Financial Hurdles for Human Capital Accumulation: Revisiting the Galor-Zeira Model

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31 December 2012

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Abstract Against the background of inconclusive evidence about the inequality–growth relation, this paper suggests that the level of inequality increases via the human capital channel with credit market imperfections and that this increasing inequality negatively affects economic growth. We expand the model presented by Galor and Zeira (1993) to represent the fact that the economy benefits from endogenous technological progress and that the government provides financial aid to reduce the financial hurdles for human capital accumulation. The presented empirical results, using Korean data from 1998 to 2008, imply that education plays a significant role in the divergence of household wealth over time and that the government's financial aid package in the form of the new student loans program positively influences equality and short-run economic growth by promoting the number of skilled workers.

Keywords Human Capital, Growth, Inequality

JEL Classification Codes I24, I25, O15

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1. Introduction

The relationship between inequality and growth remains unsolved and thus subject to ongoing debate. Since the seminal publication by Kuznets (1955), a number of researchers have drawn mixed conclusions about this implicit linkage. For example, Deininger and Squire (1996) insisted that inequality and growth correlate negatively, while Banerjee and Duflo (2003) found an inverted U-shaped relation using cross-country data. However, policymaking related to growth and reallocation rests not only on understanding the interrelation between these factors but also on finding the channel from inequality to growth, which would allow scholars to answer several outstanding questions such as is inequality good for growth and how does reallocation policy affect it.

The channel from inequality to growth has been examined with various approaches. According to Alesina and Rodrik (1994) and Persson and Tabellini (1994), inequality affects growth via fiscal channels, namely taxation and government expenditure. Governments choose how to distribute the country's financial resources and fund these decisions by levying tax on individuals' income. Therefore, in more equally distributed societies, there is less demand for reallocation, which means less taxation and more investment, resulting in more growth. Alesina and Perotti (1996) also argued in favor of the importance of sociopolitical stability. These authors insisted that inequality increases unstable sociopolitical circumstance, which in turn decreases investment. Therefore, inequality is harmful for growth from their perspective. Importantly, previous studies of the fiscal and sociopolitical channels have generally used cross-country data to prove their models.

However, the human capital channel, which is accumulated through education, with credit market imperfections has already provided a well-known explanation of inequality. Galor and Zeira (1993) constructed a macroeconomic model that assumed a wage gap between skilled and unskilled workers based on individuals' levels of education and showed that a dynasty's wealth can diverge under certain credit constraints and different initial conditions of wealth. However, few empirical studies have verified the model (but see Papageorgiou and Razak, 2009). To empirically prove the Galor–Zeira model, panel data at the national level is therefore required to conduct

an accurate analysis of intergenerational mobility through education levels. Indeed, if the wage gap in society continues to diverge, while the Galor–Zeira model retains its assumption of constant wages for skilled and unskilled workers, the divergence of a dynasty's wealth will occur even more rapidly.

In labor economics, a number of studies of the intergenerational transfer of wealth through various channels have used micro data, which contains information on individuals. As Black and Devereux (2011) explained, economists and social scientists have long been interested in intergenerational mobility, including one stream that focuses on credit constraints, on which we also focus in this paper. According to researchers such as Han and Mulligan (2001) and Grawe and Mulligan (2002), investment in human capital and the existence of credit constraints influence the channel of intergenerational mobility, even though they do not provide evidence of the interrelation between inequality and growth.

In this paper, we expand the Galor–Zeira model to incorporate the fact that the economy demonstrates endogenous technological progress and that the government provides financial aid to support college attendance. Furthermore, we verify our model using Korean panel data. Our contribution to the body of knowledge on this topic is threefold. First, in contrast to macro-level research using cross-country data, we employ national-level panel data to describe the relationship between inequality and growth. To the best of our knowledge, no previous research has investigated the feasibility of the Galor–Zeira model empirically at the national level. Second, in contrast to the original Galor–Zeira model, our research examines economic growth rates at the national level, which are also proven empirically using Korean panel data. Although the original Galor–Zeira model suggested that a larger ratio of skilled labor to unskilled would benefit the overall size of the economy, it provided no indication about its growth rate. Third, because we include the government's financial assistance into our expanded model, we can contextualize reallocation policy in terms of growth despite some agreement in the literature that policies for growth and for inequality are contrary to one another.

The remainder of this paper proceeds as follows. In section 2, we describe our expanded model. In section 3, we present our empirical results using Korean data. Finally, concluding remarks are made in section 4.

2. The Model

2.1. Basic model

As in the original Galor–Zeira model, we consider a small open economy that consists of two-period overlapping generations. Workers are divided into two heterogeneous categories, namely educated skilled labor and unskilled labor. Furthermore, our model examines the influence of education subsidies and technological progress.

The skilled and unskilled labor sectors produce homogeneous goods and the price is a numeraire. The production functions are given by

$$Y_t = Y_t^s + Y_t^u$$
$$\begin{cases} Y_t^s = (A_t^s L_t^s)^{\alpha} (K_t^s)^{1-\alpha} \\ Y_t^u = A_t^u (L_t) \end{cases} \qquad (1)$$

where Y_t^s and Y_t^u are the outputs for the skilled and unskilled sectors, while K_t and L_t represent physical capital and labor input and A_t is labor-augmenting technology.

Physical capital is assumed not to suffer from depreciation over time. Technological progress in the skilled labor sector can be described by

$$\Delta A_t^s = A_{t+1}^s - A_t^s = \beta L_t^s (A_t^s)^{\phi}, \quad 0 < \phi < 1 \qquad (2)$$

where ϕ means decreasing returns to knowledge, as characterized by the semi-endogenous growth models of Jones (1995), Kortum (1997), and Segerstrom (1998).

For simplicity, we ignore duplication effects. Owing to diminishing returns to knowledge, positive economic growth at the national level requires the sustained growth of skilled labor. Similarly, the technology in the unskilled labor sector increases, although the growth rate is slower than that in the skilled labor sector, as follows:

$$\Delta A_t^u = A_{t+1}^u - A_t^u = \chi L_t^s (A_t^u)^{\phi}, 0 < \phi < 1 \qquad (3)$$

where χ is initially smaller than β.

Wages in the skilled labor sector and the rental price of capital, which is the same as the interest rate in this model, are derived from the following profit maximization problem:

$$\max_{L_t^s, K_t^s} (A_t^s L_t^s)^{\alpha} \cdot (K_t^s)^{1-\alpha} - w_t^s L_t^s - r_t K_t^s \qquad (4)$$

The solution to this problem provides wages and the rental price of capital

$$w_t^s = \alpha A_t^s \left(\frac{K_t^s}{A_t^s L_t^s} \right)^{1-\alpha}$$
$$r_t = (1-\alpha) \cdot \left(\frac{A_t^s L_t^s}{K_t^s} \right)^{\alpha} \qquad (5)$$

Provided that capital is perfectly mobile and the global interest rate is constant over time, the above equations can be replaced by

$$w_t^s = \alpha A_t^s \Gamma^{1-\alpha}$$
$$r = (1-\alpha)\Gamma^{-\alpha} \qquad (6)$$

where $\Gamma = \frac{K_t}{A_t^s L_t^s} = \left(\frac{1-\alpha}{r} \right)^{1/\alpha}$.

In the same way, wages in the unskilled labor sector are derived from

$$\max_{L_t^u} A_t^u L_t^u - w_t^u L_t^u \qquad (7)$$

Consequently, the unskilled labor wage is given by

$$w_t^u = A_t^u \qquad (8)$$

Proposition 1 The wage gap between skilled and unskilled labor becomes larger as technology makes gradual progress.

Proof) From equations (6) and (8), the incomes of skilled and unskilled labor are given by

$$w_t^s = \alpha A_t^s \Gamma^{1-\alpha}$$
$$w_t^u = A_t^u$$

Differentiating the ratio of w_t^s to w_t^u by the ratio of technologies, we find a positive relation between the two ratios as follows:

$$\partial \left(\frac{w_t^s}{w_t^u} \right) / \partial \left(\frac{A_t^s}{A_t^u} \right) = \alpha \Gamma^{1-\alpha} > 0$$

Therefore, the larger the technology gap between sectors becomes, the more inequality in the economy there is. (Q.E.D.)

Each individual has one child, meaning that the total population in one generation remains at one. People maximize their utilities by consuming goods in the

second period and leaving their children bequests in the form of so-called warm glow altruism:

$$u_t = \gamma \log c_{t+1} + (1-\gamma)\log b_{t+1}, \quad 0<\gamma<1 \qquad (9)$$

where c_{t+1} is consumption in the second period and b_{t+1} represents the bequest.

Utility maximization with a budget constraint is given by

$$\begin{aligned} &\max_{c_{t+1}, b_{t+1}} \{\gamma \ln c_{t+1} + (1-\gamma)\ln b_{t+1}\} \\ &s.t. c_{t+1} + b_{t+1} \le W_{t+1} \end{aligned} \qquad (10)$$

where wealth in the second period is denoted by W_{t+1}.

From this solution, we know that an individual uses the wealth as

$$\begin{aligned} c_{t+1} &= \gamma \cdot W_{t+1} \\ b_{t+1} &= (1-\gamma)\cdot W_{t+1} \end{aligned} \qquad (11)$$

Moreover, we can derive the indirect utility function by substituting consumption and the bequest in equation (9) with (11) as

$$v_t = \{\gamma \ln \gamma + (1-\gamma)\ln(1-\gamma)\} + \ln W_{t+1} \qquad (12)$$

This means that individual utility is determined by second-period wealth.

2.2. Bequest dynamics

An individual decides to work as skilled or unskilled by taking into account second-period wealth. Unskilled workers receive wages for two periods as well as a bequest from their parents, meaning that total wealth is represented as

$$\begin{aligned} W_{t+1}^u &= w_t^u \cdot (1+r) + w_{t+1}^u + b_t \cdot (1+r) \\ &= A_t^u \cdot (1+r) + A_{t+1}^u + b_t \cdot (1+r) \end{aligned} \qquad (13)$$

Similarly, skilled workers invest in their education in the first period, thereby receiving a higher wage in the second period than unskilled workers, and receive a bequest. The wealth of skilled workers is thus presented by

$$W_{t+1}^s = \begin{cases} (1-\tau)w_{t+1}^s + (b_t - c_t^e + s_t)\cdot(1+i) & if\ b_t \le c_t^e - s_t \\ (1-\tau)w_{t+1}^s + (b_t - c_t^e + s_t)\cdot(1+r) & if\ b_t \ge c_t^e - s_t \end{cases} \qquad (14)$$

where c_t^e represents education costs and i is the higher interest rate for borrowers due to credit market imperfections.

The education subsidy in the first period is denoted by s_t and skilled workers pay for that in the second period based on a certain proportion of their wages, τ. In reality, we could think of this subsidy as student loans secured by the government. After completing their college educations, skilled workers repay loans through their wages. By substituting equation (6) into (14), the wealth of skilled labor is therefore represented by technology as

$$W_{t+1}^{s} = \begin{cases} (1-\tau)\cdot\alpha A_{t+1}^{s}\cdot\Gamma^{1-\alpha} + (b_t - c_t^e + s_t)\cdot(1+i) & \text{if } b_t \le c_t^e - s_t \\ (1-\tau)\cdot\alpha A_{t+1}^{s}\cdot\Gamma^{1-\alpha} + (b_t - c_t^e + s_t)\cdot(1+r) & \text{if } b_t \ge c_t^e - s_t \end{cases} \quad (15)$$

Moreover, education expenditure is assumed to increase with wages

$$\begin{aligned} c_t^e &= \theta w_t^s + (1-\theta)\cdot w_t^u \\ &= \theta\cdot\alpha A_t^s \Gamma^{1-\alpha} + (1-\theta)\cdot A_t^u, \qquad 0 \le \theta \le 1 \end{aligned} \quad (16)$$

In line with the approach presented in Eicher et al. (2009), the government borrows from the international capital market an amount to cover total student loans in the former period and provides financial aid to students in this way. In the latter period, it repays this debt and its accumulated interest by using revenues collected from the incomes of skilled workers, L_{t+1}^{s}. Hence, the government's budget constraint is given by

$$\tau L_{t+1}^{s}\cdot w_{t+1}^{s} = s_t(1+r)\cdot L_{t+1}^{s} \quad (17)$$

As in the Galor–Zeira model, we make two additional assumptions. The first assumption is that all individuals who inherit more than the level of their education costs choose to be skilled workers, which is more beneficial to their wealth than working in the unskilled labor sector:

$$(1-\tau)\cdot\alpha A_{t+1}^{s}\cdot\Gamma^{1-\alpha} + (b_t - c_t^e + s_t)\cdot(1+r) > A_t^u(1+r) + A_{t+1}^u + b_t\cdot(1+r) \quad (18)$$

The second is for individuals who have to borrow all their education costs:

$$(1-\tau)\cdot\alpha A_{t+1}^{s}\Gamma^{1-\alpha} - (c_t^e - s_t)\cdot(1+i) < 0 \quad (19)$$

From equations (13) and (14), we can find the level of bequests that determines whether an individual becomes a skilled or an unskilled worker:

$$f_t(A_t^s, L_t^s) = \frac{\left[\theta(1+i)A_t^s - (1+i\cdot\tau)\cdot A_{t+1}^s\right]\cdot\alpha\cdot\Gamma^{1-\alpha} + \left[(2+r-\theta+i-i\cdot\theta)A_t^u + A_{t+1}^u\right]}{i-r} \quad (20)$$

Proposition 2 The government's financial aid for education lowers the threshold, f, meaning that more of those individuals who were previously ineligible have the opportunity to be educated.

Proof) From (20), we can write

$$\frac{\partial f_t}{\partial s_t} = \frac{\partial f_t}{\partial \tau}\frac{\partial \tau}{\partial s_t} = -\frac{1+r}{i-r} < 0$$

This result shows that the threshold, f, is a decreasing function of the government's financial aid, s_t. (Q.E.D.)

From the solution to the utility maximization above (i.e., equation (11)), any individual can transfer a proportion of $(1-\gamma)$ of his or her second-period wealth. Hence, an inherited bequest (b_t) from previous generations and a left bequest (b_{t+1}) to next generations have the following relationship:

$$b_{t+1} = \begin{cases} (1-\gamma)\left\{A_t^u(1+r) + A_{t+1}^u + b_t \cdot (1+r)\right\} & b_t \in [0, f_t] \\ (1-\gamma)\left\{(1-\tau)\cdot\alpha\cdot A_{t+1}^s \cdot \Gamma^{1-\alpha} + (b_t - c_t^e + s_t)\cdot(1+i)\right\} & b_t \in \left[f_t, c_t^e - s_t\right] \\ (1-\gamma)\left\{(1-\tau)\cdot\alpha\cdot A_{t+1}^s \cdot \Gamma^{1-\alpha} + (b_t - c_t^e + s_t)\cdot(1+r)\right\} & b_t \in \left[c_t^e - s, \infty\right] \end{cases} \quad (21)$$

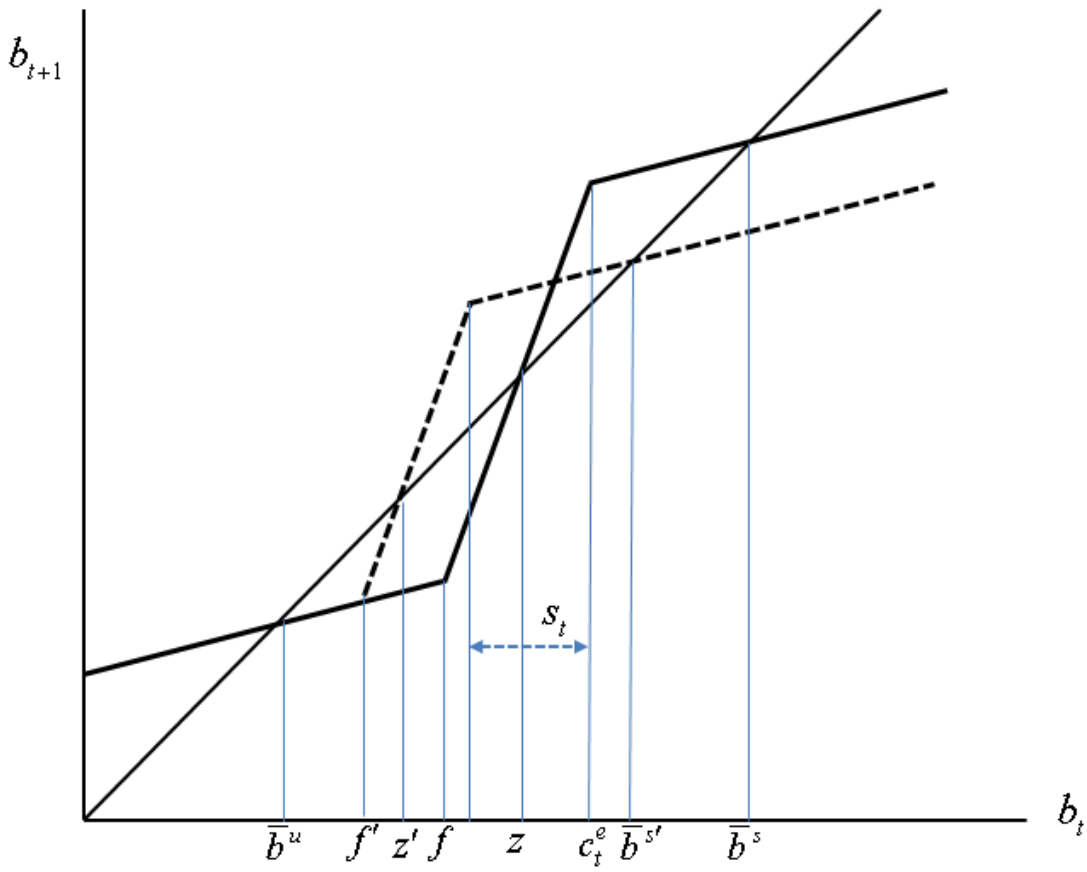

Figure 1 Bequest dynamics

The government's financial aid reduces an individual's education costs (c_t^e) by providing student loans (s_t) and this provision shifts the initial threshold, f, downwards to the new level of f', as depicted in Figure 1. In other words, more people are eligible to be educated because education costs have effectively lowered. Although more financial aid increases the skilled labor pool, it decreases the disposable incomes of skilled labor by shifting the bequest level $\bar{b}^{s'}$ instead of $\bar{b}^s$. Further, if the new threshold level is lower than the convergent level of the bequests of unskilled labor ($\bar{b}^u$), the bequests of all individuals converge to $\bar{b}^{s'}$.

2.3. Steady-state equilibrium

As technologies evolve over time, the effective bequests of skilled labor who borrow for education purposes are represented as follows:

$$\hat{b}_{t+1} = \frac{b_{t+1}}{A^s_{t+1}} = (1-\gamma)\left\{\left((1+i\cdot\tau) - \frac{\theta(1+i)}{(1+\beta L^s_t (A^s_t)^{\phi-1})}\right)\cdot \alpha\Gamma^{1-\alpha} + \frac{b_t}{A^s_t}\cdot\frac{(1+i)}{(1+\beta L^s_t (A^s_t)^{\phi-1})} - \frac{A^u_t\cdot(1-\theta)(1+i)}{A^s_t(1+\beta L^s_t (A^s_t)^{\phi-1})}\right\} \tag{22}$$

From $\lim_{t\to\infty} \beta L^s_t (A^s_t)^{\phi-1} = \lim_{t\to\infty} \frac{A^s_{t+1} - A^s_t}{A^s_t} = g^A$, the critical level of bequests in the long run is given by

$$z = \lim_{t\to\infty}\frac{b_t}{A^s_t} = \lim_{t\to\infty}\hat{b}_t = (1-\gamma)\left\{\left((1+i\cdot\tau) - \frac{\theta(1+i)}{(1+g^A)}\right)\cdot\alpha\Gamma^{1-\alpha} - \frac{\Phi(1-\theta)(1+i)}{(1+g^A)}\right\} / \left(1 - \frac{(1+i)(1-\gamma)}{1+g^A}\right) \tag{23}$$

where g^A is the growth rate of technology at the steady state and $\Phi = \lim_{t\to\infty}\left(\frac{A^u_t}{A^s_t}\right)$ should be constant in order to ensure a balanced growth path[1]. In other words, the growth rate of technology in the skilled labor sector is ultimately equal to that in the unskilled labor sector.

In the next step, we can find the bequest level that separates unskilled and skilled labor in the long run. Given the distribution of inheritance at time t, $D_t(b_t)$, the critical level of bequests, z, determines the long-run composition of the labor force. The sizes of the unskilled and skilled labor pools thus converge to $\hat{L}^s$ and $\hat{L}^u$, respectively.

$$\begin{aligned} \lim_{t\to\infty} L^u_{t+1} &= \int_0^{\hat{g}} D_t(\hat{b}_t)d\hat{b}_t \equiv \hat{L}^u \\ \lim_{t\to\infty} L^s_{t+1} &= \int_0^{\hat{g}} D_t(\hat{b}_t)d\hat{b}_t \equiv \hat{L}^s \end{aligned} \tag{24}$$

The steady-state equilibrium level of bequests is equal to

$$\lim_{t\to\infty}\hat{b}_t = \begin{cases} \bar{b}^u \equiv \dfrac{(1-\gamma)(2+r+g^A)}{1+g^A-(1-\gamma)(1+r)} \\ \bar{b}^s \equiv (1-\gamma)\left\{\left((1+r\cdot\tau) - \dfrac{\theta(1+r)}{(1+g^A)}\right)\cdot\alpha\Gamma^{1-\alpha} - \dfrac{\Phi(1-\theta)(1+r)}{(1+g^A)}\right\} / \left(1 - \dfrac{(1+r)(1-\gamma)}{1+g^A}\right) \end{cases} \tag{25}$$

The income level of a skilled worker in the second period consists of his or her wage income:

$$\begin{aligned} I^s_{t+1} &= (1-\tau)\cdot w^s_{t+1} + (b^s_t - c^e_t + s_t)\cdot r \\ &= (1-\tau)\cdot\alpha A^s_{t+1}\cdot\Gamma^{1-\alpha} + (b_t - c^e_t + s_t)\cdot r \end{aligned} \tag{26}$$

[1] The proof is presented in Appendix I.

By contrast, the income level of an unskilled worker in the second period is represented by

$$\begin{aligned} I_{t+1}^{u} &= w_{t+1}^{u} + b_t \cdot r \\ &= A_{t+1}^{u} + b_t \cdot r \end{aligned} \qquad (27)$$

and the income level of an unskilled worker in the first period is given by

$$I_t^u = A_t^u \qquad (28)$$

Therefore, the aggregate income level in the whole economy is

$$\begin{aligned} Y_t &= I_{t+1}^{s} L_{t+1}^{s} + I_{t+1}^{u} L_{t+1}^{u} + I_t^u L_t^u \\ &= \left[(1-\tau)\cdot \alpha A_{t+1}^{s} \cdot \Gamma^{1-\alpha} + (b_t - c_t^e + s_t)\cdot r\right] L_{t+1}^{s} + \left[A_{t+1}^{u} + b_t \cdot r\right] L_{t+1}^{u} + A_t^u L_t^u \end{aligned} \qquad (29)$$

Income per capita is $y = Y_t / 2$. Provided that there is a balanced growth path, the growth rates of technology in the two sectors would become the same at the steady state. Therefore, income per capita divided by technology converges to a constant as $\lim_{t\to\infty} \frac{Y_t}{A_t^s} = \lambda$. From equation (2), we know that the growth rate of technology is represented as

$$g_t^A = \beta L_t^s (A_t^s)^{\phi-1} \qquad (30)$$

By taking the logs of equation (30) and differentiating with respect to time, we obtain the relation between the growth rate of skilled labor, g^{L^s}, and that of technology, g^A, at the steady state as $g^A = \frac{1}{1-\phi} g^{L^s}$. Hence, the growth rate of income per capita, g^{y*}, can be defined by

$$g^{y*} = g^A = \frac{1}{1-\phi} g^{L^s} \qquad (31)$$

As a result, the economic growth rate is dependent on the growth rate of skilled labor. Moreover, the government's education policies have transitory effects on the national economy. Put simply, the long-run economic growth rate would be unaffected by the government's education policy.

3. Empirical Analysis

In this section, we verify the expanded Galor–Zeira model from three aspects.

First, we show that parental assets have affected children's levels of education in Korea since the 1990s. Demonstrating that parental wealth is an important determinant of the educational attainment of their children in Korea proves that education plays a substantial role in diverging inequality. Second, we test whether the wage gap between skilled and unskilled workers diverges in Korea by harmonizing it with the growth rate of technological progress. This analysis, together with the first empirical test, explains the increased polarization of wealth in Korea. Suppose that rich people raise their children to be skilled workers with a greater probability than the poor. In turn, if there were a significant difference between skilled and unskilled labor, the former would be more likely to become rich parents than the latter. In other words, wealth is passed down through education from generation to generation. Finally, we examine the effectiveness of the government's student loans program, which aims to increase the educational opportunities for the poor by reducing credit market imperfections. Effective government policy could encourage education improvements for a greater number of skilled workers even though it temporarily increases the economic growth rate.

3.1 Data description

The main data used in the presented empirical analyses are derived from the Korean Labor and Income Panel Survey (KLIPS) and Youth Panel (YP). The KLIPS is an annual panel survey of approximately 5000 households and 11,000 individuals that started in 1998. It can be thought of as the Korean version of the National Longitudinal Survey or Panel Study of Income Dynamics in the US. The survey asks various questions about the labor market and the incomes and assets of individuals and households. Preserving the original sample in each wave is important in a panel survey. In this regards, the KLIPS has sustained 74% of its original sample (as at the 11th wave in 2008).

For our dataset, we combine the parental household data of the first and second waves with the children's household data of the seventh to 11th waves, only in the case of parental households with children that moved out between the seventh and 11th

waves. These inclusion criteria generate 418 parent–child pairs for analysis (we include both genders of children that have moved out).

The YP is an annual panel survey of Korean people aged from 15 to 29 years that follows up the transition from school to work and from adolescence to adulthood. It can be thought of as the Korean version of the National Longitudinal Survey of Youth in the US and is approved by the National Statistical Office in Korea. The YP gathers detailed information on respondents' labor market behaviors and educational experiences. The first wave of the YP was YP2001, which started in 2001 and ended in 2006. The second wave (YP2007) comprised 10,000 people aged from 15 to 29 years as of 2007. In this study, we focused on the cross-sectional data of the fourth investigation of YP2007, which represented 81.7% of the initial samples and which was collected in 2010.

3.2 Korean economic development in the 1990s

As stated by Rodrik (1994), economic development in Korea began from an initial low level of inequality, which was sustained during its growth period despite the sharp economic growth rate. However, the trend of increasing inequality started in the early 1990s, and since the 2000s, the level of inequality has risen significantly, as demonstrated in Figure 2, notably following the global financial crisis that started in 2008.

We argue that this diverging inequality in Korea since the 2000s is related to the human capital channel. According to Young (1995), 84% of Korean output growth in 1960–1990 was explained by factor accumulation compared with just 7% for human capital accumulation. However, Singh et al. (1996) showed that the driving force behind Korean growth shifted from factor accumulation to TFP growth from the 1990s, suggesting that human capital gradually became the primary engine of economic growth in Korea instead of physical capital accumulation, which concurs with the argument presented by Galor and Moav (2004). This finding implies that the human capital channel of inequality is stronger when human capital plays a significant role in economic growth. This was particularly the case from the early 1990s given that the burden of college tuition fees for households had grown following the liberalization of

tuition charges in 1989. (In terms of our sample, the mean birth year was 1976, meaning that most participants were educated in the 1990s.)

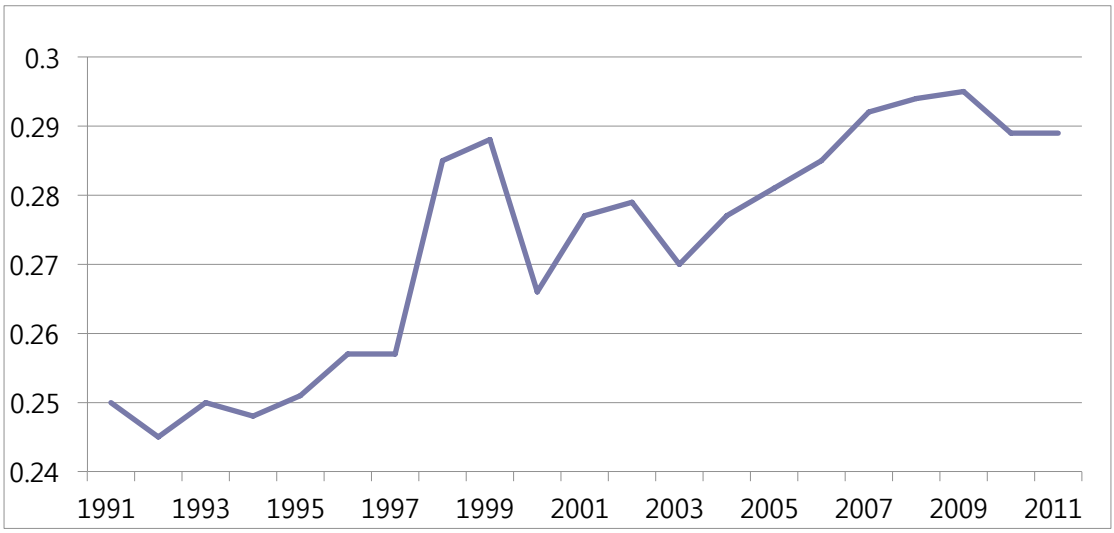

Figure 2 Gini index of South Korea (urban households with two or more household members)
Source: National Statistical Office

3.3. Results

3.3.1. Relationship between parental wealth and children's educational attainment

To test the existence of the human capital channel in the Galor–Zeira model, we examine whether a child's level of education in Korea is affected by their parental transfer (i.e., parental assets). A child's education, represented by years of schooling, is expressed as a linear function of his or her parental assets measured in logarithms. Our ordinary least squares (OLS) equation takes the following form:

$$edu_t^i = \beta_0 + \beta_1 asset_{t-1}^i + \boldsymbol{\beta}\mathbf{X} + \varepsilon^i \qquad (32)$$

where edu_t^i represents a child's educational experience and $asset_{t-1}^i$ his or her parental assets. Further, parents' and their offspring's generations are defined by $t-1$ and t, respectively. The data are derived at the household level *i*, I denotes a father–child pair, and ε^i is a random component usually assumed to be distributed as $N(0,\sigma^2)$. The covariates and their coefficients are denoted by $\mathbf{X}$ and $\boldsymbol{\beta}$, respectively. The constant term represents the level of education common to the generation, t, while the

coefficient β_1 indicates the extent to which a child's education levels are related to parental assets.

The variable edu_t^i measures a child's years of schooling. Because the data do not distinguish between graduating from and dropping out of school, we used 12 as the years of schooling in both cases. Twelve years thus represents the highest level of individual education. The mean parental year of birth was 1947 and that of the children was 1976 at the time of the survey.

The variable $asset_{t-1}^i$ is the logarithm of parental assets (shown in 10,000 KRW), which includes real estate assets, financial assets, and debts. We included the price of the house in which households live in real estate assets. These asset data are likely to be contaminated by measurement errors. To overcome this problem, we used an average level of assets over the 1998–2002 survey years.

The covariate $\mathbf{X}$ includes the following variables: (a) a logarithm of the father's annual wage, (b) the father's years of schooling, (c) the mother's years of schooling, (d) the grandfather's years of schooling, (e) an indicator of the child's health, and (f) number of children in the household. The father's annual wage is also likely to include a measurement error. To overcome this problem, we used the father's annual wage averaged over the 1998–2002 survey years. We excluded other sources of income due to collinearity between income from real estate or financial assets and the asset variables. Variables (b), (c), and (d), representing level of education, were measured by years of schooling. An indicator of the child's health was provided by the answers of individuals in the survey based on a five-point scale (5 = very good health and 1 = very poor health). We thus treated this as a continuous variable between 1 and 5.

(Insert Table 1 here)
(Insert Table 2 here)

Table 2 presents the estimates the channel of inequality obtained using the sample of father–child pairs. Every column in Table 2 presents the cross-sectional estimates of the effects of parental assets on a child's years of schooling given the variation in the covariates discussed above. In all columns, the effect of parental assets on a child's years of schooling is shown to be strongly significant.

Despite our concerns, parental assets and the father's annual wage do not show high collinearity because the data come from a time period after which divergence between dynasties' assets has already occurred. Further, the prices of assets in Korea, especially those of real estate, have increased sharply along with industrialization and urbanization. Hence, real estate asset-holders easily can accumulate considerable assets, not related to their wage incomes, in the Korean development context.

Both the father's and the mother's levels of education have significant relationships with children's level of education. When both parents' levels of education are considered at the same time, each coefficient slightly decreases because of assortative mating. The coefficient of the father's level of income becomes non-significant when the variable for the father's education is added (i.e., the father's income is explained by the father's level of education).

The coefficient of number of children was expected to be negative because if the number of children is higher, the resource for human capital investment per child will be lower. However, in contrast to our prediction, the coefficient turns out to be positive and insignificant. This result is consistent with the findings of Lee (2004), which insisted that there has been an weak quantity–quantity trade-off in Korea since the 1990s. Since the 2000s, the demographic transition, which is decreasing fertility, has saturated. Also the cost of raising each child has increased owing to the rising costs of education and growing parental opportunity cost.

(Insert Table 3 here)

We also tested the channel of inequality using an ordered logistic regression. It is reasonable to believe that the choice of having more education is a discrete one. Because we wanted to distinguish between entering college and entering graduate school, we therefore used ordered logistic regression models. We applied the values 0, 1, 2, and 3 for when a participant graduated from high school, graduated from college, gained a Master's degree, and gained a PhD, respectively.

In Table 3, the variables of the logarithms of parental assets, the father's years of schooling, the mother's years of schooling, and number of children are shown to be significant and positive as with the OLS results presented earlier. The positive

coefficient for the logarithm of parental assets means that the likelihood of receiving a higher education increases with parental assets. Similarly, the positive coefficient between the level of the father's/mother's education and number of children implies that a higher level of parental education and more children in each household increase the level of a child's education.

Further, the ordered logistic regression allows us to calculate the probability of outcomes. Based on the average values of these variables (logarithm of parental assets = 12.6, father's schooling = 10.1, mother's schooling = 8.6, and number of children = 2.8), Z is

$$Z=0.1622\times12.6 + 0.0804\times10.1+0.0953\times8.6+0.1714\times2.8=4.1553 \quad (33)$$

then,

$$p(y=0)=\frac{1}{1+\exp(Z_i-\kappa_1)}=\frac{1}{1+\exp(4.1553-2.8726)}=0.2171 \quad (34)$$

$$p(Y=1)=\frac{1}{1+\exp(Z_i-\kappa_2)}-\frac{1}{1+\exp(Z_i-\kappa_1)}=\frac{1}{1+\exp(4.1553-6.4586)}-\frac{1}{1+\exp(4.1553-2.8726)}=0.6921 \quad (35)$$

$$p(Y=2)=\frac{1}{1+\exp(Z_i-\kappa_3)}-\frac{1}{1+\exp(Z_i-\kappa_2)}=\frac{1}{1+\exp(4.1553-8.7993)}-\frac{1}{1+\exp(4.1553-6.4586)}=0.0813 \quad (36)$$

$$p(Y=3)=1-\frac{1}{1+\exp(Z_i-\kappa_3)}=1-\frac{1}{1+\exp(4.1553-8.7993)}=0.0095 \quad (37)$$

for average households, where κ_i is the particular threshold of *Y*.

This result means that in an average household in Korea, children are likely to graduate from college with a probability of 0.6921.

Next, we are interested in the threshold value of parental assets in terms of children's education. By assuming all the average values of the household, except parental assets, mentioned earlier hold, we can simulate the effect of a change in parental assets on children's level of education.

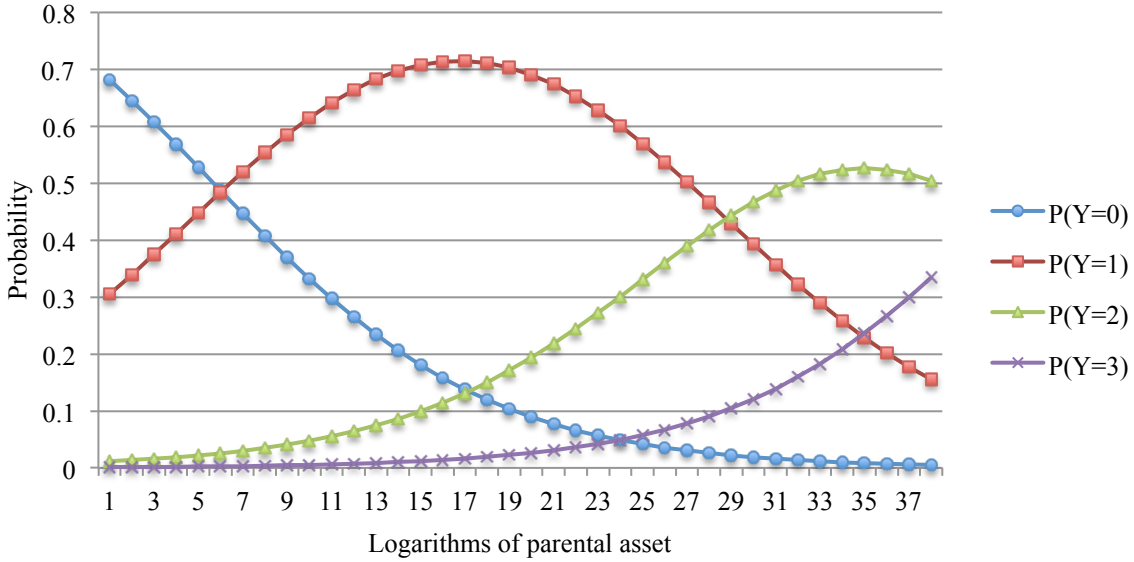

Figure 3 Changes in children's educational choices with respect to levels of parental assets

As illustrated in Figure 3, increasing parental assets induces a higher probability of the child receiving a higher level of education. If all conditions, except the level of parental assets, are fixed at their average levels, we can thus show that households that have an asset base of less than approximately five million won are likely to only graduate from high school.

(Insert Table 4 here)

We next analyzed the marginal effect when each choice has the highest possibility. The presented result supports the finding that the marginal effect of all variables, including parental assets, on a child's education is largest when households choose high school ($Y=0$) as their child's final school. A higher amount of parental assets leads to a lower marginal effect of the explanatory variables on children's level of education. Moreover, through the OLS and ordered logistic regression models, we can confirm that parental assets play a significant role in the choice of children's level of education, especially the decision of whether to enter college.

3.3.2. Relationship between the wage gap and technological progress

Greiner et al. (2004) used the term "college premium" to represent the wages of employees that have a college degree over those of employees with only a high school education. We define the wage differences between skilled and unskilled labor as the "college premium," which in this study is the ratio of the average wage per hour earned by college graduates (Bachelor's degree and higher) to the average wage per hour earned by high school graduates.

Data on employment and wages were obtained from the Ministry of Employment and Labor (MEL), while other data on the national economy were gathered from the Bank of Korea. In particular, the Survey on Labor Conditions by Type of Employment, released by the MEL, provides annual information from 1980 to 2010 on the number of employees by educational attainment, working hours, years of consecutive service, and monthly income. Figure 4 shows that the number of employees who have college degrees has increased 13-fold during the past three decades. Consequently, the ratio of college graduates to total employees rose from 12.2% in 1980 to 56.3% in 2010, whereas the ratio of high school graduates to total employees only increased from 30.4% in 1980 to 37.2% in 2010.

Based on this finding, we examine **Proposition 1** that technological differences between the skilled and unskilled sectors have induced cross-sectoral income inequality. In other words, the wage gap, $(W^{s'} / W^{u'})$, has increased relative to the technological gap, (A^s / A^u). The technological gap is represented by the growth rate of technology as in Murphy et al. (1998), because technological progress generally increases cross-sectoral technological differences. From equation (31), the growth rate of skilled labor is shown to serve as a proxy for the growth rate of technology. Therefore, comparing trends between the wage gap and the growth rate of skilled workers demonstrates the relation between the college premium and technological progress.

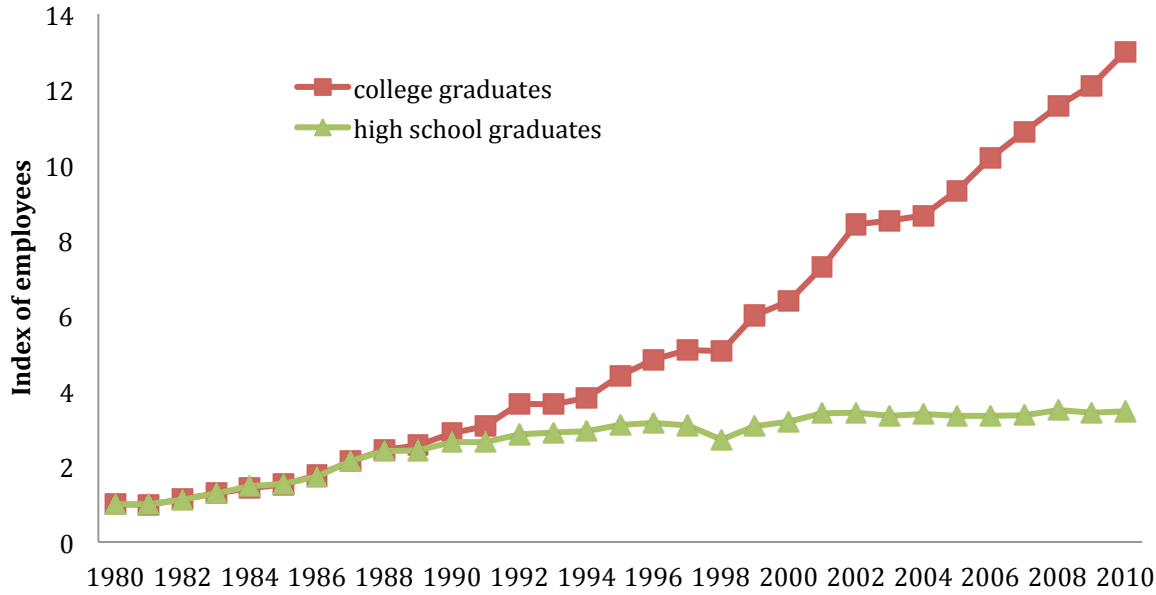

Figure 4 Employees that are college graduates and high school graduates, Korea 1980–2010
Source: MEL

Figure 5 shows that the college premium in Korea has decreased over time. To remove fluctuations and clarify general trends, we thus applied the Hodrick–Prescott filter to the growth rates of skilled labor and income per capita. The smoothness parameter of the Hodrick–Prescott filter was set to 100. From the figure, we know that there has been a significant correlation between the wage gap and the growth rate of skilled workers over the past three decades. This finding verifies the validity of Proposition 1—at least in Korea. However, owing to the foreign exchange crisis in 1997 and the global financial crisis in 2008, the trends between them have begun to diverge. The disaccord stems mainly from the mass unemployment caused by large-scale restructuring in Korea in the 1990s; however, the economic aftereffects continued until the global financial crisis.

It is noteworthy that the growth rate of skilled labor leads to the growth rate of income per capita in Figure 5. There thus seems to be a strong correlation between them throughout the study period. While the size of income per capita is dependent on the proportion of skilled labor, according to Galor (2011), the growth rate of income per capita is dependent on the growth rate of skilled labor, as predicted by equation (31).

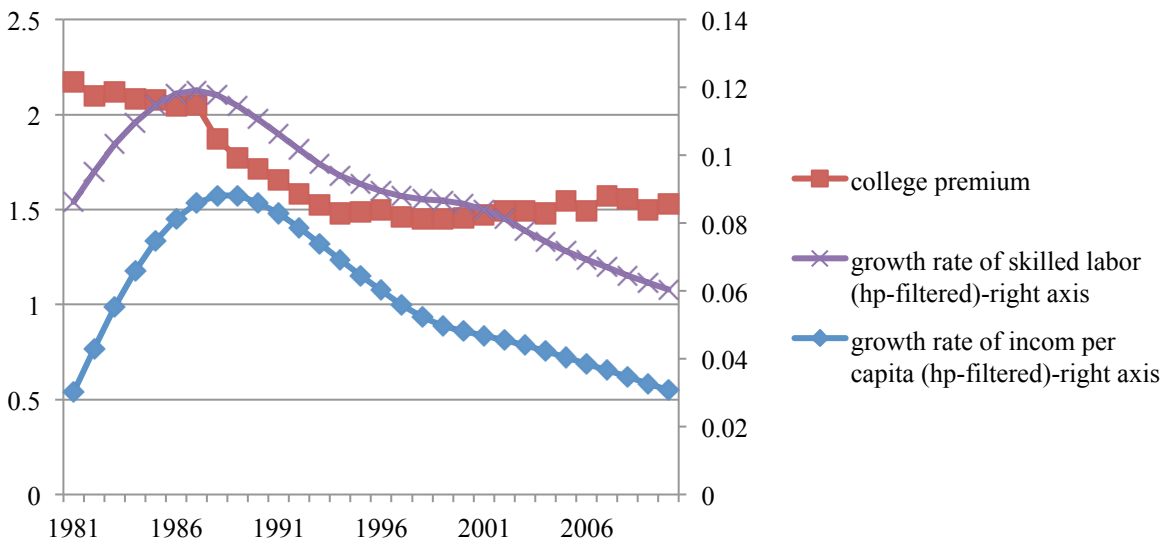

Figure 5 The trends of the college premium, growth rate of skilled labor, and growth rate of income per capita, Korea 1981–2010

Source: MEL and Bank of Korea

3.3.3. Impact of backed student loans on college attendance

The Korean government began to provide state-backed student loans from the second half of 2005. Before then, parents had to stand surety for their children to receive student loans from mainstream banks. Although student loans do not provide direct support, they are clearly characterized as a type of financial aid, because more students who were previously unable to attend college due to their parents' credit status were eligible for a student loan. Moreover, the new policy extended the longest term of loans from 14 to 20 years and increased borrowing limits considerably.

There have been few studies of the effects of these new student loans in Korea. In this subsection, we examine **Proposition 2,** namely that this change in the student loan system affects the decision to attend college. Although the change might have a more significant effect on the completion of schooling rather than attendance per se, the majority of male students who entered college after taking out a student loan did not graduate because of their call-up to participate in compulsory military service in Korea.

As explained earlier, data were derived from the fourth investigation of YP2007 (Table 5). These data cover a wide range of cohorts that became high school seniors around 2005. Specifically, interviewees born from 1987 to 1991 were considered to be in the "after" period and they thus decided whether to attend a college after the

introduction of the new student loans policy. By contrast, interviewees born from 1982 to 1986 were considered to be in the "before" period.

In order to verify the effect of this financial aid, we used the difference-in-differences methodology adopted by Dynarski (2003) and Long (2007). This methodology requires two comparable groups, the control group and the treatment group. Compared with the control group, the treatment group means newly eligible individuals. In this study, we placed those with a deceased or unemployed father in the treatment group because they would have found it difficult to receive loans from mainstream banks before the new policy. Similarly, we also added children who belonged to households in livelihood protection to the treatment group.

(Insert Table 5 here)

Table 5 shows that individuals in the treatment group have lower college attendance rates. As expected, they come from relatively low-income families and their parents have lower educational attainments consistently, although there are some differences between the two periods.

The equation for the OLS and logistic regression estimation is

$$y_i = \alpha + \beta(Treat_i \times After_i) + \delta(Treat_i) + \lambda(After_i) + \boldsymbol{\beta}\mathbf{X_i} + u_i \qquad (38)$$

where the college attendance of individual i is denoted by y_i and the other control variables are denoted by vector $\mathbf{X}_i$. The control variables include household income and parental educational attainment. The treatment effect is captured by the coefficient β.

Specifically, we find that if the sign of the coefficient is positive, the probability of attending college for new eligible individuals rises. The coefficients δ and λ explain the differences in college attendance between the two groups and between the two periods, namely before and after the introduction of the new loans policy.

(Insert Table 6 here)

Table 6 shows that college enrollment increased for newly eligible students. Moreover, the estimates of the effects of these state-backed student loans are also significant and robust in the presence of other covariates in the logistic regression. These results suggest that Proposition 2 is valid in Korea. We also find several interesting results in Table 6. Compared with the control group, the treatment group has a relatively low probability of attending college, but there is no significant difference before and after the inception of the new loans system. In addition, the father's college attendance affects children's schooling significantly more than does the mother's college attendance.

4. Summary and Conclusions

Although the Galor–Zeira model is a well-known macroeconomic model that is able to shed light on the relationships among inequality, human capital, and growth, the empirical evidence provided by the model is often insufficient, especially for the in-depth longitudinal examination of one country. In this paper, we thus showed that education channel is a key factor that influences the level of inequality in Korea by extending the Galor–Zeira model. We further expanded the original model by adding technological progress and educational policy and verified our proposed model by using Korean panel data.

The presented results suggest three main findings. First, by estimating the degree to which parental assets affect children's level of education using OLS and ordered logistic regression models, we confirmed that parental assets do influence a child's level of education level and, specifically, significantly increase the probability of a child becoming a skilled worker. Moreover, according to the ordered logistic regression, a lower asset pool induces a higher marginal effect of parental assets on children's level of education, which validates this conclusion. Second, we demonstrated empirically that governmental financial assistance reduces barriers to entering higher education, thereby allowing more people to become skilled workers, which positively affect equality as well as short-run economic growth. Third, we found that there exists diverging income inequality in Korea along with technological progress and that the

growth rate of the Korean economy has increased in proportion to the increasing number of skilled workers.

These empirical results imply that education plays an important role in the divergence of wealth by upholding income levels from generation to generation. Our conclusions can offer meaningful implications to policymakers. Even though it is commonly regarded that economic growth-inducing policies and those designed to solve the inequality problem are contrary, there exist policy options that can both boost economic growth and lessen inequality at the same time. Because the human capital channel is the main reason for growing inequality, if the government implements a policy that expands education opportunities and increases the number of skilled workers, it can reach these two targets simultaneously. Moreover, policymakers could change the threshold that determines the ratio of skilled workers to unskilled workers.

The main limitation of our research is that the empirical analysis is carried out using only Korean data. If research based on cross-country data were carried out in the future, the expanded Galor–Zeira model could become even more convincing. In addition, if such empirical research using cross-country data were to cover the human capital channel and the reduced relationship between inequality and growth at the same time, the Galor–Zeira model would become stronger still.

Appendix I

In order to produce a balanced growth path in a small economy, the following condition should be satisfied:

$$(b_t^s - c_t^e) \cdot L_t^s + b_t^u L_t^u = K_{t+1} - K_t \quad \text{(A.1)}$$

In equation (A.1), the left-hand side represents investment into physical capital and the right-hand side means an increase in physical capital stock. In the long run, the bequests of unskilled and skilled labor increase relative to technological progress

$$\lim_{t\to\infty} b_t^s = A_t^s \bar{b}^s, \ \lim_{t\to\infty} b_t^u = A_t^u \bar{b}^u \quad \text{(A.2)}$$

In addition, since the interest rate is assumed to be constant and the composition of each labor converges over time, the increased rate of physical capital is the same as the growth rate of technology:

$$K_{t+1} - K_t = \beta L_t^s K_t \qquad \text{(A.3)}$$

Over time, by substituting equations (A.2) and (A.3), equation (A.1) is presented as:

$$\left(A_t^s \bar{b}^s - \theta\alpha A_t^s \Gamma^{1-\alpha} - (1-\theta) A_t^u\right) \hat{L}^s + A_t^u \bar{b}^u \hat{L}^u = \beta \hat{L}^s \cdot \Gamma A_t^s \hat{L}^s \quad \text{(A.4)}$$

Finally, from (A.4), we can find the following relationship:

$$\lim_{t\to\infty}\left(\frac{A_t^u}{A_t^s}\right) = \frac{\left(\bar{b}^s - \theta\alpha\Gamma^{1-\alpha} - \beta\hat{L}^s\Gamma\right)\cdot \hat{L}^s}{\left((1-\theta)\cdot \hat{L}^s - \bar{b}^u \cdot \hat{L}^u\right)} = \Phi \quad \text{(A.5)}$$

(Q.E.D.)

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Table 1 Summary Statistics: KLIPS

Explanatory variables	Dependent variable: child's education (Y=0,1,2,3)	
	(1)	(2)
Logarithm of parental assets	**0.1519*** **	**0.1622*** **
	(0.0444)	(0.0434)
Father's years of schooling	**0.0282** **	**0.0804** **
	(0.0344)	(0.0337)
Mother's years of schooling	**0.0954** **	**0.0953** **
	(0.0417)	(0.0416)
Number of children	**0.1672* **	**0.1713* **
	(0.1009)	(0.1001)
Logarithm of parental wage income per year	**0.0942**	
	(0.1126)	
Grandfather's years of schooling	**-0.0178**	
	(0.0213)	
Indicator of a child's health	**0.0437**	
	(0.1549)	
/cut1	3.5284	2.8726
/cut2	7.1245	6.4586
/cut3	9.4651	8.7993
LR chi2	40.87	39.40
Prob>chi2	0.0000	0.0000
pseudo R2	0.0549	0.0529
Observations	418	418

Table 2 Relation between child's education and parental asset (OLS result)

Explanatory variables	Dependent variable: Child's years of schooling									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Logarithms of parental asset	**0.1658*** **		**0.1575*** **	**0.1455*** **	**0.1475*** **	**0.1435*** **	**0.1373*** **	**0.1423*** **	**0.1383*** **	**0.1319*** **
	(0.0464)		(0.0462)	(0.0456)	(0.0459)	(0.0456)	(0.0467)	(0.0460)	(0.0456)	(0.0470)
Logarithms of parental annual wage		**0.2567** **	**0.1957**	**0.1151**	**0.1563**	**0.1144**	**0.1115**	**0.1151**	**0.1212**	**0.1195**
		(0.1213)	(0.1211)	(0.1153)	(0.1146)	(0.1120)	(0.1119)	(0.1120)	(0.1139)	(0.1137)
Father's years of schooling				**0.1483*** **		**0.1165*** **	**0.1211*** **	**0.1171*** **	**0.1135*** **	**0.1181*** **
				(0.0294)		(0.0334)	(0.0335)	(0.0333)	(0.0330)	(0.0330)
Mother's years of schooling					**0.1414*** **	**0.0645* **	**0.0660* **	**0.0641**	**0.0908** **	**0.0906** **
					(0.0345)	(0.0391)	(0.0391)	(0.0391)	(0.0422)	(0.0420)
Grandfather's years of schooling							**-0.0195**			**-0.0164**
							(0.0204)			(0.0205)
Indicator for child's health								**0.0382**		**0.0497**
								(0.1652)		(0.1630)
The number of children									**0.1892* **	**0.1820* **
									(0.1044)	(0.1052)
constant	**12.6986*** **	**12.8106*** **	**11.3068*** **	**10.5757*** **	**10.5231*** **	**10.3746*** **	**10.4802*** **	**10.2789*** **	**9.6536*** **	**9.6440*** **
	(0.5977)	(0.9439)	(1.0669)	(1.0598)	(1.0379)	(1.0459)	(1.0569)	(1.0497)	(1.1581)	(1.2636)
R2	0.0333	0.0115	0.0400	0.1008	0.0813	0.1066	0.1084	0.1067	0.1146	0.1160
observation	418	419	418	418	418	418	418	418	418	418

Table 3 Relation between children's education and parental assets (ordered logistic regression)

Variable	Obs.	Mean	Std. dev.
Child's years of schooling	418	14.7871	2.2086
Logarithm of parental assets	418	12.5967	2.4297
Logarithm of parental annual wage	418	7.6478	0.9307
Father's years of schooling	418	10.1028	3.7142
Mother's years of schooling	418	8.5622	3.1905
Grandfather's years of schooling	418	3.2823	4.9898
Indicator of a child's health	418	2.6699	0.6793
Number of children	418	2.8565	1.1246

Table 4 Marginal effect of the variables on each child's educational choice

	P(Y=0)	P(Y=1)	P(Y=2)	P(Y=3)
Logarithm of parental assets	-0.0270***	0.0140***	0.0119***	0.0015***
	(0.00727)	(0.0047)	(0.0034)	(0.0008)
Father's years of schooling	-0.0147***	0.0070**	0.0059**	0.0008*
	(0.0057)	(0.0032)	(0.0025)	(0.0005)
Mother's years of schooling	-0.0157**	0.0082**	0.0070**	0.0009*
	(0.0070)	(0.0039)	(0.0032)	(0.0006)
Number of children	-0.0290*	0.0148	0.0126*	0.0016
	(0.0169)	(0.0091)	(0.0075)	(0.0012)

Table 5 Summary statistics: YP2007 (4th)

	Before		After		Difference-in-differences
	Control Group	Treatment Group	Control Group	Treatment Group	
Attend college	0.8717	0.7112	0.8745	0.8367	0.1227
Household income (10,000 won)[1)]	4888	3588	4613	2750	563
Female	0.5305	0.5000	0.6109	0.6776	0.0972
Father attended college	0.2932	0.2050	0.4031	0.2449	-0.0700
Mother attended college	0.1127	0.1118	0.2160	0.1388	-0.0763
Number of Observations	1917	322	2431	245	4515

Notes) 1) Non-responses or missing data are excluded from the calculations.

Table 6 Effect of eligibility for student loans on the probability of attending college

	OLS		Logistic regression	
	Difference-in-differences	Add covariates	Difference-in-differences	Add covariates
(Treat)X(After)	0.1227***	0.1317***	0.7072***	0.7904***
	(0.0310)	(0.0315)	(0.2311)	(0.2372)
Treat	-0.1605***	-0.1412***	-1.0147***	-0.8805***
	(0.0207)	(0.0210)	(0.1407)	(0.1441)
After	0.0029	-0.0020	0.0258	-0.0171
	(0.0105)	(0.0108)	(0.0917)	(0.0951)
Log(Household income)		0.0381***		0.2714***
		(0.0079)		(0.0571)
Female		0.0129		0.1126
		(0.0101)		(0.0861)
Father attended college		0.0683***		0.6571***
		(0.0122)		(0.1166)
Mother attended college		0.0131		0.1816
		(0.0156)		(0.1576)
R^2	0.0136	0.031	-	-
Number of Observations[1)]	4915	4752	4915	4752

Notes) 1) Samples with non-responses or missing data are excluded from the estimations.