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Analysis of Korea's Long-Term Growth Process and Lessons for Sustainable Development Policy

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This paper analyzes Korea's growth process, not only rapid but also sustained for six decades at 6% per year. The sources of such growth were balanced among labor market demographic factors, capital investment, human capital accumulation, and productivity growth. However, the main engine of growth evolved sequentially, e.g., labor and human capital factors in the 1960s, capital deepening in the 1970s, and then productivity growth for the following periods. We found that major sources of the six-decade sustained growth were productivity growth and human capital accumulation rather than the expansion of labor force or capital investment. Counterfactual analysis of neoclassical growth model reveals that the accelerated productivity growth after the fast capital deepening was the key to Korea's long-term growth, avoiding the middle-income trap. Appropriate calibration of the neoclassical growth model allowing time-varying transitional growth parameters explains Korea's growth experience well and provides useful lessons for sustainable development policy.

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I. Introduction

A casual observer of the Republic of Korea's remarkable development experience, which Lucas (1993) indeed called a "miracle," is often impressed by its rapid and compressed growth experience but often overlooks three important features of

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Korea's development process:[1] (i) how much adverse Korea's initial conditions were; (ii) the sustainability, not just the speed, of growth which has continued for about 60 years, overcoming various kinds of adverse initial conditions; (iii) productivity growth, not capital deepening, is behind such sustainable development. In fact, this is exactly why Korea's development experience is valuable for other developing countries.

The list of Korea's adverse initial conditions includes almost all sorts of barriers to development such as colonial experience, civil war, corruption, lack of physical and human resources, political instability, which are critical hurdles to development for most developing countries. Korea was truly a devastated nation when it took off toward the miraculous growth, being unaware of what would be coming, but could maintain the annual average growth rate of real GDP per capita at 6% for almost six decades.

Not all developing countries could achieve such sustainable and rapid growth after the Second World War, and Korea's growth experience can be a useful benchmark case for them. However, Korea's development experience per se would be of little help for the current developing countries because global environments have changed and each developing country faces different kinds of domestic socioeconomic and historical conditions, hence different challenges and development goals. Only by understanding the underlying mechanisms of Korean economic growth, Korea's successful development experience would be useful. This paper attempts to contribute to such understanding by performing two kinds of quantitative analysis. First, we decompose the sources of Korea's real GDP per capita growth via an extensive growth accounting analysis for the long-term period of 1960-2014, not only for the entire period but also for each decade, using internationally comparable data. This analysis will provide the understanding of the Korea's long-run growth process from Korea's take-off period to the recent low-growth period, which is first done in the literature of empirical studies on Korea's economic growth. It is worth mentioning that this kind of analysis for the long-term growth can be extended to other countries because the data we use are internationally comparable.

Second, using the findings from the first decomposition analysis as building blocks, we calibrate the neoclassical growth model to Korean economy and construct various kinds of counterfactuals to sort out the quantitative importance between transitional growth and long-term growth. This calibration analysis also contributes to evaluate the validity of the use of the neoclassical growth model as a growth policy prescription tool for the policy makers of developing countries, which is the World Bank's recent initiative of the Long-Term Growth Model (LTGM)

[1] Hereafter, we will simply refer "Korea" for the Republic of Korea.

project.[2] The LTGM project aims to help the policy makers of developing countries to design the national macroeconomic development policies from the perspective of the neoclassical growth model. By predicting the future growth paths from the desired changes of investment and/or labor market policies such as promotion of labor force participation or investment, policy makers can better envision and quantify their development goals. This kind of quantitative policy design would be a great help in articulating their policy goals and also in materializing the actual changes. Furthermore, an explicit use of a structural growth model in doing this kind of quantitative exercises is clearly beneficial. At the same time, however, calibration of the structural model is always a challenge, particularly for prediction purposes in response to policy changes. Therefore, it would be useful to see if such exercise can in fact be applied to a previous development experience for a country which already achieved the development goals that the current developing countries are aiming for now. In this sense, the results of the application of the LTGM to Korea's development experience would deliver useful messages to other developing countries. We will discuss about the appropriate calibration strategy for this purpose.

This paper consists of the following contents. We first describe the canonical neoclassical growth model in Section II. This model will be applied to Korea's economic growth for the 1960-2014 period to identify the underlying sources of Korea's GDP per capita growth in Section III by growth accounting analysis. Based on this analysis, we calibrate the model to Korea's economic growth in two perspectives in Section IV. First, we use the model as a prediction tool for policy prescription in terms of predicting Korea's growth process, comparing the fitting performance across different calibration methods: conventional method of assuming all key growth parameters at constant values versus a method of allowing time-varying transitional growth parameters. Second, we evaluate the model as a descriptive tool to identify the influences of the transitional and long-term growth policies for Korea's long-term growth experience via various counterfactual analysis. Both types of calibration exercises illuminate the important nature of Korea's long-run growth and also the validity of the use of the LTGM for developing countries. Section V concludes.

II. Neoclassical Growth Model as an Accounting Frame-work

We consider a standard neoclassical growth model based on the aggregate

[2] The LTGM is an Excel-based tool that allows users to simulate future long-term growth for most of the world's developing and emerging economies, building on the neoclassical growth model. See the earlier work by Hevia and Loayza (2012) and Pennings (2017) for the recent description of its usage.

production function, which was first proposed by Solow (1956) postulating the relationship between inputs of capital K_t and effective unit of labor $\tilde{L}_t$ and output Y_t at aggregate levels. We consider the Cobb-Douglas form for the specification of the aggregate production function such that

$$Y_t = K_t^{1-\beta}(\tilde{L}_t)^{\beta}, \tag{1}$$

where the parameter β corresponds to the labor share in national income account. The effective unit of labor $\tilde{L}_t$ is further decomposed into the quantity of labor L_t, the human capital per worker h_t, and the labor-augmenting technology level A_t such that

$$\tilde{L}_t = A_t h_t L_t,$$

hence the aggregate production function is specified as

$$Y_t = K_t^{1-\beta}(A_t h_t L_t)^{\beta}, \tag{2}$$

which satisfies the canonical properties of the aggregate production function of the neoclassical growth model, i.e., (i) monotonicity, (ii) diminishing returns and (iii) constant returns to scale. In terms of per worker term, this can be represented by

$$y_t = A_t^{\beta} k_t^{1-\beta} h_t^{\beta}, \tag{3}$$

where $y_t = Y_t / L_t$ and $k_t = K_t / L_t$.

Capital is accumulated according to the standard law of motion

$$K_{t+1} = I_t + (1-\delta)K_t, \tag{4}$$

where I_t denotes the capital investment and δ the depreciation rate of existing capital stock. We follow Solow's convenience assumption that the investment is determined by the exogenous investment rate γ such that $I_t = \gamma Y_t$.

Although already being well known, it is worth stating the key properties of the equilibrium dynamics for this kind of neoclassical growth model, because we use a growth accounting formula which is consistent with these properties. First, the diminishing returns property of the neoclassical growth model stabilizes the equilibrium growth dynamics, i.e., equilibrium growth path is stable to exogenous shocks unlike the knife-edge property of the Harrod-Domar type of growth models. Second, in relation to this property, there are two kinds of growth, transitional growth and steady-state growth. The steady-state growth is the growth that is maintained in the long run, i.e., when the state of the economy grows at a constant equilibrium rate. The transitional growth is the one which is manifested when the state variable is deviated from the steady state. Solow's (1956) fundamental contribution is that he articulated the following two propositions: (i) the steady-state growth is determined only by the productivity growth, i.e., the growth of the labor-augmenting technology A_t, (ii) the transitional growth driven by the pure capital investment effect is governed by the capital-output ratio K_t / Y_t. For an economy in the transitional growth path, the capital-output ratio increases when it is smaller than the steady-state value, while it decreases vice versa. That is, the capital-output ratio is an important barometer whether the economy is in steady state or in transition path. Note that capital stock can increase even in steady state driven by the productivity growth, although there is no new investment. This kind of capital accumulation does not capture investment effects but productivity growth effects. In contrast, the capital-output ratio is constant in steady state whether the productivity grows or not. These arguments suggest that genuine capital accumulation effect from investment per se, which we will call "capital deepening" effect, is captured by the capital-output ratio, not by the capital-labor ratio.

Another feature of the aggregate production function in (2) is that the "productivity" is specified in terms of the labor-augmenting technology rather than capital-augmenting technology or factor-neutral technology. In fact, this particular specification is adopted in all neoclassical growth models, not just for the Cobb-Douglas form. For the Cobb-Douglas form of production function, the three kinds of specification of productivity, in fact, can be relabeled into the so-called total factor productivity (TFP). However, our particular specification of technology is chosen in most of the growth literature because the stability of the growth equilibrium is achieved only when the productivity is specified in terms of the labor-augmenting technology, which is shown by Uzawa (1961). This critical proposition for the neoclassical growth model seems to be rarely acknowledged these days.

Based on the above arguments about the properties of the neoclassical growth model, we specify our aggregate production function in per worker term such that

$$y_t = A_t h_t (K_t / Y_t)^{\frac{1-\beta}{\beta}}, \tag{5}$$

which is another expression of the output per worker. From this specification, we obtain the growth accounting formula that we will use:

$$\hat{y}_t = \hat{A}_t + \hat{h}_t + \left(\frac{1-\beta}{\beta}\right)\widehat{\left(\frac{K}{Y}\right)}_t, \tag{6}$$

where the "hat" notation denotes the growth rate of the corresponding variable, e.g., $\hat{y}_t \equiv \frac{dy_t/dt}{y_t}$. This approach of growth accounting for the neoclassical growth model with augmenting human capital was first adopted by Mankiw, Romer and Weil (1992).[3] Klenow and Rodriguez-Clare (1997) and Jones (2002) also use this formula of growth accounting. Since these influential works on growth empirics, this specification of growth accounting has become standard.

Such articulation of the consistency between theory and empirics is important for this paper, because the distinction between steady-state growth and transitional growth matters in the counterfactual analysis via comparing various types of calibration of neoclassical growth model to Korea's growth experience, which we will perform after the growth accounting analysis. The formula in (6) decomposes the growth of output per worker into differentiated sources, i.e., the steady-state growth (represented by $\hat{A}_t$) and the transitional growth (represented by $(\frac{1-\beta}{\beta})(\frac{\hat{K}}{Y})_t$), consistently with the neoclassical growth theory. Whether to consider the human capital effect as the steady-state growth or the transitional growth depends on how to specify the human capital accumulation dynamics. Mankiw, Romer, and Weil (1992) specifies the human capital dynamics subject to diminishing returns and consider its effect as transitional growth. In earlier work, Lucas (1988) also incorporates human capital into the neoclassical growth model and shows that steady-state growth is possible through the human capital due to its spillover effect at aggregate level, despite the presence of the bounded learning at individual level. Given this possibility, we consider the human capital accumulation, $\hat{h}_t$ in (6), as a source of steady-state growth, with caution.

The conventional growth accounting formula that decomposes growth mechanically into factor accumulation effects and the so-called the total factor productivity (TFP), or the Solow residual, is given by

$$\hat{y}_t = \widehat{TFP}_t + \beta \hat{h}_t + (1-\beta)\hat{k}_t , \tag{7}$$

where the conventional total factor productivity (TFP) variable TFP_t is measured as

$$TFP_t = \frac{Y_t}{K_t^{1-\beta}(h_t L_t)^{\beta}} = A_t^{\beta} \tag{8}$$

so that

$$\widehat{TFP}_t = \beta \hat{A}_t . \tag{9}$$

[3] David (1977) is the early version of this approach without human capital.

This shows that the conventional TFP growth is a scaled-down version of our productivity growth measure by the factor of labor share. The magnitude of the human capital growth effect from the conventional growth accounting is smaller than our human capital growth effect also by the factor of labor share. In consequence, the magnitude of the capital accumulation effect for growth measured by the capital-labor ratio (as in the conventional way) is always higher than our measure of capital deepening effect for growth. This is not surprising because the capital accumulation effect in the conventional growth accounting formula includes both investment-driven effect and the productivity-induced effect, as we argued above. That is, the capital accumulation effect measured by the growth in capital-labor ratio as in the conventional growth accounting always overestimates the genuine effect of capital investment. This overestimation of capital accumulation effect is avoided in our growth accounting formula in (6).

The typical measure of the level of development or national welfare is the GDP per capita $y_{P,t} \equiv Y_t / N_t$ (where N_t is the total population size) rather than the GDP per worker $y_t \equiv Y_t / L_t$ above. GDP per capita differs from GDP per worker by the two demographic compositions of the labor market, (i) the labor force participation rate $S_{E,,t} \equiv L_t / N_{L,t}$ and (ii) the working-age population share $S_{W,t} \equiv N_{L,t} / N_t$, where $N_{L,t}$ is the working-age population (age group of 15-64) size, and L_t is the labor force size[4] such that

$$y_{P,t} = S_{W,t} S_{E,,t} y_t , \tag{10}$$

and in growth terms

$$\hat{y}_{P,t} = \hat{S}_{W,t} + \hat{S}_{E,,t} + \hat{y}_t .$$

Our empirical target is to understand how this national welfare or development level changes over time. Park and Shin (2011) also considers this kind of decomposition incorporating demographic aspects for growth, mainly focusing on changes in working-age population share.

Combining the output per worker growth accounting in (6) with this GDP per capita growth decomposition, we have our final growth accounting formula

[4] We use labor force data from WDI for L_t to maintain the consistency with the data use protocol of the LTGM project so that there are possible differences in labor force participation rate between the national sources and the WDI. Furthermore, using labor force instead of employment data may generate the different growth rate of $\hat{S}_{W,t}$. However, using the national source data, we find that labor force participation rate and employment rate tightly co-move with each other and the growth rates of $\hat{S}_{W,t}$ between the two measures differ only by 0.1% for the sample period.

$$\hat{y}_{P,t} = \hat{S}_{W,t} + \hat{S}_{E,,t} + \hat{A}_t + \hat{h}_t + \left(\frac{1-\beta}{\beta}\right)\widehat{\left(\frac{K}{Y}\right)}_t . \tag{11}$$

III. Analysis of Korea's Economic Growth

3.1. Data

The equation (11) is our framework of accounting for Korea's economic growth and also in assessing the validity of the calibration of neoclassical growth model to Korea's growth experience. The latter analysis can deliver lessons for the policy makers of other developing countries who would like to apply the neoclassical growth model in designing growth policies. To measure this equation, we use the following data series for our sample period 1960-2014, (their sources are in brackets): (1) total population size [World Development Indicators (WDI)] for N_t, (2) working-age population share [WDI] for $S_{W,t}$, (3) labor force participation rate [WDI] for $S_{E,,t}$, (4) real GDP at constant 2011 national prices (in 2011 million US$) ["rgdpna" in Penn World Table version 9.0 (PWT 9.0)] for Y_t, (5) capital stock at constant 2011 national prices (in 2011 million US$) ["rkna" in PWT 9.0] for K_t, (6) human capital per worker ["hc" in PWT 9.0] for h_t, (7) labor force size [WDI] for L_t, (8) labor share ["labsh" in PWT 9.0] for β, (9) capital depreciation rate ["delta" in PWT 9.0] for δ, (10) labor-augmenting technology level [calculated from equation (2)], and (11) investment [calculated using investment rate data "csh_i" from PWT 9.0]. The value of the average labor share which we calibrate for the parameter β is 0.602. The value of the average depreciation rate which we calibrate for the parameter δ is 0.053.[5]

Our use of the data has two significant features. First, this is the first paper that performs the growth accounting together with counterfactual calibration analysis by combining the internationally available data sources such as the Penn World Table (PWT) 9.0 and the World Development Indicators (WDI) rather than relying on country-specific national income statistics. This became possible because there were important improvements in internationally comparable measurement of output, production factors, and factor shares in the PWT 9.0, which was released recently in 2016. Second, this paper is the very first attempt to quantitatively characterize the long-run process of Korea's growth from the take-off period to the recent new normal era of growth slow down (1960-2014 period) so that we can assess the

[5] Original data source of the WDI labor variables such as working-age population, labor force participation rate is the International Labor Organization (ILO) Statistics. The labor share and the capital depreciation rate variables are time-varying in PWT 9.0 and we take the time-series averages during our sample period 1960-2014.

evolution of Korea's growth process from the neoclassical growth perspective. Obviously, the simple neoclassical growth perspective won't be able to fully capture the complex nature of Korea's growth process. At the same time, however, there is no doubt that the accounting framework of the neoclassical growth models (which is perhaps the most important strength of this class of growth models) provides us with the most critical ground work for understanding the nature of growth process. The use of the internationally comparable long-run data is first done in assessing Korea's growth process by this paper. This contributes not only to understanding Korea's growth process, but also to providing a benchmark reference study for other developing countries in designing their growth policies because the journey of Korea's economic development started from a similar starting point.

3.2. Accounting Analysis of Korea's Long-run Growth Process

Applying our accounting framework in equation (11) to the above data, we decompose Korea's growth of GDP per capita for the 1960-2014 period by constructing counterfactual GDP per capita measures as follows. Combining equations (5) and (10), we express the GDP per capita such that

$$y_{P,t} = S_{W,t} S_{E,,t} A_t (K_t / Y_t)^{\frac{1-\beta}{\beta}} h_t \,. \tag{12}$$

In order to isolate the contribution of productivity growth to GDP per capita growth, we fix the values capital-output ratio, human capital per worker, working-age population share and labor force participation rate at the 1960 values and vary only the labor-augmenting technology level as in the data. That is, the counterfactual GDP per capita measure due to the productivity change is

$$y_{P,t}^{A} = S_{W,1960} S_{E,,1960} A_t (K_{1960} / Y_{1960})^{\frac{1-\beta}{\beta}} h_{1960}$$

and the growth rate of this counterfactual measure is

$$\hat{y}_{P,t}^{A} = \hat{A}_t \,.$$

We can similarly construct counterfactual measures of GDP per capita due to the changes of other components. Figure 1 plots those counterfactual GDP per capita measures for each of the five components of productivity (labeled as "A"), human capital per worker (labeled as "HC"), capital deepening (labeled as "K/Y"), working-age population share (labeled as "WAP"), and labor force participation rate (labeled as "LFP"). Table 1 summarizes the growth rates of the actual and the above counterfactual measures of GDP per capita for the entire period as well as for each of the sub-period decades (1960s, 1970s, 1980s, 1990s and 2000s) and the remaining 2010-2014 period.

[Table 1] Decomposition of Sources of Korea's Growth of GDP per Capita (%)

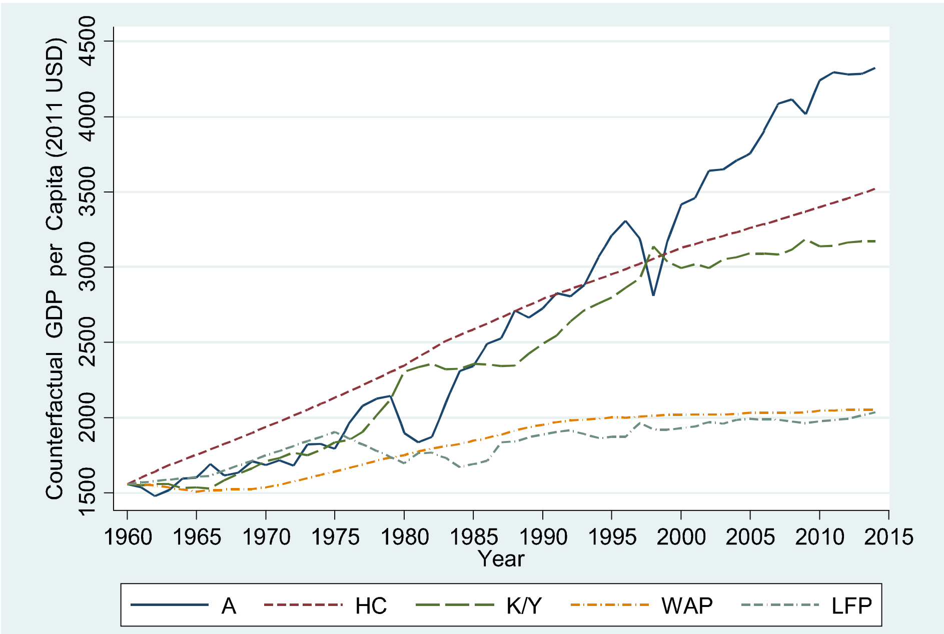
Period	Total	WAP	LFP	A	HC	K/Y	TFP
1960-2014	5.9	0.5	0.5	**1.9**	1.5	1.3	1.1
1960-1970	5.0	-0.1	1.2	0.8	**2.2**	1.0	0.5
1970-1980	7.4	1.3	-0.3	1.2	1.9	3.0	0.7
1980-1990	8.6	1.1	1.1	**3.7**	1.7	0.8	2.2
1990-2000	6.0	0.3	0.2	**2.3**	1.2	1.9	1.4
2000-2010	3.9	0.1	0.2	**2.2**	0.8	0.5	1.3
2010-2014	2.5	0.1	0.8	0.5	0.9	0.3	0.3

Notes: (1) Each column represents the contribution of each variable to the annual average growth rate of GDP per capita.

(2) "Total" Total growth of real GDP per capita, "WAP" Contribution of changes of working-age population share, "LFP" Contribution of changes of labor force participation rate, "A" Contribution of productivity growth, "HC" Contribution of human capital accumulation, "K/Y" Contribution of capital deepening, "TFP" Total factor productivity growth (which is equal to the labor share times column "A".

Figure 1 and Table 1 reveal interesting features about Korea's economic growth for the last 55 years, which are not well recognized in the literature. First, it turns out that the largest contributing component to Korea's real GDP per capita growth during the 1960-2014 period is the productivity growth rather than each of the factor growth. The contribution of the productivity growth $(\hat{A}_t)$ is 1.9% each year on average. The contribution of the human capital growth $(\hat{h}_t)$ is 1.5% each year on average. The contribution of the capital deepening $((\frac{1-\beta}{\beta})(\frac{\hat{K}}{Y})_t)$ is 1.3% each year on average. The contributions from the labor market demographic changes are 0.5% from the increase in working-age population share $(\hat{S}_{W,t})$ and also 0.5% from the increase in labor force participation rate $(\hat{S}_{E,,t})$ so that the combined contribution from the labor market demographic changes is 1%. This feature of productivity-driven growth of Korea may come at surprise, because the typical image for Korean economic growth for both external observers and internal policy makers is investment-driven. However, recalling Korea's sustained growth for about six decades, this should not be a surprise from the neoclassical growth theory's perspective, which states that long-run growth is possible only through productivity growth. Regarding the speed of growth, there were many developing countries which experienced growth as rapid as Korea during 1960s, 1970s or 1980s. Such examples include Mexico, Zambia, Gabon, and Mauritius. However, the rapid growth of those countries lasted only 10 to 20 years. The fundamental reason why Korea could maintain the 6% growth per year for about six decades unlike those countries seems to be no longer puzzling. Korea's growth experience provides an empirically valid prescription for the importance of productivity for sustainable development *à la* neoclassical growth models.

[Figure 1] Counterfactual Measures of GDP per Capita



Notes: (1) Each line represents the counterfactual path of GDP per capita from the isolated growth of each variable.
(2) "A" Productivity growth of labor-augmenting technology, "HC" Human capital growth, "K/Y" Capital deepening, "WAP" Changes of working-age population share, "LFP" Changes of labor force participation rate.

It is worth noticing that this ordering of contribution of growth components depends on our way of formulating growth accounting as in equation (6). Using the conventional growth accounting formula in equation (7), the TFP contribution is 1.1%, human capital contribution is 0.9%, and capital per worker contribution is 2.8% so that the contribution measures for both productivity and human capital decrease while the capital contribution measure increases, comparing to the results of our accounting method. However, as we argued in Section II, part of the 2.8% contribution of capital accumulation per worker is due to the productivity growth, hence the contribution of capital investment is overstated. Filtering such induced capital accumulation effect out, the contribution of the capital investment turns to 1.3%. Furthermore, as we argued again in Section II, the steady-state growth rate is determined by our productivity growth measure $\hat{A}_t$, not by the TFP growth. Bearing this in mind, however, we provide the conventional TFP growth measure in the last column of Table 1 for a reference.

Second interesting feature is that despite the above differences contribution ordering, the magnitudes of contribution are substantial for all components, ranging from 1% to 1.9%, none of which are negligible. That is, the sources of growth are *well balanced* among productivity, human capital, capital deepening and labor market demography during the long-run process of Korea's economic growth, without any of which the annual growth rate of 5.9% could not have been realized.

Table 1 provides the decade-specific growth accounting results as well. Comparing these results across decades, we find that the major contributing components have changed over time. In the initial development stage of the 1960's, human capital growth was the major driving force for Korea's growth, 2.2% each year on average. Combined labor market demographic effects contribute to increasing GDP per capita by 1.1% each year in 1960s, which is the second largest contributing component in 1960s. Interpreting the human capital as quality of labor and labor market demographic changes as the expansion of the extensive margins of labor quantity, combined labor-related growth contributed to growth by 3.3% each year in the 1960s. That is, Korea's growth in the 1960s period is driven by labor.

In the 1970's, however, capital deepening was the main engine of growth, 3% each year on average. The capital deepening effect dropped remarkably to 0.8% in the 1980s, surging back to 1.9% in the 1990s, and then diminished to 0.5% for the 2000s period and further to 0.3% for the 2010-2014 period. The 1970s was the period when Korean economy made a dramatic transformation into a modern economy by the export-oriented industrial policies and infrastructure building, which perhaps created the typical image of Korea's growth. This laid a solid physical foundation for the growth eras to follow.

However, for the remaining three decades of the 1980s, 1990s and 2000s, productivity growth was the main engine of Korea's growth. The productivity growth alone contributed to increasing the GDP per capita by 3.7% per year on average in the 1980s, 2.3% in the 1990s, and 2.2% in the 2000s. The contribution shares of the productivity growth out of the total growth of the GDP per capita were 43%, 38% and 56% during the 1980s, 1990s, and 2000s, respectively.

Summing up the above results, we find that Korea's growth process shows a sequential pattern in terms of the main engine of growth, first labor-human-capital-driven, second capital-driven, and then productivity-driven. In particular, the productivity-driven growth lasted for three decades, followed by the significant accumulation of human and physical capital. This sequential pattern is an important feature of Korea's growth, which was not acknowledged well in the literature. Furthermore, this finding delivers an important lesson for growth policy design. The sequential feature of Korea's growth experience suggests that choosing a right sequence of growth policies may matter for making the growth rapid and sustainable: initial growth policy focusing on promotion of labor participation and human capital investment (for creating the productive manpower of the economy), then focusing on promotion of capital investment (for laying physical foundation of the economy), and then shifting focus to productivity enhancing growth policies (for sustaining growth). This may explain why Korea did not fall into the so-called middle income trap.[6]

Table 1 delivers another noticeable pattern of Korea's recent growth. From the neoclassical growth theory perspective, the capital deepening effect, i.e., the change of capital-output ratio indicates how far or near the economy is to the steady state, because capital-output ratio stays constant in steady state. The changing pattern of the capital deepening effects over time from Table 1 seems to suggest that Korean economy is approaching to steady state quite quickly after 2010, when the capital-output ratio has changed little, indicating that Korean economy may be near the steady state. During this recent period (2010-2014), the productivity growth dropped to 0.5% from the 2.2% of the 2000s period. This may reflects the 2008-2009 global financial shock or perhaps the manifestation of the accumulated structural problems blocking productivity growth. This paper is silent about the causes of this sudden drop of productivity growth. However, it is worth noticing that such sudden drop of productivity growth happened when we observe a symptom showing that Korean economy is near the steady state (little change in capital-output ratio). Furthermore, for the 2010-2014 period, the largest contributing components to growth are labor related: human capital growth (0.9%) and the increase in labor force participation rate (0.8%). In particular, the increase in labor force participation rate is a big reversal of the trend. During the recent two decades of 1990-2010, the contribution of labor force participation has been only 0.2%. This contribution surged back to the pre-1990 level. In fact, the composition of contributing shares of growth components for the 2010-2014 period is a déjà vu of those of the 1960s period. All these symptoms are indeed concerning because they may be a presage of the starting of long-run stagnation. It may be too early to conclude that Korean economy indeed entered into a long-run low growth because the duration of this period is only four years. However, these features were never observed for the five-decade of growth experience of Korea before 2010 and Korea does need to pay attention to this change. At the same time, productivity growth is not predetermined and there still exist ample opportunities of promoting productivity growth for Korea. In this sense, Korean economy seems to be at a "slippery slope" for her next stage of development.

[6] See Eichengreen, Park and Shin (2012) for the recent discussion on the empirical evidence of middle-income trap.

IV. Calibration of Korea's Economic Growth

4.1. LTGM of the World Bank

We used a neoclassical growth model in accounting for Korea's economic growth in the previous section. Another way of using the same model is for policy makers to infer the necessary policies regarding the parameter values of the model to achieve pre-set growth goals for the future. This way of utilizing the neoclassical growth model is recently labeled as the "Long-Term Growth Model (LTGM)" approach by the World Bank, which was recently initiated for the purpose of helping the policy makers to design national growth policies. The model can be used as a simulation device for the future growth if we can make a reasonable conjecture about or target some key parameter values of the model that will govern in the future growth path.

In terms of contents of the model, the World Bank's basic LTGM is just the same as the neoclassical growth model in Section II. How to use such model for simulation or policy design purposes depends on the way the model is calibrated. This kind of calibration is not an easy exercise because we need to calibrate the model to fit the future that we do not observe at the moment of calibration. The analysis of Korea's economic growth in Section III can be utilized in inferring right ways of calibrating the neoclassical growth model in the following sense. Imagine a Korean policy maker who lived in the year 1970 and wanted to predict what would happen to GDP per capita growth after 1970. Suppose the only available data were the statistics of the variables of the neoclassical growth model for the 1960-1970 period. Then, we may ask what would be the best way for the policy maker to calibrate the underlying parameters of the model. We can answer this question because unlike the fictitious policy maker in 1970, we in fact know what actually happened after 1970 in Korea so that we can evaluate the calibration method by evaluating the prediction performance against the actual data. We can quantitatively compare the gaps between the model predictions and actual data ex post across different calibration methods.

We find that it is important to take the transitional growth parameters (such as investment rate and labor market demographic factors) as *time-varying* rather than taking as constant as is done in typical calibration exercises of neoclassical growth models. In contrast, the prediction gap is not large from assuming constant values for the long-run growth parameters (such as human capital growth or productivity growth rates). Related, we also find that the prediction performance of the conventional calibration method (assuming constant values for key parameters) depends on the stage of development. For example, the model with conventional calibration method works very well for Korea when prediction time is 1990, while it performs poorly from the start when prediction time is 1970 or 1980. This implies that the application of the conventional calibration of the neoclassical growth model should be done with more care, the farther the economy is from the steady state. For instance, during the initial stage of development after take-off, the target growth rate are not likely to be maintained by the policy of one-time promotion of investment rate, which is a frequent mistake made by the policy makers in developing countries. The regression to the growth rate prior to such one-time investment policy is the theoretical consequence of the force of diminishing returns of the neoclassical growth model. Indeed Korea's development experience empirically confirms this property. In other words, it is important to continue to promote investment in order to maintain or accelerate growth during the catchup period. However, after the economy enters into the mature stage of development (after 1990s in case of Korea), such effect dwindles. In the following subsection, we will fully characterize the hidden interactions among parameters of the model.

4.2. Objects of Calibration

We first need to determine the set of parameters to calibrate. The GDP per capita at period t is expressed as in equation (12)

$$y_{P,t} = S_{W,t} S_{E,,t} A_t (K_t / Y_t)^{\frac{1-\beta}{\beta}} h_t$$

and the gross growth rate of the GDP per capita between period t and $t+1$ is

$$\frac{y_{P,t+1}}{y_{P,t}} = \Lambda_{t+1}^{\beta} \left[\frac{\gamma_t \frac{Y_t}{K_t} + (1-\delta)}{1+\hat{N}_{t+1}} \right]^{1-\beta} \tag{13}$$

where

$$\Lambda_{t+1} = (1+\hat{S}_{W,t+1})(1+\hat{S}_{E,t+1})(1+\hat{A}_{t+1})(1+\hat{h}_{t+1}),$$

γ_t is the investment rate at period t, and $\hat{N}_{t+1}$, $\hat{S}_{W,t+1}$, $\hat{S}_{E,t+1}$, $\hat{A}_{t+1}$, and $\hat{h}_{t+1}$ are the growth rates of population, working-age population share, labor force participation rate, productivity, and human capital between periods t and $t+1$, respectively. The growth equation (13) clarifies two things. First, the growth rate of GDP per capita increases in investment rate γ_t, but this growth effect decreases in K_t / Y_t, i.e., the capital-output ratio of the base year. This decreasing effect of growth from investment captures the diminishing returns property of the neoclassical growth model. Second, it increases in growth rates of working-age population, labor force participation rate, productivity, and human capital but decreases in population growth rate.

Now in order to simulate the growth path using equation (13), we need to select the parameters (β, δ) and to calibrate the growth rates of $\hat{N}_{t+1}$, $\hat{S}_{W,t+1}$, $\hat{S}_{E,t+1}$, $\hat{A}_{t+1}$, and $\hat{h}_{t+1}$. When we substitute these growth rates with the actual data, we will get the precise growth rate. For the purpose of simulation, we should choose a way to calibrate the growth rates of these five growth variables at period $t+1$ as well as the time-invariant parameters β and δ from the observed data. Furthermore, to apply the growth equation (13) to the next period at period $t+2$, we need to calibrate γ_{t+1} also. Typical neoclassical growth models assume that $\hat{A}_{t+1}$, and $\hat{N}_{t+1}$ are constant for all periods, but they are silent about the changing rates of γ_{t+1}, $\hat{S}_{W,t+1}$, $\hat{S}_{E,t+1}$ and $\hat{h}_{t+1}$. For γ_{t+1}, $\hat{S}_{W,t+1}$ and $\hat{S}_{E,t+1}$, we cannot make the non-zero constant growth assumption because they are "share" variables which are upper-bounded. Thus, we need to choose a way to predict the path for γ_{t+1}, $S_{W,t+1}$ and $S_{E,t+1}$ during the targeted future period for the simulation purpose. Furthermore, these three variables are labeled as "time-varying policy parameters" which would change depending on demographics and policies.

For the human capital growth $\hat{h}_{t+1}$, the original Solow (1956) model is silent because it simply abstracts the human capital away. Mankiw, Romer and Weil (1992) augmented human capital to Solow (1956) model, assuming the diminishing returns property for the human capital, hence it is not a source of long-run growth. In contrast, Lucas (1988) augmented human capital to the same Solow (1956) model but postulated it as a source of long-run growth due to the linear dynamics and spillover effects of human capital at aggregate level. We are open to these two possible theoretical formulations and take the choice between the two formulation of human capital dynamics as an empirical question. Jeong (2017) shows the shape of the trend of the human capital per worker is rather close to linear one than to concave one, despite the incorporation of the diminishing returns of schooling in measuring human capital as in Hall and Jones (1999). Based on the above arguments, we categorize human capital growth as a similar kind of parameter to productivity growth at least for the sample period of this study, although the underlying dynamics of human capital would be different from productivity dynamics. However, the measurement of human capital only from years of schooling should be taken with caution.

4.3. Calibration 1: Status-quo Simulation Approach

To evaluate the neoclassical growth model as a simulation tool as the World Bank's LTGM project does, we would like to vary the calibration method and compare the patterns as well as the performance of the prediction of the model to seek the best way to choose the calibration objects, i.e., the future growth rates $(\hat{N}_{t+1}, \hat{A}_{t+1}, \hat{h}_{t+1})$ and the time-varying policy parameters regarding $(\gamma_{t+1}, S_{W,t+1},$

$S_{E,t+1}$), in order to simulate the growth path of GDP per capita. The labor share and the depreciation rate parameters will be fixed at the same values as in the decomposition analysis of the actual Korean economy in Section III.[7]

The first and the most straightforward way of calibration is to simply follow the canonical neoclassical growth model, where the productivity and population grow at constant rates, i.e., $\hat{A}_{t+1} = g_A, \hat{N}_{t+1} = g_N$ for all periods. We take similar constant growth rate assumption for the human capital as well such that $\hat{h}_{t+1} = g_h$ for all periods, based on the empirical observation above. The canonical neoclassical growth model also assumes that investment rate is constant such that $\gamma_{t+1} = \gamma_t = \gamma_0$. This assumption of "constant rates" in fact can be a reasonable one when the economy is near the steady state and the economy grows close to the balanced growth path, along which the growth rates are determined mainly by the fundamental parameters of technology and preferences. Consistent way of calibrating the labor market demographic factors with this "steady-state assumption" is to choose that $S_{W,t+1} = S_{W,t} = S_{W,0}$ and $S_{E,t+1} = S_{E,t} = S_{E,0}$ (so that $\hat{S}_{W,t+1} = 0$ and $\hat{S}_{E,t+1} = 0$) for all periods.

Suppose that the imaginary Korea's policy maker made this set of "steady-state assumptions" in 1970, and then applied the benchmark growth model to simulate the GDP per capita for the future period of 1971-2014. Suppose that the data available for this policy maker in 1970 are the 1960-1970 period data. Once deciding to take the "steady-state" approach, the best way to calibrate the constant growth rates of g_A, g_h, and g_N would be to form an *adaptive expectation* such that the constant growth rate parameters would be the annual average growth rates of the corresponding variables for the data-available period, i.e., the 1960-1970 period. In selecting the constant values for the investment rate, working-age population share, and labor force participation rate, we may want to take the average values for the past sample period to smooth out the shocks. However, if taking the averaging period too long, the average values would not represent the true values of the parameters for the simulation period. Thus, the average values for the initial five-year period prior to the starting date of simulation, for example, the 1966-1970 period values for the 1970 simulated prediction, are used to calibrate the investment rate, working-age population share, and labor force participation rate.

We can repeat the above simulation exercise by changing the prediction year from 1970 to 1980 (using the 1970-1980 data) or to 1990 (using the 1980-1990 data) using the same calibration method. Comparison of the three sets of prediction results would be informative because Korean economy has presumably evolved from a transition economy toward a steady-state economy for the 1960-2014 period. The calibrated parameter values for the three sets of simulated prediction exercises, labeled as "Pred_70", "Pred_80", and "Pred_90", respectively for the 1970, 1980,

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[7] To recall, $\beta = 0.602$ and $\delta = 0.053$.

and 1990 simulation, by the above steady-state calibration method are summarized in Table 2. For the purpose of referencing with other countries, in Table 2, we also indicate the average purchasing-power-parity adjusted real GDP per capita level for each period when the parameter values of γ_0, $S_{W,0}$ and $S_{E,0}$ are chosen.[8] For example, Korea's average PPP-adjusted real income level was $1,466 in 1960s when the investment rate was 0.27, working-age population share was 0.54 and the labor force participation rate was 0.56.

[Table 2] Calibrated Parameter Values from Status-quo Approach

Simulation	g_A	g_h	g_N	γ_0	$S_{W,0}$	$S_{E,0}$	PPP Real Income (2011 USD)
Pred_70	0.8%	2.2%	2.6%	0.27	0.54	0.56	1,466 (1960s)
Pred_80	1.2%	1.9%	1.7%	0.37	0.61	0.59	3,844 (1970s)
Pred_90	3.7%	1.7%	1.2%	0.35	0.68	0.61	7,688 (1980s)

Note: " g_A " Annual growth rate of productivity of labor-augmenting technology, " g_h " Annual growth rate of human capital per worker, " g_N " Annual growth rate of population, " γ_0 " Investment rate, " $S_{W,0}$ " Working-age population share, " $S_{E,0}$ " Labor force participation rate.

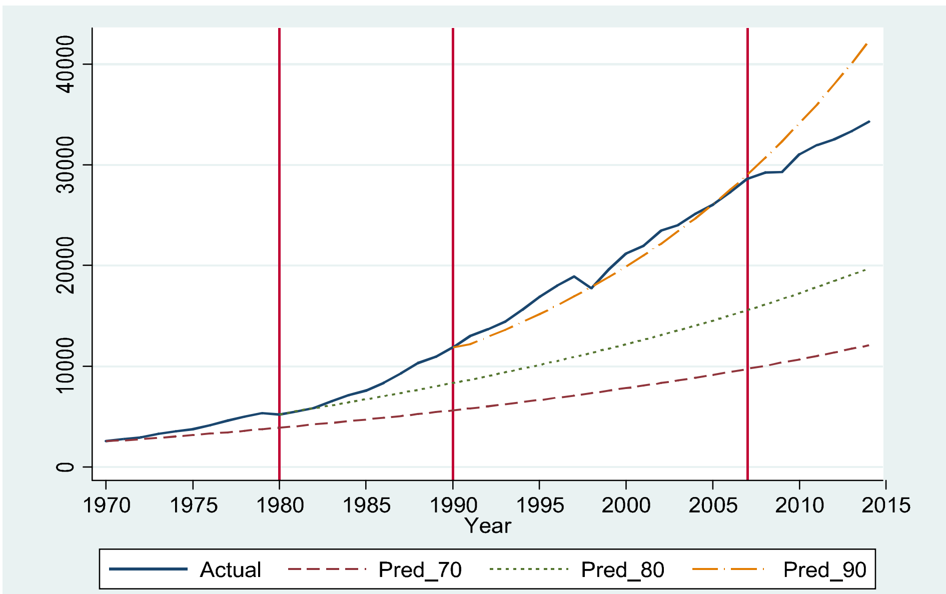
Figure 2 compares the predicted paths of GDP per capita of the three simulations (similarly labeled as in Table 2), overlaid with the actual path (labeled as "Actual"). This comparison illuminates important features of the LTGM as a simulated prediction device as follows.

First, notice that the "Pred_70" simulation under-predicts the GDP per capita as shown in Figure 2. It fits only the very beginning-of-period data, i.e., for the 1971-1973 period. The prediction diverges away below the actual one afterwards. This result is not a surprise because the investment rate, working-age population share, and labor force participation rate all increased during the 1960s, hence the 5-year average values underestimate the future values. Furthermore, the investment rate and the working-age population share further increased in the 1970s compared to the 1960s values. The investment rate got stabilized after the early 1980s, and the increase of the working-age population share also slowed down after the 1990s. The labor force participation rate continues to show an increasing trend except the substantial dip during the 1977-1986 period. Furthermore, Korea's population growth rate has fallen monotonically during the entire sample period from 3% in the 1960 to 0.4% in 2014. All these changes have increasing effects of GDP per capita, which are not captured by the current calibration method. The growth rate

[8] Note that this real income measure is obtained from the "rgdpe" in PWT 9.0 divided by the WDI population data, hence is different from our GDP per capita measure which is calculated from the "rgdpna" in PWT 9.0. In Table 2, we use the "rgdpe" measure to facilitate the cross-country comparison of development level.

of human capital decreased after the 1990s, but the magnitude of decrease is small, much smaller than the decreasing rate of capital deepening. The productivity growth rate has been more or less constant during the sample period. Thus, current calibration method is a reasonable one regarding productivity growth and human capital growth. In sum, the under-prediction of the Pred_70 using the steady-state cum status-quo approach calibration method is due to the postulation of constant rates of investment, working-age population, and labor force participation.

[Figure 2] Comparison of Predictions from Different Simulations



Notes: (1) Each line represents the actual or the predicted path of GDP per capita at different starting date of simulation.
(2) "Actual" Actual GDP per capita, "Pred_70" Predicted GDP per capita in the year 1970, "Pred_80" Predicted GDP per capita in the year 1980, "Pred_90"; Predicted GDP per capita in the year 1990.

Observing the "Pred_80" simulation, we get similar results, although the fitting performance improves over the "Pred_70" simulation. In contrast, the 1990 prediction, which uses the 1980s data, fits the data very closely during the 17-year period (1991-2007), and then the model over-predicts the GDP per capita after 2008 with increasing gap. The main reason behind the good fit for the 1991-2007 period is that there were no clear trends for the investment rate, despite its fluctuations, so that the capital-deepening effects are well captured by constant investment rate assumption during this period. The over-prediction of the "Pred_90" for the 2008-2014 period seems to be caused by various reasons: (i) the gradual slowdown of human capital accumulation, (ii) decreasing investment rate, particularly after 2005,

(iii) the stagnation of working-age population share after 2000, (iv) the sudden stagnation of productivity after 2010, which can be confirmed from Table 1.

Comparing the above patterns of predictions across Pred_70, Pred_80, and Pred_90, we learn that the prediction performance of the LTGM would be good when the economy grows in the stabilized environments, but the LTGM tends to under-predict when the parameters of investment rate, working-age population share, and labor force participation rate are actively changing. The prediction performance of the conventional calibration method (assuming constant values for key parameters) depends on the stage of development. The model with conventional calibration method works very well for Korea when Korean economy entered into the stable stage after 1990, while it performs poorly for the early catchup periods of 1970s and 1980s. This illustrates that the application of the conventional calibration of the neoclassical growth model should be done with more care, the farther the economy is from the steady state.

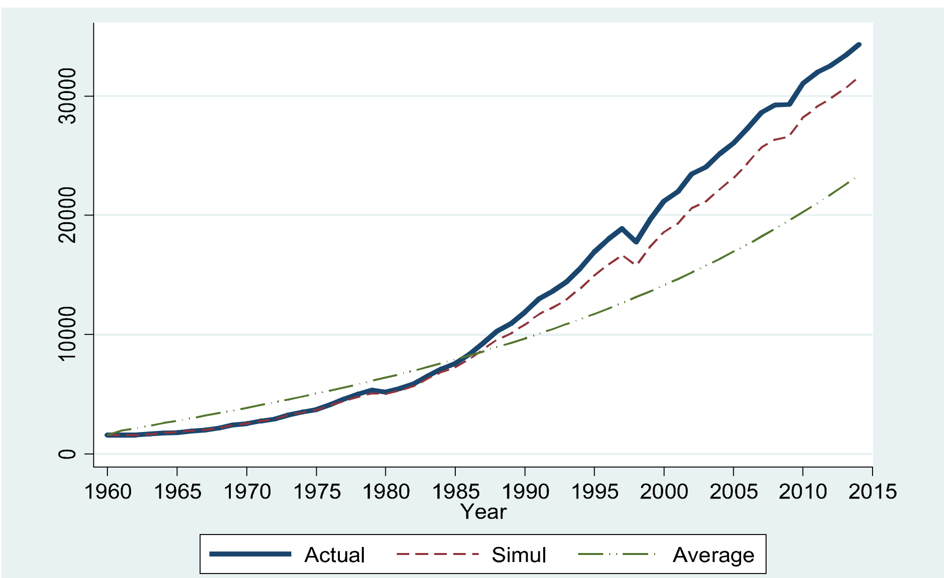
4.4. Calibration 2: Time-varying Parameter Embedded Simulation Approach

Another way of using the LTGM is to evaluate the expected changes of income growth in response to the different parameters of growth. For this exercise, we categorize the six parameters of calibration of the LTGM in the following manner. The rates of productivity growth and human capital growth are considered as the determinants of the steady-state growth. We call these two growth rates as "fundamental growth parameters." The changes of the rest of the variables are related to "transitional growth." The changes of working-age population share, labor force participation rate, and population growth rate affect the growth via the demographic changes in labor market, hence we call the growth rates of these variables as "demography parameters." The change of investment rate affects growth via the capital accumulation process and we call this an "investment parameter."

From this perspective, we can use the LTGM in order to evaluate the roles of different kinds of growth sources as follows. First, we simulate Korea's GDP per capita from the neoclassical growth model in Section II by calibrating the six parameters varying over time as in the data, and consider this as the benchmark simulation. We label this version of simulation as "Simul." Second, we simulate by fixing all six growth parameters by their time-invariant long-run averages, i.e., by the 1960-2014 period annual average growth rates of productivity, human capital, population, and by the 1960-2014 period average values of investment rate, working-age population rate, and labor force participation rate. We label this version of simulation as "Average," which will capture the long-run growth effects in the sense that this simulation does not allow the time-varying patterns of the growth parameters. For this "Average" simulation, the six parameters are set by $g_A = 1.9\%$, $g_h = 1.5\%$, $g_N = 1.3\%$, $S_{W,0} = 0.65$, $S_{E,0} = 0.61$, and $\gamma_0 = 0.32$.

Figure 3 compares these two sets of simulations with the actual data. The full simulation, "Simul", captures the growth path of the actual real GDP per capita very well. The gap between the actual data and the "Simul" is due to the differences in the capital accumulation between the measured capital stock in PWT 9.0 data ("rkna" variable) that reflects the heterogeneous composition of capital goods and the simulated capital stock which is constructed as in the law of motion equation (4) of the model which does not differentiate the different types of capital.[9] Thus, the gap between the "Actual" and the "Simul" represents the compositional changes of heterogeneous types of capital assets over time in the process of Korean economic growth. It is interesting to notice that there are virtually no gap until the mid-1980s and the gap started to emerge only after 1985 and gradually widened afterward. This implies that the compositional changes in aggregate capital seems to matter only after the mid-1980s.

[Figure 3] Comparison of Predictions from Fully Time-varying and Average Constant Simulations



Notes: (1) Each line represents the actual or the predicted path of GDP per capita using different calibration methods.

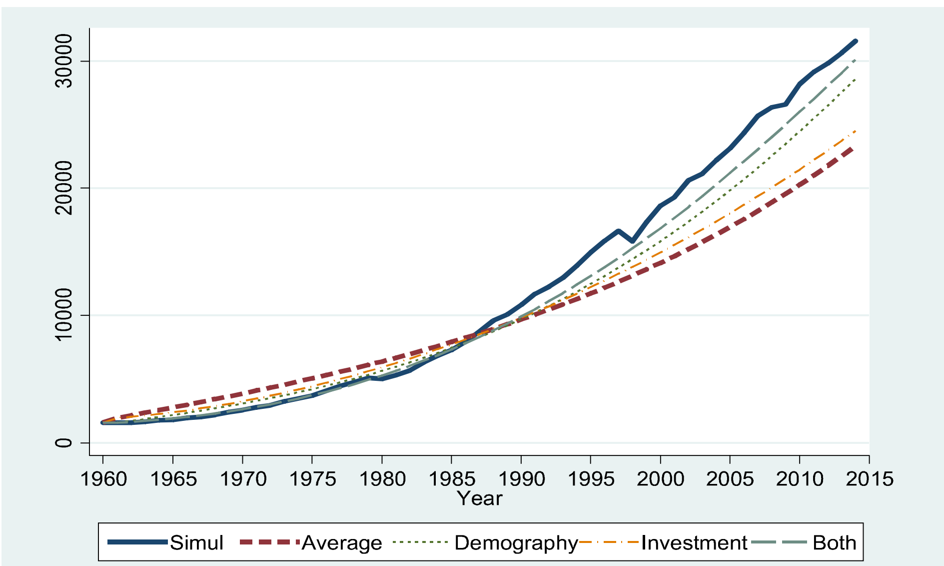
(2) "Actual" Actual GDP per capita, "Simul" Predicted GDP per capita calibrating at fully time-varying parameters, "Average" Predicted GDP per capita calibrating at constant parameters of average values during the sample period.

[9] See Feenstra, Inklaar, Timmer (2015) and User Guide of PWT 9.0 for more detailed discussion about the capital construction of the PWT 9.0 data.

The "Average" represents mainly the long-run average growth effect holding the labor market demography and investment rates fixed. Therefore, the difference between "Average" and "Simul" reflects the contribution of promotion of transitional growth policies such as changes in investment rate, working-age population, labor force participation, and population growth. This effect seems to be substantial so that promotion of transitional growth policies did matter for Korea's growth.

We can further decompose the time-varying transitional growth policy effects between the effects only from labor demography changes and the effects only from changes in investment rate.[10] The simulations labeled as "Demography" and "Investment" in Figure 4 represent such effects, respectively. "Both" captures the combined effect. It is interesting to notice that using the nonlinear trends of labor market demography and investment parameters, the model (simulation "Both") can

[Figure 4] Labor and Investment Policy Effects



Notes: (1) Each line represents the actual or the predicted path of GDP per capita using different calibration methods.

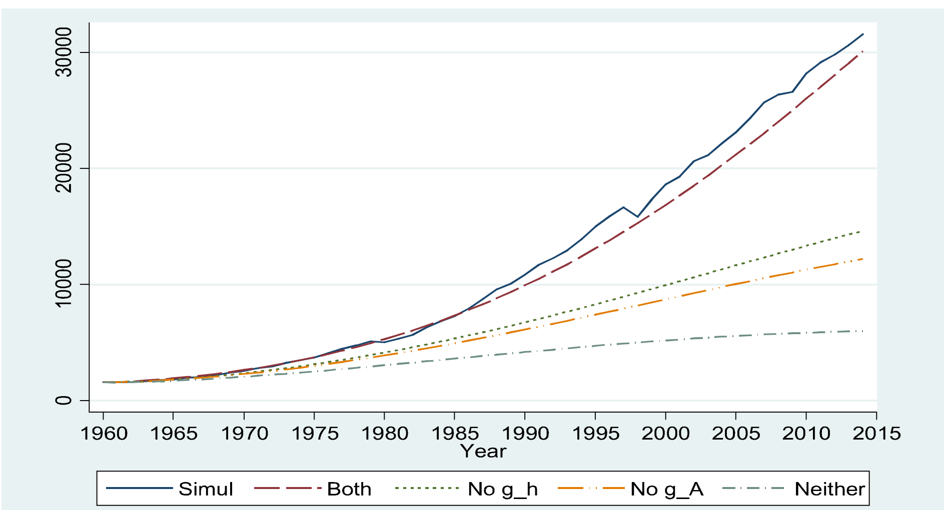
(2) "Simul" Predicted GDP per capita calibrating at fully time-varying parameters, "Average" Predicted GDP per capita calibrating at constant parameters of average values during the sample period, "Demography" Predicted GDP per capita allowing time-variation only for the labor market demography parameters, "Investment" Predicted GDP per capita allowing time-variation only for the investment rate parameter, "Both" Predicted GDP per capita allowing time-variation for both labor market demography and investment rate parameters.

[10] Here, we use the quartic-polynomial-fit trend for each time-varying variable rather than using the actual data.

fit the data very well, even though we fix the "fundamental growth parameters" of human capital growth rate and productivity growth rate. In this sense, the LTGM can be a promising tool to predict what would happen in response to the changes of labor market and investment policies and environments, with the appropriate selection of the long-run growth rates of productivity and human capital.

The good fit of the model simulation to Korean economic growth by allowing the time-varying labor market demography and investment parameters does not imply that the main engine of Korea's growth comes from the transitional growth sources. Such fitting performance is based on the productivity and human capital growth rates of 1.9% and 1.5% every year in the background. To evaluate the role of such fundamental growth parameters, we simulate the model at the time-varying labor market demography and investment parameters, but turning off the productivity growth, human capital growth, or both to zero. The simulated paths of the real GDP per capita of these simulations, are labeled as "No g_h," "No g_A," and "Neither," respectively, in Figure 5. This shows that Korea's growth performance would have been *unimpressive*, although the investment and labor market demographic factors had been actively promoted as actually happened in Korea, if they had been the only sources of growth.

[Figure 5] Long-run Growth Effects



Notes: (1) Each line represents the actual or the predicted path of GDP per capita using different calibration methods.

(2) "Simul" Predicted GDP per capita calibrating at fully time-varying parameters, "Both" Predicted GDP per capita calibrating at constant fundamental parameters of human capital and labor-augmenting productivity growth, "No g_h" Predicted GDP per capita with no human capital growth, "No g_A" Predicted GDP per capita with no labor-augmenting productivity growth, "Neither" Predicted GDP per capita with neither human capital nor labor-augmenting productivity growth.

In the year of 2014, Korea's real GDP per capita is $34,300 in 2011 USD using national prices and $35,103 using PPP adjusted prices according to the PWT 9 data. The Korea's PPP-adjusted real GDP per capita in 2014 is slightly lower than that of Japan ($35,358) and a little higher than that of Spain ($33,864) in the same year. In 1960, Korea's PPP-adjusted real GDP per capita was $1,175 which was lower than those of Kenya, Tanzania, Bangladesh and Haiti, while those of Japan and Spain were $5,351 and $5,741. Without human capital growth, Korea's 2014 real income level would have been $14,597 (close to level of Brazil in 2014). Without productivity growth, Korea's 2014 real income level would have been $12,178 (close to level of South Africa in 2014). With neither of productivity and human capital growth, Korea's 2014 real income level would have been $5,970 (close to level of Bolivia in 2014). The above comparison clearly illustrates that the main backbones of Korea's "miraculous growth," as is asserted by Lucas (1993), are the productivity growth and human capital accumulation, although the active promotion of labor market demography and investment played an non-negligible role as well. That is, Korea's growth experience shows that the most critical factors for successful and sustainable growth are the productivity and human capital growth, i.e., the fundamental sources of long-run growth rather than the sources of transitional growth, which confirms the key insights of the neoclassical growth theory.

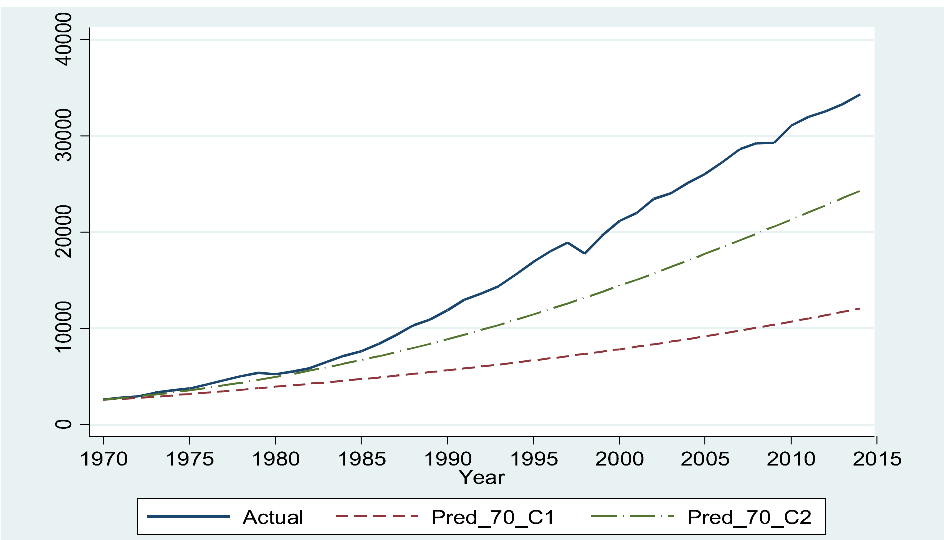
The above counterfactual analysis of varying growth sources quantitatively identifies the roles of transitional versus long-run growth. It suggests that the major sources of sustainable and fast growth for Korea were the productivity and human capital growth, although the time-varying promotion of investment and labor force participation also played significant roles as well. It is worth mentioning that the two types of growth (transitional and fundamental growth) are not independent from each other so that the above counterfactual analysis results do not sum up in an accounting way. In fact, this result is the key difference from the simple growth accounting results in Section III. For example, the difference in the simulated the GDP per capita in 2014 between the "Simul" and "Neither" in Figure 5 captures the whole effect of productivity and human capital growth. However, the simulated GDP per capita in 2014 from "Average" simulation in Figure 3 captures the growth from the constant rates of productivity and human capital growth at average values. The size of the former is larger than that of the latter. This happens because the magnitude of the diminishing returns to capital investment changes over the capital accumulation process, and it interacts with the fundamental growth parameters. During the initial stage of development when the capital stock is not abundant relative to output (i.e., capital-output ratio is low), the magnitude of diminishing return is not big, hence the size of the induced extra capital accumulation from productivity growth would not be large. Such interaction effect between capital and productivity becomes larger as the capital-output ratio increases. From the growth accounting analysis in Table 1, we discussed the sequential feature of Korea's growth such that productivity growth was accelerated after 1980 and became the major engine of Korea's growth. This is exactly the period when the speed of capital deepening started to slow down so that the rapid productivity growth (2.2% to 3.7% per year) during the 1980-2010 period played an important role of overcoming the diminishing returns to capital investment. This seems to be a critical reason behind the sustained growth of Korea for six decades.

The above calibrations use the long-run average rates of growth of human capital and productivity for the entire period. For the policy maker in 1970 might not have the precise estimates for the six-decade long-run growth of productivity and human capital growth. For them, the best estimates would have been formed by the adaptive expectation using the average values during the 1960-1970 period, which we used in Calibration 1 in the previous subsection. We found that the model simulation "Pred_70" predicts much lower than the actual data, and the discrepancy emerges very shortly after the beginning of simulation. Then, from the viewpoint of the 1970 policy maker, it is an interesting exercise to predict what Korea's growth path would look like if Korea had implemented the growth policies of increasing the transitional growth parameters for investment and labor force, maintaining the 1960-1970 growth rates of productivity and human capital ($g_A = 0.8\%$, $g_h = 2.2\%$). From this counterfactual analysis, we can evaluate the effects of time-varying promotion of the transitional growth parameters at the moment of 1970, when the policy maker would use the estimates for the productivity and human capital growth from the past data from the 1960-1970 period.

Figure 6 compares the predicted path of such simulation "Pred_70_C2" with that of conventional calibration "Pred_70_C1" (same as the "Pred_70" in Figure 2). The gap between "Pred_70_C1" and "Pred_70_C2" measures the expected effect of increasing the transitional growth parameters for investment and labor force for the 1970 policy maker. Figure 6 suggests that the effect of such transitional growth policy is substantial. Furthermore, the model fit for the first decade or so after the prediction time is very close to the data, which shows that the simple neoclassical growth model can be a good device for the policy makers for the decade-period growth prediction. That is, the LTGM can be used for the policy makers of developing countries in assessing the short or medium term growth effects from the promotion of investment and labor force participation, based on the above analysis of Korea's growth experience. A caveat here is that the 1960-1970 period human capital growth rate of 2.2% is higher than the entire sample period average of 1.5%.

At the same time, however, we should emphasize that such growth effect from the promotion of transitional growth parameters is conditional on sustaining the productivity and human capital growth at fairly high rates, 0.8% and 2.2%, respectively. We already showed in Figure 5 that turning off the engines of fundamental growth could have made Korea's growth performance negligible. So, it would be an error for the 1970 policy maker to expect the substantial growth only from the investment and labor force participation promotion. Furthermore, Korea's stellar performance of growth was not simply based on maintaining the 1960-1970 growth rates of productivity and human capital. The "Actual" GDP per capita in 2014 ($34,300) still exceeds the "Pred_70_C2" GDP per capita in 2014 ($24,265) in a big order of magnitude by $10,000, which is attributed to the *acceleration of productivity growth*. Thus, we may conclude that the proper advice for the 1970 policy maker (i.e., for the policy maker of developing countries where their GDP per capita levels are close to that of Korea in 1970) would be to bolster the fundamental growth parameters, particularly, the productivity growth, together with the expansion of investment and labor force.

[Figure 6] Role of Time-varying Transitional Growth for Policy Prescription in 1970



Note: "Actual"; Actual GDP per capita, "Pred_70_C1" Predicted GDP per capita calibrating both transitional and fundamental parameters at constant values from the 1960-1970 data, "Pred_70_C2" Predicted GDP per capita calibrating both fundamental parameters at constant values from the 1960-1970 data but allowing time-varying values for transitional growth parameters.

V. Conclusion

Korea's remarkable growth experience itself may inspire the developing world because Korea started such development from the comprehensive set of adverse conditions (colonization, massive civil war, corruption, lack of physical and human resources, political instability and incessant ideological conflicts etc.) that are often mentioned as critical barriers to development among the current developing countries. However, without clarifying and quantifying what are actually behind such growth process, Korea's development experience would be useless for other developing countries. This paper attempted to provide such quantitative analysis to shed lights on the underlying mechanisms of Korea's growth from the macroeconomic perspective using the framework of the neoclassical growth model, which is the workhorse of the World Bank's LTGM project.

From the decomposition analysis, we found that the most important source of Korean economic growth for the 1960-2014 period was productivity growth, contributing to the growth of GDP per capita by 1.9% each year on average for 55 years. The second largest contributing component was human capital accumulation (1.5% each year), and the capital deepening effect was the third (1.3% each year). The labor market demographic compositional changes such as the increases in working-age population share and labor force participation rate also contributed to the GDP per capita growth substantially by 1% each year. These results show that the underlying sources of Korea's growth were fairly balanced among different growth components, while the productivity growth was the main driving force behind the scene. Furthermore, the major contributing components to growth evolved over time from labor demography and human capital in 1960s to capital deepening in 1970s to productivity growth for the following three decades. In particular, the accelerated productivity growth after 1980 was a critical reason for the sustainable growth for Korea because such productivity growth contributed to overcoming the force of diminishing returns to capital investment which tends to slow down growth.

This picture is different from what many of the first generation of Korea's development policy makers used to have in mind, who would consider the human and physical capital accumulation as the main engines of Korean growth. It was, in fact, the case in the 1960s and 1970s. In the 1960s, human capital growth, based on rapid expansion of universal education at primary and secondary levels of schooling, was the main engine of Korea's growth. In the 1970s, capital deepening due to the increasing investment rate promoted by export-oriented industrial policies indeed was the main engine of Korea's growth. However, what bolstered Korea's sustaining growth throughout, particularly for the 1980-2010 period, was the productivity growth, which has been rarely emphasized in most discourses about Korea's economic growth.

We characterized the important features of the LTGM as a simulated prediction or policy prescription tool, by calibrating the model to Korea's growth experience ex post in various ways. We found that conventional calibration (assuming constant growth parameters) of the neoclassical growth model poorly fits Korea's growth path when Korean economy was in early transition periods. However, for the period after 1990 (when we consider Korean economy started to enter the stability period), even the conventional calibration of the model predicts the actual growth fairly well. Even for the fast transition period before 1990, we found that the model fits Korea's growth path very well by allowing *time-varying* transitional growth parameters (labor market demographic composition changes and investment rate) with maintaining fundamental growth parameters (productivity and human capital growth rates) at constant values. Such goodness of fit of the neoclassical growth model is a (pleasant) surprise because the model is not built to fit the data in a reduced-form way. This tells us that the LTGM can provide a useful tool for policy guidance for the policy makers in designing their growth policies.

Finally, our counterfactual calibration analysis suggests that the fundamental importance of productivity and human capital for sustainable growth is confirmed by the Korea's growth experience, despite the significant contribution of the promotion of investment and labor force expansion. This is the ultimate lesson from Korea's growth experience which should be delivered to the policy makers of the developing countries that aim to achieve such miraculous transformation as Korea. This paper leaves the studies about more concrete micro mechanisms and policy measures behind for future research. The main contribution of this paper is to point where the priority of the development policy and strategy should be directed to, and to quantify its effects on growth, based on Korea's development experience.

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