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A Macroeconomic Theory of Technology Adoption: A Dynamic Vintage Approach

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Abstract

The cleansing effect of recessions by Caballero and Hammour (1994) has received considerable attentions as a theory to explain a rapid productivity growth right after a serious slump. In their explanation a resession forces outdated firms to exit the market, which enhances the productivity in the economy. However it is ambiguous whether the productivity in the economy rises in their model since a recession also decreases the new entry of firms with high productivity. In contrast to their analysis, this paper focuses on the role of asset prices in the productivity and firm's exit and entry. In our model, it is key factor that assets have two roles; the role as the productive resources and the role as collateral for loans. During a recession, the unprofirable firms are forced to exit the market and to release their assets to the market, which in turn decreases the asset prices. Since the lower asset prices foster the entry of potential entrants with new and high technologies, the economy-wide productivity may increases. During a boom, in contrast, incumbent firms are able to survive even if their productivity is low, which rises asset prices since assets released from them decrease. The rise in asset prices decreases the new entry, and moreover it promotes the continuance of less productive firms by improving their finance. The importance of expectations on the future asset prices are also pointed out in the evolution of economy. The adaptive expectations bring about the prolonged cleansing effect with the continuous decline of the asset prices.

Keywords: Technology Adoption, Asset Prices, Collateral for loans, Cleansing Effect of Recessions.

JEL classifications: E32, O31, O40

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1 Introduction

The process of creation and destruction of production units (firms or machines) play a key role in model of economic growth and busines cycles. The mainstream approach to the process is vintage model of embodied technical progress. Production units embodied the newest technology are being created, and outdated units are being scrapped, which was first analyzed in the context of economic growth thanks to the seminal contributions by Johansen (1959), Solow (1960) and others.

The idea of vintage capital makes it possible to clarify the difference between technological progress and the rise in productivity. Without any technological advances, creating new production units has no role to play. Without creating ones with new technology, on the other hand, technological progress cannot contribute to overall economic development. However, the recent literature on economic growth and fluctuations focuses mainly on the progress rather than on the creative destruction process. Therefore, whether creation of units with advanced technology and destruction of outdated ones are promoted is as important as, or even more important in the senses than technological advances in an economy.

Then, what environment makes the creation-destruction process easy to facilitate?, and when does productivitiy growth become high? In the framework of vintage approach, Caballero and Hammour (1994) show that outdated production units are scrapped intensively in the recessions, which enhances productivity in the economy as a whole. This is called "cleansing effect of recessions", which implies that recessions are desiable events. The existence of the effect is verified by the recent empirical studies of Gittleman et al. (2006) that estimate the age structure of capital based upon a vintage model. Gali and Hammour (1991) also document the supporting empirical evidence for the cleansing effect of recessions.

The results are also consistent with historical events. For example, the fact is clear from such empirical investigations as those of Solow (1957), Kendrick (1961) and Gordon (2000) that productivity growth rates are high during the Great Depression of the 1930s. Recently, reinvestigating numerous former studies, Field (2003, 2006) concludes that the productivity growth rates in terms both of total productivity and of multifactor productivity in the 1930s are the highest throughout the 20th century in the United States. However, according to the theory of the creansing effect of recessions, the high productivity growth observed in the recessions was caused by not the creation of new production units but the destruction of outdated ones. Can it really be so ?

Following Field's research, Alexopoulos (2006) creates and uses new indicators to measure US productivity growth in the 20th century, and verifies Field's findings. In addition, she shows that the productivity slowdown was not a factor in the sharp decline in output during the Great Depressions although massive innovation activities after 1933 were major factors in the US economic recovery from the Depression. Shared by various researchers such as Mensch (1979), Kleinknecht (1987), and Mowery and Rosenberg (2000) is the view affirmed here that accelerated technological advances contributed to the rapid recovery. It implies that new production units were created, which contributed to high productivity growth in the depression.

One reason why productivity is hightened in recessions lies "opportunity cost" argument, in which firms put efforts into productive-improving activities more than directly productive activities since the return to the latter is lower in recessions. The idea is formalized by Hall (1991), who constructed a model dealing with allocation of a constant labor force and is supported by many empirical works [e.g. Bean(1990), Gali and Hammour (1991), and Saint-Paul (1992)]. Following the argument, the procyclical behavior of productivity can be explained not by the exit of less productive units but by the activating productive-improving activities in recessions.

This paper sheds light on the other virtue of bad times, and asserts that asset prices play a important role in the creation and destruction of production units and then productivity. Especially, we regard two roles of assets, which are the productive resources and the collateral for loans. It is as follows to think these to be important. To begin with, almost all firms have to purchase assets (or the real estate) when they newly start (create) their businesses (production units). If asset prices rise, the set up cost rises, and which makes creation of new firms difficult. Consequently, the productivity is lowered. Economic planning agency of Japan (1996) points out the height of land prices as the background that new entry of firms are decreasing and the venture business cannot grow up easiliy in Japan. They emprically show the negative relation the creation (opening) rate and land prices. The relation is also verified by Papke (1991). Next, consider the role of assets as the collateral for loans. In Japan, the land was considered as an especially advantageous asset, and then banks carried out active loan secured on the land (or ral estate). In such the situation, the rise in land prices facilitates the funding of firms and decreases the destruction of the less productive firms, and which lowers the productivity. Thus, the asset prices play a crucial role in the determaination of creating new firms and destructing less productive ones.

For this purpose, instead of assuming that a single firm has different vintages of capital, we assume that the economy is a continuum of firms, each of which has one particular vintage of capital. Put it differently, the economy as a whole consists of different vintages of capital. New firms surely have the latest technology because they have no incentive to enter the market with old technologies. Therefore, the introducing new technology takes place largely through creating firms with new technologies and destructing less productive ones. To make the macroeconomic aspects of technology adoption clear, some productive resources or structures such as lands are assumed to be exogenously given in the model in this paper. This assumption implies that some resources become available to potential entrants only through the retirement of incumbent firms. During boom periods even firms with old technologies can continue to earn profits, and hence those firms are not destroyed and do not release their productive resources for the use of potential new entrants. During recessions, by contrast, firms with relatively new technologies might be destroyed. As a result, many new firms come into existence, which implies that massive creation of new firms takes place during the slumps.

The rest of our paper is organized as follows. Section 2 sets up the model and characterizes an within-period equilibrium, and sees the relation between technology adoption and aggregate productivity growth. Section 3 deals with the steady state of the economy, and Section 4 investigates the dynamic relation between cleansing effect of recessions and asset price. Finally, section 5 provides some concluding remarks.

2 The model

2.1 The economy

Consider an economy consisting of continuum of firms, each of which has one particular vintage technology for production. In the economy, the level of frontier technology ω_t grows at the constant rate $\gamma(> 0)$ [1]. Hence newly-entering firms have the latest (therefore, the most productive) technology of the period. Once the firms create the production units with their technologies, the productivity level of the technology is not influenced by future technological changes [2]. Thus, as the level of innovative technology rises, technologies that have been embodied into existing units become outdated ones and less productive. For convenience, we deflate the technology level introduced at $t - v$ by the latest one.

$$\omega_{t-v} = \frac{\bar{\omega}}{(1+\gamma)^{v-1}}. \tag{1}$$

The economy-wide productivity can increase through only the creation of production units with new technologies [3]. Each firm's production needs fixed amount (one unit) of asset which has a fixed total supply $\bar{A}$ and does not depreciate.

2.2 The creation of production units with new technologies

In each period, new firms appear with the latest technology $\bar{\omega}$. Each production requires one unit of asset and operating costs z as productive resources. In addition, set up costs ϕ^j are needed when new firms create the units with the latest technology. The ϕ^j is uniformly distributed between $\phi^{\min}$ and $\phi^{\max}$, which implies that the new firms with lower ϕ^j have potentially higher abilities. Thus, they try to set up their businesses by creating new production unit. However, since they have no initial endowments, they must raise funds to start up their businesses. Since these costs are financed from a financial intermediary that requires a constant rate of return $r(> 0)$ [4], the newly-entering firms can raise funds by making a one-period's financial contract with the intermediary. The firms that have succeeded in setting up their bussinesses in Period t produce $\theta_{t+1}\bar{\omega}$ units of output with probability π in Period $t+1$. However, they fails in their businesses to declare bunkruptcy with probability $1 - \pi$. We call this "natural destruction" [5]. θ_t represents a macro productivity shock including monetary, fiscal and other various factors. We take θ_t to be i.i.d. with a mean $\bar{\theta}$. Thus, in the economy, there are two factors determining the output that each firm produce; the macro productivity shock θ and the firm's productivity ω.

[1] This model does not consider endogenous technological progress. Our objective is not to explain technological progress in a economic system but rather to investigate the macroeconomic factors influencing creation and destruction of production units.

[2] Bahk and Gort (1993), Power (1998), and Jensen et al. (2001) investigate the relationship between the volume of output or labor productivity and the ages of firms, and conclude that the productivity of young firm is higher than that of the old ones.

[3] We do not consider the case in which the firms replace old technologies with latest ones. We can exclude such a case by assuming that the replacements would incur enormous outlays. Cooley et al. (1997) and Zou (2006) study a vintage model in which firms can invest not only new vintage technology, but also existing one.

[4] Hence the economy may considered be as a small open economy.

[5] The bankruptcy rate π is exogenous regardles of continuance of firm. Therefore, both old and new firms retire with probability π in each period.

Each of newly-entering firms must satisfy the following condition to set up a business in Period t,

$$\pi\bar{\theta}\omega_t \geq (1+r)(P_t + z + \phi^j), \tag{2}$$

where P_t denotes the asset prices in Period t, which means the funds required to purchase one unit of asset. The left-hand side (LHS) of the equation represents expected profits obtained from undertaking productions while the right-hand side (RHS) represents the debts with interest, i.e., Eq.(2) is the lender's incentive constraint [6]. Letting $\bar{\phi}_t$ be the maximum level of ϕ^j that satisfies Eq.(2), and it is represented as follow:

$$\bar{\phi}_t \equiv \frac{\pi\bar{\theta}\bar{\omega}}{(1+r)} - P_t - z. \tag{3}$$

Since the new firms with $\phi \leq \bar{\phi}_t$ succeed in creating the production units with latest technology and each of them demands one unit of asset, the aggregate asset demand in Period t is obtained as follows:

$$D_t = \frac{1}{\phi_{\max} - \phi_{\min}} \left[\frac{\pi\bar{\theta}\bar{\omega}}{(1+r)} - P_t - z - \phi_{\min} \right]. \tag{4}$$

The firms, which start up their businesses and succeed their production with probability π, produce $\theta_{t+1}\bar{\omega}$ units of output in Period $t+1$ and repay their debts.

However, firms that can not satisfy following equation have to liquidate their assets to pay off their debts and release them in declaring bankruptcy:

$$\theta_{t+1}\bar{\omega} \geq (1+r)\left(P_t + z + \phi^j\right). \tag{5}$$

Now, let $\tilde{\phi}_{t+1}$ be the maximum level which satisfies Eq.(5), the firms with $\phi^j \leq \tilde{\phi}_{t+1}$ can pay off their debt without liquidating their own asset.

$$\tilde{\phi}_{t+1} \equiv \frac{\theta_{t+1}\bar{\omega}}{(1+r)} - P_t - z \geq \phi^j. \tag{6}$$

However, the firms with $\tilde{\phi}_{t+1} < \phi^j$ are destroyed and release asset. From Eqs.(3) and (6), since $\bar{\phi}_t < \tilde{\phi}_{t+1}$ when $\theta_{t+1} \geq \pi\bar{\theta}$, $\tilde{\phi}_{t+1}$ does not bind. In other words, there is no firm who creates the production units with the latest techonology in Period t and declares bankruptcy in Period $t+1$.

The asset supplied by t period's newly entering firms for the reason except for the natural dectruction at the time of debt payment in Period $t+1$ becomes as follow:

$$\begin{aligned} S_{t+1}^{\text{New}} &= \pi \left[\frac{1}{\phi_{\max} - \phi_{\min}} \frac{\bar{\omega}}{(1+r)} (\pi\bar{\theta} - \theta_{t+1}) \right] \qquad \text{if} \quad \pi\bar{\theta} > \theta_{t+1}, \\ S_{t+1}^{\text{New}} &= 0 \qquad \text{if} \quad \pi\bar{\theta} \leq \theta_{t+1}. \end{aligned} \tag{7}$$

We assume that all the profit earned by the firms with $\phi^j \leq \tilde{\phi}_{t+1}$ are distributed among their owners. Therefore, to stay in business, they must raise funds z through the contracts with the intermediary in succeeding periods [7]. In Period $t+1$, since new firms with the most advanced technologies will appeare in the economy, the production units created in Period t become relatively obsolete compared with the newer ones created in Period $t+1$. We also assume that the firms can not replace old technologies with new ones. Figure.1 shows the time line of such firms' behaviors.

[6] Here we assume that the price of output is a numeraire.

[7] Since the assets do not depreciate at all over time, the firms do not need to buy assets again.

[Insert Figure.1 around here]

2.3 The destruction of outdated production units

In this subsection, we consider the destruction of outdated firms or production units. Let us denote $\omega_{t-\underline{v}_t}$ as the oldest vintage technology in use, which is determined in each period t.

The incumbent firm doing production using the production unit with vintage technology ω_{t-v} produces $\theta_t \omega_{t-v}$ in Period t. Since the firms that create the production units before Period $t-1$ do not need the set up cost, they have only to raise operating costs z to continue their productions. Therefore, the incumbent firms with ω that satisfy following condition can pay off their debt without liquidating asset.

$$\theta_t \omega_{t-v} \geq (1+r)z \quad \Leftrightarrow \quad \theta_t \frac{1}{(1+\gamma)^{v-1}} \bar{\omega} \geq (1+r)z. \tag{8}$$

Suppose that v_t^P is the maximum vintage which satisfies (8). Then,

$$v_t^P = \frac{\ln\left(\frac{\theta_t \bar{\omega}}{(1+r)z}\right)}{\ln(1+\gamma)} + 1. \tag{9}$$

The cut off vintage v_t^P depends on only the macro productivity shock θ_t. In Period t, the incumbent firms with vintage production units before $t - v_t^P$ declare bankruptcy and their production units are destroyed when they pay off their debt.

In contrast, the incumbent firms with vintage production units after $t - v_t^P$ can pay off their debt without liquidating their assets and continue the productions. Since all the profit earned by the firms are distributed among their owners, they have to raise the operating costs z to continue their production again. Thus, the incumbent firms have to clear the following condition to raise funds.

$$\pi\bar{\theta}\omega_{t-v-1} + P_{t+1}^E \geq (1+r)z \quad \Leftrightarrow \quad \pi\bar{\theta}\frac{1}{(1+\gamma)^v}\bar{\omega} \geq (1+r)z - P_{t+1}^E. \tag{10}$$

Where, P_{t+1}^E is a expected asset price, which is the expected value of one unit of asset. Different from to newly entering firms, the incumbent firms can barrow from the intermediary using P_{t+1}^E as the collateral for loans.

Let v_t^R be the maximum vintage that satisfies Eq.(10), we obtain it as follows:

$$v_t^R = \frac{\ln\left(\frac{\pi\bar{\theta}\bar{\omega}}{(1+r)z - P_{t+1}^E}\right)}{\ln(1+\gamma)}. \tag{11}$$

From this, the cut-off vintage v_t^R depends on the expected asset price P_{t+1}^E. If P_{t+1}^E declines, v_t^R decreases and the oldest vintage of the production unit in use in Period t becomes newer. Therefore, the bankruptcy of incumbent firms increases and then asset supplied to the market increases.

As we discussed in the above, there are two cases that the incumbent firms are forced to declare in each period, in other words, there are two cases that the production units are destroyed in each period : one is when they pay off their debt (where, v_t^P is determined) and the other is when they raise funds (where, v_t^R is determined).

When $v_t^P < v_t^R$ holds, $t - \underline{v}_t$ is determined by $t - v_t^P$ and $t - v_t^R$ does not bind, therefore, the vintages of production units destroyed in Period t are $t - (\underline{v}_{t-1} + 1) \leq t - v \leq t - v_t^P$. Since the firms with these vintages of units declare bankruptcy and supply one unit of assets, the total assets supplied by these firms becomes

$$S_t^{\text{Old,P}} = \sum_{v=v_t^P}^{\underline{v}_{t-1}+1} \pi^v G_{t-v} \qquad \text{if} \quad v_t^P < v_t^R, \tag{12}$$

where, G_{t-v} represents the number of the firms that have created production units in Period $t - v$.

In contrast, vintage production units $t - (\underline{v}_{t-1} + 1) \geq t - v \geq t - v_t^R$ are scrapped when $v_t^P > v_t^R$ holds. Therefore, the assets supplied by the incumbent firms with these vintages units are as follows:

$$S_t^{\text{Old,R}} = \sum_{v=v_t^R}^{\underline{v}_{t-1}+1} \pi^v G_{t-v} \qquad \text{if} \quad v_t^P > v_t^R, \tag{13}$$

From Eqs.(9) and (11), we derive the following condition that satisfies $v_t^P = v_t^R$:

$$P_{t+1}^E = (1+r)z\left(1 - \frac{\pi\bar{\theta}}{(1+\gamma)\theta_t}\right). \tag{14}$$

If $P_{t+1}^E > (1+r)z\left(1 - \frac{\bar{\theta}}{(1+\gamma)\theta_t}\right)$, $v_t^P < v_t^R$ is in effect, and then the assets supplied by the incumbent firms are determined by Eq.(12). On the other hand, if $P_{t+1}^E < (1+r)z\left(1 - \frac{\bar{\theta}}{(1+\gamma)\theta_t}\right)$, $v_t^P > v_t^R$ is in effect, and then the assets supplied by the incumbent firms are determined by Eq.(13). Which constraint is in effect, $t - v_t^P > t - v_t^R$ or $t - v_t^P < t - v_t^R$, plays an important role in determining the dynamics of the economy.

2.4 Within-period equilibrium

In this subsection let us characterize an within-period equilibrium of the asset market. The asset demand in each period is obtained from Eq.(4).

Since the assets each firm needs is one unit, the number of firms must be equal $\bar{A}$ in each period. The firms declare bankruptcy with probability $1 - \pi$ and liquidate the assets:

$$S_t^{\text{Min}} = (1-\pi)\bar{A}. \tag{15}$$

S^{Min} denotes the asset supply caused by "natural bankruptcy". In addition, the assets supplied by the firms, which newly introduced technology in Period $t-1$ and can not pay their debt including set up costs without liquidating the assets, becomes:

$$\begin{aligned} S_t^{\text{New}} &= \pi\left[\frac{1}{\phi_{\max} - \phi_{\min}} \frac{\bar{\omega}}{(1+r)}(\pi\bar{\theta} - \theta_t)\right] \qquad \text{if} \quad \pi\bar{\theta} > \theta_t, \\ &= 0 \qquad \text{if} \quad \pi\bar{\theta} < \theta_t. \end{aligned} \tag{16}$$

Moreover, the assets supplied by the incumbent firms that introduced technology before Period $t-1$ is determined by Eq.(12) or Eq.(13).

Hence, the asset market clearing condition in Period t is expressed as follows:

$$D_t = S_t^{\text{Min}} + S_t^{\text{New}} + S_t^{\text{Old,P}} \quad \text{if} \quad v_t^P < v_t^R, \tag{17}$$
$$D_t = S_t^{\text{Min}} + S_t^{\text{New}} + S_t^{\text{Old,R}} \quad \text{if} \quad v_t^P > v_t^R, \tag{18}$$

where $S_t^{\text{New}} = 0$ when $\pi\bar{\theta} \leq \theta_t$.

Solving Eq.(17) gives

$$\begin{aligned} P_t &= \Phi(\theta_t) - \Psi(\theta_t), \qquad (19)\\ where, \quad \Phi(\theta_t) &\equiv \frac{\pi\bar{\theta}\bar{\omega}}{(1+r)} - \frac{\bar{\theta}\bar{\omega}}{(1+r)}(\pi\bar{\theta} - \theta_t) - z - \phi_{\min} - \phi_{\max}(1-\pi)\bar{A},\\ \Psi(\theta_t) &\equiv \phi_{\max} \sum_{v=v_t^P}^{\underline{v}_{t-1}+1} \pi^v G_{t-v}. \end{aligned}$$

In this case, the asset price depends only on the macro productivity shock θ.

By contrast, we get the following equation by solving Eq.(18):

$$\begin{aligned} P_t &= \Phi(\theta_t) - \lambda(P_{t+1}^E), \qquad (20)\\ where, \quad \lambda(P_{t+1}^E) &\equiv \phi_{\max} \sum_{v=v_t^R}^{\underline{v}_{t-1}+1} \pi^v G_{t-v}. \end{aligned}$$

If the asset market clearing condition is determined by Eq.(18), then the asset price depends on the expected asset price. From Eqs.(19) and (20), we find that $\Psi(\theta_t) > \lambda(P_{t+1}^E)$ is always satisfied when $v_t^P < v_t^R$, and vice versa.

2.5 Technological progress, cteation of new production units and productivity growth

Although $t - \underline{v}_t$ is determined by either $t - v_t^P$ or $t - v_t^R$ (the oldest vintage of production units in use in Period t), the incumbent firms with old vintage production units go to bankruptcy since the productivity decreases relatively over time. Therefore, creating and destructing production units occur continuously, and economy-wide productivity also increases over time.

Figure.2 illustrates the relationship between creating and destructing production units in the simple case that G_{t-v}'s are constant at $\bar{G}$ regardless of $v(>0)$.

[Insert Figure.2 aroung here]

The economy-wide productivity increases only through introducing new technology. In this sense, creating prodution units with new technology is an essential element for productivity growth. In what follows we will analyze the macroeconomic factors (especially asset prices) influencing it.

Let us turn to the economy-wide productivity growth and the production level. Suppose that $\underline{v}_{t-1}$ is given, and $\underline{v}_t(< \underline{v}_{t-1})$ is determined in Period t. Then $\sum_{v=\underline{v}_t}^{\underline{v}_{t-1}} \pi^v G_{t-v}$ units of asset become available for the potential entrants since the vintage production units with $t-\underline{v}_t \leq t-v \leq t-\underline{v}_{t-1}$ are destroyed. Thanks to this creating new production units, the economy-wide productivity ω^w increases as follows,

$$\Delta\omega_t^w = \sum_{v=1}^{\underline{v}_{t-1}+1} \left\{(\bar{\omega} - \omega_{t-v})(1-\pi)\pi^{v-1}G_{t-v}\right\} + \sum_{v=\underline{v}_t}^{\underline{v}_{t-1}+1} \left\{(\bar{\omega} - \omega_{t-v})\pi^v G_{t-v}\right\}, \tag{21}$$

where, the first term on the right-hand side (RHS) is an increase in the economy-wide productivity caused by the "natural destruction" of firms, and the second term is an increment in the productivity coming from the replacement of production units due to economic obsolescence.

Since the aggregate output, Y_t, in each period is represented by $Y_t = \pi\theta_t\omega_t^w$, the growth rate of the aggregate output is given as follow:

$$\frac{\Delta Y_t}{Y_t} = \frac{\Delta\theta_t}{\theta_t} + \frac{\Delta\omega_t^w}{\omega_t^w}.$$

Thus, the growth rate of the aggregate output is the sum of the rate of change in macro productivity and the rate of the economy-wide productivity through technology adoption. If θ declines, which leads to increasing $\Delta\omega_t^w$, then this negative shock may contibute to a rapid increase in the aggregate output during the recovery period.

3 The steady state and the transitional dynamics

The expectation of the economic agents is an important factor to consider the economic dynamics. In this model, the expected asset price also plays a key role in characterizing the economic dynamics. Here, we assume that the expected asset price is formed according to the adoptive expectation as follows:

$$P_{t+1}^E = P_t^E + \epsilon(P_t - P_t^E), \tag{22}$$

where, ϵ is a parameter, $0 < \epsilon < 1$. From (22) and the asset market clearing condition Eq.(19) or Eq.(20), we can obtain the difference equation for the expected asset price P_{t+1}^E that characterizes the dynamics of the economy.

When $v_t^P < v_t^R$, the difference equation becomes as follows:

$$P_{t+1}^E = (1-\epsilon)P_t^E + \epsilon\left[\Phi(\theta_t) - \Psi(\theta_t)\right]. \tag{23}$$

By contrast, when $t - v_t^P < t - v_t^R$, the difference equation becomes as follows:

$$P_{t+1}^E = (1-\epsilon)P_t^E + \epsilon\left[\Phi(\theta_t) - \lambda(P_{t+1}^E)\right]. \tag{24}$$

From (14), $t - v_t^P > t - v_t^R$ is satisfied and the difference equation is given by Eq.(23) when $P_{t+1}^E > (1+r)z\left(1 - \frac{\pi\bar{\theta}}{(1+\gamma)\theta_t}\right)$, on the other hand, when $P_{t+1}^E < (1+r)z\left(1 - \frac{\pi\bar{\theta}}{(1+\gamma)\theta_t}\right)$, $t - v_t^P < t - v_t^R$ holds and the difference equation becomes Eq.(24). v^P and v^R lines in Figure.3 are the graphs of Eqs.(23) and (24) [8] .

[Insert Figure.3 around here]

[8]Since $v^R < v^P$ is in effect in the area below the switching line, $\lambda(P_{t+1}^E)$ always becomes larger than $\Psi(\theta_t)$, and then v^R line obtained from Eq.(24) is located under v^P line in Eq.(23). In contrast, v^R line is located upper v^P line in the area above a switching line where $v^R > v^P$ is in effect. And v^R and v^P lines intersect on the switching line.

In what follows, θ_t is assumed to be constant over time(or, $\theta_t = \bar{\theta} = \theta$), we will analyze the steady state and transitional dynamics of the system with phase diagrams. The economy has some cases according to the value of macro productivity shock θ.

First, we consider the case in which the economy has a high θ (that is, in the boom period). When the economy has a high θ, v^P and v^R lines are in an upper area in (P^E_{t+1}, P^E_t) plane as is shown in Figure.4, and then the economy has one stable steady state in the area above a switching line, in which $t - v^P_t > t - v^R_t$ holds.

[Insert Figure.4 around here]

Since the steady state, E^*, is located above the switching line, the asset price is determined by Eq.(19) and the oldest vintage of production units in use $t - \underline{v}_t$ is determined by Eq.(9). When θ is large, $t - \underline{v}_t$ becomes relatively old and firms with old vintage production units can survive. Therefore, the asset price becomes higher and then creation of new production unit is deterred. Thus, when the economy has large θ, the economy approaches the steady state with the higher asset price, and creating new production units becomes inactive.

Next, let us consider the case that the economy has low θ (that is, in the recession). In the case, v^P and v^R lines are located in the lower area in the (P^E_{t+1}, P^E_t) plane, and the economy has one stable steady state in the area below the switching line as is shown in Figure.5.

[Insert Figure.5 around here]

Since the steady state E^* is located below the switching line, the asset price and the oldest vintage of production units in use $t - \underline{v}_t$ are determined from Eqs.(20) and (11). When the economy has small θ, $t - \underline{v}_t$ becomes relatively new and many incumbent firms with old vintage production units are forced to declare bankruptcy. Therefore, the asset price decreases, and massive creation of new units takes place, and then the economy approaches the steady state with a low asset price and the creation of new units becomes active in the recession.

In the above two, the economy converges in the unique stable steady state with fluctuations of the asset price and the economy-wide productivity.

4 The effects of the macro productivity shocks

In this section, we consider the effects of the macro productivity shocks on the fluctuations of the land price and the economy-wide productivity.

At first, let us consider the effects of negative macro productivity shocks (that is, a decline in θ). Suppose that θ is comparatively high (the economy is in booms). Then, v^P and v^R lines are located in an upper area in (P^E_{t+1}, P^E_t) plane as is shown in Figure.6 or Figure.7.

[Insert Figure.6 and Figure.7 around here]

Since the steady state E^{Old} in the economy is located in the area above the switching line, the asset price and the oldest vintage of production units in use $t - \underline{v}_t$ are determined depending only the fundamentals represented by θ.

Suppose a recession takes place or θ falls, which shifts v^P and v^R lines to the downward. Then, the economy gradually moves to the new steady state located in the southwest to the original steady state E^{Old}, and the expected asset price starts to decrease. The decline in θ causes increase in the oldest vintage production units in use $t - \underline{v}_t$, which causes the bankruptcy of incumbent firms. Therefore, the assets owned by them are released to the asset market and the asset price decreases, which lowers the barrier that prevents potential entrants from entering market. Therefore, active creation of new production units takes place, which leads to increase in economy-wide productivity. This constitutes "the cleansing effect".

However, when the decline in θ is small, then the effects on the asset price and the oldest vintage of production units in use $t - \underline{v}_t$ are once-and-for-all since new steady state E^{New} is also located in the area above the sqitching line as is shown in Figure.6. Therefore, the cleansing effect in recesions becomes temporary.

On the other hand, when θ declines significantly (a negative macro productivity shock is very large), v^P and v^R lines shift downward largely as is shown in Figure.7. As a result, the economy moves gradually to a new steady state E^{New} in the area below the switching line from the old steady state E^{Old} with a decrease in the expected asset price. If the economy enters the area below the switching line, then the asset price declines gradually and the oldest vintage of production units in use $t - \underline{v}_t$ also decreases over time. The $t - \underline{v}_t$ becomes shorter with a decline in the asset price, which fosters destructing old vintage production units (the bankruptcy of incumbentfirms) and creating new one. As a result, the economy-wide productivity increases. In sum, the economy moves gradually to the new steady state E^{New} with decreasing the asset price and inducing the exit and entry of many firms. In other words, the economy has prolonged cleansing effects together with a decline in the asset price when the significant negative macro productivity shock occurs.

Next, let us consider the effects of positive macro productivity shocks (that is, a rise in θ). Suppose that θ is comparatively small (the economy is in recessions). Then, v^P and v^R lines are located in a lower area in (P^E_{t+1}, P^E_t) plane in Figure.8.

[Insert Figure.8 aroungd here]

Since the steady state E^{Old} in the economy is located in the area below the switching line, the asset price and the oldest vintage of production units in use $t - \underline{v}_t$ are determined depending not only on the fundamental factor θ but also on the expected asset price.

Now, suppose a boom takes place or θ rises, which shifts v^P and v^R lines upward in Figure.8. The economy gradually moves to the new steady state E^{New} together with an increase in the expected asset price, which makes the oldest vintage production units in use $t - \underline{v}_t$ older and helps the survival of incumbent firms. Therefore, the assets released from old vintage production units decrease and the asset price increases, which raises the barrier that prevents firms from entering market and deters the creation of new production units, and then economy-wide productivity decreases. Thus, the positive macro productivity shocks cause the persistent decrease in the firm-wide productivity together with the increase in the asset price, that is, the economy has persistent reverse cleansing effects in the boom period.

The massive exit and entry of firms (or destruction and creation of new production units) take place and the economy-wide productivity is increased when the asset price decreases. In other words, the decline in the asset price plays a key role in the destruction and creation of new production units and hence in the growth of the economy-wide productivity.

5 Conclusions

Having been motivated by the empirical facts, this paper try to explain the mechanism of "the clansing effect of recessions" with a dynamic vintage approach. As a result, it was shown that the destruction of outdated production units is accelerated (the phenomena have been analyzed by various researchers and have become known as "the cleansing effect of recessions" by Caballero and Hammour, 1994), and much new ones with leading technologies is created during slumps.

However, differ from Caballero and Hammour (1994), the expectation and the asset price play a crucial role to occur the cleansing effect of recessions: A negative macro productivity shock (recessions) promotes the bankruptcy of firms with old vintage production units and the asset owned by them supplies to the asset market, which decreases the asset price. The decrease in the asset price lowers the barrier that prevents new firms from entering newly market, which leads to massive creation of new production units, and then firm-wide productivity increases. Thus, the decline in the asset price that plays a role as the essential productive resource creates new business chances and becomes the source activating creation of new production units. The new technology adoption or the metabolism of firm advanced in the recessions can be a driving force for economic recovery from recessions.

The opposite mechanism is in effect. That is, a positive macro productivity shock (booms) promotes the survive of incumbent firms, which decreases asset supply and therefore, increases the asset price. This prevents the new firms from creating new production units with high productivity, which deters firm-wide productivity. Thus, the positive macro productivity shock causes the reverse cleansing effects together with asset price appreciation.

Although the exit and entry of many firms take place and hence the economy-wide productivity is enhanced when the asset price decreases, the creation of new production units is deterred in the economy with high asset prices. The asset price plays a crucial role in technology adoption and the growth of the economy-wide productivity.

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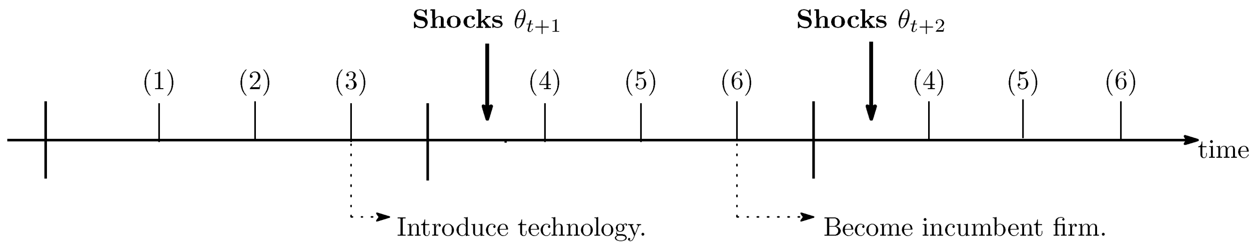

(1)Potential entrants appear with latest technology.
(2)Potential firms raise funds using a one-period contract with a financial intermediary.
(3)Potencial firms introduce their technologies and input productive resources.
(4)Output realised, and firms clear their debt from previous periods.
(5)Firms distribute the profits among their owners.
(6)Incumbent firms rise funds for wage payments and continue their businesses.

Figure 1: Timeline of Events

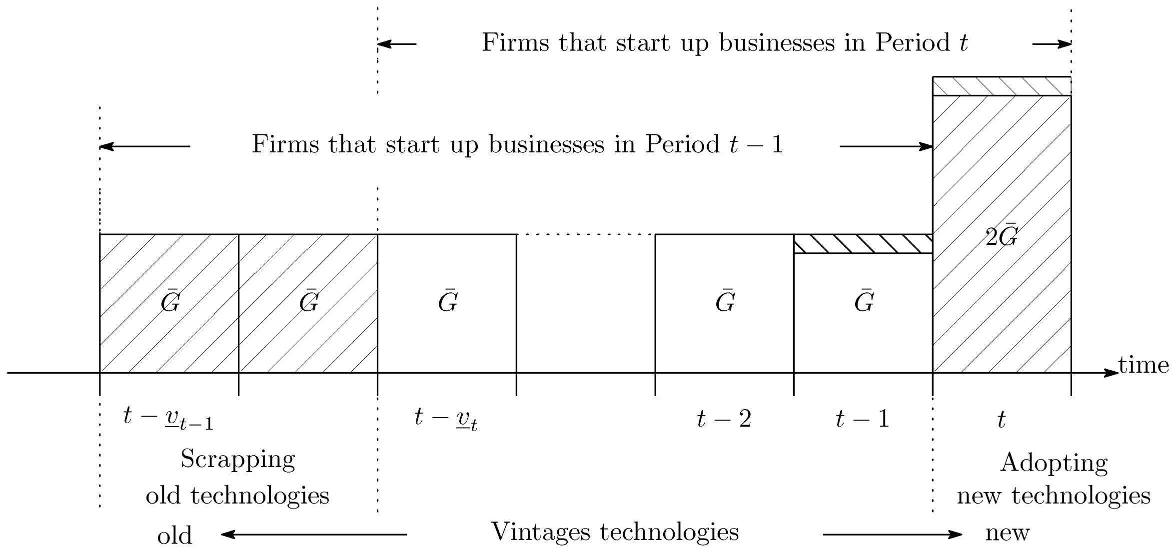

Figure 2: Scrapping old technologies and introducing new ones.

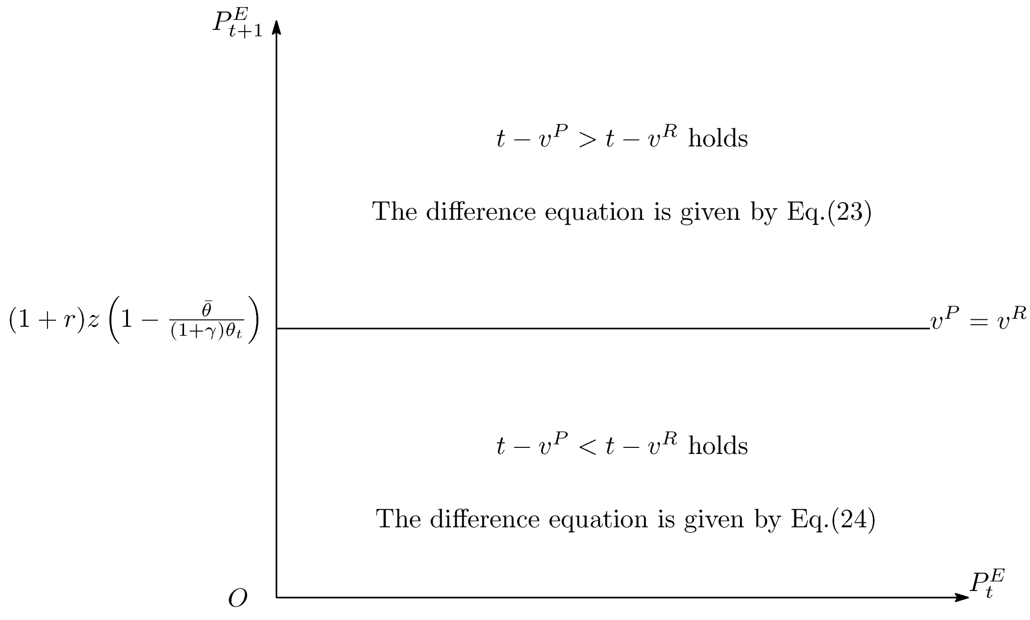

Figure 3: The bifucation line which determines the economic dynamics

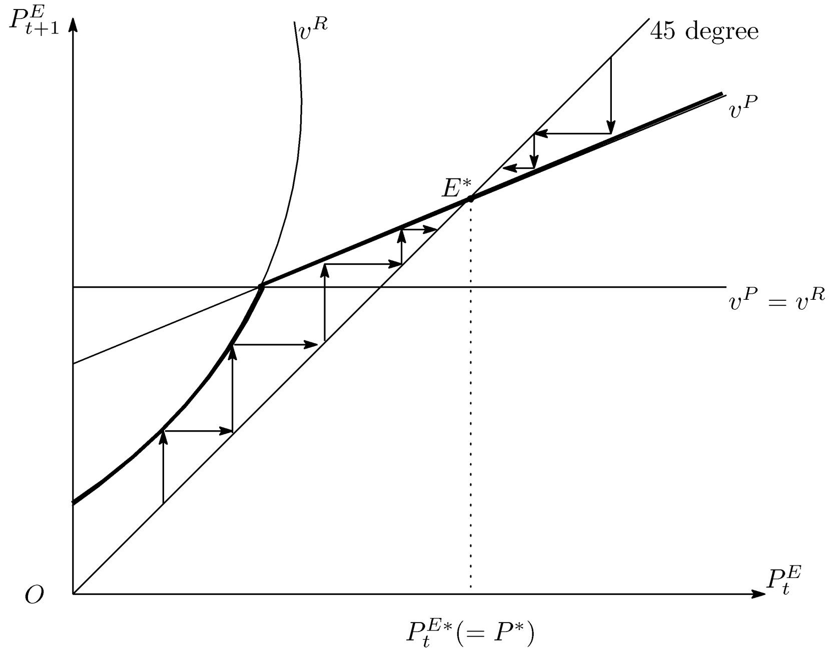

Figure 4: Ths transitional dynamics inthe case that the economy has large θ

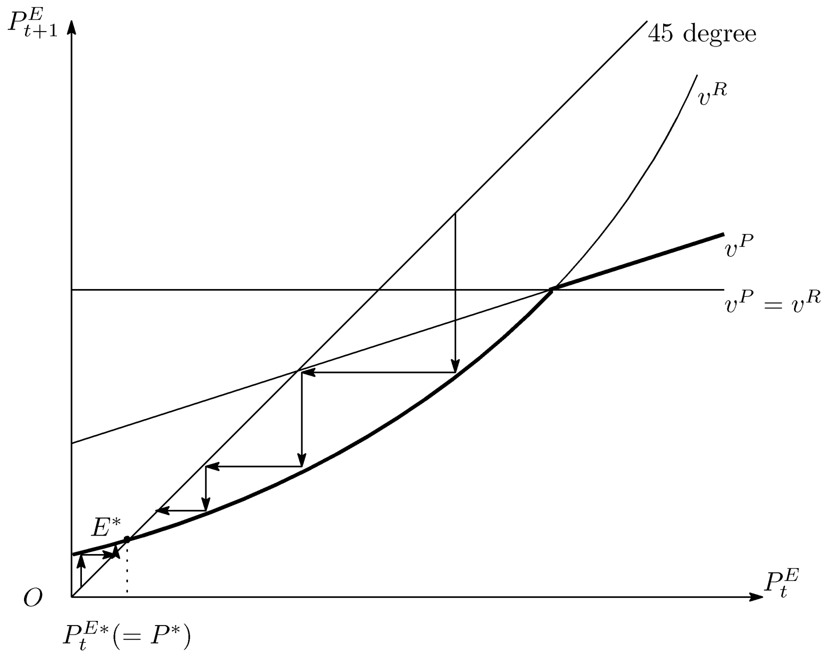

Figure 5: The transitional dynamics in the case that the economy has small θ

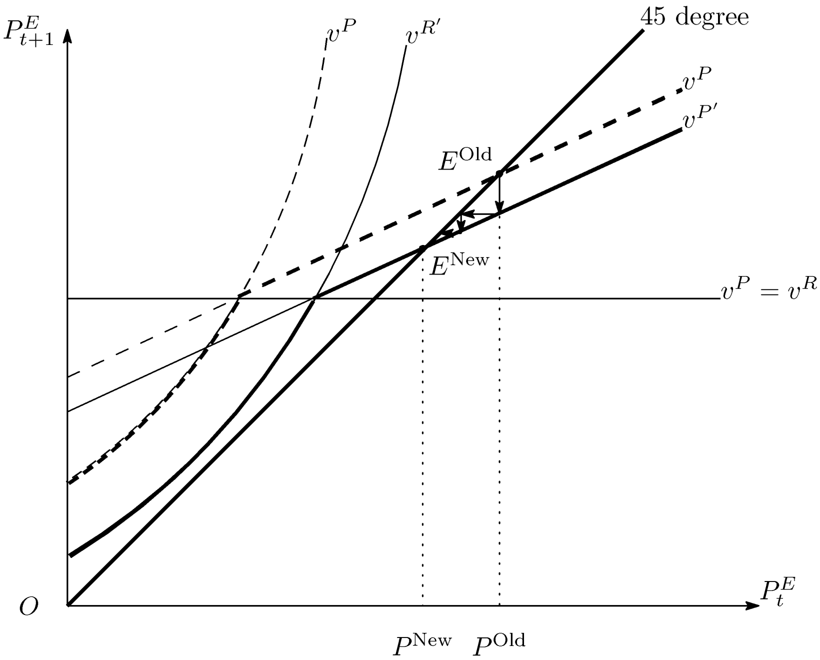

Figure 6: The effects of the small decline in θ

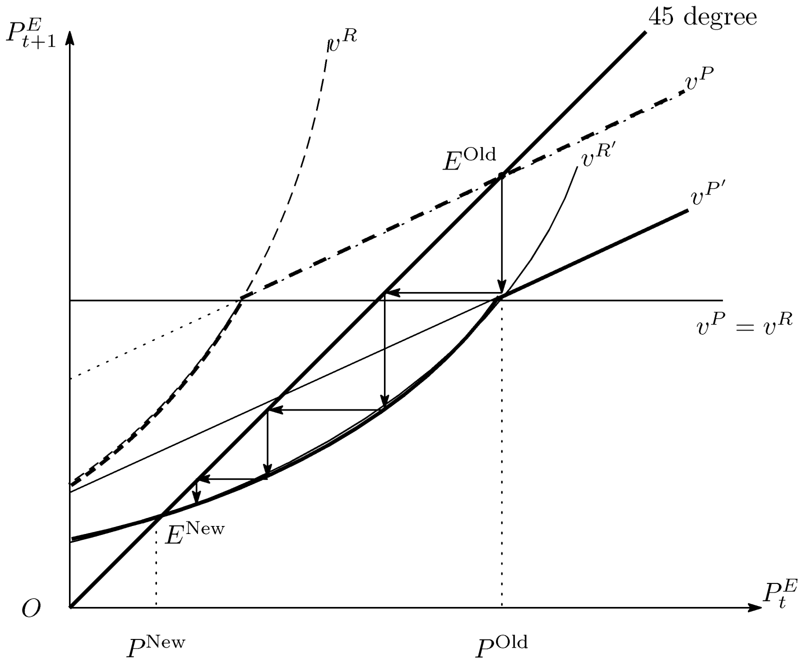

Figure 7: The effects of the significant decline in θ

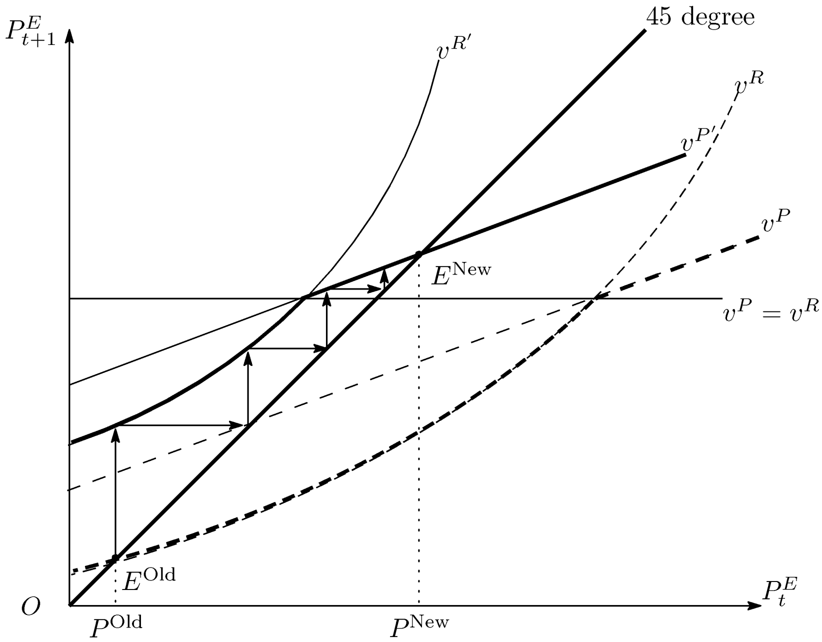

Figure 8: The effects of the rise in θ