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THE TRADEOFF BETWEEN FERTILITY AND EDUCATION: EVIDENCE FROM THE KOREAN DEVELOPMENT PATH

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Abstract

Unified Growth Theory suggests the demographic transition and the associated rise in human capital formation were critical forces in the transition from Malthusian stagnation to modern economic growth. This paper provides empirical evidence in support of this hypothesis based on the Korean industrialization in the late 20th century. Using a fixed effects model and a fixed effect two-stage least squares model, this study exploits variations in fertility and in human capital formation across regions in Korea over the period 1970 to 2010. This analysis finds a virtuous cycle, where technological progress increased the demand for human capital, leading to an increase in the level of education and, in turn, to a demographic transition. This establishes the existence of a quantity–quality tradeoff on the Korean development path.

Keywords Demographic transition, Quantity–quality trade-off, Malthusian stagnation, Unified Growth Theory

JEL Classification I25, J13, N15

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1 Introduction

Unified growth theory suggests that the demographic transition and the associated rise in human capital formation were critical forces in the transition of the world economy from Malthusian stagnation to modern economic growth. The rise in the demand for human capital in the course of industrialization induced parents to increase their children's level of education and reduce their fertility rate (Galor and Weil, 2000; Galor, 2011).

Empirical studies of the Unified Growth Theory have primarily focused on the slow transition of Western Europe and its offshoots from the Malthusian epoch to the modern growth regime, abstracting from the important and more rapid transition process of the underdeveloped regions in Asia and Africa. Focusing on these important regions, this paper establishes that the demographic transition and the associated quantity–quality tradeoff were, indeed, important components of Korea's transition from an underdeveloped economy in the 1970s to an advanced economy in the subsequent decades.

As Figure 1 shows, the Korean transformation from an underdeveloped to an advanced economy was associated with a demographic transition. This paper suggests that the quantity–quality tradeoff played a critical role in this transition from a Malthusian regime to a modern economy. This tradeoff is therefore likely to be a significant factor in the development process of other underdeveloped countries as well.

(Insert Figure 1 here)

Recent research has used a variety of identification strategies to establish the importance of the quantity–quality tradeoff in the transition of a wide range of European societies from stagnation to growth during the nineteenth century. In particular, evidence of such tradeoffs was found for Prussia (Becker et al., 2010), England (Klemp and Weisdorf, 2011), Ireland (Fernihough, 2011), France (Murphy, 2010), and Spain (Basso, 2012).

This study analyzes panel data on fertility and school enrollment rates in 11 regions across nine time points at 5-year intervals during the period 1970–2010. The study uses the high school enrollment rate (the number of high school students per person in the 15−19 age group) as an indicator of child education and the crude birth rate (CBR— the number of births per 1,000 people in a year) to measure parents' fertility. As will become apparent, although the Korean government's 1961 fertility control policy contributed to a fertility decline over this period, regional variations allow us to capture the relationship between fertility and education.

The empirical analysis in this paper uses a fixed effects model, controlling for unobserved regional-level factors that may affect both fertility and education. The panel data also allow us to control for time-invariant unobserved heterogeneity. The empirical results, which are consistent with the Unified Growth Theory, show a significant negative relationship between child education and parents' fertility. These results are robust to the use of alternative measures of fertility and education.

To enhance the credibility of our results, this study further tests the existence of the quantity–quality trade-off using instrumental variables. The instrument is the number of newly applied patents and utility model rights, representative of the technological environment. Our instrumental variable analysis successfully supports the Unified Growth Theory, which argues for a logical relationship among technological progress, human capital accumulation, and the demographic transition, and stresses the existence of the quantity–quality tradeoff.

The remainder of this paper proceeds as follows. Section 2 explains the theoretical background and reviews the related literature. Section 3 describes the empirical analysis and presents the results. Finally, section 4 concludes.

2 Theoretical Background and Related Literature

A demographic transition characterized by decreasing fertility and a falling population growth rate is crucial for society to escape from the Malthusian trap and emerge as a modern economy. Without such a demographic transition, the increasing output resulting from technological progress would be canceled out by an increasing population, and GDP per capita would remain stagnant. The first such demographic transition occurred in Western Europe in the late nineteenth century and provided sustained economic benefits from the Industrial Revolution, which began in the late eighteenth century.

The occurrence of the demographic transition in the late nineteenth century, a century after the beginning of the Industrial Revolution, has several possible explanations. Becker (1960) and Becker and Lewis (1973) argue that increasing income from the Industrial Revolution led to a decline in fertility because of the opportunity cost of raising children. Child quality has higher income elasticity than does child quantity, creating a quantity–quality tradeoff. This argument, however, cannot explain the historical fact that the demographic transition occurred simultaneously in most of Western Europe despite an income gap between the countries. This preference-based theory, moreover, postulates that parents' preferences reflect an innate bias against quantity beyond a certain level of income (Galor, 2011).

Demographers also argue that the fall in infant and child mortality prior to the change in fertility was the major cause of the demographic transition. According to this argument, lower infant and child mortality implies that more children survive; thus, parents give birth to fewer children because they are chiefly concerned about the number of surviving children. However, Doepke (2005) shows empirically that the change in the net reproduction rate is explained not only by the change in infant and child mortality but by other factors as well. Murphy (2010) also shows, through empirical research with French data, that decreasing infant mortality does not reduce fertility.

Following another approach, Caldwell (1976) and Morand (1999) try to explain the demographic transition using a household utility function that models old-age support rather than parental altruism. In their argument, in the absence of a financial market, children function as investment goods for their parents. In the modern era, with developed financial markets, parents have fewer children because they have other ways of investing for their old age. Their argument, however, is not logical, considering that the young of all natural species seldom care for their parents. Furthermore, the fact that financial institutions that provide insurance for old age existed before the demographic transition began weakens their argument in the sense that although the rich have greater access to financial intermediaries, they do not tend to have fewer babies relative to the poor. The old-age security hypothesis, therefore, is not sufficient to explain the demographic transition (Hindle, 2004; Pelling and Smith, 1994)

Galor and Moav (2002, 2004), Galor and Weil (1999, 2000), and Galor (2011) suggest that technological progress due to the Industrial Revolution increased the demand for human capital. This increasing demand accelerated in the late nineteenth century, inducing parents to decrease their fertility and to increase their children's education levels. In other words, these parents made a quantity–quality tradeoff. Accelerating technological progress, accompanied by increasing parental income, affected the rate of population growth in two ways. First, increasing parental income relaxed the parental budget constraint, making room for investment in both the quality and the quantity of children. Second, increasing demand for human capital, triggered by technological progress, led parents to reallocate their budget toward investments in their children's quality rather than in their quantity. This process created a virtuous cycle: technological progress increased demand for human capital, which promoted further technological progress, which encouraged still more human capital, which promoted parental investment in children's quality, and a decreasing fertility rate. Thus, economies were released from the Malthusian trap, and entered the era of modern growth.

Empirical evidence for the quality–quantity tradeoff continues to accumulate. Using data from Anglican parish registers of the period c. 1700–1830, Klemp and Weisdorf (2011) show the existence of a quantity–quality tradeoff in England during the Industrial Revolution. Murphy (2010) also provides evidence of a quantity–quality tradeoff in France, using data from 1876 to 1896. He shows that neither republicanism nor political participation during the French Revolution had a significant effect on fertility, whereas the proportion of children in school did. This implies that, along with cultural factors, the quantity–quality tradeoff played a significant role in decreasing fertility. Moreover, he shows that financial development has a slightly negative effect on fertility, providing weak evidence for the old-age security hypothesis. Becker et al. (2010)

demonstrate a quantity–quality tradeoff in nineteenth-century Prussia even before industrialization began. As instrumental variables, they use inequality in land ownership and distance to Wittenberg, where Luther preached that every Christian should be able to read the Bible. They find that educational preferences have a significant relationship with fertility. Fernihough (2011) compares two Irish cities, Belfast and Dublin, using a dataset on Irish families dating from 1911, and confirms the existence of a quantity–quality tradeoff, particularly in industrialized cities. Basso (2012) establishes that children's education had a negative and causal effect on parents' fertility, using Spanish provincial-level data from the early twentieth century.

Most of this study considers Western industrialized countries, which achieved industrialization in the nineteenth century. However, an increasing demand for human capital, along with industrialization and the quantity–quality tradeoff, may also have played an important role in the development paths of Asian countries during the twentieth century. If the newly industrialized Asian countries followed the Western-led development path, this would enable us to offer a meaningful blueprint for economic growth to countries still caught in the Malthusian trap.

According to Bloom and Williamson (1997), the demographic transition and its cohort effects are major factors in the Asian economic miracle, including Korean economic development. They argue that the demographic transition resulted in a growing working-age population from 1965 to 1990, temporarily expanding per capita productivity. However, they do not consider the relationship between the decreasing quantity and increasing quality of children. Analyzing the effect of human capital policies, Doepke (2004) also describes the fertility transition in Korea in the middle of the twentieth century. He shows that education reform and child labor regulation played an important role in Korea's demographic transition and growth by lowering the opportunity cost of education. He also points out that the share of skilled labor increased from 5% in 1950 to 70% in 2000. None of these papers, however, demonstrated the existence of a quantity–quality tradeoff in Korea. Thus, to capture the link between the demographic transition, increasing income per capita, and increasing share of skilled labor, this study must show that such a tradeoff does exist.

To do so, this paper uses the quantity–quality framework described above to derive a simple model explaining this tradeoff in the spirit of Galor (2011). Suppose the household's utility function is based on altruism and consists of consumption, c, number of (surviving) children, n, and the human capital of each child, h.

$$u = (1-\gamma)\ln c + \gamma[\ln n + \beta \ln h] \tag{1}$$

where $0 < \gamma < 1$ and $0 < \beta < 1$ are constant parameters. Here, β is the preference for education.

Suppose the household is endowed with one unit of time. Then, the unit cost of raising a child with education level e is $\tau^q + \tau^e e$, where τ^q is the fraction of the household's unit-time endowment needed to raise a child and τ^e is the fraction of the household's unit-time endowment needed to give the child an education level of e.

If the household uses its entire time endowment to earn income, its labor wage will be y, which is allocated toward parental consumption and the cost of raising children.

$$yn(\tau^q + \tau^e e) + c \le y \tag{2}$$

Suppose that an individual's accumulated human capital depends on his level of education and his technological environment. If technology changes rapidly, existing human capital will become less adaptable, but education can improve its adaptability. Thus, the time needed to learn new technology is shorter when the level of education is high or when the speed of technological change is low. Therefore, a child's level of human capital, h, is a function of his or her education and the technological environment.

$$h = h(e, g) \tag{3}$$

where g is the rate of technological progress and h is an increasing, strictly concave function of e and a decreasing, strictly convex function of g.

Then, the household optimizes with respect to the quantity and quality of children, as follows:

$$n = \gamma / (\tau^q + \tau^e e) \tag{4}$$

$$\tau^e h(e, g) = \beta h_e(e, g)(\tau^q + \tau^e e) \tag{5}$$

Given the parameters of the economy $(g, \beta, \tau^e, \tau^q)$, we can determine the household's optimal quantity and quality of children as follows:

$$e = e(g, \beta, \tau^e, \tau^q) \tag{6}$$

$$n = \gamma / [\tau^q + \tau^e e(g, \beta, \tau^e, \tau^q)] \tag{7}$$

Equations (4) and (7) show the negative relationship between the quantity and quality of children. This quantity–quality tradeoff depends on the cost of child rearing, the cost of education, the household's preference for education β, and the rate of technological progress g.

3 Empirical Analysis

3.1 Data Description

The data for this analysis were obtained from the Korean Population and Housing Census for 1966–2010. Since 1925, the census has been collecting demographic, educational, and economic information on the population every 5 years. Although the census gathers data on every individual, only aggregated data, categorized into administrative divisions, are open to the public. We also used data from Education Statistics, which has been collecting information every year since 1963 on every educational institution, including preschools, elementary schools, middle schools, high schools of all types, colleges, graduate schools, and other advanced educational institutions**.** From these datasets, we create a panel of 11 regions and nine time periods (once every 5 years between 1970 and 2010). We can get data on the independent and the dependent variables from the Census and the Education Statistics.

The dependent variable, fertility, is measured by the crude birth rate (CBR), the number of births per 1,000 people per year in province *i* in period *t*. The major explanatory variable, level of education, is the high school student ratio, defined as the number of high school students divided by the number of people aged 15–19 years eligible for high school enrollment in province *i* in period *t*. The actual rate may be higher than the computed rate because the population aged 15–19 years includes some middle school students as well. This computed enrollment rate varied regionally from 15% to 25% in 1970 and from 53% to 60% in 2010. This paper argues that most of this variation stems from the variation in human capital demand across regions and time. The high school enrollment rate is more appropriate than the primary school enrollment rate for this analysis because, after the education reform of 1950, every Korean was required to enter primary school, so the gross primary school enrollment rate was already 100% by the 1980s. The high school enrollment rate is also more appropriate for this study than is the college enrollment rate, because regional mobility for college entry is extremely high.

However, a problem of endogeneity might arise because parents make simultaneous decisions on fertility and on their children's education. A variety of instrumental variables have been used to solve this endogeneity problem (Basso, 2012; Becker et al., 2010; Fernihough, 2011; Klemp and Weisdorf, 2011; Murphy, 2010). This study solves the problem of endogeneity by using the change in technological environment in each region as the instrumental variable for the high school student ratio. The change in technological environment is measured by intellectual property rights, especially the number of newly applied patents and utility model rights in province *i* in period *t*. While patents and utility model rights are positively related to the level of human capital in the sense that technological progress leads to increasing demand for human capital, i.e. to higher levels of education, they are exogenous variables, unrelated to parents' choice. Therefore, they satisfy the conditions for instrumental variables.

The data sources for the instrumental variable analysis are the Commerce and Industry Statistics Yearbook of Korea, the Annual Report of the Office of Patents of Korea, and the Korean Statistical Information Service. From these sources, we can construct a variable representing the change in technological environment of each region.

(Insert Table 1 here)

As shown in Table 1, the control variables in the model are the share of married women, defined as the number of married women aged 15–44 years divided by the total number of women aged 15–44 years in province *i* in period *t*; the share of agriculture, defined as the number of people making a living from agriculture, forestry, and fisheries divided by the number of employed people in province *i* in period *t*; and the level of urbanization, defined as the number of people employed in the service sector divided by the population of province *i* in period *t*. Table 2 provides definitions and summary statistics.

(Insert Table 2 here)

This paper uses country-level data, which aggregate individual data to a regional level, reflecting average behavior in a province. Therefore, the variables in this study share some common features with those of Becker et al. (2012), which uses country-level data to reflect regional differences.

3.2 Empirical Specification: Fixed-Effects Model

The empirical analysis examines the effect of education on fertility. We use the following empirical specification:

$$Fertility_{i,t} = \beta_0 + \beta_1 Education_{i,t} + BX_{i,t} + \upsilon_{i,t} \tag{8}$$

where the X s are vectors of the control variables described above. This formula captures the fact that current economic, social, and educational conditions affect a household's fertility decisions.

There could be some unobserved factors correlated with education that affect fertility at the province level. Such factors would compromise a causal interpretation of the results. To solve this problem, we control for regional fixed effects, η_i , which represent time-invariant unobserved heterogeneity in fertility across the provinces, where

$$\upsilon_{i,t} = \eta_i + e_{i,t} \tag{9}$$

To test the existence of η_i, which represents regional time-invariant heterogeneity, we evaluate the p-value of the F statistic for the hypothesis $H_0 = \eta_1 = \eta_2 = ... = \eta_i$. We find that is less than 0.01, allowing us to reject H_0. In addition, as a result of the Hausman test for checking whether η_i is a constant or a random variable, we chose a fixed effects model rather than a random effects one.

If there are no time-invariant explanatory variables, the partial effects can be estimated even in the presence of omitted variables, which could be correlated with the explanatory variables, by considering the time-invariant fixed effect in the error term (Wooldridge, 2010). Therefore, this paper can capture the partial effect of education on fertility, controlling for regional fixed effects, even if there are omitted variables.

(Insert Table 3 here)

(Insert Table 4 here)

Table 3 presents the correlations between variables. Even without a time lag, a highly correlation between CBR/child-woman ratio and education can be observed. All the correlations have the expected signs. However, a high correlation between the co-variables can cause a multicollinearity problem. The variance inflation factor (VIF) is tested to check for this problem. As depicted in Table 4, the VIF values are below 10, confirming that a multicollinearity problem does not exist.

3.3 Results

3.3.1 Fixed Effects Model

The negative correlation between changes in the CBR and changes in education is apparent in Figure 2 and is shown in the fitted values plotted from an OLS regression.

(Insert Figure 2 here)

(Insert Table 5 here)

Table 5 presents the results of these estimates from 1970 to 2010 in columns (1)–(5). The level of education, measured by the high school enrollment rate, has a highly significant negative relation with fertility, measured by the CBR, when regional fixed effects are controlled for. Moreover, the highly significant effect of education on the CBR holds when the share of married women, agriculture, and urban residents are controlled for. As one would expect, column (2) shows that the share of married women has a positive effect on the CBR. Columns (3) and (4) show that the share of agriculture and the level of urbanization affect fertility positively and negatively, respectively. These results are reasonable because a high proportion of urban residents, which is an index of the share of human-capital-intensive occupations, should encourage lower fertility. However, the significant effect of the level of urbanization disappears when the share of agriculture and the level of urbanization are used at the same time, because of the high correlation between these two variables.

3.3.2 Robustness Check

(Insert Table 6 here)

In Table 6, instead of the CBR, fertility is measured using the child-woman ratio, defined as the number of children aged 0–4 per woman of childbearing age (15–44), as in Becker et al. (2010). In addition, instead of the high school enrollment rate, the ratio of high school graduates who want to go to college is used to measure the level of education, as a robustness check. The highly significant effect of changes in education on fertility continues to hold.

3.3.3 Instrumental Variables Estimation

We include an instrumental variable analysis in this section to enhance the credibility of our results on the negative effect of education (caused by the rising demand for human capital induced by technological progress) on fertility. The variable representing the change in the technological environment, which is a driver of a human capital demand in Korea, is a possible instrument. In addition, the possible instrumental variable needs to be related to exogenous variations in education; it should not influence fertility directly. With these requirements, our instrument, therefore, is the technological environment as measured by the number of newly applied patents and utility model rights in province i in period t. As shown in Table 2, the standard deviation of the instrumental variable is quite high. This can be understood in the light of Korea's growth strategy, which is the development of growth poles. It can also be explained by the fact that Korea has experienced very fast structural change towards a knowledge-based economy.

A necessary condition for instrumentation is that the level of education be strongly correlated with the number of patents. This condition is supported by previous research. First, at the individual level, Mariani and Romanelli (2006) state that better educated inventors tend to produce more patents. Faggian and McCann (2004) also argue that each region's level of human capital explains its innovation performance. At the country level, Furman et al. (2002) show that increases in public expenditure on education lead to an increase in the number of patents. Dakhli and De Clercq (2004), Varsakelis (2006), de Rassenfosse and van Pottelsberghe (2009), and Danguy et al. (2009) also demonstrate a strong and positive relationship between the number of patents and the level of education at the country level. In addition, the instrumental variable should be exogenous in equation (8). Since our instrumental variable is unrelated with the decisions of parents, it is exogenous in this setting. The variable, therefore, satisfies both the necessary conditions.

(Insert Table 7 here)

Table 7 presents the results of the instrumental variable estimation. To make sure of the effect of education on the CBR, both variables for education are tested. Every case in Table 7 provides further support for an adverse causal effect of education on fertility, showing that the Korean development path exhibits a quantity–quality tradeoff. When the coefficients on educational variables are compared, the analysis using the high school enrollment rate shows a smaller gap between the coefficient in FE and that in FE2SLS, and the coefficients have a higher level of significance, relative to the analysis using the ratio of high school graduates who want to go to college. Since the ratio of high school graduates who want to go to college is likely to reflect children's willingness to go to college, as opposed to parental preferences, the variable "high school enrollment" may better capture parents' resource allocation decisions with a view to their children's education.

In addition, it is meaningful that the variable representing the change in technological environment works well as an instrumental variable. As shown in Equation (7), the quantity–quality tradeoff relies on the rate of technological progress as well as the child education level. Since this instrument does not influence changes in fertility, but is strongly correlated with the level of education, it further supports the main argument of Unified Growth Theory. It shows that the acceleration in the rate of technological progress increases the demand for human capital and induces parents to invest more heavily in their children's human capital. The increase in the rate of technological progress induced a reduction in fertility, generating a decline in population growth and an increase in the average level of education.

4 Conclusion

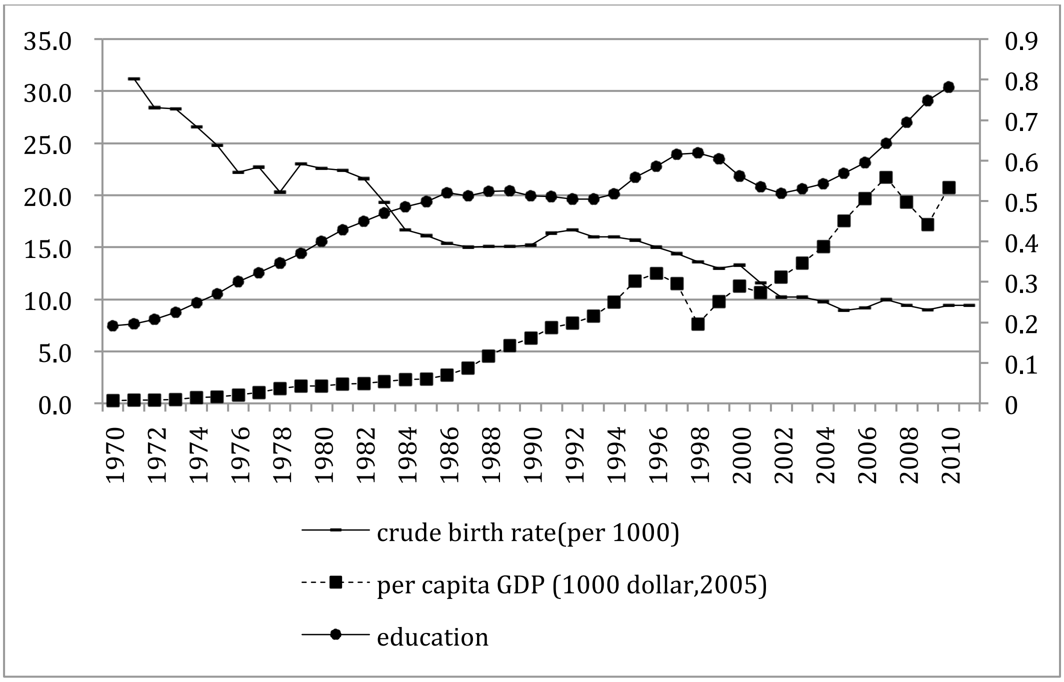
The transition from a Malthusian economy to a modern growth economy, first triggered in late eighteenth-century England, was one of the most significant events in human history. Even though productivity increased before the transition, it was counterbalanced by an increasing population. With the emergence of the modern economy, however, GDP per capita could now substantially increase. Unified Growth

Theory suggests that the transition from stagnation to modern growth is associated with a rise in the demand for human capital in the course of industrialization. This rise in human capital had adverse effects on fertility rates, allowing income per capita to increase.

Consistent with previous empirical findings, primarily from the European continent, this paper aims to show the existence of a quantity–quality tradeoff in Korea. It finds that regions with higher levels of education have lower fertility. Using a fixed effects model with panel data on 11 provinces for the years 1970 to 2010, controlled for unobserved heterogeneity, the study finds a significant correlation between increasing education and decreasing fertility.

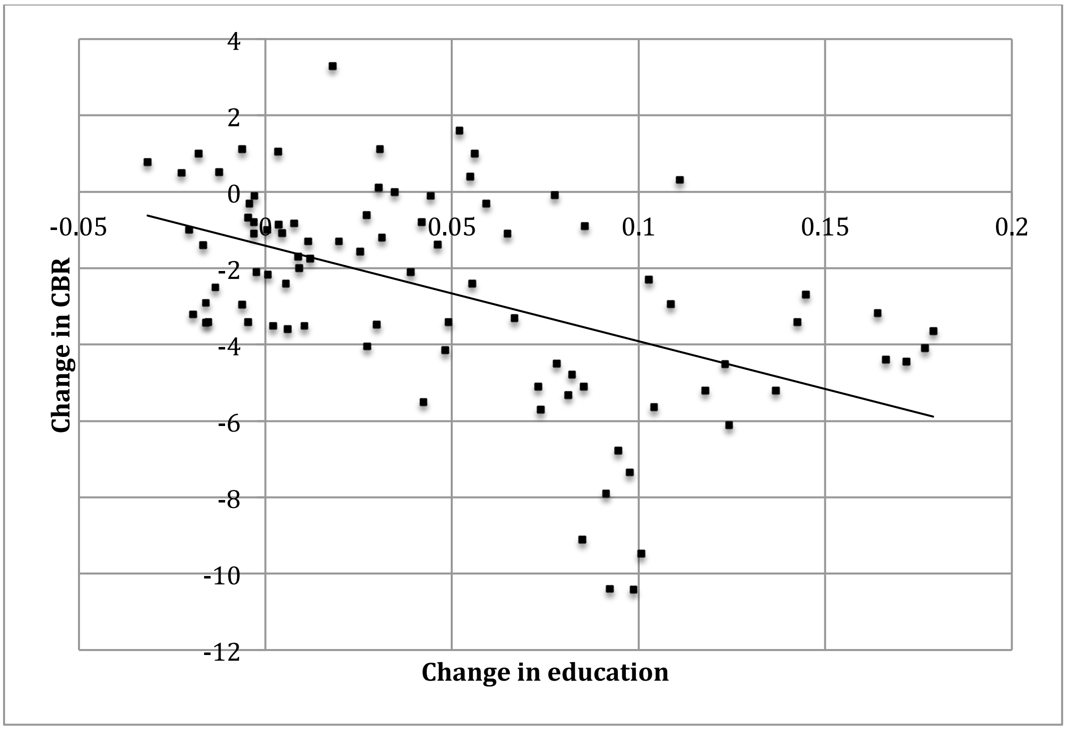
The finding is strengthened by the instrumental variable analysis. The index of change in the technological environment, which is a driver of human capital demand in Korea, is used as an instrument, and supports the existence of a quantity–quality tradeoff on the Korean development path. This analysis finds a virtuous cycle, where technological progress increases the demand for human capital, leading to an increase in the level of education and, in turn, to a demographic transition. Furthermore, we hope that the results on the Korean development path unveiled in this paper will suggest important policy implications for underdeveloped countries still experiencing Malthusian stagnation.

Figure 1 The trends in education, crude birth rate (CBR), and GDP per capita



The crude birth rate (CBR) is the number of births per 1,000 people per year.
Source: Korean Population and Housing Census and Education Statistics

Figure 2 Changes in CBR and education



Source: Korean Population and Housing Census and Education Statistics

Table 1 Variables to estimates of the quantity–quality trade-off -- Summary of previous literature

Variables		Becker et al. (2012)	Fernihough (2011)	Murphy (2010)	Klemp and Weisdorf (2011)	This paper
Main Variables	Quantity	Child-women ratio	Sibship size	Fertility	Sibship size	CBR/Child-woman ratio
	Quality	School enrollment rate	School attendance	School enrollment rate	Literacy	School enrollment rate
Economic control	Income			✓		
	Savings			✓		
	Industry	✓		✓	✓	
	Agriculture	✓				✓
	Urban	✓		✓		✓
	Retail				✓	
	Social class	✓			✓	
Demographic control	Population density	✓				
	Infant mortality		✓	✓		
	Net immigration			✓		
	Foreigners	✓	✓	✓		
	Married women	✓				✓
	Marital duration		✓		✓	
	Parental age		✓		✓	
	Life expectancy	✓				
Education	Parental Literacy		✓	✓	✓	
Culture	Religious group	✓	✓	✓	✓	
	Political group			✓		
Data	Data level	Country	Individuals	Département	Family	Country
	Data type	Cross sectional data	Cross sectional data	Panel data	Cross sectional data	Panel data
	Control for endogeneity	IV	IV	IV	IV	IV
Instrument Variables		Distance from Wittenberg/Landownership inequality	The presence of twin or multiple births	Climate	Fecundability	Patents and utility model rights

Table 2 Descriptive statistics of the Korean Population and Housing Census and Education Statistics

Variable	Definition	Mean	Std. Dev.	Min	Max
Crude Birth Rate	The number of births per 1,000 people per year	15.7564	6.7014	6.7	34.55
Child-woman ratio	The number of children aged 0-4 per each woman of child bearing age (15-44)	0.3766	0.1704	0.1558	0.8585
Education	The number of high school students divided by the number of people aged 15-19 who are eligible for high school	0.4636	0.1390	0.1505	0.6079
College	The number of high school (general + vocational) graduates who want to go college by total high school graduates	0.6562	0.1816	0.2909	0.9519
Married woman	The number of married woman in age 15-44 per the number of woman in age 15-44	0.5681	0.0584	0.3819	0.7014
Agriculture	The number of people making their living of agriculture, forestry and fisheries per the number of employed people	0.3264	0.2352	0.0020	0.7406
Urban	The number of people employed in service sector per population	0.0775	0.0448	0.0229	0.2078
Technology	The newly applied number of patents and utility model rights	6134.101	13737.45	4	64006

Source: Korean Population and Housing Census, Education Statistics, the Commerce and Industry Statistics Yearbook of Korea, the Annual Report of the Office of Patents of Korea, and the Korean Statistical Information Service.

Table 3 Correlation between variables

	Crude Birth Rate	Child-woman ratio	Education	College	Married woman	Agriculture	Urban	Technology
Crude Birth Rate	1							
Child-woman ratio	0.9316	1						
Education	-0.9219	-0.9092	1					
College	-0.8708	-0.8437	0.8231	1				
Married woman	0.6484	0.6813	-0.5216	-0.6588	1			
Agriculture	0.6005	0.7529	-0.5431	-0.6379	0.5127	1		
Urban	-0.7372	-0.7206	0.6099	0.8528	-0.7402	-0.6462	1	
Technology	-0.2690	-0.3477	0.2670	0.3374	-0.3020	-0.4895	0.4541	1

Source: Korean Population and Housing Census, Education Statistics, the Commerce and Industry Statistics Yearbook of Korea, the Annual Report of the Office of Patents of Korea, and the Korean Statistical Information Service.

Table 4 Variance Inflation Factor between the variables

Variable	VIF	1/VIF
Education	1.72	0.581551
Married Woman	2.25	0.443701
Agriculture	1.83	0.546424
Urban	3.02	0.330973
Mean VIF	2.21	

Table 5 The Relationship between education and fertility over 1970-2010 (Fixed effects Model)

Explanatory variables	Dependent variable: CBR				
	(1)	(2)	(3)	(4)	(5)
education (high school enrollment rate)	**-45.2108***** 1.8029	**-38.2065***** 1.7351	**-33.4247***** 2.4795	**-35.3759***** 1.7142	**-34.9042***** 2.3929
married women		**32.7286***** 4.5625	**30.6066***** 4.4881	**17.9534***** 5.3999	**18.4090***** 5.6612
agriculture			**5.3036***** 2.0238		**0.6775** 2.3845
urban				-30.4238*** 7.0881	**-28.9276***** 8.8613
R^2 (within)	0.8785	0.9240	0.9296	0.9375	0.9376
F-statistic	2.24	4.24	4.79	4.76	4.69
P-value	0.0222	0.0001	0.0000	0.0000	0.0000
Number of observations	99	99	99	99	99

Note: ***denotes significance at the 1% level, ** at 5%, and * at 10%

Table 6 Robustness check: The Relationship between education and fertility over 1970-2010 using child-woman ratio to measure the fertility and the ratio of high school graduates who want to go to college to measure the education (Fixed effects model)

Dependent variable	CBR	Child-woman ratio	CBR	Child-woman ratio
Explanatory variables	high school enrollment	high school enrollment	college want	college want
education	**-33.4247*** **	**-0.7914*** **	**-19.3417*** **	**-0.2367** **
	2.4795	0.0449	4.1977	0.1002
married women	**30.6066*** **	**0.6908*** **	**28.1786*** **	**0.8286*** **
	4.4881	0.0812	7.8318	0.1870
agriculture	**5.3036*** **	**0.2084*** **	**9.9511** **	**0.4949*** **
	2.0238	0.0366	3.9909	0.0953
R^2 (within)	0.9296	0.9629	0.8234	0.8377
F-statistic	4.79	4.87	2.77	2.34
P-value	0.0000	0.0000	0.0052	0.0173
Number of observations	99	99	99	99

Note: ***denotes significance at the 1% level, ** at 5%, and * at 10%

Table 7 The Instrument Variable Analysis

	Dependent variable: CBR			
Explanatory variables	high school enrollment		college want	
	FE	FE2SLS	FE	FE2SLS
education	**-33.4247*** **	**-36.1185*** **	**-19.3417*** **	**-25.4616** **
	2.4795	9.2228	4.1977	10.3585
married women	**30.6066*** **	**29.4266*** **	**28.1786*** **	**22.7777** **
	4.4881	5.9622	7.8317	11.5053
agriculture	**5.3036*** **	**3.6855**	**9.9511** **	**5.0690**
	3.1973	5.7091	3.9909	8.5507
R^2 (within)	0.9296	0.9287	0.8234	0.8189
First stage F-statistic		4.27		2.13
First stage p-value		0.0001		0.0304
Number of observations	99	99	99	99

Note: ***denotes significance at the 1% level, ** at 5%, and * at 10%

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