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Abstract This paper aims to show that the level of inequality increases via the human capital channel with credit market imperfections generating negative effects on 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. We use Korean data from 1998 to 2008 to empirically confirm 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 programme positively influences equality and short-run economic growth by promoting the number of skilled workers.

Keywords Human Capital, Economic Growth, Inequality
JEL Codes: I24, I25, O15

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 a policy of reallocation 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) argued in favour 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 also 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 (see Papageorgiou and Razak, 2009). To empirically prove the Galor-Zeira model, panel data at the national level is 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.

A number of labour economics studies on intergenerational wealth transfer provided evidence of human capital affecting inequality. These studies use 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, which we focus on 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.

On the other hand, Piketty and Saez (2003) and Piketty (2014) perform empirical analysis using very long time series of data for France, the US, the UK, German, and Sweden. According to them, the belief that technological progress will result in the triumph of human capital over financial capital accumulation, in other words, meritocracy, is illusory, because the nature of capitalism inevitably increases inequality over the growth/development of capitalism. The small elite that has a higher propensity of savings can enjoy income from capital from which a large share can grow over time. This accumulated capital is likely to transfer to their inheritors through bequests, perpetuating generations of families to remain in the wealthy class. This process of accumulation, expansion and inheritance of capital, which is supported by the two fundamental laws of capitalism, leads society unequal under the situation that the return of capital is greater than the rate of economic growth (Piketty and Saez 2003; Piketty 2014).

In this paper, we aim to expand the Galor-Zeira model by introducing technological progress and government fiscal policy and verify the results of our model using Korean panel data. Our study also shows that the government provides financial aid to support college attendance. Although Li and Zuo (2002) and Yue (2011) have showed that inequality has a negative impact on economic growth, using Korean and Asian data respectively, they don't provide the theory behind the negative relationship. Therefore, this paper, which provides theory on the channel of inequality and its impact on economic growth together with empirical analysis, can be complementary to these previous findings. In addition, thanks to the newly introduced government in the model, we can figure out the effect of a government policy that reduces the financial hurdle for human capital accumulation.

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

The theory given in this paper is based on Galor-Zeira model (Galor and Zeira 1993). This seminal work developed the modern perspective on inequality in terms of economic growth by introducing heterogeneity among agents' income. However, technological progress and the role of government were not included in their work. Therefore, our paper expands the model by adding technological progress and government taxation/expenditure. Considering that technological progress is one of the major factors in understanding modern economic growth and implementing proper policy for national competency, our expanded Galor-Zeira model can provide an advanced framework that embraces technological progress. Moreover, the expanded Galor-Zeira model that includes government taxation and expenditure can offer policy implications directly from the 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 labour and unskilled labour. Furthermore, as already mentioned above, our model examines the influence of technological progress, A_t^s and A_t^u, which will be explained momentarily.

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

$$Y_t = Y_t^s + Y_t^u$$
$$where, \quad \begin{cases} Y_t^s = (A_t^s L_t^s)^{\alpha} \cdot (K_t^s)^{1-\alpha} \\ Y_t^u = A_t^u L_t^u \end{cases} \tag{1}$$

In equation (1), Y_t^s and Y_t^u represent the outputs for the skilled and unskilled sectors at time t. Moreover, K_t^s is physical capital input of the skilled sector at time t, while L_t^s and L_t^u represent labour input of the skilled and unskilled sector at time t respectively. A_t^s and A_t^u stand for labour-augmenting technology of the skilled and unskilled sector at time t.

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

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

where ϕ means decreasing returns to knowledge, as characterised 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 labour. Similarly, the technology in the unskilled labour sector increases, although the growth rate is slower than that in the skilled labour sector, as follows:

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

where χ is initially smaller than β.

Wage in the skilled labour sector, w_t^s, and the rental price of capital, r_t, which is the same as the interest rate in this model, are derived from the following profit maximisation problem:

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

The solution to this problem provides wage of skilled worker, w_t^s, and the rental price of capital, r_t.

$$\begin{cases} w_t^s = \alpha A_t^s \left(\dfrac{K_t^s}{A_t^s L_t^s} \right)^{1-\alpha} \\ r_t = (1-\alpha) \cdot \left(\dfrac{A_t^s L_t^s}{K_t^s} \right)^{\alpha} \end{cases} \tag{5}$$

Provided that capital is perfectly mobile and the global interest rate is constant over time, which means $r_t = r$, the above equations can be replaced by

$$\begin{cases} w_t^s = \alpha A_t^s \Gamma^{1-\alpha} \\ r_t = r = (1-\alpha)\Gamma^{-\alpha} \end{cases} \tag{6}$$

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

In the same way, wage in the unskilled labour sector, w_t^u, is derived from

$$\max_{L_t^u} A_t^u L_t^u - w_t^u L_t^u \tag{7}$$

Consequently, the unskilled labour wage is given by

$$w_t^u = A_t^u \tag{8}$$

This model assumes that each individual has only one child, meaning that the total population in one generation remains at one. Although this assumption seems to be unrealistic, this assumption allows us to ignore the effect of population growth and to focus on the bequest dynamics of two different workers' group. People maximise their utilities by consuming goods in the second period and leaving their children bequests in the form of so-called warm glow altruism:

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

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

Utility maximisation with a budget constraint is given by

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

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

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

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

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

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

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 wage for two periods as well as a bequest from their parents, meaning that total wealth is represented as

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

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

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

where c_t^e represents education costs, s_t reflects the education subsidy, τ is the tax rate, and i is the higher interest rate for borrowers due to credit market imperfections.

Again, 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 in the sense that government pays the interest of the loan and cost for borrowing money, and through this, student can face cheaper education cost than that of the case without subsidy. After completing their college educations, skilled workers repay loans through their wages. By substituting equation (6) into (14), the wealth of skilled labour is therefore represented by technology as

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

Moreover, education expenditure is assumed to increase with wage

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

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

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

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 labour sector:

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

This assumption truly holds in Korean context, considering the Korean context on educational fever and status desire (Kang 2008).

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

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

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

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

From the solution to the utility maximisation 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:

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

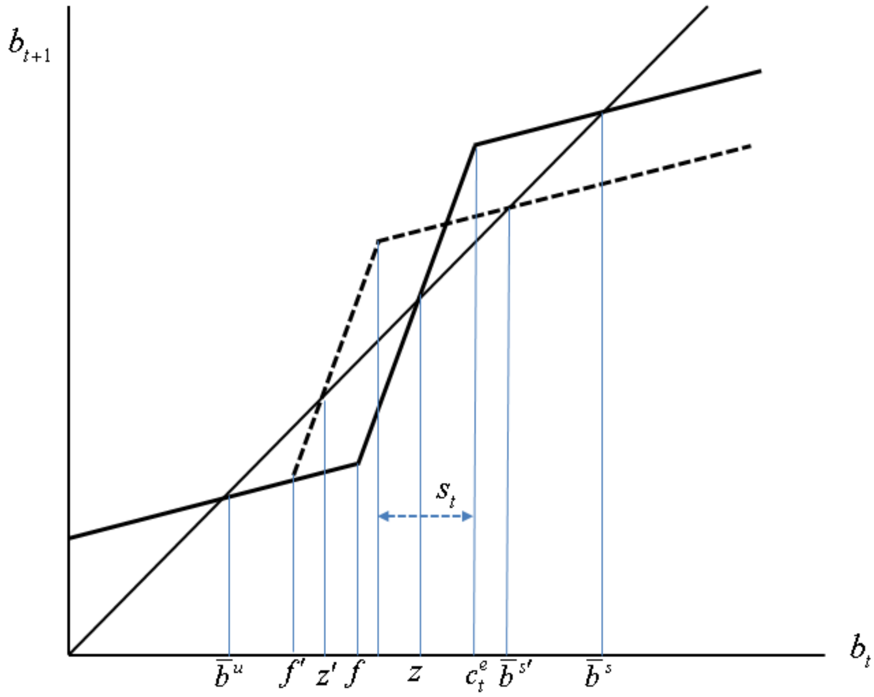

Figure 1 Bequest dynamics

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 labour pool, it decreases the disposable incomes of skilled labour 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 labour ($\bar{b}^u$), the bequests of all individuals converge to $\bar{b}^{s'}$.

3. Empirical Analysis

In this section, we verify the expanded Galor-Zeira model from two aspects. First, we show that parental assets 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. This analysis, together with the first empirical test, explains the increased polarisation 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 was a significant difference between skilled and unskilled labour, 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 programme, which aims to increase the educational opportunities for the poor by reducing credit market imperfections. Effective government policy could encourage education improvements to increase the number of skilled workers by decreasing financial hurdles for human capital accumulation.

3.1 Data description

The main data used in our empirical analyses is the Korean Labor and Income Panel Survey (KLIPS) and Youth Panel (YP). The KLIPS is an annual panel survey of approximately 5,000 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 labour 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 regard, the KLIPS has sustained 74% of its original sample (as of 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 eleventh waves, only in the case of parental households with children that moved out of their parents' house between the seventh and eleventh waves. This inclusion criteria generates 418 father–child pairs for analysis (we include both genders of children that have moved out).

The YP is an annual panel survey of Korean people between the ages of 15 to 29 that follows their 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' labour market behaviours 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 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.

We argue that the rise of 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, as shown by Lee (2012), higher education was soaring from the early 1980s and led a virtuous cycle between higher education and economic growth in Korea, which concurs with the argument presented by Galor and Moav (2004). Lee (2012) added that higher education had a positive impact on economic growth in Korea. This finding implies that the human capital channel of inequality is stronger when in the early 1990s since the burden of college tuition fees for households grew following the liberalisation of tuition charges in 1989. In terms of our sample, the mean birth year was 1976 and therefore most participants were educated in the 1990s.

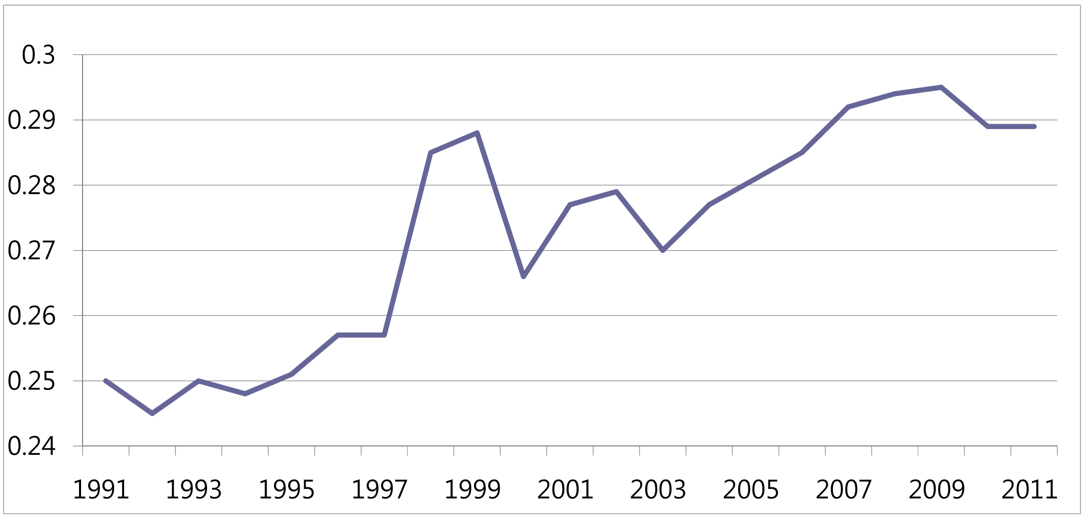

Figure 2 Gini index of South Korea (urban households with two or more household members)

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 parental transfer (i.e., parental assets) affects a child's level of education in Korea. A child's education, represented by years of schooling, is expressed as a linear function of his or her parental assets in natural logarithm units. Our ordinary least squares (OLS) model takes the following form:

$$edu_{s,i} = \beta_0 + \beta_1 \cdot asset_{f,i} + \mathrm{BX}' + \varepsilon_{s,i} \tag{22}$$

where $edu_{s,i}$ represents a child's educational experience, $asset_{f,i}$ his or her parental assets and $\varepsilon_{s,i}$ is the error term. Further, parents' and their offspring's generations are defined by *f* and *s*, respectively. The data are derived at the household level i, which denotes a father–child pair, and $\varepsilon_{s,i}$ is a random component. The covariates and their coefficients are denoted by **X** and **B**, respectively. The coefficient β_1 indicates the marginal effect of an increase in parental assets on a child's education level.

The variable $edu_{s,i}$ measures a child's years of schooling. Because the data does not distinguish the cases between graduating from and dropping out of school, we regard both cases as the case of graduation. For example, if a student drops out his or her school in the 5th grade of elementary school, his or her years of schooling is 6 as if it is the same if they graduated.

The variable $asset_{f,i}$ is the natural logarithm of parental assets (measured in 10,000 KRW), which includes real estate assets, financial assets, and debts. We included the price of owner occupied homes in our measurement of real estate assets. 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 and applied instrumental variables.

The covariate $\mathbf{X}$ includes the following variables: (a) the natural 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) the number of children in the household. We also used the father's annual wage averaged over the 1998–2002 survey years to smooth wages and ensure that the particular year we analyse doesn't bias our results. For example, the father happened to earn less in 2002 than the previous year because his wages were impacted by the 2001 recession. 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). Table 1 provides summary statistics.

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 1 Summary Statistics: KLIPS

Explanatory variables	Dependent variable: Child's years of schooling								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Logarithm of parental assets	0.166***		0.157***	0.145***	0.148***	0.144***	0.142***	0.137***	0.138***
	(0.046)		(0.046)	(0.046)	(0.046)	(0.046)	(0.046)	(0.046)	(0.046)
Logarithm of parental annual wage		0.241**	0.196	0.115	0.156	0.114	0.115	0.122	0.139
		(0.120)	(0.121)	(0.115)	(0.115)	(0.112)	(0.112)	(0.114)	(0.119)
Father's years of schooling				0.148***		0.117***	0.117***	0.114***	-0.030
				(0.029)		(0.033)	(0.033)	(0.033)	(0.069)
Mother's years of schooling					0.141***	0.065	0.064	0.090**	-0.075
					(0.035)	(0.039)	(0.039)	(0.042)	(0.079)
Indicator of child's health							0.038	0.039	0.038
							(0.165)	(0.162)	(0.160)
Number of children								0.189*	0.168
								(0.104)	(0.103)
Interaction of both parents' education									0.016**
									(0.007)
Constant	12.70***	12.94***	11.31***	10.58***	10.52***	10.37***	10.28***	9.544***	10.85***
	(0.598)	(0.933)	(1.067)	(1.060)	(1.038)	(1.046)	(1.113)	(1.250)	(1.243)
Observations	418	418	418	418	418	418	418	418	418
Adjusted R^2	0.031	0.008	0.035	0.094	0.075	0.098	0.096	0.102	0.110
RMSE	2.174	2.200	2.169	2.102	2.125	2.098	2.100	2.093	2.084

Standard errors in parentheses

Robust standard errors

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 2 OLS results of the relationship between a child's education (years of schooling) and parental assets

Table 2 shows that wealth may affect the opportunity of education for a child, thereby exacerbating inequality through the human capital channel. Every column in Table 2 presents the OLS 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 significant at the 1% level.

We suspected that there would be high collinearity between parental assets and father's annual wage because wealthy families would likely have children who earn high wages (i.e. grandparents' assets would affect father's earnings). We believe this is because the data come from a time period after which divergence between dynasties' assets has already occurred. The multicollinearity between assets and earnings affects our standard errors and thus, to ensure that they both have an effect on child's education, we conducted an F-test on regression 8, which confirmed they jointly have an effect on child's education (see Appendix E). Assets may be a more important factor than wages because the prices of assets in Korea, especially those of real estate, have increased sharply along with industrialisation and urbanisation. Hence, real estate asset-holders can easily 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 their children's level of education (regression 8). The coefficient of father's income was upwardly biased as income is partly explained by the father's level of education (comparing regression 3 and 4). We further our model specification and add an interaction term between mother and father's education and find that there is an additional positive effect when both parents have higher education levels[1]. The negative signs of the mother or father's level of education is not a concern for us. This is because our marginal effects show that there is a positive effect of education for the child if the father has at least approximately .54 years of education and the mother approximately .21 years of education and there is no parent that has less than one year of education in our dataset. Thus, there is a positive effect of parents' education on child's years of schooling.

[1] We also apply a joint F-test for mother's education, father's education and their interaction term and find that the parents' educations are jointly significant (see Appendix E).

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 marginally significant just under the 10% level. This result is consistent with the findings of Lee (2004), which insisted that there has been a weak quantity–quantity trade-off in Korea since the 1990s (Jun & Lee 2014). Since the 2000s, the demographic transition of 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.

3.3.2 Instrumental variables estimation

The OLS regressions revealed that there is a strong positive relationship between parental assets and their children's level of education while holding all other variables constant. Yet, it's reasonable to suspect the coefficient of parental assets to be inconsistent. To ensure that our effect not only impacts the child's education level, but is also an important effect, we apply instrumental variables (IVs) on parental assets. We use grandparent's education, which has been applied by previous scholars (Solon 1995, 2015; Lindahl 2012) and a second IV, the birthplace of the father, which is categorised into five regions (See Appendix E). This will deal with two potential sources of biasness in our estimate, measurement errors in assets and omitted variable bias, particularly the effect of the children's individual characteristics, such as IQ and ability. It is unlikely that endogeneity is a concern, as children's years of education can't affect the level of parental assets, as parental assets were formed prior to the child's education.

We argue that grandparents' education affects the level of education of their children (Figure 3 left), which indirectly affects the level of education of their grandchildren. It is particularly the father's education during that generation that is likely impacted as boy's education was often preferred over other household members. More highly educated heads of the household tend to earn more and therefore have an effect on the (parental) household assets (Figure 3 right). Since we can hold parent's level of education constant, grandparents' education can be used as an instrument.

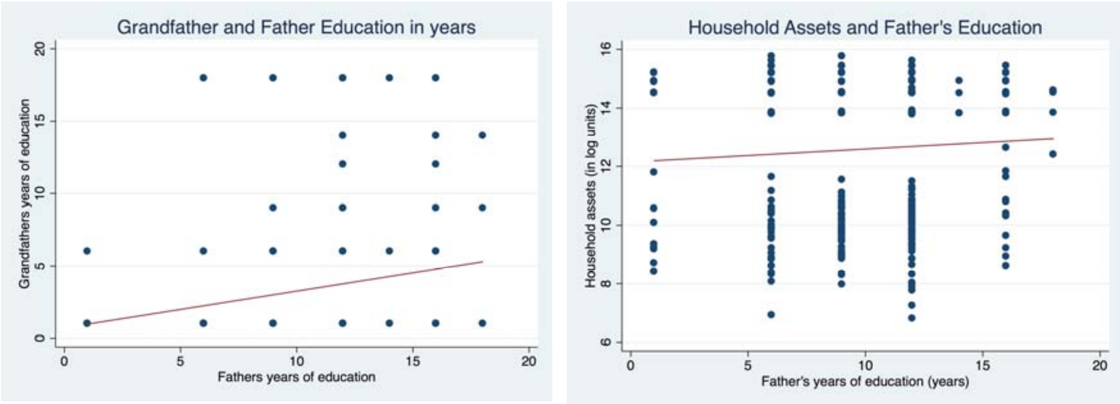

Figure 3 Relationship between grandfather and father’s level of education (**left**), and between household asset and father’s level of education (**right**)

For our second IV, birthplace of the father, we construct 5 regions in Korea and create a binary variable for each region. Regions in Korea are diverse, not only because of urban or rural divide, but also by assets, access to education and cultural differences. We suppose that a region that has higher asset accumulation and access to education (number of high school and universities in the region) impacts a person’s level of education. If a father is born in a more educated and wealthy area, which is exogenously determined, he is more likely to have higher levels of education and assets thereby impacting his child to have more education. Additionally, children of the father continue the educational and wealth lineage because the majority of children, around 69.17% are born in the same region as their father.

To ensure our IVs are valid, we test to see if we meet the relevance and exogeneity assumptions. For the relevance assumption, we apply the Kleibergen-Paap rk Wald F statistic to ensure the strength of our IV when we apply Eicker-Huber-White robust standard errors in our 2SLS regression (Montiel Ole and Pflueger (2013)). We also provide the correlation tables (see Appendix E). We obtain a F-statistic of approximately 10.70 in the first stage and a Kleibergen-Paap rk Wald F statistic of 10.7 and reject the null that our model is under-identified in both cases and thus, our IV is relevant (Appendix E). Further, since our model is over-identified, we used the Hansen J-statistic to test for exogeneity. We fail to reject the null, providing additional evidence that both of our IVs are likely exogenous (Appendix E).

We apply a two stage least squared method with our reduced form model as:

$$\Pi_{assets} = \Pi_0 + \Pi_1 Gedu + \delta Rg + \gamma X' + \varepsilon \tag{23}$$

Where $Gedu$ is grandfather's years of schooling, Rg represents the binary variable set for the region of which the father is born (5 separate binary variables, with Region 1 excluded in the reduced form regression as a baseline), and X' the set of covariates, natural log of father's wages, father's years of education, mother's years of education, child's health and number of children, which were described in detail earlier. Regarding $Gedu$, the education system or environment is different from that of their son and grandson, because they are likely to spend their childhood under Japanese rule, which is from 1910 to 1945. During this era, Korean students had a choice to attend either a modernised school system given by the colonial government or a traditional school (Jun and Kim, 2015). Most Korean students could only complete up to common school (which is equivalent to elementary school) in the modernised system. It is difficult to compare grandfather's level of education with that of their son or grandson, but we can compare the level of education among grandfathers.

Variables	OLS (1)	IV 2SLS (2)
Logarithm of parental assets	0.138***	0.468***
	(0.046)	(0.140)
Logarithm of parental wages	0.139	0.048
	(0.119)	(0.140)
Father's years of schooling	-0.030	-0.041
	(0.069)	(0.070)
Mother's years of schooling	-0.075	-0.093
	(0.079)	(0.083)
Interaction of both parents' education	0.016**	0.016**
	(0.007)	(0.007)
Indicator of child's health	0.038	-0.081
	(0.160)	(0.175)
Number of children	0.168	0.120
	(0.103)	(0.116)
Constant	10.85***	8.068***
	(1.243)	(1.741)
Observations	418	418
RMSE	2.084	2.210

Standard errors in parentheses

Robust standard errors

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 3 Comparison of OLS and instrumental variables estimations

As shown in Table 3, our results reveal that our estimate for the effect of parental assets on child's education was downwardly biased and thus, the effect is more than 3 times higher when applying IVs. This is consistent with previous work by Solon who applied grandparent's education as an IV and also found that the effect of intergenerational mobility was downwardly biased (1995). Our estimates are statistically significant at the 1% level and suggest that if parental assets are 20 times more than the median, this will lead to an approximately 10 year increase in child's education. It is also interesting to note, as we suspected earlier, that the estimate for wages decreased, likely because wages partly explained assets.

3.3.3 Relationship between parental wealth and children's educational attainment

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. We wanted to distinguish between entering college and entering graduate school and 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 4, 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.

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 chi^2	40.87	39.40
Prob>chi^2	0.0000	0.0000
Pseudo R^2	0.0549	0.0529
Observations	418	418

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 4 Relation between children’s education and parental assets (ordered logistic regression)

Further, the ordered logistic regression allows us to calculate the probability of outcomes. We calculate the partial effect at the average, is using the average of each of our variables, which follows as the natural log of parental assets at 12.6, father’s years of schooling at 10.1 years, mother’s schooling with 8.6 years, and number of children as 2.8.

According to the result, children from an average household in Korea are likely to graduate from college with a probability of 69.21%.

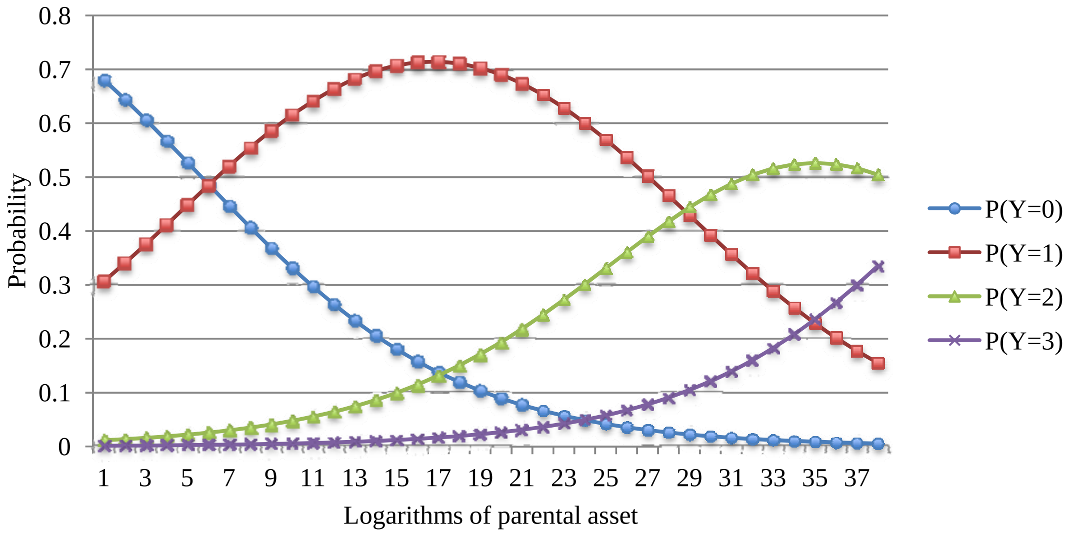

Figure 4 Changes in children's educational choices with respect to levels of parental assets

As illustrated in Figure 4, 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 show that households that have an asset base of less than approximately 5 million are likely to only graduate from high school.

Our empirical analysis, through the OLS, two-staged least squares and ordered logistic regression models, confirms that parental assets play a significant role in the choice of children's level of education, especially the decision of whether to enter college. Furthermore, as derived in Proposition 1 (see Appendix A), the wage gap between skilled and unskilled labour becomes larger as technology makes gradual progress, leading worsening the inequality. From previous work, we know that technological progress occurred in Korea during the same period of analysis (Kwon et al. 2015).

3.3.3 Impact of backed student loans on college attendance

Since we expand the Galor-Zeira model by introducing government, we can empirically examine the policy effect that the model predicts (see Appendix B). In this section, we check whether the government's financial aid that reduces individual's education cost allows more people become eligible to be educated. The Korean government began to provide state-backed student loans during the second half of 2005. Prior to this programme, parents had to provide surety for their children to receive student loans from mainstream banks. Although student loans do not provide direct support, they are characterised as a type of financial aid, because more students who were previously unable to attend college due to their parents' credit status became eligible for a student loan. Moreover, the new policy extended long term loans from 14 to 20 years and increased borrowing limits considerably.

In order to verify the effect of this financial aid, we design a quasi-experiment and estimate the effects with a difference-in-differences methodology adopted by Dynarski (2003) and Long (2007). As explained earlier, data were derived from the fourth investigation of YP2007 (Table 5). The 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 thus decided whether to attend 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.

This methodology requires two comparable groups, the control group and the treatment group. The control group includes individuals who were eligible and took out student loans. The before treatment group includes individuals who could not borrow money for their education without this policy because of their financial conditions and their parental assets. The after treatment group are those who were newly eligible individuals who could borrow money after the policy, despite their financial situation. In this study, we placed individuals that are not eligible to borrow money for their education before the new policy in the treatment group. For example, students with a deceased or unemployed father are 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.

	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)	4888	3588	4613	2750	563
Female	0.5305	0.5	0.6109	0.6776	0.0972
Father attended college	0.2932	0.205	0.4031	0.2449	-0.07
Mother attended college	0.1127	0.1118	0.216	0.1388	-0.0763
Observations	1917	322	2431	245	4515

Table 5 Summary statistics: YP2007 (4th)

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 model for the OLS and logistic regression estimation is:

$$y_i = \alpha + \beta(Treat_i \times After_i) + \delta(Treat_i) + \lambda(After_i) + \mathrm{B}\mathrm{X}' + u_i \quad (38)$$

where the college attendance of individual i is denoted by y_i and the other control variables are denoted by vector X_i. The control variables include household income and parental educational attainment. The treatment effect is captured by the coefficient B.

Specifically, we find that if the sign of the coefficient of the interaction of treatment and after is positive, the probability of attending college for newly eligible individuals increases. 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 loan policy.

	OLS		Logistic regression	
	Difference-in-differences	Add covariates	Difference-in-differences	Add covariates
(Treat)x(After)	0.123***	0.132***	0.707***	0.79***
	(0.031)	(0.032)	(0.231)	(0.237)
Treat	-0.161***	-0.141***	-1.015***	-0.881***
	(0.021)	(0.021)	(0.141)	(0.144)
After	0.003	-0.002	0.026	-0.017
	(0.011)	(0.011)	(0.092)	(0.095)
Logarithm of household income		0.038***		0.271***
		(0.008)		(0.057)
Female		0.013		0.113
		(0.01)		(0.086)
Father attended college		0.068***		0.657***
		(0.012)		(0.117)
Mother attended college		0.013		0.182
		(0.016)		(0.158)
R^2	0.0136	0.031	-	-
Observations	4915	4752	4915	4752

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

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

Table 6 shows that college enrolment increased for newly eligible students as the interaction term is significant and positive. 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 (see Appendix B) is valid in Korea. We also find several interesting results in Table 6. Compared with the control group, the treatment group has a relatively lower 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

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. However, the empirical evidence provided by the model is often insufficient, especially for in-depth longitudinal examination of a country. We extended the original model by adding technological progress and educational policy and verified our proposed model through Korean panel data. From the results, we showed that the education channel is a key factor that influences the level of inequality in Korea with the extended Galor-Zeira model.

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 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 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.

Appendix A (Proposition 1)

The wage gap between skilled and unskilled labour becomes larger as technology makes gradual progress.

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

$$\begin{cases} w_t^s = \alpha A_t^s \Gamma^{1-\alpha} \\ w_t^u = A_t^u \end{cases} \tag{A. 1}$$

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:

$$\partial\left(\frac{w_t^s}{w_t^u}\right) / \partial\left(\frac{A_t^s}{A_t^u}\right) = \alpha\Gamma^{1-\alpha} > 0 \tag{A.2}$$

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

Appendix B (Proposition 2)

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

Proof) From equation (20), we can write

$$\frac{\partial f_t}{\partial s_t} = \frac{\partial f_t}{\partial \tau}\frac{\partial \tau}{\partial s_t} = -\frac{1+r}{i-r} < 0 \tag{A.3}$$

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

Appendix C (Steady-state equilibrium)

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

$$\hat{b}_{t+1} = \frac{b_{t+1}}{A_{t+1}^s} = (1-\gamma)\left\{\left((1+i\cdot\tau) - \frac{\theta(1+i)}{(1+\beta L_t^s (A_t^s)^{\phi-1})}\right)\cdot\alpha\Gamma^{1-\alpha} + \frac{b_t}{A_t^s}\cdot\frac{(1+i)}{(1+\beta L_t^s (A_t^s)^{\phi-1})} - \frac{A_t^u\cdot(1-\theta)(1+i)}{A_t^s(1+\beta L_t^s (A_t^s)^{\phi-1})}\right\} \tag{A.4}$$

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

$$z = \lim_{t\to\infty} \frac{b_t}{A_t^s} = \lim_{t\to\infty} \hat{b}_t = (1-\gamma)\left\{\left((1+i\cdot\tau) - \frac{\theta(1+i)}{(1+g^A)}\right)\cdot\alpha\Gamma^{1-\alpha} - \frac{\Phi(1-\theta)(1+i)}{(1+g^A)}\right\} / \left(1 - \frac{(1+i)(1-\gamma)}{1+g^A}\right) \tag{A.5}$$

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

In the next step, we can find the bequest level that separates unskilled and skilled labour 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 labour force. The sizes of the unskilled and skilled labour pools thus converge to $\hat{L}^s$ and $\hat{L}^u$, respectively.

$$\begin{aligned} \lim_{t\to\infty} L_{t+1}^u &= \int_0^{\hat{g}} D_t(\hat{b}_t)\, d\hat{b}_t \equiv \hat{L}_t^u \\ \lim_{t\to\infty} L_{t+1}^s &= \int_0^{\hat{g}} D_t(\hat{b}_t)\, d\hat{b}_t \equiv \hat{L}_t^s \end{aligned} \tag{A.6}$$

The steady-state equilibrium level of bequests is equal to

$$\lim_{t\to\infty} \hat{b}_t = \begin{cases} \bar{b}^u \equiv \dfrac{(1-\gamma)(2+r+g^A)}{1+g^A-(1-\gamma)(1+r)} \\ \bar{b}^s \equiv (1-\gamma)\left\{\left((1+r\cdot\tau) - \dfrac{\theta(1+r)}{(1+g^A)}\right)\cdot\alpha\Gamma^{1-\alpha} - \dfrac{\Phi(1-\theta)(1+r)}{(1+g^A)}\right\} / \left(1 - \dfrac{(1+r)(1-\gamma)}{(1+g^A)}\right) \end{cases} \tag{A.7}$$

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

$$\begin{aligned} I_{t+1}^s &= (1-\tau)\cdot w_{t+1}^s + (b_t - c_t^e + s_t)\cdot r \\ &= (1-\tau)\cdot \alpha A_{t+1}^s \cdot \Gamma^{1-\alpha} + (b_t - c_t^e + s_t)\cdot r \end{aligned} \tag{A.8}$$

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

$$\begin{aligned} I_{t+1}^u &= w_{t+1}^u + b_t \cdot r \\ &= A_{t+1}^u + b_t \cdot r \end{aligned} \tag{A.9}$$

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

$$I_t^u = A_t^u \tag{A.10}$$

Therefore, the aggregate income level in the whole economy is

$$\begin{aligned} Y_t &= I_{t+1}^s L_{t+1}^s + I_{t+1}^u L_{t+1}^u + I_t^u L_t^u \\ &= \left[(1-\tau)\cdot \alpha A_{t+1}^s \cdot \Gamma^{1-\alpha} + (b_t^s - c_t^e + s_t)\cdot r\right] L_{t+1}^s + \left[A_{t+1}^u + b_t \cdot r\right] L_{t+1}^u + A_t^u L_t^u \end{aligned} \tag{A.11}$$

Income per capita is $y_t = Y_t / 2$. 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

$$g_t^A = \beta L_t^s (A_t^s)^{\phi-1} \tag{A.12}$$

By taking the logs of equation (30) and differentiating with respect to time, we obtain the relation between the growth rate of skilled labour, 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

$$g^{y*} = g^A = \frac{1}{1-\phi} g^{L^s} \tag{A.13}$$

As a result, the economic growth rate is dependent on the growth rate of skilled labour. 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.

Appendix D (Balanced growth path)

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

$$(b_t^s - c_t^e) \cdot L_t^s + b_t^u L_t^u = K_{t+1} - K_t \tag{A.14}$$

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 labour increase relative to technological progress

$$\lim_{t\to\infty} b_t^s = A_t^s \overline{b}^s, \quad \lim_{t\to\infty} b_t^u = A_t^u \overline{b}^u \tag{A.15}$$

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

$$K_{t+1} - K_t = \beta L_t^s K_t \tag{A.16}$$

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

$$(A_t^s \overline{b}^s - \theta\alpha A_t^s \Gamma^{1-\alpha} - (1-\theta) A_t^u) \hat{L}^s + A_t^u \overline{b}^u \hat{L}^u = \beta \hat{L}^s \cdot \Gamma A_t^s \hat{L}^s \tag{A.17}$$

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

$$\lim_{t\to\infty}\left(\frac{A_t^u}{A_t^s}\right) = \frac{(\overline{b}^s - \theta\alpha\Gamma^{1-\alpha} - \beta\hat{L}^s\Gamma)\cdot \hat{L}^s}{\left((1-\theta)\cdot \hat{L}^s - \overline{b}^u \hat{L}^u\right)} = \Phi \tag{A.18}$$

(Q.E.D.)

Appendix E (OLS and IV Two Staged Least Squares Regression)

Index	Region	No. Father's births
1	Seoul, Incheon and Gyeonggi-do (Seoul & surrounding area)	159
2	Gyeongsang-do	130
3	Chungcheong-do	49
4	Jeolla-do	66
5	Gangwon-do, Jeju	14

Table A.1 Regions in Korea and the number of fathers born in that region

	Joint F-test
(1)	Father's years of schooling = 0
(2)	Mother's years of schooling = 0
(3)	Mother's schooling * Father's schooling = 0
	F(3, 410) = 11.13
	Prob > F = 0.0000

Table A.2 Joint F-tests

The joint F-test on mother's education, father's education and their interaction term rejects the null at the 1% significance level indicating that these three estimates are jointly not equal to zero and therefore have a statistically significant effect on child's years of schooling.

Variables	Logarithm of parental assets	Grandparental education	Region 1	Region 2	Region 3	Region 4	Region 5
Logarithm of parental assets	1.000						
Grandparental education	-0.143	1.000					
Region 1	-0.223	0.127	1.000				
Region 2	-0.000	-0.100	-0.526	1.000			
Region 3	0.137	-0.022	-0.286	-0.245	1.000		
Region 4	0.131	-0.032	-0.339	-0.291	-0.158	1.000	
Region 5	0.093	0.021	-0.146	-0.125	-0.068	-0.081	1.000

Table A.3 Cross-correlation table

The IVs provide some evidence for the relevance condition, as grandparents' and mother's years of schooling are correlated to the natural log of average assets.

Instrumented variable	F(5,407)	p-value	K-P Wald F	p-value
Logarithm of parental assets	10.70	0.0000	10.70	0.0000

Table A. 4 First-stage regression summary statistics

The F-test is 10.70, which exceeds the usual minimum of 10, which suggests that the IVs are strong. However, since the first stage F-statistic is only valid with homoskedastic errors, we use the Kleibergen-Paap Wald rk F statistic (K-P Wald F) with more confidence as we apply Eicker-Huber-White robust standard errors in our regression. We reject the null at the 1% significance level and confirm that our IVs are strong instruments.

Hansen J Statistic	χ^2 p-value
3.158	0.5318

Table A.5 Tests of endogeneity

We use the Hansen J statistic to test for endogeneity and fail to reject the null. This suggests that our error term is not correlated with our instrumental variables providing evidence that our IVs are exogenous.

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