Policy Research Working Paper 9285

Productivity Growth and Efficiency Dynamics of Korean Structural Transformation

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WORLD BANK GROUP
Development Economics
Development Research Group
June 2020

Policy Research Working Paper 9285

Abstract

This paper documents the sources of the Republic of Korea's economic growth, as well as the associated productivity growth and efficiency dynamics during its process of structural transformation from 1970 to 2016. The analysis includes land as a separate production factor to sort out the significant effect of changes in intersectoral land allocation, which makes significant differences in measuring the magnitudes and directions of change in sectoral total factor productivity (TFP). Input-based growth and structural changes contributed to the early take-off stage of growth in the 1970s. However, in the following three decades, the source of growth switched to productivity improvements, mainly engineered by the industry sector. This was the reason behind the country's sustained growth and escape from the "middle-income trap." Furthermore, agricultural TFP growth also made an important contribution to structural transformation by pushing out factors from agriculture to industry. Since 2011, however, when the Korean economy seemed to reach a steady state of constant capital-output ratio, TFP has suddenly stagnated. The wedge analysis suggests that the intersectoral allocation of labor was biased toward agriculture while that of capital and land was biased toward industry, compared to efficient levels. Meanwhile, the inter-temporal wedge analysis suggests that the Korean economy was in an over-investment mode throughout its structural transformation. The analysis also shows that the periods of productivity growth are not always associated with the enhancement of allocative efficiency, while growth-disturbing external macroeconomic shocks, such as joining the WTO and the Asian financial crisis, led to improvements in allocative efficiency.

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Productivity Growth and Efficiency Dynamics of Korean Structural Transformation

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Keywords: Structural Transformation, Measurement of TFP and Wedges, Productivity Growth, Efficiency Dynamics, Korean Economy, Sustainable Development.

JEL Classification: O11, O2, O41, O47, N15, N55.

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1. Introduction

This paper documents two major points. First, we address the evolution of the sources of the Republic of Korea's economic growth, identifying the contribution of productivity growth and the patterns of efficiency dynamics during its process of structural transformation from 1970 to 2016. During this period, Korea's real GDP per capita grew at an annual average rate of 6% and the Korean economy went through various sorts of structural transformation so that the urban population share doubled from 41% to 82%, the working population share increased from 31% to 53%, and the employment share of the agricultural sector decreased from 48% to 5%. Jeong (2018) shows that the start of such rapid growth in fact dates back at least to 1960. That is, Korea's growth experience is featured by the six percent growth per annum for six decades. This paper quantifies the changing patterns of the dominant driving forces and allocational efficiency of the "six-percent-six-decade" growth performance during the long-run process of Korea's structural transformation, revisiting the validity of the conventional wisdom of the "input-based growth" of East Asia.

Second, we articulate the role of the explicit incorporation of land allocation in measuring sectoral as well as the aggregate TFPs. The effect of inter-sectoral re-allocation of land can be significant for an economy going through an active process of structural transformation. However, this feature of growth process has been ignored in the empirical literature of economic growth and structural transformation, either treating land as a part of capital stock or as a fixed factor if it is isolated. We show that the magnitude of the effect of incorporating land in the sectoral production functions is indeed substantial in measuring both sectoral and aggregate TFPs, so that this paper sheds new light on the existing framework and results of growth accounting in the context of structural transformation.

There were myriads of cross-country episodes of rapid growth in the era of modern economic growth since 1950. According to the concept of "growth accelerations" of Hausmann, Pritchett, and Rodrik (2005), there were at least 80 such episodes with a critical duration of 8 years or longer of maintaining accelerated growth. Furthermore, in terms of counts of such episodes, the growth accelerations happened more frequently in the Sub-Saharan Africa and Latin America and Caribbean regions rather than in Asia. Thus, the

speed of the growth of real GDP per capita at the annual average rate of 6% itself is hardly a surprising or unique part of Korea's economic growth. The truly genuine feature of Korea's economic growth is that such rapid growth has maintained for about six decades, because most of the episodes of growth acceleration did not last longer than 20 years.

Korea's *six-percent six-decade* growth experience is puzzling, considering the findings of Krugman (1994) and Young (1995) who illustrated that the major sources of the East Asian emerging economies including Korea were mobilization of capital and labor. In other words, the types of East Asian economic growth were mainly input-driven rather than productivity-driven so that East Asia's rapid catch-up growth based on input accumulation would not last long due to the simple but powerful law of diminishing returns. The sample period of Young's (1995) is the 1966-1990 period. Three more decades have passed since 1990. It would be an interesting exercise to check if such conventional perspective on East Asian growth remains still valid. It turns out that such perspective of input-driven growth as the main engine of growth for East Asia does tno seem to apply to Korea's development experience of six-percent six-decade growth.

The essential goal of this paper is to seek the reasons behind Korea's sustained rapid growth in the framework of a two-sector growth model, refining the measurement of inputs at the sectoral as well as aggregate level as precisely as possible so that we can obtain better estimates of the aggregate and sectoral TFPs. Using the two-sector growth model, we can decompose the aggregate TFP growth into the effect of within-sector TFP growth and the effect of the inter-sectoral compositional changes of resource allocation. This way we can better address the role of input-driven versus productivity-driven growth for an economy which went through various sorts of substantial structural transformation during the long-term development process.

The importance of the structural changes for poor nations to enter into the modern economic growth regime has been well recognized in the literature of growth empirics dating back to Chenery (1960), Kuznets (1966, 1971), and Syrquin (1988), and recently emphasized by Rodrik (2013). The theoretical literature on the mechanisms of such structural transformation has evolved, focusing on different aspects. The studies of Kongsamut, Rebelo, and Xie (2001), Hansen and Prescott (2002), Ngai and Pissarides (2007), and Jeong and Kim (2015) pay more attention to the role of productivity growth of the industrial or modern sector to attract resources, while Gollin, Parente, Rogerson

(2002) and Alvarez-Cuadrado and Poschke (2011) emphasize the role of agriculture and non-homothetic preferences. Herendorf, Rogerson, and Valentinyi (2015) provide a useful survey on this literature of the models of structural transformation, and a comprehensive multi-sector growth model that encompasses the previous models of structural transformation.

A common feature of all the above literature of structural changes is that the fundamental driving force underlying the structural changes is the sectoral TFP growth, so that the precise measurement of the sectoral TFP is crucial in minimizing the fictitious understanding of the genuine growth process of an economy undergoing an active process of structural transition. However, although there are many empirical studies measuring TFP at the aggregate level, refined measurement of sectoral TFPs for the long-term period in the context of structural transformation is rare. Often, labor is measured at the sectoral level only using the number of workers without adjusting the different evolution of human capital accumulation or hours of work between sectors. This may generate significant mismeasurement of sectoral TFPs. However, the most significant omitted factor would be land in measuring the long-term process of the sectoral TFPs for economies in active structural transformation. For an analysis of growth accounting at the aggregate level or for a short-term period of structural transformation, adding land as a separate factor may not play a significant role in measuring the sectoral TFPs. However, for an economy in active structural transformation over a period of multiple decades, the reallocation of land use from agriculture to non-agriculture is a serious part of the growth process, and omission of land as a separate factor in the sectoral production function would result in serious mismeasurement of sectoral TFP, which in turn will distort the understanding of the long-term growth process of the economy from both empirical and theoretical perspectives. Furthermore, feeding wrong series of the sectoral TFPs, the fundamental driving forces of structural transformation, into any growth models of structural transformation would deliver wrong simulation outcomes, which will distort the evaluation of the models in hand. It turns out that adding land into the sectoral production functions makes substantial differences for the sectoral TFP growth measurement, not just for the size in the first order of magnitude but also for the direction of change in the case of agriculture. In this sense, this paper provides a set of new findings in the empirical literature of structural transformation, which sheds new light on implementing growth

accounting exercises.[2]

Thus, we include sectoral land use as a separate production factor for each sector in the framework of a two-sector growth model to understand Korea's long-term process of structural transformation. We adjust the quality differences in land between the two sectors by incorporating the real price of land. We also incorporate the different evolution of work hours and human capital between the agriculture and non-agriculture sectors in measuring sectoral labor input. We use the sectoral capital measures which incorporate the differences in quality adjustment and depreciation rates over different categories of fixed capital investment.

We also perform a wedge analysis to address the efficiency dynamics of the structural transformation, using a workhorse model of two-sector growth similar to those of Herendorf, Rogerson, and Valentinyi (2015) and Cheremukhin, Golosov, Guriev and Tsyvinsky (2017), although neither of these models includes land, unlike ours. Rapid structural transformation does not mean the process itself was efficient. The inter-sectoral as well as inter-temporal efficiency in allocating resources is another critical aspect of structural transformation, the analysis of which needs to be accompanied with the productivity growth analysis to grasp full understanding of the structural transformation. It is worthy of noting that the continual accumulation of inefficiency in inter-sectoral and inter-temporal allocation of resources would eventually affect the evolution of productivity in the long run. Such effect is not captured by the growth accounting exercise per se, so that the wedge analysis accompanies our two-sector growth accounting exercises. We calibrate the Korean economy for the 1970-2016 period to assess the dynamic evolution of the efficiency of the inter-sectoral and inter-temporal allocation of resources during the period of Korea's rapid structural transformation. We also document whether the critical moments of changes in efficiency dynamics are associated with the internal policy changes or external macroeconomic shocks. Our wedge analysis follows the business accounting method, which was proposed by Chari, Kehoe, and McGrattan (2007). A similar method was used by Cheremukhin, Golosov, Guriev and Tsyvinsky (2017), who study the Chinese structural transformation in relation to political regime cycles in a different context from

[2] Caselli and Feyrer (2007) documented that adding land and resources as a separate category of factor makes significant difference in measuring the marginal product of capital at the aggregate level. The spirit of their study is aligned with this paper.

ours.

Implementation of the above growth accounting and wedge analysis requires an extensive measurement of sectoral-level variables, many of which are not available from the existing database. Thus, we construct many sectoral variables by combining both micro and macro data from various sources such as the Bank of Korea, Statistics Korea, government documents from the Ministry of Land, Infrastructure and Transport, Korea Appraisal Board, library archives for historical records, population census, Economically Active Population Surveys, Agricultural Household Surveys, and the input-output tables.[3] We consolidate these data to measure the sectoral TFPs and wedges variables consistently with our postulated two-sector growth model.

Our growth accounting exercises suggest that Korea's economic growth during its structural transformation is featured such that: (i) input-driven growth and structural changes indeed played a critical role in Korea's economic growth but mainly for the early take-off periods; (ii) the main reason for Korea's sustained growth was the growth regime switch from an input-driven to productivity-driven one, mostly engineered by the industry sector, and the maintenance of strong productivity growth for three decades; (iii) TFP growth and human capital accumulation in the agricultural sector also played an important role in releasing production factors to the industry sector, so that agricultural sector growth contributed to promoting structural transformation; (iv) the magnitudes of income growth due to the input factor accumulation and the compositional changes of the labor market demography gradually decreased, which is the reason behind the declining trend of the income growth rate after the 1990s, so that the observed decrease of economic growth was a natural process from the perspective of neoclassical growth theories; and (v) there was another critical turning point for the evolution of Korea's productivity growth such that the TFP growth rates suddenly dropped in both sectors in the beginning of the 2010s. The last observation is concerning for Korea because this happened around the same period when the capital-output ratio became constant, which signals that the Korean economy is approaching a steady state.

In the case of Korea, the overall allocation of labor has been biased toward agriculture

[3] Construction of this integrated and comprehensive database during the long-run period of structural transformation is first done for the Korean economy in this paper.

relative to the industry sector, while the allocation of land and capital is biased toward the industry sector relative to agriculture. The intertemporal wedge indicates that the Korean economy has been in a state of overinvestment.

We also find that the degrees and directions of the inter-sectoral and intertemporal efficiency wedges change over time, seemingly in response to growth and regulation policies, as well as to macroeconomic shocks. In some cases, there were trade-offs between growth and efficiency, particularly during the input-driven take-off growth period. In other cases, the growth and efficiency were aligned together, particularly during the productivity-driven growth period.

The contents of this paper consist as follows. Section 2 describes a simple two-sector growth model that is adequate for growth accounting analysis. Section 3 explains the growth accounting methods for the two-sector growth model. Section 4 presents the description of the raw data and the methods of measuring the variables of the model. Section 5 presents the features of inputs and output growth, structural changes, and the measurement of sectoral TFPs. We also perform the sensitivity analysis of measuring sectoral TFPs, depending on the postulation of the production functions, clarifying the role of explicit inclusion of land for the empirical analysis of economic growth during structural transformation. Section 6 documents the method of measuring the inter-sectoral and intertemporal efficiency wedges and analyzes the efficiency dynamics by calibrating an optimal two-sector growth model to Korea's structural transformation. Section 7 concludes the paper.

2. Model

We consider a neoclassical two-sector growth model as our workhorse in order to analyze the sources and efficiency of Korea's long-run growth during the process of structural transformation from the agriculture to the industry sector. The economy is partitioned into two (instead of three) sectors of agriculture and non-agriculture simply because the long-run series of the necessary data separate for the service sector are not available, and also because the dominant shifts of resources were indeed from agriculture to non-agriculture and the shift of resources from manufacturing to services within non-

agriculture was not substantial in Korea during our sample period. Given that our objective is to study the long-run process of Korea's structural transformation, this two-sector partitioning properly serves our purpose. We label the non-agriculture sector as the "industry sector" for simplicity and also because the major sector into which the resources flew from agriculture was indeed industry for our sample period.

2.1. Technology

We index the two sectors of agriculture and industry by i, where $i = a$ for the agriculture and $i = b$ for the industry. The sector i output $Y_{i,t}$ at date t is produced by the technology represented by the sectoral production function F_i such that

$$(1) \quad Y_{i,t} = F_i\left(T_{i,t}, K_{i,t}, \widehat{N}_{i,t}, L_{i,t}\right),$$

where $T_{i,t}$ denotes the total factor productivity (TFP), $K_{i,t}$ the capital, $\widehat{N}_{i,t}$ the effective unit of labor, and $L_{i,t}$ the land use. The sectoral production function F_i is specified as the Cobb-Douglas form:

$$(2) \quad Y_{i,t} = T_{i,t} K_{i,t}^{\alpha_i^K} \left(N_{i,t} h_{i,t} \nu_{i,t}\right)^{\alpha_i^N} L_{i,t}^{\alpha_i^L},$$

where α_i^K denotes the capital share, α_i^N the labor share, and α_i^L the land share. The factor shares sum up to unity, i.e., $\alpha_i^K + \alpha_i^N + \alpha_i^L = 1$. Note that the effective unit of labor $\widehat{N}_{i,t}$ is decomposed into three terms of $N_{i,t}$ the number of workers (which we will interchangeably call "employment"), $h_{i,t}$ the human capital per worker, and $\nu_{i,t}$ the hours of work per worker such that $\widehat{N}_{i,t} = h_{i,t} \nu_{i,t} N_{i,t}$. We take $T_{i,t}$, $h_{i,t}$, and $\nu_{i,t}$ as exogenously given as in the data.

To capture the "genuine" productivity and efficiency contents from the measured TFP variable as much as the data allow, we incorporate the sectoral human capital, sectoral hours of work $\nu_{i,t}$ and the sectoral land use $L_{i,t}$ variables. This refined specification of the sectoral production function can be important for the precise measurement of the sectoral TFP, particularly for an economy undergoing active structural transformation, because the movements of these variables are typically asymmetric between the agriculture and industry sectors. For example, although the total land use is almost fixed for the aggregate

economy, the land use gradually but steadily shifts from the agriculture to the industry sector as the other production factors of capital and labor move toward the industry sector. Thus, omitting land use in the sectoral production function for an economy undergoing active structural transformation would underestimate the agricultural productivity growth, while overestimating the industrial productivity growth. Furthermore, the hours of work per worker tend to decline after a critical level of development. However, the speed of such decrease may differ between the two sectors. Similarly, the speed of human capital accumulation may also differ between the two sectors during the structural transformation. This would be another source of bias in measuring the sectoral productivity growth. So, we explicitly incorporate these effective unit of labor adjustment factors in the sectoral production function.

Note that we allow for the asymmetric factor shares of capital, labor, and land between sectors. This also benefits the precise measurement of the sectoral TFP, because the within-sector relative growth rates of factors differ among capital, labor, and land, and such differences differ between the two sectors.

2.2. Preferences

The economic welfare is represented by the following lifetime utility function of the representative agent

(3) $U = \sum_{t=0}^{\infty} \beta^t u(c_{a,t}, c_{b,t})$

where β denotes the time discount factor, $c_{a,t}$ the per capita agricultural consumption goods, and $c_{b,t}$ the per capita industry sector consumption goods.

For the instantaneous utility function, we take the following CRRA specification:

(4) $u(c_{a,t}, c_{b,t}) = \frac{c_t^{1-1/\sigma}}{1-1/\sigma}$

where c_t denotes the composite consumption of agricultural goods consumption $c_{a,t}$ and industrial goods $c_{b,t}$ such that

(5) $c_t = \left[\eta_a^{\frac{1}{\epsilon}}(c_{a,t} - \zeta_a)^{\frac{\epsilon-1}{\epsilon}} + \eta_b^{\frac{1}{\epsilon}}(c_{b,t} + \zeta_b)^{\frac{\epsilon-1}{\epsilon}}\right]^{\frac{\epsilon}{\epsilon-1}}$.

The preference parameters have the following interpretation: $\sigma > 0$ corresponds to the intertemporal elasticity of substitution of composite consumption, $\epsilon > 0$ the pseudo inter-sectoral elasticity of substitution between agricultural and industrial consumption goods, η_i the relative weight for the sector i goods such that $\eta_a + \eta_b = 1$, $\zeta_a > 0$ the subsistence level of agricultural consumption goods, $\zeta_b > 0$ the income-elasticity parameter for the industry sector consumption goods. In the presence of the positive value of the parameter ζ_a, the income-elasticity of the demand for agricultural consumption becomes is less than unity, which bears the robust empirical pattern of Engel's law. In contrast, adding the ζ_b parameter to the industrial consumption makes its expenditure share increase over the income growth. These non-homothetic demand parameters play an important role in structural transformation.

2.3. Feasibility Constraints and Optimal Allocation Rules

The allocation of the sectoral inputs should satisfy the following feasibility constraints:

(6) $N_{a,t} + N_{b,t} = N_t$

(7) $K_{a,t} + K_{b,t} = K_t$

(8) $L_{a,t} + L_{b,t} = L_t$

where the aggregate labor N_t and aggregate land L_t are exogenously given, while the aggregate capital stock accumulates according to the standard law of motion such that

(9) $K_{t+1} = I_t + (1 - \delta)K_t$

We assume that the capital investment I_t comes from the industry sector, and δ is the constant depreciation rate parameter.[4]

The within-sector resource constraints are as follows:

[4] This conventional way of postulating the investment coming only from industry sector rather than the sector-specific investment is based on the empirical observation that the agricultural investment expenditure share of the total investment expenditure is very small at 1.5% on average during our sample period according to Korea's input-output tables.

(10) $Y_{at} = \Xi_t c_{a,t} + G_{a,t} + NX_{a,t}$

(11) $Y_{bt} = \Xi_t c_{b,t} + G_{b,t} + I_t + NX_{b,t}$

where Ξ_t denotes the total population, $G_{i,t}$ the government expenditure of the sector i, and $NX_{i,t}$ the net export of the sector i at date t. We take Ξ_t, $G_{a,t}$, $G_{b,t}$, $NX_{a,t}$, and $NX_{b,t}$ exogenously given as in the data.

Given the above representations of technology, preferences, and feasibility conditions, the optimal allocation rules are determined by maximizing the lifetime utility function specified in equations (3) to (5), subject to the production functions in equations (1) and (2), and the feasibility conditions in equations (6) to (11). At each date t, the labor, capital, and land are allocated between the two sectors by equalizing the marginal products of each input between the two sectors in utility units. These inter-sectoral allocation rules can be summarized such that the "inter-sectoral marginal rates of substitution" of τ_t^N, τ_t^K, and τ_t^L, which are defined as below, are equal to one for each input:

(12) $\tau_t^N \equiv \frac{F_{b,t}^N}{F_{a,t}^N}\frac{u_{b,t}}{u_{a,t}} = 1,$

(13) $\tau_t^K \equiv \frac{F_{b,t}^K}{F_{a,t}^K}\frac{u_{b,t}}{u_{a,t}} = 1,$

(14) $\tau_t^L \equiv \frac{F_{b,t}^L}{F_{a,t}^L}\frac{u_{b,t}}{u_{a,t}} = 1.$

The investment is determined by equalizing the marginal values of consumption over time in utility terms, i.e., the inter-temporal optimal allocation rule can be described by setting the "inter-temporal marginal rate of substitution" τ_t^I to one, which is simply the Euler equation such that:

(15) $\tau_t^I \equiv \beta\frac{u_{b,t+1}}{u_{b,t}}\left(1 + F_{b,t+1}^K - \delta\right) = 1.$

Given the functional forms of the technology and preferences, the inter-sectoral and inter-temporal marginal rates of substitution are to be written as:

(16) $\tau_t^N = \frac{\alpha_b^N}{\alpha_a^N}\left(\frac{Y_{b,t}/N_{b,t}}{Y_{a,t}/N_{a,t}}\right)\left[\frac{\eta_b}{\eta_a}\left(\frac{c_{a,t}-\zeta_a}{c_{b,t}+\zeta_b}\right)\right]^{\frac{1}{\epsilon}},$

(17) $\tau_t^K = \frac{\alpha_b^K}{\alpha_a^K}\left(\frac{Y_{b,t}/K_{b,t}}{Y_{a,t}/K_{a,t}}\right)\left[\frac{\eta_b}{\eta_a}\left(\frac{c_{a,t}-\zeta_a}{c_{b,t}+\zeta_b}\right)\right]^{\frac{1}{\epsilon}}$,

(18) $\tau_t^L = \frac{\alpha_b^L}{\alpha_a^L}\left(\frac{Y_{b,t}/L_{b,t}}{Y_{a,t}/L_{a,t}}\right)\left[\frac{\eta_b}{\eta_a}\left(\frac{c_{a,t}-\zeta_a}{c_{b,t}+\zeta_b}\right)\right]^{\frac{1}{\epsilon}}$,

(19) $\tau_t^I = \beta\left(\frac{c_{t+1}}{c_t}\right)^{\frac{1}{\epsilon}-\frac{1}{\sigma}}\left(\frac{c_{b,t+1}+\zeta_b}{c_{b,t}+\zeta_b}\right)^{-\frac{1}{\epsilon}}\left(\alpha_b^K\frac{Y_{b,t+1}}{K_{b,t+1}}+1-\delta\right)$.

Note that the three inter-sectoral marginal rates of substitution decrease in ϵ, η_a, ζ_a, and ζ_b. Not surprisingly, the inter-sectoral marginal rates of substitution do not depend on σ and β. The inter-temporal marginal rate of substitution increases in σ and β. The effect of increasing ϵ on the inter-temporal marginal rate of substitution varies, mainly depending on the ratio between the composite consumption and the industry goods. The effect of increasing ζ_b on the inter-temporal marginal rate of substitution also varies depending on the industry goods consumption growth. The distance between each of the calibrated marginal rates of substitution in the data and unity (the value of those rates under the optimal allocation) measures the degree and direction of the distortion of inter-sectoral and inter-temporal allocation of resources.

3. Accounting Framework of the Two-Sector Growth Model

From the two-sector growth model in Section 2, we can formulate a framework accounting for the economic growth of any given economy as below, which decomposes the observed growth rate of the GDP per capita. This growth accounting framework in fact does not require any model specification issue. We will utilize the Cobb-Douglas form of the production function, but it is not necessary. Same accounting formulae can be derived only assuming the competitive factor markets. The only complication is that the model has two sectors and there are 13 sources of growth (three kinds of compositional changes and ten categories of productivity and input growth terms), which we will identify for the Korean economy in Section 5. Spelling out this framework articulates what kinds of data are needed for the growth accounting exercises for the two-sector growth model.

The GDP per capita y_t, our measure of economic development, can be expressed such that

(20) $y_t \equiv \frac{Y_t}{\Xi_t} = \lambda_t y_t^N$

where Y_t denotes aggregate output (or GDP), Ξ_t the total population, $\lambda_t = \frac{N_t}{\Xi_t}$ the aggregate employment to population ratio (which we will simply call "employment rate"), $y_t^N = \frac{Y_t}{N_t}$ the aggregate output per worker, i.e. the aggregate labor productivity. The employment rate indicates the magnitude of contribution of the labor to GDP per capita at the extensive margin, while the GDP per worker indicates the productivity of labor at the intensive margin of employment. Thus, the growth rate of the GDP per capita is decomposed into the growth due to the expansion of employment among population at the extensive margin g_{λ_t}, and the labor productivity growth $g_{y_t^N}$ such that

(21) $g_{y_t} = g_{\lambda_t} + g_{y_t^N}$.

In the two-sector model, we can further decompose the aggregate employment rate into sectoral level such that

$\lambda_t = \varphi_{a,t}\lambda_{a,t} + \varphi_{b,t}\lambda_{b,t}$

where $\varphi_{i,t} = \frac{\Xi_{i,t}}{\Xi_t}$ denotes the population share of sector i and $\lambda_{i,t} = \frac{N_{i,t}}{\Xi_{i,t}}$ the employment rate of sector i. This shows that the changes of the economy-wide employment rate depend not only on the changes of within-sector employment rates, but also on the population movement between sectors. This effect is rarely isolated in the typical growth accounting literature. The growth rate of the aggregate employment rate can be expressed into the two sectoral terms, such that

(22) $g_{\lambda_t} = \sum_{i=a,b} s_{i,t}^{\lambda}(g_{\lambda_{i,t}} + g_{\varphi_{i,t}})$,

where $s_{i,t}^{\lambda} = \varphi_{i,t}\lambda_{i,t}/\lambda_t$. The term $\sum_{i=a,b} s_{i,t}^{\lambda} g_{\lambda_{i,t}}$ captures the growth effect due to the "within-sector employment rate changes" (denoted by "WER"). The other term $\sum_{i=a,b} s_{i,t}^{\lambda} g_{\varphi_{i,t}}$ captures the growth effect due to the population shift from agriculture to industry, which we will label "urbanization" effect (denoted by "URB").

The aggregate labor productivity, i.e., the GDP per worker, can also be decomposed into the sectoral level, such that

$y_t^N = \sum_{i=a,b} s_{i,t}^N y_{i,t}^N$

where $s_{i,t}^N = \frac{N_{i,t}}{N_t}$ denotes the employment share of sector i and $y_{i,t}^N = \frac{Y_{i,t}}{N_{i,t}}$ the labor productivity of sector i, so that the growth rate of the aggregate labor productivity is given by

$$(23) \quad g_{y_t^N} = \sum_{i=a,b} s_{i,t}^Y (g_{y_{i,t}^N} + g_{s_{i,t}^N})$$

where $s_{i,t}^Y = \frac{Y_{i,t}}{Y_t}$ denotes the sector i's output share, $g_{y_{i,t}^N}$ the within-sector labor productivity growth rate of sector i, and $g_{s_{i,t}^N}$ the growth rate of sector i's employment share.

From the sectoral production function in equation (2), the sectoral labor productivity $y_{i,t}^N$ is expressed as

$$y_{i,t}^N = T_{i,t} k_{i,t}^{\alpha_i^K} (h_{i,t} v_{i,t})^{\alpha_i^N} l_{i,t}^{\alpha_i^L}$$

where $k_{i,t} = \frac{K_{i,t}}{N_{i,t}}$ denotes the capital per worker, and $l_{i,t} = \frac{L_{i,t}}{N_{i,t}}$ the land per worker of sector i, so that the sectoral labor productivity growth rate $g_{y_{i,t}^N}$ can be decomposed into the growth rates of sectoral inputs per worker and the sectoral TFP growth rate:

$$(24) \quad g_{y_{i,t}^N} = g_{T_{i,t}} + \alpha_i^K g_{k_{i,t}} + \alpha_i^N (g_{h_{i,t}} + g_{v_{i,t}}) + \alpha_i^L g_{l_{i,t}}.$$

Combining the equations (23) and (24), the aggregate labor productivity growth is given by

$$(25) \quad g_{y_t^N} = \sum_{i=a,b} \left[s_{i,t}^Y \left(g_{T_{i,t}} + \alpha_i^K g_{k_{i,t}} + \alpha_i^N (g_{h_{i,t}} + g_{v_{i,t}}) + \alpha_i^L g_{l_{i,t}} \right) \right] + \sum_{i=a,b} \left[s_{i,t}^Y g_{s_{i,t}^N} \right]$$

The first term $\sum_{i=a,b} \left[s_{i,t}^Y \left(g_{T_{i,t}} + \alpha_i^K g_{k_{i,t}} + \alpha_i^N (g_{h_{i,t}} + g_{v_{i,t}}) + \alpha_i^L g_{l_{i,t}} \right) \right]$ in equation (25) measures the "within-sector labor productivity" effect (denoted by "WSG"), and the second term $\sum_{i=a,b} \left[s_{it}^Y g_{s_{at}^N} \right]$ in equation (25) measures the growth effect from the movement of labor from agriculture to industry, which we will label as the "industrialization" effect (denoted by "IND").

Combining equations (22) and (25), the sources of the growth rate of the GDP per capita in our two-sector growth model can be expressed by the following decomposition

formula

$$(26)\quad g_{y_t} = URB + WER + IND + WSG$$

where the component terms are defined as

$$(27)\quad URB = \sum_{i=a,b} s_{i,t}^{\lambda} g_{\varphi_{i,t}},$$

$$(28)\quad WER = \sum_{i=a,b} s_{i,t}^{\lambda} g_{\lambda_{i,t}},$$

$$(29)\quad IND = \sum_{i=a,b} s_{i,t}^{Y} g_{s_{i,t}^{N}},$$

$$(30)\quad WSG = \sum_{i=a,b}\left[s_{i,t}^{Y}\left(g_{T_{i,t}} + \alpha_i^K g_{k_{i,t}} + \alpha_i^N\left(g_{h_{i,t}} + g_{v_{i,t}}\right) + \alpha_i^L g_{l_{i,t}}\right)\right].$$

The growth accounting formula in equations (26) to (30) articulate the sources of economic growth and also the list of required variables to measure them.

4. Data

We construct the variables in the growth accounting framework in equations (26) to (30) using the following sources of data and methods of measurement.

4.1. Output

For our aggregate output variable Y_t, we use real GDP data in 2010 KRW obtained from the Economic Statistics System (ECOS), which is Korea's nationally representative online data archive compiled by the Bank of Korea.[5] This variable coincides with the real GDP variable 'rgdpna' (real GDP at constant 2005 national prices in million 2005 USD) in Penn World Table 9.0 when adjusting the currency unit and the base year of the GDP deflator. The ECOS of the Bank of Korea presents sectoral output data as well. We use the

[5] ECOS web URL is www.ecos.bok.or.kr.

"Gross Domestic Product - Agriculture and Fishery" in 2010 KRW for our agricultural output variable $Y_{a,t}$. The industrial output variable $Y_{b,t}$ is measured by the real GDP of the remaining sectors.

4.2. Population

The population census is conducted every five year by Statistics Korea, and it contains population data for the rural and urban areas as well as for the entire economy, which we use in measuring the population variables Ξ_t, $\Xi_{a,t}$, and $\Xi_{b,t}$, respectively.[6] The intermediate missing values between the census periods are linearly interpolated.[7] Using these population data with the real GDP data above, the GDP per capita variables of the aggregate, agricultural, and industry sectors are measured.

4.3. Factor Inputs

4.3.1. Employment

The employment variables are measured by the "Number of People Employed" data from the *Economically Active Population Survey* conducted by Statistics Korea. This nationally representative annual survey provides the employment total number, demographic characteristics, and types of workers at the national, as well as the sectoral levels. We take the total national employment data for measuring our N_t variable, the "Number of People Employed - Agriculture, Forestry, and Fishery" for the $N_{a,t}$ variable, the number of the employed people in the rest of sectors for the $N_{b,t}$ variable.

Combining the employment data here with the population data in sub-section 4.2, the sectoral and aggregate employment rates (λ_t, $\lambda_{a,t}$, $\lambda_{b,t}$) and the sectoral population shares ($\varphi_{a,t}$, $\varphi_{b,t}$) are calculated, which will be used in analyzing the contribution of the

[6] Statistics Korea's web URL is www.kostat.go.kr. The "urban" area is identified by the municipal areas of 'Dong' and 'Si' regions in Korean, and the "rural" area is identified by the areas categorized by 'Eup', 'Myeon', and 'Bu' regions in Korean

[7] The population data count people with Korean nationality only, and the foreigners living in Korea are not counted.

expansion of the employment at the extensive margin to GDP per capita growth. Using the above employment data, the labor productivity variables y_t^N, $y_{a,t}^N$, and $y_{b,t}^N$ are calculated by the GDP per worker variables for the national economy, agriculture, and industry, respectively.

4.3.2. Hours of Work

The economy-wide hours of work per worker variable v_t, is measured by the "Average Hours Worked per Week – Total" data from the *Economically Active Population Survey* compiled by Statistics Korea. The hours of work data here are also sorted by sectors. We take the average hours of work data under the category "Agriculture, Forestry, and Fishery" for the hours of work per worker of agricultural sector $v_{a,t}$. The hours of work data here are the per-worker average values, so that the hours of work data for the industry sector are not the simple difference between the total average hours of work and the agricultural sector hours of work. We calculate the industry sector hours of work $v_{b,t}$ from the following accounting identity $v_t = s_{a,t}^N v_{a,t} + s_{b,t}^N v_{b,t}$, such that

$$v_{b,t} = \frac{1}{s_{b,t}^N}\left(v_t - s_{a,t}^N v_{a,t}\right).$$

4.3.3. Human Capital

We follow the convention of imputing the human capital from the years of schooling with incorporating the nonlinear schedule of returns to schooling $r(s)$, as is done in Hall and Jones (1999) such that

$$h(s) = exp[s * r(s)]$$

where the schedule of returns to schooling $r(s)$ is given by

$$r(s) = \begin{cases} 0.134 \times s, & if\ s \leq 4 \\ 0.134 \times 4 + 0.101\ (s-4), & if\ 4 < s \leq 8 \\ 0.134 \times 4 + 0.101 \times 4 + 0.068\ (s-8), & if\ s > 8 \end{cases}.$$

The human capital index "hc" in the Penn World Table 9.0 is calculated in this manner, so that the data for the human capital per worker of the aggregate economy are readily

available, and we adopt these data for the h_t variable.[8]

However, the sectoral human capital data are not available from the existing database, hence we construct the sectoral human capital data following the same method of Hall and Jones (1999). However, the challenge is to construct the sectoral years of schooling themselves. For this purpose, we use the Census data from Statistics Korea, which contains the information about the demographic composition of population by age, education level, and community type. The community type is classified in the same manner as we distinguished the population between rural and urban areas before. Using the age composition, we first sort out the population of ages of 15 or higher, so that the human capital index is calculated for the working-age population group (the so-called "production possibility group"). Then, we classify the working-age population group into six education groups (no schooling, primary schooling, middle school, high school, two-year college, and four-year college groups) by each community type, from which we calculate the compositional shares of the education groups for each of the rural and urban areas. We assign zero for the "no schooling" group, six for the "primary schooling" group, nine for the "middle school" group, twelve for the "high school" group, fourteen for the "two-year college" group, and sixteen for the "four-year college" group for the years of schooling for those educational groups.[9] The average years of schooling of the rural area is the average value of the six schooling groups weighted by their population shares. Then, we convert the average years of schooling of the rural area into human capital index in the same way as the aggregate human capital index is constructed by the Penn World Table 9.0, according to the returns to schooling schedule $r(s)$ specified above. The population census has been conducted every five-year period so that the human capital index is constructed every five years, and the human capital data for the intermediate period are linearly interpolated using the period-specific annual average growth rates. We take the human capital data of the rural areas for the human capital per worker of the agricultural sector $h_{a,t}$.

Given the measurement of the two human capital indices of h_t and h_{at} as above, the

[8] The PWT 9.0 reports the data up to the year 2014 and the values of the aggregate human capital for years 2015 and 2016 are linearly extrapolated from the previous years.

[9] The four-year college group includes the graduates of the graduate schools.

industrial human capital per worker $h_{b,t}$ is constructed following the same idea of imputing from the accounting identity as in the average hours of work data such that

$$h_{b,t} = \frac{1}{s_{b,t}^N}\left(h_t - s_{a,t}^N h_{a,t}\right).$$

Note that we use the "hc" variable from the Penn World Table 9.0 for the aggregate human capital per worker, rather than applying the same method to Korea's census data for the entire population for the purpose of facilitating the international comparison of the results of this paper with other countries as compatible as possible. However, we did construct the average years of schooling and the human capital index for the aggregate economy using the population census data to check the validity of our method of constructing human capital data. We found that the average years of schooling estimated from the census data are very close to the years of schooling of the Barro-Lee data. The aggregate human capital index estimated from the census data is also very close to the Penn World Table 9.0 "hc" variable, although the census estimate is slightly higher than the PWT "hc" variable.

4.3.4. Capital

The capital variables are measured by the "Production Capital Stock" in 2010 KRW data from the ECOS database of the Bank of Korea. This capital stock series has been estimated at the sectoral level and the aggregate level since the year 1970. This is the main reason our sample period starts from 1970 in order to use the consistent capital stock series for the two-sector growth accounting. The agricultural capital stock is measured by the "Production Capital Stock – Agriculture, Forestry, and Fishery", and the industrial capital stock is measured as the capital stock of the remaining sectors. Using the employment data $N_{i,t}$ in 4.3.1, the sectoral capital per worker data are calculated.

4.3.5. Land

Land data come from a different source, i.e., the "Cadastral Statistics Annual Report" issued by Ministry of Land, Infrastructure and Transport of Korea for the 1970-2016 period. This Report includes the total, as well as detailed categories of land size in hectare

unit according to their uses. From this Report, we calculate the total area of the "land use" by the total land size subtracted by the categories of forests, rivers, roads, railways, water supply reserves, and levees. We consider this measure as the total land use L_t for the aggregate economy.

Agricultural land use variable $L_{a,t}$ is measured by adding up the areas under the categories of land use of paddy field, dry field, salt field, orchard, pasture, and fish farm. Industrial land use $L_{b,t}$ is calculated by subtracting the $L_{a,t}$ from the total land use L_t. Using the employment data $N_{i,t}$ in 4.3.1, the sectoral land per worker data are computed.

The contribution of the same amount of land may differ between agriculture and industry so that we may need to make quality adjustment for the sectoral land use variables. This would affect not only the calculation of the sectoral TFP but also the inter-sectoral marginal rate of substitution for land, which in turn influences the wedge analysis. We consider the "real price of land" as the best proxy for the quality adjustment factor for the land use. Challenge again is to differentiate the real price of land by sectoral level.

The series of the real price of land for each sector are calculated as follows. We first obtain the nominal unit price of land of each lot from the *Public Open Data Portal*, a nationally representative micro survey of land price for 500,000 lots for the 1995-2016 period. We exclude the lots for the categories of forests, rivers, roads, railways, water supply reserves, and levees, consistently with the measurement of the areas of the land in use. Furthermore, we exclude the lots in the development-restriction areas and residence areas in measuring the unit price of land to better measure the quality of land for production uses. This data reports the community type of each lot, as in the land area data so that we calculate the average unit price of land by community type, weighted by the lot area size. For the period before the year 1974-1995, the changing rate data rather than the level of the unit price of land are reported for each primary local administration unit, differentiated by the community type, from the *Korea Appraisal Board*. From this database, we calculate the series of the changing rates of the nominal unit price of land for urban and rural areas for the 1974-1995.[10] Combining these two series of data, we construct the series of the

[10] For the 1974-1985 period, the aggregated data for the changing rates of the unit price of land by three community types ("si," "gu," and "goon") are reported by the *Korea Appraisal Board*, which already reflects the size distribution of the lots. We calculate the average growth rate of land price for the urban areas by aggregating the unit prices of land of "si" and "gu" by weighting the areas between the two types. For the

nominal unit price of land for urban and rural areas. Then, we convert this series of nominal land price into the real one by deflating the series by the GDP deflator with the base year of 2010, as we do for other real variables. We use this data the real unit price of land by community type for our quality-adjustment factor for the land variables.

4.4. Factor Shares

For Korea's agricultural factor shares, there exists a precedent research by Hwang (2015) who estimates the capital, labor and land shares using the *Agricultural Household Survey* conducted by Statistics Korea. We use these estimates for our agricultural factor shares α_a^K, α_a^N, and α_a^L for capital, labor and land.[11] The *Agricultural Household Survey* provides detailed micro data about the farming activities, including prices and quantities of various agricultural inputs categorized by labor, capital, and land, so that the data provide fairly precise information in estimating the agricultural technology. A caveat is that the estimated factor shares from this study fluctuate much because such micro-data estimation is sensitive to the price fluctuations of the agricultural inputs.

The factor shares of the industry sector are constructed as follows. We first estimate the labor share from the national income accounts for the industry sector. The factor income data are reported by the Bank of Korea, which divides the national income into two broad categories of "employee compensation" and "business surplus". This classification of factor income is done both at the aggregate and sectoral levels. The "business surplus" includes not only the genuine profits and rental income, but also the income of the self-employed and the unpaid workers. Adopting Gollin's (2002) idea of sorting out the "imputed wage" from the second source of the business income, we assign 30% (being consistent with the typical value in the literature) of the "business surplus" income to the imputed wage income. The labor share α_b^N of the industry sector is the share of the sum of the total employee compensation and the imputed wages out of the industry

growth rate of unit price of rural land, we take the growth rate of unit price of "goon" area as is reported by the *Korea Appraisal Board*.

[11] Hwang (2015) studies the 1955-2012 period of agricultural growth. For the agricultural factor shares for the 2013-2016 period, Dr. Hwang is updating the analysis and he kindly provided us the updated estimates of the factor shares for this recent period.

sector income.

In the typical macroeconomic growth accounting analysis, the residual income share is used for the "capital" share. However, our analysis requires further refinement of splitting the residual share into the capital and land shares because we explicitly incorporate the land as a separate production factor in both sectors, so that we can capture the effect of the long-term shifts of land use from agriculture to industry. This separation involves further data construction procedure as follows.

The Bank of Korea's "*Business Management Analysis*" report provides the real asset values of the land and fixed capital separately. Using this database, we can split the total business surplus R_b (after subtracting the imputed wages) of the industry sector, into the factor income from land (denoted by R_b^L) and the factor income from capital (denoted by R_b^K) in the industry sector. From the *Business Management Analysis* report, we calculate the ratio μ_b^L of the land asset value to the fixed capital asset value, which we consider as the proxy for the ratio between land factor income and capital factor income, such that

$$\mu_b^L \equiv \frac{v_b^L}{v_b^K} \approx \frac{R_b^L}{R_b^K},$$

where v_b^L is the real value of land asset, and v_b^K is the real value of fixed capital asset, implying $R_b^K = \frac{R_b^L}{\mu_b^L}$. This approximation holds good if the asset price is determined by the perpetual value of rental income, i.e., the inverse of the rental rate, which is a reasonable assumption for the industry sector.[12] Given this relationship and using the accounting identity $R_b = R_b^L + R_b^K$, we obtain

$$R_b^L = \frac{\mu_b^L}{1+\mu_b^L} R_b$$

$$R_b^K = \frac{1}{1+\mu_b^L} R_b$$

where μ_b^L and R_b are measurable from the data. From this decomposition of the business income, the capital share α_b^K and the land share α_b^L of the industry sector is calculated by

[12] This is because $\frac{v_b^L}{v_b^K} = \frac{V_b^L/P_b^L}{V_b^K/P_b^K} = \frac{r_b^L V_b^L}{r_b^K V_b^K} = \frac{R_b^L}{R_b^K}$ where V_b^L and V_b^K denote the nominal asset values, P_b^L and P_b^K are the asset prices, and r_b^L and r_b^K are the real rental rates of land and capital assets, respectively.

$$\alpha_b^K = (1 - \alpha_b^N)\frac{R_b^K}{R_b},$$

$$\alpha_b^L = (1 - \alpha_b^N)\frac{R_b^L}{R_b},$$

where α_b^N is measured as we explained above.

The aggregate labor share α^N is calculated from the national income account similarly for the industry sector, i.e., assigning 30% of the "business surplus" income to the imputed wage income. This can be a reasonable imputation considering the large share of the self-employed business in Korea. Given this labor share data, the residual share of $1 - \alpha^N$ is split between the aggregate capital share α^K and the aggregate land share α^L such that

$$\alpha^K = (1 - \alpha^N)\frac{(R_a^K + R_b^K)}{(R_a + R_b)},$$

$$\alpha^L = (1 - \alpha^N)\frac{(R_a^L + R_b^L)}{(R_a + R_b)},$$

where R_a and R_b are obtained from the National Income account, R_b^K and R_b^L are obtained from *Business Management Analysis* report, R_a^L is computed using the similar formula between agricultural land share and the land asset ratio, $R_a^K = R_a - R_a^L$.

Note that our way of calculating factor shares yields the time-varying factor shares, while the Cobb-Douglas production functions that we assume postulate constant factor share parameters. We first consider the case where the factor share parameters are constant as the benchmark model presumes. In this case, we take the time-series average values of the time-varying factor shares data for the factor share parameters. However, the Cobb-Douglas form of the production function is just a convenience assumption for the purpose of facilitating the specification of technology and the derived optimal resource allocation conditions. Furthermore, the growth accounting formula that we will use does not depend on the functional form of the production functions, as long as the factor markets are competitive. Thus, we will also perform the growth accounting analysis allowing for the time-varying factor share parameters.

4.5. TFP

From the output, factor inputs, and factor shares data, the aggregate and the sectoral TFP variables T_t, $T_{a,t}$, and $T_{b,t}$ are calculated as the residual components of the production functions such that

(31) $T_t = \frac{Y_t}{Q_t}$

(32) $T_{i,t} = \frac{Y_{i,t}}{Q_{i,t}},\ for\ i = a, b,$

where the aggregate composite input Q_t and the sectoral composite input $Q_{i,t}$ are defined as

(33) $Q_t = K_t^{\alpha^K}(N_t h_t \nu_t)^{\alpha^N} L_t^{\alpha^L},$

(34) $Q_{i,t} = K_{i,t}^{\alpha_i^K}(N_{i,t} h_{i,t} \nu_{i,t})^{\alpha_i^N} L_{i,t}^{\alpha_i^L}.$

5. Growth Accounting for Korea's Structural Transformation

Here, we identify the sources of the real income growth of the Korean economy for the sample period of 1970-2016, which is the maximum span of time period during which the required measurement of the two-sector growth model is possible for now, using the accounting framework of Section 3 and using the data described in Section 4.[13]

5.1. Real GDP per Capita Growth

For the 46-year period of 1970-2016, Korea's real GDP per capita grew 14 times (from $2,609 in 1970 to $36,714 in 2016 in 2011 real value terms) at an annual average rate of 5.9%. One part of this growth is due to the expansion of the employment relative to the population, accounting for 1.2% of the 5.9% (20%), and the other part is due to the output growth per worker, i.e., the labor productivity growth, accounting for 4.7% of the 5.9% (80%). The aggregate employment rate increased from 30.6% in 1970 to 53% in 2016, contributing to increasing real income by 1.2% each year, which is substantial indeed. However, the major source of income growth was the increase in labor productivity, 4.7% per year. Figure 1 shows the growth paths of these three variables.

The within-sector growth paths of the same variables are displayed for the industry and agricultural sectors in Figures 2 and 3, respectively. Within the industry sector, the GDP per capita grew eight times during the sample period at an annual average rate of 4.7%, 1.1% of which is due to the growth of employment rate and 3.6% due to the labor productivity growth. Within the agriculture sector, the GDP per capita grew five times for our sample period at an annual average rate of 3.6%. Unlike the industry sector, the employment rate increased from 26.2% to 31.5% only shortly for the 1970-1976 period, and then monotonically fell to 14% until 2016. This decline of the agricultural employment rate contributes to decreasing the agricultural income at an annual average rate of -1.4%. In contrast, the agricultural labor productivity grew fast at an annual average rate of 5.1%, which is even faster than that of the industrial labor productivity growth rate of 3.6%. That

[13] For a descriptive study of Korea's structural transformation before 1970, Kim and Roemer (1979) provide a useful study.

is, although the diverging paths of employment rates between the two sectors made agricultural income grow slower than industrial income, labor productivity grew much faster in the agricultural sector than in the industry sector. This is a noticeable feature of Korea's structural transformation.

Figure 1. Aggregate Growth of GDP per Capita, GDP per Worker, and Employment Rate

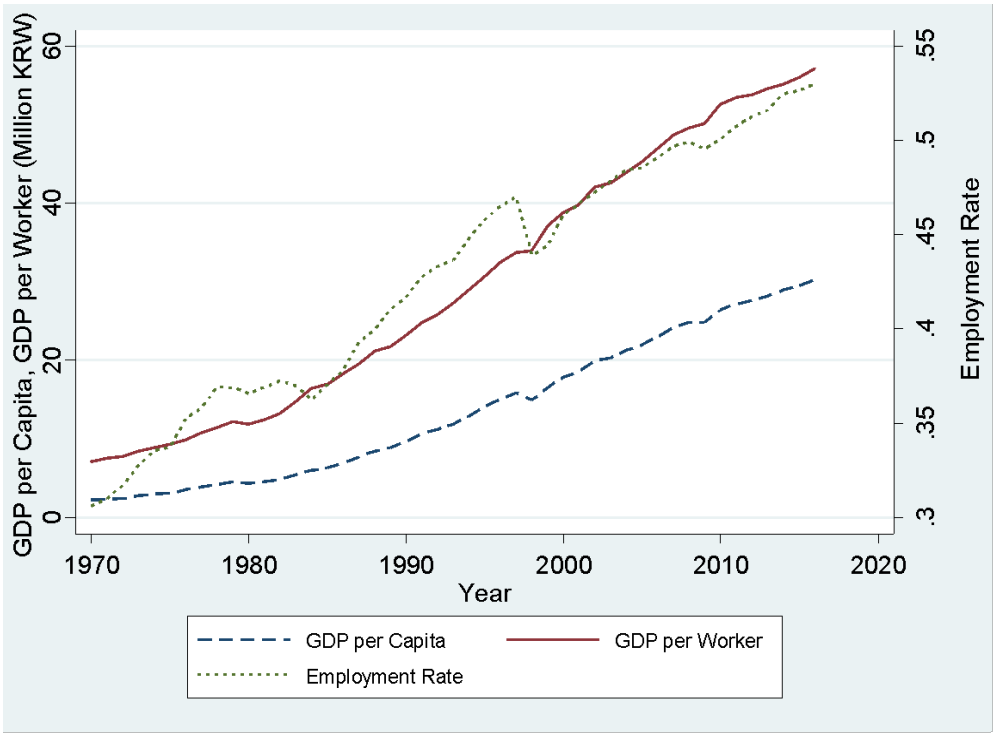


Figure 2. Industry Sector Growth of GDP per Capita, GDP per Worker, and Employment Rate

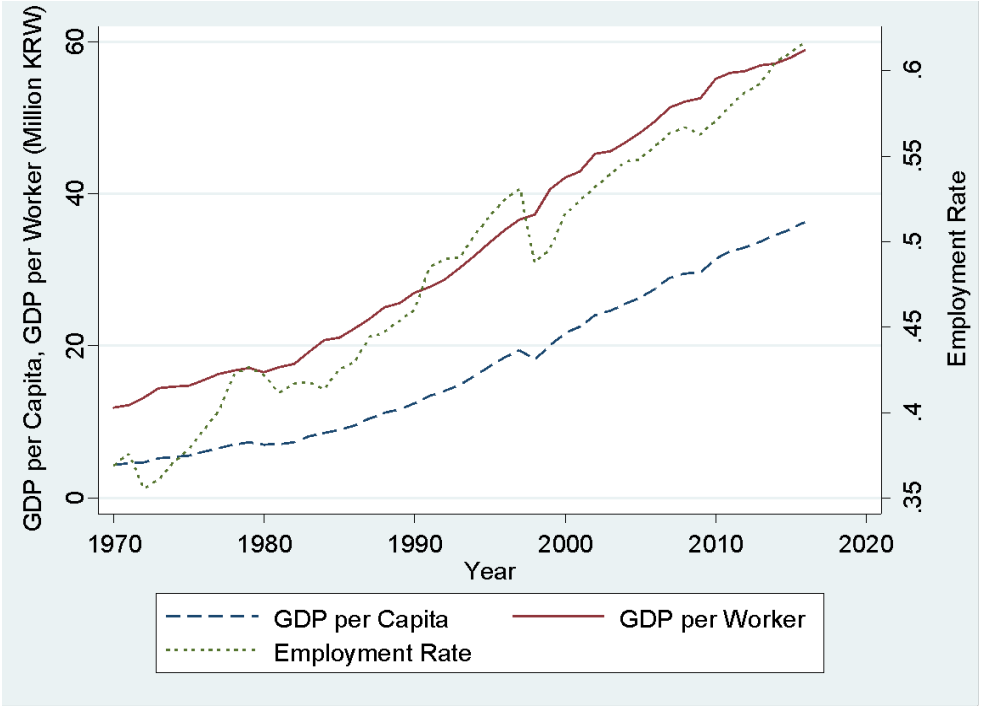
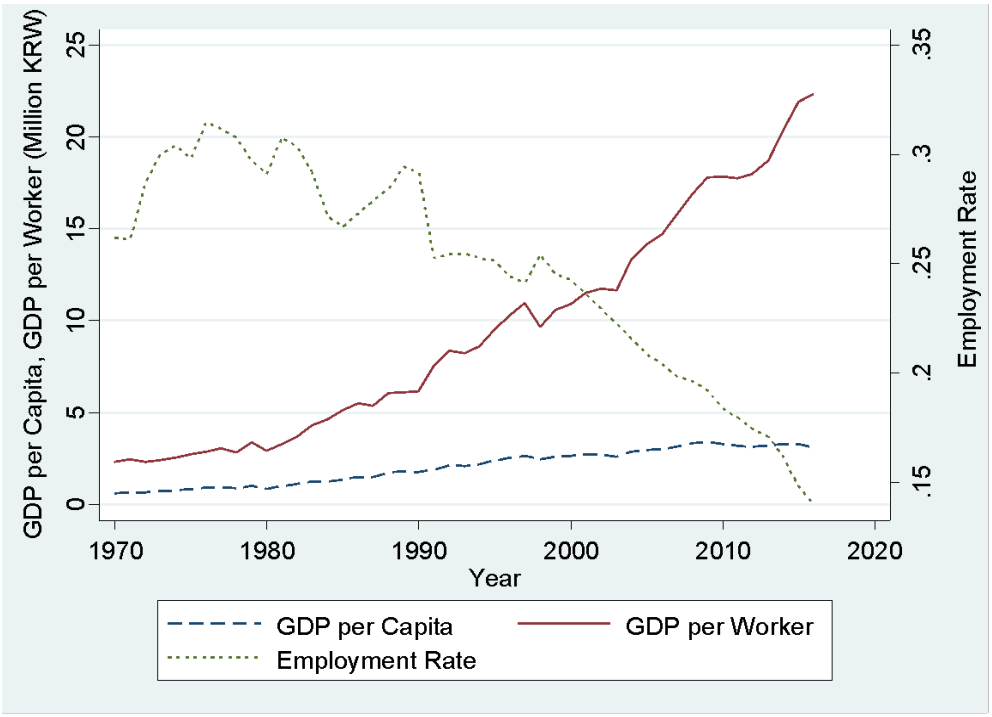


Figure 3. Agriculture Sector Growth of GDP per Capita, GDP per Worker, and Employment Rate



5.2. Output and Input Growth

The paths of the aggregate output and aggregate inputs of the Korean economy for the 1970-2016 period are displayed in Figure 4. Aggregate output grew 22 times at 7% per year on average (Figure 4.A). In the meantime, aggregate capital grew 66 times at 9.5% per year on average (Figure 4.B), aggregate employment grew 2.8 times at 2.2% per year on average (Figure 4.C), and aggregate land grew 14% at 0.3% per year on average (Figure 4.D).

Figure 4.A shows that there is only one noticeable dip of aggregate output for the Asian financial crisis period (1997-1998) and another noticeable stagnation of aggregate output for the global financial crisis period (2008-2009). However, the magnitudes of these changes in output production are not substantial compared to the long-run growth path. That is, the process of Korea's structural transformation was very smooth indeed, and the inquiry into the nature of the long-run growth seems to be more important than that into the business fluctuations in understanding the process of Korea's structural transformation.

Another interesting observation from comparing the changes in aggregate output and inputs is that the dip of output during the Asian financial crisis and the stagnation during the global financial crisis are associated with the changes of employment, rather than those of capital. This suggests that the main channel of responses to Korea's major business cycles is the employment of labor rather than capital.

Figure 4. Aggregate Output and Inputs Growth

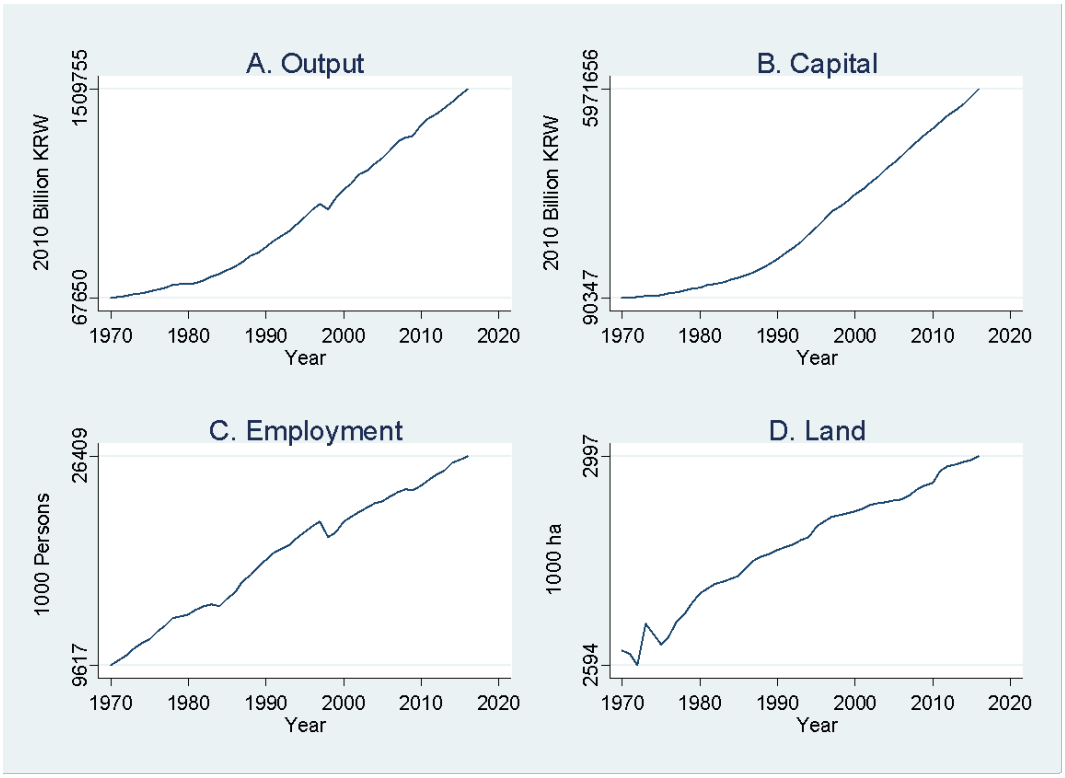


Figure 5 contrasts the growth paths of output and inputs between the agricultural and industry sectors. Not surprisingly, the agricultural output movement was more volatile than the industrial output (Figure 5.A). The industrial output grew much faster at 7.4% per annum than the agricultural output at 2% per annum. Figures 5.B to 5.D suggest that the absolute amount of inputs were either declining or stagnating in agriculture, while all inputs were increasing in industry, so that the aggregate input growth is mainly driven by the industry sector.

It is also interesting to note that the capital stock in agriculture in fact increased rapidly since 1970 till the mid-1990s. However, as Figure 5.B shows the agricultural capital stock started to stagnate around the mid-1990s, when the new multilateral trade framework of the World Trade Organization came into effect, and then gradually fell afterwards until the year 2012. Agricultural employment also increased sharply for the 1970-1976 period but monotonically decreased for the following 40 years (Figure 5.C). The land use for agriculture also monotonically decreased after 1980 (Figure 5.D). In contrast, all industrial inputs of capital, employment, and land have been increasing during the entire sample period. That is, the shifts of resources during the structural transformation were significant

not only for the capital and labor but also for the land.

The series of inputs normalized by the number of workers are shown in Figure 6 for the aggregate economy and in Figure 7 for the two sectors. Here, we include the series of the human capital per worker, as well as the work hours per worker. These four variables together with the TFP consist of the labor productivity.

Figure 5. Sectoral Output and Inputs Growth

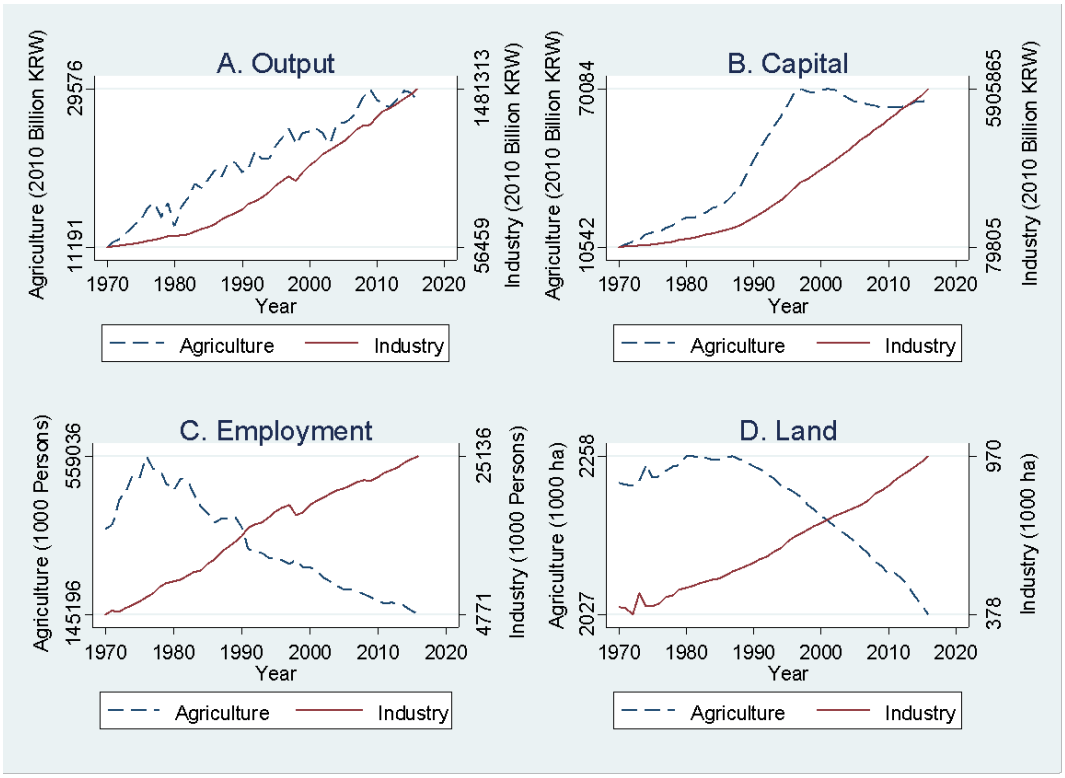


Figure 6 suggests that the capital per worker and the human capital per worker monotonically grew at the annual rates of 7.2% and 1.3%, respectively. The average weekly hours of work show a hump-shaped pattern: increasing from 48 in 1970 to 56 in 1988, then decreasing to 43 in 2016, at the annual average rate of -0.3%. The land use per worker has monotonically declined from 0.27 hectare in 1970 to 0.11 hectare in 2016 at the annual average rate of -1.9%. Note that the TFP growth is calculated as the residual part of the labor productivity growth, subtracting the above four variables (capital per worker, human capital per worker, work hours per worker, and the land use per worker) from the given labor productivity growth. The above findings of declining work hours per worker and the land use per worker suggest that omitting the work hours or land use in growth accounting would *underestimate* the TFP growth.

Figure 7 shows that per worker input levels are higher in industry than in agriculture for all inputs except the land. The capital per worker monotonically increased in both sectors but with differential growth rates of 7.1% for the industry and 5.9% for agriculture, so that the capital per worker diverged between the two sectors. The human capital per worker also diverged between the two sectors but only slightly. This is because of the substantial growth of human capital per worker in agriculture growing at an annual average rate of 1.1%. The industrial human capital per worker grew only slightly higher at an annual average rate of 1.3%. This substantial human capital growth in agricultural sector in an order of magnitude comparable to industry sector is another noticeable feature of Korea's structural transformation. Typically for most developing countries, the educational expansion used to happen dominantly in urban areas and the educated workforce move out of rural areas to find jobs in the industry sector, leaving the promotion of the rural education behind. There indeed was a substantial rural-urban migration during Korea's structural transformation in particular among the college graduates. However, there were almost equal promotion of general education in rural areas and agricultural workforce as well in the case of Korea.

The hump-shaped pattern of the over-time change of the average work hours is similar between the two sectors (Figure 7.C), although the speed of decrease was much faster in industry than in agriculture. Figure 7.D shows that the land use per worker increased rapidly in agriculture at an annual average rate of 2.7%, while it decreased in industry at an annual average rate of -1.7%. We already observed that the total amount of land use

decreased in agriculture but increased in industry (Figure 5.D), while the opposite happened for the employment of labor. Thus, these changes of land use *per worker* happened because the magnitudes of the between-sector compositional changes of employment were much larger than those of land use.

Figure 6. Aggregate Inputs per Worker Growth

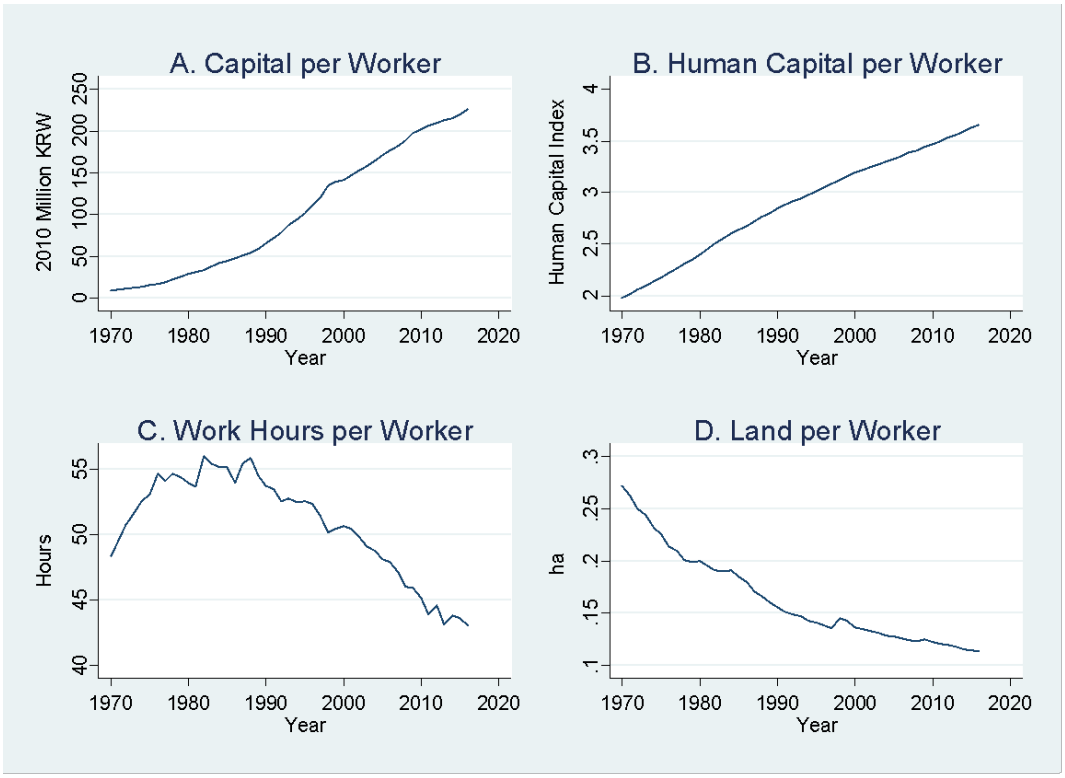
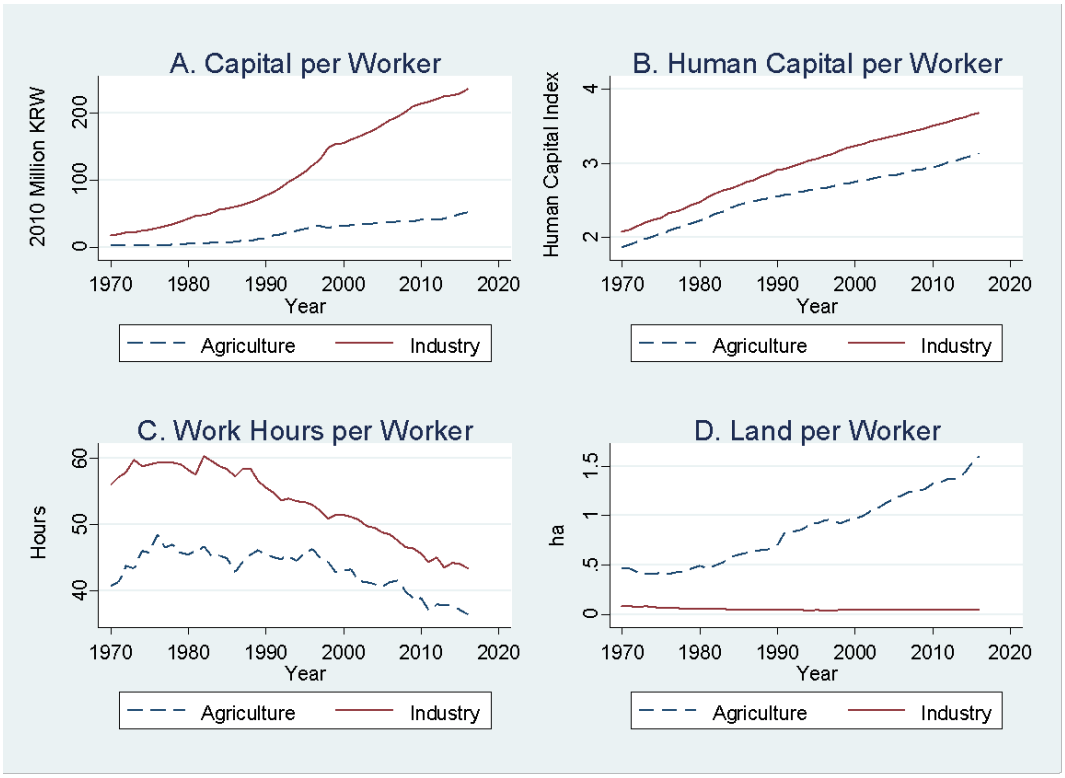


Figure 7. Sectoral Inputs per Worker Growth

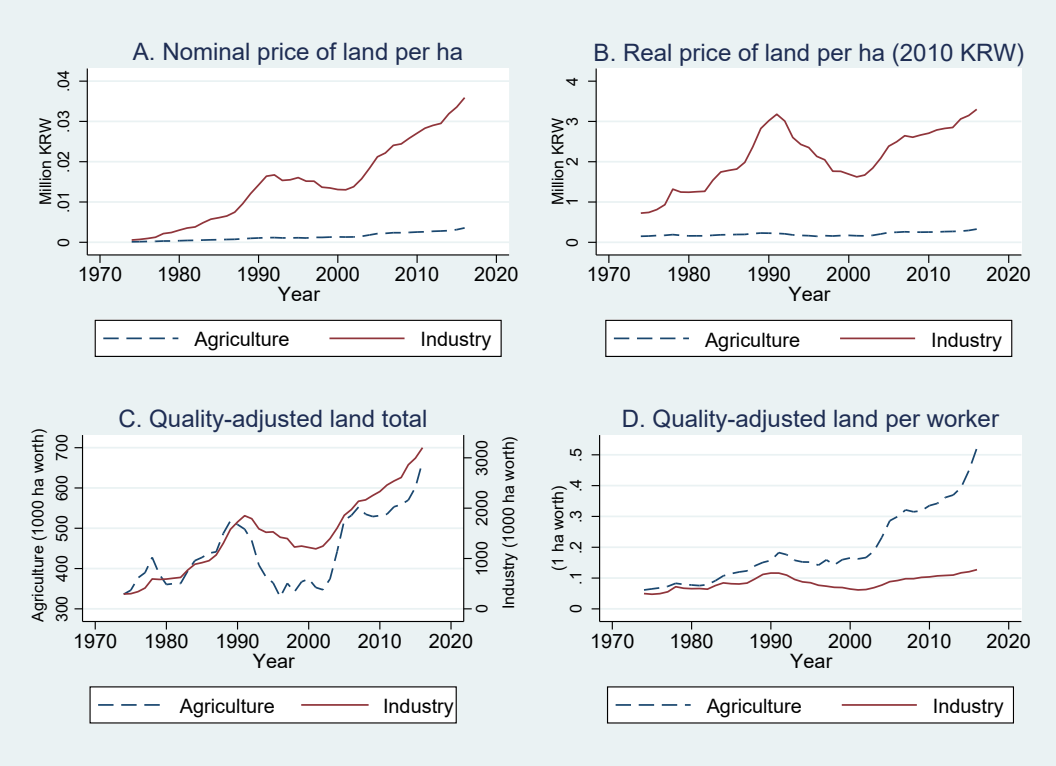


The land variable in the above discussion is the amount of land use measured in hectares. To reflect the "quality" or value differences of land between the agriculture and industry sectors, we incorporate the real price of land as a quality-adjustment factor in measuring the contribution of land to production. The land prices for the entire economy as well as those of individual administration lot units of Korea are available, but there are no data available directly measuring the price of land for the agricultural use and industrial use in isolation. Thus, we proxy the land price of agriculture by the average unit price of land in rural areas, and that of industry by the average unit price of land in urban areas, and label the rural land price as the land price of the agriculture sector and the urban land price as the land price of the industry sector. Obviously, this is an imperfect proxy for the genuine sectoral land prices which represent the "value" of sectoral land use. However, given that our community type variable (differentiating the administration regions into rural and urban areas) has a close relation between agriculture and industry, this proxy would serve our purpose of controlling for the quality of sectoral land use, though not perfect.

The series of the nominal price of land for the agriculture and industry sectors are displayed in Figure 8.A, showing the clear divergence in land values between the two sectors. The land price of the industry sector, proxied by the urban land price, grew much faster and the price ratio of industrial land to agricultural land increased from 5.8 in 1974 to 12.6 in 2016. Figure 8.B displays the sectoral land price in real terms (2010 KRW value) by dividing the nominal price series in Figure 8.A by the GDP deflators. It turns out that the land price started to decrease in real terms since early 1990s. This in fact is due to the stabilized nominal prices of land beginning of the early 1990s as shown in Figure 8.A, in response to the various policy efforts in the early 1990s to control the prices of real estate mainly by changing ordinances in relation to the motives of the ownership and transaction of land such as comprehensive land property tax, introduction of the real-name property ownership system, and the land excess-profit tax act. However, the land price bounced back to an increasing trend since the early 2000s.

Using the real price of land at the sectoral level as the quality-adjustment factor, the evolution of the total amount of sectoral land is shown in Figure 8.C, which looks different from that of the quantity of land in Figure 5.D. Figure 8.D displays the quality-adjusted land per worker. Comparing this figure with Figure 7.D (the quantity of land per worker), we find that the increasing speed of the per-worker agricultural land becomes higher with the quality-adjustment. Another interesting finding is that the per-worker land slightly decreased during 1990s in both sectors, it turned into an increasing trend since early 2000s, much more saliently in agriculture than in industry.

Figure 8. Quality-adjustment of Land



5.3. Factor Shares

Measuring TFP depends not only on the amount measurement of factor inputs, but also on their shares. Figure 9 shows the series of the measured factor shares for the aggregate economy, the agricultural sector, and the industry sector from the data we described in Section 4. We find that the aggregate labor share increased steadily from 58% in 1970 to 73% in 1996 and then stabilized around that level with minor increase to 75% by 2016. The aggregate capital share shows almost the mirror image movement of the labor share, decreasing from 31% in 1970 to 21% in 1996 and then stabilizing around 22%. The aggregate land share rapidly decreased from 11% in 1970 to 6.6% in 1983 and then stabilized around that level.

The agricultural factor shares fluctuate more than those of the aggregate economy and the industry sector. However, we observe the falling trend of labor share (from 51% in 1970 to 13% in 2016) and the rising trend of capital share (from 28% in 1970 to 37% in 2016). The agricultural land share also shows an increasing trend from 22% in 1970 to 50% in 2016.

The industry sector factor shares moved smoothly compared to the agricultural ones. The industry sector labor share also increased but only slightly from 67% in 1970 to 75% in 2016, while the industrial capital share decreased from 29% in 1970 to 19% in 2016. Thus, the directions of the factor share movements contrast between industry and agriculture sectors. The industrial land share increased only slightly from 4% to 6% during the sample period.

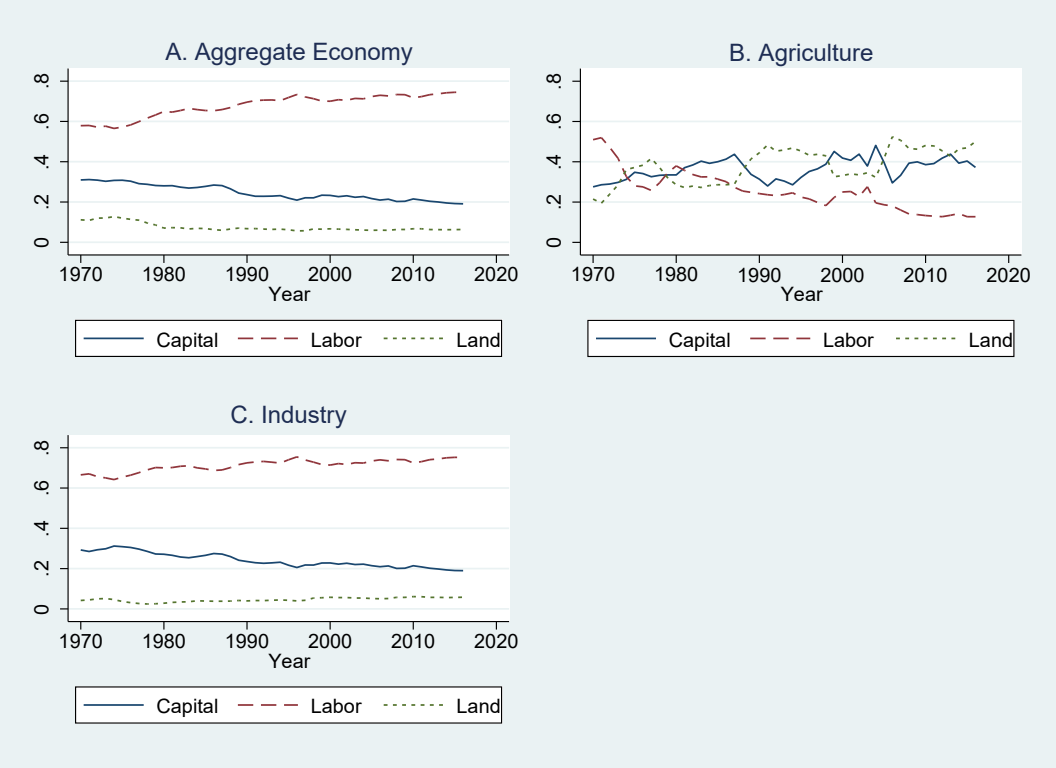
Our model postulates the Cobb-Douglas form for the production functions, which imply constant factor shares. We will consider this Cobb-Douglas production function for our benchmark specification in measuring the aggregate as well as the sectoral TFP variables, such that the time-series averages of the factor share data will be used for our factor share parameters in measuring the TFP variables. This specification has a clear benefit of tracing the sources of the output growth from the accounting point of view, in the sense that decomposition results are more consistently comparable across different time periods by fixing the weighting parameters in growth accounting formula. Furthermore, when we compare the simulated results with the actual data, we have to measure the actual variables consistently with the model, so that this benchmark specification is needed for the purpose of consistent comparison between the model and the data. Our factor share values are summarized in Table 1.

Table 1. Factor Share Values

Factor Shares	α^K	α^N	α^L	α_a^K	α_a^N	α_a^L	α_b^K	α_b^N	α_b^L
Values	0.247	0.679	0.074	0.364	0.255	0.381	0.242	0.713	0.046

Using different functional forms of production functions, we may have time-varying factor shares. Thus, we will also perform the growth accounting exercises allowing for the time-varying factor shares as a sensitivity analysis and compare the results with those of the benchmark.

Figure 9. Factor Shares



5.4. TFP Growth

Figure 10 shows the growth paths of the aggregate and sectoral composite inputs and TFPs, which are measured as in equations (31) to (34) using the land quantity. The aggregate TFP was more or less stagnant during the entire period of the 1970s and started to grow only after 1982, while the aggregate composite input monotonically grew throughout the sample period. The overall average growth rate of the aggregate TFP for the 1970-2016 period was 1.6%.

The composite input of the agricultural sector shows a hump-shaped pattern, increasing for the 1970-1996 period and then decreasing afterwards. The agricultural TFP fluctuated much but grew at an annual average rate of 1.2%. The agricultural TFP did not show a robust increasing trend during the 1970s. It is interesting to note that the agricultural TFP started to accelerate since the early 1990s. This is related to the increasing openness of Korea's agriculture to foreign markets. Partial trade liberalization of the agricultural products already started in 1992. The fundamental changes for the agricultural trade liberalization, however, happened with the launch of the WTO in 1995. Recall that Figure

5.B showed the agricultural capital stock stagnated around this time and even started to decrease in absolute terms since 1998, the Asian financial crisis period.

Upon abolishing the existing price subsidies and lowering tariffs for most of the agricultural products in response to Korea's participation in the WTO, substantial changes of composition of agricultural production, e.g., from rice to non-rice crop varieties, and also from field crops to organic vegetables and fruits and processed meats production, began around this time. Such product compositional changes were the main driving force of the productivity growth of the agriculture sector. Thus, the 1990s were a critical period for Korean agriculture to switch its growth mechanism from capital-driven to productivity-driven one in response to the external macroeconomic shocks. The annual average rate of agricultural TFP growth for the 1998-2016 period was 2.4%. Another noticeable pattern of the agricultural TFP is that its growth has stagnated since 2010.

Figure 10.C shows that the industrial composite input grew much smoother than that of the agriculture, and the shape of the industrial TFP growth resembles the aggregate one, growing at an annual average rate of 1.7%. This indicates that the movement of the aggregate TFP was driven mainly by the industrial TFP, although the agricultural TFP growth also reinforced the aggregate TFP growth after the late 1990s.

A more important observation from Figure 10.C perhaps is that there are two critical turning points for the industry sector TFP. In the year 1982, the industrial TFP growth turned from slightly negative to strong positive. However, this suddenly turned to near-zero after the year 2011. The industrial TFP grew by 2.8% per year on average during the 1982-2011 period, while its annual average growth rate was only 0.4% during the 2011-2016 period.

For the 1974-2016 period, we constructed the quality-adjusted land data. The composite inputs and the TFPs with adjusting the quality of land are displayed in Figure 11. From Figures 11.A and 11.C, we find that the evolving patterns of the composite inputs and TFPs are similar for the aggregate economy and industry sector either with or without adjusting the quality of land. The only noticeable difference by adjusting the quality of land is that the magnitudes of the TFP growth become slightly smaller and the negative TFP growth in the 1970s become much more salient. For example, the annual average TFP growth rate of the industry sector in the 1970s becomes -1.51% by adjusting the quality of

land, while it was -0.18% when using only the quantity of land. Not surprisingly, this is because of the rapid increase of the land price during the sample period except the 1990s.

The effects of such changes in TFP reflecting the changes in land price seem larger in agriculture than in agriculture. Figure 11.C shows that we no longer observe the declining trend of the composite input in agriculture after the mid-1990s. Rather the agricultural composite input stagnates after 1990 and the increasing pattern of the agricultural TFP in the 1990s becomes more visible. However, the overall magnitude of the agricultural TFP becomes smaller by adjusting the quality of land. The annual average rate of the agricultural TFP growth was 1.18% using only the quantity of land, while it becomes 0.62% with reflecting the increase of the unit price of agricultural land.

Figure 10. Aggregate and Sectoral TFP Growth

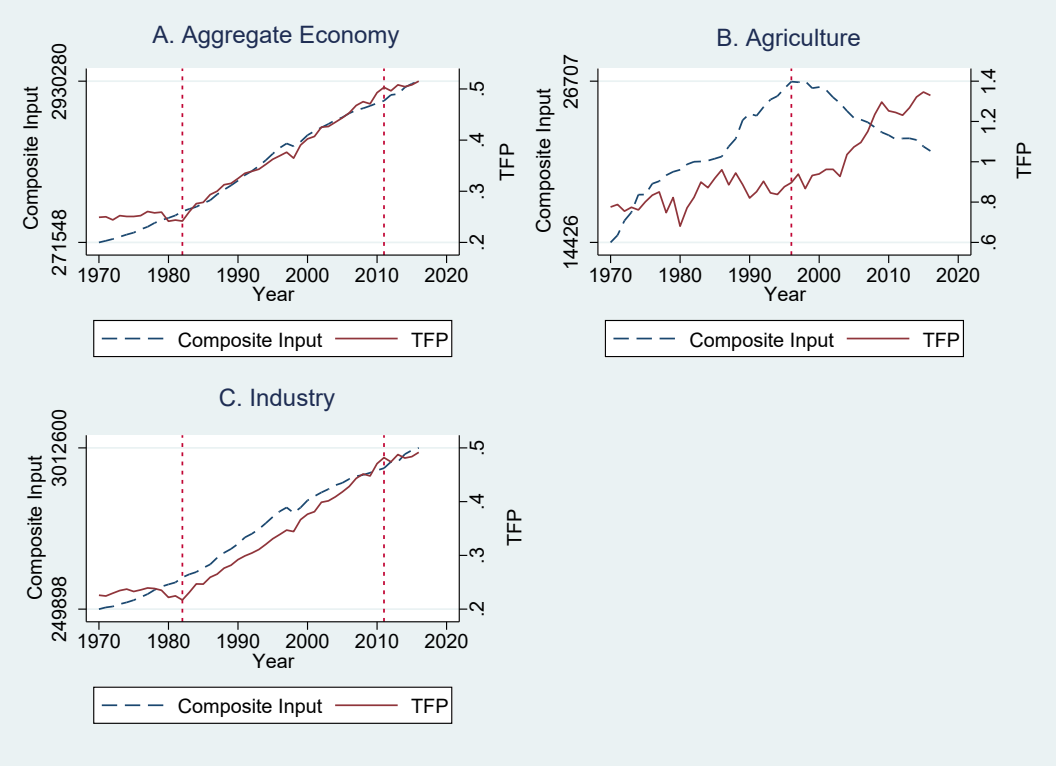
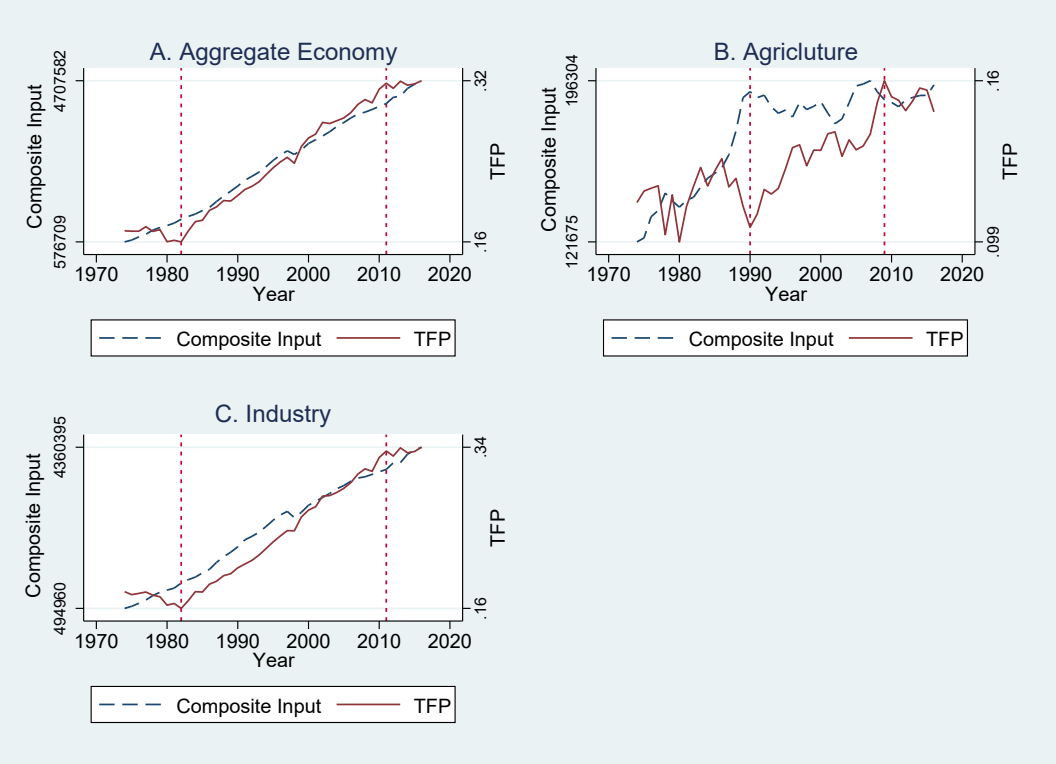


Figure 11. Aggregate and Sectoral TFP Growth with Quality-adjustment of Land



5.5. Structural Transformation from Compositional Changes

There are three kinds of compositional changes in our growth accounting framework: (i) the inter-sectoral population shift, (ii) within-sector changes of the employment-to-population ratio, and (iii) the inter-sectoral employment shift. We labeled them by urbanization effect ("URB"), within-sector employment rate change effect ("WER"), and industrialization effect ("IND"), respectively, which are expressed in equations (27), (28), and (29) in Section 3. We may call all these compositional changes affecting the aggregate economic growth as "structural transformation" in a broad sense, although the literature focuses on the industrialization effect as the structural transformation.

Figure 12.A displays the path of the urban population share during the sample period, increasing from 41% in 1970 to 82% in 2016. The urban employment rates have been higher than the rural employment rates throughout the sample period, as shown in Figure 12.B. Thus, the population shift from the urban to rural areas contributed to raising the aggregate employment rate from 30.6% in 1970 to 53% in 2016. This urbanization effect contributed to increasing the GDP per capita by 0.35% each year on average out of the 1.2% of GDP per capita growth due to the increase in aggregate employment rate.

Furthermore, the urban employment rate has increased from 36.9% in 1970 to 61.7% in 2016, while the rural employment rate decreased from 26.2% in 1970 to 14.0% in 2016, as Figure 12.B shows. These changes of the within-sector employment rates contributed to the 0.89% of the GDP per capita growth per year on average during the sample period.

The employment share of the industry sector has increased from 50% in 1970 to 95% in 2016 (Figure 12.C). This industrialization effect contributed to the 1.04% of the GDP per capita growth per year on average during the sample period.

We will present the detailed decomposition results for Korea's economic growth in the following subsection. However, it is worth noting that the combined effect of these compositional changes alone contributes to 2.28% of the GDP per capita growth per year on average for the 1970-2016 period. This is a substantial magnitude of growth, which would enter into the TFP growth at the aggregate level.

Along the process of the above structural transformation, the output and the other inputs shares of the industry sector also increased. Figure 13 compares their paths. The

output share of the industry sector increased from 83% in 1970 to 98% in 2016.

The capital share of the industry sector increased from 88% in 1970 to 99% in 2016. The industry sector of the effective unit of labor (adjusting the human capital and hours of work per worker) increased from 60% in 1970 to 97% in 2016. Comparing the movements between the share of industrial employment and the share of industrial effective unit of labor, we find that they move together and the gap is closing over time. This suggests that the shift of the "labor" input from agriculture to industry is mainly driven by the number of workers, rather than by the work hours and human capital per worker.

The industry-sector share of land in terms of quantity only increased from 15% in 1970 to 32% in 2016. With adjusting the quality factor, the industry-sector share of land increased from 47% in 1974 to 83% in 2016. It is worth noticing that the industry sector share of land in 2016 becomes 83% when the land price differences are taken into account, while it is only 32% using the land quantity only. In the conventional literature of Korea's structural transformation, there are many discussions that Korea's structural transformation was mainly driven by the "forced shift of labor" into the industry sector engineered by the government's intervention. The above observations suggest that the all sorts of production factors, not just the labor, shifted from agriculture to industry. Whether the inter-sectoral shifts were "balanced" across factors is one of the key issues of efficiency dynamics which we will articulate in Section 6.

Combining the two effects of urbanization and industrialization, the "structural transformation" alone directly accounts for 1.39% out of the total income growth of 5.92% (about 24% of the total growth). This would be an important part of the aggregate TFP growth.

Figure 12. Three Kinds of Compositional Changes

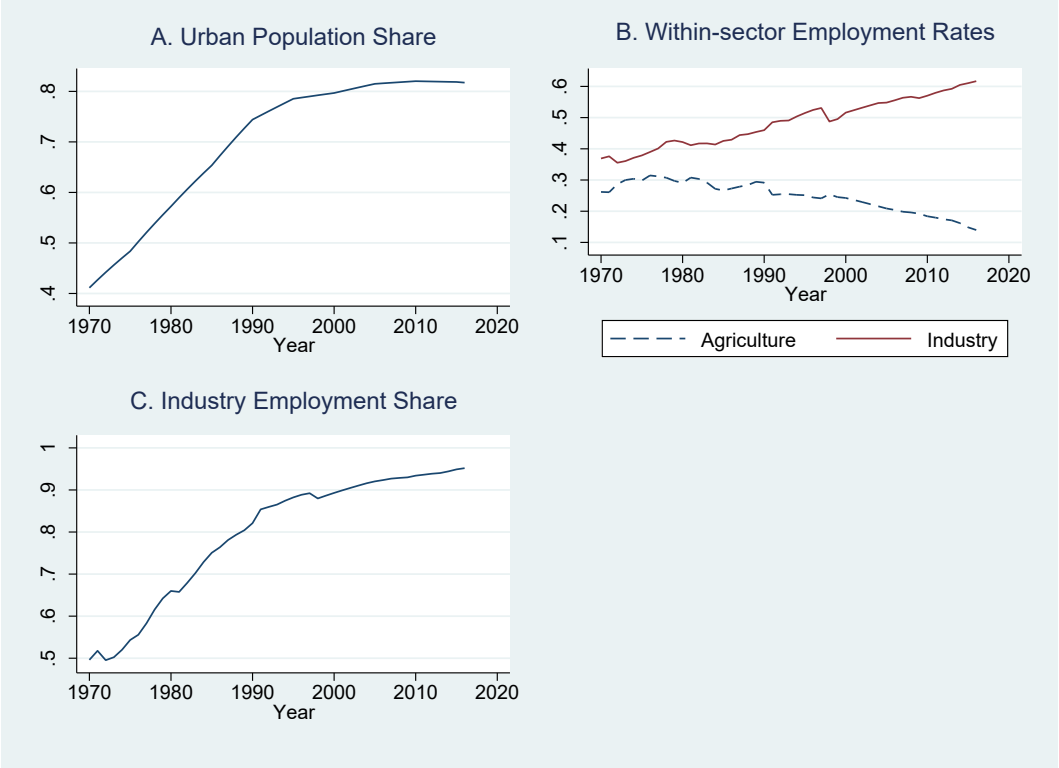
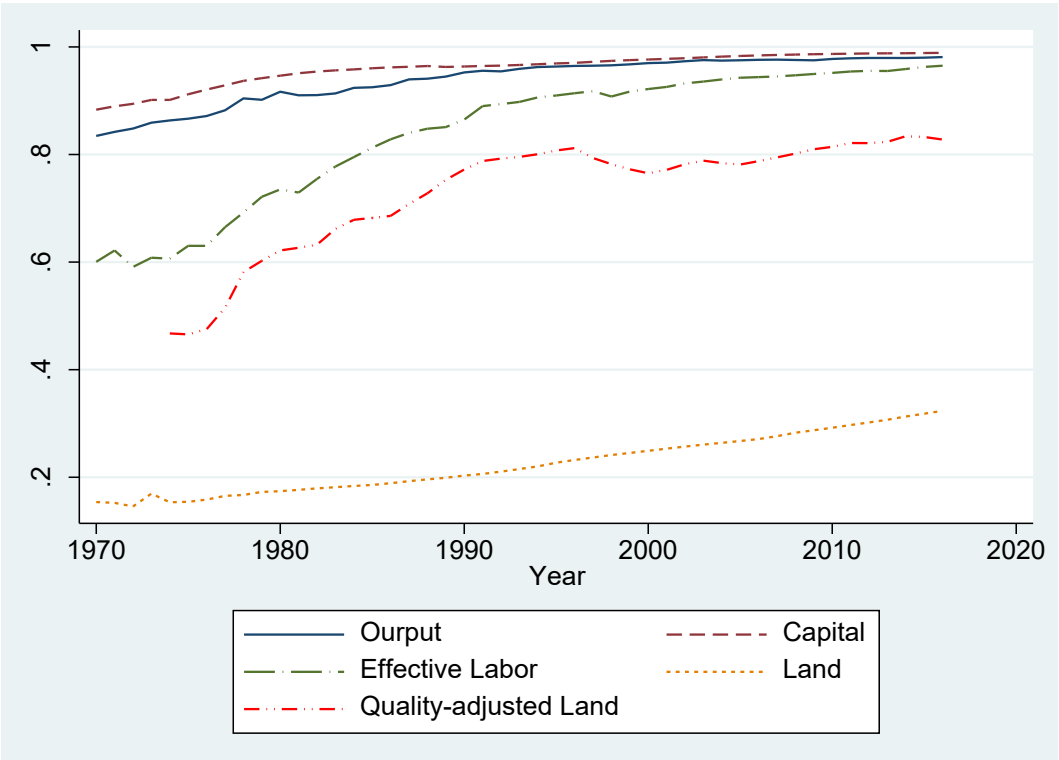


Figure 13. Industry Sector Output and Inputs Shares



5.6. Growth Accounting Results

5.6.1. Summary of Growth of Outputs and Inputs Measures

Table 2 summarizes the annual average growth rates of the aggregate and sectoral GDP per capita, and the aggregate and sectoral labor productivity for the entire sample period (1970-2016) as well as for each of the sub-periods of the four decades and the last six-year period under the heading of each corresponding variable of y, y_a, y_b, y^N, y_a^N, and y_b^N, respectively. The annual average growth rates of the sectoral TFPs and the sectoral inputs per worker (T_a, k_a, h_a, v_a, l_a, T_b, k_b, h_b, v_b, l_b) are shown in Table 3. The variables of (T_a^{QA}, l_a^{QA}, T_b^{QA}, l_b^{QA}) in the last four columns are the sectoral land per worker and the corresponding TFP variables with adjusting the quality of land. The quality-adjusting land price data are available for the 1974-2016 period, hence the values of these four variables in the first row are for the 1974-2016 period, and those in the second row are for the 1974-1980 period.

Table 2. Annual Average Growth Rates of Output Variables (%)

Period	y	y_a	y_b	y^N	y_a^N	y_b^N
’70-’16	5.92	3.63	4.71	4.66	5.06	3.55
’70-’80	7.31	3.45	4.80	5.41	2.37	3.41
’80-’90	8.29	7.75	5.89	6.89	7.72	4.98
’90-’00	6.32	3.96	5.79	5.27	5.89	4.58
’00-’10	3.98	2.19	3.76	3.11	5.06	2.73
’10-’16	2.34	-0.81	2.46	1.38	3.82	1.12

Table 3. Annual Average Growth Rates of Inputs and TFP Variables (%)

Period	T_a	k_a	h_a	v_a	l_a	T_b	k_b	h_b	v_b	l_b	T_a^{QA}	l_a^{QA}	T_b^{QA}	l_b^{QA}
’70-’16	**1.18**	7.13	1.12	-0.24	2.75	**1.70**	5.91	1.25	-0.56	-1.69	**0.62***	5.23*	**1.58***	2.27*
’70-’80	-1.30	7.74	1.74	1.10	0.57	-0.18	9.59	1.78	0.40	-4.62	-2.25†	3.95†	-1.51†	4.73†
’80-’90	1.89	11.20	1.38	-0.02	3.63	2.79	6.22	1.61	-0.48	-3.09	0.53	7.35	2.38	5.89
’90-’00	1.37	8.82	0.75	-0.52	3.29	2.57	7.28	1.09	-0.75	-0.11	2.43	0.49	2.85	-5.72
’00-’10	2.92	2.62	0.70	-1.02	3.22	2.25	3.32	0.77	-1.22	0.06	1.40	7.33	2.03	4.87
’10-’16	1.00	4.38	0.99	-1.06	3.23	0.73	1.57	0.85	-0.83	0.11	-0.62	7.70	0.59	3.46

Note) *: average values of 1974-2016 period instead of 1970-2016 period

†: average values of 1974-1980 period instead of 1970-1980 period

5.6.2. Growth Accounting Method: Counterfactual Decomposition

Our growth accounting formulae in equations (26) to (30) are precise when the data are recorded in continuous time. Being applied to the discretely recorded data, the formulae involve approximation errors. Typical treatment for this discrete data use is the index approximation method using the average weights. However, this method does not work for the following two reasons. First, due to the long series of the sample period, using the intermediate average weights does generate sizable errors because the weigh variables are either output or employment shares, which vary substantially in the context of our structural transformation for the span of forty-six-year period. Second, unlike the single-sector aggregate growth accounting, the objective of growth is the "sum" of two nonlinear functions (with the time-varying weights for the sectoral variables) so that the typical method of log-linear index decomposition simply does not work for the two-sector model growth accounting.

Thus, we adopt the following "counterfactual decomposition method" for our growth accounting analysis. Taking the initial year 1970 GDP per capita level as given, we create a counterfactual income level for the following year solely from one growth component of a chosen variable using the above accounting formula *for a single year interval* and taking the weighting variables at the average values for the period of the single year interval, so that the approximation error can be minimized. Then, at such counterfactual level of income at the second year by varying only one component, we apply the same method to generate the counterfactual income level at the third year. We repeat this procedure until the last sample period year 2016 to create the counterfactual income path, which is ascribed to the income growth of that particular growth component. By calculating the growth rates over our selected period, we can isolate the contribution of the specific growth component to the aggregate GDP per capita over the chosen period. For example, the counterfactual income path for the 1970-2016 period due to the industry sector TFP growth is generated such that

$$y_{1970+s}^{CF\_T_b} = \prod_{j=1}^{s}\left(1+\bar{s}_{b,1970+j}^{Y} g_{T_{b,1970+j}}\right) y_{1970}, \text{ for } s = 1, \cdots, 46,$$

or the counterfactual income path for the 1970-2016 period due to industrialization is generated such that

$$y_{1970+s}^{CF\_IND} = \prod_{j=1}^{s}\left(1+\sum_{i=a,b}\bar{s}_{i,1970+j}^{Y} g_{s_{i,1970+j}^{N}}\right) y_{1970}, \text{ for } s = 1, \cdots, 46,$$

where $\bar{s}_{b,1970+j}^{Y} = \frac{1}{2}\left(s_{i,1970+j}^{Y} + s_{i,1970+j-1}^{Y}\right)$.

All other counterfactual income paths of the underlying growth components are generated this way to isolate each component's contribution to the GDP per capita growth, which are displayed in Figure 14 for the case of land use measured in quantity only.

Figure 14.A shows the counterfactual income paths due to the effects of the compositional changes: increase of the urban population share (labeled as "URB"), the changing within-sector employment rates (labeled as "WER"), and the increase of the industry sector employment share (labeled as "IND"). Figure 14.B displays the counterfactual income paths due to the changes of the industry sector variables of the TFP (labeled as "T_b"), capital per worker (labeled as "k_b"), human capital per worker (labeled as "h_b"), work hours per worker (labeled as "nu_b"), and the land use per worker (labeled as "l_b"). Figure 14.C displays similarly for the agriculture sector variables of the TFP (labeled as "T_a"), capital per worker (labeled as "k_a"), human capital per worker (labeled as "h_a"), work hours per worker (labeled as "nu_a"), and the land use per worker (labeled as "l_a"). The scales of the Figures 14.A to 14.C are unified, so that we can compare the order of magnitudes of the contributions to aggregate growth of the GDP per capita among those components simply by comparing the heights of the counterfactual income paths in the final year of 2016. Figure 14.D magnifies the Figure 14.C for the counterfactual income paths in agricultural sector, in order to better visualize the relative contributions of the inputs and TFP within the agricultural sector.

From the comparison of Figures 14.A to 14.C, it is clearly visible that the top three contributing factors to the economic growth for the overall period, i.e., the top three tallest paths in 2016, are the TFP growth of the industry sector ("T_b"), the capital accumulation of the industry sector ("k_b"), and the industrialization, i.e., the shift of workers from agriculture to non-agriculture ("IND") in order.

Figure 15 displays the same decomposition results for the 1974-2016 period with quality adjustment of land, suggesting that the above order of contributions remains robust even with such adjustment. The only noticeable change is that the contribution of agricultural land becomes larger reflecting the changes of land prices.

Figure 14. Counterfactual Income Growth Paths with Land Quantity

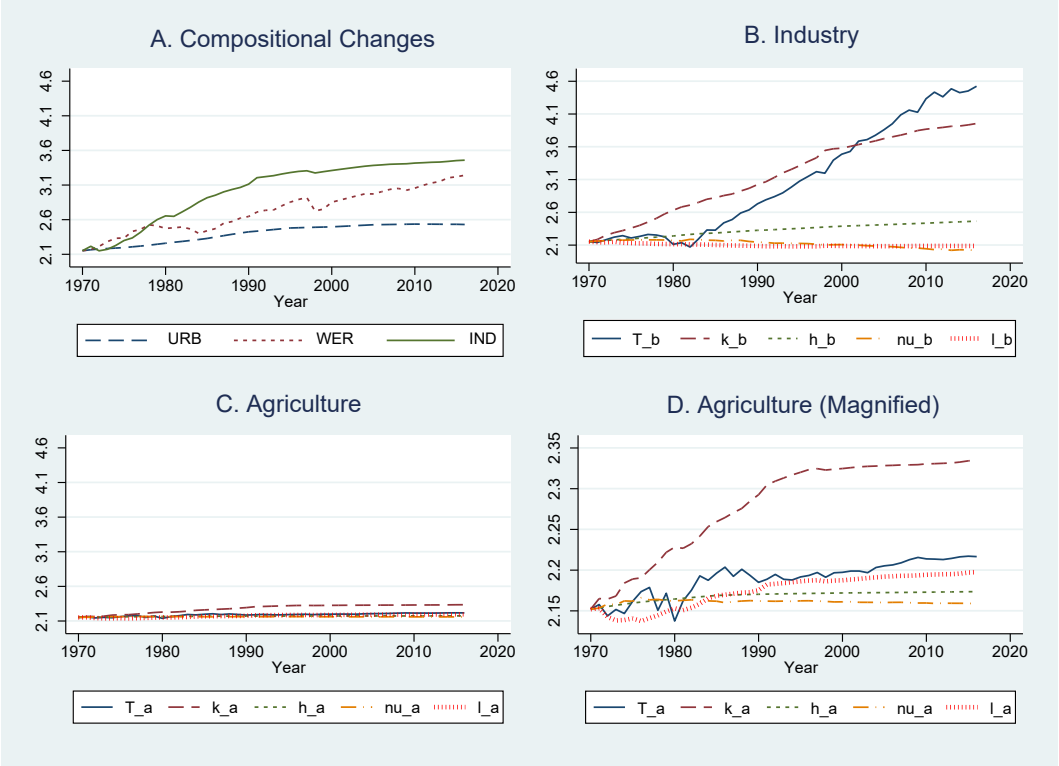
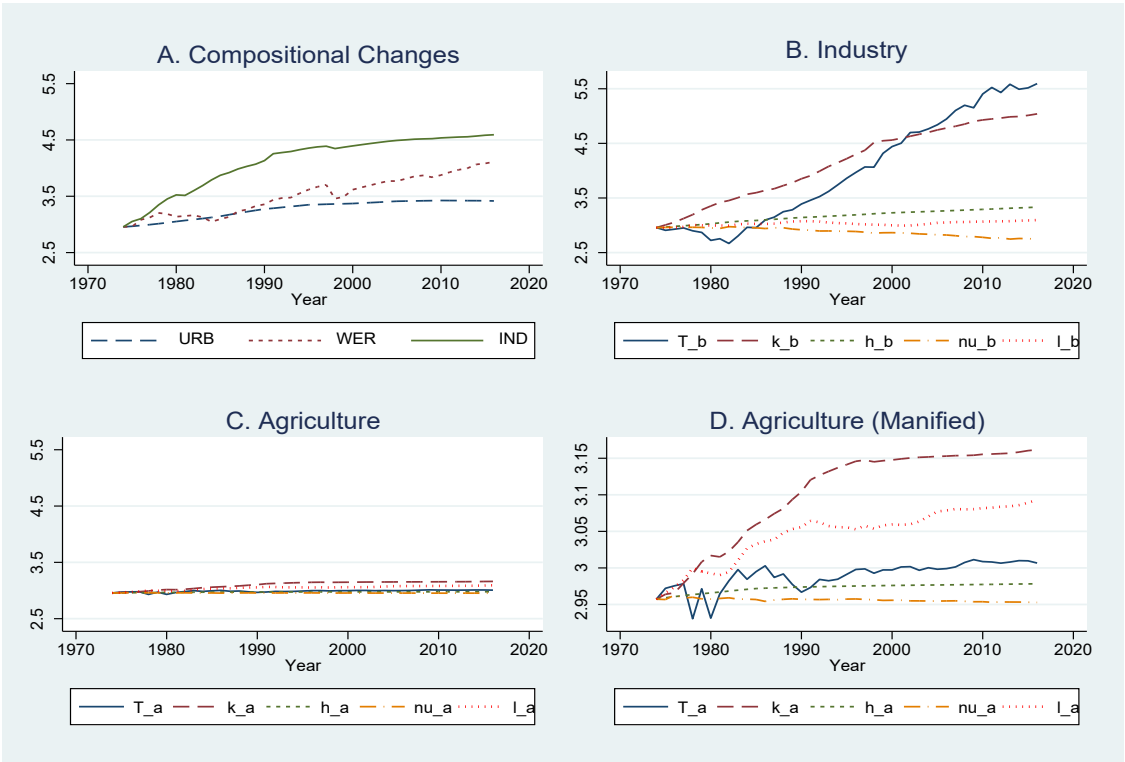


Figure 15. Counterfactual Income Growth Paths with Quality-adjusted Land



5.6.3. Growth Accounting Results

Using the above counterfactual decomposition method, Table 4 presents the quantitative contributions of each of the 13 components to the GDP per capita growth, which are in the growth accounting formulae in equations (26) to (30), for the entire sample period as well as for each sub-period by decade, where the land quantity variables are used. Table 5 shows the growth accounting results with the quality-adjusted land variables. The patterns and order of magnitudes are very close between the two cases. The size of the sectoral TFP growth contributions becomes slightly smaller when using the quality-adjusted land variables. We consider the growth accounting results with the quality-adjusted land variables as our benchmark results and focus to discuss the results in Table 5.

Table 4. Decomposition of GDP per Capita Growth with Land Quantity (%)

Period	URB	WER	IND	T_a	k_a	h_a	ν_a	l_a	T_b	k_b	h_b	ν_b	l_b
’70-’16	0.35	0.89	1.04	0.06	0.18	0.02	0.01	0.05	**1.63**	1.33	0.30	-0.14	-0.07
’70-’80	0.49	1.40	**2.12**	-0.07	0.35	0.06	0.05	0.00	-0.19	**2.03**	0.40	0.08	-0.17
’80-’90	0.71	0.68	1.61	0.22	0.29	0.03	0.00	0.10	**2.60**	1.40	0.38	-0.11	-0.13
’90-’00	0.29	0.75	0.62	0.06	0.14	0.01	0.00	0.06	**2.48**	1.70	0.27	-0.18	0.00
’00-’10	0.16	0.69	0.32	0.07	0.02	0.00	-0.01	0.03	**2.20**	0.78	0.19	-0.30	0.00
’10-’16	-0.04	**0.99**	0.20	0.02	0.03	0.01	-0.01	0.03	0.72	0.37	0.21	-0.20	0.00

Table 5. Decomposition of GDP per Capita Growth Contribution with Quality-adjustment of Land (%)

Period	URB	WER	IND	T_a	k_a	h_a	ν_a	l_a	T_b	k_b	h_b	ν_b	l_b
’74-’16	0.34	0.79	1.05	0.04	0.16	0.02	-0.004	0.11	**1.53**	1.28	0.28	-0.18	0.11
’74-’80	0.52	0.99	**2.97**	-0.15	0.33	0.05	0.001	0.20	-1.36	**2.11**	0.39	-0.03	0.22
’80-’90	0.71	0.68	1.61	0.12	0.29	0.03	-0.001	0.21	**2.21**	1.40	0.38	-0.11	0.26
’90-’00	0.29	0.75	0.62	0.10	0.14	0.01	-0.004	0.01	**2.74**	1.70	0.27	-0.18	-0.25
’00-’10	0.16	0.69	0.32	0.04	0.02	0.005	-0.01	0.07	**1.98**	0.78	0.19	-0.30	0.22
’10-’16	-0.04	**0.99**	0.20	-0.01	0.03	0.01	-0.01	0.06	0.57	0.37	0.21	-0.20	0.16

Considering the conventional image that East Asian growth is driven by mobilizing

inputs of capital and labor rather than by the productivity, the most significant influence of which is made by Young (1995), it is rather surprising to find that Korea's largest contributing component of growth is the productivity growth, neither capital accumulation, nor the increasing the number of workers and work hours. During the process of Korea's structural transformation for the 1974-2016 period, the industry sector TFP growth alone contributed to increasing Korea's real GDP per capita by 1.53% each year on average. The capital accumulation in the industry sector did contribute to the growth substantially by 1.28% each year on average, but it was the second largest component.

It is also interesting to note that the growth effect of the industrialization (inter-sectoral reallocation of workers) is third largest at 1.05%, which is greater than that of the within-sector employment changes at 0.79% (fourth largest growth component). Taking the urbanization effect at 0.34% (fifth largest growth component) also into account as another growth effect from the labor market compositional changes, the overall growth effect of the labor market compositional changes is 1.39%, which is much larger than the growth from the within-sector job creation.

The sixth largest component is the human capital growth in the industry sector, contributing 0.28% each year. The seventh largest one is the effect of the expansion of the agricultural capital per worker by 0.16% each year. The above seven largest contributing components (industrial TFP growth, industrial capital per worker growth, industrialization, within-sector employment rate growth, urbanization, industrial human capital growth, and agricultural capital per worker growth) occupy *95%* of Korea's GDP per capita growth for the 1974-2016 period. Each of the remaining six components contributed to income growth by less than 0.11%, the sum of which occupies 5% of the total GDP per capita growth. The declining work hours contributed slightly negatively.

It is important, however, to emphasize that the above accounting figures do not suggest that the role of the agricultural TFP growth was insignificant for Korea's structural transformation. Table 3 already illustrated that the annual average agricultural TFP growth rate was 1.18% with measuring land in quantity, which is only slightly lower than the industrial TFP growth rate of 1.7%. Adjusting the quality factor for land, the agricultural TFP growth becomes smaller at 0.62% per year, but still a significant size.

The agricultural human capital growth rate of 1.12% is also similar to the industrial

human capital growth rate of 1.25%. The agricultural capital per worker grew at 7.13% each year, even faster than that of the annual average growth rate of the industrial capital per worker at 5.91%. The agricultural land use per worker grew fast at 2.75%, while that of the industry sector declined at -1.69%. However, the contributions of all this active within-agriculture growth to the overall growth are small simply because both output and input shares of the agricultural sector has declined rapidly due to the successful structural transformation. In fact, the agricultural TFP growth promotes the structural transformation by "pushing out" the resources from agriculture to industry, with the feature of non-homothetic preferences for agricultural products as we postulate in our model. This effect is to be indirectly captured as a part of the industrialization effect.

In sum, the rapid growth of the agriculture was indeed an important underlying driving force of Korea's successful structural transformation, but it resulted in a small contribution to the aggregate GDP per capita growth in an accounting sense exactly because of such success.

Comparing the sub-period growth decomposition results across the decades, we find that the major sources of growth have changed over time. In 1970s, which was the take-off period of the Korean economy, two outstanding sources of economic growth were the industrialization (2.97% each year on average) and the capital accumulation in the industry sector (2.11% each year on average), not productivity growth. In fact, the contributions of the sectoral TFP growth to real GDP per capita growth were negative in 1970s, -0.15% for agriculture and -1.36% for industry.

Note that the 1970s was the period when the Korean economy pursued to switch its manufacturing structure from light manufacturing to heavy and chemical industries and also shaped and implemented the export promotion and industrial policies. Furthermore, the rural development initiative, so-called "*Saemaul Undong* (SMU)," which mainly aimed to modernize the rural areas by building the infrastructure of transportation within and nearby villages and irrigation system, reforestation, improving housing, promoting mechanization of farming, and developing new varieties of rice, spread nationwide. Despite these development policy innovations in the 1970s, the overall productivity gains were negligible, in fact slightly negative. However, these changes rather led to tremendous accumulation of capital stock in both agriculture and industry sectors. The capital stock per worker grew by 7.74% for agriculture and 9.59% for industry per year in the 1970s

(see Table 3), contributing to real GDP per capita growth at 0.35% and 2.03%, respectively (see Table 4).

Furthermore, the employment ratio to population increased substantially during the same period. This job creation contributed to real GDP per capita growth by 1.4% each year. People moved from rural to urban areas actively in the 1970s, which contributed to GDP per capita growth by 0.49% during this decade. The human capital growth was also fast in the 1970s and symmetric between two sectors, 1.74% for agriculture and 1.78% for industry (Table 3), contributing to 0.06% and 0.40% to GDP per capita growth, respectively.

In sum, there were so many active development policy innovations during the take-off period of the 1970s, which indeed led to huge economic growth, but the main channels of growth were the within-sector input growth (capital accumulation, job creation, and human capital accumulation), and the employment shift from agriculture to industry, rather than the productivity growth. This is the typical image of the so-called "East Asian miracles" in the literature and also in the policy dialogues.

For the following three decades between 1980 and 2010, however, the largest component of Korea's economic growth was the industry sector TFP growth in magnitudes of 2.21%, 2.74%, and 1.98% per annum on average, respectively for the 1980s, 1990s, and 2000s. That is, Korea's growth mechanism switched from the input-driven (or the "perspiration-based") to productivity-driven (or the "inspiration-based) one, starting in the 1980s and being maintained for three decades. This seems to be the most critical "transformation" of the Korean economy.

This feature of Korea's transformation of the main driving force for growth during the long-term process of structural transformation is not well recognized in the literature, which in fact is the fundamental reason for Korea's rapid *and* sustainable economic growth, and this created a new phase of growth of the Korean economy since it started its modern economic growth in the 1960s.

The above feature presents an image of the process of Korea's economic growth different from the conventional wisdom about East Asian miracles, for example described in Young (1995). However, this does not mean our findings conflict with his. Young's growth accounting exercise was done for the 1960-1990 period for the economy *excluding*

agriculture (so that his "economy" corresponds to our industry sector).[14] This implies that he missed out the growth effects from industrialization and urbanization. Furthermore, his study period ends in 1990 so that the industry-sector productivity growth only in the 1980s was included and for most of the sample period of his study covers the input-driven growth period of Korea. In fact, the TFP growth of his "economy" excluding agriculture in Young (1995) was 2.4-2.6% for the 1980s, which is close to our industry sector TFP growth of 2.21% for the same period. Young (1995) did not seem to have observed long enough to envision the long-run process of structural transformation, at least for Korea.

There were other important aspects of Korea's growth during the three-decade productivity-driven growth era. In the 1980s, the growth effects of industrialization and urbanization were still significant at 1.61% and 0.71% per year, respectively. However, the growth effects from such compositional changes of labor market demography quickly diminished for the following three decades. In contrast, there was no noticeable trend for the growth effect of the within-sector employment rate changes since the 1980s. The growth effect from capital accumulation also started to diminish after the 1990s and onward. This declining trend of capital accumulation effect was much more salient for agriculture than for industry. The per worker human capital growth effect also declined over time but much more slowly. The growth effects from the changes of per worker work hours were negligible in agriculture, but they were negative in industry. As we explained previously, the per worker land increased in agriculture and decreased in industry, particularly during the early periods of the 1970s and 1980s, mainly because the magnitudes of the reallocation of workers were larger than those of the amount of land use.

Table 3 suggests there was another critical moment for the Korea's TFP by the end of the sample period. The industry sector growth rate of TFP suddenly dropped from 2.03% in the 2000s to 0.59% for the following six years. The agricultural TFP growth rate also dropped from 1.4% in the 2000s to -0.62% for the 2010-2016 period.

Table 6 re-groups the growth components of Table 5 into the broad categories of "Compositional Changes" (summing the two effects of compositional changes, IND and URB terms), "Within-sector Employment Rate" (WER), "Within-sector TFP" (summing the effects of T_a and T_b), and "Within-sector Inputs per Worker" (summing up the rest of

[14] See Table VII on page 660 in Young (1995) for his growth accounting results for Korea.

the effects of per worker inputs of capital, human capital, work hours, and land of both sectors).[15] The comparison of the changing patterns of these four terms suggests the overarching patterns of Korea's economic growth during its structural transformation.

Table 6. Broad Categories of GDP per Capita Growth (%)

Period	'74-'16	'74-'80	'80-'90	'90-'00	'00-'10	'10-'16
GDP per Capita	5.70	6.68	8.29	6.32	3.98	2.34
Compositional Changes	1.39	3.49	2.32	0.91	0.48	0.16
Within-sector Employment Rate	0.79	0.99	0.68	0.75	0.69	0.99
Within-sector TFP	1.57	-1.51	2.33	2.84	2.02	0.56
Within-sector Inputs per Worker	1.78	3.27	2.46	1.70	0.98	0.63

The top row of Table 6 shows that the growth rate of GDP pe capita peaked in the 1980s at 8.29%, and then monotonically declined over decades, eventually reaching at 2.34% for the 2010-2016 period, so that the current low growth era is in fact not a surprising phenomenon for Korea. It has been following the trend and current low growth should have been expected since the 1990s.

Table 6 clarifies what are the major sources contributing to such declining trend of growth. The growth effect from the compositional changes (industrialization and urbanization effects) declined from 3.49% in the 1970s to 0.16% for the 2010-2016 period. The growth from the within-sector per worker inputs expansion also declined from 3.27% in the 1970s to 0.63% for the 2010-2016 period. The correlation coefficient between the GDP per capita growth rates and the growth due to the structural transformation (the compositional changes term) turns out to be very high at 0.75, and the correlation coefficient between the GDP per capita growth rates and the growth due to the within-sector per worker inputs expansion is also high at 0.83.

The growth from the compositional changes is supposed to decline because there exist upper bounds, the sectoral share being bounded by one. As we discussed before, due to Korea's successful structural transformation, the growth effect from the compositional changes of Korea's labor market was very high during the early take-off periods. However,

[15] The sum of the four broad categories of growth terms does not include the approximation error, so that this sum is slightly different from the actual GDP per capita growth.

their contribution quickly diminished in later periods, obviously approaching zero.

Furthermore, the simple force of the "diminishing returns" for factor accumulation, envisioned by Solow (1956), tends to lower the growth owing to the expansion of inputs. The Korean economy was not an exception. Such force of diminishing returns began to reveal its power to Korea's growth process particularly after the year 2000. From Table 5, where the within-sector inputs contributions are further decomposed into eight kinds of input factors (four factors by two sectors), we can confirm that the declining contribution to growth is the most salient for the industry sector capital accumulation. The declining trend of the growth from human capital accumulation was much more gradual and moderate. In sum, the declining trend of economic growth seems to be a "natural" process for Korea over such a long-term period.

Unlike the above two categories of growth sources, the growth effects from the changes of within-sector employment rate and also from the within-sector TFP growth do not show such monotonic decreasing trends. The within-sector employment rate effect was the largest in the 1970s at 0.99%, which dropped to the level around 0.7% being maintained for the following 30 years, and then jumped to 0.99% for the 2010-2016 period when the GDP per capita growth rate decreased below 2.5%.[16]

The within-sector TFP growth effect shows two critical turning points of 1982 (from near-zero to strong positive rate) and 2011 (sudden drop toward zero from strong positive rate) rather than following gradual movements. The correlation coefficient between GDP per capita growth and the within-sector employment rate effect is negative at -0.40. That is, the growth from the increasing within-sector employment tends to happen during the low-growth era. The correlation coefficient between GDP per capita growth and the within-sector TFP growth effect is insignificant at 0.13.

5.6.4. Sensitivity Analysis for the Time-Varying Factor Shares

Here, we check if the main features of Korea's economic growth during the long-run

[16] This sudden increase of the growth effect from the employment to population ratio changes is due to the off-trend increase of the labor force participation among women and the elderly population, because of the low growth.

process of structural transformation remain robust to the specification of production function by allowing the time-varying factor shares.

Table 7 shows the growth accounting results when we allow the factor shares to vary over time for the case of adjusting the quality of land. We find that the contribution of the within-sector TFP during the overall period of 1974-2016 slightly decreases from 1.57% (1.53% from industry and 0.04% from agriculture) to 1.43% (1.32% from industry and 0.11% from agriculture). Comparing the TFP growth between Table 5 and Table 7 for each decade, within-sector growth components such as TFP, capital, and human capital growth fluctuate more by allowing the time-varying factor shares than the specification of Cobb-Douglas form of production function. This is not surprising because the weight variables of output and input shares vary more when allowing time-varying factor shares. However, time-varying patterns of each growth component remain robust to the changes of the factor shares. The only noticeable change is that the contribution of the agricultural TFP growth in 1970s turns to slightly positive (0.05%) from the slightly negative one (-0.15%). All the rest of the temporal and long-run growth patterns of the benchmark specification of fixed factor shares are not disturbed by the changes of factor share specification.

Table 7. Decomposition of GDP per Capita Growth Contribution Allowing Time Varying Factor Shares (%)

Period	URB	WER	IND	T_a	k_a	h_a	v_a	l_a	T_b	k_b	h_b	v_b	l_b
’74-’16	0.34	0.79	1.05	0.11	0.15	0.02	-0.003	0.10	**1.32**	1.29	0.28	-0.14	0.10
’74-’80	0.52	0.99	**2.97**	0.05	0.31	0.06	-0.001	0.21	-2.77	**2.52**	0.47	-0.06	0.11
’80-’90	0.71	0.68	1.61	0.23	0.30	0.03	-0.002	0.17	**1.93**	1.49	0.45	-0.11	0.22
’90-’00	0.29	0.75	0.62	0.19	0.12	0.01	-0.004	0.01	**2.91**	1.56	0.23	-0.15	-0.25
’00-’10	0.16	0.69	0.32	0.01	0.03	0.003	-0.005	0.08	**2.02**	0.69	0.14	-0.22	0.26
’10-’16	-0.04	**0.99**	0.20	-0.04	0.04	0.003	-0.003	0.08	0.71	0.30	0.11	-0.10	0.20

5.7. “Omitted Variable Biases” of Measuring TFP

From the nature of measuring TFP, i.e. measured by the residual of output growth subtracted by the growth of all “specified inputs,” the measured TFP depends on the specification of the production functions. The typical list of the specified inputs includes

the capital, the labor employment, often the human capital, and sometimes the work hours. The agricultural literature often includes land in the list of specified inputs. However, the literature of structural transformation omits land in the list of specified inputs for the sectoral production functions.

As we argued earlier, the inter-sectoral transfer of resources is a key feature of the structural transformation. In particular, for the economies in the process of structural transformation from agriculture to industry, the changes of the land use between the two sectors are critical in characterizing the process of the structural transformation itself. Thus, the omission of land would have substantial effects on the measurement of the sectoral as well as the aggregate TFPs.

It is important to notice that there is an additional measurement error for the within-sector TFP growth in relation to the within-sector factor shares and factor accumulation, as long as we maintain the conventional method of measuring capital share from the residual share of the wage bill share from the national income account. To be specific, suppose the land is omitted in the sectoral production function such that

$$Y_{i,t} = \tilde{T}_{i,t}^{L} \, K_{i,t}^{\tilde{\alpha}_i^K} (N_{i,t} h_{i,t} \nu_{i,t})^{\alpha_i^N},$$

and the capital share is measured as the residual share of the wage bill from the national income account such that $\tilde{\alpha}_i^K = 1 - \alpha_i^N$, while the genuine capital share is given by $\alpha_i^K = 1 - \alpha_i^N - \alpha_i^L$. Then, comparing this specification of sectoral production function with the genuine one in equation (2), we find that the relationship between the mis-measured sectoral TFP $\tilde{T}_{i,t}^{L}$ owing to the omission of land and the genuine sectoral TFP $T_{i,t}$ can be characterized by

$$\tilde{T}_{i,t}^{L} = T_{i,t} L_{i,t}^{\alpha_i^L} K_{i,t}^{-\alpha_i^L}. \quad (35)$$

The measurement error for the sectoral TFP from the added term $L_{i,t}^{\alpha_i^L}$ in equation (35) is related to the re-allocation of land during the structural transformation. Through this term, the agricultural TFP is under-estimated, while the industry sector TFP is over-estimated, if land is omitted in the sectoral production function. However, there is the second term $K_{i,t}^{-\alpha_i^L}$ in equation (35), which is related to the mis-specification of the capital share from the conventional way of measuring capital share as a residual of the wage bill

share. This term tends to under-estimate for both sectors when the sectoral capital expands. Combining these two effects, the agricultural TFP would be under-estimated for sure if omitting land, and the overall effect of omission of land for the industry sector is unclear a priori, depending on the relative speed of expansion between capital and land. We may well consider the capital accumulation to be faster than the expansion of land for the industry sector so that the industry sector TFP growth tends to be under-estimated as well, when the land input is measured in physical amount. However, the relative speed of expansion between capital and land is unclear a priori when the quality adjustment is made for land use. This is an empirical question, which we seek to answer here.

A corollary of equation (35) is that there may be no measurement errors for the TFP growth from omitting land if the land-to-capital ratio $L_{i,t}/K_{i,t}$ is maintained constant. This corollary holds good regardless of the value of the land share α_i^L. This shows that the fundamental source of the measurement error for the TFP growth from omitting land is the disparity between the changes of the land and the capital accumulation. When the changes of the land and the capital accumulation differ in the course of economic growth, the magnitude of the measurement error of the TFP growth increases in land share. Our case of mis-measurement of the sectoral TFP growth due to the inter-sectoral transformation of land use provides one such example.

The work-hours per worker is another typical omitted variable in measuring the sectoral level TFP, because quantifying these variables at sectoral level requires intensive measurement exercises using micro data. In fact, there are no previous empirical studies of structural transformation which include separate measurement of the work-hours. The relationship between the mis-measured sectoral TFP $\tilde{T}_{i,t}^N$ owing to this omission of the per worker work-hours $\nu_{i.t}$ and the genuine sectoral TFP $T_{i,t}$ can be characterized by

$$\tilde{T}_{i,t}^N = T_{i,t}(\nu_{i.t})^{\alpha_i^N}. \quad (36)$$

Equation (36) illustrates that the sectoral TFP would be over-estimated when the within-sector work-hours increase, and under-estimated otherwise.

In sum, the mis-measured sectoral TFP $\tilde{T}_{i,t}$ from the combined omission of land and work-hours is given by

(37) $\tilde{T}_{i,t} = T_{i,t}\left(\frac{L_{i,t}}{K_{i,t}}\right)^{\alpha_i^L}(\nu_{i.t})^{\alpha_i^N}$.

Figure 16 compares the different sectoral TFP paths across the varying specifications of production factors. Figure 16.A illustrates that both the patterns of movement and the order of magnitudes of TFP change substantially for agriculture, depending on the inclusion of land. Omission of work hours does not affect the agricultural TFP much. However, omission of land substantially underestimates the agricultural TFP such that the positive growth rate of 0.62% per year over the 1974-2016 period becomes -0.08% if omitting the land in the agricultural production function. Omission of work hours also underestimates the agricultural TFP, but only slightly from 0.62% to 0.47%. If only the land quantity is used without adjusting the quality factor, the agricultural TFP is overestimated at 1.34% per year. Thus, inclusion of land as an explicit production factor as well as filtering the price effect of land seem to be an important adjustment for correctly measuring agricultural TFP.

Figure 16.B shows that the temporal patterns of movement of the industry sector TFP seem fairly robust to the changes of specification of production factors such as omission of land amount, land quality, or the work hours. The patterns of the fall in the 1970s, the steady and rise for the following three decades, and the stagnation after 2011 remain virtually the same for the industrial TFP whether to include the quantity and quality of land, or work hours within the industry sector. However, the order of magnitudes of the industrial TFP growth changes substantially depending on the inclusion of work hours, but not much on land. For example, the annual average rate of industrial TFP growth at 1.58% falls to 1.06% omitting work hours, but only to 1.44% omitting land. Without adjusting the land quality, annual average rate of industrial TFP growth becomes 1.75%. Combined omission of both land and work hours makes the industrial TFP growth at 0.91%. Furthermore, this underestimation effect kicks in for the later period after 1990, so that we observe the widening gap across specifications in Figure 16.B. Thus, Korea's industry sector TFP may appear to have slowed down since the 1990s if omitting land and work hours, even though its growth rate was steady and strong during the 1990-2011 period.

In sum, omission of land (quantity and quality) and work hours substantially affects the measurement of the sectoral TFP paths during the long-run process of structural transformation.

Figure 16. Comparison of Sectoral TFPs across Factor Specifications

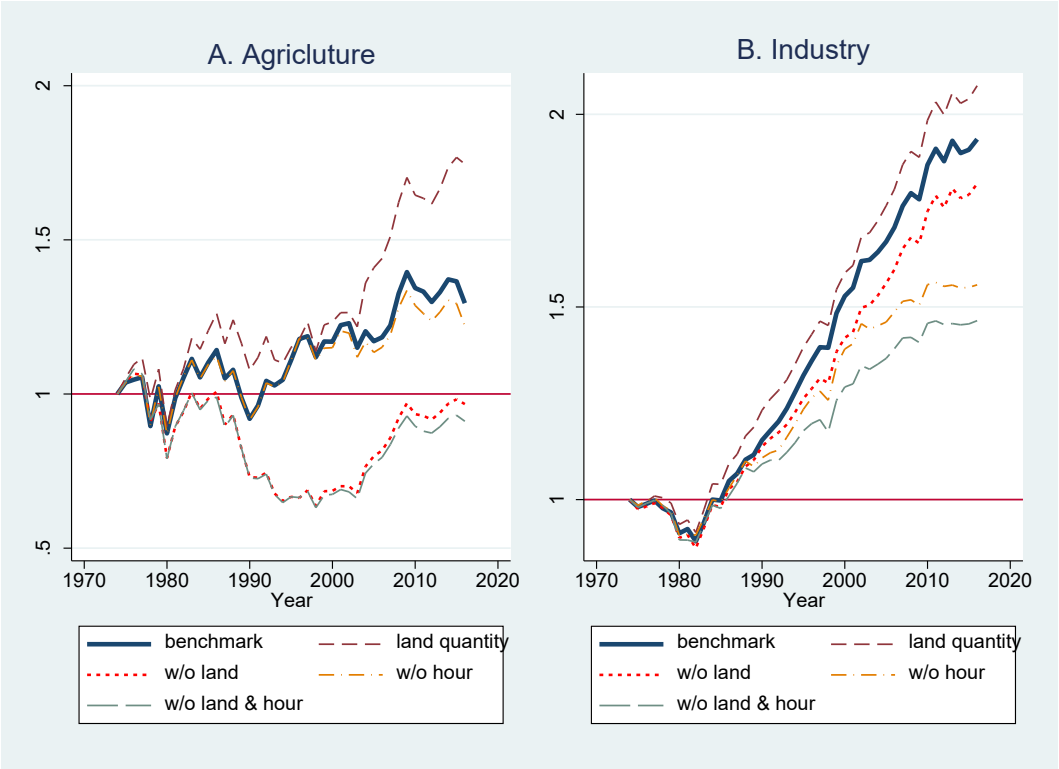
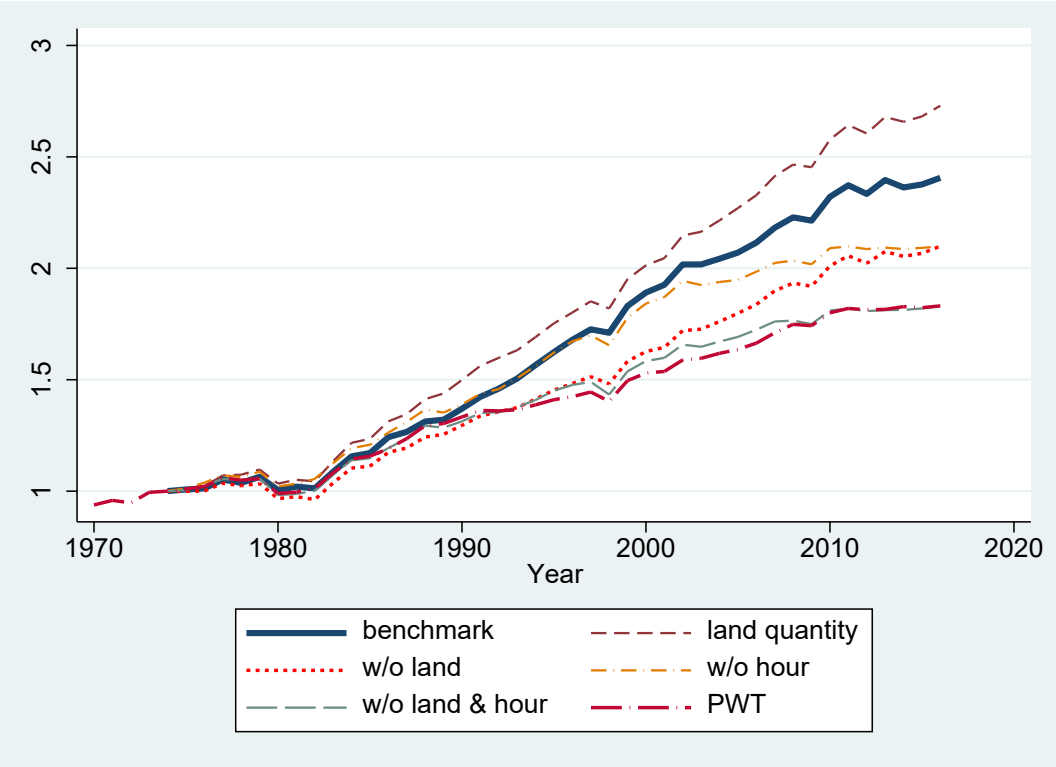


Figure 17 shows the effects of omission of land and work hours for the aggregate TFP. The annual average rate of aggregate TFP growth is 2.11% for our benchmark specification which fully includes quantity and quality of land as well as the work hours. Such growth rate reduces to 1.78% by omitting land, and further reduces to 1.45% by omitting land and work hours. The effect of omission of land started to be sizable early at 1990, but the effect of omission of work hours became significant only after the mid-2000s. We also compare our aggregate TFP with the Korean TFP from Penn World Table version 9.1 (measured by the "rtfpna" variable). The annual average rate of the Korean TFP growth from the PWT data is 1.45%, which is similar to our aggregate TFP growth rate if omitting land and work hours. In fact, the temporal patterns of movement between our measure of the aggregate TFP with omitting land and work hours and the TFP from the PWT data are very similar. This comparison suggests a possibility that the TFP growth from the PWT underestimates the genuine TFP growth because of its omission of land as a production factor.

Detailed comparison of changes of sectoral and aggregate TFP growth from omitting

land itself, work hours, and land quality adjustment for each decade is reported in Tables A2 to A4 in the Appendix.

Figure 17. Comparison of Aggregate TFPs across Factor Specifications



5.8. Interpreting the Critical Momentum of Korea's TFP Growth

We observed that there were two critical momentums for Korea's TFP growth during its long-term process of structural transformation. Figure 18 illustrates the entire paths of the aggregate and sectoral TFP series to sort out the turning points of the TFPs precisely. First momentum was the switch from negative to strong positive TFP growth, starting in the 1980s and being maintained for the following three decades. Second one was the sudden drop of the long-standing positive TFP growth into negligible or negative TFP growth, starting from the year 2011.

The level of Korea's GDP per capita (PPP adjusted and in 2011 real value term) belong to the range of $5,000 to $11,000 in the 1980s, which shifted to the range of $12,000 to $20,000. According to the World Bank classification of country income groups, the

upper bound of the middle-income group is around $12,000. That is, Korea crossed from the middle-income to high-income country group in the 1980s, which coincides with the period of the switch of Korea's growth mechanism from input-driven to productivity-driven one. That is, the Korean economy was not caught into the so-called "middle-income trap," because of the first momentum of TFP growth in the 1980s. For the remaining three decades, Korea's GDP per capita further increased to the level of $37,000 without experiencing significant medium-term or long-term recessions. Jeong (2018) performed an interesting counterfactual calculation in a single-sector growth model that Korea's real GDP per capita level would have been the level of South Africa in 2014 if Korea's economic growth were based only on inputs growth without productivity growth. Thus, the 1980s momentum of TFP growth switching the growth mechanism was the most critical reason behind the sustainable development of Korea for the last six decades.

Identifying the underlying reasons of such critical switch would be an ultimate agenda for researchers and policy makers to understand and promote the growth process. This paper does not provide direct causal evidence for such agenda yet. This would require different modeling strategy and deeper level of data. However, this paper does provide some important insights. First of all, our study suggests that such switch is *possible* from Korea's development experience. Perhaps this can be the most important lesson for other developing countries. Second, we found that such triggering of TFP growth happened in both the agriculture and industry sectors, although the magnitude was stronger and more lasting in industry than in agriculture. That is, the switch from the input-based growth to productivity-based growth seems to be related to some sort of the transformation of the entire economy rather than to the sectoral phenomena. Our detailed decomposition analysis by sector and by decade shows that substantial accumulation of physical and human capital preceded during the initial stage of structural transformation before the strong TFP growth turned on in both sectors. This suggests a possibility that such precedent and active capital accumulation might have served a basis for the future productivity growth, being materialized via some channels like learning-by-doing effects (through human and/or physical capital), in particular for the industry sector, or changing comparative advantages (through industrial and/or promotion of external competition policies). Another hypothesis for the underlying cause for the aggregate change of the Korean economy would be the initiation of the shift of resource allocation mechanism in the 1980s from a more or less government-intervened one to a decentralized one relying more on markets, although the

government's visible hands were still there. It is interesting to notice that Korean politics also started to make significant progress toward democracy in the 1980s. They all can be critical reasons for turning the TFP growth on.

These are informed guesses in the literature about Korean or East Asian growth, but yet to be confirmed by future studies. We believe that all the above reasons contributed to the switch from the input-based to productivity-based growth for the Korean economy, but perhaps with different weights. Whatever the underlying reasons are, Korea's development experience emphasizes that the activation of the long-lasting TFP growth did not come out of the air. Enough accumulation of physical and human capital together with political economic institutions seems to be a necessary pre-condition.

The second momentum of Korea's TFP growth was a negative one and we already mentioned that the sudden drop of TFP growth around the year 2011 happened also in both sectors (dropping from 2.03-2.85% in 1990s and 2000s to 0.59% in 2010s for industry sector, from 1.4-2.43% in 1990s and 2000s to -0.62% in 2010s for agriculture) so that such turn-off of the TFP growth is likely to be related to some economy-wide factors.

One obvious observation is that such sudden change in trend of the sectoral TFP is not the consequence of the Asian financial crisis in terms of timing, which happened in 1998. Indeed, the industry sector TFP dropped around the year 1998 but quickly recovered to the previous trend after only a year. Another guess could be that it might have something to do with the 2008-2009 global financial crisis. However, Figure 18 shows that this is not the case either, at least for the industry sector. The industry sector TFP indeed decreased during the global financial crisis period, but again recovered back to the previous trend within a year. The stagnation of the industry sector TFP started in 2011 in fact after its strong recovery for the 2009-2011 period. The agricultural TFP actually increased during the 2008-2009 period, although it stagnated a year after. Thus, two most important external financial shocks do not seem to be direct reasons behind the sudden decrease of the TFP growth, although we may not be able to rule out their indirect effects.

Identifying the underlying reasons of this second momentum for Korea's TFP growth is another important challenge and this is a current issue for Korea. This paper does not provide direct causal evidence for this change either. However, this paper does provide circumstantial evidence being consistent with the previous perspective of explaining the

first momentum, but in opposite direction. The annual growth rate of per-worker physical capital accumulation in the industry sector more than halved from 7.28% in 1990s to 3.32% in the 2000s, which further dropped to 1.57% after 2010. In fact, such sudden drop of the growth of the capital per worker is due to the drastic decrease of capital investment among large conglomerate companies. There are many possible reasons at deeper level such as the regulation and labor marker rigidity or the various kinds of uncertainties in relation to the future technical progress or to the global market economy. Furthermore, it is well documented in Lee, Jeong, and Hong (2018) that Korea's human capital accumulation failed to transform from quantity-based to quality-based model. In sum, the recent stagnation of Korea's TFP growth after 2011 may be the consequence of the failure of investing in right amount and right kinds of capital, both physical and human. Furthermore, at deep down level, the institutional and organizational inertia of Korean society which did not properly and actively adapt to the changes of global and technological changes might well be the root cause of such malfunctioning investment.

The timing of the second momentum is particularly concerning for Korea, observing that the stagnation of TFP growth happened around the time when the capital-out ratio became stabilized. This is because the proper variable in making judgement about the distance of the economy from the steady state is the *capital-output ratio* and the only source of growth is the productivity growth in steady sate.

Figure 19 displays the aggregate and the sectoral capital-output ratios of the Korean economy during its structural transformation. It is interesting to notice that the periods of the short-term jumps of the capital-output ratios are associated with those of the TFP shocks. This is not surprising because the capital accumulation was much smoother than the TFP changes. A more important observation is that the aggregate and sectoral capital-output ratios became constant after the year 2011, so that we may consider that Korean economy reached nearby the steady state with the arrival of the second momentum of the stagnant TFP growth. This observation manifests that the Korean economy might be captured by the "high-income trap" and fall behind from the frontier unless the root causes of the current stagnation of TFP are sorted out and innovative breakthroughs are implemented.

Figure 18. Turning Points of TFP

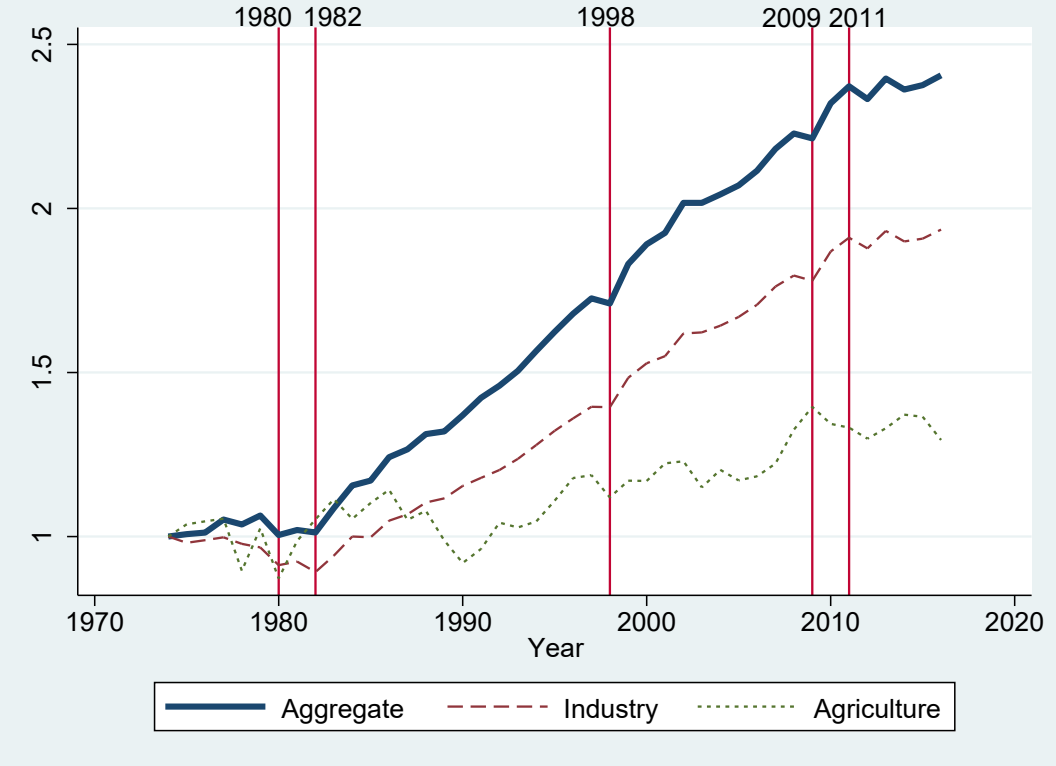
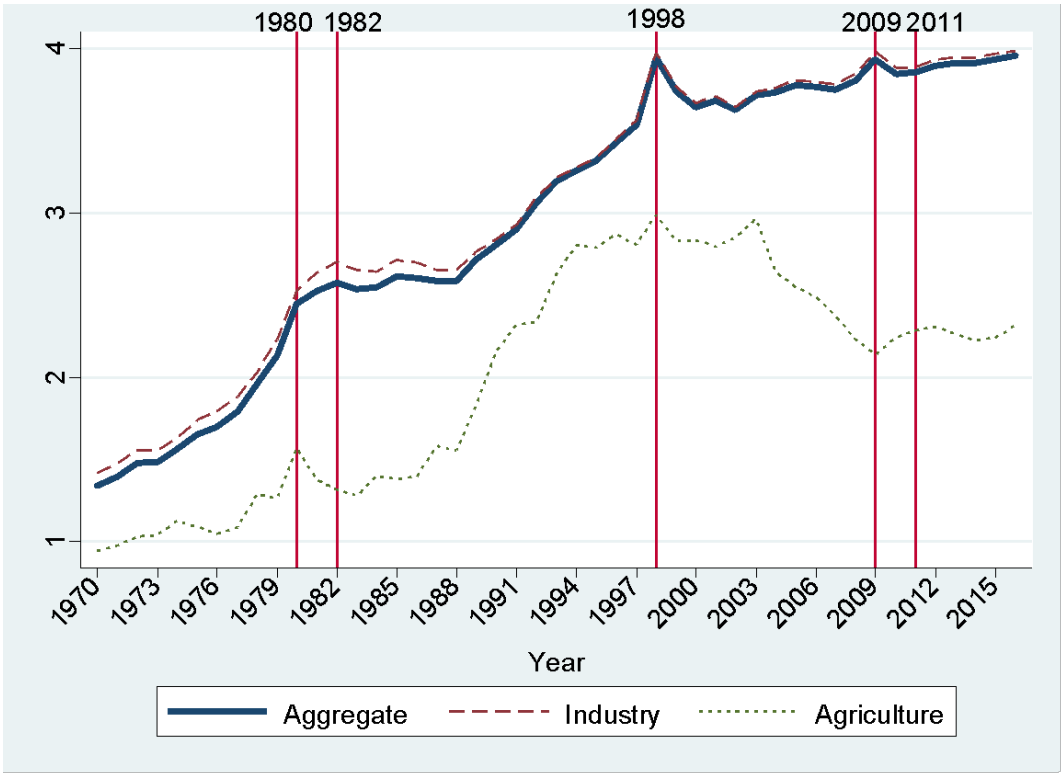


Figure 19. Trends of Capital-Output Ratio



6. Efficiency Dynamics of Korea's Structural Transformation

6.1. Method of Wedge Analysis for Structural Transformation

A key idea of our wedge analysis is to measure the distance of the optimality conditions from the data, and to trace its movements over time to identify the changing patterns of the potential distortions in resource allocation.

In the context of our two-sector growth model with the three factors of capital, labor, and land, there are four optimality conditions: three conditions of the inter-sectoral allocation for each factor and the fourth one about the intertemporal allocation of investment goods. These optimality conditions can be summarized such that three "inter-sectoral marginal rates of substitution" of τ_t^N, τ_t^K, and τ_t^L, and an "inter-temporal marginal rate of substitution" τ_t^I should be set to unity, where the marginal rates of substitution are defined as:

$$\tau_t^N \equiv \frac{F_{b,t}^N}{F_{a,t}^N}\frac{u_{b,t}}{u_{a,t}},\ \tau_t^K \equiv \frac{F_{b,t}^K}{F_{a,t}^K}\frac{u_{b,t}}{u_{a,t}},\ \tau_t^L \equiv \frac{F_{b,t}^L}{F_{a,t}^L}\frac{u_{b,t}}{u_{a,t}},\ \text{and}\ \tau_t^I \equiv \beta\frac{u_{b,t+1}}{u_{b,t}}\left(1+F_{b,t+1}^K-\delta\right).$$

If any one of the marginal rates of substitution deviates from unity, there exists a room to increase the consumer welfare by reallocating the resources. For example, suppose τ_t^N exceeds unity, then we have $F_{b,t}^N u_{b,t} > F_{a,t}^N u_{a,t}$. This means that the marginal contribution of industrial employment to consumer welfare exceeds that of the agricultural employment, so that by moving labor from agriculture to industry sector, overall welfare can be improved. This implies that observing $\tau_t^N > 1$ evaluated at the actual data, the current industrial employment level relative to the agricultural employment is lower than the optimal level. This may indicate the presence of some (distortionary) policies or institutional measures that prevent the movement of labor from agriculture to industry at the optimal level. The increase of τ_t^N (exceeding unity) suggests that such tendency gets reinforced, while its decrease toward unity implies such distortionary tendency gets relaxed. We can interpret the other wedge measures of τ_t^K and τ_t^L in a similar way.

Regarding the investment wedge, suppose $\tau_t^I > 1$, i.e., $\beta u_{b,t+1}\left(1+F_{b,t+1}^K-\delta\right) > u_{b,t}$. This means that the marginal value of future consumption from investment exceeds that of the current consumption, so that there exists room to expand the current investment (i.e.,

to move the current consumption to future consumption) to increase consumer welfare. In other words, $\tau_t^I > 1$ indicates that current level of investment is lower than optimum, i.e. "under-investment." Similarly, $\tau_t^I < 1$ signals "over-investment" of actual resource allocation.

In this sense, the deviations of these four ratios from unity can be considered to measure the magnitudes of the distortions of resource allocation, which might be related to some underlying policies or institutional features of the economy. Thus, we call the above four ratios of the marginal rates of substitution τ_t^N, τ_t^K, τ_t^L, and τ_t^L as "labor wedge," "capital wedge," "land wedge," and "investment wedge", respectively.

6.2. Calibration of Wedges for Korea's Structural Transformation

The four ratios of the marginal rates of substitution from the functional forms of the technology and preferences of our model were described in equations (16) to (19) in Section 2, which are rewritten here for convenience:

(16) $\tau_t^N = \frac{\alpha_b^N}{\alpha_a^N}\left(\frac{Y_{b,t}/N_{b,t}}{Y_{a,t}/N_{a,t}}\right)\left[\frac{\eta_b}{\eta_a}\left(\frac{c_{a,t}-\zeta_a}{c_{b,t}+\zeta_b}\right)\right]^{\frac{1}{\epsilon}}$,

(17) $\tau_t^K = \frac{\alpha_b^K}{\alpha_a^K}\left(\frac{Y_{b,t}/K_{b,t}}{Y_{a,t}/K_{a,t}}\right)\left[\frac{\eta_b}{\eta_a}\left(\frac{c_{a,t}-\zeta_a}{c_{b,t}+\zeta_b}\right)\right]^{\frac{1}{\epsilon}}$,

(18) $\tau_t^L = \frac{\alpha_b^L}{\alpha_a^L}\left(\frac{Y_{b,t}/L_{b,t}}{Y_{a,t}/L_{a,t}}\right)\left[\frac{\eta_b}{\eta_a}\left(\frac{c_{a,t}-\zeta_a}{c_{b,t}+\zeta_b}\right)\right]^{\frac{1}{\epsilon}}$,

(19) $\tau_t^I = \beta\left(\frac{c_{t+1}}{c_t}\right)^{\frac{1}{\epsilon}-\frac{1}{\sigma}}\left(\frac{c_{b,t+1}+\zeta_b}{c_{b,t}+\zeta_b}\right)^{-\frac{1}{\epsilon}}\left(\alpha_b^K\frac{Y_{b,t+1}}{K_{b,t+1}}+1-\delta\right)$,

where $c_t = \left[\eta_a^{\frac{1}{\epsilon}}(c_{a,t}-\zeta_a)^{\frac{\epsilon-1}{\epsilon}} + \eta_b^{\frac{1}{\epsilon}}(c_{b,t}+\zeta_b)^{\frac{\epsilon-1}{\epsilon}}\right]^{\frac{\epsilon}{\epsilon-1}}$.

A similar wedge analysis was implemented for China from a different motivation by Cheremukhin, Golosov, Guriev, and Tsyvinsky (2017). The specification of technology and preferences of their model is a nested case of ours. Their sectoral production functions

are similarly specified as ours, but without land, human capital, and work hours.[17] Their utility function is a special case of ours, where they assume perfect substitutability between intertemporal consumptions (i.e., $\sigma = \infty$) and no non-homothetic parameter for the industry sector consumption (i.e., $\zeta_b = 0$). We allow imperfect substitution of intertemporal consumption and also the non-zero non-homothetic parameter for the industry sector consumption as we specified in equations (4) and (5) in Section 2.

We calibrate the parameters for our calculation of wedges as follows. The time discount factor $\beta = 0.96$, capital depreciation rate $\delta = 0.06$, the weight parameter for agricultural consumption $\eta_a = 0.15$ (the value of the long-run food expenditure share in the historical literature), and the inter-sectoral elasticity of substitution parameter $\epsilon = 1$ (i.e., the Stone-Geary preferences).[18]

The intertemporal elasticity of substitution parameter $\sigma = 1$, referencing the study of Gandelman and Hernandez-Murillo (2014).[19] This is the same specification of the log-linear intertemporal utility of Herrendorf, Rogerson, and Valentinyi (2014).

We select the subsistence level of the agricultural consumption by referencing the internationally accepted daily poverty line of $2. We measure the per capita consumption in unit of million KRW in annual frequency. Converting the daily value of $2 into annual million KRW using the PPP-adjusted KRW-USD exchange rate, the poverty income threshold is 0.6 million KRW. The average food expenditure share of Korea in the 1970s was 40%, so that we choose $\zeta_a = 0.6 * 0.4 = 0.24$.

For the non-homothetic constant parameter for the industry sector, we follow the discussion of Herrendorf, Rogerson, and Valentinyi (2014) about the generalized balanced-growth-path condition for the multiple-sector growth model with non-homothetic preference parameters in Stone-Geary form, which requires:

[17] We discussed the "omitted variable biases" from excluding the land, human capital, and work hours in measuring the sectoral and aggregate TFP variables and the potential danger of analyzing the two-sector growth model by feeding the mis-measured TFP variables.

[18] These parameters are common between the model of Cheremukhin, Golosov, Guriev, and Tsyvinsky (2017) and ours, and we calibrate them as they do for the purpose of promoting comparability between the two studies.

[19] Their survey shows that the distribution of the estimates of the CRRA parameter from the 127 countries is concentrated around the average value of 0.98.

(38) $\frac{\zeta_a}{\zeta_b} = \frac{T_{a,0}}{T_{b,0}}$.

Given our choice of $\zeta_a = 0.24$ and the sectoral TFP estimates at the initial period, we calibrate $\zeta_b = 0.36$, being consistent with this generalized BGP condition.[20] Our way of choosing the parameter ζ_b has cons and pros. Calibrating ζ_b with satisfying the generalized BGP condition, our wedge analysis is considered to be consistent with the context of the long-run growth path. This is an important benefit. However, this calibration method relies on the estimates of the initial sectoral TFP, which may change as the specification of production functions does, so that the calibration of preference parameter hinges on the specification of technology. Some may think this as a con while the other may think as a pro condition in choosing ζ_b.[21] We choose to follow the way of being consistent between preferences and technology specifications in calibrating ζ_b and will perform sensitivity analysis to check the quantitative importance of this way of calibrating ζ_b. Table 8 collects the benchmark values of the calibrated parameter for our wedge analysis.

Table 8. Benchmark Calibration Parameter Values

Parameters	β	δ	σ	ϵ	η_a	ζ_a	ζ_b
Values	0.96	0.06	1.00	1.00	0.15	0.24	0.36

The same output and input variables which were used in calculating the sectoral TFP in the previous analysis are also used in calculating the wedges. The aggregate and sectoral real consumption per capita in the wedges are obtained from the series of the *Input-Output Tables* from the Bank of Korea for the sample period.

[20] The estimates of the initial sectoral TFPs are obtained from the sectoral TFP calculation in Section 5 with adjusting the quality of land such that $T_{a,0} = 0.114$ and $T_{b,0} = 0.173$, which are the average values of the agricultural and industrial sector TFPs during the initial period of 1974-1979.

[21] However, this seems to be better than choosing $\zeta_b = 0$ as in Cheremukhin, Golosov, Guriev, and Tsyvinsky (2017), which cannot be the case as long as the sectoral TFPs are positive-valued variables.

6.3. Efficiency Dynamics from the Wedge Analysis

All four wedges defined in equations (16) to (19) are measured using the data above and at the calibrated parameter values in Table 8, which are displayed in Figure 20. The first thing we notice from this comparison is that the labor wedge exceed unity before the mid-1990s, while the capital and land wedges are clearly lower than unity during the entire period, land wedge and the investment wedge is mostly lower than unity, though not by much.

Considering that the "measured" wedges depend on how we model the preferences and technology and also on the calibrated parameter values, the comparison of the wedge values too tightly with unity can be misleading. However, the order of magnitudes of the deviation from unity is fairly big for all wedges so that interpreting the signs and changing directions of those wedges from the optimal allocation point of view seems to be plausible. We will perform sensitivity analysis to check if the observed patterns are robust to the disturbance of preferences and technology parameters.

The labor employment wedge with $\tau_t^N > 1$ before the mid-1990s (observed in Figure 20.A) implies that the agricultural employment relative to the industrial employment is higher than optimum, considering the inter-sectoral difference in marginal products of labor. In other words, there was room to improve the efficiency of labor allocation by promoting the shift of labor from agriculture to industry before the mid-1990s. Such tendency of inter-sectoral labor misallocation had declined fast since 1977, and almost disappeared after the mid-1990s.

In contrast, the capital wedge (shown in Figure 20.B) has been lower than unity throughout the sample period, meaning that too much capital has been allocated in the industry sector relative the agriculture during the structural transformation. Similar interpretation is possible for the efficiency of the inter-sectoral land allocation (in Figure 20.C), too much land use for the industry sector relative the agriculture. However, the tendency of inter-sectoral misallocation of land was stabilized around the mid-1990s and there was a slight reversal in direction since the late 1990s.

The investment wedge in Figure 20.D is also below unity during the most of sample period. This implies that the marginal utility of current consumption exceeds the present value of the marginal utility of future consumption obtained from investment, so that the

overall utility would have increased by shifting future consumption to current consumption. That is, there has been *overinvestment* in capital during Korea's structural transformation, although the magnitude of deviation of the investment wedge from unity is smaller than those of other wedges. We find an interesting U-turn of the investment wedge. Figure 20.D shows that the tendency of overinvestment has been reinforced since 1980 when Korea's rapid growth was around the peak and input-expansion-driven. Upon occurring the Asian financial crisis in 1998, such tendency was reversed and the intertemporal efficiency of capital investment started to improve.

Figure 21 illustrates the components of the intersectoral wedges of the three factors into the inter-sectoral marginal rate of substitution $\left[\frac{\eta_b}{\eta_a}\left(\frac{c_{a,t}-\zeta_a}{c_{b,t}+\zeta_b}\right)\right]^{\frac{1}{\epsilon}}$ in Figure 21.A, and each of the relative marginal products of industry sector to agriculture for labor, capital and land, respectively in Figures 21.B to 21.D. The comparison of Figures 21.A to 21.D suggests that that the main driving force of the hump-shape of the inter-sectoral wedges around 1977 is the changes of the inter-sectoral marginal rate of substitution. That is, the agricultural consumption grew faster than the industry sector consumption initially, but such trend of sectoral consumption growth turned to opposite around the year 1977, so that the intersectoral marginal rate of substitution first increased until 1977, declined until the end of the 1990s, and then stabilized. This pattern of changing intersectoral marginal rate of substitution commonly affects the efficiency dynamics of the intersectoral allocation of all three production factors.

However, the main determinant of the deviation of those intersectoral wedges seems to be the differences in marginal products between the two sectors. For example, the labor wedge exceeds unity mainly because the ratio of the marginal productivity of industrial labor to that of the agricultural labor is very high, ranging between 4 to 12. We also find an interesting pattern that the intersectoral gap between the marginal products of labor monotonically decreased during the sample period. Note that this happened because of the fast shift of labor from agriculture to industry, correcting the allocational status of the excessive labor in agriculture relative to industry, while consumption grew faster in industry than in agriculture.

In the case of capital allocation, the marginal product of capital was lower in industry than in agriculture (see Figure 21.C) so that capital is expected to move from industry to

agriculture, i.e. the marginal product of capital of industry relative to agriculture would increase. However, this happened only during the 1983-1994 period, not for the rest of the period, hence the efficiency of the intersectoral allocation of capital worsened during the structural transformation, except for the 1983-1994 period when the agricultural capital growth was the fastest during the entire period of Korea's structural transformation.

Regarding the land allocation, the relative marginal products of industry to agriculture is smaller than one before 1998 and greater than one afterward. That is, for the purpose of improving the efficiency of intersectoral land allocation, we expect the land use would shift from industry to agriculture before 1998, and vice versa afterwards. However, the land allocation was sorted out this way only shortly for the 1992-1998 period and the 2006-2009 period. For the most of period of structural transformation, the direction of changes of the land allocation was opposite. In particular, the status of excessive land allocation in industry relative to agriculture was reinforced during the initial two decades of structural transformation.

The investment wedge is also decomposed into two components, the "intertemporal marginal rate of substitution" term $\beta\left(\frac{c_{t+1}}{c_t}\right)^{\frac{1}{\epsilon}-\frac{1}{\sigma}}\left(\frac{c_{b,t+1}+\zeta_b}{c_{b,t}+\zeta_b}\right)^{-\frac{1}{\epsilon}}$ and the returns to capital investment $\left(\alpha_b^K \frac{Y_{b,t+1}}{K_{b,t+1}}+1-\delta\right)$ term as in Figure 22. We observe a declining trend of the intertemporal marginal rate of substitution before 1997, meaning the consumption growth was faster in the industry sector than the aggregate economy. The increase of capital investment is required to meet such consumption growth. However, whether the speed of increasing capital stock is on the "right track" depends on the magnitude of the returns to investment. Figure 22 shows that the returns to capital investment has decreased rapidly until 1997, and then stabilized afterwards, showing that the law of diminishing returns to capital investment was rather strong for Korea's structural transformation. The investment wedge previously shown in Figure 20.D suggests that the speed of increasing capital stock was too fast taking these two factors into account all together. Figure 22 also shows that such tendency of declining intertemporal marginal rate of substitution was sharply reversed around the time of Asian Financial Crisis in 1998, due to the slowdown of consumption growth, while the returns to investment was stabilized (though at low level). This helped to improve the efficiency of intertemporal allocation of capital investment.

Figure 20. Comparison of the Inter-sectoral and Inter-temporal Wedges

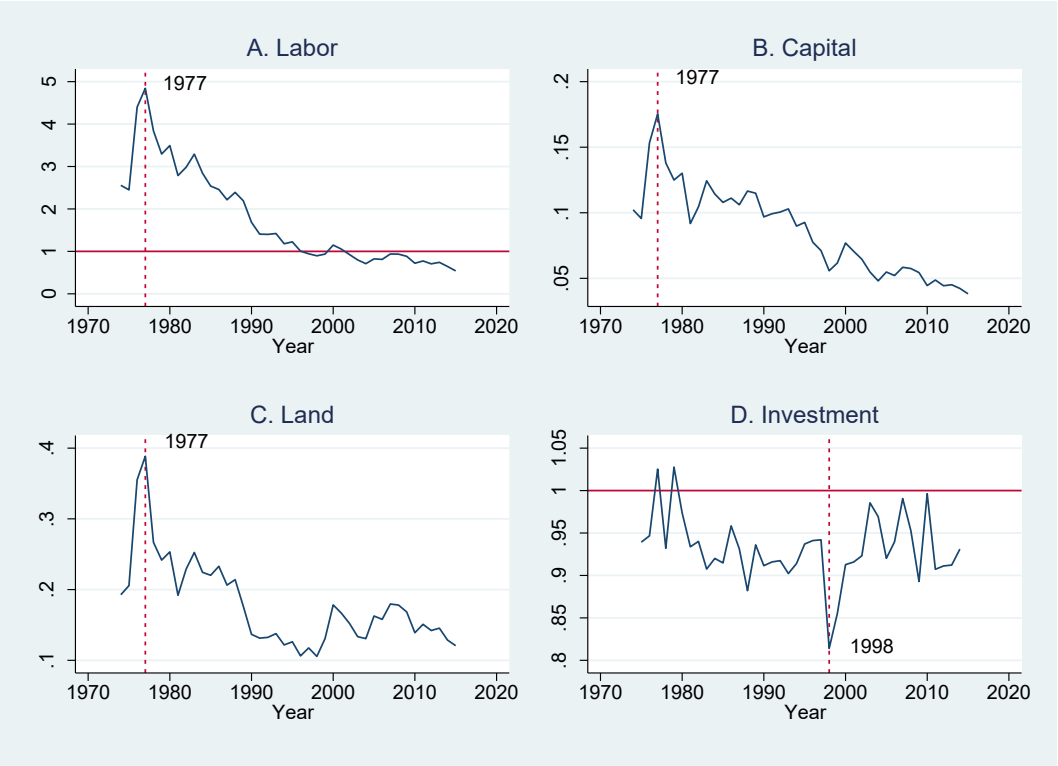


Figure 21. Components of Intersectoral Wedges

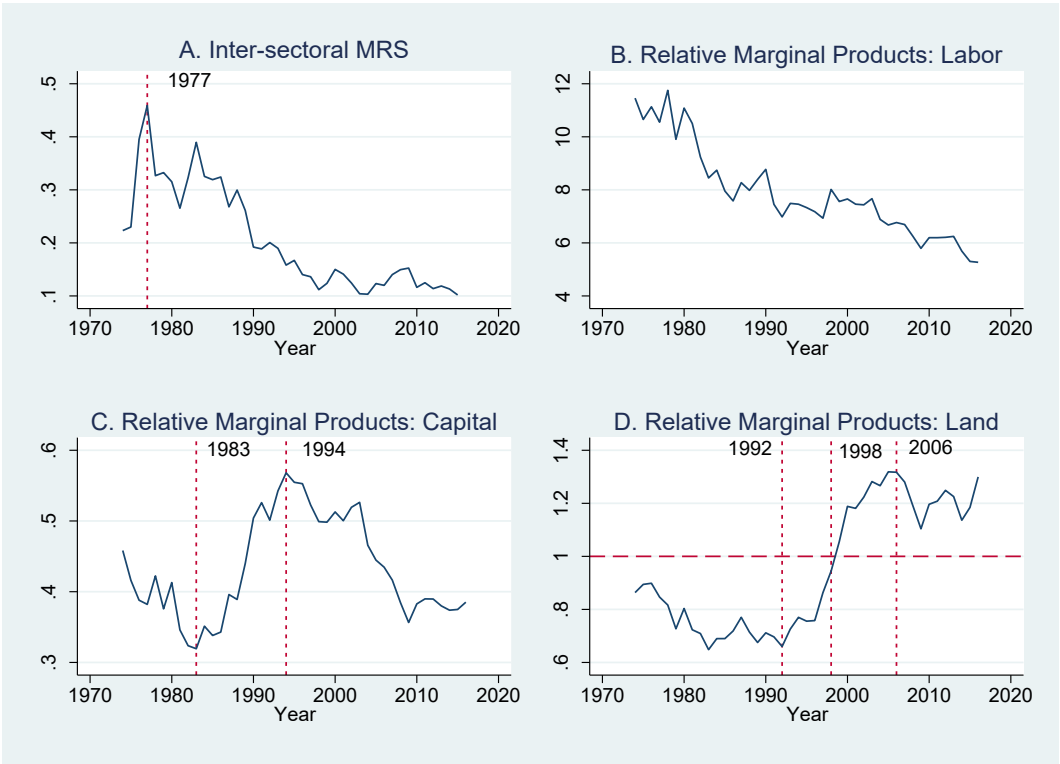
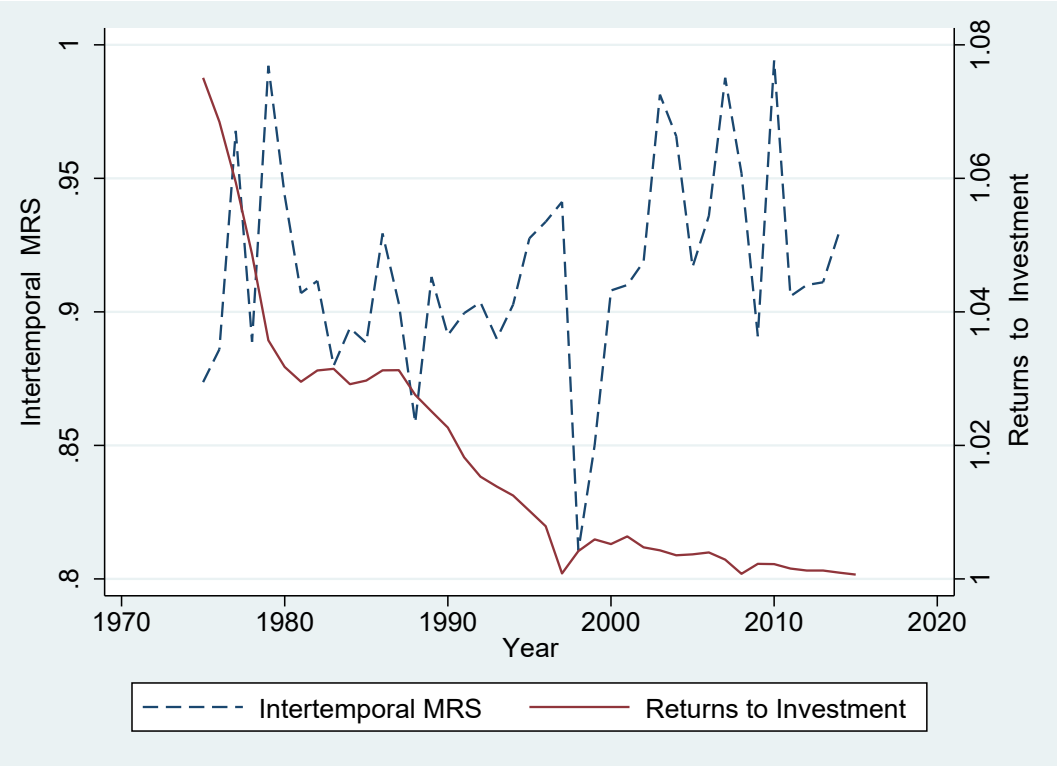


Figure 22. Components of Intertemporal Wedge



6.4. Sensitivity Analysis of Efficiency Dynamics

We find that all the above patterns of efficiency dynamics during Korea's structural transformation remain robust to the disturbances of the benchmark parameter values presented in Table 8. The results of such sensitivity analysis are reported in Figures A.1 to A.10 in the Appendix. The magnitudes of wedges change as we change the parameter values. However, the qualitative nature of intersectoral and intertemporal excess allocation and the shape of dynamic changes of the wedges remain all the same.

The effect of changing the intersectoral elasticity of substitution parameter ϵ on intersectoral wedges depends on whether $\frac{\eta_b}{\eta_a}\left(\frac{c_{a,t}-\zeta_a}{c_{b,t}+\zeta_b}\right)$ is greater or smaller than one, which in turn depends on the choice of ζ_a and ζ_b. For our benchmark calibration, $\frac{\eta_b}{\eta_a}\left(\frac{c_{a,t}-\zeta_a}{c_{b,t}+\zeta_b}\right)$ is less than one, hence the decrease of ϵ would reduce the magnitude of the three intersectoral wedges, as we can confirm in panels of A to C of Figure A.1 where we decrease ϵ by 20% from one to 0.8. However, the shapes of the dynamic paths of wedges and the signs of their deviation from unity remain the same. Increasing ϵ by 20% from one to 1.2 increases the

magnitudes of wedges but again the qualitative features of the wedges remain all the same (Figure A.2).

The effect of changing ϵ on intertemporal wedge depends on the ratio of aggregate consumption growth to industrial goods consumption growth, where the aggregate consumption itself depends on ϵ. We find that either lowering ϵ to 0.8 or increasing to 1.2 makes negligible effects on the investment wedge, as shown in the panel D of Figures A.1 and A2.

The "non-homothetic parameters" ζ_a and ζ_b also affect the intersectoral rate of substitution. In particular, they influence the effects of the differences of sectoral consumption growth on the wedges. We choose them together linked by the generalized BGP condition in (38) so that as we change ζ_a, ζ_b is also changed according to equation (38). Figures A.3 and A.4 show that decreasing ζ_a tends to increase the magnitudes of the three intersectoral wedges, and vice versa. However, the features of the benchmark calibration remain robust. The investment wedge is virtually the same to the disturbance of ζ_a.

To explore the significance of incorporating the non-homothetic preferences for our efficiency analysis, we first check what happens if we set $\zeta_b = 0$, ignoring the BGP condition. Figure A.5 displays the wedges setting $\zeta_b = 0$. We find that this does not play a critical role. However, when we set both ζ_a and ζ_b to be zero, the case of homothetic preferences, not only the magnitudes but also the dynamic paths of the intersectoral wedges become different, as shown in Figure A.6. Furthermore, the sign of deviation from unity changes in case of land wedge. There are no significant effects on investment wedge. This sensitivity analysis shows that incorporation of the non-homothetic preferences via the reasonable positive value of ζ_a is crucial.

The effects of increasing the intersectoral weight parameter η_a are similar to those of increasing ζ_a, and the benchmark results remain virtually the same, as shown in Figures A.7 and A.8.

Changing the intertemporal elasticity of substitution parameter σ affects only the investment wedge. Figures A.9 and A.10 illustrate that decreasing σ by 20% from 1 to 0.8 increases the magnitude of the investment wedge, and vice versa by increasing σ by 20% from 1 to 1.2. However, the shape of the path of the investment wedge and the diagnosis

of overinvestment during Korea's structural transformation again remain robust to changing σ.

7. Conclusion

All poor countries seek to transform their economies into modern and advanced ones, and economic growth is a powerful instrument to achieve such goals. However, such success stories are rare. Korea's experience of sustained economic growth and structural transformation provides an example of those rare stories, so that the precise understanding of its development experience may deliver some useful lessons for other developing nations, as well as for its own future development.

We compiled the sectoral-level database of outputs, population, employment, work hours, human capital, physical capital, land, factor shares, factor prices, and consumptions from various scattered sources of macro and micro data from data archives and surveys, official government statistics from different Ministries, library archives for historical records, hard copies of statistical yearbooks, and government documents, and combined them to measure the sectoral TFPs and intersectoral and intertemporal wedges as precisely as possible in a manner which is consistent with the postulated two-sector growth model. Construction of this integrated and comprehensive database is first done for the Korean economy, which itself is an important contribution of this paper.

In particular, we found that explicit inclusion of land variables in the sectoral production functions makes significant differences in measuring sectoral TFPs because the inter-sectoral shifts of factor inputs play an important role not only for capital and labor but also for land, for an economy in the process of active structural changes. For example, the estimated annual average agricultural TFP growth rate of -0.08% without land turns to 0.62% with land.

During our full sample period 1970-2016, the Korean economy went through substantial structural transformation and has approached a steady state. During this period, Korea's real GDP per capita grew 14 times, from $2,609 in 1970 to $36,714 in 2016 in 2011 real valued PPP term at the annual average growth rate of 5.9%. Along such rapid and sustained growth for the 46-year period, substantial structural transformation processes also occurred: the urban population share increased from 41% to 82%, the population share of the working people increased from 30.6% to 53%, and the employment share of the agricultural sector decreased from 48% to 5%.

Our two-sector growth accounting analysis revealed many interesting features of

Korea's long-term growth process. There were diverse sources of economic growth rather than a single dominant one for Korea's growth during the structural transformation. Of the 5.9% annual income growth, 1.2% is due to the expansion of employed workers among the population (0.35% of which is ascribed to urbanization), and the remaining 4.7% is due to labor productivity growth.

Incorporating the quantity and quality data for land, the labor productivity growth was further decomposed for the 1974-2016 period when the quality-adjusted land data can be constructed. The largest contributing component of the labor productivity growth for this period was industry sector TFP growth (contributing 1.53% per year on average). The second largest one was the increase of the industry sector capital per worker (contributing 1.28% per year on average), and the third one was the industrialization, i.e., the employment shifts from agriculture to the industry sector (contributing 1.05% per year on average). The increase of the within-sector employment and urbanization as well as the human capital accumulation also played an important role in both agriculture and industry.

Direct contributions to economic growth from the agricultural inputs and TFP were small relative to those of the industry sector. However, this is not because the agricultural inputs and TFP grew little, but because the output share of the agricultural sector diminished fast due to the industrialization. In particular, the largest contributing factor from agriculture was the agricultural capital per worker, which grew by 7.13% per year on average (contributing 0.16% of income growth per year). This was even higher than the annual average growth rate of the industrial capital per worker at 5.91%. It is worth noting that the human capital per worker in rural areas increased at a similar rate (1.12%) as that of the urban area (1.25%). Such accumulation of human capital in rural areas might well contribute to promoting the TFP growth of agriculture. Furthermore, although the direct contribution of agricultural TFP growth was small, agricultural TFP growth tended to release the production factors of labor, capital, and land from agriculture to industry, so that it indirectly contributed to the sizable income growth from industrialization. For the above reasons, agriculture played a critical role in the structural transformation of the Korean economy.

Perhaps the most important feature of Korea's long-term process of economic growth is the sequential changes of the main engine of growth over the different stages of development. Specifically, the largest contributing source of growth in the 1970s (the take-

off period) was the shift of employment from agriculture to industry and the shift of population from rural to urban areas. These labor market compositional changes alone contributed to 2.61% of income growth per year on average in the 1970s. The second largest contributing component in the 1970s was the capital accumulation per worker in the industry sector (contributing to 2.03% of income growth per year). It is interesting to note that TFP did not grow in either sector during this period of massive structural transformation and industrial capital accumulation.

However, the main engine of growth for the following three decades (1980-2010) was within-sector TFP growth, mostly driven by the industry sector. The industry sector TFP growth alone contributed to 1.98% to 2.74% of Korea's income growth during this period. This switch around the 1980s from the input-based growth regime to the productivity-based growth regime, or from growth by "perspiration" to the growth by "inspiration," using Krugman's (1994) analogy, was the most critical transformation of the Korean economy. Korea could break the shackles of the middle-income trap because of this transformation and maintained rapid growth for three decades.

Jeong (2018) made this point by analyzing the growth process in a single-sector growth model for the 1960-2014 period, suggesting that the genuine feature of Korea's long-term growth lies in its sustainability based on productivity and human capital growth, rather than its rapid speed of growth and capital accumulation, which used to attract the attention of the development economists and policy makers about Korea's growth experience. In this sense, although some key messages of evaluating East Asian economic growth from Krugman (1994) and Young (1995) are valid, Korea's growth experience of maintaining the solid TFP growth rate above 2% for three decades suggests that their evaluation seems to bear only partial truth, at least in the case of the Korean economy. In the 1960s and 1970s, Korea's growth was indeed driven by the expansion of inputs and compositional changes. After the early 1980s, such an input-driven growth regime switched to a productivity-driven one in Korea.

The GDP per capita growth rate monotonically decreased after 1980. We found that this was mainly due the combined effects of the diminishing within-sector input growth and compositional growth effect. This is related to the typical diminishing returns to factor accumulation, so that such declining trend of income growth is a natural process, signaling that the Korean economy is approaching toward steady state. In fact, we confirmed that

this is indeed the case by observing the almost constant capital-output ratio of the Korean economy after 2011.

We also found a puzzling and concerning feature of Korea's TFP dynamics, i.e., the sudden drop of TFP growth in both sectors after 2011. The 1.4% agricultural TFP growth in the 2000s dropped to -0.62% for the 2010-2016 period. The 2.03% industrial TFP growth in the 2000s dropped to 0.59% for the 2010-2016 period. This is particularly concerning because the Korean economy seems to have approached the steady state when the only source of growth is productivity. This recent drop of TFP growth does not seem to be related to macroeconomic shocks, such as the Asian financial crisis in 1998 or the global financial crisis in 2009. The noticeable changes in TFP trend happened only after 2011.

Our wedge analysis, measuring the degrees and directions of the deviations of the allocation efficiency in terms of inter-sectoral allocation of factors and intertemporal investment, also revealed interesting features of Korea's structural transformation. We found that despite Korea's extensive structural transformation, the allocation of labor was more biased toward agriculture relative to industry before the mid-1990s. However, the allocation of capital and land was more biased toward industry relative to agriculture than the optimal level throughout the entire sample period. The investment wedge suggests that the Korean economy was in the status of overinvestment.

We found that two external shocks disturbed Korea's economic growth but seem to improve either allocational efficiency or productivity growth. For example, the tendency of overinvestment has been reinforced during Korea's structural transformation and such tendency peaked right before the Asian financial crisis. Upon the arrival of this shock, the Korean economy was disturbed seriously but this improved the efficiency of investment after going through the Asian financial crisis. The launch of the WTO, which can be considered as a disturbed trade liberalization, had adverse effects for the Korean economy, in particular for agriculture. This deteriorated the allocational efficiency of capital but improved the allocational efficiency of land. Indeed, the capital growth of Korea's agriculture began to rapidly slow down upon Korea's joining the world trade order of the WTO. However, this eventually led to promote agricultural TFP growth in 1990s because of the diversified varieties of agricultural products to survive in the environment of global competition.

Our wedge analysis for Korea's structural transformation suggests that its rapid growth and even its maintenance based on TFP growth for three decades do not guarantee inter-sectoral and intertemporal allocation efficiency. Korea's growth experience shows that allocation efficiency does respond to policy measures and macroeconomic shocks. In some cases, there were trade-offs between growth and efficiency, particularly during the input-driven take-off growth period. In other cases, growth and efficiency were aligned together, particularly during the productivity-driven growth period. Subduing the possible distortions from growth-promotion policy or institutional measures would accumulate allocation inefficiency over time. When such accumulated inefficiency exceeds a threshold, this may start to stifle the motive for innovations and proper investment. Perhaps this is one of the critical reasons behind the sudden stagnation of TFP growth which recently happened in Korea. This conjecture invites future research identifying the deeper sources of Korea's productivity and efficiency dynamics.

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Appendix

A.1. Appendix Tables

Table A1. Decomposition of GDP per Capita Growth for 1974-2016 with Land Quantity Only (%)

Period	URB	WER	IND	T_a	k_a	h_a	v_a	l_a	T_b	k_b	h_b	v_b	l_b
’74-’16	0.34	0.79	1.05	0.08	0.16	0.02	-0.004	0.06	1.68	1.28	0.28	-0.18	-0.05
’74-’80	0.52	0.99	2.97	-0.07	0.33	0.05	0.001	0.11	-1.00	2.11	0.39	-0.03	-0.17
’80-’90	0.71	0.68	1.61	0.22	0.29	0.03	-0.001	0.10	2.60	1.40	0.38	-0.11	-0.13
’90-’00	0.29	0.75	0.62	0.06	0.14	0.01	-0.004	0.06	2.48	1.70	0.27	-0.18	-0.002
’00-’10	0.16	0.69	0.32	0.07	0.02	0.005	-0.01	0.03	2.20	0.78	0.19	-0.30	0.003
’10-’16	-0.04	0.99	0.20	0.02	0.03	0.01	-0.01	0.03	0.72	0.37	0.21	-0.20	0.005

Table A2. Changes of Annual Average Rate of TFP Growth from Omitted Land and Work Hours by Decades (%): Agriculture

Period	Benchmark	W/o Land	W/o Hours	W/o Land and Hours	W/o Land Quality
’74-’16	0.62	-0.08	0.47	-0.22	1.34
’74-’80	-2.25	-3.81	-2.30	-3.85	-1.86
’80-’90	0.53	-0.81	0.52	-0.82	1.89
’90-’00	2.43	-0.62	2.30	-0.76	1.37
’00-’10	1.40	3.14	1.13	2.87	2.92
’10-’16	-0.62	0.57	-0.89	0.30	1.00

Table A3. Changes of Annual Average Rate of TFP Growth from Omitted Land and Work Hours by Decades (%): Industry

Period	Benchmark	W/o Land	W/o Hours	W/o Land and Hours	W/o Land Quality
’74-’16	1.58	1.44	1.06	0.91	1.75
’74-’80	-1.51	-1.72	-1.61	-1.82	-1.11
’80-’90	2.38	2.36	2.02	2.01	2.79
’90-’00	2.85	2.24	2.30	1.69	2.57
’00-’10	2.03	2.10	1.14	1.21	2.25
’10-’16	0.59	0.67	-0.01	0.08	0.74

Table A4. Changes of Annual Average Rate of TFP Growth from Omitted Land and Work Hours by Decades (%): Aggregate Economy

Period	Benchmark	W/o Land	W/o Hours	W/o Land and Hours	W/o Land Quality
’74-’16	2.11	1.78	1.78	1.45	2.42
’74-’80	0.07	-0.57	0.35	-0.30	0.55
’80-’90	3.15	2.97	3.12	2.95	3.79
’90-’00	3.28	2.30	2.86	1.89	3.00
’00-’10	2.07	2.14	1.27	1.35	2.50
’10-’16	0.60	0.72	0.06	0.18	0.96

A.2. Appendix Figures: Sensitivity Analysis for Wedge Dynamics

Figure A.1. Wedges for $\epsilon = 0.8$

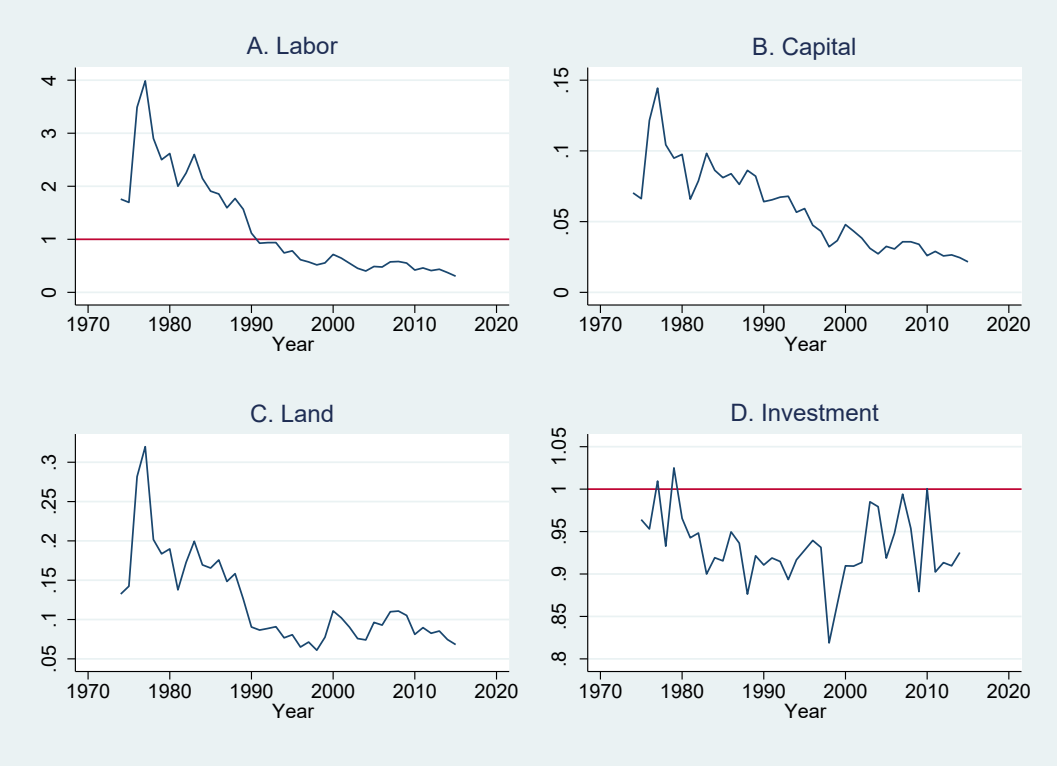

Figure A.2. Wedges for $\epsilon = 1.2$

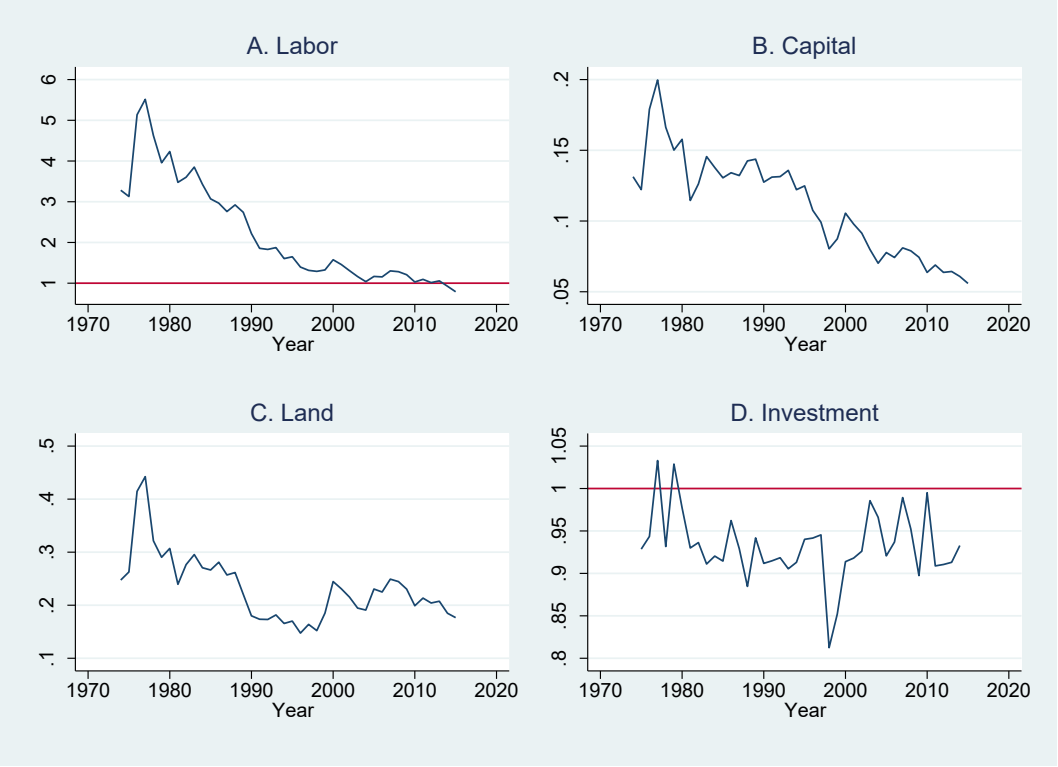

Figure A.3. Wedges for $\zeta_a = 0.20$

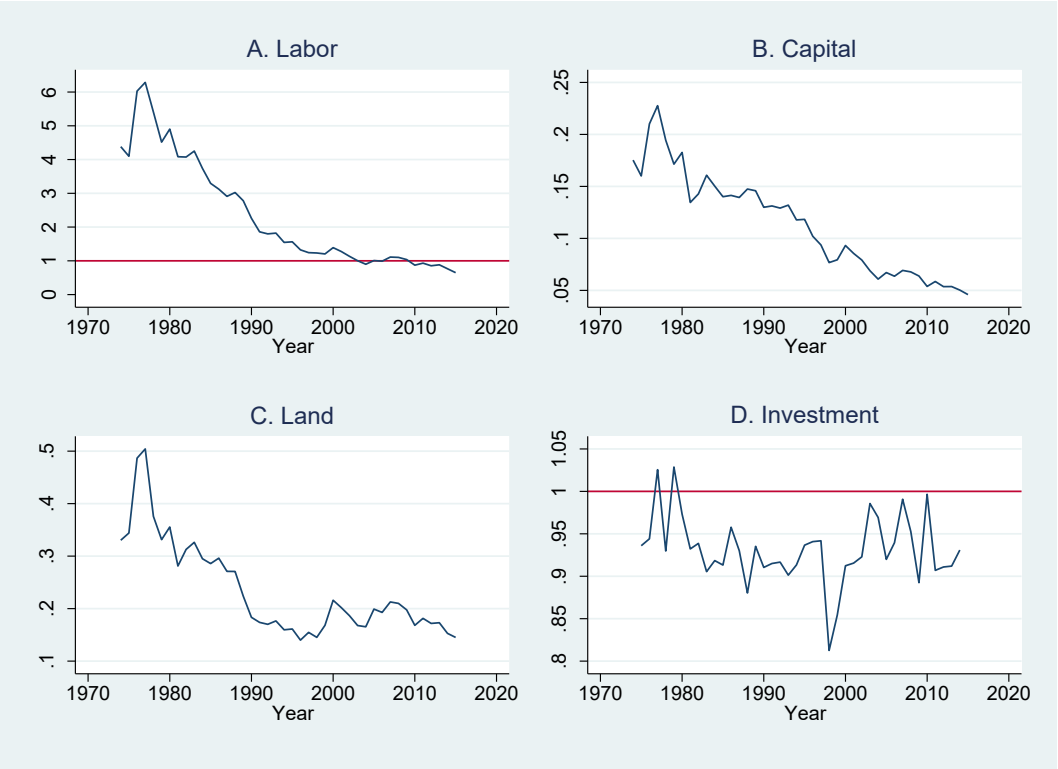

Figure A.4. Wedges for $\zeta_a = 0.28$

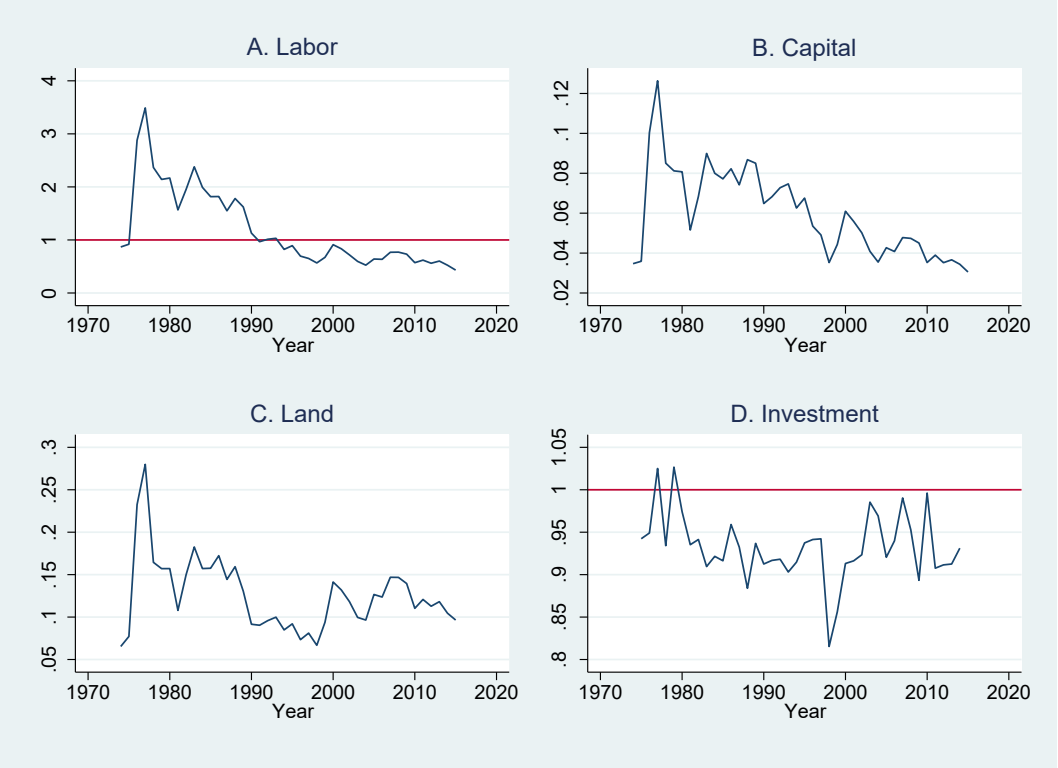

Figure A.5. Wedges for $\zeta_b = 0$

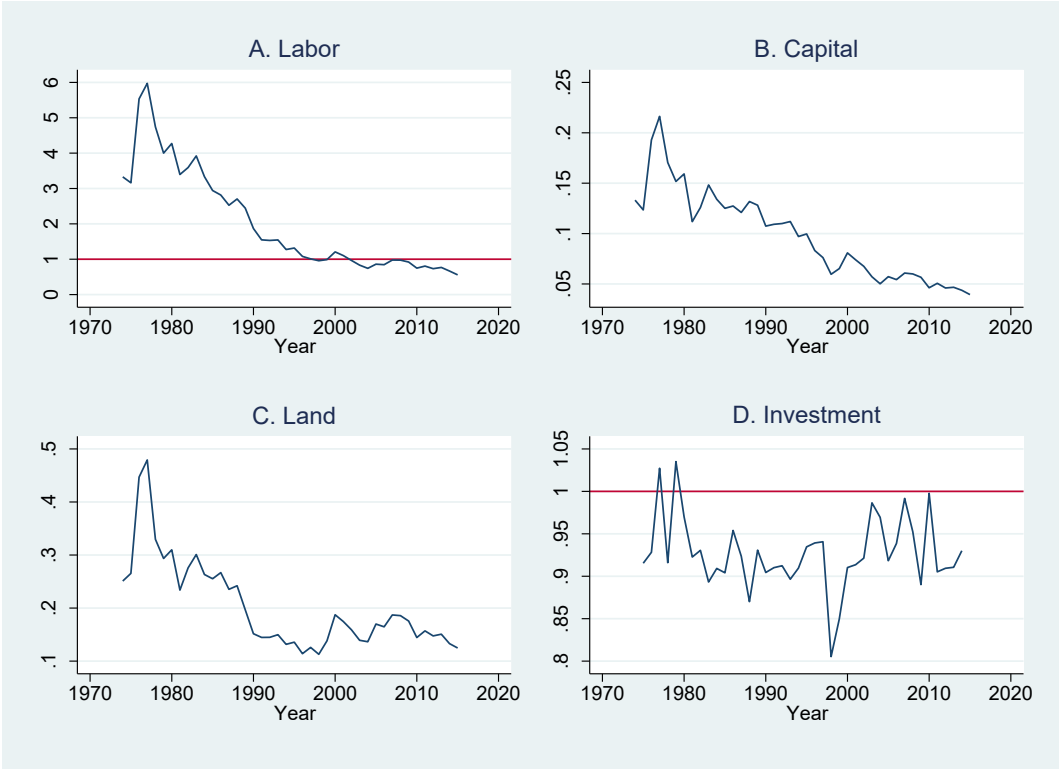

Figure A.6. Wedges for $\zeta_b = 0$ and $\zeta_a = 0$

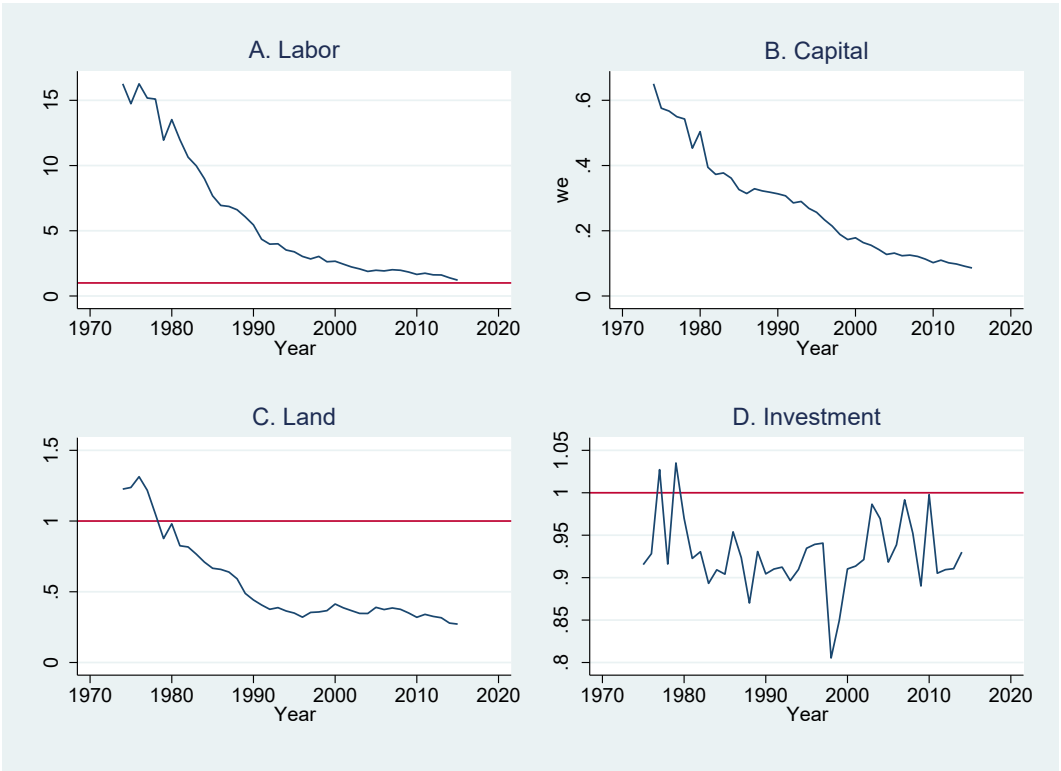

Figure A.7. Wedges for $\eta_a = 0.10$

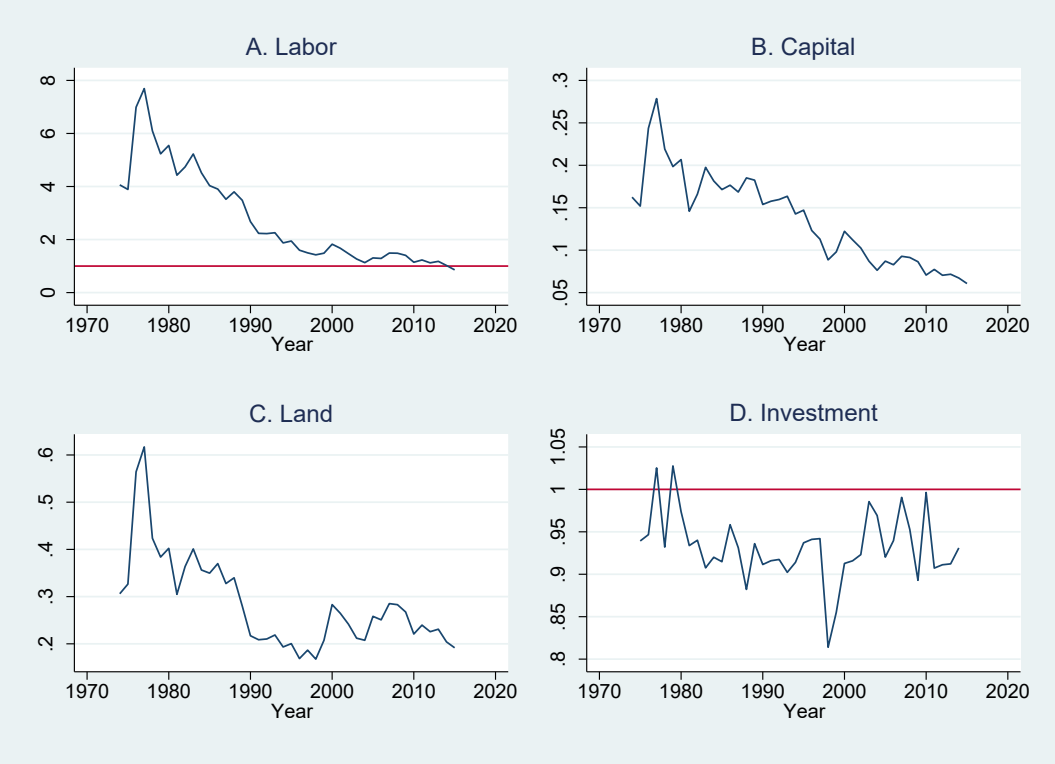

Figure A.8. Wedges for $\eta_a = 0.20$

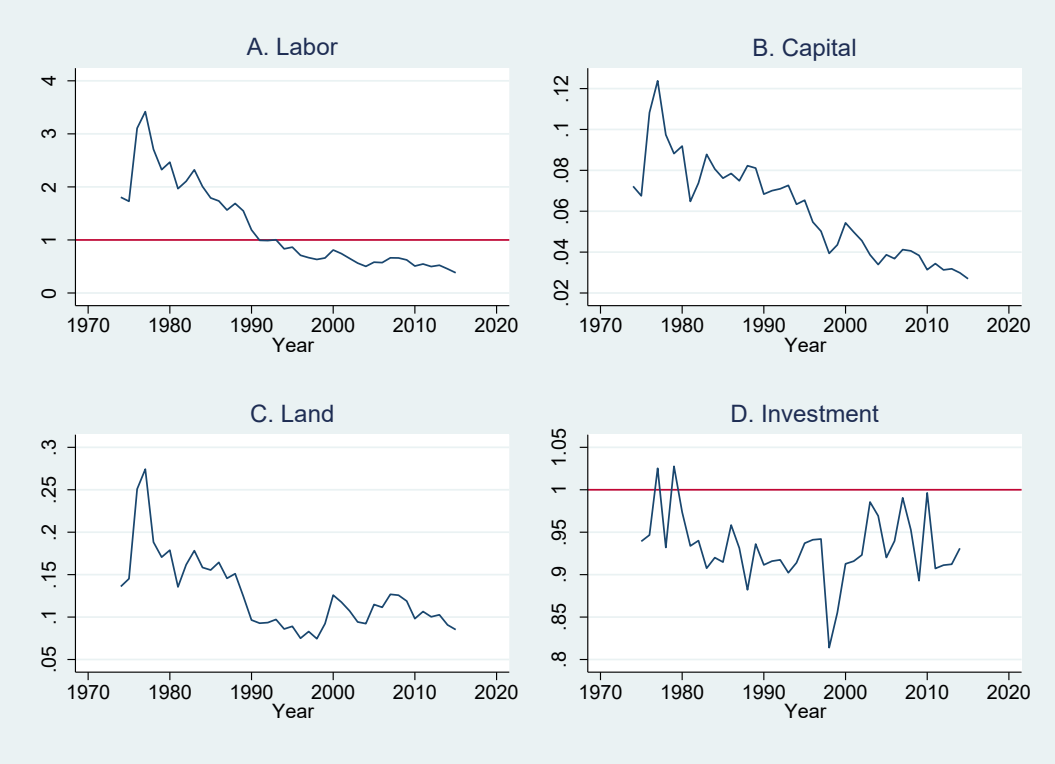

Figure A.9. Wedges for $\sigma = 0.8$

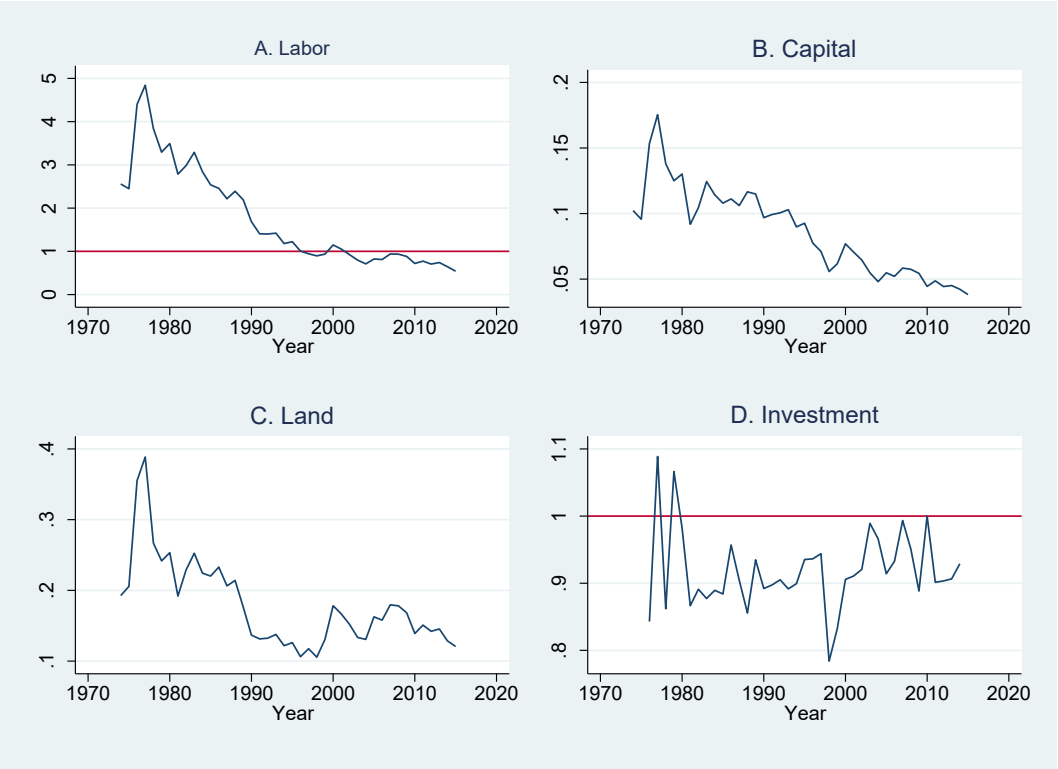

Figure A.10. Wedges for $\sigma = 1.2$