Fixed Capital, Accelerated Depreciation and Economic Growth: Mathematical Analysis Based on Marxist Political Economics

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- In 2014, The Ministry of Finance and the State Administration of Taxation jointly issued the *Notice on improving the enterprise income taxation policy on accelerated depreciation of fixed assets* (hereinafter referred to as the *Notice*).
    - It encouraged enterprises in all industries to adopt the accelerated depreciation method for the pre-tax deduction of instruments and equipment used for research.
    - It specifically stipulated that the same for the instruments and equipment used for production and operation by enterprises in six industries, such as bio-pharmaceutical manufacturing industry.
- In 2015, it was further expanded to four key industries including light industry, textile, machinery and automobile, which is of great practical significance.

- Domestic scholars took this as an opportunity to carry out relevant studies, which positively supported the implementation of accelerated depreciation.
  - Ren Zeping (2014) summarized the advantages of accelerated depreciation.
  - Li Yongchen, Tang Jingxiong and Gao Ruiyuan (2015) combined cases and examples to elaborate the effect of tax preferences for enterprises. Although the profit is deteriorated in accounting, the cash flow is improved in practice, which is consistent with the theoretical analysis of Edgerton (2012).
  - Liu Xing, Ye Kangtao and Lu Zhengfei (2018) regarded the issuance of the *Notice* as a “quasi-natural experiment” and found that enterprises affected by accelerated depreciation significantly expanded fixed capital investment and improved capital allocation efficiency after the implementation of the policy, which was conducive to economic growth.

Discussion on accelerated depreciation in developed countries

- In fact, there was a theoretical discussion on accelerated depreciation before the publication of *Notice*.
  - Xue Jingxiao (1984)
  - Wu Dakun (1985): In effect, it is a tax preferences given by the government to encourage monopolies to invest more.
- This perspective was widely used in later studies, so some domestic scholars called for accelerated depreciation to facilitate enterprises to convert tax preferences into investment in fixed capital.
  - Song Guilan and Ren Shengjun (1991)
  - Liu Haisheng (2009)
  - Tang Weimo and Song Shigao (2012)
- Existing literature has focused on the impact of accelerated depreciation on corporate tax preferences and investment promotion. However, there are few systematic studies on the impact of accelerated depreciation on economic growth, which is even more important.

- Marx's two-Sector reproduction schema and surplus value theory provide a preliminary framework for the systematic analysis of macroeconomic issues such as the priority of production goods from the perspective of political economy (Dong Fureng, 1980).
- Based on this, it is crucial to note that the value of fixed capital is not a single transfer but rather as a result of the gradual transfer of wear to the cost of the product or the circulation and service of the goods. Because of the unity of opposites of gradual value compensation and one-time material substitution, depreciation can be used as the investment of new fixed capital or general production goods.
- In fact, enterprises usually do not immediately use the depreciation fund for fixed capital compensation, but for the investment of new fixed capital or general production goods.

Main work of this paper

- From the perspective of Marxist political economy, this paper constructs a three-Sector structure table and mathematical model contains fixed capital, and simulates the accelerated depreciation of fixed capital to investigate its impact on economic growth.
  - The results show that accelerated depreciation significantly promotes economic growth.
- Further, by splitting the promoting effect, this article will explore the principle and concrete conditions, thus systemic research conclusion.
  - The renewal investment from shortened accounting depreciation period is the main source of economic growth, which is accompanied by the imbalance and insufficiency of production capacity released under the adjustment of corresponding physical depreciation period.
  - There is an endogenous inflection point.
  - The judgment method of inflection point is set forth, and the determination and specifications of the key indicators are discussed in connection with the depreciation-profit-growth curve of China from 1987 to 2015.

Overview

- The influence of fixed capital is reflected in not only the short-term technical conditions of production and the macro-operational efficiency but also the long-term changes of production structure.
  - In the third part of the second volume of *Das Kapital*, Marx has laid out the two-Sector reproduction schema including production goods and consumption goods, and preliminarily discussed the influence of the compensation and renewal of fixed capital on reproduction.
  - Li and Zhao (2017) further proposed that the impact of fixed capital on the supply side on the production of total social products and the formation of total social output value is characterized by proactivity and continuity.
- Therefore, it is necessary to expand the reproduction schema of the two departments by including fixed capital, and strengthen the identification of the contribution of fixed capital in the process of economic system construction, so as to effectively guide the implementation of relevant practices.

- The following papers indicate that domestic scholars have made preliminary achievements in the research on fixed capital, which provides an empirical basis.
  - Wang Yixuan, Wu You (2003) calculates the fixed capital stock of China state-owned economy
  - Zhang Jun and Zhang Yuan (2003), Shan Haojie (2008), Xu Jie, Duan Wanchun and Yang Jianlong (2010), Li Bin (2011)
  - Chen Changbing (2014)
- However, how to adequately reflect fixed capital and its influence in the growth theory and matrix mathematical model of political economy is still the technical difficulty in construction. Fixed capital is invariable in form and function in the production process, but should be differentiated according to age (or servitude).
  - Sraffa (1960)
  - Okishio and Nakatani (1975), Fujimori (1982), Schefold (1989), Kurz and Salvadori (1995) and Li (2017)

- In order to distinguish and reflect fixed capital from general production goods and consumption goods, it may be assumed that the share of product input into the three departments is α_i, β_i and γ_i. The calculation formula is as follows:

$$\alpha_i = \frac{S_i}{H_i}, \beta_i = \frac{\sum_{j=1}^{n} x_{ij} + \Delta a_i}{H_i}, \gamma_i = \frac{C_i}{H_i} \tag{1}$$

  where x_{ij} is the input from sector i to sector j, C_i, S_i and Δa_i respectively represents the consumption, fixed capital formation and inventory increase of the final demand item of sector i; H_i is the total domestic demand, regardless of international trade, obviously.
- $H_i = S_i + \sum_{j=1}^{n} x_{ij} + \Delta a_i + C_i$. The input between sectors shall be adjusted and summed to obtain the input between the Sectors.

Construction of three-Sector structure table

Table: three-Sector structure

	I	II	III	Demand	Net Export	Total Output
I	(k_I^*)	(k_{II}^*)	(k_{III}^*)	S	$E_I - M_I$	Y_I
II	a_I	a_{II}	a_{III}	K	$E_{II} - M_{II}$	Y_{II}
III	0	0	0	C	$E_{III} - M_{III}$	Y_{III}
Profit	Π_I	Π_{II}	Π_{III}			
Wage	W_I	W_{II}	W_{III}			
Total Input	Y_I	Y_{II}	Y_{III}			

- The depreciation of fixed capital, input of general production goods and total output of the three Sectors are denoted by k^*_m, a_m and Y_m respectively, $m = I, II, III$ to indicate the Sector. The specific calculation formula is as follows:

$$k^*_I = \sum_{i=1}^{n} \alpha_i \Delta k_i, k^*_{II} = \sum_{i=1}^{n} \beta_i \Delta k_i, k^*_{III} = \sum_{i=1}^{n} \gamma_i \Delta k_i \tag{2}$$

$$a_I = \sum_{i=1}^{n} \sum_{j=1}^{n} \alpha_i a_{ij} x_j, a_{II} = \sum_{i=1}^{n} \sum_{j=1}^{n} \beta_i a_{ij} x_j, a_{III} = \sum_{i=1}^{n} \sum_{j=1}^{n} \gamma_i a_{ij} x_j \tag{3}$$

$$Y_I = \sum_{i=1}^{n} \alpha_i x_i, Y_{II} = \sum_{i=1}^{n} \beta_i x_i, Y_{III} = \sum_{i=1}^{n} \gamma_i x_i \tag{4}$$

where Δk_i and x_i respectively represent the depreciation of fixed capital and total output by sector i.

- s_i and w_i are used to represent the profits and wages in the input-output table, then the profits and wages of the three Sectors, Π_m and W_m, are calculated as follows:

$$\Pi_I = \sum_{i=1}^{n} \alpha_i s_i, \Pi_{II} = \sum_{i=1}^{n} \beta_i s_i, \Pi_{III} = \sum_{i=1}^{n} \gamma_i s_i \tag{5}$$

$$W_I = \sum_{i=1}^{n} \alpha_i w_i, W_{II} = \sum_{i=1}^{n} \beta_i w_i, W_{III} = \sum_{i=1}^{n} \gamma_i w_i \tag{6}$$

- In addition, capital formation S_m of the three Sectors, total capital formation S, accumulation of general production goods K, and consumption C can be expressed as:

$$S_I = \sum_{i=1}^{n} \alpha_i S_i, S_{II} = \sum_{i=1}^{n} \beta_i S_i, S_{III} = \sum_{i=1}^{n} \gamma_i S_i \tag{7}$$

$$S = \sum_{i=1}^{n} S_i, K = \sum_{i=1}^{n} \Delta a_i, C = \sum_{i=1}^{n} C_i \tag{8}$$

- In this paper, the above model is extended to the open economy, using $E_m - M_m$ to represent the net exports of three Sectors. The corresponding three-Sector structure table then shall be constructed (see Table 1).

- According to the equation (7), the three-Sector investment matrix

$$\begin{pmatrix} S_I & S_{II} & S_{III} \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix}$$

and the ratio of net fixed capital to total fixed capital

$$\epsilon = 1 - (1+g)^{-\tau}$$

can be obtained (τ is the average depreciation period of fixed capital and g is the growth rate), and the fixed capital input coefficient of the three Sectors can be calculated as

$$k_I = \frac{\epsilon S_I}{g x_I}, k_{II} = \frac{\epsilon S_{II}}{g x_{II}}, k_{III} = \frac{\epsilon S_{III}}{g x_{III}} \tag{9}$$

Model

- Further, define the production price system as follows:

$$pB = (1 + r)pM \tag{10}$$

- Expand the equation (10):

$$pB = (1 + r)p(A + cFL) \tag{11}$$

Matrix

$$A = \begin{pmatrix} k_1 & 0 & \cdots & 0 & k_2 & 0 & \cdots & 0 & k_3 & 0 & \cdots & 0 \\ 0 & k_1 & & & 0 & k_2 & & & 0 & k_3 & & \\ \vdots & & \ddots & & \vdots & & \ddots & & \vdots & & \ddots & \\ 0 & & & k_1 & 0 & & & k_2 & 0 & & & k_3 \\ a_1 & \cdots & \cdots & a_1 & a_2 & \cdots & \cdots & a_2 & a_3 & \cdots & \cdots & a_3 \\ 0 & \cdots & \cdots & 0 & 0 & \cdots & \cdots & 0 & 0 & \cdots & \cdots & 0 \end{pmatrix}_{(\tau+2)\times 3\tau}$$

$$F = \begin{pmatrix} 0 \\ \vdots \\ 0 \\ f \end{pmatrix}_{1\times(\tau+2)}$$

$$L = \begin{pmatrix} l_1 & \cdots & l_1 & l_2 & \cdots & l_2 & l_3 & \cdots & l_3 \end{pmatrix}_{3\tau\times 1}$$

- It is necessary to consider the value transfer of fixed capital involved in the production process and the increase of age (or servitude).
- For example, take age (or servitude) to 0 .

$$\begin{pmatrix} k_1 \\ 0 \\ \vdots \\ a_1 \\ cfl_1 \end{pmatrix} \to \begin{pmatrix} 1 \\ k_1 \\ 0 \\ \vdots \\ 0 \\ 0 \end{pmatrix}, \begin{pmatrix} k_2 \\ 0 \\ \vdots \\ a_2 \\ cfl_2 \end{pmatrix} \to \begin{pmatrix} 0 \\ k_2 \\ 0 \\ \vdots \\ 1 \\ 0 \end{pmatrix}, \begin{pmatrix} k_3 \\ 0 \\ \vdots \\ a_3 \\ cfl_3 \end{pmatrix} \to \begin{pmatrix} 0 \\ k_3 \\ 0 \\ \vdots \\ 0 \\ 1 \end{pmatrix}$$

Matrix

$$B = \begin{pmatrix} 1 & \cdots & \cdots & 1 & 0 & \cdots & \cdots & 0 & 0 & \cdots & \cdots & 0 \\ k_1 & & & & k_2 & & & & k_3 & & & \\ & \ddots & & & & \ddots & & & & \ddots & & \\ & & k_1 & 0 & & & k_2 & 0 & & & k_3 & 0 \\ 0 & \cdots & \cdots & 0 & 1 & \cdots & \cdots & 1 & 0 & \cdots & \cdots & 0 \\ 0 & \cdots & \cdots & 0 & 0 & \cdots & \cdots & 0 & 1 & \cdots & \cdots & 1 \end{pmatrix}_{(\tau+2)\times 3\tau}$$

- The matrixed inputs and outputs in the above model are structurally dependent only on the physical depreciation period τ. To be precise, they should be written as M_τ and B_τ.
- The accounting depreciation period for accelerated depreciation may well be set as τ', which is shorter than the physical depreciation period. Further, accelerated depreciation is defined as $\Delta\tau = \tau' - \tau$.
- It's important to note that when we talk about accelerated depreciation, some fixed capital whose age (or service age) exceeds the accounting depreciation period will be regarded as scrapped in the input matrix and output matrix.
- Therefore, this paper will represent the input matrix and output matrix in terms of $M_\tau^{(\Delta\tau)}$ and $B_\tau^{(\Delta\tau)}$, which can also be denoted as $M_\tau^{\tau'}$ and $B_\tau^{\tau'}$ under the condition of $\tau' < \tau$.

Accelerated depression

input matrix $M_\tau^{(-1)} = M_\tau^{\tau'} =$

$$
\begin{pmatrix}
k_1 & 0 & \cdots & \cdots & 0 & k_2 & 0 & \cdots & \cdots & 0 & k_3 & 0 & \cdots & \cdots & 0 \\
0 & k_1 & & & & 0 & k_2 & & & & 0 & k_3 & & & \\
\vdots & & \ddots & & & \vdots & & \ddots & & & \vdots & & \ddots & & \\
0 & & & k_1 & & 0 & & & k_2 & & 0 & & & k_3 & \\
0 & & & & {\color{red}0} & 0 & & & & {\color{red}0} & 0 & & & & {\color{red}0} \\
a_1 & \cdots & \cdots & \cdots & a_1 & a_2 & \cdots & \cdots & \cdots & a_2 & a_3 & \cdots & \cdots & \cdots & a_3 \\
cfl_1 & \cdots & \cdots & \cdots & cfl_1 & cfl_2 & \cdots & \cdots & \cdots & cfl_2 & cfl_3 & \cdots & \cdots & \cdots & cfl_3
\end{pmatrix}_{(\tau+2)\times 3\tau}
$$

output matrix $B_\tau^{(-1)} = B_\tau^{\tau'} =$

$$
\begin{pmatrix}
1 & \cdots & \cdots & \cdots & 1 & 0 & \cdots & \cdots & \cdots & 0 & 0 & \cdots & \cdots & \cdots & 0 \\
k_1 & & & & & k_2 & & & & & k_3 & & & & \\
& \ddots & & & & & \ddots & & & & & \ddots & & & \\
& & k_1 & & & & & k_2 & & & & & k_3 & & \\
& & & {\color{red}0} & 0 & & & & {\color{red}0} & 0 & & & & {\color{red}0} & 0 \\
0 & \cdots & \cdots & \cdots & 0 & 1 & \cdots & \cdots & \cdots & 1 & 0 & \cdots & \cdots & \cdots & 0 \\
0 & \cdots & \cdots & \cdots & 0 & 0 & \cdots & \cdots & \cdots & 0 & 1 & \cdots & \cdots & \cdots & 1
\end{pmatrix}_{(\tau+2)\times 3\tau}
$$

Accelerated depreciation

input matrix $M_\tau^{[-(\tau-2)]} = M_\tau^2 =$

$$
\begin{pmatrix}
k_1 & 0 & \cdots & \cdots & 0 & k_2 & 0 & \cdots & \cdots & 0 & k_3 & 0 & \cdots & \cdots & 0 \\
0 & k_1 & & & & 0 & k_2 & & & & 0 & k_3 & & & \\
\vdots & & 0 & & & \vdots & & 0 & & & \vdots & & 0 & & \\
0 & & & \ddots & & 0 & & & \ddots & & 0 & & & \ddots & \\
0 & & & & 0 & 0 & & & & 0 & 0 & & & & 0 \\
a_1 & \cdots & \cdots & \cdots & a_1 & a_2 & \cdots & \cdots & \cdots & a_2 & a_3 & \cdots & \cdots & \cdots & a_3 \\
cfl_1 & \cdots & \cdots & \cdots & cfl_1 & cfl_2 & \cdots & \cdots & \cdots & cfl_2 & cfl_3 & \cdots & \cdots & \cdots & cfl_3
\end{pmatrix}_{(\tau+2)\times 3\tau}
$$

output matrix $B_\tau^{[-(\tau-2)]} = B_\tau^2 =$

$$
\begin{pmatrix}
1 & \cdots & \cdots & \cdots & 1 & 0 & \cdots & \cdots & \cdots & 0 & 0 & \cdots & \cdots & \cdots & 0 \\
k_1 & & & & & k_2 & & & & & k_3 & & & & \\
 & 0 & & & & & 0 & & & & & 0 & & & \\
 & & \ddots & & & & & \ddots & & & & & \ddots & & \\
 & & & 0 & 0 & & & & 0 & 0 & & & & 0 & 0 \\
0 & \cdots & \cdots & \cdots & 0 & 1 & \cdots & \cdots & \cdots & 1 & 0 & \cdots & \cdots & \cdots & 0 \\
0 & \cdots & \cdots & \cdots & 0 & 0 & \cdots & \cdots & \cdots & 0 & 1 & \cdots & \cdots & \cdots & 1
\end{pmatrix}_{(\tau+2)\times 3\tau}
$$

- A new equilibrium equation can be obtained:

$$pB_{\tau}^{\tau'} = (1+r)pM_{\tau}^{\tau'} \tag{12}$$

- Multiply the Moore–Penrose pseudo-inverse matrix $B_{\tau}^{\tau'+}$ on both sides

$$\frac{1}{1+r}p = pM_{\tau}^{\tau'}B_{\tau}^{\tau'+} \tag{13}$$

which can be simplify to

$$\lambda p = pM_{\tau}^{\tau'}B_{\tau}^{\tau'+}, \lambda = \frac{1}{1+r} \tag{14}$$

- To examine the economic growth at the macro level, this paper uses the *Cambridge Equation* to calculate the potential growth rate of GDP.
- The results are reflected in the *red line*, as shown in Figure 1 - Figure 12.

Depreciation-profit-growth curve

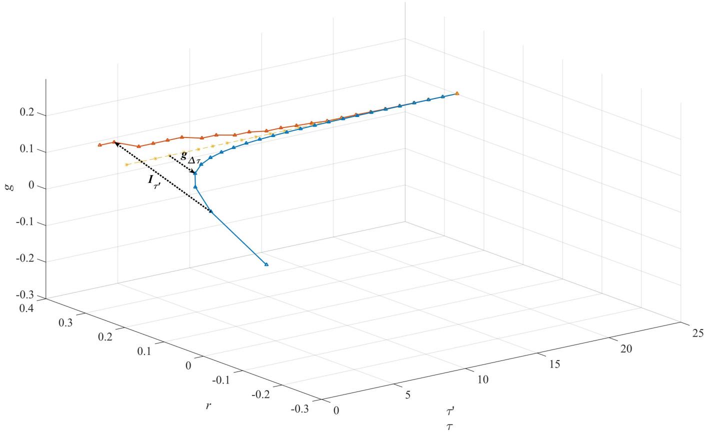

Figure: Depreciation-profit-growth in 1987

Depreciation-profit-growth curve

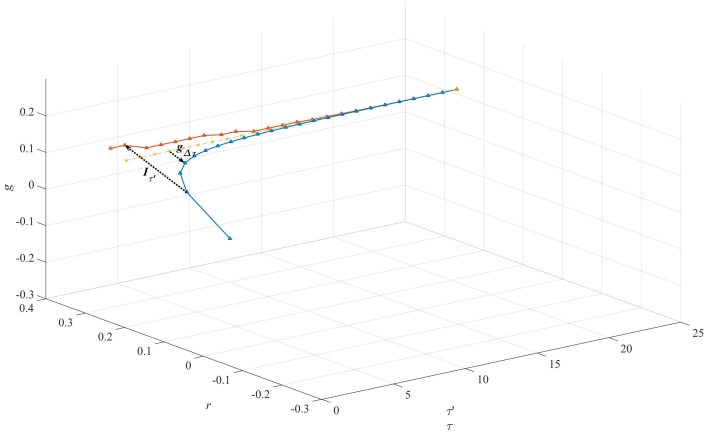

Figure: Depreciation-profit-growth in 1990

Depreciation-profit-growth curve

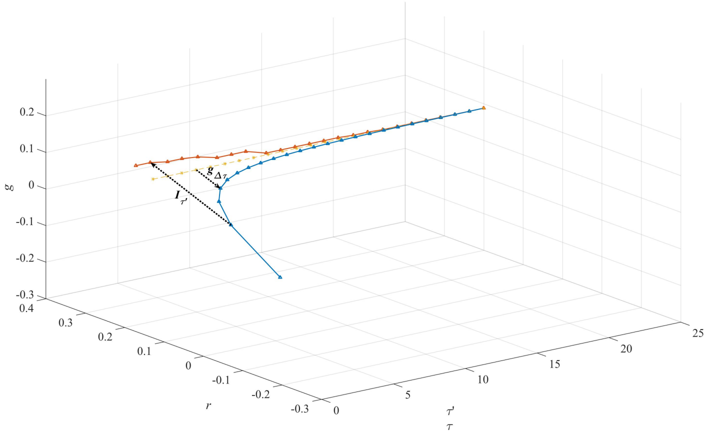

Figure: Depreciation-profit-growth in 1992

Depreciation-profit-growth curve

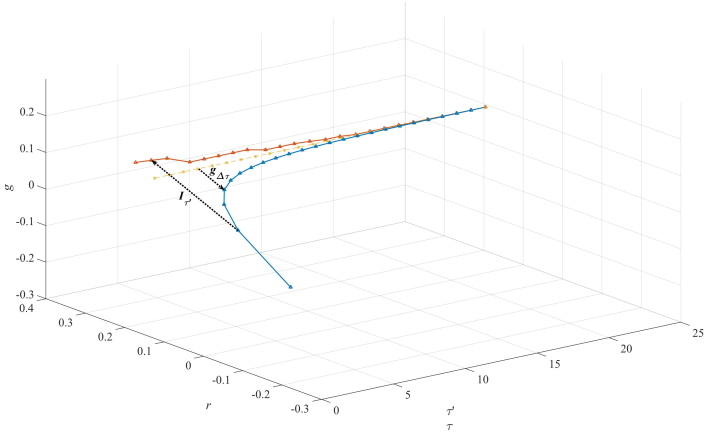

Figure: Depreciation-profit-growth in 1995

Depreciation-profit-growth curve

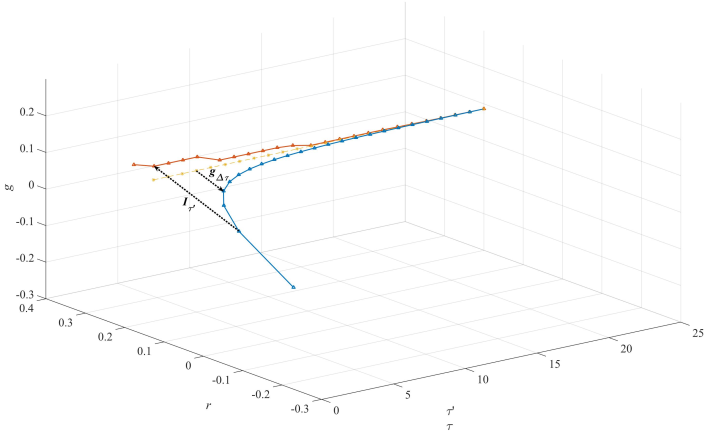

Figure: Depreciation-profit-growth in 1997

Depreciation-profit-growth curve

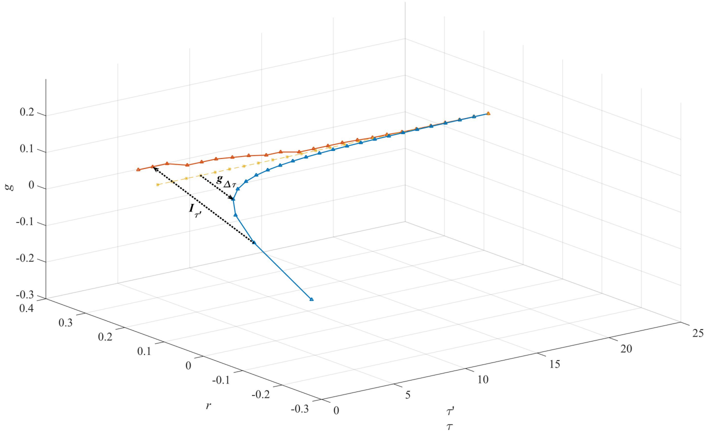

Figure: Depreciation-profit-growth in 2000

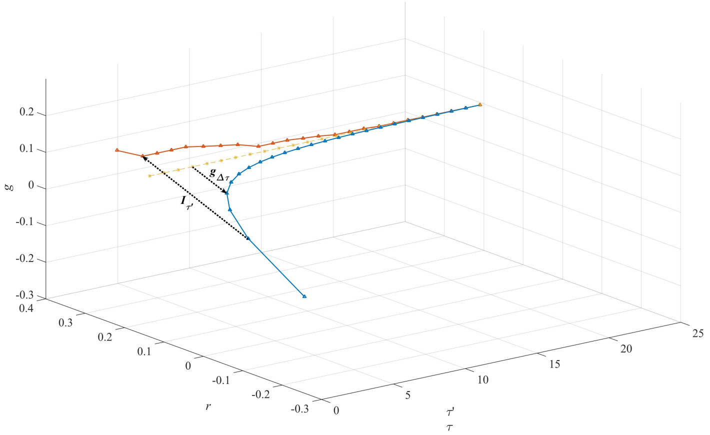

Figure: Depreciation-profit-growth in 2002

Depreciation-profit-growth curve

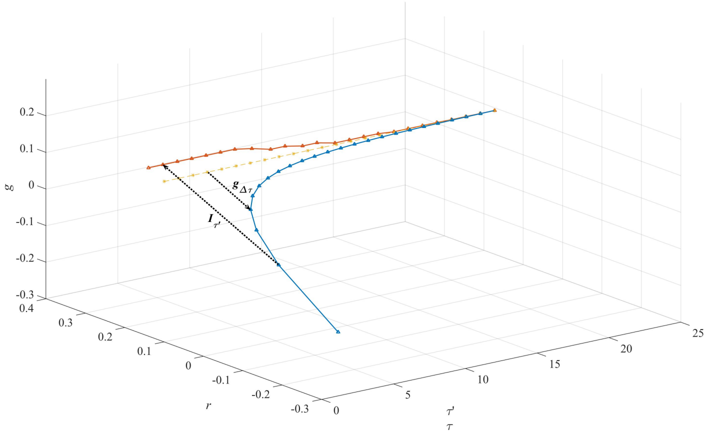

Figure: Depreciation-profit-growth in 2005

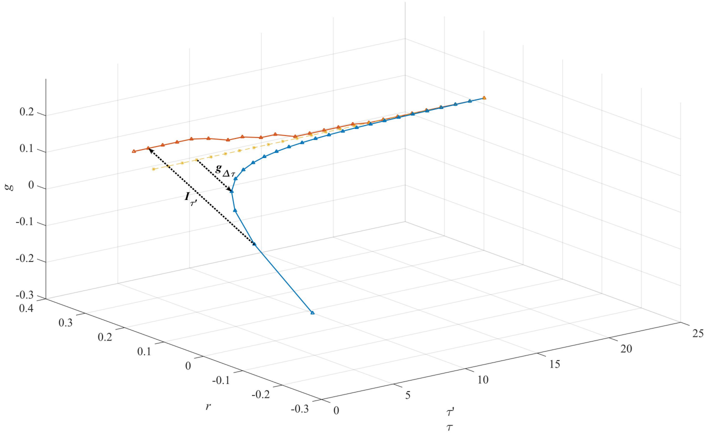

Figure: Depreciation-profit-growth in 2007

Depreciation-profit-growth curve

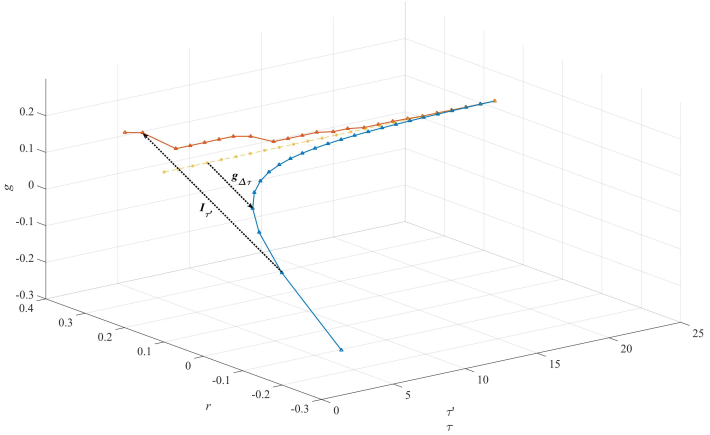

Figure: Depreciation-profit-growth in 2010

Depreciation-profit-growth curve

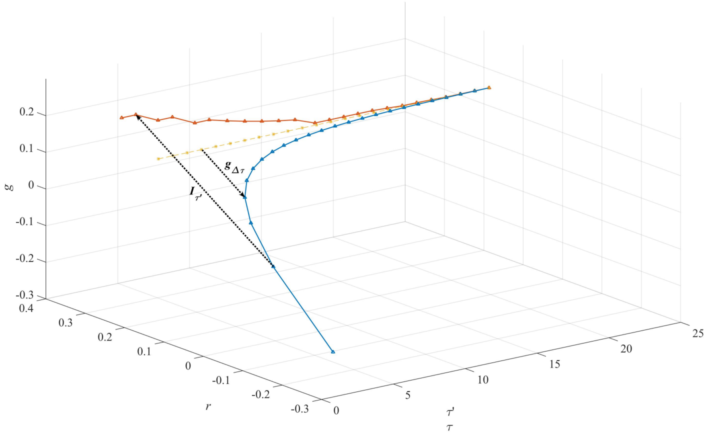

Figure: Depreciation-profit-growth in 2012

Depreciation-profit-growth curve

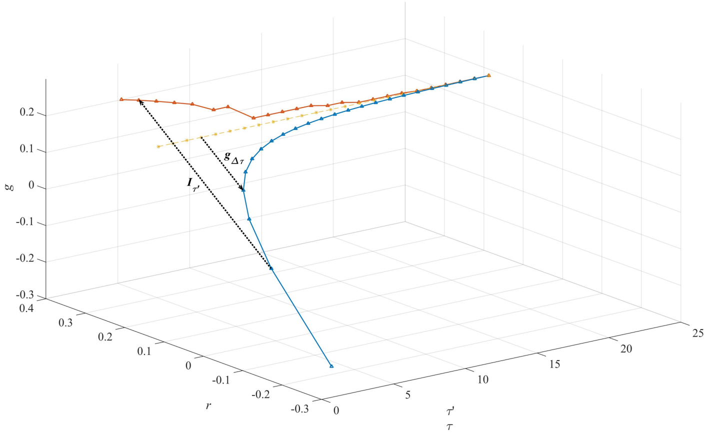

Figure: Depreciation-profit-growth in 2015

- It is not difficult to find that, compared with the general depreciation, the profit rate and the potential growth rate of GDP in accelerated depreciation both have obvious improvement.
- Further, there is an important conclusion that with the gradual shortening of the accounting depreciation period as exogenous variables and away from the physical depreciation period, the degree of accelerated depreciation becomes deeper and the promoting effect on economic growth becomes more significant.
- Existing literature focuses mainly on the advantages of accelerated depreciation in tax preferences, investment promotion and technological progress, while this paper proposes and directly verifies the contribution of accelerated depreciation to economic growth.

Table: Ratio of the promotion effect of acceleration depreciation ($A_{\Delta\tau}$)

$\Delta\tau =$	-2	-3	-5	-10	-20
1987	0.0003	0.0003	0.0013	0.0188	0.1579
1990	0.0002	0.0002	0.0002	0.0082	0.0799
1992	0.0001	0.0011	0.0020	0.0232	0.1827
1995	0.0005	0.0005	0.0023	0.0253	0.1076
1997	0.0005	0.0005	0.0038	0.0090	0.1740
2000	0.0002	0.0015	0.0015	0.0311	0.1833
Mean value	0.0004	0.0009	0.0028	0.0245	0.2203

Promotion effect

Table: Ratio of the promotion effect of acceleration depreciation ($A_{\Delta\tau}$)

$\Delta\tau =$	-2	-3	-5	-10	-20
2002	0.0006	0.0014	0.0047	0.0165	0.2589
2005	0.0011	0.0011	0.0045	0.0244	0.2317
2007	0.0000	0.0016	0.0016	0.0244	0.2499
2010	0.0003	0.0026	0.0047	0.0484	0.2519
2012	0.0003	0.0003	0.0069	0.0232	0.3971
2015	0.0003	0.0003	0.0003	0.0421	0.3688
Mean value	0.0004	0.0009	0.0028	0.0245	0.2203

- In addition, the contribution of small accelerated depreciation to economic growth within 5 years shortened in 2010, 2012 and 2015 in Table 2 gradually slows down, which confirms that China first implemented accelerated depreciation in 2009 for fixed capital which is in a state of strong vibration or high corrosion all year round due to rapid product upgrading due to technological progress.
- It is an appropriate time in 2014 to allow enterprises in all industries to adopt the pre-tax deduction of accelerated depreciation method for the instruments and equipment specially used for research and development.
- Comprehensive encouragement in 6 industries and 4 key industries expanded in 2015 is also an appropriate incentive measure.

- On the basis of the above mathematical model analysis and verification, we have to answer but not yet discussed: in order to promote economic growth, whether the deeper the degree of accelerated depreciation should be pursued?
- Since accelerated depreciation means that the fixed capital needs to be depreciated within an accounting depreciation period shorter than the physical depreciation period, how to determine the accounting depreciation period will affect the reinvestment of the depreciation fund and the adjusted capacity, and further affect the economic growth.
- In this section, this paper will firstly analyze and explain the promoting effect: what is the mechanism of promoting effect and what conditions should be met, and further put forward relevant policy suggestions.

- In this paper, the promoting effect of accelerated depreciation is attributed to the investment effect, because accelerated depreciation reduces the investment cost of enterprises in the form of tax preferences, and enhances technological advances and increases investment income.
- Existing literatures generally believe that the direct impact of accelerated depreciation on enterprises is tax preference, which is to some extent transformed into the promotion of renewal investment.
- However, this explanation is controversial in theory.
  - Hall and Jorgenson (1967) advocated and pointed out that the increase of the present value of tax-deductible income was the main factor.
  - Edgerton (2012) questioned the investment effect because the management may only care about accounting profit, rather than the cash flow affected by accelerated depreciation.

- There are few empirical studies on the impact of accelerated depreciation on enterprise investment.
  - House and Shapiro (2008) and Zwick and Mahon (2017) studied the impact of accelerated depreciation in the United States on the investment changes of all enterprises, and the empirical results showed that there were incentives.
  - Liu Xing, Ye Kangtao and Lu Zhengfei (2018) chose the regulations in the *Notice* that only apply to six industries to carry out the research of "quasi-natural experiment" and found that the affected enterprises have significantly increased the investment range.
    - In fact, although the three other tax preferences in the *Notice* apply either to small and micro enterprises or to all enterprises, thus do not interfere with the significance of their conclusions, this paper tends to think that it even underestimates the impact of accelerated depreciation on macroeconomic growth after the release of the *Notice*.

The risk of investment effect

- The mathematical model analysis in this paper supports the theoretical expectation of Hall and Jorgenson (1967), which is also consistent with the conclusions of the above three empirical studies.
- Even so, this paper still needs to point out the risk.
  - Yamada and Yamada (1960)
  - Ruchti (1942) and Lohmann (1949)
  - Kalecki (1954)
  - Steindl (1952)
  - Li Bangxi and Zhao Feng (2017)
    - *Marx-Engels-Ruchti-Lohmann-kaletsky-Kalecki-Steindl effect* (*MERLKS*)
    - They theoretically discuss the influence of depreciation and renewal of fixed capital on economic cycle and capacity fluctuation.
  - Therefore, discussing the potential impact on sustainable growth and high-quality development cannot be underestimated.

From accounting depreciation period to physical depreciation period

- However, the investment effect is only one aspect of accelerated depreciation, and the theoretical explanation is not complete.
    - The relationship between promoting effect and investment effect needs to be sorted out.
    - Existing literature rarely involves, and there is no clear distinction.
- This paper believes that the latter is the source of the former, the former is a reflection of the latter. There is conditional difference between the two, that is, the investment effect and its conditions jointly constitute the whole picture of the promoting effect.
- Define the potential growth rate of GDP (the same as the profit rate) under the general depreciation and accelerated depreciation as g_τ and $g_\tau^{\tau^{'}}$, for the macro economy with the physical depreciation period as τ.

$$A_{\Delta\tau} = g_\tau^{\tau'} - g_\tau \tag{15}$$

- The investment effect is denoted as $I_{\tau'}$, not being numerically directly equal to changes in profit margins and the potential growth rate of GDP.
- Because the physical depreciation period of fixed capital cannot be ignored, it also plays a role: corresponding to the shortening of the accounting depreciation period, the physical depreciation period is also adjusted and the economic accounting is carried out accordingly.
- Therefore, when discussing accelerated depreciation, the investment effect of accounting depreciation period is based on the economic growth when fixed capital participates in social reproduction and reaches equilibrium with adjusted physical depreciation period (see the *arrow* representing investment effect in Figure 1 - Figure 12).

$$g_{\tau}^{\tau'} = I_{\tau'} + g_{\tau'} \tag{16}$$

- Let's substitute that into the formula 16,

$$A_{\Delta\tau} = I_{\tau'} + g_{\tau'} - g_{\tau} = I_{\tau'} + g_{\Delta\tau} \tag{17}$$

where $g_{\Delta\tau}$ refers to the change in profit margin and potential GDP growth rate caused by the adjustment effect of physical depreciation.

- This is an identity that systematically splits the promoting effect: the investment effect of shortened accounting depreciation period and the adjustment effect of shortened physical depreciation period.
- It is interesting to note that both components contribute to the promoting effect but role in the opposite direction, which can be obtained rigorously

$$\underset{(+)}{A_{\Delta\tau}} = \underset{(+)}{I_{\tau'}} + \underset{(-)}{g_{\Delta\tau}} \tag{18}$$

- Formula 18 is a systematic study on the promoting effect of accelerated depreciation.

$$\underset{(+)}{A_{\Delta\tau}} = \underset{(+)}{I_{\tau'}} + \underset{(-)}{g_{\Delta\tau}}$$

- The corresponding literal expression is: the promoting effect of accelerated depreciation is composed of the positive investment effect caused by the shortening of accounting depreciation period and the negative adjustment effect caused by the shortening of physical depreciation period, and finally makes a positive contribution to economic growth.
- Unlike existing literature, this split proposed by this paper takes into account both the important role of investment ($I_{\tau'} > A_{\Delta\tau}$) and the economic significance of adjustment, the latter of which will be fully discussed in the next section.

A little discussion on the split

- In fact, the unity of opposites between accounting depreciation period and physical depreciation period is an important perspective and method of Marxist political economy in discussing the depreciation of fixed capital, and can also be applied to the explanation of related issues.
  - Mentioned above, Li Bangxi and Zhao Feng (2017) have proved that if the fixed capital is depreciated within a shorter period than its physical depreciation period, and the depreciation fund is immediately used for the reinvestment of fixed capital, then the production process will have more violent capacity fluctuations, and the macro economy as a whole will suffer more disturbances accordingly.
  - This paper will discuss the explanatory power of the split of the accounting depreciation period and the physical depreciation period in combination with the calculation examples (see Table 3 and Table 4).

Example

Table: *MELRKS* with general depreciation ($\tau = 5, \tau' = 5$)

Time		1	2	3	4	5	6	7
Capacity		1000.00	1200.00	1440.00	1728.00	2073.60	1488.32	1585.98
	1	1000.00	200.00	240.00	288.00	345.60	414.72	297.66
	2		1000.00	200.00	240.00	288.00	345.60	414.72
Age	3			1000.00	200.00	240.00	288.00	345.60
	4				100.00	200.00	240.00	288.00
	5					1000.00	200.00	240.00
Depreciation		200.00	240.00	288.00	345.60	414.72	297.66	317.20

Example

Table: *MELRKS* with accelerated depreciation ($\tau = 5, \tau' = 4$)

Time		1	2	3	4	5	6	7
Capacity		1000.00	1250.00	1562.50	1953.13	2441.41	1801.76	1939.70
Age	1	1000.00	250.00	312.50	390.63	488.28	360.35	387.94
	2		1000.00	250.00	312.50	390.63	488.28	360.35
	3			1000.00	250.00	312.50	390.63	488.28
	4				1000.00	250.00	312.50	390.63
	5					1000.00	250.00	312.50
Depreciation		250.00	312.50	390.63	488.28	360.35	387.94	406.80

Example

Table: The split of *MELRKS* with accelerated depreciation (compared with $\tau = 4$)

Time		1	2	3	4	5	6	7
Capacity		1000.00	1250.00	1562.50	1953.13	2441.41	1801.76	1939.70
Age	1	1000.00	250.00	312.50	390.63	488.28	360.35	387.94
	2		1000.00	250.00	312.50	390.63	488.28	360.35
	3			1000.00	250.00	312.50	390.63	488.28
	4				1000.00	250.00	312.50	390.63
Depreciation		250.00	312.50	390.63	488.28	360.35	387.94	406.80
Finding		**1250.00**	**1562.50**	**1953.13**	**2441.41**	**1801.76**	**1939.70**	**2034.00**

- The MERLKS effect of accelerated depreciation can be divided, that is, the capacity of accelerated depreciation can be obtained by summing the value of depreciation because of the shortened accounting depreciation period and the capacity of general depreciation accounting with the physical depreciation period adjustment, as shown in Table 5.
- It is not difficult to find that the “Finding”, which is equal to the capacity calculated in Table 4, can be calculated on the basis of the sum of production capacity and depreciation amount after adjusting the physical depreciation period to the accounting depreciation period, which is completely consistent with the splitting proposed in this paper.
    - It can also explain that besides the investment effect of the accounting depreciation period, the adjustment effect of the physical depreciation period is an indispensable part of the economic growth change.
    - This example verifies the logic of equation 16 and equation 18, and thus fully reveals another aspect of the promoting effect.

Influence of physical depreciation period adjustment

input matrix $M_{\tau'}$ =

$$
\begin{pmatrix}
k_1 & 0 & \cdots & 0 & k_2 & 0 & \cdots & 0 & k_3 & 0 & \cdots & 0 \\
0 & k_1 & & & 0 & k_2 & & & 0 & k_3 & & \\
\vdots & & \ddots & & \vdots & & \ddots & & \vdots & & \ddots & \\
0 & & & k_1 & 0 & & & k_2 & 0 & & & k_3 \\
a_1 & \cdots & \cdots & a_1 & a_2 & \cdots & \cdots & a_2 & a_3 & \cdots & \cdots & a_3 \\
cfl_1 & \cdots & \cdots & cfl_1 & cfl_2 & \cdots & \cdots & cfl_2 & cfl_3 & \cdots & \cdots & cfl_3
\end{pmatrix}_{(\tau'+2)\times 3\tau'}
$$

output matrix $B_{\tau'}$ =

$$
\begin{pmatrix}
1 & \cdots & \cdots & 1 & 0 & \cdots & \cdots & 0 & 0 & \cdots & \cdots & 0 \\
k_1 & & & & k_2 & & & & k_3 & & & \\
 & \ddots & & & & \ddots & & & & \ddots & & \\
 & & k_1 & 0 & & & k_2 & 0 & & & k_3 & 0 \\
0 & \cdots & \cdots & 0 & 1 & \cdots & \cdots & 1 & 0 & \cdots & \cdots & 0 \\
0 & \cdots & \cdots & 0 & 0 & \cdots & \cdots & 0 & 1 & \cdots & \cdots & 1
\end{pmatrix}_{(\tau'+2)\times 3\tau'}
$$

- The results are reflected in the *blue line*, as shown in Figure 1 - Figure 12.

Depreciation-profit-growth curve

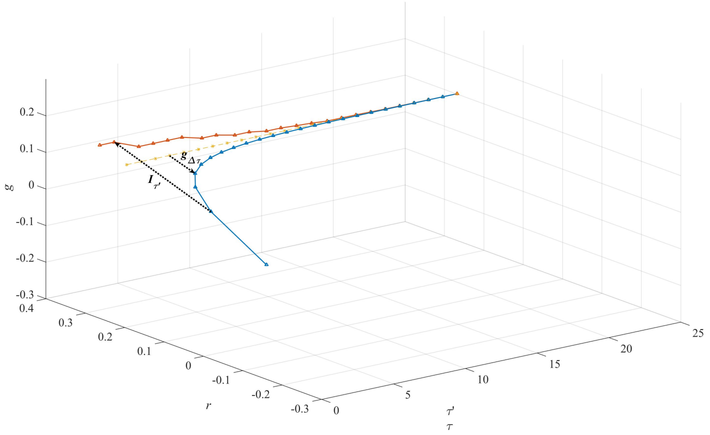

Figure: Depreciation-profit-growth in 1987

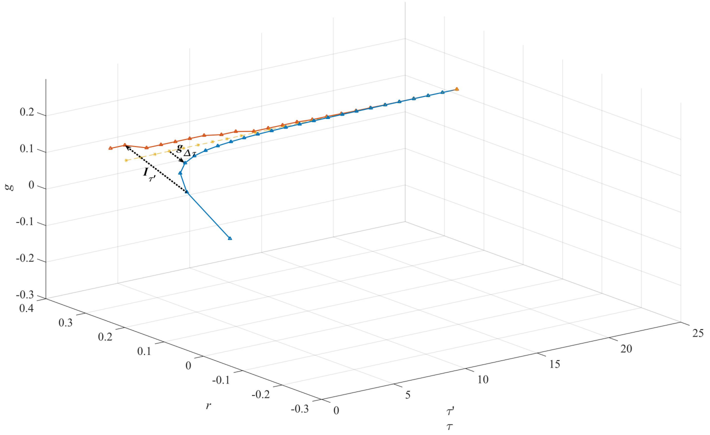

Figure: Depreciation-profit-growth in 1990

Depreciation-profit-growth curve

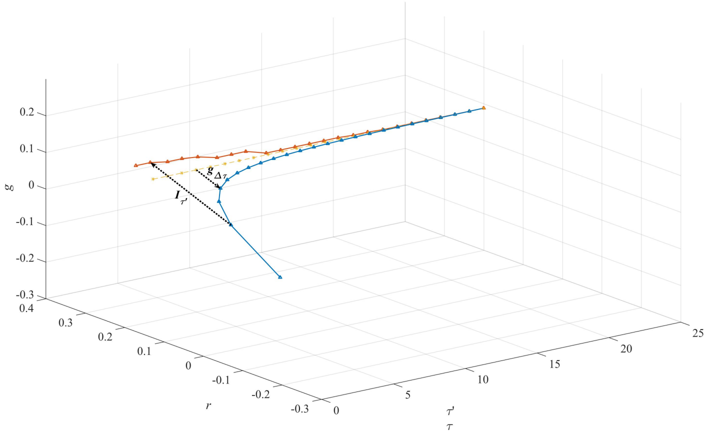

Figure: Depreciation-profit-growth in 1992

Depreciation-profit-growth curve

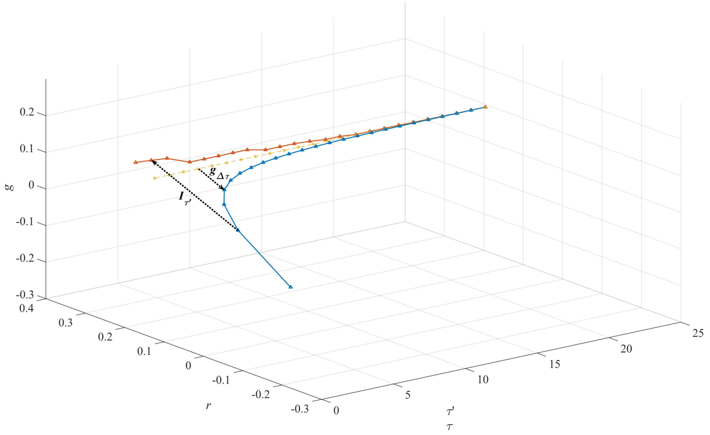

Figure: Depreciation-profit-growth in 1995

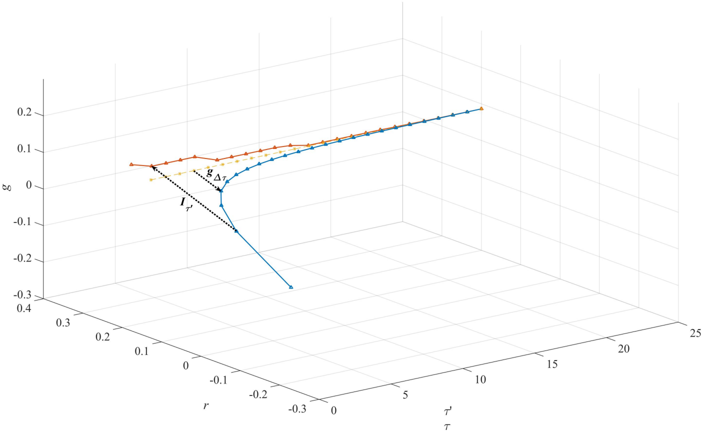

Figure: Depreciation-profit-growth in 1997

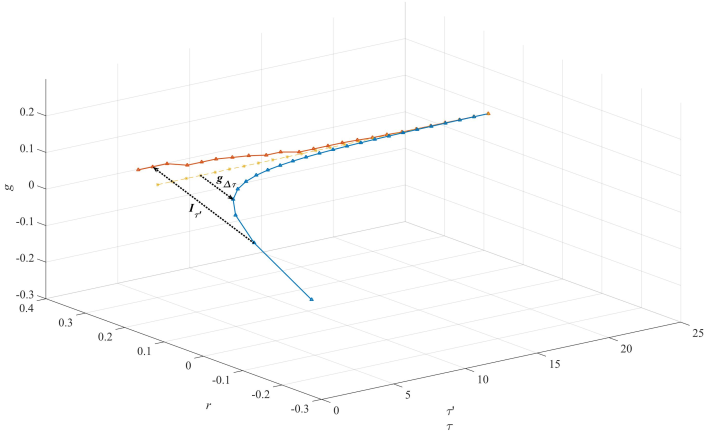

Figure: Depreciation-profit-growth in 2000

Depreciation-profit-growth curve

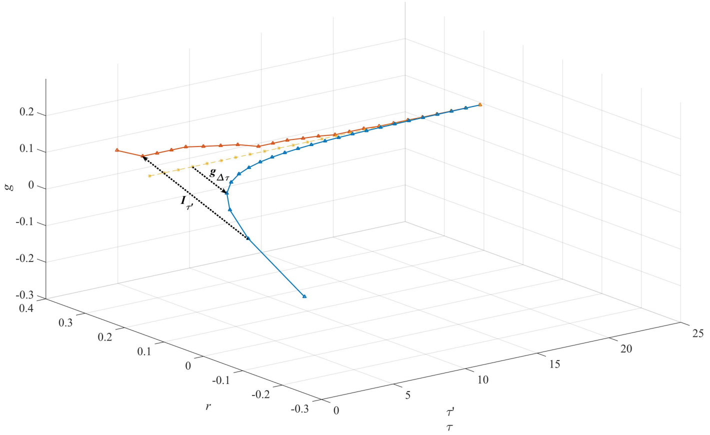

Figure: Depreciation-profit-growth in 2002

Depreciation-profit-growth curve

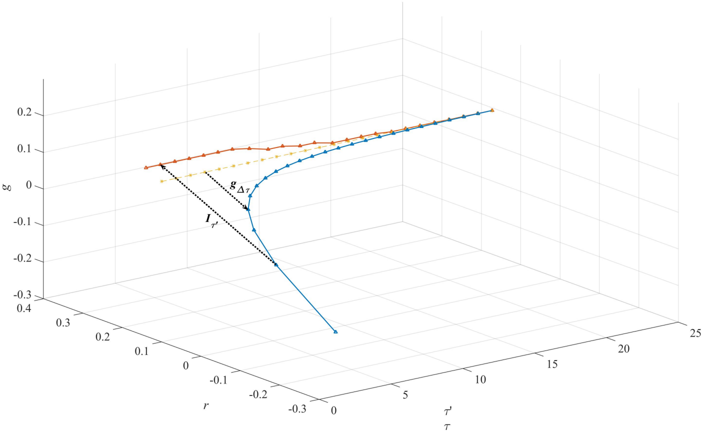

Figure: Depreciation-profit-growth in 2005

Depreciation-profit-growth curve

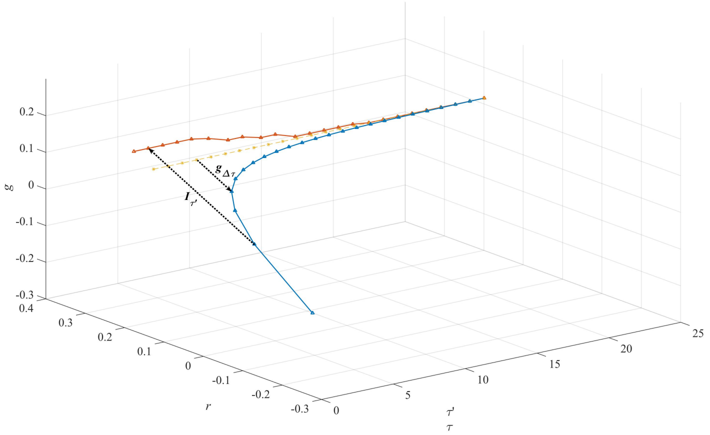

Figure: Depreciation-profit-growth in 2007

Depreciation-profit-growth curve

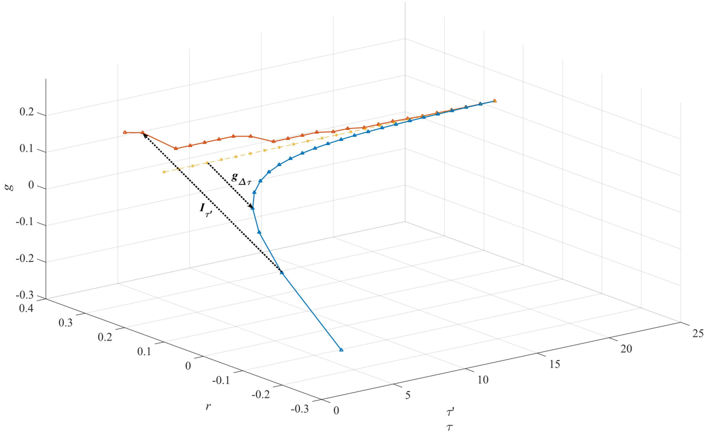

Figure: Depreciation-profit-growth in 2010

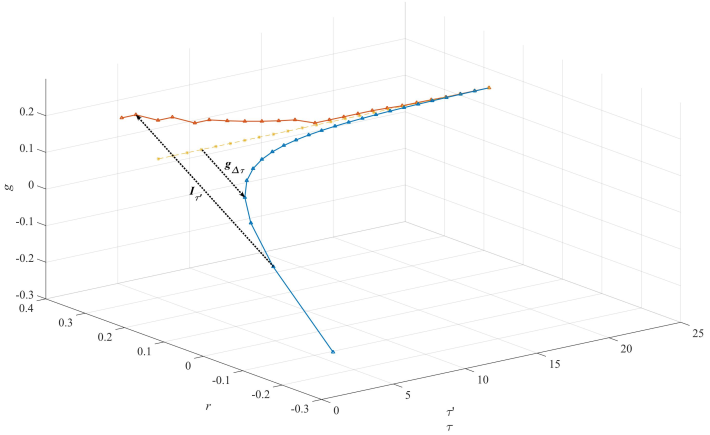

Figure: Depreciation-profit-growth in 2012

Depreciation-profit-growth curve

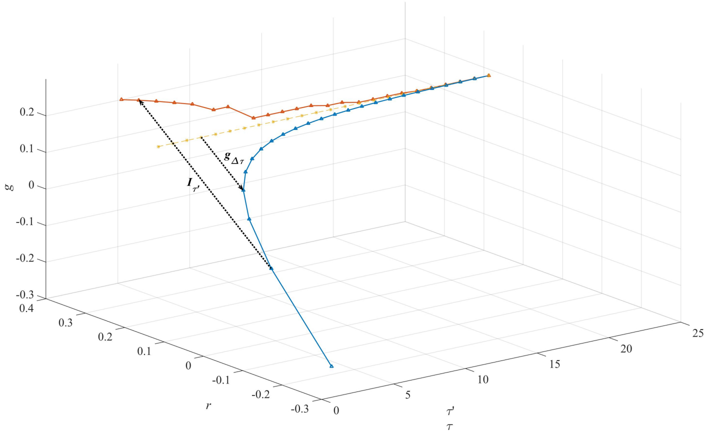

Figure: Depreciation-profit-growth in 2015

Table: Ratio of the adjustment effect of acceleration depreciation ($g_{\Delta\tau}$)

$\Delta\tau =$	-2	-3	-5	-10	-20
1987	-0.0007	-0.0011	-0.0025	-0.0111	-0.2388
1990	-0.0004	-0.0007	-0.0015	-0.0069	-0.1476
1992	-0.0016	-0.0026	-0.0054	-0.0203	-0.3041
1995	-0.0018	-0.0030	-0.0062	-0.0230	-0.3397
1997	-0.0017	-0.0029	-0.0059	-0.0223	-0.3409
2000	-0.0024	-0.0040	-0.0082	-0.0300	-0.4324
Mean value	-0.0023	-0.0039	-0.0080	-0.0297	-0.4265

Table: Ratio of the adjustment effect of acceleration depreciation ($g_{\Delta\tau}$)

$\Delta\tau =$	-2	-3	-5	-10	-20
2002	-0.0020	-0.0033	-0.0070	-0.0269	-0.4134
2005	-0.0042	-0.0069	-0.0140	-0.0496	-0.6358
2007	-0.0023	-0.0038	-0.0079	-0.0298	-0.4437
2010	-0.0044	-0.0073	-0.0148	-0.0528	-0.6681
2012	-0.0034	-0.0057	-0.0117	-0.0430	-0.5867
2015	-0.0033	-0.0054	-0.0112	-0.0410	-0.5670
Mean value	-0.0023	-0.0039	-0.0080	-0.0297	-0.4265

- Table 6 selects representative shortened period of accelerated depreciation and compares the ratio of profit rate and potential growth rate of GDP with the adjustment of physical depreciation period with the general depreciation ($\Delta\tau = 0$).
  - It is not difficult to find that under the adjustment effect, both the profit margin and the potential growth rate of GDP decline slowly, and initially in a quasi-linear way gradually enlarged, until an inflection point began to change rapidly.
  - So far, this paper puts forward the existence of adjustment effect between physical depreciation period and accounting depreciation period, and proves its negative correlation with economic growth.
- Obviously, combined with the empirical results of promoting effect, the range of investment effect can be calculated while determining the value of adjustment effect, which is a descriptive supplement to the previous section, as shown in Table 7.

Table: Ratio of the investment effect of acceleration depreciation ($I_{\tau'}$)

$\Delta\tau =$	-2	-3	-5	-10	-20
1987	0.0010	0.0014	0.0038	0.0299	0.3967
1990	0.0006	0.0009	0.0017	0.0151	0.2275
1992	0.0017	0.0037	0.0074	0.0435	0.4868
1995	0.0023	0.0035	0.0085	0.0483	0.4473
1997	0.0022	0.0034	0.0097	0.0313	0.5149
2000	0.0026	0.0055	0.0097	0.0611	0.6157
Mean value	0.0027	0.0048	0.0108	0.0542	0.6468

Table: Ratio of the investment effect of acceleration depreciation ($I_{\tau'}$)

$\Delta\tau =$	-2	-3	-5	-10	-20
2002	0.0026	0.0047	0.0117	0.0434	0.6723
2005	0.0053	0.0080	0.0185	0.0740	0.8675
2007	0.0023	0.0054	0.0095	0.0542	0.6936
2010	0.0047	0.0099	0.0195	0.1012	0.9200
2012	0.0037	0.0060	0.0186	0.0662	0.9838
2015	0.0036	0.0057	0.0115	0.0831	0.9358
Mean value	0.0027	0.0048	0.0108	0.0542	0.6468

Inflection point and related policy recommendations

- Table 6 also reveals the existence of the inflection point of the adjustment effect curve in Figure 1 - Figure 12: before the inflection point, the adjustment effect is not obvious; after the inflection point, the adjustment effect of sharply accelerated depreciation will even cause the potential growth rate of the macro economy to be lower than zero!
  - Once the constraint of inflection point is broken, the economic growth contributed by the adjustment of physical depreciation period to accounting depreciation period will be seriously insufficient. At this time, it is structurally unstable to rely entirely on the possibility of making up for the depreciation fund as an investment.
- Therefore, to calculate and stipulate the minimum period of depreciation and control the accelerated depreciation of fixed capital within the inflection point is the key to the improvement of taxation policy and the optimization of industrial structure.

- In order to calculate and specify this minimum period, we can consider the inflection point as an anomaly of the profit margin and the potential growth rate of GDP that occurs first in the accelerated depreciation adjustment process. In this paper, *Grubbs criterion* (1950) will be used for testing to eliminate data anomalies from the smallest to the largest at the 1% level of statistical significance, as shown in Table 8.

Table: The minimum depreciation period corresponding to the inflection point

$\tau = 25, \alpha = 0.01$	1987	1990	1992	1995	1997	2000
Minimum	8	8	7	7	7	7
$\tau = 25, \alpha = 0.01$	2002	2005	2007	2010	2012	2015
Minimum	7	6	7	7	7	7

Inflection point and related policy recommendations

- Policy suggestions can be made on the calculation and provisions of the minimum depreciation period at the macro level. On average, the minimum depreciation period is 7 years.
    - Considering that the physical depreciation period of fixed capital such as electronic equipment is relatively short and the proportion put into use is extremely large, it is basically consistent with the provisions in the *Regulations for the implementation of the enterprise income tax law of the People's Republic of China* passed in 2007.
- Therefore, accelerated depreciation should be encouraged, but only before an inflection point in the physical depreciation period occurs.
    - Otherwise, adjustment effect of excessively accelerated depreciation has a relatively large negative impact on economic growth, while the promoting effect is excessively dependent on the positive contribution of investment effect, resulting in increased risks and increased volatility, which is not conducive to sustainable growth and high-quality development.

- This paper focuses on the supply-side reform and economic growth, and discusses the accelerated depreciation of fixed capital.
    - First, this paper expands the two-Sector of reproduction diagrams into a three-Sector general equilibrium dynamic model including fixed capital, which provides a theoretical model analysis framework for verifying and quantifying the promoting effect of accelerated depreciation.
    - Second, based on the above model, this paper proposes a systematic study of accelerated depreciation from the perspective of Marxist political economy. It not only summarizes the investment in the renewal, but also points out the imbalance and insufficiency of production capacity release under the adjustment.
    - Third, this paper used China's input-output table to draw the depreciation-profit-growth curve from 1987 to 2015, and found the existence of inflection point. After a strict mathematical definition, this paper calculates the minimum depreciation period of the macro economy, which provides a theoretical basis for policies.

- The research framework of this paper can make use of the relevant data of the international input-output association to carry out international comparative research and learn from the implementation experience of foreign countries, which is also conducive to the formulation of policies related to accelerated depreciation that match the particularity of China's economic development.
- Of course, this article has some limitations in terms of data.
  - Since the input-output table is not compiled in consecutive years, it is more meaningful to make relevant policy suggestions based on the construction of three-Sector structure table of continuous time series.
  - In addition, this paper selects the average of the physical depreciation years of various industries, and further discussion on the influence of different types of fixed capital is more conducive to enrich and strengthen the policy implications of the study.

Fixed Capital, Accelerated Depreciation and Economic Growth: Mathematical Analysis Based on Marxist Political Economics

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