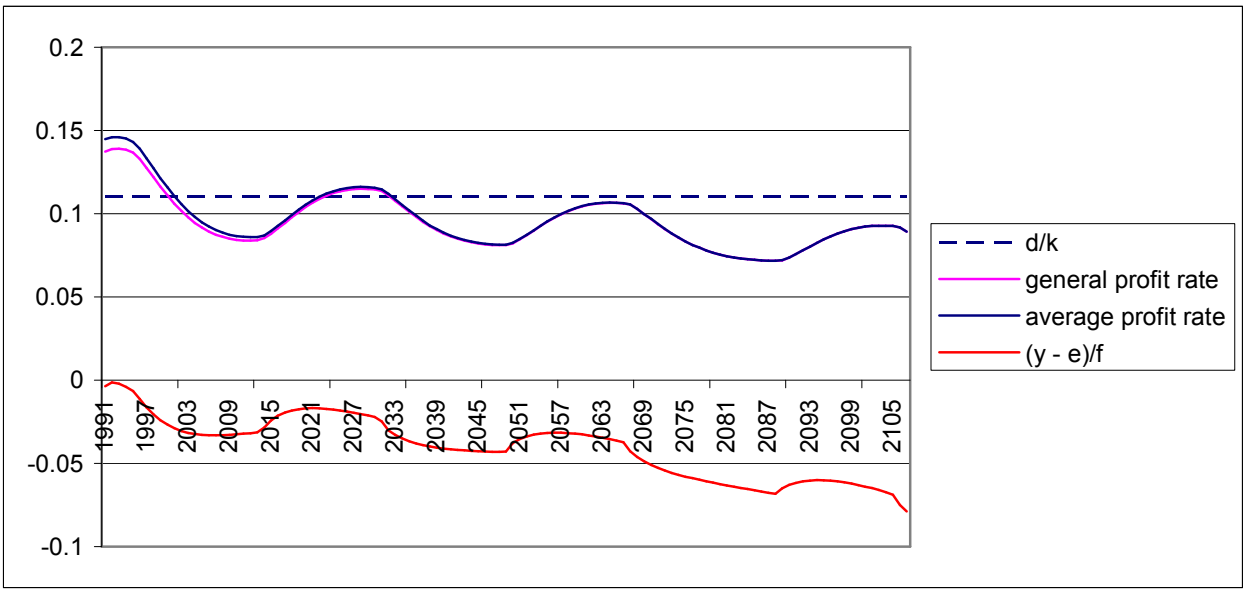

Figure 1 The average profit rate $(1 - u - y)/s$, general profit rate $(1 - u - e)/(s + f)$ versus the benchmark (d/k), and net mineral rent rate $(y - e)/f$, in the inertia scenario, 1991–2107

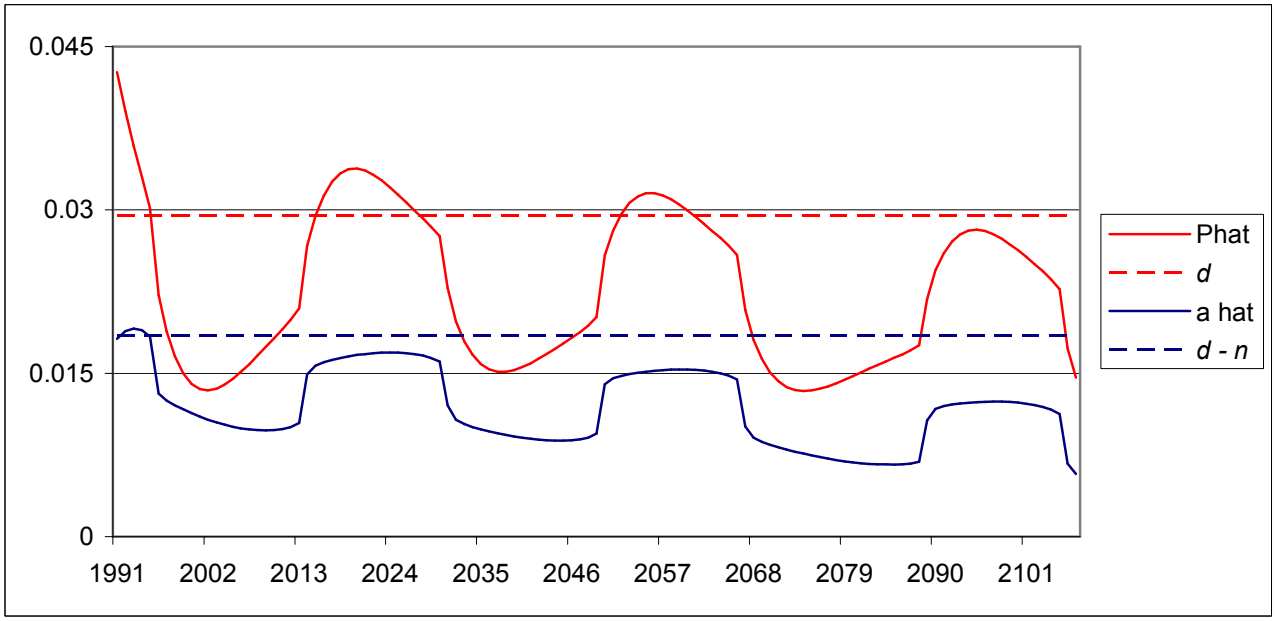

Figure 2 The growth rates of net output ($\hat{P}$) and labour productivity ($\hat{a}$) versus benchmarks (d and $d - n$, respectively) in the inertia scenario, 1991–2107

The excessive depletion of the proved mineral reserves slows the economic growth (Figure 2). The secular deceleration of the labour productivity and real labour compensation is relentless (Figures 2 and 3).

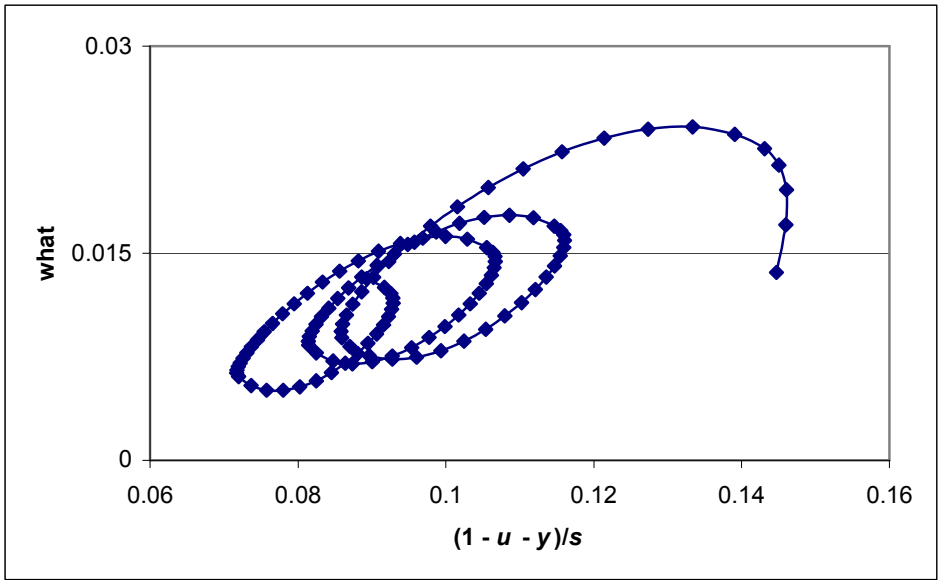

Figure 3 Average profit rate $(1 - u - y)/s$ and growth rate of real labour compensation $\hat{w}$, counter-clockwise, in the inertia scenario, 1991–2107

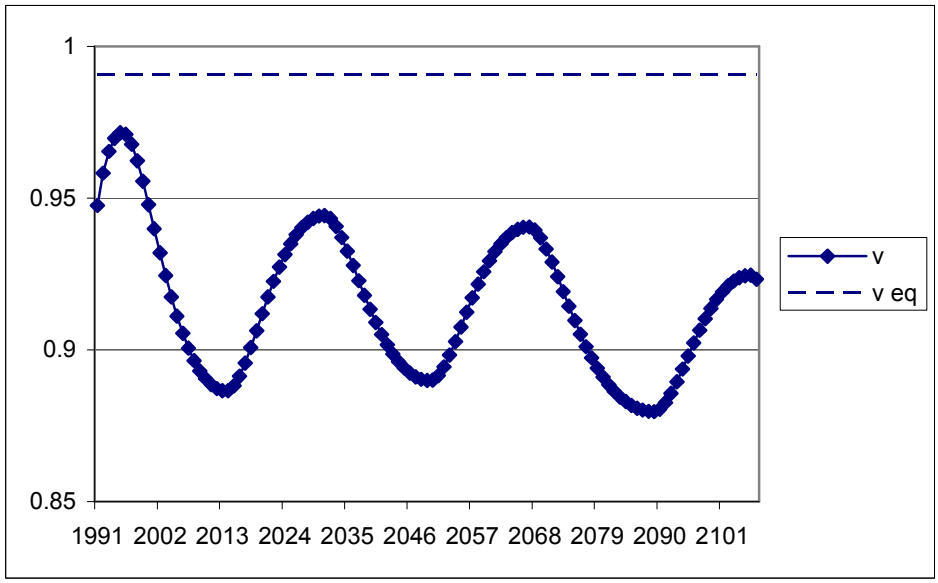

Figure 4 Employment ratio (v) versus its stationary magnitude (v eq = v_a) in the inertia scenario, 1991–2107

Let us return to the equation (12) for the time derivative of the gross unit mineral rent. According to a statistical estimation, the second parameter in this equation is negative as expected ($o_2 < 0$), whereas the first parameter is paradoxically negative ($o_1 < 0$) too (Ryzhenkov 2001, 2002a).[10] Therefore the expected combination of the proportional and derivative controls over proved mineral reserves has been probably absent in the reality.

The observable excessive depletion of some proved mineral reserves supports empirically at least partially this formal result.[11] Positive feed-back loops foster the gap between the indicated and actual proved mineral reserves that possibly destabilizes the U.S. economy. It is likely that voluminous imports of goods and services, produced abroad with a high direct or total input of minerals (such as oil, gas, metal ores), offset this destabilizing tendency only partially.[12]

---

[10] Perhaps a rationale for negative o_1 is a tendency to a greater substitution of extraction of non-renewable resources inside the USA by import. A stronger U.S. reliance on foreign resources could be reflected by a new hypothetic equation $e_1 = 0.0054(128.14f/c)$ or by another equation with a positive partial derivative $\frac{\partial e_1}{\partial(f/c)} > 0$, where e_1 is the element of the equation (16). A reservation of the national non-renewable and renewable natural resources for future generations may underline this tendency. See also footnotes 11–12 below.

[11] In my opinion, the report (Energy Information Administration 2006) provides additional empirical support for the assertion on declining proved reserves of crude oil and of some kinds of natural gas over 1977–2005 in the USA as a whole. Whether an excessive depletion of *proved* mineral reserves facilitates conservation of total non-renewable and renewable natural resources for future generations is not quite clear on this stage of research.

[12] A stronger substitution of extraction of non-renewable natural resources inside the USA by import could be modelled by lowering the magnitude of the constant e_1 from the equation (16) or by turning this constant into declining variable. Extreme condition tests for $e_1 = 0$ or for $e_1 = 0.0054(128.14f/c)$ when this variable approaches zero asymptotically while the ratio f/c declines steadily nearly to zero in these both cases do not alter results of this section qualitatively if the other conditions remain the same. Still decoupling the growth rate of labour productivity from dynamics of proved mineral reserves per labourer (additionally setting $m_5 = 0$ in the equation (4) in particular) due to a slowing growth and stagnation of production in the extraction industry in the USA ($\hat{Z}$ approaches zero) permits overcoming the tendency of growth rate of labour

In spite of these imports, the excessive depletion of proved mineral reserves counter-acts tendencies to a stable stationary growth or to stably oscillating cyclical motion. The economic fluctuations can surpass viable boundaries if multiple positive feed-back loops, involving proved reserves, continue to run unchecked.

To avoid this, a more efficient policy is necessary. The next section designs such a policy.

5. The normative scenario I based on modified HL1: extending the proved mineral reserves

The first normative scenario corresponds to a new investment policy in relation to proved mineral reserves. Although the form of the equation (12) for the gross unit mineral rent remains the same, the sign of the parameter o_1 is changed (now $o_1 = 0.0001 > 0$ instead of $o_1 < 0$). This numerical change is simultaneously structural one. It addresses the critical shortcoming of the inertia scenario, namely the excessive depletion of the proved mineral reserves.

It is reasonable to stress that the substantial numerical change in parameter o_1 of the equation (12) is the single alteration of the above compact model. Only 0.35 per cent of the net output is invested additionally in the proved mineral reserves each year on the average in 1991–2107 in relation to the inertia scenario. Still this partial redistribution of the NNP produces desirable additional positive effects over the whole period on the average:

- the growth rates of labour productivity and net output rate are increased (Figures 2 and 6);
- the proved mineral reserves instead of been excessively depleted are extended (Figure 1 and Figure 5);
- the secular fall in average and general rates of profit is moderated (Figures 1 and 5);
- there are gains in the employment ratio and growth rate of real labour compensation (compare Figures 3 and 7, Figures 4 and 8).

In the normative scenario I, the economic growth is quasi-cyclical with a period of about 32–35 years. This period is shorter than in the inertia scenario due to a higher average growth rate of labour productivity. Quasi-periodic ups and downs with substantial amplitude represent the shortcomings of this normative sce-

---

productivity to fall in 1991–2107 without over-extending the employment ratio (v) in other extreme condition tests.

These modified inertia scenarios would represent a drastically declining share of the U.S. mineral production in the world. As it is hardly realistically, the next sections apply $e_1 = const > 0$ only.

nario. The tendency to over-extending the employment ratio is especially unsafe as v tends to hit the top limit of unity (Figure 8). These shortcomings require overt closed-loop control over capital accumulation.

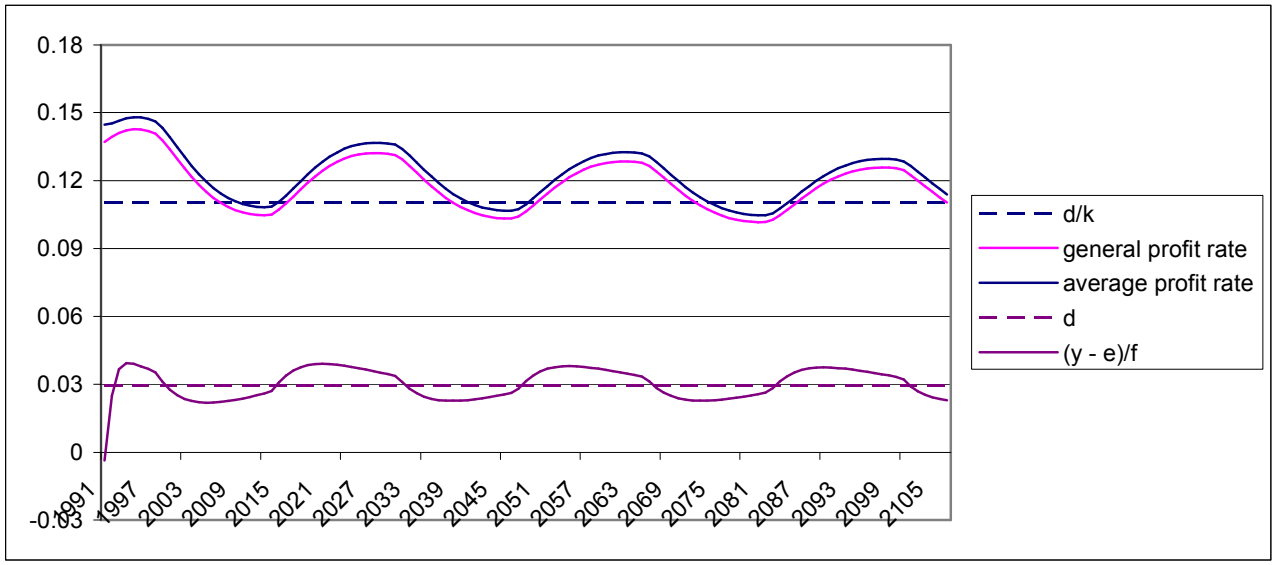

Figure 5 The net mineral rent rate $(y - e)/f$, average profit rate $(1 - u - y)/s$ and general profit rate $(1 - u - e)/(s + f)$ versus their benchmarks in the normative scenario I, 1991–2107

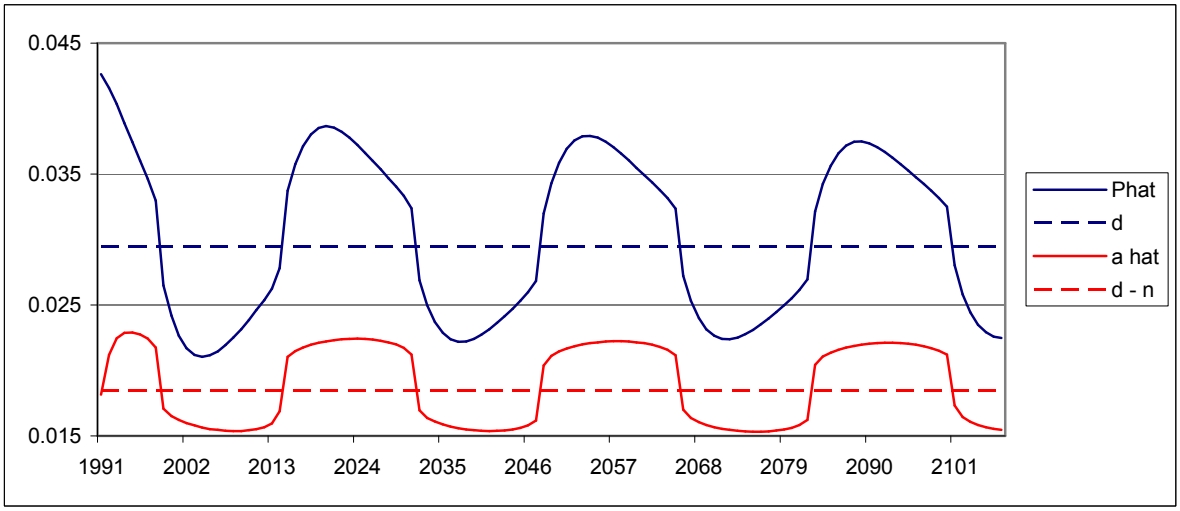

Figure 6 Growth rates of net output and labour productivity versus their stationary magnitudes in the normative scenario I, 1991–2107

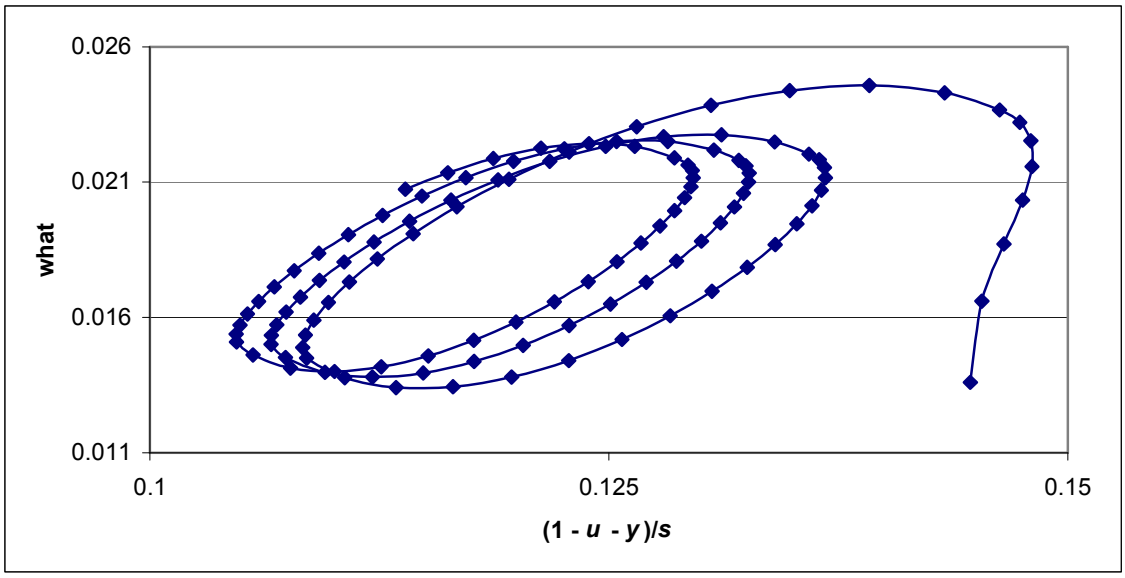

Figure 7 Average profit rate, $(1 - u - y)/s$, and growth rate of real labour compensation, $\hat{w}$, in the normative scenario I, 1991–2107 (counter-clockwise)

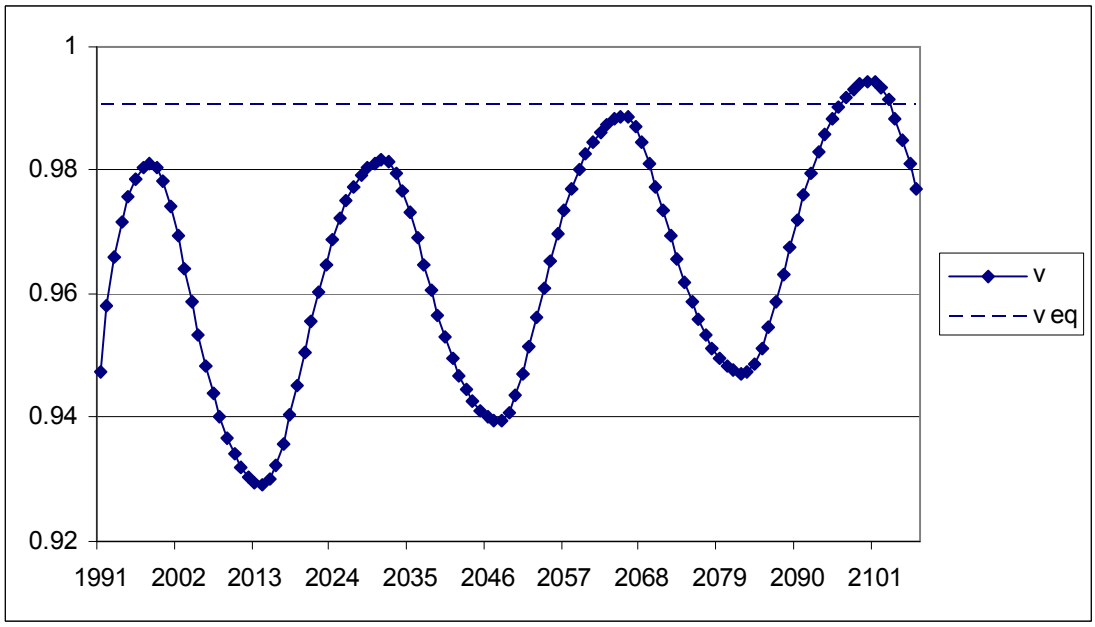

Figure 8 Employment ratio (v) versus its stationary magnitude (v eq = v_a) in the normative scenario I, 1991–2107

.

6. The normative scenario II: extending proved reserves, controlling employment and profitability

There has been substantial labour compensation moderation accompanied by accelerated growth of labour productivity in the USA after 2001. In my opinion, this moderation has been caused (skipping reference to other factors), first, by the economic crisis; second, it has been due to the state military-mobilising policy; third, outsourcing, competition with China, India and other countries have played a role too.

It has been shown in my previous paper (Ryzhenkov 2005) that setting aggregate real labour compensation at a level that is too high relative to labour productivity raises unemployment in a business-as-usual scenario. I have identified open-loop and closed-loop policies affecting real labour compensation for improving labour market performance and profitability against this business-as-usual scenario. The overt closed-loop control does not cause over-extending of the controlled economy unlike the open-loop control.

That analysis is not complete since the previous papers have not explored changes in the wage-setting and other relevant institutions implied by supposed closed-loop control over capital accumulation as a whole. In particular, it is not yet clear, first, whether such a closed-loop control is to be achieved through coercive and/or voluntary cooperation; second, what arrangement of coincidence, coercion and co-adjustment is mostly suited to provide superior social outcomes.[13]

The section 7 of the present paper (below) gives a preliminary answer to these complicated questions. A socially desirable transition to a target employment ratio, profit enhancement and an extending of proved reserves will be realised through excess income levy.

It has been assumed in the previous research that the decision-makers (the state officials, owners of capital, labourers) set timely (without delay) a desirable growth rate of total profit ($M = (1 - u)P$) depending on a difference between an indicated ($\tilde{v}$) and current (v) employment ratios:

$$\hat{M} = -\frac{\dot{u}}{1-u} + \hat{P} = o_3(\tilde{v} - v),$$

where $v < \tilde{v}$ is typical for recessions and depressions, $o_3 > 0$. This equation is to be modified now taking into account gross unit mineral rent (y):

$$\hat{M} = -\frac{\dot{u} + \dot{y}}{1-u-y} + \hat{P} = o_3(\tilde{v} - v), \qquad (26)$$

where $o_3 > 0$.[14]

[13] What is a complex outcome of these so far hidden socio-economic interactions may even appear superfluously as a result from one-shot game of the state and social classes.

[14] The notation of (Ryzhenkov 2005) is changed for better fit with the present story.

A new partial dynamic law for the relative labour compensation is derived correspondingly from the equations (19) and (26):

$$\dot{u} = (\hat{P} - \hat{M})(1-u-y) - \dot{y} = (\hat{a} + \hat{v} + n - \hat{M})(1-u-y) - \dot{y}$$

$$= \left[\frac{k(1-u-y)}{s} - (\hat{K/L} + n) + \hat{P/L} + n - \hat{M}\right](1-u-y) - \dot{y}$$

$$= \left[\frac{k(1-u-y)}{s} - \hat{s} - \hat{M}\right](1-u-y) - \dot{y}$$

$$= \left[\frac{k(1-u-y)}{s} - \hat{s} + o_3(v-\tilde{v})\right](1-u-y) - \dot{y}. \qquad (27)$$

The system of the ordinary differential equations (18), (19), (21)–(24) and (27) represents the deterministic form of the modified control law of capital accumulation. This system has a continuum of non-trivial stationary states with the same positive relative labour compensation, employment ratio, relative depletion of proved reserves; this continuum contains the following one, in particular:

$$E_b = (s_b, v_b, u_b, f_b, c_b, y_b, e_b), \qquad (28)$$

where

$$s_b = s_0,$$

$$f_b = (1 - u_b - e_b)/d - s_b/k,$$

$$c_a = f_b,$$

$$v_b = \tilde{v} - d/o_3,$$

$$u_b = \frac{d - n_1 - n_3(v_b - v_c) - e_b n_5}{n_2},$$

$$d = \frac{m_1}{1 - m_2 - m_5} + n,$$

$$y_b = e_b + d f_b,$$

$$e_b = e_1,$$

$$i = d.$$

At this stationary state, $\hat{L}_b = n$. The stationary average profit rate is $(1 - u_b - y_b)/s_b = d/k$. The target employment ratio is the stationary employment ratio v_b.

A new equation for a growth rate of real labour compensation follows from the equations (3) and (27):

$$\hat{w} = \hat{u} + \hat{a} = (\hat{P} - \hat{M})\frac{1-u-y}{u} - \frac{\dot{y}}{u} + \hat{a} = (\hat{a} + \hat{v} + n - \hat{M})\frac{1-u-y}{u} - \frac{\dot{y}}{u} + \hat{a} =$$

$$= \hat{a}\frac{1-y}{u} + (\hat{v} + n - \hat{M})\frac{1-u-y}{u} - \frac{\dot{y}}{u}$$

$$= \hat{a}\frac{1-y}{u} + \hat{L}\frac{1-u-y}{u} - o_3\tilde{v}\frac{1-u-y}{u} + o_3\frac{1-u-y}{u}v - \frac{\dot{y}}{u}. \qquad (29)$$

The following magnitudes of the two new parameters are chosen for simulations: $o_3 \approx 8.521$, $\tilde{v} \approx 0.963$. Correspondingly, the new stationary employment ratio (v_b) equals 0.961 (compared with 0.991 in the previous two scenarios). Only 0.354 per cent of the net output is invested additionally in the extension of proved reserves each year on the average in 1991–2107 in relation to the inertia scenario. This increment is about the same as in the normative scenario I.

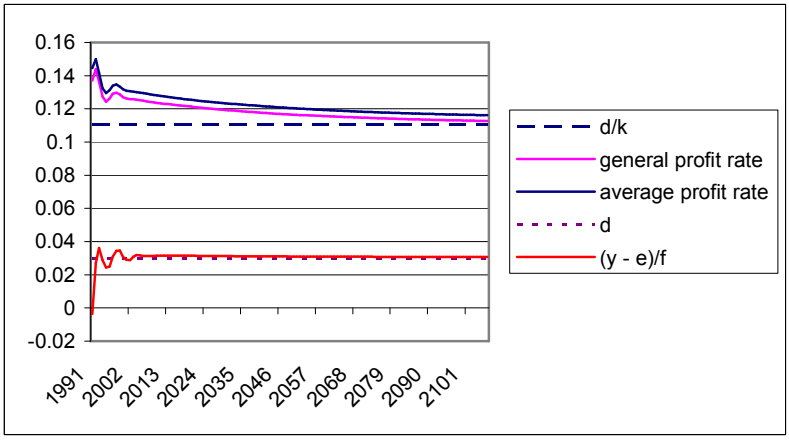

Figure 9 The net mineral rent rate $(y - e)/f$, average profit rate $(1 - u - y)/s$ and general profit rate $(1 - u - e)/(s + f)$ versus their benchmarks in the normative scenario II, 1991–2107

The structural changes produced desired effects. The pro-growth stabilization policy eradicates long-term economic fluctuations and extends proved reserves; moreover, it maintains relative labour compensation, profitability and employment ratio in vicinity of their reasonably high stationary magnitudes even during the most of the transition period (Figures 9–11).

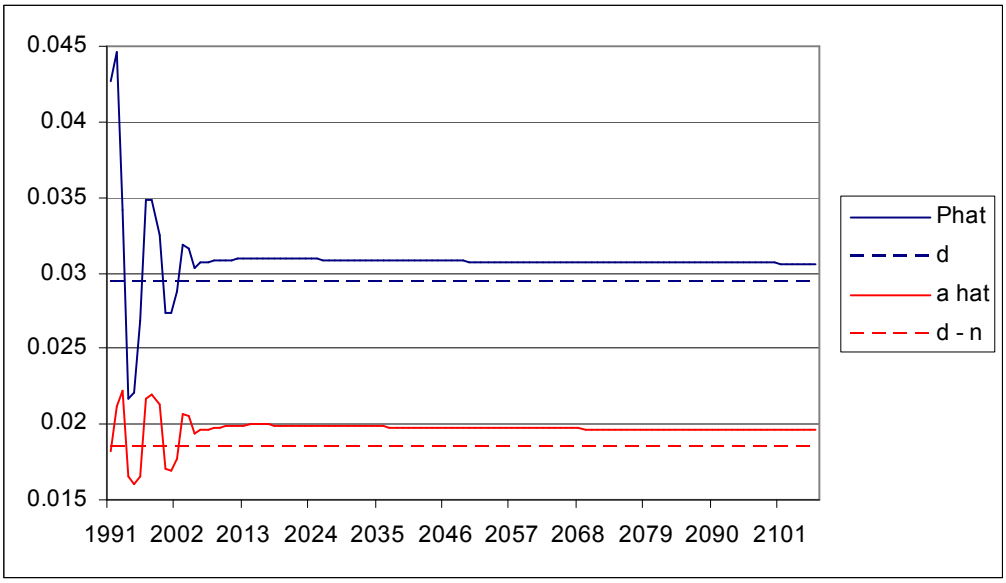

Figure 10 Growth rates of net output and labour productivity versus their stationary magnitudes in the normative scenario II, 1991–2107

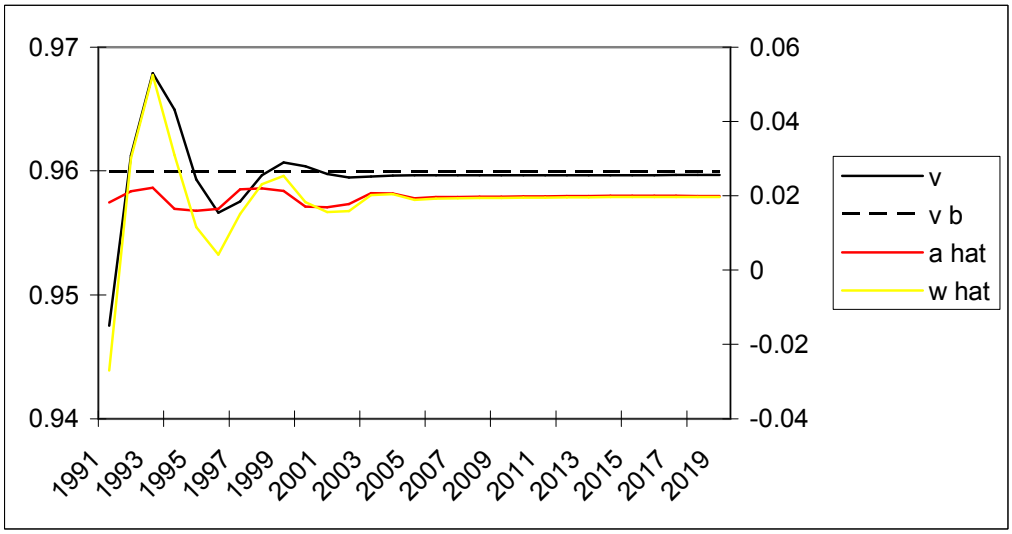

Figure 11 Employment ratio v versus its stationary magnitude v_b (scale on the left), growth rates of labour productivity (a hat) and of real labour compensation (w hat) after excess labour compensation levy (scale on the right) in the normative scenario II, 1991–2107

The transitional dynamics are contained within reasonable limits. In particular, the transitional motion in the first ten years is shaped as converging fluctuations of the main variables that move to their stationary magnitudes rapidly. The relative labour compensation decreases by –1.25 percentage points of net output in 1992 against 1991 for the almost complete compensating the initial step-wise increase in gross unit mineral rent (0.32 percentage points of net output) and the subsequent step-wise increase in profit share due to pro-

growth stabilization policy (0.93 percentage points of net output).[15] The real labour compensation is roughly unmoving in 1991–1992 only and increases in all other years (faster on the average than in the other two scenarios).

Figures A.1–A.6 in Appendix add information on the all three above scenarios. These Figures support the above contention on benefits of the strengthened social control over capitalist reproduction on the increasing scale under the explicit (although not precisely known and fixed) constraint of proved reserves.

A progress in statistics and in the theory of ecological-economic reproduction will allow including remaining non-renewable as well as renewable and environmental resources in similar models of sustainable development in future research. Ideally, the upgraded modelling process has to take into explicit account:

the environmental consequences of mining, including the costs of environmental compliance and the effects of using best practices in the environmental management of mining;

effects of improved environmental management and restoration ecology associated with mining and mineral processing (Committee on Earth Resources, 1997).

As a result new information will be delivered to scientific community, policymakers and public about how mining affects the environment and how environmental degradation can be minimized.

7. Enhancing sustainable development through excess income levy

This section discusses advantages of adopting a more pro-growth policy of primary distribution of income through levy on excess income (labour compensation or profit).[16] The notion of excess income levy is used in this paper as a general notion for the reduction in pre-levy primary income.

The term excess labour compensation levy is for the reduction in pre-levy primary labour compensation. The counter-part of excess labour compensation levy is subsidy (of the same quantity) on pre-levy primary profit. In the opposite case, excess profit levy equals subsidy on labour compensation receivable. For simplicity, it is the state that can levy surcharges on excessive income of labourers (or capitalists) and pay equivalent subsidies to capitalists (or labourers). The levy year and base are sliding.

[15] Comparisons of the normative scenario I with the inertia scenario and the normative scenario II with the normative scenario I yield these magnitudes (0.32 and 0.93, respectively).

[16] Chapter 3 "Pro-Growth Tax Policy" of the Economic Report of the President 2007 treats almost exclusively taxation within the secondary distribution of income.

Let w_{pt} is the pre-levy labour compensation used as the levy base. Its rate of change is determined according to the bargaining equation (8). The after-levy labour compensation is denoted as before by w; its rate of change ($\hat{w}$) is determined by the equation (29) based on the above deterministic form of the modified control law of capital accumulation.

The rate of excess labour compensation levy (as a fraction of unit) in non-probabilistic setting is

$$x_w = (\hat{w}_{pt} - \hat{w}) \cdot 1[\text{year}]. \tag{30}$$

The overall excess labour compensation levy equals overall subsidy on pre-levy primary profit

$$T_w = x_w wL = S_P. \tag{31}$$

The total profit is now

$$\begin{aligned} &P - (w_{pt}L - T_w) - Y = P - w_{pt}L + S_P - Y \\ &= P - wL - Y. \end{aligned} \tag{32}$$

The labour share in net output is higher than 50 per cent in the American economy, so the relative subsidy on pre-levy primary profit exceeds relative excess labour compensation levy in this theoretical model.

Using the new stationary employment ratio from the equation (28) we get the stationary relative excess labour compensation levy (as a fraction of unit)

$$\begin{aligned} \bar{x}_w &= [(\hat{w}_{pt})_b - \hat{w}_b] \cdot 1[\text{year}] = [-g + rv_b + bK_b \hat{/} L_b + qF_b \hat{/} L_b - (d-n)] \cdot 1[\text{year}] \\ &= [-g + r(\tilde{v} - d/o_3) + (b+q-1)(d-n)] \cdot 1[\text{year}] \\ &= [r(\tilde{v} - d/o_3) - rv_a] \cdot 1[\text{year}] = r(v_b - v_a) \cdot 1[\text{year}]. \end{aligned} \tag{33}$$

The stationary share of excess labour compensation levy in net output (i.e., unit excess income levy) is $\bar{x}_P = \bar{x}_w u_b$. The stationary relative subsidy on pre-levy primary profit is $\bar{x}_M = \bar{x}_w u_b / (1 - u_b - y_b)$.

Depending on relation between the target employment ratio (v_b) in the normative scenario II and the stationary employment ratio in the inertia scenario (v_a) there are, *ceteris paribus*, three cases:

1) if $v_b = v_a$ the all three stationary levy (subsidy) ratios $\bar{x}_w$, $\bar{x}_M$ and $\bar{x}_P$ are zero;

2) if $v_b > v_a$ these ratios are positive;

3) if $v_b < v_a$ these ratios are negative.

These three cases are a particular manifestation of the employment ratio – relative labour compensation trade-off. In the second case, labourers, having a higher stationary employment ratio than in the inertia scenario, pay levy to the state that provides subsidies to capitalists. In the opposite (third) case when the target employment ratio is lower than the stationary employment ratio in the inertia scenario, capitalists pay levy to

the state that provides subsidies to labourers. In the first case, when these both employment ratios are equal, the stationary relative levy (subsidy) is zero. Still excess income levy is pertinent even in this case since employment ratio varies on the transient to the stationary state.

If the society could raise the former stationary growth rate of labour productivity ($d - n$) to a higher level ($d - n + \delta$), then, assuming that the target employment ratio remains the same, this increment in labour productivity brings about the absolute reduction in the relative stationary excess labour compensation levy by $(1 - b - q)\delta$, where $1 - b - q > 0$ and $\delta > 0$. Moreover, relative excessive labour compensation levy may be negative except few initial years on a transient to the stationary state if there is a substantial increment in the stationary growth rate of labour productivity that raises v_a to a level higher than v_b, as in the above third case.

The following Figures 12–14 in this section relate to the normative scenario II as in the previous section. They illustrate a rather fast convergence of pre-levy labour compensation to post-levy labour compensation as well as narrowing difference between pre-subsidy and post-subsidy profitability (respectively, Figure 12 and Figure 13). The scatter of employment ratio and unit excess income levy (Figure 14) illustrates similar rapid convergence to the target employment ratio.

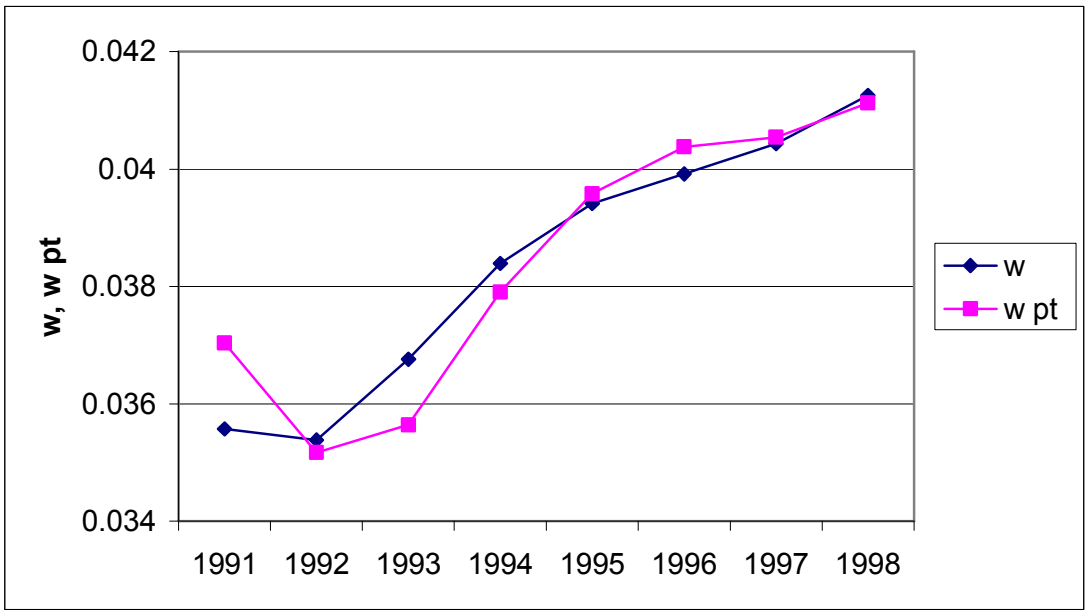

Figure 12 Pre-levy (w_{pt}) and post-levy labour compensation (w) in the normative scenario II, 1991–1998

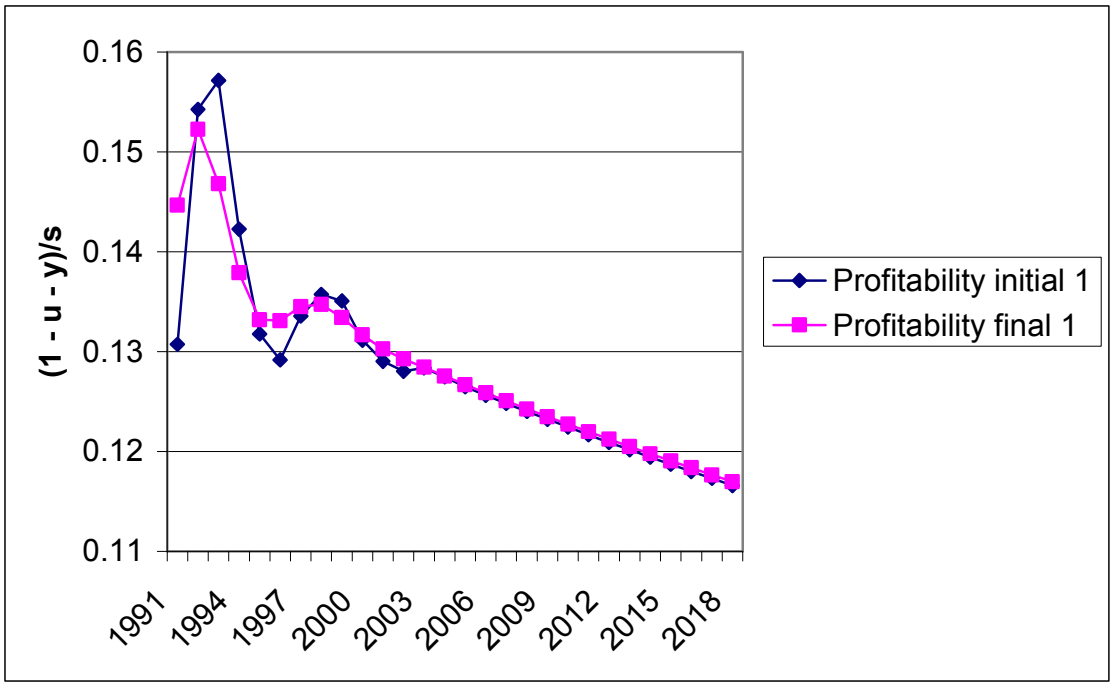

Figure 13 Rates of return on produced capital $(1 - u - y)/s$ before and after levy in the normative scenario II, 1991–2018

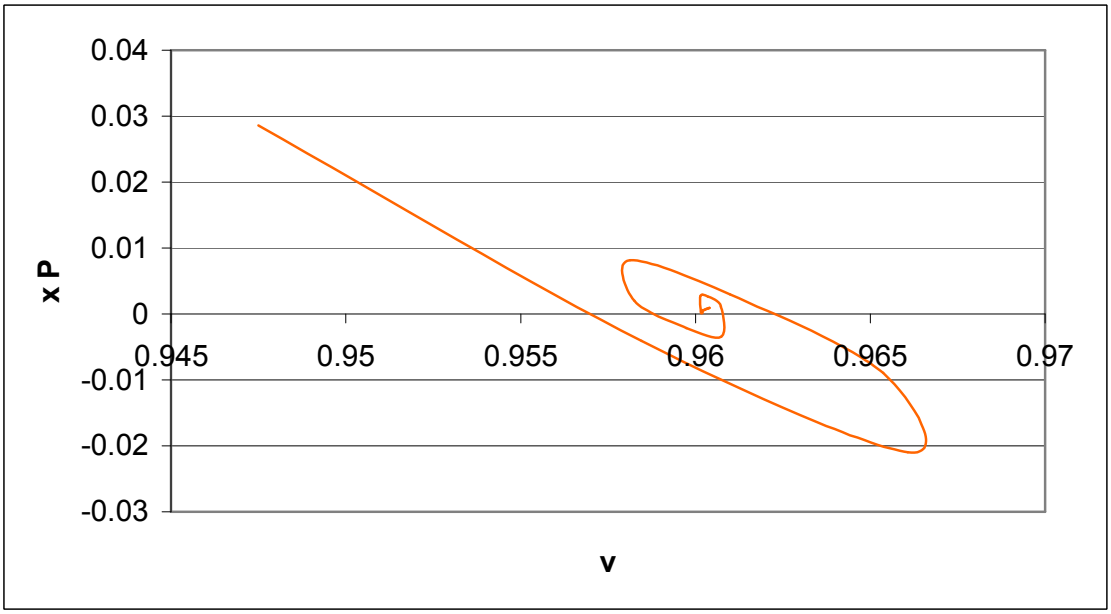

Figure 14 The scatter of unit excess income levy (x_P) against employment ratio (v) in the normative scenario II, 1991–2018

Measurement errors and external influences not taken into explicit account complicate practical realization of the supposed overt closed-loop control over capital accumulation. These limitations necessitate future concretization of above results for the real economy with fuller account of risk and uncertainty.

Conclusion

A sustainable development point of view has shaped the author's research aimed at reinforcement of the system dynamics paradigm. This paper offers, firstly, elementary building blocks for generic models of national and international sustainable development. Secondly, it suggests, for the U.S. economy specifically, strengthening the conscious societal control over the proved mineral reserves that facilitates converting the probable unsustainable evolution of the inertia scenario into the strongly sustainable development in the normative scenario I. Thirdly, this paper describes the deterministic forms of the enhanced closed-loop control over total profit and employment that could bring the substantial additional social gain as the given comparisons of the normative scenario II with normative scenario I demonstrate. As shown, the supposed alteration of the feedback structure and information links in the U.S. economy is a reasonable prerequisite for these possible improvements.

This paper offers, in particular, the novel outline of excess income levy within attainable bounds that may enhance long term sustainable development. It suggests the appropriate levy base and appropriate levy rates for primary distribution of income in the modern U.S. economy encouraging efficient investment into produced capital as well as into exploration and development of mineral reserves. Thus, this paper demonstrates with a help of system dynamics methodology rather realistic opportunities for moderating substantial dynamic inefficiency in modern capitalism and exposes its potential structural changes for maintaining resilience of the social organism. To what extent does the uncovered excessive depletion of *proved* mineral reserves in the USA facilitate conservation of total non-renewable and renewable natural resources for future generations is still the unresolved question.

The presented theoretical model ought to be generalized. This presupposes improved statistical account of mineral, renewable and environmental resources on the national and global scales as well as deeper theoretical understanding of ecological-economic reproduction. Different policies of substitution of minerals import for their extraction deserve more attention, than given in this paper, in particular.

References

Board of Trustees of the Federal Old-age and Survivors Insurance and Federal Disability Insurance Trust Funds. 2006. *The 2006 Annual Report*. Washington, D.C.: U.S. GPO.

http://www.ssa.gov/OACT/TR/TR06/I_intro.html#wp1000302

Committee on Earth Resources. 1997. *Mineral Resources and Sustainability: Challenges for Earth Scientists*. Board on Earth Sciences and Resources, Commission on Geosciences, Environment, and Resources, National Research Council. Washington, D.C.: National Academy Press.

Economic Report of the President. 2007. Washington, D.C.: U.S. GPO.

Energy Information Administration. 2006. *U.S. Crude Oil, Natural Gas, and Natural Gas Liquids Reserves*. 2005 Annual Report. DOE/EIA-0216 (2005).

http://www.eia.doe.gov/pub/oil_gas/natural_gas/data_publications/crude_oil_natural_gas_reserves/historical/2005/pdf/arr.pdf

Commission of the European Communities – Eurostat, IMF, OECD, UN, World Bank. 1993. *System of National Accounts 1993*. Brussels.

Forrester J. 1983. *Future Development of the System Dynamics Paradigm*. Keynote Address for the 1983 International System Dynamics Conference. Edited August 18, 2001.

http://www.systemdynamics.org/newsletters/PresAddrss83Conf.pdf

Ryzhenkov AV. 2000. *Unfolding the Eco–wave: Why Renewal Is Pivotal*. John Wiley & Sons: Chichester.

------. 2001. Birth Pangs of the U.S. Natural Capitalism in the XXI Century. *GEM Discussion Paper* 01–3 (June). The Research Institute of Economics and Management. Gakushuin University: Tokyo. 36 p.

------. 2002. A historical fit of a model of the US long wave. In *Proc. of the 20th International Conference of the System Dynamics Society*. Davidsen, PI, Mollona, E, Diker, VG, Langer, RS, Rowe, JI (eds.) The System Dynamics Society: Palermo. CD-ROM.

------. 2003. *Models of Cyclical Growth*. IEIE SB RAS: Novosibirsk (Russian).

------. 2005. Supposing a control law of primary income distribution for the modern US economy. In *Proc. of the 23rd International Conference of System Dynamics Society*. JD Sterman, NP Repenning, RS Langer, JI Rowe, JM Yanni, eds. System Dynamics Society: Boston. CD-ROM.

Sterman JD. 2002. All models are wrong: reflections on becoming a systems scientist. *System Dynamics Review* **18** (4): 501–531.

Appendix

Comparison of the three scenarios of the U.S. economic growth

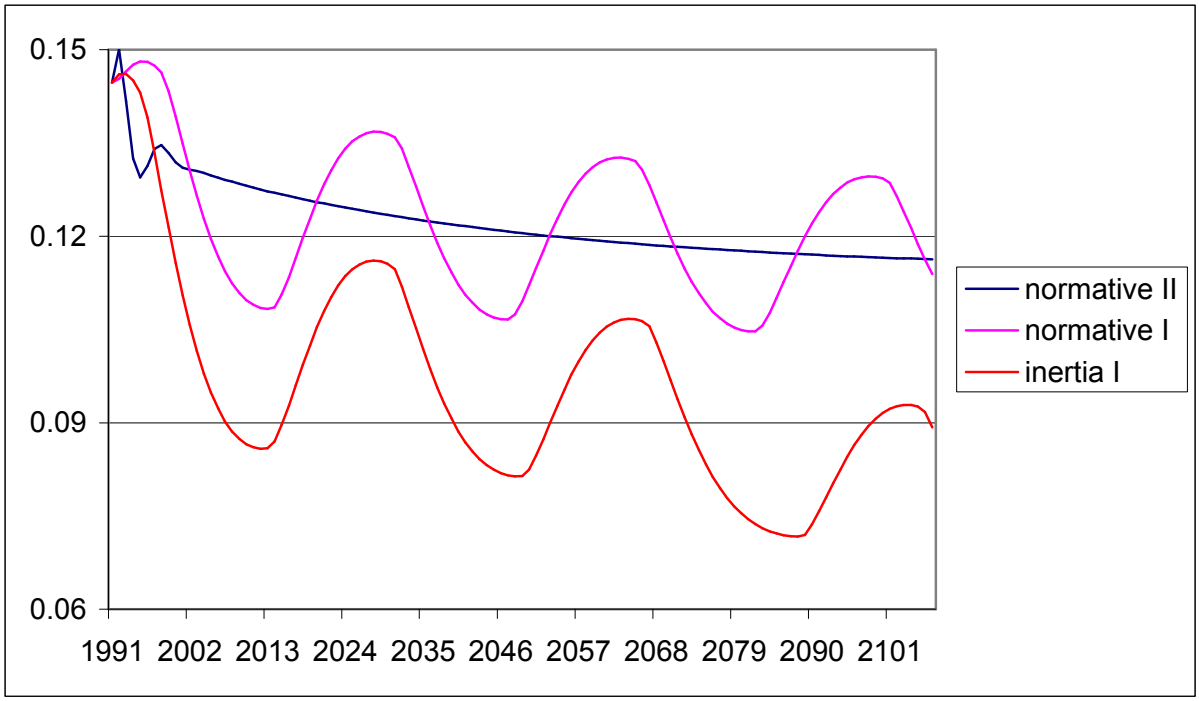

Figure A.1 The average profit rate $(1 - u - y)/s$ in the three scenarios, 1991–2107

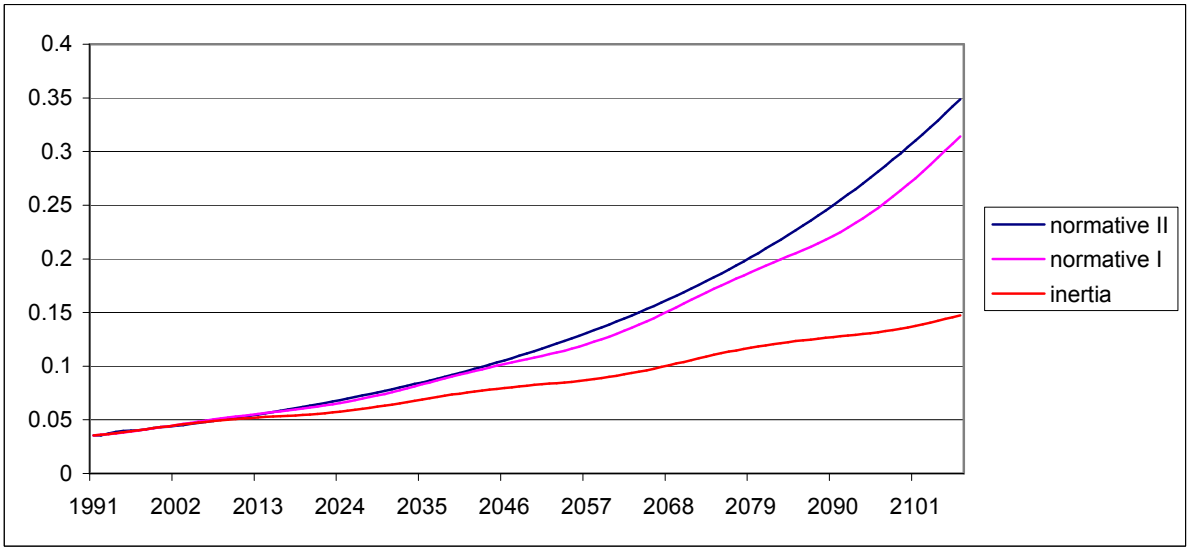

Figure A.2 The real labour compensation (w) in the three scenarios, 1991–2107

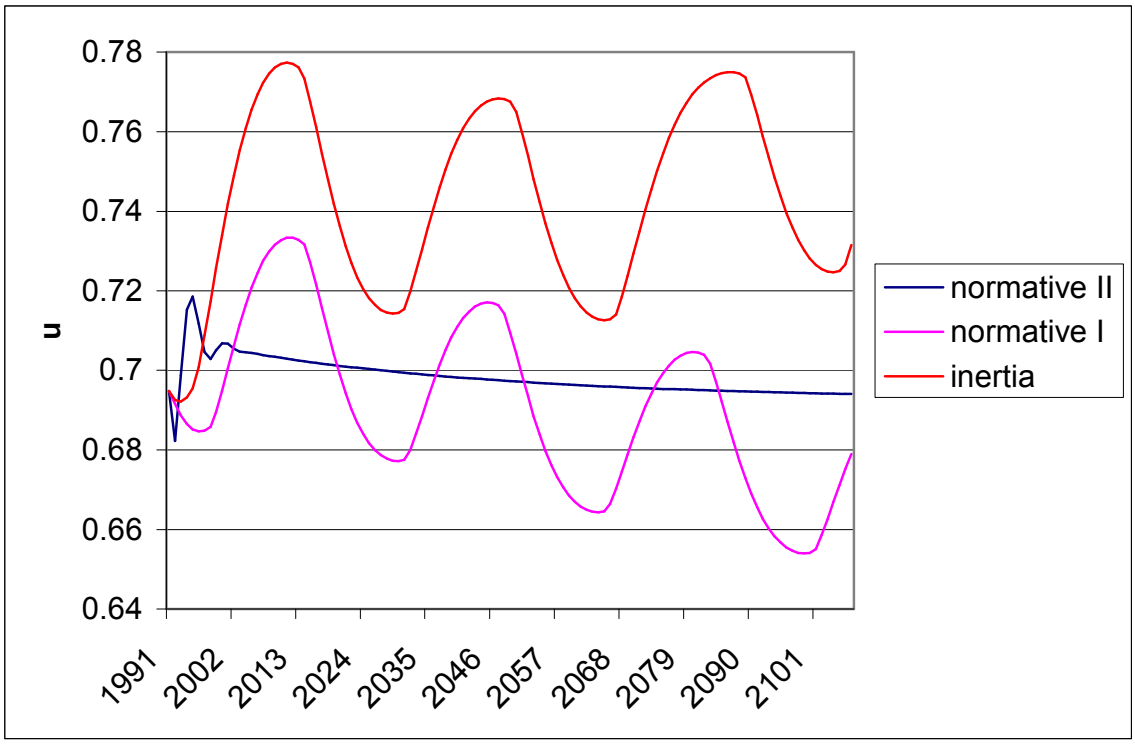

Figure A.3 The relative labour compensation (*u*) in the three scenarios, 1991–2107

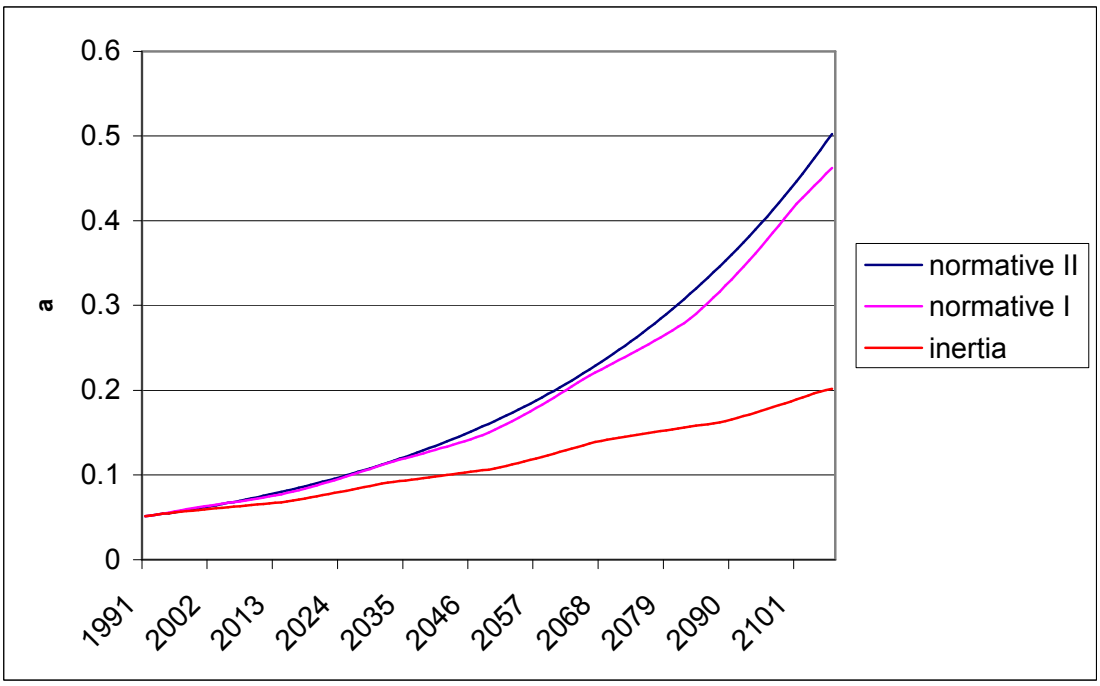

Figure A.4 The labour productivity (*a*) in the three scenarios, 1991–2107

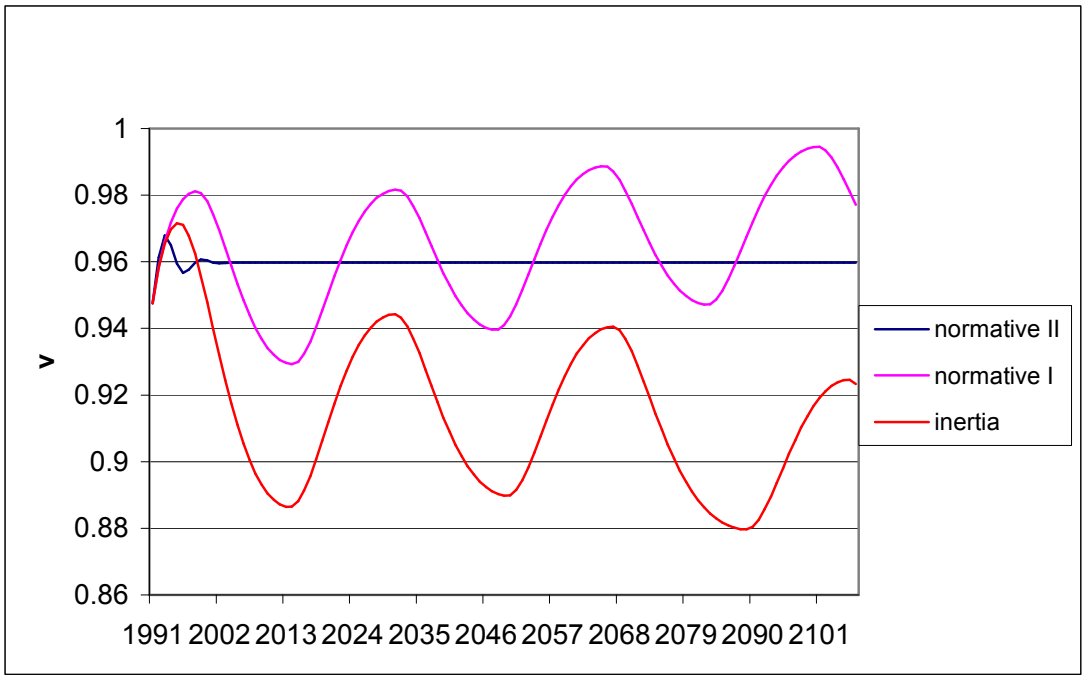

Figure A.5 The employment ratio (v) in the three scenarios, 1991–2107

Figure A.6 The gross unit mineral rent (y) in the three scenarios, 1991–2107