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Agent-Based Model to Analyze the Role of Women's Education on Fertility: The Case of Korea

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Abstract. Education has long been recognized as a crucial factor influencing women's childbearing patterns. The rapid decline in fertility and marked improvements in women's educational attainment over the last several decades, South Korea represents an ideal case for studying this dynamic association. It is very well known that fertility has been steadily declined to a remarkably lower level in Korea The aim of the paper is to explain the pattern of fertility transitions by level of education and the contribution of the changes in women's educational attainment to the fertility decline during the fertility transition. We propose a model applying both micro-simulation and agent-based model (ABM) to investigate the women's education influence by using agent's education and its feedback on fertility transition. Our model applies event history analysis while using empirical micro data from 1970 to 2010. Our method appears to be a good approximation in describing the fertility decision based on women's various education levels. Our results show that women acquiring education have the lowest probability to become mother. Women having higher education have the maximum probability toward fertility transition than the low level education.

Keywords: Total fertility rate, education level, trend and agent-based model, micro-simulation, macro-simulation

1 Introduction

Educational change is related with a number of economic and social changes that can change the link between education and childbearing. As a result, although rising education generally leads to falling birth rates, the importance of educational trends varies. Women's education is usually associated with lower fertility at both the population and the individual levels [1], [2]. However, the empirical relationship between changes in educational levels and changes in fertility rates at the population level is more cumbersome. The impact of educational change likely depends on the starting levels of education and fertility, as well as other contextual factors. Despite the theoretical importance of education as a contributing factor in the fertility transition, there have been relatively few longitudinal studies on education and fertility. In this article, we are using census data from South Korea to analyze

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changing associations between education and fertility, and look at how compositional changes in education contributed to the decline in fertility across the transition from a high to a lowest-low level. Korea experienced one of the fastest fertility declines in the world. The Korean total fertility rate was 6.0 in the 1960s, but it had plummeted to sub-replacement levels by 1983 [3].

It took Korea less than 25 years to go from a pre-transitional stage to sub-replacement levels of fertility. In this period, there were marked improvements in women's education. Among the 1960 birth cohort, the proportion of women who had graduated from high school was negligible; but among the 1970 birth cohort, the share was more than 95%. The combination of a dramatic decline in fertility and a rapid increase in women's education makes the country an ideal case for studying this relationship during the fertility transition. Given the general association between fertility and education, we can predict that the expansion of women's education was a major factor that contributed to the rapid transition from high to low fertility rates in Korea.

In this paper, we explore various educational levels in fertility and the changes over the course of the fertility transition in Korea. The result display the trend of educational in fertility among women that are married, having in fertility range i.e. between 16 to 45, and then examine the association between changes in fertility and in the composition of women's educational attainment levels. I also analyze the education-specific pattern of falling fertility over the transition. This paper contributes to the literature on the association between women's education and fertility, and has implications for population policies in both developing and developed countries.

2 Education over the fertility transition

As the fertility decline begins, the gaps in fertility widen between the higher and lower educational groups. These educational differentials then diminish as the transition progresses. In [1] summarized the changes in educational differentials over different stages of the fertility transition, and suggested two theoretical models: (1) the “leader-follower” model and (2) the “permanent difference” model. This model, which builds on the microeconomic perspective that fertility, is influenced by socioeconomic conditions [4. In this model, falling fertility is largely attributable to socioeconomic changes.

A rise in educational attainment directly contributes to a fertility decline when the negative association between fertility and education remains constant. As a result, the fertility differentials by education persist at the end of the transition, even though the overall fertility rate decreases while the overall level of education increases. The literature also suggests that any efforts to explain the decline in fertility over the course of the transition should take into account both structural and diffusion effects [5].

Fertility differentials by education may vary in developed countries. For instance, in Nordic countries the inverse association between fertility and level of education has substantially weakened among recent cohorts [16]. It is not clear whether the negative

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association between education and fertility diminishes or becomes reversed in the late and post-transitional stages, but it is apparent that the intensity of the association changes over the fertility transition. The dynamic features of this association have so far been underexplored. In this paper, try to apply noth agent based model to set the priorcriteria of women's agent and using empirical data of the Korean census data with five years gape i.e. 1990, 1995, 2000, 2005 and 2010.empirical evidence on the dynamic changes of fertility differentials by level of education using data covering the entire period of transition from well above replacement level to well below replacement level. I assess the contribution of changes in women's educational attainment to changes in completed fertility, and demonstrate how the trend toward having fewer children was transmitted across levels of education.

3 Model Development

3.1. Agent Based Modeling

Agent-based modeling is a bottom-up approach computational framework for simulating dynamic-processes that involves autonomous and heterogeneous agents having their own decision criteria and growing the population. The ABM offers a new approach to the problem of social phenomena in order to analyze the dynamic mutual-independent relationship among individual behaviors that could lead to emerging evolution. Agent based computational demography includes also micro-simulation that has been used to derive macro-level outcomes from empirical models of micro-level demographic processes, but also formal models of demographic behavior that describe micro-level decision with macro-level outcomes [10].

We are using ABM methodology to explore the economic influence of education of an agent and its feedback on the childbirth decision. In population dynamics, it is obvious that female plays a remarkable role in determining macro-level indexes. In ABM of population dynamics, it is possible to design female agent to be both autonomous and heterogeneous in their decision making about when and how many childbirth they would have or not [4]. Individual micro behavior results in a macro outcome which is could feedback to the individual decisions. Likewise, micro-macro independency could be obtained, which can't be modeled in a traditional micro-simulation [11].

The problem of addressing Korea's declining fertility rate is not simply a matter of predicting that the population is getting 'smaller', but addressing 'why', which inherently rests on individual choices that cause macro-level consequences. Only by addressing the actual ratio of women involved in Korean's population crisis can one begin to experiment with policies that might help turn the problem around.

3.2. Model Specification and Implementation

We are using a single sex model, limited our model to consider only 'female agent' the most influential partner regarding childbirth decision, although both partners play

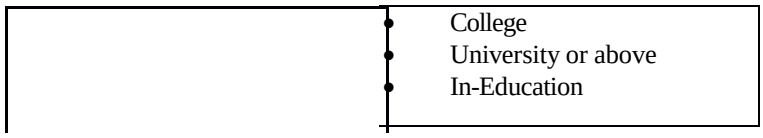
a major role while deciding about childbirth. In our ABM, we can observe the aggregate effects of decentralized decision making without very strong assumptions to limit agent's behaviors to the scope of the current work. In our model the fertile period of an agent is from 16 to 45 years. In our model, We assume that only married female can give birth to child mean there is no cohabiting state in the context of Korea, every married female is fertile, all mothers are real, the time spent between the childbirth and actual conception is ignored, the minimum childbirth space is one year, childbirth could be either single or twin and each female agent has an expecting number of desired childbirth, but may not have as many children as expected due to the mother education or other social factors.

We apply our model to analyze the causes and effects of women's education on fertility with the bottom-up approach using Korean census data from 1990 to 2010, since 1990, the Korea TFR (total fertility rate) declined rapidly as the country struggled through the financial crises in 1997, below 1.2 in 2000 and 1.08 in 2005, the lowest in the world [6]. Each individual agent has a household-member-id and three characteristics. The first and foremost time varying dependent variable "agent education status' with levels characteristics like elementary, middle, high, college, university or above and in-education in case the women is still enrolled.

Therefore, our two time varying control variables are "agent age' grouped into 16~20, 21~25, 26~30, 31~35, 36~40 and 40~45 years in order to analyze the relation of education levels on various age groups. We are in the process to build agent-based simulation model that incorporates both historical census data on population characteristics that allow us to study the influence of women's education levels on fertility decision by the interaction of various agent characteristics and behavior assumptions at different stages.

Table 1. Summary of agent variable and parameters

Agent Variable	Variable Values
Age	• 16~20 • 21~25 • 26~30 • 31~35 • 36~40 • 41~45
Year	• 1990 • 1995 • 2000 • 2005 • 2010
Education	• In-education • Elementary • Middle • High



The model is implementing using Anylogic 7.0 professional software, both because of its simple, natural programming style as well as its user-friendly interface [14]. After marriage, couples determine if they want to have children first based on the female agent age, in our model the agent age must be within biological fertility range i.e. 15 to 45 years. The agent must be married, because regarding Korean population there is no custom of cohabitating fertility. After marriage the agent decide the desired family size and the minimum fertility gape based on the employment condition. The female agent age and fertility gape can be tested again in the model after a period of one year in the simulation environment.

In our model, the female can give maximum two kids at one time as normal fertility outcome. There are several variables that affect the fertility outcome, but here we are interesting to analyze the relationship of women's education and fertility as shown in table-1. We are in the process to use various empirical models about initial demographic setup and transition from one state to another. Apart from these empirical methods, we are building the interactions model based on these agent characteristics at various stages that affecting the fertility over time.

4 Model Experimental Results

To examine the relationship of women's education and childbirth, we are using event history analysis. The observation starts when a woman reaches the age of sixteen. We apply piecewise constant exponential model depicted below.

(**1**)

Where the predictors X1, ..., Xp are assumed to act additively on log h(t/x), log h(t/x) changes linearly with the 3s. The effect of the predictor is the same at all time"t'.In our model, the covariates X1, ..., X4are women age, year,women's education level of the women respectively and 31, ... 34 are the respective hazard ratio of our three covariates (variables).

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sample data regarding the agent‟s variables. We are analyzing the Korean census data from 1990 to 2010 with five years interval and see the trends of childbirth event under various conditions.Table-2 indicates the amount of time in months of the number of the women in a specific year and the number of childbirth event occurred in those women. Our agent based model work shows in figure-1 below.

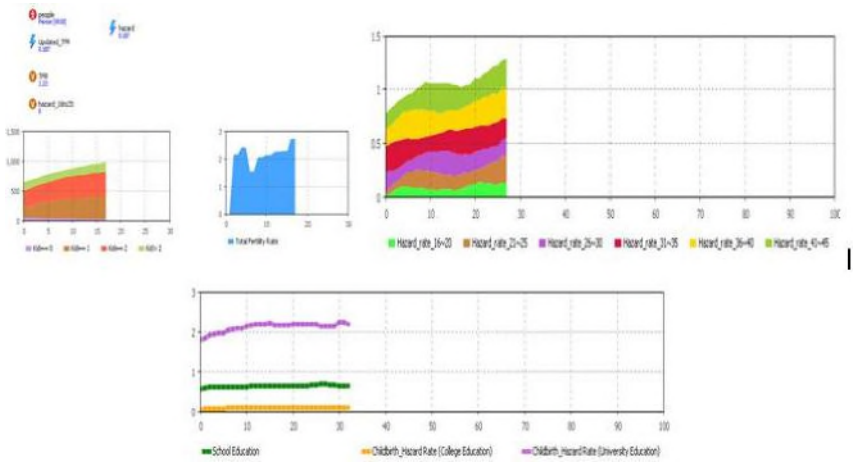

Fig.1. Agent based model Interface using Anylogic

Table-2. Distributions of women time and childbirth event by main variables

Variables	Variables Categories	Women Time (months)	Childbirth Event (First Birth)
Year	1990	27672	134
	1995	27290	120
	2000	26625	110
	2005	26245	102
	2010	25890	93
Education Level	In-school	10109	76
	Elementary	21578	112
	Middle	20314	88
	High	21322	68
	College	38243	144
	University or above	32265	177

Our main variable explanatory variable is the time varying education of Korean women. Here we are considering the all the categories of education in the context of Korea education policy. The main categories are elementary, middle, high, college, university or above and in-education. Another time-varying variable is women education level. It is categorized into three broad groups: School level education combined elementary, middle and high school level. The college and university level indicates the college and university level education respectively.

5 Experimental Results

Our result shows the fertility transition effected by education levels with other covariates. Using the Cox proportional hazard model, we calculated the hazard ratio of our all 3 variables. Results shown in table-3 indicate the hazard ratios based on women's age, year and education levels of the women. The hazard ratio-1 include only women's age and colander year to find the calendar year effect on women likelihood to become mother. The hazard ratio-2 includes the education levels to investigate the effects on fertility transition. The hazard ratio-2 indicates that women from age 26 to 30 have more than double intensity to become a mother than other age group. The overall reduction of first childbirth event has been detected. The involvement of, education level does not change this decline trend. The hazard ratio-2 discovered the effects of education levels on childbirth. Women who completed their education or have college level education are most likely to become mothers than the low educated women. It shows that the highly educated women once get married then they are more committed toward childbirth. Women still continuing their education have the lowest level of fertility rate, because very few women may think about fertility during education.

Table-3. Fertility transition estimation from the main effect model

Variables	Variables Categories	HR-1	HR-2
Woman's Age	16~20	0.12***	0.27***
	21 ~25	0.98***	1.08***
	26~30	2.11***	2.06***
	31 ~35	0.75***	0.67***
	36 ~40	0.53***	0.46***
	41 ~ 45	0.25***	0.18***
Year	1990	1.70***	1.74***
	1995	1.53***	1.58***
	2000	1.12***	1.15***
	2005	0.65***	0.68***
	2010	0.58***	0.63***
Education Levels	In-education		0.03***
	Elementary		0.62***
	Middle		0.94***
	High		1.01***
	College		1.08***
	University or above		1.27***

6 Conclusion

This study investigates the relation between the education and fertility in the context of South Korea. The model develop in this paper appears to be a good first approximation in describing the fertility based on education level using agent-based simulation technique. We applied agent-based model to study the role of different characteristics interaction for explaining the observed demographic patterns on the transition to motherhood. I have applied event history analysis to the Korean census data to estimate how education levels characteristics are related to motherhood entry. Main effects models along with women's education characteristics were specified to address our research questions.

The results showed that women who study relate to the effect of women education characteristics on motherhood entry. The results reveals that among women who completed their education and women at college level or above are most likely to become mothers. The higher educated women once gets married then those women are more committed to become mother than the lower educated women. Our results reveal that the structure of a society represented by parameters specifying education patterns has the potential to alter the role of family policies, because the educated women who become mothers are faced with the decision on whether to return to the labor force or when to return.

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