Journal of Evolutionary Economics
https://doi.org/10.1007/s00191-018-0596-y

REGULAR ARTICLE

# Entrepreneurial cyclical dynamics of open innovation

JinHyo Joseph Yun[1] · DongKyu Won[2] · KyungBae Park[3]

Published online: 19 November 2018


## Abstract

This study addresses the following matters: What is the structure and mechanism of modern capital economic dynamics that motivates the growth limits of capitalism? The modern economy can be modeled as Entrepreneurial Cyclical Dynamics of Open Innovation with three sub-economies such as market open innovation by SMEs and start-ups, closed open innovation by big business, and social open innovation. When there is low balance among the three sub-economies, which is to say, if any of the sub-economies is too big, or too small, the economy dynamics decreases, and the economic growth rate slows down to nearly zero or even negative according to the model simulation. South Korea, with a low internal reserve policy, is in this situation. When there is medium balance among three sub-economies, which is to say, any of the sub-economies is big enough to lead the total economy but is not sufficiently big to control totally the other two economies, the economy dynamics increases and the economic growth rate will be maintained at a high level according to the model simulation. India, with its grassroots innovation festival, demonstrates this situation. When there is a high balance among the three sub-economies, which is to say, the three sub-economies are well balanced and there is no change in the economic system, the economy dynamics become too low and the economic growth rate stays at a low level according to the model simulation. Japan's Hitachi is moving from this situation to a medium balance.

**Keywords** Entrepreneurial cyclical dynamics · Market open innovation · Closed open innovation · Social open innovation · New combination

**JEL Classification** P16

✉ JinHyo Joseph Yun
jhyun@dgist.ac.kr

✉ KyungBae Park
kbpark@sangji.ac.kr

Extended author information available on the last page of the article

## 1 Introduction

The idea that the dynamics of economic life in the capitalistic social order is not of a simple and linear but rather of a complex and cyclical character is nowadays generally recognized (Kondratieff 1979).

In accordance with the development of capitalism, the world is experiencing a new economic trend—business dynamics—along with stagnant economic growth, which has become a general trend that characterizes twenty-first century capitalism. As shown in Fig. 1, major countries such as the U.S.A., the world's top economy; Japan and Germany, which followed the U.S.A. in the 1980s–1990s; and China and India, which are catching up with the U.S.A. in the 2000s–2010s, in addition to South Korea, reached phases of stagnant growth.

Surprisingly, Korea, Japan, the US, and Germany have not been able to avoid stagnant economic growth, although they have increased the R&D investment share of gross domestic product (GDP) (Fig. 2**)**. These phenomena drove us to focus on Schumpeterian economic development dynamics. It was proposed by Schumpeter that the development of a capitalistic economy is not led by technology itself but by entrepreneurs or a conglomerate-oriented combination of technologies and markets through big businesses (Schumpeter 1939, p. 15).

In an evolutionary approach to macroeconomics, the market disequilibrium dynamics resulting from structural change was properly represented at the aggregate level by Witt and Brenner (2008).

What is the structure and mechanism of modern capital economic system dynamics under the growth limits of a capitalist situation?

This study investigates the structure and mechanism of economic dynamics. This study initially established a new Entrepreneurial cyclical dynamics model (ECDM). In addition to this, logical validation of the ECDM was performed through causal loop building and simulation of ECDM. We simulate three ECDM conditions including unbalance, medium balance, and high balance among the social open innovation based sub economy (SIE), the market open innovation based sub economy (OIE), and the closed open innovation based sub economy (CIE). Third, we apply this model to

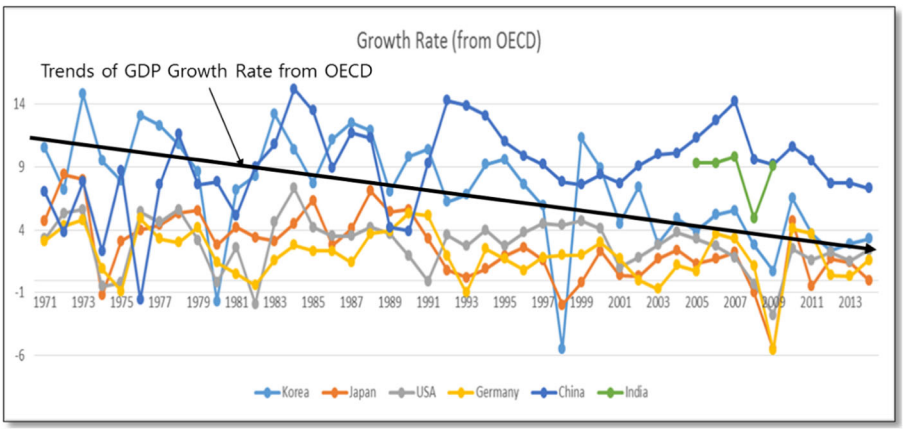


**Fig. 1** Change of growth rate of six countries over 40 years. Source: OECD Statistics

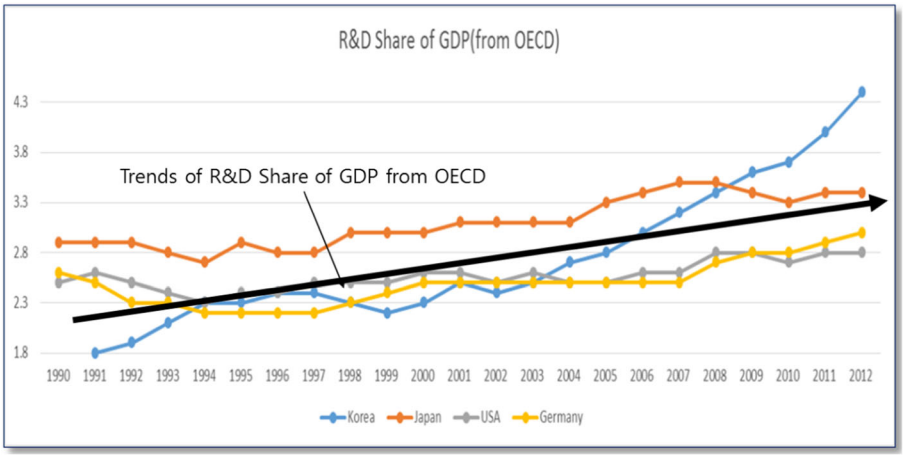


**Fig. 2** Change of R&D share of GDP. Source: OECD Statistics

concrete cases. From analyses of three cases, we acquire practical validation of the Entrepreneurial Cyclical Dynamics Model. The conditions and layers of the ECDM were subsequently discussed.

## 2 Theory

### 2.1 Economy dynamics from Schumpeter, Simon to Chesbrough

Social phenomena constitute a unique process in historical time, and incessant and irreversible change is their evolutionary characteristic (Schumpeter 1954, p. 435). Economies, as with other aspects of nature and human existence, evolve (Day 1984). Evolution, either genetic or non-genetic—as in economics–involves a number of complementary core elements and processes: (1) Diversity (variety, variation): populations of agents, strategies, products or technologies; (2) Selection: processes that reduce existing diversity; (3) Innovation (adoption): processes that generate new diversity; (4) Inheritance (transmission): replication through reproduction or copying (imitation); and (5) Bounded rationality: individuals and organizations(group) behave automatically according to adapted or selected habits and routines because risk and uncertainty can be introduced (Simon 1972; Van den Bergh 2004).

Factors of change internal to the economic system are changes in taste, changes in quantity (or quality) of factors of production, and changes in methods of supplying commodities (Schumpeter 1939, p. 66). New combinations by entrepreneurs who obtain credit and capital may grow out of old methods through continuous and gradual adjustment (Schumpeter 1934). A "new combination" will appear discontinuously, and then phenomena characterizing the development emerge such as (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, again irrespective of whether this source already exists or whether it has first to be created,

and (5) the new organization of an industry, such as the creation of a monopoly position (Schumpeter 1934, p. 66).

According to the Schumpeterian linear perspective, a new combination formed by individual entrepreneurship, which is called Schumpeter Mark 1, motivates the process of creative destruction, which leads to monopolistic practices of big businesses with widening large and highly turbulent population of innovators; Schumpeterian Mark 2, the so-called closed season, features the vanishing of investment opportunity; in the end, capitalism arrives at the socialist blueprint, so to speak, the civilization of capitalism with being deepened by a concentrated and rather stable population of innovators (Schumpeter 1942, pp. 81, 87; Breschi et al. 2000). This is to say, the Schumpeterian linear perspective treats individual entrepreneurship, monopolistic practices of big businesses, and Socialist blueprints as linear steps without any rotation or circle.

The evolutionary model of economic growth was embodied in a computer simulation program by Schumpeterian economists (Nelson 1982). However, nothing in this kind of Schumpeterian economic development model recognizes that growth as we have known it has centrally involved the birth of new products and industries and the decline and death of others, a perspective incompatible with thinking about and measuring growth simply as an aggregate phenomenon (Nelson et al. 2018, p. 153).

According to the Neo-Schumpeterian perspective, the dynamics of economics include industry, finance, and publishing sectors on the way to an uncertain future of development (Hanusch and Pyka 2006). With the creation of new sectors, or micro and macro dynamics by industry life cycles, and inter-sector coordination, economic development and aggregate economic growth can be fostered (Saviotti and Pyka 2004, 2008). As an economic development from a Neo-Schumpeterian perspective, economic catch-up can take place by path-creating leapfrogging (Lee 2013; Lee and Lim 2001).

The dynamics of economic development are very diverse. Agencies of dynamics also are diverse, from evolutionary macroeconomics with its novelty and bounds of knowledge to firm dynamic capability (Witt 2009; Witt and Brenner 2008). A nonlinear Schumpeterian dynamics perspective, however, treats the evolution of efficiency distribution as a mechanism of technological change, with the creation of new technologies and their adoption (Henkin and Polterovich 1991). This is to say, the nonlinear Schumpeterian dynamics perspective of this research treats individual entrepreneurship, monopolistic practices of big businesses, and the Socialist blueprint as not linear steps but as a rotation or circle dynamics.

In Schumpeter's view of capitalist development, two contrasting patterns of industrial development, technological change and the technological regime, coexist (Winter 1984). In addition, change that is endogenously generated within the economy is brought about by the innovative activities of entrepreneurs (Witt 2002). The disturbance caused by entrepreneurs who enter the market, and who introduce new products, generates a growth path with cycles for the economy as an agent-based whole (Bruun 2003). In addition, entrepreneurs must take on debt to start up production, and to arrive at an emergent property of the economic system, otherwise known as economic development. Economic growth focuses on the real engines of economic development—the investment behavior of capitalists and the innovative activity of entrepreneurs–and locates the sources of change in entrepreneurial functions (Mathews 2002).

If fact, the development of the industrial structure as a dynamic process is affected by complex interactions among innovations, imitations, and investments of

participating firms striving for survival and growth (Iwai 2000). Indeed, destroying the stable state that was brought about by the imitation process and creating a new industrial structure is the role of Schumpeterian entrepreneurs, or innovative firms (Malerba and Orsenigo 1996).

Through the Schumpeterian dynamics of open innovation, the growth limits of capitalism can be conquered by encouraging micro-level open innovation for a firm's emergent and new combinations and growth through a complex adaptive system, and employing business models that use new combinations for the growth of sectors such as autonomous cars and intelligent robots (Chesbrough 2006, p. 43, 2013; Yun 2015; Yun et al. 2015; Yun et al. 2016a, b).

Enterprises with strong dynamic capabilities are intensely entrepreneurial because dynamic capabilities enable such business enterprises to create, deploy, and protect the intangible assets that support superior long-run business performance (Teece 2007). Open connections between technology and the market represents a new kind of Schumpeterian combination, especially between technology and the market, which means a kind of open business model (Teece et al. 1997; Yun 2015).

The literature on economic dynamics shows four distinctive features. First, although there are plenty of studies on economics that mainly deal with speed, most focus on the quantitative aspects of dynamics. So, the requirement is for an economic development model that can also analyze the qualitative aspects of economy dynamics. Second, the literature on the analysis of economic dynamics has not been balanced between micro and macro aspects, which means that a considerable portion of the analysis has been performed on the macro side, or on the micro side. So, the requirement is for an economic development model that can connect between micro and macro. Third, works in the literature relevant to Schumpeter's theory have mainly focused on either speed or quantity. So, we need a distinguishable approach with comprehensive analysis of speed and amount, generally presented in Section 7 of the original "The Theory of Economic Development" (Schumpeter 1934). Fourth, most works in the literature affected by Schumpeter's theory have applied approaches based on either micro or macro analysis. We need a dynamic economic development model that will be useful for comprehensive analysis of "The Theory of Economic Development" (Schumpeter 1934).

### 2.2 Entrepreneurial cyclical dynamics of open innovation

Even though the concept of open innovation is a kind of innovation type, it can also be understood as pointing to another important dimension of the learning economy, one that expands the boundaries of Schumpeter's economics (Lundvall 2013). We expanded the open innovation concept to a kind of economy model in that the meaning of open innovation is a new combination between technology and the market or society, a new combination that is the fundamental phenomenon of economic development according to Schumpeter (Schumpeter 1934).

By applying a new combination of Schumpeter's work to modern economy dynamics in the name of open innovation, Entrepreneurial cyclical dynamics of the open innovation model can be set up. If the economic cycle describes economic life from the standpoint of a "circular flow," similar to the circulation of blood in an animal organism, entrepreneurial cyclical dynamics of open innovation also follows this analogy (Schumpeter 1934, p. 61).

The Schumpeterian linear model is changed as Entrepreneurial circling dynamics in the economic reality of twenty-first century capitalism, as can be seen in Fig. 3. This study models the characteristics of the present capitalistic economy as Entrepreneurial cyclical dynamics of open innovation in a multidimensional domain, which consists of corporate, sectorial, industrial or national innovative system units (Jeon et al. 2015). A specific case related with open innovation through a new combination of entrepreneurs corresponds to the literature on Schumpeterian individual entrepreneurs and subsequent opinions (Kodama and Shibata 2015). Closed Open innovation by big businesses also matches Schumpeter's opinion on conglomerate innovation and closed innovation (Patra and Krishna 2015). In this system, big businesses basically choose closed innovation such as internal R&D, but open innovation such as M&A or partnership with SMEs; donation and investment in social enterprises can also be chosen. Lastly, social open innovation by social enterprises is consistent with Schumpeter's opinion on socialism and the entrepreneurial state, and with Keynes's opinion on big government (Keynes 1937; Mazzucato 2011).

In the market open Innovation sub economy, the entrepreneur motivates innovation through open connection and new combinations between technology and the market. The leaders in this economy are start-ups, or SMEs. Entrepreneurs in this sub economy develop open connections, and a new business model between society and technology, to market open innovation by joining or interacting with the social open innovation sub economy. They make changes to develop their enterprises as they dominate the design of the closed open innovation sub economy, belonging to the sectorial innovation system through M&As, good partnerships, licensing, or other open innovation channels.

In the closed open innovation sub economy, an entrepreneurial firm motivates innovation through closed innovation with internal R&D. However, this firm is also actively motivated to engage in open innovation continuously to obtain new business models with start-ups, or SMEs, in the market open innovation sub economy, or with social enterprises in the social open innovation sub economy. The leaders in this economy are large enterprises that produce products and services on a large scale and dominate the market of sectorial innovation systems. In addition, big enterprises in this sub economy produce and maintain dominant designs and technological regimes through open innovation with start-ups, SMEs, and social enterprises.

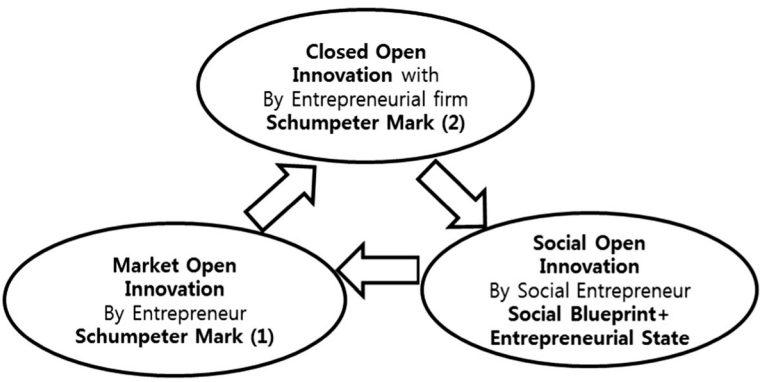


**Fig. 3** Entrepreneurial cyclical dynamics of open innovation

In the social open innovation sub economy, the social entrepreneur motivates innovation through open connections, and new combinations between technology and society. The leader in this economy is social enterprises. Even though contributions from big enterprises have the goal of obtaining long term customers or a good business model, they motivate creative open innovations and new combinations between society and technology, which are difficult to pursue in a profit seeking market. In addition, investment and support from governments for the social open innovation sub economy are becoming part of a new socialist blueprint, that is to say, a social economy, or a sharing economy. Social entrepreneurs can substitute the hierarchical and bureaucratic socialist organization with democratic and effective social enterprises.

Innovation of the economy does not consist only of market open innovation, closed innovation, and social open innovation. However, entrepreneurial cyclical dynamics of open innovation can show simply the dynamics of the modern economy as a kind of concept model of market open innovation, closed open innovation, and social open innovation, which are compared to Schumpeter Mark 1, Mark 2, and Social Close. Entrepreneurial cyclical dynamics of open innovation include not just quantitative growth but also qualitative development, in that they include social innovation and an increase of social innovation (Pyka 2017).

The relation between the degree of balance among OI, CI, and SI, and the economic growth rate will appear as in Fig. 4**.** At a very low balance degree among OI, CI, and SI, such as between 0 and $\alpha$, the economic growth rate will appear to be negative. But, after this, in some areas such as between $\alpha$ and $\beta$, the economic growth rate will increase if the balance degree among OI, CI, and SI grows. The $\beta$ point is the point at which the growth rate at the top in the balance degree spectrum exists in any national innovation system (NIS), regional innovation system (RIS), or sectorial innovation system (SIS). The accurate location of $\beta$ in the balance degree spectrum is different according to the system, whether NIS, RIS, SIS, etc.

At other balance degree areas among OI, CI, and SI, between $\beta$ and $\gamma$, the economic growth rate will decrease even though it is positive. A too-high balance among OI, CI, and SI will decrease chances of new combinations between technology and the market

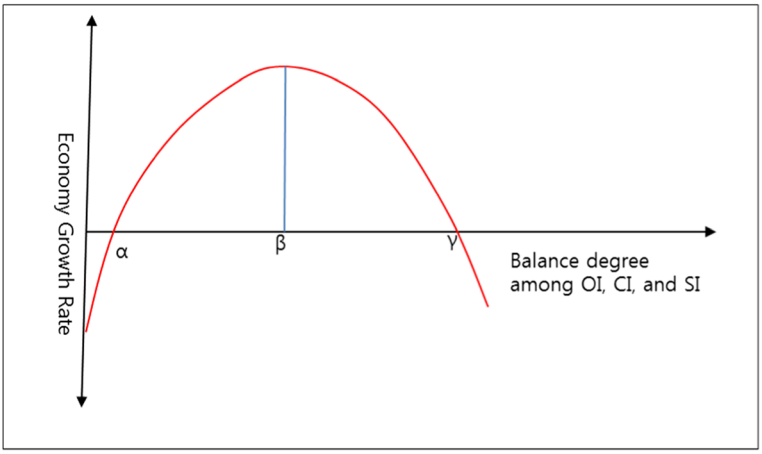


**Fig. 4** Relation between economic growth rate and balance degree among OI, CI, and SI

or society. So, in this area, if the balance among OI, CI, and SI increases, the economic growth rate will decrease while still remaining at a positive level.

"Economic development" between $\alpha$ and $\gamma$ is a distinct phenomenon, entirely foreign to what may be observed in the circular and discontinuous change in the channels of flow and disturbance of equilibrium; this growth forever alters and displaces the equilibrium state previously existing (Schumpeter 1934, p. 64).

Last, at the other balance degree area among OI, CI, and SI, such as between $\gamma$ and the maximum balance degree, the economic growth rate will be negative, and increase the negative growth of the economy if the balance degree approaches the maximum. In this area, the obsolescence of the entrepreneurial function deepens, and the destruction of the protecting strata appears (Schumpeter 1942, pp. 131, 134).

The dynamics balance because the condition of high growth of economy at Fig. 4 does not mean that sluggish growth happens only because of stagnation of innovation in the economy. Not high innovation, but high dynamic balance among social open innovation, market open innovation, and closed open innovation can motivate high economic growth. The economic development of the twentieth century depended on diverse balances such as the structure of inequality, the dynamics of the capital or income ratio, and the global inequality of wealth (Piketty 2015). In the United States, the price of inequality, which is to say a kind of non-dynamic balance, also appeared in the growth of the economy after the 1980s and until the twenty-first century (Stiglitz 2012).

The idea of dynamic balance has several meanings. First, dynamic balance means that innovation is not the only factor of economic development. Second, three open innovations include diverse non-economic factors as internal factors of economic development, as in Schumpeter's theory of economic development, which emphasized entrepreneurial profit, credit and capital, and the interest of capital, in addition to new combinations. Third, this dynamic balance models finds the new value of social open innovation as an essential factor of economic development. Social open innovation can operate by multiplying close social ties with entrepreneurial profit.

## 3 Simulation of entrepreneurial cyclical dynamics

### 3.1 System dynamics model building

#### 3.1.1 Entrepreneurial cyclical dynamics causal model

There exist strong cyclical reinforcing relations among OI, CI, and SI. If "SMEs(OI)" can grow successfully, there will be more "big companies (CI)." If big companies (CI) maintain their social responsibility by donating and contributing to social problem solving, SI will grow. Such contributions and responsibilities of CI include donation and investment into social enterprises, academic work, new venture companies, and so on. "Social enterprises and academic work (SI)" are initially not profit seeking, but for social problem solving. But if they start to be fueled by profit seeking and resources from profit, they can also successfully grow into "SMEs (OI)."

Although there exist cyclical mutual reinforcing relations among OI, CI, and SI, there also exist big delays, or chasms, between them. For SI to grow into OI requires "profit-seeking motivation and social conditions for those profit seeking." For OI to

grow into CI requires "sustained capital growth" in the economy. For CI to donate and contribute to SI, there must be enough social pressure to enforce CI to make donations and contributions.

In Fig. 5, the Entrepreneurial cyclical dynamics causal model is presented.

The "basic loop (R1)" is the reinforcing loop among OI, CI, and SI. These factors reinforce each other cyclically. However, there exist great delays or chasms among OI, CI, and SI. So, excessive imbalance between them, which comes from too-big or too-small values of OI, CI, or SI, can increase the delay effects and cause a speed-down of the cycle. Some loops such as the "Economy-wide creativity loop (R2)", which comes from creativity from the SI, and the "positive concentration loop (R3)," which comes from moderate concentration to CI, reinforce the main Entrepreneurial cyclical dynamics of open innovation. However, there also exists a slowing-down balancing loop, the "negative concentration loop (B1)", which comes from excessive concentration in CI. Thus, the relation balance among the three innovations and the economic growth rate is an inverted U curve. Because of the existence of the big chasm among OI, CI, and SI, there exist fluctuations in the economic growth, as shown in Fig. 7.

As expressed in the causal model, the role of social factors in economic growth has long been recognized. Abramovitz (1986) early argued for the essential role of 'social capability' in economic growth and economic catching-up. He emphasized the role of social capability in economic growth with the notion that "One should say, therefore, that a country's potential for rapid growth is strong not when it is backward without qualification, but rather when it is technologically backward but socially advanced.

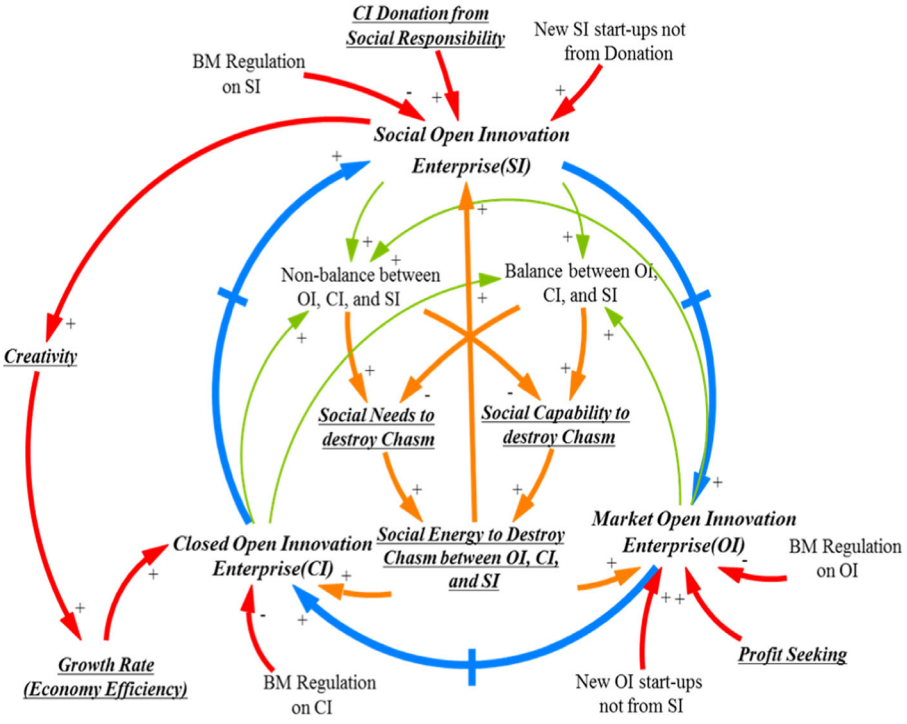


**Fig. 5** Entrepreneurial cyclical dynamics causal model

(Abramovitz 1986)" Social capability is responsiveness of a society to fundamental needs of its economic actors. It is a nation's ability to manage its scarce resources, determined by institutions, social attitudes, and education (Abramovitz 1995; Abramovitz and David 1996; Koo and Perkins 1995; de Felice 2014). Social absorption capability and social capital were also widely mentioned as important societal factors for sustained innovation and long-term economic growth (Dahlman and Nelson 1995; Temple and Johnson 1998; Woolcock 2001).

As for 'social needs' for change, Thomas Piketty (1995) is a famous researcher who has studied the impact of inequality on social needs and aspirations for social reform. Piketty argued in depth about the impact of social mobility on redistributive politics. He argued for the influence of current income and belief in social mobility, i.e. parent's income, on political voting for redistribution. He has found strong evidence that income inequality and social mobility are strong determinants of political voting for social change, that is, redistribution.

The chasm, or delay, among OI, CI, and SI requires "Social Energy" to destroy, and it makes dynamic fluctuations of OI, CI, and SI. "Social Energy" to destroy the chasm comes from "Social Needs" and "Social Capability." "Social Needs" arise from imbalances among OI, CI, and SI, and, "Social Capability" comes from balance among them. For an economy to have "Social Energy" to destroy chasms requires both "Social Needs" and "Social Capability." This means that there will be a dynamic inverted U shape relation between balance degree and economic growth ("Social Energy" is a multiplication of "Social Needs" and "Social Capability").

A simple mathematical explanation for impacts of social factors on economic growth is expressed below. Here, we simplified economic growth into a simple linear function of social energy to express positive impacts of social energy on economic growth. But, actual relationship will be far more complex in the real world; the graph may be concave or, sometimes convex. Similarly, the balance between social needs/capability is much simplified as a simple linear relationship. Also, for easy and intuitive understanding, social energy is expressed as a simple multiplication of social needs and social complexity.

We define the related variables and set their relationships as below for simple understanding.

(Definition)

S.Energy: Social Energy to destroy chasm among OI, CI, and SI
S.Needs: Social Needs to destroy chasm
S.Capability: Social Capability to destroy chasm
E.Growth: Economic Growth that can be achieved by overcoming chasm
Balance: Balance among OI, CI, and SI

(Basic relations)

E.Growth = a + b(S.Energy)
S.Energy = k(S.Needs)*(S.Capability)
S.Capability = m(Balance)
S.Needs = (n-n(Balance))
a, b, k, m, n: constants; b, k, m, $n > 0$; C = bkmn >0

From the definition and basic relations we can obtain a very simple but also very intuitive conclusion that economic growth has an inverted U-shape relationship with the balance among OI, CI, and SI because of social factors such as social energy, social needs, and social capability to destroy big chasms among OI, CI, and SI, simply displayed as below.

(Simple Computation)

$$
\begin{aligned}
&\text{E.Growth} = a + b(\text{S.Energy}) \\
&= a + b(k(\text{S.Needs})*(\text{S.Capability})) \\
&= a + b(k(n\text{-}n(\text{Balance}))*(m(\text{Balance})) \\
&= a + bkmn(\text{Balance})\text{-}bkmn(\text{Balance})\text{^}2 \\
&= a + C(\text{Balance}) - C(\text{Balance})\text{^}2
\end{aligned}
$$

### 3.1.2 System dynamics model for simulation

The System dynamics (SD) model in Fig. 6 was developed according to the causal model. When the SD model was developed, it was based on the Lotka–Volterra equations, also known as the predator–prey equations, which are a pair of first-order, nonlinear, differential equations frequently used to describe the dynamics of biological systems in which two species interact, one as a predator and the other as prey (Lotka 1920).

Every business ecosystem develops in four distinct stages: birth, expansion, leadership, and self-renewal—or, if not self-renewal, death. What remains the same from business to business is the process of co-evolution: the complex interplay between competitive and cooperative business strategies (Moore 1993). As such, business and market models can be seen from a sort of ecological point of view.

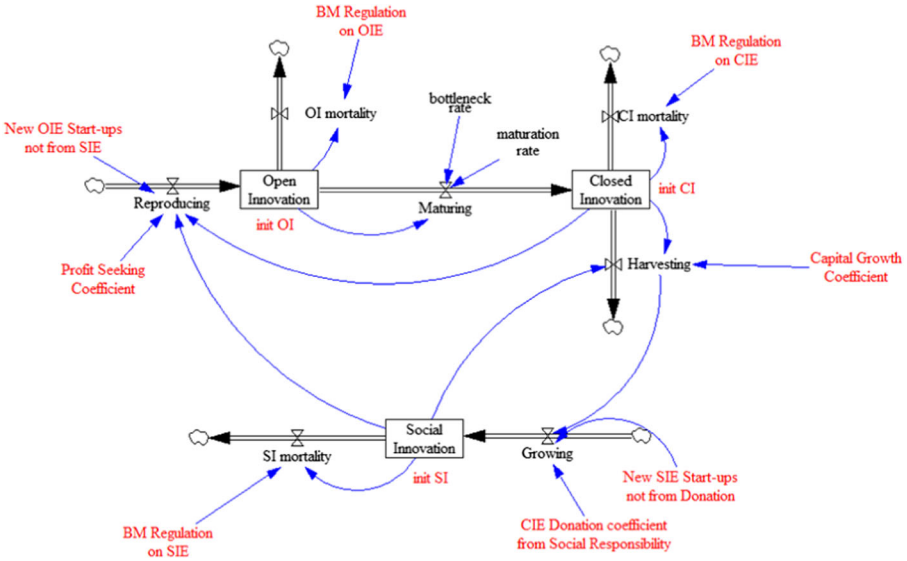


**Fig. 6** System dynamic model of entrepreneurial cyclical dynamics

The preliminary eco-dynamics model, as it is commonly referred to, begins with a methodology that explains the exponential growth of populations, as raised by Malthus; later, Verhulst, Lotka, and Voltera tried to explain the dynamics (Kofoid 1925; Maltus 2006; Verhulst 2009; Volterra 1926).

The study of the epidemiology of population fluctuations mainly explains ecological processes such as competition, parasitism, symbiosis, and predation. Innovative ecosystems are also a study of the symbiotic relationship between these innovators. The factors related to innovation are the business model adjustment, which determines the connectivity between elements; the capital growth coefficient and open innovation are taken on a scale of 0.1 points (one point is 100%).

Through simulations, we were able to explore the qualitative characteristics that suggest the possibility of sustainable growth among OI, CI, and SI.

The prey-predator model began with the classic Lotka-Volterra system, which is a theoretical model from ecology, the theoretical background of the system dynamics model. A balanced population of two species in a prey-predator relationship is determined by ecological characteristics such as the breeding extinction rate of the counterpart populations, which is related to necropsy or nutrients; the long-term sustainability and the coevolution of the two species can be considered separately.Various extensions have been attempted for the classical model, as described above, the first of which concerns interspecific competition. This is called the competitive Lotka-Volterra. In contrast to the competitive model, a cooperative Lotka-Volterra can be conceived. In other words, when one population increases, it acts to increase another population.

The ecosystem that we wish to model is a kind of feedback loop chain of three species, in which the lowest-level prey $x$ is preyed on by a mid-level species $y$, which, in turn, is preyed up by a top level predator $z$, which, in turn, *is* preyed up by a predator x. The model consists of the following system of differential equations (Chauvet et al. 2002).

$$\frac{dx}{dt} = -\mathrm{ax} + \mathrm{bzx} - \mathrm{cxy}$$
$$\frac{dy}{dt} = -\mathrm{dy} + \mathrm{exy} - \mathrm{fyz}$$
$$\frac{dz}{dt} = -\mathrm{gz} + \mathrm{hyz}, - \mathrm{izx}$$

for a, b, c, d, e, f, g, h, $i > 0$.

and:

- b, e, and h represent the cooperative effect on species by species z, x, and y.
- c, f, and i represent the interspecific variation of species y, z, and x.
- a, d, and g represent the natural mortality of species x, y, and z.

This system has two critical points. One is the origin; the other is in the first quadrant.

$$\mathrm{x}\,(-\mathrm{a} + \mathrm{bz} - \mathrm{cy}) = 0$$
$$\mathrm{y}\,(-\mathrm{d} + \mathrm{ey} - \mathrm{fz}) = 0$$
$$\mathrm{z}\,(-\mathrm{y} + \mathrm{hy} - \mathrm{ix}) = 0$$

Therefore, the critical points are (0, 0, 0) and $(\frac{h(fa+bd)-g(eb-fc)}{i(eb-fc)}, \frac{fa+bd}{eb-fc}, \frac{ae-cd}{eb-fc})$.

The Jacobian matrix is as follows.

$$J = \begin{bmatrix} -a & bz-cy \\ -d & ex-fz \\ -g & hy-ix \end{bmatrix}$$

As for the stability of the dynamic balance of the above system, it can be deduced that the stability can be sufficiently ensured by the adjustment loop if the value of the normal parameter satisfying the range condition that does not apply the excessive extinction ratio leading to extinction is satisfied. However, in order to prove this analytically, it is necessary to obtain the Jacobian matrix of the linear differential equation and perform a test using the eigenvalues of the matrix. Since this is beyond the scope of this study, we intend to estimate the relationship between the parameters by using the system dynamics model of (Fig. 6).

### 3.2 Simulation of entrepreneurial cyclical dynamics

The simulation results shown in Fig. 7 indicate very diverse results according to the balance among OI, CI, and SI. First, the simulation results for the low balance condition include a very negative economic growth rate, less than zero. According to our model simulation, high unbalance among OI, CI, and SI motivates negative and low positive growth rate.

Second, the simulation results for the medium balance conditions include a lot of fluctuations and a high economic growth rate, especially in an open innovation

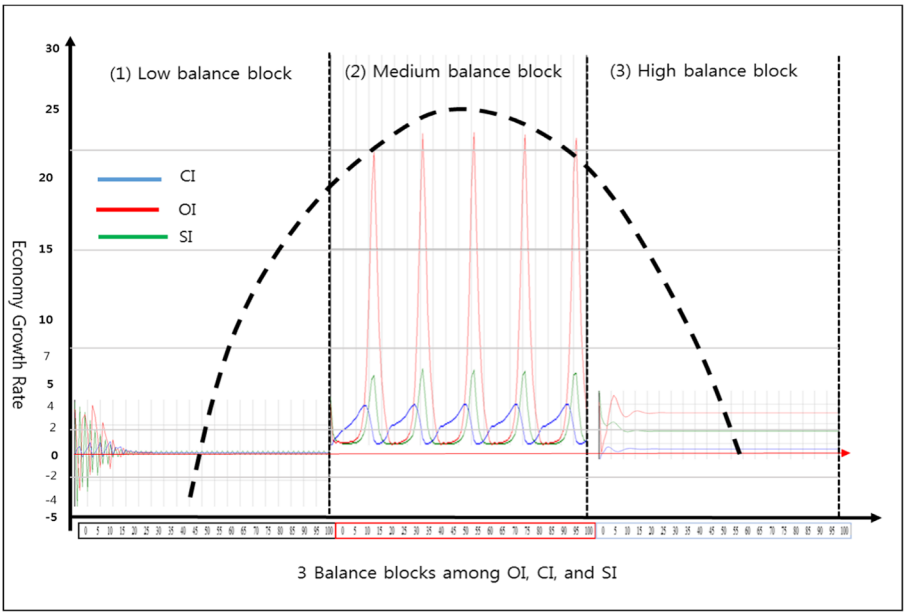


**Fig. 7** Simulation results

economy. This means that if there is a leading economy among three, and the leading power has minimum balance with the two others, the growth rate of the economy is high even though there is an economic fluctuation.

Third, the simulation results for the high balance conditions include no fluctuation, and low economic growth rate. This means that if there is not any leading economy among three, and there is high balance among the three sub-economies, the growth rate of the economy is low even though there is no economic fluctuation.

Most of all, the trends of the simulation results form an inverted U curve, which is similar to the logical concept of Entrepreneurial Cyclical Dynamics of Open Innovation, as shown in Diagram 4. Model validation constitutes an important step in system dynamics methodology, involving both formal/ quantitative tools and informal/ qualitative ones (Barlas 1994). From the simulation results, we can add quantity validation by simulation results in addition to logical validation by theory. That is to say, the mental model was validated first using a written data base, such as literature reviews, and by theory based model building. Second, it was validated using a numerical data base, which was derived by comparing simulation results and model logics (Luna-Reyes and Andersen 2003).

From the three sets of simulation results, we are able to see a diverse complexity of the SD Model of Entrepreneurial Cyclical Dynamics of Open Innovation; the model is constantly changing, tightly coupled, governed by feedback, nonlinear, history-dependent, self-organizing, adaptive, characterized by trade-offs, counterintuitive, and policy resistant (Sterman 2001).

First, simulation results for the low balance block in Fig. 7 show that the economic growth rate will fluctuate for the time being, and approach zero in the end. This means that extreme dominance of CI, SI, or OI will decrease the growth rate of the economy to near the no growth rate, which is to say, zero.

Second, simulation results for the medium balance block in Fig. 7 show that the economy will fluctuate very much but the growth rate will be high on average. Dynamic balance, which means the balance among CI, OI, and SI, is changing continuously and will motivate a high growth rate of the economy.

Third, simulation results for the high balance block in Fig. 7 show that economic growth rate will be maintained without fluctuation, but the growth rate will not be high. This means that the static high balance among CI, SI, or OI will motivate the static low economic growth rate.

So, according to the three blocks of balance level among CI, OI, and SI, the economic growth rate has an inverted U curve as shown in Fig. 7. This coincides with the mathematical equation of the causal loop relations among OI, CI, and SI, in 3.1.1.

## 4 Case study to validate Schumpeterian cyclical dynamics of open innovation

### 4.1 Locations of three cases in entrepreneurial cyclical dynamic model

Based on the above cases, implicative analysis can be performed. First, in the case of Hitachi, a large business was able to create innovation, markets, and a new business model by shifting its business focus to social innovation, which resulted in an

acceleration of economic dynamics at the (1) stage of the entrepreneurial Cyclical Dynamics of Open Innovation, as shown in Fig. 8.

Second, in the case of South Korea, the economy is experiencing degraded household income, increased corporate income, strong conglomerate economic impact, stagnant economic growth, and aggravated polarization, all of which are significantly affected by the large-scale internal reserves of companies at the (2) stage of Entrepreneurial Cyclical Dynamics of Open Innovation, as shown in Diagram 7. More specifically, tax exemptions and the increase of internal reserves prevent conglomerates from pursuing challenges of new technology and markets through M&A, as well as preventing them from donating or investing for social innovation. As a result, large-scale internal reserves are decreasing the dynamics of the Korean economy. Third, along with accumulated experience and cases of social innovation, the large-scale investment of the Indian government and domestic conglomerates is swiftly creating and fostering start-ups and SMBs. Some of these start-ups are gaining opportunities that will allow them to further their self-growth, so that they will develop into big businesses or achieve M&A within a short period.

Grass roots innovation by India (2), as shown in Fig. 8, demonstrates an Indian case in which social innovation accumulated via various national polices is transferred to large-scale start-ups through national support. It can be considered a case in which—with conglomerate support—it is possible to clarify the knowledge of founders and experienced entrepreneurs in open innovation, thus guaranteeing the successful transition to and growth of creative start-ups.

First, Korea is seeing a decreasing economic growth rate after its internal reserve regulations were freed after the IMF economic crisis 1997 (Fig. 9). This means that the degree of balance is continuously decreasing under the focal point (β). Second, India has seen an increase of its economic growth rate after its Grassroots innovation policy was undertaken. This means that the degree of balance is continuously increasing toward the focal point (β). Third, Hitachi has seen an increase of its economic growth rate at the firm level after the start of high and direct investment in social innovation. This means that the degree of balance is continuously decreasing to the focal point (β).

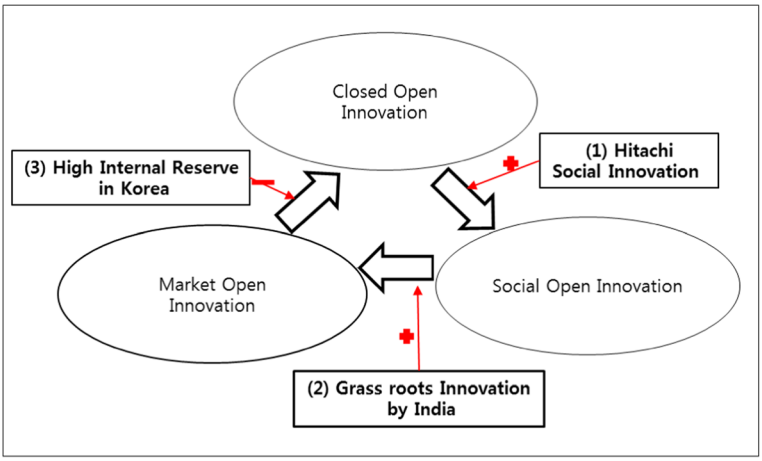


**Fig. 8** Cases in entrepreneurial cyclical dynamics of open innovation

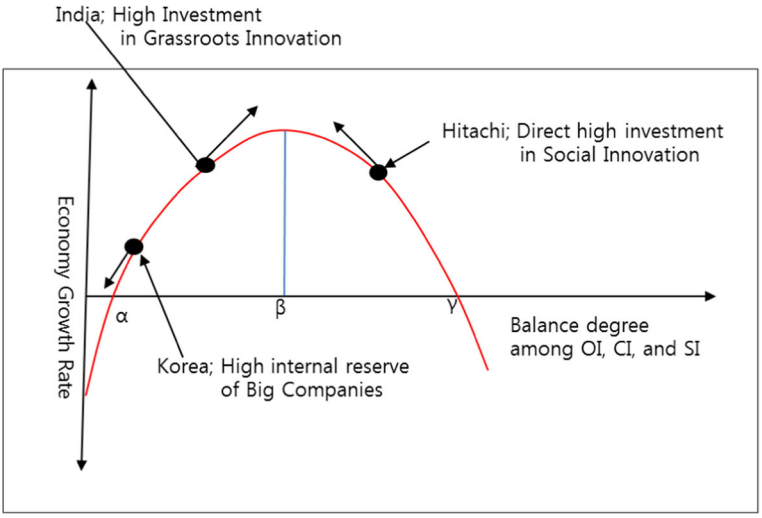


**Fig. 9** Three cases of inverted U curve of entrepreneurial cyclical dynamics of open innovation

### 4.2 Hitachi social innovation

The Hitachi case is a micro case; at first, it seems not to meet the entrepreneurial cyclical dynamic model, which basically has a macro level structure. But, the Entrepreneurial cyclical dynamic model can be applied to the macro level and the concrete micro model at the same time. When the Entrepreneurial cyclical model is applied to the micro case, it is used to describe the growth strategy of firms, not economic development.

Social innovation by Hitachi starts with the idea that someone with power can change everything. Hitachi is bringing together the world's greatest minds to help breathe life into new possibilities. Hitachi talks about the idea that "The challenges around us can seem insurmountable, but when we come together, thinking on a global scale, we can create novel solutions to social problems" (Hitachi Home Page). They say that "through collaborative creation, we are bringing thinkers and doers together to make innovations for a better future" (Hitachi social business page). Hitachi realizes that increasing social innovation will grow the market. The company believes that "The growing digital era is accelerating social innovation, while opening up new market opportunities" (Hitachi social business page).

Although Hitachi started its business in electric facility repair, the anticipated challenge of working with Samsung Electronics and the struggle for business success after the merging of NEC and Mitsubishi into Elpida in 2003 enabled Samsung Electronics to outperform Hitachi in 2008, and led to a profit loss for Hitachi of JPY 787.3 billion. With that, Kawamura Takashi—who became the CEO of Hitachi in 2009—tried to expand the company's business area from electronics to social infrastructure by presenting a new vision of "social innovation." He recognized the mature economic status of Japan and noticed new social demands of developing countries in electricity and urban development. In this regard Hitachi, through M&A, took over infrastructure companies including Horizon Nuclear Power, a UK nuclear company, and Leonardo-Finmeccanica, an Italian railway company, to lead a new business area that merged technology, the market, and society. In parallel, while Hitachi has old

major business divisions such as those of appliances and semiconductors, it also put more of its R & D efforts into sensors, artificial intelligence, and robots, which are challenging social matters. As a result, Hitachi has consistently earned surpluses since 2010, the year in which a surplus of JPY 238.8 billion was accomplished.

In April 2017, according to information on the Hitachi homepage (http://social-innovation.hitachi/en/index.html), Hitachi was working in seven areas of social innovation including urban development (12), energy (11), manufacturing (5), life & economy (29), transportation (9), water (6), and R&D (12). Even though not all of these are social innovation cases, diverse approaches to social innovation such as collaborative creation to solve energy problems in Hawaii (urban development), lowering emissions through cleaner energy (energy), offering culture and leisure with comfort and sustainability (manufacturing), and greater flexibility in financial accounting tasks (life and economy) have motivated Hitachi to develop new creative market innovations and new business models. In addition, in cities in Japan and elsewhere, progress is being made toward the creation of smart cities as social open innovations, with demand for optimization and efficient operation of social systems, including sophisticated transportation systems, reductions in $CO_2$ emissions, and upgrading of aging infrastructure. In these ways, Hitachi has increased its response to the requirements of social open innovation (Yoshikawa et al. 2012; Morioka et al. 2015).

When Hitachi focused on social innovation, the high balance among three sub-economies decreased to the medium level, the innovation dynamics of the company increased, and the company has grown to a high level.

### 4.3 High internal reserve of Korean big enterprises

In this section, the increased internal reserves of Korean conglomerates, the economic slump, and accelerated social polarization are analyzed (Jang 2014, p. 56). First, social polarization is being radically aggravated. While the portion of household income was 69% of Korea gross national income in 2000, the portion dropped to 62% in 2012 (Jang 2014, p. 44). In contrast, corporate income increased from 17% to 23% during the same period. Additionally, corporate income marked an annual average increase rate of 7.5% during the period from 2000 to 2009, but household income only increased by 2.4%. It is noticeable that the income of small- and medium-sized businesses (SMB) did not increase. On the other hand, the internal reserves of the top 30 conglomerates reached KRW 551 trillion from KRW 206 trillion during the period from 2008 to 2009; this percentage of increase even exceeded 710 trillion KRW in 2015. The salary difference for employees between conglomerates and SMBs dramatically increased from 10% in 1980 to 40% in 2014 (Jang 2015, p. 87). In the case of the automobile business, the salaries of subcontractors and those in the lower level are just half and one third, respectively, of prime contractors' salaries. The Korean government has focused on less essential policies, such as decreases of improper supply costs, unfair contract regulations, and technical infringement, instead of charging heavy taxes on conglomerates' internal reserves. Although a few positive policies have recently been discussed for potential application—such as output sharing between conglomerates and suppliers, benchmarking from Japanese automobile businesses, profit sharing and benchmarking from Chrysler, Carrier, and Dana Holdings, and net profit sharing between movie

companies—they have failed to be effective. Also, it was proposed that taxes could be levied on the conglomerates' internal reserves beyond a specific amount and that profit sharing should be exempt from taxes, but these policies are still far from being executed.

As shown in Table 1, although the internal reserves of Korea's top four big businesses have radically increased, this money has not been shared in wage increases or stock dividends. Also, unlike other Organization for Economic Co-operation and Development (OECD) countries, Korea has exempted companies from paying internal reserve taxes since 1995. Consequently, the profit increase of the four biggest businesses does not contribute to any economic effects such as increased wages or income, capital, or tax. This tax exemption on internal reserves has nonetheless not stopped big businesses from innovating by building start-ups with SMBs that possess new technology and markets. By blocking their chances of ordinary restructuring, this hoarding of reserves can significantly affect the global competitiveness of big Korean businesses, particularly in the transitional phase of global industry structure or during a global economic depression. Hoarding could then result in an increased cost of a posteriori restructuring, which would put a severe burden on the entire Korean economic system. This matter was clearly demonstrated by the May 2016 situation of the Korean shipbuilding industry, which was undoubtedly caused by a lack of effort to innovate; shipbuilders had simply held onto their internal reserves over the previous 10 years. It is difficult not to blame the internal reserve tax exemption established by the Korean government for fostering this trend of cash hoarding in large Korean businesses.

Based on Table 2, although total M&A in Korea in 2014 increased more than it did over the previous year, only a slight portion (KRW 0.4 trillion, or 0.78%) consisted of global M&A. In contrast, the US, Japan, and Europe had amounts of about 30% for global M&A, which is interpreted as indicative of a struggle for innovation and attempts to acquire new technology and markets. The large portion of internal reserves in big Korean businesses and total businesses, including the Korean government's tax exemption on corporate internal reserves, decreased the motivation of companies to pursue M&A; these Korean companies thus missed chances to acquire global companies with innovative technology and the potential for new market creation and failed to accomplish large-scale production within a short period of time compared with that needed in other OECD countries.

**Table 1** Keeping of benefits within firms without distribution by Large Korean Businesses

| Big Korean businesses | 2014 | 2015 |
|---|---|---|
| Samsung Electronics | 1,739,334 | 1,895,403 |
| Hyundai Motors | 587,843 | 635,553 |
| LG Electronics | 121,691 | 121,046 |
| LG Chemical | 118,483 | 126,902 |
| SK Hynix Inc. | 144,206 | 185,026 |
| SK Innovation | 143,841 | 151,977 |

Source: AJU Business Daily, March 31, 2016. "Top 4 Manufacturing Companies, More Increased Internal Reserve"

USD 100,000; exchange rate: KRW 1000 = USD 1

**Table 2** M&A of Korean companies from 2010 to 2014

| Year | Domestic M&A | Korean firms' M&A of foreign firms | Foreign firms' M&A of domestic firms | Sum |
|---|---|---|---|---|
| 2010 | 26.2 | 1.9 | 2.9 | 31.0 |
| 2011 | 30.0 | 0.3 | 2.7 | 33.0 |
| 2012 | 18.0 | 1.7 | 1.9 | 21.6 |
| 2013 | 18.1 | 0.5 | 2.1 | 20.7 |
| 2014 | 37.8 | 0.4 | 13.0 | 51.2 |

Source: The Korea Economic Daily, Nov. 28, 2015. "Let's Increase Support for Takeover of Overseas Companies and Build a Control Tower"

USD 1000 million dollars; exchange rate: KRW 1000 = USD 1

Because Korea has been in low balance among the three sub-economies due to the high internal reserve of big businesses for last nearly 20 years, the economic dynamics of Korea decreased and economic growth rate slowed down to nearly zero.

### 4.4 Grassroots innovation of India

Here, the case of India—which achieved the world's highest economic growth in 2015 and 2016—is described. Currently, India is experiencing a start-up boom that has boosted the country to the position of world's third largest economy. This boom is being led by the US (47,000) and the UK (4500), followed by India (4200), Israel (3900) and China (3300). In 2015, 1200 start-ups appeared in India, including Ola Cabs, an Indian vehicle-sharing, mobile service, and e-commerce company. Moreover, there has been a USD 5 billion investment in India. "Startup India" was a forum held by Prime Minister Narendra Modi at the New Delhi Convention Center, Vigyan Bhawan, on January 16, 2016, in which about 1000 guests, including start-up entrepreneurs and venture capitalists, participated. Indian start-up entrepreneurs under 35 years old account for 72% of the total number of entrepreneurs, and the number of startup employees is 80,000–85,000. Sixty-five percent of the total start-ups are located in central IT areas—such as Bengaluru and Delhi—and their metropolitan areas. Moreover, the number of active investors in 2015 was reported to be 490—a 2.3 increase compared to the previous year.

Among Indian unlisted companies valued at over USD 1 billion are the following (descending order): Flipkart (e-commerce), Ola Cabs (cab service), Snapdeal (e-commerce), One97 Communications (online payment), ShopClues (e-commerce), Zomato Media (restaurant information service), and Quikr (e-commerce). Their fund scales correspond to USD 15, USD 5, USD 2.5, USD 2, USD 1.1, USD 1, and USD1 billion, respectively. It can thus be seen that India is evolving from a global outsourcing base into a haven for start-ups. The Indian government is making tremendous efforts to foster start-ups. For example, 500,000 students are being trained as future start-up entrepreneurs; among them, 100 have been invited to the presidential palace to participate in a large-scale innovation festival. Although most of these firms are related with social innovations initiated out of a concern for social issues, the Indian government, as well as domestic and global big businesses, is investing and providing support

so that these firms will be able to develop their new ideas as start-ups. In addition, the Indian government is offering awards of USD 15,000 for 20 students who are selected through the Grand Challenger program.

The Indian government, especially the president, hosts a "grass roots innovation festival of India" at the Presidential palace every year for more than one week. Grassroots innovation movements seek innovation processes that are socially inclusive of local communities in terms of knowledge, processes, and outcomes (Smith et al. 2014). The Indian government, with its 'honey bee network', is motivating people to move from social innovation to market open innovation through consulting, support for setting up patents, help with Mock-up production, and connecting of social entrepreneurs with engineers, investors, or marketing agencies. Grassroots innovations, because they involve serendipity, systematic experimentation, trial and error, or the combining of solutions in new ways, emerge when existing systems and practices fail to serve people's needs (Gupta 2013). India's "grass roots innovation festival' is motivating grass roots innovation in India by pushing social innovation to move to open innovation.

When India approached a medium balance among the three sub-economies via its grassroots innovation policy, the economy dynamics of India increased and the economic growth rate grew to the world's top, the opposite of its low level over the past 50 years.

## 5 Discussion and future research topic

### 5.1 The way to an entrepreneurial state

First, the Schumpeterian linear model needs to be prevented from occurring by regulation of too-big enterprises. Capitalism can be further developed by a new combination of entrepreneurial technology and markets because new start-ups and SMEs can be generated through open innovation between technology and markets. Some companies that have the potential to grow into conglomerates can lead innovation through large-scale investment; they can then advance to a monopolistic position using economies of scale In the process of the Schumpeterian linear model, conglomerates oriented by uncontrolled big business are seen in the socialist economy, with degraded profit and high employment. In this process, the consistent acceleration of an uncontrolled large business consequently brings the depletion of new combinations among entrepreneurs. This, then, is the first condition of the Entrepreneurial Dynamic Cycle of Open Innovation, which can, through regulations and control, prevent in advance future monopolistic positions of big enterprises.

Second, in the Entrepreneurial Cycle social open innovation is not the goal of capitalism but a driving force that can consistently develop capitalism in both quantitative and qualitative manners. Thus, it is important to generate constantly new social open innovations at a certain level. In the situation of modern capitalism, in which the dependency on big businesses tends to be accelerated, social open innovation should be encouraged. As shown by the case of Hitachi, a new generation of social innovation—through a merging process between socially necessary

matters, technology, and society—guaranteed the growth of start-ups and SMEs, as well as the innovation of big businesses. Therefore, the roles of conglomerates and government investment are indispensable in sustaining constant and creative social open innovation above a certain level.

Third, cooperative efforts between governments and conglomerates are required to foster and sustain market open innovation, which is produced by a new combination—a creative unification—of technology and markets. To induce an entrepreneur into a new combination, various channels for the growth of start-ups and SMEs, including support from the financial system, M&A with conglomerates, or easier crowd funding, need to be provided and fostered by the government and by market conditions. Excessive internal reserves of conglomerates can become a critical barrier to such growth of start-ups and SMBs.

### 5.2 Implications and future research topics

According to our modeling and case studies, world economic growth limits cannot be avoided by Schumpeter Entrepreneurial Cyclical dynamics of open innovation.

First and foremost, high dynamics achieved through a medium balance of the three sub-economies is required. Not high balance or low balance but medium balance of the three sub-economies can motivate the dynamics of the economy, which is the trigger of high economic growth rate.

Second, an economy that is too centered on big business, a too-big social economy, or an SME- or start-up- centered economy will decrease the dynamics of the economy. In addition, in these cases, the growth rate of the economy will approach near zero or negative growth.

Third, if any economy approaches a high balance of the three sub-economies, the dynamics of the economy will decrease to a low level, and the growth rate will also become low. This means that the dynamics of any economy can be motivated by an unbalance of the three-sub economies. So, according to the situation of belonging to a national innovation system, a sectorial innovation system, or a regional innovation system, agencies should choose a balance-breaking strategy or policy.

This study requires additional simulation of various factors and effects through a mathematical modeling of Entrepreneurial Cyclical Dynamics of Open Innovation. This must be done to formulate the Entrepreneurial Cyclical Dynamics of Open innovation according to whether certain aspects belong to the NIS, SIS, or RIS. In mathematical modeling and simulation, the lowest conditions and layers for activation require optimization. For simulation, first, the speed of the dynamics of the three factors requires establishment of a model for economic growth. That is, a mathematical model is required to define the overall products in consideration of the circulating relations of the three factors. Second, we should simulate high fluctuation and arrival at a low growth rate of GDP; we should also simulate low fluctuation and arrival at a high growth rate of GDP using our fascinating mathematical model of Schumpeterian cycling dynamics. Third, a model to synthesize growth, depression, and unpredictable features of economic development needs to be built by reflecting on the feature of emergence.

**Acknowledgements** This work was supported by the DGIST R&D Program of the Ministry of Science, ICT and Future Planning (16, and 17). This paper was first presented at ISS 2016, and SOItmC, and was fully updated based on several anonymous reviewers' comments. JinHyo Joseph Yun has created original ideas and provided basic concepts, wrote the all the drafts, and has taken the role of first and corresponding author. KyungBae Park made the entrepreneurial cyclical dynamics causal model and mathematical model. DongKyu Won performed system dynamics simulations of total and individual cases. So, JinHyo Joseph Yun as corresponding author wants to point out KyungBae Park, and DongKyu Won as co-corresponding author together with the agreement of all authors.

## Compliance with ethical standards

**Conflict of interests** None of the authors have any conflict of interest.

## References

Abramovitz M (1986) Catching up, forging ahead, and falling behind. J Econ Hist 46(2):385–406

Abramovitz M (1995) The elements of social capability. In: Koo BH, Perkins DH (eds) Social capability and long-term economic growth. Palgrave Macmillan, London

Abramovitz M, David PA (1996) Convergence and deferred catch-up: productivity leadership and the waning of American exceptionalism. In: Landau R, Taylor T, Wright G (eds) The mosaic of economic growth. Stanford University Press, Stanford

Barlas Y (1994) Model validation in system dynamics. In: Monaghan C, Wolstenholme E (eds) System dynamics: methodological and technical issues, conference proceedings of the 12th International System Dynamics Conference, University of Stirling, Scotland. UK. System Dynamics Society, New York, pp 1–10

Breschi S, Malerba F, Orsenigo L (2000) Technological regimes and Schumpeterian patterns of innovation. Econ J 110:388–410

Bruun C (2003) The economy as an agent-based whole—simulating Schumpeterian dynamics. Ind Innov 10: 475–491

Chauvet E, Paullet JE, Previte JP, Walls Z (2002) A Lotka-Volterra three-species food chain. Math Mag 75(4): 243–255

Chesbrough HW (2006) Open innovation: the new imperative for creating and profiting from technology. Harvard Business School Press, Boston

Chesbrough HW (2013) Open business models: how to thrive in the new innovation landscape. Harvard Business School Press, Boston

Dahlman CJ, Nelson R (1995) Social absorption capability, National Innovation Systems and economic development. In: Koo BH, Perkins DH (eds) Social capability and long-term economic growth. Palgrave Macmillan, London

Day RH (1984) Disequilibrium economic dynamics: a post-Schumpeterian contribution. J Econ Behav Organ 5:57–76

de Felice A (2014) Measuring the social capabilities and the implication on innovation: evidence from a special industrial cluster. J Econ Stud 41(6):907–928

Gupta AK (2013) Tapping the entrepreneurial potential of grassroots innovation. Stanf Soc Innov Rev 11:18–20

Hanusch H, Pyka A (2006) Principles of neo-Schumpeterian economics. Camb J Econ 31(2):275–289

Henkin GM, Polterovich VM (1991) Schumpeterian dynamics as a non-linear wave theory. J Math Econ 20: 551–590

Hitachi Home Page, http://www.hitachi.com/

Iwai K (2000) A contribution to the evolutionary theory of innovation, imitation and growth. J Econ Behav Organ 43:167–198

Jang HS (2014) Capitalism in Korea (Korean). Heybooks, Seoul

Jang HS (2015) Why should we be angry?; capitalism in Korea 2nd inequality of Korean which was made by the failure of distribution(Korean). Heybooks, Seoul

Jeon JH, Kim SK, Koh JH (2015) Historical review on the patterns of open innovation at the national level: the case of the Roman period. J Open Innov Technol Mark Complex 1:1–17
Keynes JM (1937) The general theory of employment. Q J Econ 51:209–223
Kodama F, Shibata T (2015) Demand articulation in the open-innovation paradigm. J Open Innov Technol Mark Complex 1:1–21
Kofoid C (1925) Elements of physical biology. American Public Health Association
Kondratieff ND (1979) The long waves in economic life. Rev (Fernand Braudel Center):519–562
Koo BH, Perkins DH (1995) Social capability and long-term economic growth. Palgrave Macmillan, London
Lee K (2013) Schumpeterian analysis of economic catch-up: knowledge, path-creation, and the middle-income trap. Cambridge University Press, Cambridge
Lee K, Lim C (2001) Technological regimes, catching-up and leapfrogging: findings from the Korean industries. Res Policy 30(3):459–483
Lotka AJ (1920) Analytical note on certain rhythmic relations in organic systems. Proc Natl Acad Sci U S A 6: 410–415
Luna-Reyes LF, Andersen DL (2003) Collecting and analyzing qualitative data for system dynamics: methods and models. Syst Dyn Rev 19:271–296
Lundvall B-Å (2013) Innovation studies: a personal interpretation of the state of the art. In: Innovation studies: evolution and future challenges, pp 21–70
Malerba F, Orsenigo L (1996) The dynamics and evolution of industries. Ind Corp Chang 5:51–87
Maltus TR (2006) An essay on the principle of population, vol 1. Cosimo, Inc., New York
Mathews J (2002) A resource-based view of Schumpeterian economic dynamics. J Evol Econ 12:29–54
Mazzucato M (2011) The entrepreneurial state. Soundings 49(49):131–142
Moore JF (1993) Predators and prey: a new ecology of competition. Harv Bus Rev 71(3):75–86
Morioka M, Kuramochi K, Mishina Y, Akiyama T, Taniguchi N (2015) City management platform using big data from people and traffic flows. Hitachi Rev 64:52–57
Nelson RRWSG (1982) An evolutionary theory of economic change. Harvard University Press, Cambridge
Nelson, R. R., Dosi, G., Helfat, C. E., Pyka, A., Saviotti, P. P., Lee, K., . . . Malerba, F. (2018). Modern evolutionary economics: an overview. Cambridge University Press, Cambridge
Patra SK, Krishna VV (2015) Globalization of R&D and open innovation: linkages of foreign R&D centers in India. J Open Innov Technol Mark Complex 1:1–24
Piketty T (1995) Social mobility and redistributive politics. Q J Econ 110(3):551–584
Piketty T (2015) About capital in the twenty-first century. Am Econ Rev 105(5):48–53
Pyka A (2017) Transformation of economic systems: the bio-economy case. In: Knowledge-driven developments in the bioeconomy. Springer, Berlin, pp 3–16
Saviotti PP, Pyka A (2004) Economic development by the creation of new sectors. J Evol Econ 14(1):1–35
Saviotti PP, Pyka A (2008) Micro and macro dynamics: industry life cycles, inter-sector coordination and aggregate growth. J Evol Econ 18(2):167–182
Schumpeter JA (1934) The theory of economic development: an inquiry into profits, capital, credit, interest, and the business cycle, vol 55. Transaction Publishers, Piscataway
Schumpeter JA (1939) Business cycles: a theoretical, historical, and statistical analysis of the capitalist process, vol 1. McGraw-Hill, New York
Schumpeter JA (1942) Capitalism, socialism and democracy. Routledge, London
Schumpeter JA (1954) History of economic analysis. Oxford University Press, New York
Simon HA (1972) Theories of bounded rationality. In: McGuire CB, Radner R (eds) Decision and organization. North-Holland Pub. Co., Amsterdam, pp 161–176
Smith A, Fressoli M, Thomas H (2014) Grassroots innovation movements: challenges and contributions. J Clean Prod 63:114–124
Sterman JD (2001) System dynamics modeling: tools for learning in a complex world. Calif Manag Rev 43:8–25
Stiglitz JE (2012) The price of inequality: how today's divided society endangers our future. WW Norton & Company, New York City
Teece DJ (2007) Explicating dynamic capabilities: the nature and microfoundations of (sustainable) enterprise performance. Strateg Manag J 28:1319–1350
Teece DJ, Pisano G, Shuen A (1997) Dynamic capabilities and strategic management. Strateg Manag J 18: 509–533
Temple J, Johnson PA (1998) Social capability and economic growth. Q J Econ 113(3):965–990
Van den Bergh JC (2004) Evolutionary analysis of the relationship between economic growth, environmental quality and resource scarcity, Tinbergen Institute Discussion Paper, No. 04-048/3
Verhulst P-F (2009) Notice sur la loi que la population poursuit dans son accroissement. Correspondance Mathématique et Physique 10:113–121

Volterra V (1926) Fluctuations in the abundance of a species considered mathematically. Nature Publishing Group, London
Winter SG (1984) Schumpeterian competition in alternative technological regimes. J Econ Behav Organ 5: 287–320
Witt U (2002) How evolutionary is Schumpeter's theory of economic development? Ind Innov 9:7–22
Witt U (2009) Novelty and the bounds of unknowledge in economics. J Econ Methodol 16(4):361–375
Witt U, Brenner T (2008) Output dynamics, flow equilibria and structural change—a prolegomenon to evolutionary macroeconomics. J Evol Econ 18(2):249–260
Woolcock M (2001) The place of social capital in understanding social and economic outcomes. Can J Pol Res 2(1):11–17
Yoshikawa Y, Sato A, Hirasawa S, Takahashi M, Yamamoto M (2012) Hitachi's vision of the smart city. Hitachi Rev 61:111
Yun JJ (2015) How do we conquer the growth limits of capitalism? Schumpeterian dynamics of open innovation. J Open Innov Technol Mark Complex 1:17
Yun JJ, Won D, Hwang B, Kang J, Kim D (2015) Analysing and simulating the effects of open innovation policies: application of the results to Cambodia. Sci Public Policy 42:743–760
Yun JJ, Won D, Jeong E, Park K, Yang J, Park J (2016a) The relationship between technology, business model, and market in autonomous car and intelligent robot industries. Technol Forecast Soc 103:142–155
Yun JJ, Won D, Park K (2016b) Dynamics from open innovation to evolutionary change. J Open Innov Technol Mark Complex 2:7

## Affiliations

**JinHyo Joseph Yun [1] · DongKyu Won [2] · KyungBae Park [3]**

DongKyu Won
dkwon@kisti.re.kr

[1] Daegu Gyeongbuk Institute of Science and Technology (DGIST), 333 Techno Jungang Daero, Hyeonpung-myeon, Dalseong-gun, Daegu 42988, Republic of Korea

[2] Korea Institute of Science and Technology Information (KISTI), 66 Hoegi-ro, Dongdaemun-gu, Seoul 02456, Republic of Korea

[3] Department of Business Administration, Sangji University, 83 Sangjidae-gil, Wonju, Gangwon 26339, Republic of Korea