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VARIETY EXPANSION AND SUSTAINABLE GROWTH IN EAST ASIA*

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This paper presents an endogenous growth model in which a sustained long-term growth can be achieved by a continuous expansion of varieties of goods despite Neo-classical diminishing returns in capital and no productivity-augmenting technological progress. The model contrasts the existing endogenous growth models of the product-varieties expansion by emphasizing that the introduction of new final goods occurs by raising capital accumulation rather than productivity growth. The model may well explain the coexistence of rapid introduction of new goods, high investment ratios, high income growth, and high welfare, even with a low growth rate of total factor productivity as we observe from the experience of the fast growing countries in East Asia.

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I. INTRODUCTION

This paper presents an endogenous growth model which can explain a sustained growth, accompanied by rapid introduction of new final goods despite low productivity growth. The model is a multi-good general equilibrium model, which has the following key features.

First, the model highlights the role of variety-augmenting technological progress, meaning the increase in the number of final goods that are produced in an

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economy. The variety-augmenting technical progress is initiated by the introduction of new final goods without raising productivity.[1] This type of technological progress contrasts traditional productivity-augmenting technological progress such as in Stokey (1988) and Young (1991). In particular, we assume a positive variety-augmenting but no productivity-augmenting technological progress, so that the former is the sole driving force behind sustained growth. Hence, the introduction of new goods here does not have to imply a move to higher quality goods as in Stokey (1988).

Second, the model emphasizes a strong complementarity between the technology of introducing new goods and (human and physical) capital stock. As a new good production is initiated, the capital to produce the new good is needed. The more goods are newly introduced, the more (physical and human) capital is needed. In this way variety-aug22menting technical progress raises the rate of capital accumulation rather than productivity growth.[2]

Third, the model assumes Neo-classical technology of diminishing returns in capital for each product line, so that capital accumulation on a fixed set of final goods is subject to diminishing marginal returns.

The model we present in this paper shows some interesting features. First, the model shows that a sustained growth can be achieved despite Neoclassical diminishing returns in capital as far as variety of goods continuously expands. The intuition is clear. Given the diminishing returns technology for each product line, increases in capital for the production of each existing good is subject to diminishing marginal returns. However, a continuous expansion of variety and the ensuing shift of resources to new good industries allow to dodge away the diminishing marginal returns, and consequently achieve higher aggregate capital accumulation and sustained income growth.[3] In this way the introduction of new goods raises the rate of capital accumulation.

Second, it then easily follows that an economy with more rapid introduction of new goods or more rapid expansion of variety of goods has a more rapid income and consumption growth. The country with a high speed of introducing new goods has more investment in physical and human capital, which leads to a higher income growth.

Third, the model suggests that total factor productivity (TFP) growth does not fully capture the progress in technology of introducing new goods. For the countries whose growth is largely based on variety-augmenting technological progress rather than productivity-augmenting technological progress, therefore, the

[1] In our model, new good introduction is a sufficient condition to keep expanding the variety of goods because, by construction, no old goods drop out. In case of more rapid dropout of old goods, the number of goods produced can be reduced despite new good introduction.

[2] Our model is also related to recent literature, which emphasizes the complementarity between technology and capital (e.g., human skills), such as Galor and Moav (1998) and Caselli (1999).

[3] Concave utility function for each final goods further strengthens this effect since a continuous increase in capital for newer goods helps to evade the diminishing marginal utility.

TFP growth can be very low. This is because production of newly introduced final goods should be accompanied by capital investment in the goods. Due to the technology-capital complementarity, variety-augmenting technical progress raises capital accumulation, and therefore may have only a limited effect on TFP growth given little productivity-augmenting technical progress.

Finally, we consider that the model may well explain the most salient features of the growth process we can observe from the fast-growing economies such as the four East Asian newly industrializing economies (NIEs)--Hong Kong, Singapore, South Korea and Taiwan. The unprecedentedly high and enduring growth of these East Asian economies for the last four decades- often referred to a "miracle"- has been accompanied by several salient and interrelated features such as rapid introduction of new final goods (sectors) and expansion of product varieties, high investment ratio, high capital accumulation and low productivity (TFP) growth.[4]

This paper is organized as follows. Section II discusses background and related literature, and section III presents a multi-sector growth model. In Section IV, we study the effect of variety expansion on steady state growth. Section V discusses total factor productivity growth and the implications of our model to the experience of the East Asian fast growing economies. Section VI concludes.

II. BACKGROUND AND RELATED LITERATURE

A key objective of recent growth literature including this paper has been to explore a model that can explain simultaneously the key features of the East Asian economies that had enjoyed a rapid growth sustained for more than three decades. The development process of the fast growing economies is first of all characterized by the rapid introduction of new goods and the subsequent expansion of product varieties. The speed of introducing new final goods in the East Asian NIEs has been dramatic. For example, Korea started to produce an automobile 75 years after the first car appeared on earth, and a TV set 26 years after its first invention. However, it took only 6 years to produce a personal computer, and 3 years for a 4 mega-Dram semiconductor. Korea has now become the first country to produce a 16-Mega Dram.[5]

[4] The recent financial crises in East Asia must not imply that the East Asian growth "miracle" is just a "myth". The extremely high growth rate of over 8 percent on average per year for the last four decades was unprecedented and brought extraordinary improvements in welfare to people in these economies. The quick recovery from the crises, most notably in Korea (together with the fact that the countries sporadically had a plunge in the growth rate before), may reflect that long-term growth potential of the East Asian countries still remains strong.

[5] See Lee (1996) for more details on this process in Korea. More evidence on the rapid expansion of product varieties can be easily found. For example, Feenstra (1996)'s data set on U.S. imports shows that the four East Asian NIEs has rapidly increased the variety of exports to the U.S. market (defined at the five digits SITC) for 1972-94.

Another key feature of the development process of the fast growing economies is that the rapid introduction of new goods is not accompanied by high productivity growth but by high capital accumulation. The observation of the rapid expansion of product varieties leads many people to believe a rapid narrowing-down of technology gaps between the East Asian countries and advanced countries through rapid introduction of new goods. Along this line, Stokey (1988, 1991a), Young (1991), and Lucas (1993) have provided formal models where the rapid introduction of new final goods is the driving force for productivity-augmenting technological progress and income growth in East Asia. In his "Making a Miracle" paper, Lucas (1993) emphasizes that "[a] growth miracle sustained for a period of decades clearly must thus involve the continual introduction of new goods, not merely continued learning of a fixed set of goods," and the Asian growth miracles should be "productivity miracles". However, recent empirical studies on East Asian growth suggest that the rapid growth in East Asia has been caused by rapid capital accumulation rather than rapid advances in total factor productivity (TFP). Young (1995) found that TFP growth in Singapore was -0.3 percent on average for the period 1966-1990. During the same period, the TFP growth was 2.3 percent for Hong Kong, 1.7 percent for Korea, and 2.4 percent for Taiwan. Therefore, much higher contributions to the high output growth rates of over 8 percent during the period were made from the growth of capital and labor inputs, rather than from the improvements in TFP.[6] Apparently, such empirical findings of low TFP growth appear in contrast to the rapid introduction of new goods and implied technology progress.

An advantage of our model seems to be that it reconciles these seemingly-inconsistent observations, and explains well the other salient features of the growth process we can observe from the fast-growing economies. We import some of the key elements of our model (notably diminishing returns in capital, new good introduction and no productivity-augmenting technical progress) from some existing literature. However, the novelty of our model lies in presenting a new combination of the key elements, and moreover our model seems to represent a better combination in terms of explaining empirical evidence that we observe from the East Asian growth process, compared to the existing literature.

First, our model is close to Solow-Cass growth model in that production technology exhibits diminishing returns in capital. In contrast to this Neoclassical

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[6] Kim and Lau (1994), by estimating a meta-production function, also found low contribution of technological progress to economic growth in the East Asian countries. Based on the empirical results, Krugman (1994) challenged the convention of calling the phenomenal growth of the East Asian economies a miracle, and even compared the experience of East Asia to that of the former Soviet Union, suggesting that the growt driven by mere increase in inputs without technological progress, will not sustain. Collins and Bosworth (1996) also confirm the low TFP growth in East Asia. Hsieh (1997) shows that price-base(dual) estimates of TFP growth for Singapore and Taiwan are higher than the estimates by Young (1995), but those for Korea and Hong Kong change little.

one sector model, however, our multi-sector model allows for the introduction of new goods and ensuing increases in variety of goods produced in an economy. Although production of each good (or each industry) is subject to diminishing marginal returns, such an expansion in product varieties allows aggregate capital to persistently build up without being subject to diminishing marginal returns. Therefore, in our model, a sustainable growth can be achieved through capital accumulation despite assuming a Neo-classical diminishing returns technology. In addition, the main engine of growth in our model is the variety-augmenting technological progress, in contrast to Solow model where traditional productivity-augmenting technological progress is the driving force behind growth. Further, our model suggests a relatively small TFP growth given a reasonable range of capital income share parameter, while the Solow model predicts TFP growth to account for most of long-run steady state growth.

Second, our model is similar to Stokey-Young-Lucas model in that the introduction of new final goods plays a major role in growth process, but with several key differences. Note that in their model, the introduction of new final goods, induced by learning-by-doing and spillovers, implies advancing to higher productivity activities, so that new good introduction must raise productivity growth. In addition, concentrating the workforce on new good industries, combined with rapid movement of the labor force to newer good industries, accelerates growth. In our model, however, new good sectors do not have to be high productivity sector, so that variety-augmenting technology progress can occur without a rise in productivity. As a result, rapid new good introduction is not enough for high growth in our model unlike theirs. In our model, a real key for growth is the increase in the varieties of goods in production rather than new good introduction. More rapid dropout of old goods than new good introduction would reduce the varieties of goods produced, which would reduce the growth rate. Further, in contrast to our model, Stokey-Young model (like Solow model) suggests that TFP growth plays a dominant role in economic growth and hence it has difficulty in explaining why the rapid introduction of new goods has not accompanied high TFP growth in the fast growing economies such as the East Asian NIEs. Romer (1990) and Grossman and Helpman (1991a, 1991b) also present models of growth driven by the introduction of new intermediate goods. In these models too, TFP growth plays a dominant role.

Third, our model is also related to AK models (e.g., Rebelo (1991), King and Rebelo (1990), Jones and Manuelli (1990), Kim (1998), Stokey and Rebelo (1995)) in that capital accumulation plays an important role in growth process. Notably, however, our model assumes diminishing returns in capital, in contrast to AK model where technology of constant returns in capital is assumed. Empirical evidence supports for the diminishing-returns-in-capital technology, both at the sectoral and the aggregate level.[7] In addition, there is expansion in the

[7] Recent empirical evidence supports for decreasing returns in capital at the disaggregated

variety of goods in our model, while there is not in AK model. Further, capital accumulation is initiated by expansion in variety of goods in our model, while it is not in AK model. Finally, AK model suggests that TFP growth is zero, while our model suggests that TFP growth will be positive, though not huge.

Ⅲ. THE BASIC MODEL

This section presents a multi-sector general equilibrium model which can effectively explain a sustained growth with rapid expansion of variety of goods, high investment ratio, and low TFP growth. To build up the model, we discuss technology, consumers, firms and competitive equilibrium in order.

Ⅲ.1 Technology

An economy's technology level is defined in two dimensions: how efficiently an economy can produce each good for a given amount of inputs; and how many varieties of goods the economy can produce. So we distinguish between two types of technology: technology of producing existing goods, and technology of introducing new goods.

Consider the first type of technology. We assume that each (old or new) good is produced by the good-specific capital. So the j-th good specific capital $(k_t(j))$ cannot be used for the production of the other goods, say the l-th good $(l \neq j)$. Here capital means a broad capital including both human and physical capital.[8] So the j-th good-specific capital can represent either specific machines or human skills for production of the j-th goods. More specifically, each agent in the economy is given identical technology for any industry indexed by j, which is represented by the following production function:

$$y_t(j) = A_t(j)k_t(j)^{\gamma} \tag{1}$$

where γ is capital income share parameter and $A_t(j)$ represents the technology of producing the j-th goods at time t. When a progress occurs in this type of technology $(A_t(j))$, the output of the existing goods increases for a given amount of inputs.

manufacturing sectors. This evidence and another evidence of no externality across industries support decreasing returns in the aggregate manufacturing sector as well. See Bartelsman (1995) and Burnside (1996).

[8] Instead of using composite capital, we could explicitly distinguish between human and physical capital by assuming that $y_t(j) = A_t(j)k_{p,t}(j)^{\alpha_1}k_{h,t}(j)^{\alpha_2}$ where $k_{p,t}$ and $k_{h,t}$ represent physical and human capital, respectively. However, we can easily show that this complication does not affect the main results, while in this case, k_t can be written as $k_t = k_{p,t}(j)^{\alpha_1/\gamma}k_{h,t}(j)^{\alpha_2/\gamma}$ where $\gamma = \alpha_1 + \alpha_2 < 1$.

In particular, we assume a Neo-classical production function for each individual good

$$\gamma < 1 \tag{2}$$

so that output of each good exhibits a diminishing-returns-to the good-specific capital.[9]

Now consider the second type of technology. We assume that all the firms in an economy can produce a continuum of goods that can change over time and therefore are indexed by j_{t+s} (or interchangeably by l_{t+s}) on the real line $[0, N_{t+s} \in R_+]$ at time $t+s$. Then the number of goods produced at time $t+s$, N_{t+s}, represents the economys technology level of the second type (or how many different goods an economy can produce) at time $t+s$. With progress in this type of technology (or an increase in N_{t+s}), newer goods will be produced. For notational simplicity, we index a good produced at time $t+s$ by j_{t+s} (or by l_{t+s}), $s \geq 1$, but a good produced at time t by j (or by l) without a time subscript.

Therefore, the technology of an economy at time t is represented by the vector $[A_t(j), N_t]$. Then the increase in $A_{t(j)}$ represents technical progress of increasing the productivity of producing individual goods, and the shift from the j-th sector to the l-th sector having higher productivity $(A_t(j) < A_t(l))$, represents productivity-augmenting progress through moving from lower to higher productivity goods. Distinguished from the above types of productivity-augmenting technical progress, the increase in N_t captures variety-augmenting technical progress.

To explain East Asian growth experience of low TFP growth, this paper focuses on variety-augmenting technical progress. Particularly, we assume, for simplicity, that $A_{t+s}(j_{t+s})$ is constant at A both across goods and over time, so that there is neither individual-good-productivity-augmenting technical progress nor productivity-augmenting technology progress through moving from lower to higher productivity industries.[10] But assume that there is a variety-augmenting technology shock and it occurs in the following way. At the beginning of each period,

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[9] We may assume that $\gamma = 1$, so that the production function take a constant-returns-to-scale form as in Ak model. But this modification would not alter the main results of the paper.

[10] Our model could be easily modified to allow for $A_{t(j)}$ to change over time. In particular, we can easily incorporate bounded learning-by-doing into the model. For example, we may assume that if a type of good is first produced at time t, the productivity is determined as: $A_{t(j)} = A$ for time t, and $A_{t+s}(j) = (1+\lambda)A$ for $s = 1, 2\cdots$.Then this type of bounded learning-by-doing, without spillovers across goods, will modify the model solutions only slightly if λ is small. In particular, TFP growth can be small but positive, and the main qualitative results of the paper continue to hold (note that the basic model is the case where $\lambda = 0$). Of course, we may instead assume that λ is large compared to ϕ or there is spillovers across goods (as assumed in Young (1991)). With these assumptions, however, the TFP growth becomes the main engine of growth, which may not closely match the East Asian growth experience.

a technology to produce a new good happens to each and every one of the currently available goods ($j_{t+s} \in [0, N_{t+s}]$) independently of each other, with a probability θ.[11 12] Thus, at the beginning of each period, new technologies of producing new goods occur for the θ fraction of currently available goods. This is an aggregate shock, so that any agent in the economy can enjoy this new technology of producing new goods.

Let j_{t+s} index the new good that is derived from the j_{t+s}-th good which experiences technology shock at time $t+s$. It takes one period to accumulate new-good-specific capital so that the good indexed by j_{t+s} can be produced from $t+s+1$. Note that for notational convenience, we use the notation without time subscript, j, instead of j_t for t, while we would explicitly use a subscript for j_{t+s}, for $s \geq 1$. All the individual agents, at time t, expect that they will be able to produce new goods following the production function at $t+1$:[13]

$$y_{t+1}(j') = Ak_{t+1}(j')^{\gamma} \tag{3}$$

With technology shock occurring at the rate of θ at t, the number of technologically feasible goods at $t+1$ is given by:

$$\tilde{N}_{t+1} = (1+\theta)N_t \tag{4}$$

where $\tilde{N}_{t+1}$ is the number of technologically feasible goods at $t+1$, and N_t is the number of goods produced at time t. Without current investment in new capital by agents, the technology of producing new goods will not be fully materialized next period. So the actual number of goods produced (N_{t+1}) may be determined at lower than the number of potentially feasible goods.

$$N_{t+1} = (1+\phi_t)N_t \leq \tilde{N}_{t+1}. \tag{5}$$

where ϕ_t denotes the actual speed of introduction of new good, which is equal to the growth rate of the number of goods (without drop-off of old goods).

Ⅲ.2 Consumers

The model economy consists of a continuum of infinitely-lived identical agents

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[11] This can be understood as a type of externality across goods.

[12] We can assume that the older a good is, the less the θ is. In this case, the economy's aggregate shock depends on the composition of new and old goods. If the new goods are not introduced, the economy's θ can decline to zero over time.

[13] Note that $j' \equiv j_t'$ belongs to $[0, N_{t+1}]$, so that Eq. (3) can be rewritten as: $y_{t+1}(j_{t+1}) = Ak_{t+1}(j_{t+1})^{\gamma}$, for $j_{t+1} \in [0, N_{t+1}]$.

indexed by $i \in [0, 1]$.[14] Each agent maximizes the intertemporal utility, which is additively separable over goods with logarithmic momentary utility function:

$$\sum_{t=0}^{\infty} \int_0^{N_t} \beta^t B_t(j_t) \log c_t(j_t) dj_t \tag{6}$$

where $c_t(j_t)$ is the consumption of the j_t-th goods at time t, β is the subjective discount rate, and $B_t(j_t)$ is the weight given to the utility from the consumption of the j_t-th good at time t.[15]

To highlight the variety-expanding technological progress, we assume that $B_t(j_t)$ is constant at one, both across goods and over time. So the utility function can be rewritten as[16]

$$\sum_{t=0}^{\infty} \int_0^{N_t} \beta^t \log c_t(j_t) dj_t \tag{7}$$

This type of preference that is additively separable and symmetric across goods implies a preference for diversity in goods consumed, which is a strong force against abandoning the production of any good in a closed economy.[17]

In each period, after technology shock is revealed, the agents decide investment in capital for old and new goods. Then, in the next period, the agents supply the accumulated capital (for either old or new goods) to a firm, and receive rentals in return. For simplicity, we assume that the accumulation of old-good specific capital is a linear function of resources devoted.

$$k_{t+1}(j) - k_t(j) = I_{t+1}(j) - \delta k_t(j), \quad j \in [0, N_t] \tag{8}$$

where $I_{t+1}(j)$ is the investment made in old-good specific capital at time t and δ is the depreciation rate.

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[14] Under this assumption, aggregate value of a variable is equal to its per capita value. For example, aggregate output is equal to output per capita since $\int_0^1 y(t)di = y(t)$.

[15] As momentary utility function, we may assume $\log(c_t(j_t)+1)$ instead of $\log c_t(j_t)$

[16] We can easily incorporate dropping out of old goods into the model by distinguishing between two types of new goods: newer variety goods, and better quality goods. The latter type can be defined in terms of utility function as follows: the consumption of newer goods (better-quality goods than the j_t-th good) affects utility as $B_{t+1}(j_{t+1})\log(c_{t+1}(j_{t+1})), B_{t+1}(j_{t+1})>1$ while the consumption of an old good affects utility as $\log(c_{t+1}(j_t))$ (or we may instead introduce the characteristics of preferences as in the model of Stokey (1988)). The introduction of this type of newer goods implies the dropping-off of the older ones, because the newer goods have better quality. The introduction of this type of new goods will be largely captured by TFP growth.

[17] The additively separable preference is a good proxy for the East Asian countries where introduction of new good has been much faster than dropping out of old goods.

To produce new goods derived from the j-th good (i.e., the j'-th good), the j'-th good-specific capital is required. We assume a similar linear function for the accumulation of new-good specific capital as:

$$k_{t+1}(j') = \chi I_{t+1}(j') \qquad j' \in [N_t, \widetilde{N}_{t+1}] \tag{9}$$

where $I_{t+1}(j')$ is the investment made in new good-specific capital at time t, and $\chi \in (0,1)$ represents the efficiency of capital in producing new good-specific capital.[18]

The investment for old-good and new-good specific capital ($I_{t+1}(j)$ and $I_{t+1}(j')$) can be accomplished by any existing good indexed by $l \in [0, N_t]$. In particular, we assume that

$$I_{t+1}(j) = \int_0^{N_t} I_{t+1}(j,l)dl \quad \text{and} \quad I_{t+1}(j') = \int_0^{N_t} I_{t+1}(j',l)dl \tag{10}$$

where $I_{t+1}(j,l)$ is the investment in old good j made by inputting the l-th good, and $I_{t+1}(j',l)$ is the investment in new good j' accompanied by inputting the l-th good ($l, j \in [0, N_t]$). In addition, for simplicity, we assume that all the capital depreciates one hundred percent at the end of the next period ($\delta = 1$) so that $k_{t+1}(j) = I_{t+1}(j) = \int_0^{N_t} I_{t+1}(j,l)dl$, and $k_{t+1}(j') = \chi I_{t+1}(j') = \chi \int_0^{N_t} I_{t+1}(j',l)dl$.

Technology described in eq. (1) is available to all the agents in the economy who are identical. Each of the agents owns a firm in each industry and rents capital in competitive markets. For simplicity, assume that the firm cannot rent capital from the owner of the firm but from non-owners, so that there is a separation between entrepreneurs and capital renters.[19]

The agents have three sources of income: rentals from old-good specific capital and from new good specific capital, and profits. The agents spend their current income on the consumption of goods available, and the accumulation of two types of capital. Thus, the representative agent's budget constraint is

$$\begin{aligned}&\int_0^{N_t} p_t(l)c_t(l)dl + \int_0^{N_t}\left[\int_0^{N_t}[p_t(l)I_{t+1}(j,l)]dl\right]dj + \int_{N_t}^{\widetilde{N}_{t+1}}\left[\int_0^{N_t}[p_t(l)I_{t+1}(j',l)]dl\right]dj' \\ &= \int_0^{N_{t-1}}[r_t(j_{t-1})k_t(j_{t-1})]dj_{t-1} + \int_{N_{t-1}}^{N_t}[r_t(j'_{t-1})k_t(j'_{t-1})]dj'_{t-1} + \int_0^{N_t}\pi_t(j)dj\end{aligned} \tag{11}$$

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[18] We can view this assumption as reflecting the fact that producing new capital is often more difficult than producing old capital due to the lack of experience and knowledge. But this assumption is not necessary to derive the main results of the paper which, even in case where $\chi > 1$.

[19] Such a separation could also be attained by explicitly introducing heterogenous agents some of which work only as entrepreneurs while others only as capital owners in equilibrium. However, this complication of the model would not alter the main propositions of the paper.

where $p_t(l)$ is the price of the l-th good, $r_t(j_{t-1})$ is the rental rate of the old-good-specific capital, and $r_t(j'_{t-1})$ is the rental rate at time t of new-good-specific capital which was accumulated at $t-1$ for the goods which start being produced from t, and $\pi_t(j)$ is the profit of the firm in the j-th good-producing industry that the agent owns at time t, not a choice variable of the household, but a firm.

At time t, the agents choose consumption of each goods, and investment in old and new good-specific capital, taking prices as given. We focus on the case where old goods continue to be produced, but new goods may or may not be produced depending on their rates of return. Under the assumption that $[c_t(l)>0, I_{t+1}(j,l)>0, I_{t+1}(j',l)\geq 0,$ for $j,l\in[0,N_t]$, and $j'\in[N_t, \tilde{N}_{t+1}]]$, the maximization problem yields the Kuhn-Tucker conditions as follows:

$$\frac{dL}{dc_t}=\beta^t\frac{1}{c_t(l)}-\lambda_t p_t(l)=0 \qquad l\in[0,N_t] \tag{12}$$

$$\frac{dL}{dI_{t+1}(j,l)}=-\lambda_t p_t(l)+\lambda_{t+1}r_{t+1}(j)=0 \qquad j,l\in[0,N_t] \tag{13}$$

$$\frac{dL}{dI_{t+1}(j',l)}=-\lambda_t p_t(l)+\lambda_{t+1}r_{t+1}(j')\chi\leq 0 \quad j'\in[N_t,\tilde{N}_{t+1}] \text{ and } l\in[0,N_t] \tag{14}$$

$$\left[\frac{dL}{dI_{t+1}(j',l)}\right]I_{t+1}(j',l)=[-\lambda_t p_t(l)+\lambda_{t+1}(j')\chi]I_{t+1}(j',l)=0 \tag{15}$$

where λ_t is the Lagrange multiplier associated with budget constraint at time t.

The equilibrium outcomes depend critically on the rates of return from investment in existing goods $\left(R^{old}=\frac{r_{t+1}(j)}{p_t(l)}\right)$ and new goods $\left(R^{new}=\frac{r_{t+1}(j')\chi}{p_t(l)}\right)$.[20] For example, if the parameters are such that the rate of return from existing goods is greater than new goods, equation (13) holds with equality, but equation (14) would hold with inequality. Consequently, the agents may not invest in capital for new goods, but for old goods, and therefore the growth rate of the number of new goods would be determined as $\phi_t=0$. But if the rate of return from existing goods and new goods are the same, both equations (13) and (14) hold with equality. Then the growth rate of the number of new goods is determined as $\phi_t=\theta$.

[20] Given our assumptions of separatial between firm owners and capital renters, the Kuhn-Tucker condition (14) does not include any profit term.

Ⅲ.3 Firm

For any good j, there are a large number of firms, each of which is headed by one of the agents. The firms maximize the profit, taking the rental rate $(r_t(j))$ and the price as given: $\pi_t(j) = p_t(j)y_t(j) - r_t(j)k_t(j)$. The competitive firm's maximization problem yields the first-order condition:

$$r_t(j) = p_t(j)\gamma A k_t(j)^{\gamma-1} = p_t(j)\gamma \frac{y_t(j)}{k_t(j)} \tag{16}$$

which tells us that the rental rate is equal to the marginal product of capital.

Ⅲ.4 Competitive Equilibrium and Steady State

The equilibrium in this closed economy is determined as follows. The consumer's maximization problem yields a set of demand function for consumption and a supply function of capital. Likewise, the firm's behavior yields demand function for good-specific capital and supply for output in terms of price parameters. Then equilibrium prices of goods, wages, rental rates, and growth rates of output are obtained from the market clearing conditions. Given our assumption that investment for each good can be accomplished by any good, the market clearing condition for each good is given by:

$$c_t(l) + \int_0^{N_t} I_{t+1}(j, l)\,dl + \int_0^{N_t} I_{t+1}(j', l)\,dl = y_t(l) \quad \text{for } l \in [0, N_t] \tag{17}$$

Throughout the paper, we focus on a steady state growth path along which output and consumption of each existing good grow at the same rate and new goods are introduced at a constant rate $\phi_t = \phi \geq 0$. Along the steady state where $\frac{c_{t+1}(j)}{\beta c_t(j)} = \frac{y_{t+1}(j)}{\beta y_t(j)}$, Eq · (12)(by putting $l = j$) yields)

$$\frac{\lambda_t}{\lambda_{t+1}} = \frac{p_{t+1}(j)}{p_t(j)} \frac{c_{t+1}(j)}{\beta c_t(j)} = \frac{p_{t+1}(j)}{p_t(j)} \frac{y_{t+1}(j)}{\beta y_t(j)} \tag{18}$$

where $p_{t+1}(j)$ is the price of the same j-th good (whose price at time t was $p_t(j)$) at time $t+1$.

Ⅳ. SUSTAINABLE GROWTH

This section illustrates how a sustainable growth can be achieved in the model developed in the previous section. To address the issue, we examine how the rate of variety expansion is determined in the basic model, and more importantly how the variety expansion affects aggregate investment, and the growth rate of national income and consumption.

In the basic model, the rate of variety expansion is determined as follows. First, we want to show that in equilibrium, the following should hold

$$\frac{r_{t+1}(j')\chi}{p_t(l)} = \frac{r_{t+1}(j)}{p_t(l)} \quad \text{or} \quad r_{t+1}(j')\chi = r_{t+1}(j) \tag{19}$$

so that the rates of return on new goods are equal to those of existing goods (and both Kuhn-Tucker conditions (13) and (14) hold with equality).

To show this, consider what would happen if the condition does not hold. If $r_{t+1}(j')\chi < r_{t+1}(j)$, then there would not be any investment in new goods, which will drive the prices of new goods ($p_{t+1}(j')$) to infinity.[21] So this is not an equilibrium. On this off-the-equilibrium path with prices of infinity, agents would have incentive to invest in the new-good specific capital. Similarly, if $r_{t+1}(j')\chi > r_{t+1}(j)$, the prices of old goods would go to infinity. So this is also not an equilibrium. In this case, agents would try hard to invest in the old-good specific capital. This suggests that, in equilibrium, the agents invest in both new and old goods; consequently new goods will be certainly produced in the next period, and any of old goods will not be dropped out.

As a result, the growth rate of the number of goods along the steady state growth path is determined to be equal to the rate of new good introduction in this closed economy model.[22] The variety expansion rate is determined to be the same as the rate of technology shock, which is positive ($\phi = \theta > 0$). It also follows that $N_{t+1} = \tilde{N}_{t+1} = (1+\phi)N_t = (1+\theta)N_t > N_t$.

Note that the key issue of this paper concerns the role of variety expansion in ensuring a sustainable growth. For this reason, we focus only on the case where a positive technology shock ($\theta > 0$) always induces a new good introduction, rather than address various cases including where despite the occurrence of a new technology shock, new goods are not introduced.[23]

Now we investigate how the expansion in the number of goods, which is

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[21] The price of a new good can be conceived as: $p_t(j') = \beta^t \frac{1}{c_t(j')\lambda_t}$, which goes to infinity if $c_t(j')$ is close to zero.

[22] In a model where old goods are dropped out (for example, open economy model), the rate of variety expansion can easily differ from the rate of new good introduction.

[23] We could also analyze the case where the occurrence of a new technology shock may not always induce the introduction of new goods. Consider a situation where in order to introduce new goods, an economy needs to have a social absorption capacity large enough to adopt the new technology of producing new goods. More specifically, consider the case where technology shock of new goods can be materialized only when the economy's average level of new-good-specific capital reaches at least a certain threshold level, while newer goods require higher average capital of an economy. In this variant model, we can show that new good introduction may not be initiated in a market economy despite positive shocks, but can be stimulated by some government policies.

determined as shown above ($\phi = \theta > 0$), affects aggregate investment. By putting $l = j$ in Eq. (13), together with (16), we have

$$\frac{\lambda_t}{\lambda_{t+1}} = \frac{r_{t+1}(j)}{p_t(j)} = \frac{p_{t+1}(j)}{p_t(j)} \frac{\gamma y_{t+1}(j)}{k_{t+1}(j)} \tag{20}$$

From a comparison of the above equation with Eq. (18), the equilibrium level of each of old-good-specific capital along the steady state, denoted by $k^*_{t+1}(j)$, is derived as:

$$k^*_{t+1}(j) = \gamma\beta y_t(j) \tag{21}$$

which implies that the old-good-specific capital is a constant fraction of the output of the old good j, regardless of the speed of introducing new goods, ϕ.

Using Eq. (12) and market clearing conditions, we have

$$p_{t+1}(j)c_{t+1}(j) = p_{t+1}(j')c_{t+1}(j') \tag{22}$$

or

$$p_{t+1}(j)y_{t+1}(j) = p_{t+1}(j')y_{t+1}(j') \tag{23}$$

which implies that the consumption or income share of each good (including new goods) in total income is identical across goods along the steady state.

Using the above equations, together with Eqs. (16) and (19), the equilibrium level of each of new-good-specific capital, denoted by $k^*_{t+1}(j')$, can also be derived as

$$k^*_{t+1}(j') = \chi k^*_{t+1}(j) = \chi\gamma\beta y_t(j) \tag{24}$$

So the income share of each of new-good-specific capital is also constant, whatever the speed of introducing new goods is.

Note that Eq. (13) implies that $p(l) = p(j)$ for any l, j, that is, prices of goods are the same in equilibrium. Using this, total investment in capital (I_{t+1}), including both new- and old-good-specific capital, is then given by

$$I_{t+1} = (1+\phi)\gamma\beta \int_0^{N_t} p_t(j)y_t(j)dj. \tag{25}$$

The equation tells us that there will be new investment as far as new goods are introduced. More importantly, it suggests that expansion in variety of goods may lead to an increase in aggregate investment compared to the case of no expansion, though investment in each of old goods remains constant over time.

Finally, we explore how the expansion in the number of goods and the ensuing increases in aggregate investment affect the steady state growth rate of national income. To derive the steady state growth rate of real GNP, we first examine the growth rate of real output for each individual good (or industry), denoted by $g^y(j)$. Given Neo-classical diminishing returns technology ($\gamma<1$) and 100 percent depreciation, capital stock for an individual good (or industry) remains constant at a steady state level over periods.

Therefore the steady state growth rate of each good (or each industry) is determined as:

$$g^y(j)=\frac{y_{t+1}(j)}{y_t(j)}-1=0. \tag{26}$$

which tells us that Neoclassical technology of diminishing returns in capital leads the steady state growth rate of each existing goods to be zero. The steady state capital and output of each goods are obtained by using Eqs. (1), (21) and (26), from $\frac{y_{t+1}(j)}{y_t(j)}=\frac{A(\gamma\beta Ak_t(j)^\gamma)^\gamma}{Ak_t(j)^\gamma}=1$.

What will then happen to aggregate output along the steady state? Let Y_t, Y_{t+1} and P_{t+1} denote the real aggregate output (or real GNP) at time t and $t+1$, and the GNP deflator at $t+1$, respectively. Suppose time t is a base year of real GNP calculation. Then the real GNP at time t (or GNP at time t prices), is the same as the nominal GNP at time t:

$$Y_t=\int_0^{N_t} p_t(j)y_t(j)dj. \tag{27}$$

Real GNP at time $t+1$ is calculated as follows. The nominal GNP at time $t+1$ is given by:

$$P_{t+1}Y_{t+1}=\int_0^{N_t}[p_{t+1}(j)y_{t+1}(j)]dj+\int_{N_t}^{N_{t+1}}[p_{t+1}(j')y_{t+1}(j')]dj'. \tag{28}$$

Then the real value of old goods at time $t+1$ is derived from dividing its nominal value by the GNP deflator:

$$Y_{t+1}^{old}=\frac{\int_0^{N_t}[p_{t+1}(j)y_{t+1}(j)]dj}{P_{t+1}} \tag{29}$$

By definition, the real value of old goods (at time t prices) at time $t+1$ is

$$Y_{t+1}^{old} = \int_0^{N_t} [p_t(j) y_{t+1}(j)] dj \tag{30}$$

Equating the right side of the above two equations, GNP deflator (P_{t+1}) is calculated as:

$$P_{t+1} = \frac{\int_0^{N_t} [p_{t+1}(j) y_{t+1}(j)] dj}{\int_0^{N_t} [p_t(j) y_{t+1}(j)] dj}. \tag{31}$$

Using this deflator and Eq. (23), the real value of output of new goods (at time t prices) is given by

$$Y_{t+1}^{new} = \phi\left(\int_0^{N_t} [p_t(j) y_{t+1}(j)] dj\right) \tag{32}$$

and the GNP at time t prices is calculated as:

$$Y_{t+1} = Y_{t+1}^{old} + Y_{t+1}^{new} = (1+\phi)\left(\int_0^{N_t} [p_t(j) y_{t+1}(j)] dj\right) \tag{33}$$

The steady state growth rate of real GNP (g^y), then, is given by:

$$g^y = \frac{Y_{t+1}}{Y_t} - 1 = (1+\phi)\frac{\int_0^{N_t} [p_t(j) y_{t+1}(j)] dj}{\int_0^{N_t} [p_t(j) y_t(j)] dj} - 1 = \phi \tag{34}$$

The equation indicates that given diminishing returns in capital, which drives the steady state growth of existing goods to zero, the growth rate of aggregate output hinges on ϕ. Particularly in our basic model where ϕ is determined to be equal to θ which is positive, the growth rate is positive.

The above discussion establishes the following proposition.

Proposition 1 *Given* $\phi > 0$, *it holds that*

$$g^y > 0 \text{ and } \frac{dg^y}{d\phi} > 0.$$

The proposition tells us that as far as new industries continue to be introduced (and therefore vareity of goods continue to expand), sustainable growth can be achieved even though each industry exhibits Neo-classical diminishing returns in capital. In addition an economy with a faster introduction of new goods has a faster growth of real income. The reason is straightforward. Under diminishing returns, a country's growth cannot be driven by a continuous capital accumulation in the same old specific capital because the steady state growth of existing goods is zero. Despite diminishing returns, however, a continuous introduction of new goods and the ensuing shift of resources to new good sector allow to dodge away the diminishing returns, and consequently the rate of aggregate output growth can remain positive. The output growth also rises as the number of goods produced in the economy increases. So the economy with a rapid variety-augmenting technical progress (or high ϕ) induces high investment, which leads to a high growth.

Note also that along the balanced growth path, aggregate consumption grows at the same rate with aggregate output. Therefore, a faster expansion of vareity of goods induces a higher growth of real aggregate consumption and momentary utility $\left(\int_0^{N_t}\beta^t \log c_t(j)dj\right)$.[24]

V. TOTAL FACTOR PRODUCTIVITY AND INVESTMENT

The model developed in the previous section can be used to address two interesting questions: how the variety-augmenting technological progress affects the contribution of total factor productivity growth to national income growth and investment ratio of an economy? and how well the results derived from the model match the growth experiences we observe for East Asian NIEs?

V.1 TFP Growth and Investment Ratio

To address the above issues, we first calculate the growth rate of real aggregate capital. For this, note that, using arbitrage condition (i.e., the revenue from selling capital is the same as that from renting the capital whose depreciation rate is one), prices of capital are determined from production function as:

$$p_t^{k(j)}k(j) = r_t^{k(j)}k(j) = \gamma p_t(j)y(j) \tag{35}$$

where $p_t^{k(j)}$ is the price of the j-th good specific capital at time t.

Let $\hat{K}_t$ denote the real aggregate capital at time t. Then, using the above equation, the real aggregate capital at time t, is given by:

$$\hat{K}_t = \int_0^{N_t} p_t^{k(j)}k_t(j)dj = \int_0^{N_t} \gamma p_t(j)y_t(j)dj. \tag{36}$$

[24] Note that, for an economy with higher ϕ, higher aggregate investment may be desirable in the sense that it maximizes the utility of agents. So an economy with more rapid introduction of new goods has higher optimal investment-output ratio.

In an analogous way to real GNP, real aggregate capital at time $t+1$ is also calculated as:

$$\hat{K}_{t+1} = \int_0^{N_t} [p_t^{k(j)} k_{t+1}(j)]dj + \int_{N_t}^{N_{t+1}} \left[\frac{p_{t+1}^{k(j')}}{P_{t+1}^K} k_{t+1}(j') \right] dj'$$
$$= (1+\phi) \left(\int_0^{N_t} \gamma [p_t(j) y_{t+1}(j)] dj \right) \tag{37}$$

where P_{t+1}^K is the aggregate capital deflator, which can be shown to be equal to GNP deflator in this case.

The steady state growth rate of real aggregate capital (g^k) is calculated as:

$$g^k = \frac{\hat{K}_{t+1}}{\hat{K}_t} - 1 = (1+\phi) \frac{\int_0^{N_t} [p_t(j) y_{t+1}(j)] dj}{\int_0^{N_t} [p_t(j) y_t(j)] dj} - 1 = \phi \tag{38}$$

This tells us that the growth rate of capital is equal to the rate of variety expansion as is the case of the growth rate of output.

Once we know the growth rate of the aggregate capital, the TFP growth rate is easily calculated as:

$$g^{TFP} = g^y - \gamma g^k = (1-\gamma) g^y = (1-\gamma)\phi \tag{39}$$

Then we can establish following proposition.

Proposition 2

$$\frac{g^{TFP}}{g^y} \left(= \frac{g^{TFP}}{\phi} \right) = (1-\gamma).$$

This proposition tells us that, variety-augmenting technological progress and the ensuing income growth may not be fully captured by TFP growth. Particularly in case where γ is large, total factor productivity (TFP) growth can capture only a small portion of the variety-augmenting technical progress (ϕ) or income growth (g^y). With large γ, the contribution of TFP growth to income growth $\left(\frac{g^{TFP}}{g^y} \right)$ can be low. The reason is clear. Variety-augmenting technical progress is accompanied by and therefore mostly captured by the increase in capital. The growth in capital, in turn, is accompanied by the increase in the value of capital to the extent in which it is dictated by the capital income share parameter. The higher income share parameter an economy has, the higher fraction of income is distributed to the rental of capital and hence the value of capital. In addition, we focus on an economy where there is no change in the efficiency of producing existing goods, that is, $A_t(j) = A$, so that the growth is largely driven by the continuous introduction of new goods rather than the technology progress of existing goods.

Note that an economy with a large γ may have a moderate TFP growth (g^{TFP}), as far as it is compensated by a faster variety expansion. This can be easily seen from Eq. (39). In this case, however, the contribution of TFP growth $\left(\frac{g^{TFP}}{g^{y}}\right)$ will be very low, regardless of the rate of variety expansion.[25]

We can also calculate aggregate investment as a fraction of national output. Using Eq. (25), the investment ratio is calculated as

$$\frac{I_{t+1}}{Y_t} = \gamma\beta + \phi\gamma\beta \tag{40}$$

The first term in the right side represents the contribution of investment in old good specific capital, and the second term the contribution of new-good-specific capital. This tells us that an economy with more rapid expansion of variety of goods (or higher ϕ) can induce higher investment-output ratio than economies with a lower ϕ.

V.2 East Asian Growth

The predictions of the model are consistent with the experience of East Asian countries, in particular, a rapid introduction of new goods, a high investment ratio, and an impressive GNP growth sustained for four decades. The model suggests that the stylized features of the East Asian growth can happen in countries whose main engine of growth is a rapid increase in the number of goods.

With a more rapid expansion of variety of goods (initiated by rapid introduction of new goods), people accumulate more aggregate capital without suffering a declining rate of return on capital, which leads to a continuation of high investment ratio and income growth rate. So rapid introduction of new goods may have been a key factor behind the rapid accumulation of both human and physical capital and income growth of the countries.

In addition, the model reconciles the two seemingly-inconsistent observations for East Asian countries: the rapid introduction of new goods, and relatively small contribution of TFP growth. The model suggests that an economy can grow fast even with a low total factor productivity growth when the countries'

[25] If we allow for A_t to exogenously increase over time, TFP growth can be raised by $\frac{A_{t+1}}{A_t} - 1$. In this case, as long as the change of A_t is small compared to ϕ, TFP growth will remain low. In addition, if the increase in A_t requires a new capital stock as the increase in new varieties does, the TFP growth rate will be even smaller. See Barro (1998) for a discussion of TFP growth in endogenous growth models.

growth is based on a rapid introduction of new goods rather than a rapid exogenous progress in technology of producing existing goods. Hence, Young (1995)'s and Kim and Lau (1994)'s results of low contribution of TFP growth in East Asia can be interpreted as indicating that these countries have experienced a rapid variety-augmenting technology progress which was accompanied by continuous accumulation of human and physical capital. Note that γ represents the income share of broad capital including both physical and human capital. Hence, it is most likely that, when γ is within a range of 0.8 as in Young (1995), the contribution of TFP growth rate on economic growth $\left(\frac{g^{TFP}}{g^{y}}\right)$ will not be very large as in the East Asian NIEs.[26]

Further, if it is the case for East Asia, we may consider that the size of TFP growth is not an important issue. Regardless of the relative contribution of TFP growth, fast growing economies may enjoy faster variety-augmenting technological progress and higher growth rates of consumption and utility than other countries over a long-run period. In addition, given concave utility function, progress in variety-augmenting technology can be more effective in raising utility than quality-augmenting progress of existing goods.

Ⅵ. CONCLUSION

This paper presents a growth model where the main engine of growth is vareity expansion, which is initiated by the introduction of new goods. In the model, the variety expansion allows for a sustainable growth despite diminishing returns in capital in each product line. As more goods are newly introduced, more capital is newly needed. In this way the introduction of new goods allows capital accumulation and output growth to persist. Within the model, we also show that a rapid introduction of new goods can induce high investment ratio and fast income growth, despite low TFP growth. These predictions are considered to be well consistent with the East Asian growth experiences.

The current model has several interesting extensions. First, we could endogenize the probability of having a technology of producing new goods. This paper assumes that technological changes of introducing new goods occur exogenously. We could instead allow for the probability of having a technological change to be influenced substantially by the agents' R & D efforts to invent new goods. Although this extension will not alter the main results of this paper, the extended model can be applied to a broader set of problems. Second, some rigorous empirical analyses would be worthwhile which explore whether the East Asian growth is consistent with the model in this paper. In particular, it would

[26] The level of TFP growth rate is determined by relative magnitudes of two parameters, γ and ϕ, as indicated by Eq. (39). If an economy undergoes relatively stronger variety expansion (faster ϕ) compared to γ, it may have a moderate TFP growth (g^{TFP}) as in case of Hong Kong and Taiwan.

shed a new light on the mechanics of the East Asian growth if some cross-country data on the key variables of the model (e.g., the frequency of introducing new goods, and TFP growth of old and new industries) are well documented. Third, the model suggests that the more important issue in the East Asian fast growth would be to identify mechanisms with which these economies were able to continue the introduction of new goods without interruption. Government industrial and trade policy may play a role in stimulating the variety-augmenting technology progress and output growth. We investigate this issue in a companion paper.

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