Eurasian Studies in Business and Economics 10/2
Series Editors: Mehmet Huseyin Bilgin · Hakan Danis

Mehmet Huseyin Bilgin
Hakan Danis
Ender Demir
Ugur Can *Editors*

Eurasian Economic Perspectives

Proceedings of the 22nd Eurasia Business and Economics Society Conference

EBES 2008

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Ender Demir • Ugur Can
Editors

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Preface

This is the second volume (Eurasian Economic Perspectives) of the tenth issue of the Springer's series *Eurasian Studies in Business and Economics*, which is the official book series of the **Eurasia Business and Economics Society** (EBES, www.ebesweb.org). This issue includes selected papers in the field of economics presented at the 22nd EBES Conference that was held on **May 24–26, 2017** at the **Faculty of Economics of Sapienza University of Rome** in Rome, Italy, with the support of Istanbul Economic Research Association. Jonathan Batten, Giuseppe Ciccarone, Giovanni Dosi, Klaus F. Zimmermann, and Marco Vivarelli joined the conference as the keynote speakers. All accepted papers for the issue went through peer-review process and benefited from the comments made during the conference as well. In 2015, EBES Executive Board decided to honor academicians for their lifetime contributions to their fields once a year. The EBES Fellows Award is given to acknowledge a lifetime of contributions to the corresponding academic field. Contributions may be theoretical, empirical, or methodological. The recipients for the EBES Fellow Award are determined by the EBES Executive Board and the Award is given every year at the EBES Conference in May. EBES Executive Board selected **Giovanni Dosi** as the EBES Fellow Award 2017 recipient for his outstanding contribution to the fields of the economics of innovation and technological change and evolutionary theory.

During the conference, participants had many productive discussions and exchanges that contributed to the success of the conference where 265 papers by 435 colleagues from 59 countries were presented. In addition to publication opportunities in EBES journals (Eurasian Business Review and Eurasian Economic Review, which are also published by Springer), conference participants were given opportunity to submit their full papers for this Issue.

Theoretical and empirical papers in the series cover diverse areas of business, economics, and finance from many different countries, providing a valuable opportunity to researchers, professionals, and students to catch up with the most recent studies in a diverse set of fields across many countries and regions.

The aim of the EBES conferences is to bring together scientists from business, finance, and economics fields, attract original research papers, and provide them publication opportunities. Each issue of the Eurasian Studies in Business and Economics covers a wide variety of topics from business and economics and provides empirical results from many different countries and regions that are less investigated in the existing literature. The current issue (Eurasian Economic Perspectives) covers fields such as:

1. Economics of innovation
2. Regional studies
3. Empirical studies on emerging markets

Although the papers in this issue may provide empirical results for a specific county or regions, we believe that the readers would have an opportunity to catch up with the most recent studies in a diverse set of fields across many countries and regions and empirical support for the existing literature. In addition, the findings from these papers could be valid for similar economies or regions.

On behalf of the Series Editors, Volume Editors, and EBES officers, I would like to thank all presenters, participants, board members, and the keynote speakers, and we are looking forward to seeing you at the upcoming EBES conferences.

Istanbul, Turkey Ender Demir

Eurasia Business and Economics Society (EBES)

EBES is a scholarly association for scholars involved in the practice and study of economics, finance, and business worldwide. EBES was founded in 2008 with the purpose of not only promoting academic research in the field of business and economics but also encouraging the intellectual development of scholars. In spite of the term "Eurasia," the scope should be understood in its broadest terms as having a global emphasis.

EBES aims to bring worldwide researchers and professionals together through organizing conferences and publishing academic journals and increase economics, finance, and business knowledge through academic discussions. To reach its goal, EBES benefits from its executive and advisory boards which consist of well-known academicians from all around the world. Every year, with the inclusion of new members, our executive and advisory boards became more diverse and influential. I would like to thank them for their support.

EBES conferences and journals are open to all economics, finance, and business scholars and professionals around the world. Any scholar or professional interested in economics, finance, and business is welcome to attend EBES conferences. Since 2012, EBES has been organizing three conferences every year. Since our first conference, around *9132* colleagues from *92* different countries have joined our conferences and *5240* academic papers have been presented. Also, in a very short period of time, *EBES has reached 1713 members from 84 countries.*

Since 2011, EBES has been publishing two academic journals. One of those journals, *Eurasian Business Review—EABR*, is in the fields of industry and business, and the other one, *Eurasian Economic Review—EAER*, is in the fields of economics and finance. Both journals are published thrice a year, and we are committed to having both journals included in SSCI as soon as possible. Both journals have been published by *Springer* since 2014 and are currently indexed in *Scopus,* the *Emerging Sources Citation Index* (Thomson Reuters), *EconLit*, *Google Scholar*, *EBSCO*, *ProQuest*, *ABI/INFORM*, *Business Source*, *International Bibliography of the Social Sciences (IBSS)*, *OCLC*, *Research Papers in Economics (RePEc)*, *Summon by ProQuest*, and *TOC Premier*.

Furthermore, since 2014 Springer has started to publish a new conference proceedings series (*Eurasian Studies in Business and Economics*) which includes selected papers from the EBES conferences. Also, the 10th, 11th, 12th, 13th, 14th, 15th, and 17th EBES Conference Proceedings have already been accepted for inclusion in the Thomson Reuters' *Conference Proceedings Citation Index*. The 16th, 18th, and subsequent conference proceedings are in progress.

On behalf of the EBES officers, I sincerely thank you for your participation and look forward to seeing you at our future conferences. In order to improve our future conferences, we welcome your comments and suggestions. Our success is only possible with your valuable feedback and support.

With my very best wishes,

Jonathan Batten, PhD
President

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Part I
Economics of Innovation

Two Types of Innovation and Their Economic Impacts: A General Equilibrium Simulation

Toshitaka Fukiharu

Abstract In the traditional two-sector growth model, we show that the real wage rate and the rate of profit converge to positive values when the "constant returns to scale" is assumed. When the "decreasing returns to scale" is assumed, however, the real wage rate converges to zero. Thus, we examine how the trajectories are modified by the creation of a third sector, under the "decreasing returns to scale". First, we examine the downstream innovation: i.e. the third sector produces a new luxury. This innovation is temporarily effective since it raises the average rate of profit, while the rate converges to the same positive value as in the basic model. Next, we introduce the third sector which produces a new energy: the upstream innovation. This innovation is temporarily effective in raising the real wage rate and the rate of profit so long as it takes place in the early stage. These rates, however, converge to zero. Although the effect on the rate of profit in the downstream innovation is greater than the upstream innovation, it is because the total investment in the latter is greater than the former. Thus, we conclude that the upstream innovation has stronger economic impact.

Keywords Innovation · General equilibrium · Simulation · Capital accumulation · Real wage · Rate of profit

1 Introduction

Fukiharu (2013, 2018) examined the innovation and globalism from the viewpoint of income distribution, where "innovation" was defined as the creation of new consumption good and "globalism" as the established world trade, following the present-day usage. This usage is somewhat different from Schumpeter 1911 [1955], which is regarded as the first contribution on innovation. Five types of innovation [neue Kombination] are classified as follows in Schumpeter (1955, p. 66):

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1. The introduction of a new good.
2. The introduction of a new method of production.
3. The opening of a new market.
4. The conquest of a new source of supply of raw materials or half-manufactured goods.
5. The carrying out of the new organization of any industry, like the creation of a monopoly position or the breaking up of a monopoly position.

According to this classification, "innovation" in Fukiharu (2013, 2018) corresponds with Type 1 innovation, while "globalism" corresponds with Type 3 innovation. In this paper, Type 1 and 4 innovations are called the "downstream" and "upstream" innovations, respectively, and their economic impacts are compared. This examination may be important when we consider the history after the financial crisis of 2007–2008. This crisis was regarded in those days as the resurgence of the financial crisis of 1930. As the history reveals, after the crisis, the world economy recovered strongly and the depression of the 1930s did not re-emerge. In this decade, on the one hand, new consumption goods stemming from informational technology have been invented: i.e. downstream innovation. On the other hand, new energy sources, shale oil and gas, have been exerting strong lowering pressure on the energy price: i.e. upstream innovation. Admitting that both types of innovation have exerted a strong effect on the recovery from the financial crisis of 2007–2008, there remains a curiosity in knowing which type has stronger effect than the other. Constructing two-, and three-sector economic models, this paper attempts to answer this curiosity from a purely theoretical viewpoint.

The present paper begins with the construction of a discrete version of Uzawa (1961)'s neo-classical two-sector growth model, originally formulated in a continuous version. With this discrete version of our basic model, we focus our attention on the variations of the real wage and the rate of profit on the process of capital accumulation. We proceed to an examination of the comparison of the economic impact of the two types of innovation, by introducing a third sector into the basic two-sector model. Incidentally, this modification of focus allows us to shed some light on the comparison between the classical and neo-classical growth models.

Formally, in Sect. 2, we compare the "constant returns to scale" case and the "decreasing returns to scale" case of the basic two-sector model. In Sect. 3, we introduce a third sector into the basic model, producing a new consumption good. The modification of the variations of the real wage and the rate of profit is examined on this three-sector growth model. In Sect. 4, we introduce a third sector into the basic model, producing a new energy source. The modification of the variations of the real wage and the rate of profit is examined on this three-sector growth model. In this way, we attempt to derive a conclusion on the examination of which type has a stronger economic effect than the other. In the Appendix, we apply this approach to the classical capital accumulation model.

2 Basic Two-Sector Growth Model

The present paper begins with the construction of a basic two-sector model of capital accumulation, similar to Uzawa (1961). The main difference between this paper and Uzawa (1961) is the treatment of fixed capital. Formulating the two-sector growth model in terms of continuous version, Uzawa (1961) assumed that the decision of installment of fixed capital is decided within each period, t, in exactly the same way as labor input. In the present paper, the fixed capital is installed at the end of previous period, $t - 1$, and cannot be modified during the present period, t. It can only be modified at the end of the present period, t, which cannot be modified during the succeeding period, $t + 1$. In other words, our model is rather similar to Arrow and Hahn (1971). In order to make this point clear the basic model is formulated in a discrete version. On this basic model, we first examine the variation of real wage and the rate of profit on the capital accumulation, while Uzawa (1961) focused its attention solely on the stability of the growth process: e.g. the stability of the trajectories of per capita outputs. Following Uzawa (1961), we start with an examination for the case of "constant returns to scale" of the two sectors' production functions.

2.1 "Constant Returns to Scale" Case

In the basic two sector model, first, we assume that the production functions: $y_1 = f_1[N_1, C_1]$ for the first sector, producing a consumption good, y_1, a necessity, $y_2 = f_2[N_2, C_2]$ for the second sector, producing (fixed) capital good y_2; are of Cobb-Douglas type as in the following, where N_i is the labor input, and C_i is the capital input in the i-th sector ($i = 1, 2$).

$$f_1[N_1, C_1] = {N_1}^{a_1} {C_1}^{b_1} \tag{1}$$

$$f_2[N_2, C_2] = {N_2}^{a_2} {C_2}^{b_2} \tag{2}$$

$$a_1 = \frac{1}{2}, b_1 = \frac{1}{2}, a_2 = \frac{1}{2}, b_2 = 1/2 \tag{3}$$

In Eq. (3), we make the assumption of "constant factor intensity". In the beginning of the t-th period, the capital inputs $C_1(t - 1)$ and $C_2(t - 1)$ are already installed and cannot be modified in this period. In the t-th period, investment of capital good in the i-th sector, $M_i(t)$ is decided and added to $C_i(t - 1)$ ($i = 1, 2$), and $C_1(t) = C_1(t - 1)(1 - g_1) + M_1(t)$ and $C_2(t) = C_2(t - 1)(1 - g_1) + M_2(t)$ are installed, where g_1 is the rate of capital depreciation. In the beginning of the $(t + 1)$-th period, the capital inputs $C_1(t)$ and $C_2(t)$ are given and cannot be modified in this period. In the $(t + 1)$-th period, investment of capital good in the i-th sector, $M_i(t + 1)$ is decided and added to $C_i(t)$ ($i = 1, 2$), and $C_1(t + 1) = C_1(t)(1 - g_1) + M_1(t + 1)$ and

$C_2(t+1) = C_2(t)(1-g_1) + M_2(t+1)$ are determined. The capital accumulation proceeds in this way ($t = 2, 3 \ldots$).

In what follows, we explain how the investment of capital good is decided. Suppose that the initial endowment of fixed capital at the first period are given as $C_1(1) = 100$ and $C_2(1) = 200$, as well as the one of labor, $N(1) = 100$. Given these data, we must determine $C_1(2)$ and $C_2(2)$. Each sector demands labor, $N_i^D(2)$ ($i = 1, 2$) by profit maximization, given $C_i(1)$:

$$\text{Max } \pi_i \equiv p_i f_i[N_i, C_i(1)] - wN_i \ (i = 1, 2)$$

where p_i is the price of the output of the i-th sector and w is the wage rate. Profit accruing to the i-th sector is

$$\pi_i^0 \equiv p_i f_i[N_i(2), C_i(1)] - wN_i(2) \ (i = 1, 2)$$

This profit is used for the capital accumulation, so that the demand for the capital good of the i-th sector, $M_i^D(2)$, is given by

$$M_i^D(2) = \frac{\pi_i^0}{p_2} \ (i = 1, 2)$$

It is also assumed that workers use all of their labor income, $wN(1)$, for the consumption of the first good. Market equilibrium conditions are stipulated as in what follows.

$$N_1^D(2) + N_2^D(2) = N(1) \tag{4}$$

$$M_1^D(2) + M_2^D(2) = f_2\left[N_2^D(2), C_2(1)\right] \tag{5}$$

$$\frac{wN(1)}{p_1} = f_1\left[N_1^D(2), C_1(1)\right] \tag{6}$$

From these equilibrium conditions, we can determine $p_1{*}(2)$ and $p_2{*}(2)$, given $w = 1$. These equilibrium prices determine equilibrium investment: $M_1{*}(2)$ and $M_2{*}(2)$. Thus, we have

$$C_i(2) = C_i(1)(1 - g_1) + M_i^*(2) \ (i = 1, 2)$$

It is assumed that $N(2) = (1 + g_0)N(1)$, where $g_0 = 0.01$. Now, given $C_1(2)$ and $C_2(2)$, and $N(2)$, we must determine $C_1(3)$ and $C_2(3)$ following the above procedure. This process is continued.

It is easy to show that $p_1{*}(2)$ and $p_2{*}(2)$ can be solved analytically (without numerical specification) given $C_1(t-1)$ and $C_2(t-1)$, and $N(t-1)$.

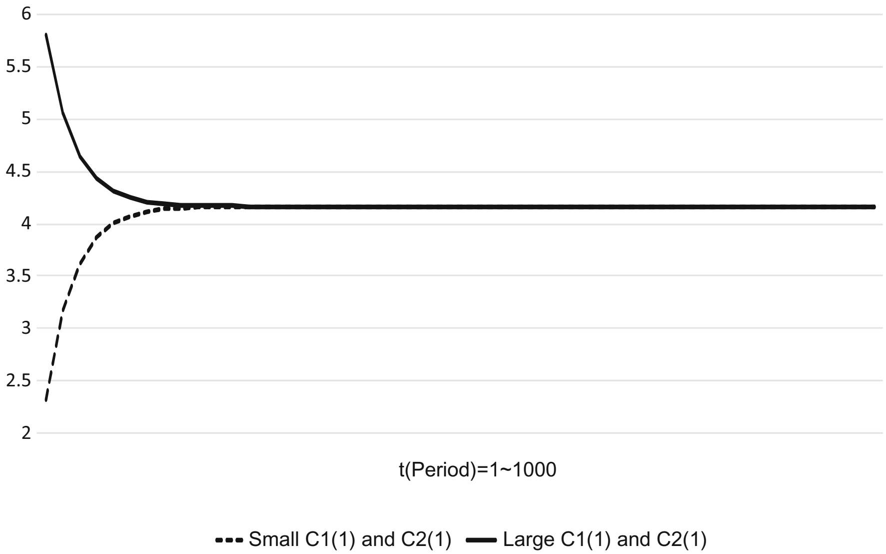

Fig. 1 Trajectory of $w/p_1{}^*(t)$ under constant returns to scale for the neo-classical discrete version under the Eq. (3). Source: Fukiharu (2017a)

$$p_1^*(t) = {a_1}^{-a_1} C_1(t-1)^{-b_1} N(t-1)^{-a_1}$$

$$p_2^*(t) = (1-a_1)^{1-a_2} {a_2}^{-1} C_2(t-1)^{-b_2} N(t-1)^{1-a_2}$$

The trajectory of the real wage: $w/p_1{}^*(t)$, is shown as the dashed curve in Fig. 1, rising continuously, converging to 4.16667 finally. In Fig. 1, the dashed curve is derived for $C_1(1) = 100$, $C_2(1) = 200$, and, $N(1) = 100$. When the endowment of fixed capital is relatively large: $C_1(1) = 10{,}000$, $C_2(1) = 10{,}000$, and, $N(1) = 100$, we have the solid curve, declining continuously, converging to $w_c = 4.16667$. On this dynamic process, the rates of profit of two sectors: $\pi_i^0/(p_2{}^*(t)C_i(t) + wN_i^D(t))$ converge to $r_c = 0.0566038$, while declining in the beginning, as the dashed curve in Fig. 2. In Fig. 2, when the endowment of fixed capital is relatively large: $C_1(1) = 10{,}000$, $C_2(1) = 10{,}000$, and, $N(1) = 100$, we have the solid curve, rising continuously, converging to $r_c = 0.0566038$. Thus, independently of the initial endowments, the real wage converges to $w_c = 4.16667$, while the rate of profit converges to $r_c = 0.0566038$. There appears to be no serious problem to worry about when the assumption of constant returns to scale is guaranteed.

Remark 1 This conclusion is independent of the Eq. (3): "constant factor intensity". When the consumption good is *capital intensive*:

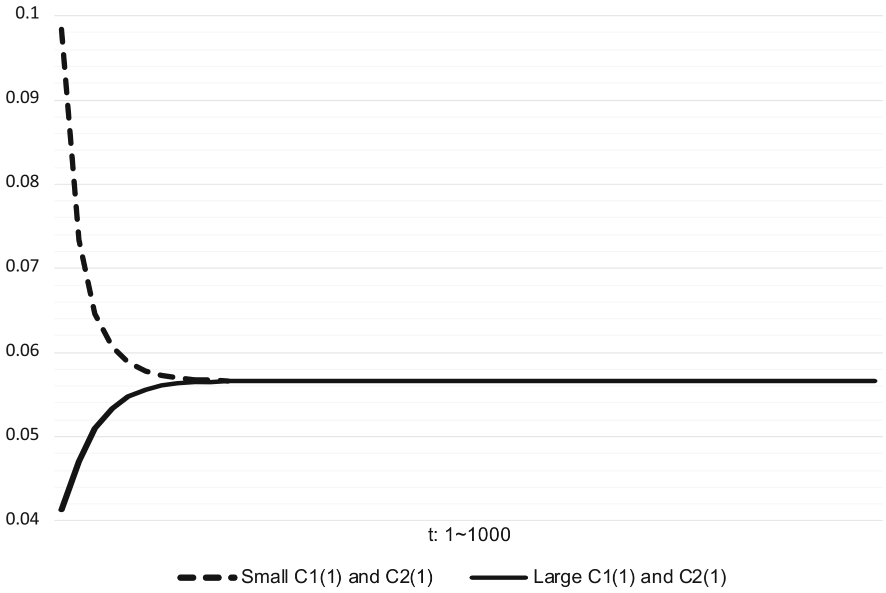

Fig. 2 Trajectory of $\pi_i^0/(p_2^*(t)C_i(t) + wN_i^D(t))$ under constant returns to scale for the neo-classical discrete version under the Eq. (3). Source: Fukiharu (2017a)

$$a_1 = \frac{2}{3}, b_1 = \frac{1}{3}, a_2 = \frac{1}{3}, b_2 = \frac{2}{3} \tag{7}$$

the real wage converges to 4.66637, while the rate of profit for the sector 1 converges to 0.0535714285714286 and the one for the sector 2 converges to 0.0582524 (Fukiharu 2017b). When the consumption good is *labor intensive*:

$$a_1 = \frac{1}{3}, b_1 = \frac{2}{3}, a_2 = \frac{2}{3}, b_2 = \frac{1}{3} \tag{8}$$

the real wage converges to 4.66637, while the rate of profit for the sector 1 converges to 0.0582524 and the one for the sector 2 converges to 0.0535714 (Fukiharu 2017c).

Remark 2 The main concern in (Uzawa 1961) is the stability of the *per capita* variables on the continuous dynamic system. In our discrete dynamic system, we have the following result when $C_1(1) = 100$, $C_2(1) = 200$, and $N(1) = 100$.

1. Under Eq. (3), $y_1(t)/N_1{}^D(t)$: *per capita* output of consumption good; converges to 8.33333 and $C_1(t)/N_1{}^D(t)$: *per capita* fixed capital; converges to 69.4444 (Fukiharu 2017a).
2. Under Eq. (7), $y_1(t)/N_1{}^D(t)$ converges to 6.99956138830484 and $C_1(t)/N_1{}^D(t)$ converges to 342.9355281207124 (Fukiharu 2017b). Finally,
3. Under Eq. (8), $y_1(t)/N_1{}^D(t)$ converges to 13.9991 and $C_1(t)/N_1{}^D(t)$ converges to 52.3783 (Fukiharu 2017c).

2.2 "Decreasing Returns to Scale" Case

In the previous subsection, it was concluded that there appears to be no serious problem to worry about when the assumption of constant returns to scale is guaranteed. We proceed to the "decreasing returns to scale" case with "constant factor intensity":

$$a_1 = \frac{1}{2}, b_1 = \frac{1}{3}, a_2 = \frac{1}{2}, b_2 = \frac{1}{3} \tag{9}$$

Since ${M_1}^D(t)$ and ${M_2}^D(t)$ can be derived analytically (without numerical specification of parameters), the simulation on this case is nothing but the repetition of the previous section's program with different specification of parameters.

When $C_1(1) = 100$, $C_2(1) = 200$, and $N(1) = 100$, the simulation result under Eq. (9) is shown as the dashed curve in Fig. 3: i.e. the trajectory of real wage first rises and after reaching the peak (0.473996) it begins to decline, continuously declining to zero. When the initial endowments of fixed capital are relatively large: $C_1(1) = 10{,}000$, $C_2(1) = 10{,}000$, and $N(1) = 100$, simulation result under Eq. (9) is shown as the solid curve in Fig. 3: i.e. the trajectory of real wage monotonously declines to zero. These simulation results reveals that under "decreasing returns to scale", at least after some period, the real wage declines monotonously, converging to zero. This simulation result is a serious problem to worry about.

We proceed to the analysis of the variation of the rate of profit on the capital accumulation process under "decreasing returns to scale". When $C_1(1) = 100$, $C_2(1) = 200$, and $N(1) = 100$, the simulation result under Eq. (9) is shown as the dashed curve in Fig. 4: i.e. the trajectory of the rate of profit declines continuously, converging to a positive value: $r_d = 0.0543651739063128$. When the initial endowments of fixed capital are relatively large: $C_1(1) = 10{,}000$, $C_2(1) = 10{,}000$, and $N(1) = 100$, the simulation result under Eq. (9) is shown as the solid curve in Fig. 4: i.e. the trajectory of the rate of profit continuously rises, converging to the same positive value: $r_d = 0.0543651739063128$. These simulation results reveals that, under "decreasing returns to scale", the rate of profit converges to a positive value: i.e. there is no serious problem to worry about.

Remark 3 We may say that this conclusion is rather robust. It is confirmed in Fukiharu (2017b, c) that we have essentially the same figures as Figs. 3 and 4 under assumptions similar to Eqs. (7) and (8): e.g.

$$a_1 = \frac{1}{2}, b_1 = \frac{1}{3}, a_2 = \frac{1}{3}, b_2 = \frac{1}{2} \tag{10}$$

$$a_1 = \frac{1}{3}, b_1 = \frac{1}{2}, a_2 = \frac{1}{2}, b_2 = \frac{1}{3} \tag{11}$$

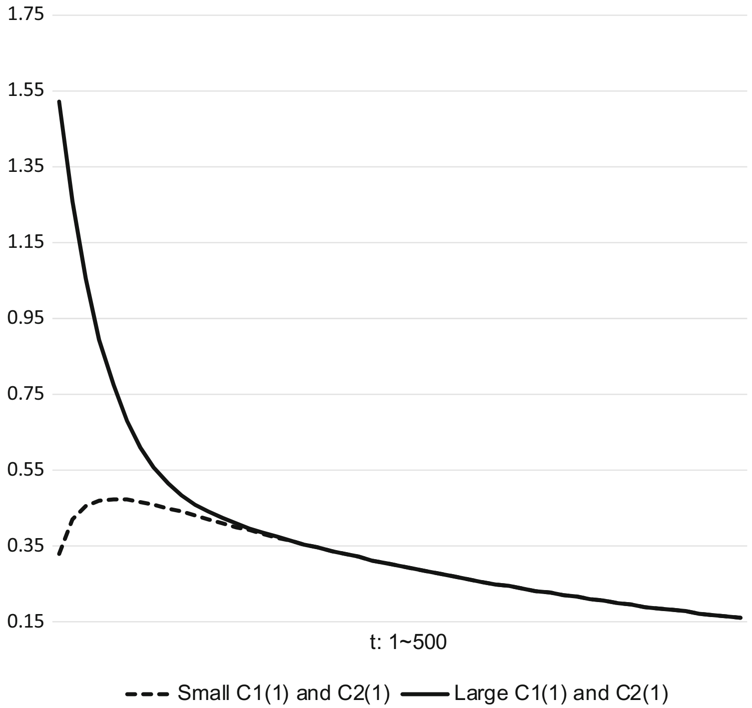

Fig. 3 Trajectory of $w/p_1*(t)$ under decreasing returns to scale for the neo-classical discrete version. Source: Fukiharu (2017a)

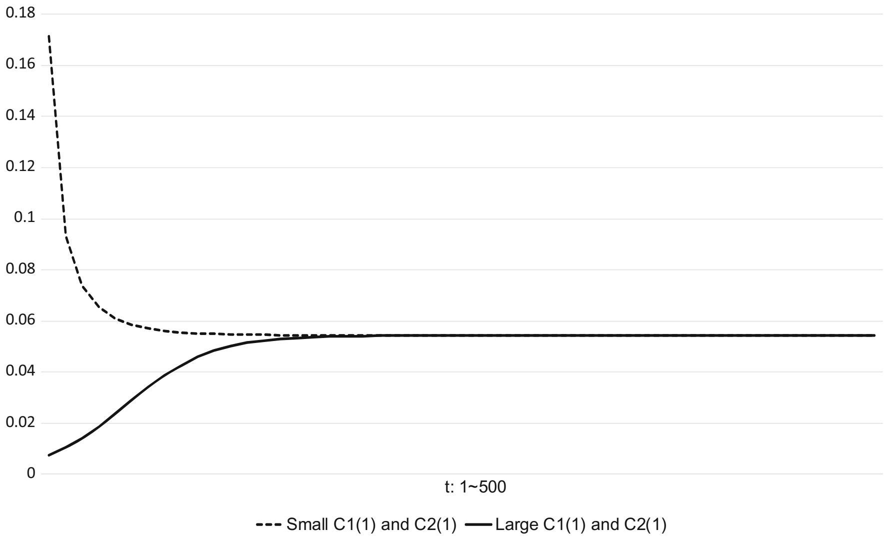

Fig. 4 Trajectory of the rate of profit under decreasing returns to scale for the neo-classical discrete version. Source: Fukiharu (2017a)

3 Downstream (Type 1) Innovation Under Decreasing Returns to Scale

As shown in the previous subsection, under the "decreasing returns to scale" case, the real wage rate converges to zero, independently of the endowment of fixed capital. The difference of endowment influences only the period at which the declining of the real wage begins. In other words, when the endowment of fixed capital is large, the real wages declines monotonously from the first period. Meanwhile, when the endowment is small, the wage rate rises in the beginning. Unfortunately, it starts declining from the 100th period after reaching a peak before the 100th period. In this section, we examine the consequence of "downstream (or Type 1) innovation" under the "decreasing returns to scale" case with small endowment of fixed capital: $C_1(1) = 100$ and $C_2(1) = 200$, in which a new commodity, a luxury good, is invented after the peak (at $t = 200$), or before the peak ($t = 20$). Note that Schumpeter (1955, p. 66) defined five types of innovation (new combination). The first type is the introduction of a new commodity-that is one with which consumers are not yet familiar-or of a new quality of a good. This first type of innovation is defined as "downstream innovation" in this paper. Since there are two consumption goods now, the workers are supposed to maximize utility under income constraint in this section. The production function of this third commodity, $y_3 = f_3[N_3, C_3]$, is assumed to be of the following CES type under "decreasing returns to scale", where y_3 is quantity of consumption good, a luxury, N_3 is labor input and C_3, is fixed capital.

$$\boldsymbol{y_3 \equiv f_3[N_3, C_3] = N_3^{\frac{1}{2}} + C_3^{\frac{1}{2}}}$$

3.1 Downstream Innovation Takes Place After the Peak: At t = *200*

We starts with the examination of the case in which the innovation takes place after the peak, at $t = 200$: i.e. the examination of "if the innovation overcomes the serious problem". At $t = 200$, fixed capitals and the values of other parameters are given by the following.

$$C_1(200) = 2128.73$$
$$C_2(200) = 2128.74$$
$$N(200) = 724.358 \tag{12}$$
$$\text{The rate of profit for the first sector} = 0.0542188$$

$$\text{The rate of profit for the second sector} = 0.0542188$$

The third sector demands labor, ${N_3}^D$ by profit maximization, given C_3:

$$\text{Max } \pi_3 \equiv p_3 f_3[N_3, C_3] - wN_3$$

where p_3 is the price of the output of the third sector. Profit accruing to the third sector is

$$\pi_3^0 \equiv p_3 f_3\left[N_3^D, C_3\right] - wN_3^D$$

This profit is used for the capital accumulation of this sector, so that the demand for the capital good of the third sector, ${M_3}^D$, is given by

$$M_3^D = \pi_3^0/p_2$$

By assumption, capitalists do not consume consumption goods, and the workers maximize utility, from the consumption of y_1 and y_3. The utility function, $u[y_1, y_3]$, is specified to be of the following Cobb-Douglas type.

$$u[y_1, y_3] = {y_1}^{1/2}{y_3}^{1/2}$$

The workers' demand functions for consumption goods, ${y_1}^D$ and ${y_3}^D$, are derived from the maximization of utility under income constraint as in what follows:

$$\text{Max } u[y_1, y_3] \; s.t. \; p_1 y_1 + p_3 y_3 = wN$$

The capital accumulation process newly starts at $t = 1$ as follows. Equilibrium prices, p_1*, p_2*, p_3*, and $w = 1$ are determined by the following equilibrium conditions.

$$N_1^D(2) + N_2^D(2) + N_3^D(2) = N(1) \tag{13}$$

$$M_1^D(2) + M_2^D(2) + M_3^D(2) = f_2\left[N_2^D(2), C_2(1)\right] \tag{14}$$

$$y_1^D(2) = f_1\left[N_1^D(2), C_1(1)\right] \tag{15}$$

$$y_3^D(2) = f_3\left[N_3^D(2), C_3(1)\right] \tag{16}$$

where $N(1) = 724.358$, $C_1(1) = 2128.73$, $C_2(1) = 2128.74$, and $C_3(1) = 0$. Under Eq. (3), from these equilibrium conditions, (13)–(16), p_1*, p_2*, and p_3*, with $w = 1$, are derived analytically as follows:

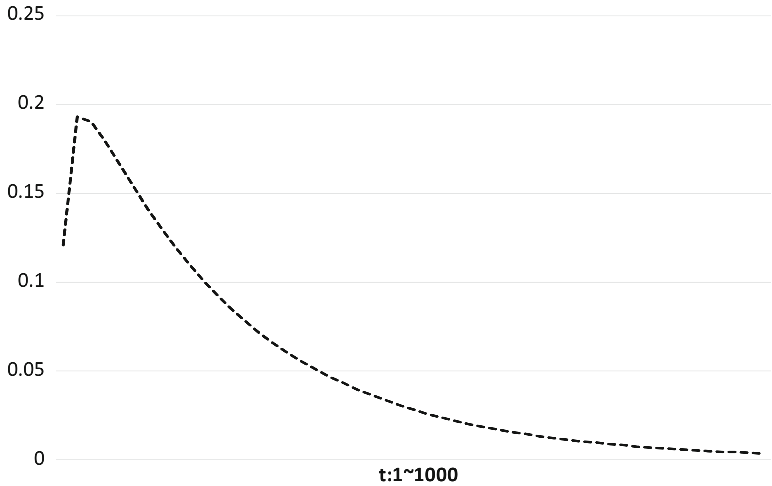

Fig. 5 The new trajectory of the per capita utility for the downstream innovation. Source: Fukiharu (2017a)

$$p_1^* = N^{1/2}/{C_1}^{1/3}$$

$$p_2^* = 2^{\frac{1}{2}}\left(N - C_3 + {C_3}^{\frac{1}{2}}(C_3 + N)^{\frac{1}{2}}\right)^{1/2}{C_2}^{-1/3}$$

$$p_3^* = (C_3 + N)^{1/2} - {C_3}^{1/2}$$

Utilizing these equilibrium prices, $M_1(2)$, $M_2(2)$, and $M_3(2)$ are determined, so that $C_1(2) = C_1(1)(1 - g_1) + M_1(2)$, $C_2(2) = C_2(1)(1 - g_1) + M_1(2)$, and $C_3(2) = C_3(1)(1 - g_1) + M_3(2)$ are determined, as well as $N(2) = (1 + g_0)N(1)$. In this way, the new capital accumulation process begins with the initial conditions stipulated in Eq. (12). Under the new capital accumulation process, the price of the necessity, $p_1(t)$, rises continuously, while the price of the luxury, $p_3(t)$, declines sharply in the beginning and after reaching the bottom before $t = 100$, it rises continuously. Thanks to the decline of the price of luxury good, per capita utility, a different expression of real wage, rises in the beginning, declining later continuously after reaching the peak before $t = 100$. Finally, it converges to zero as shown in Fig. 5. Unfortunately, utility function is introduced after the innovation, so that it is not possible to compare the workers' situation between before and after the invention of luxury good.

Thanks to the rising $p_1(t)$, the rate of profit of the first sector also rises in the beginning. After reaching a peak at around $t = 300$, the rate declines monotonously afterwards. Meanwhile, the trajectory of the three sectors' average rate of profit is depicted as the dashed curve in Fig. 6. Note that the peak (0.0733999) of the new trajectory reached after the innovation is greater than 0.0542188, the average of the two sectors' rates of profit, the rate just before the invention of luxury good. Thus,

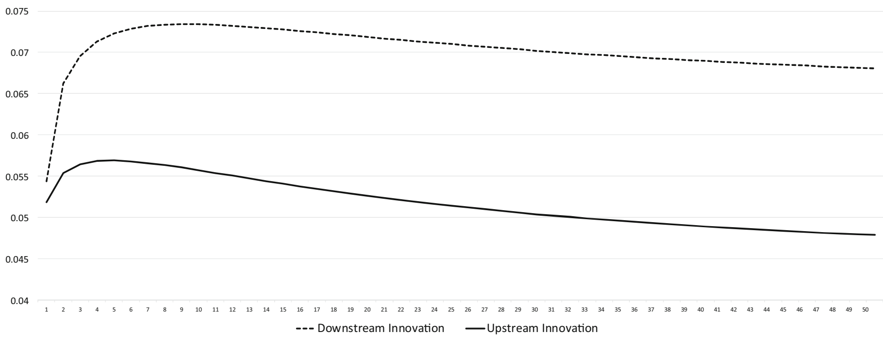

Fig. 6 The new trajectories of the average rate of profit starting from $t = 200$ when the downstream and upstream innovations take place. Source: Fukiharu (2017a)

the downstream (Type 1) innovation is effective to the economy as a whole. The new trajectory converges to $r_d = 0.0543651739063128$: the limit of the old trajectory.

Remark 4 We may say that this conclusion is rather robust. It is confirmed in (Fukiharu 2017b, c) that we have essentially the same figures as Figs. 5 and 6 under Eqs. (10) and (11).

3.2 *Downstream Innovation Takes Place Before the Peak: At* t = *20*

We proceed to the examination of the case in which the innovation takes place before the peak: at $t = 20$: i.e. the examination of "if the downstream Innovation overcomes the serious problem".

At $t = 20$, fixed capitals and other values of parameters are given by the following.

$$\begin{aligned} C_1(20) &= 350.134 \\ C_2(20) &= 387.87 \\ N(20) &= 120.811 \end{aligned} \tag{17}$$

$$\text{The rate of profit for the first sector} = 0.0748802$$

$$\text{The rate of profit for the second sector} = 0.0748802$$

Starting from the initial conditions stipulated in Eq. (17), the new trajectory of the three sectors' average rate of profit is depicted as the dashed curve in Fig. 7. Note that the peak (0.0918332) of the new trajectory reached after the innovation is greater than 0.0748802, the average of the two sectors' rates of profit, Eq. (17), the rate just before the innovation of luxury good. Thus, the downstream (Type 1) innovation is

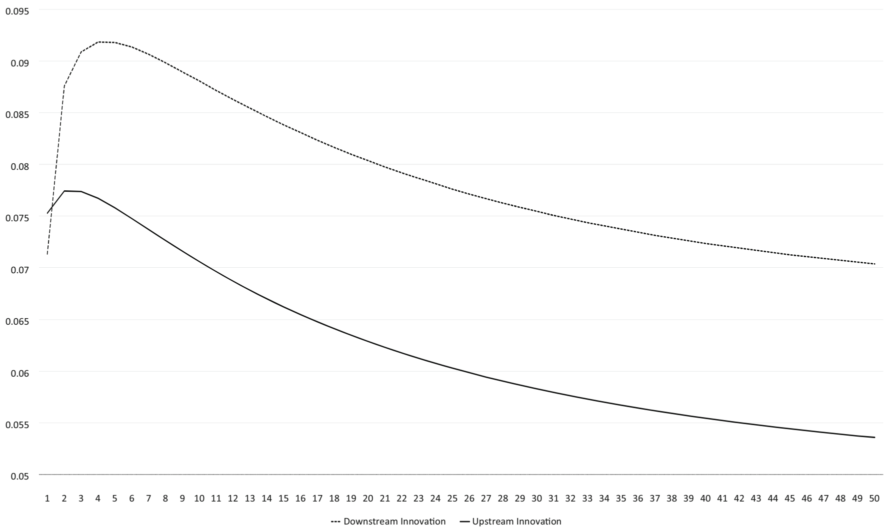

Fig. 7 The new trajectories of the average rate of profit starting from $t = 20$ when downstream and upstream innovations take place. Source: Fukiharu (2017a)

effective to the economy as a whole. As in Sect. 3.1, the new trajectory converges to $r_d = 0.0543651739063128$: the limit of the old trajectory.

Remark 5 We may say that this conclusion is rather robust. It is confirmed in Fukiharu (2017b, c) that we have essentially the same figures as Figs. 5 and 7 under Eqs. (10) and (11).

4 Upstream (Type 4) Innovation Under Decreasing Returns to Scale

As shown in Sect. 2, under the "decreasing returns to scale" case, the real wage rate converges to zero, independently of the endowment of fixed capital. In this section, we examine the consequence of upstream (Type 4) innovation under the "decreasing returns to scale" case with small endowment of fixed capital: $C_1(1) = 100$ and $C_2(1) = 200$, in which a new source of energy is invented after the peak (at $t = 200$), or before the peak ($t = 20$). The production function of this third commodity, $y_3 = f_3[N_3, C_3] = N_3^{1/2} + C_3^{1/2}$, is assumed to be of the same CES type under "decreasing returns to scale" used in Sect. 3.