UNIVERSITY OF COPENHAGEN   DEPARTMENT OF ECONOMICS

The Determinants of Fertility

Empirical Analysis of Japan

Tae Maki

Supervisor: Jacob Weisdorf

According to unified growth theory, the demographic transition is the necessary condition for sustained economic growth. However, conventional theories have little to say about levels of population in post-transitional societies. In this report, I will empirically test data on fertility in Japan based on the model introduced by Oded Galor, focusing on the hypothesis that fertility is affected negatively by the increase in the education cost and the low mortality rate over time.

Table of contents

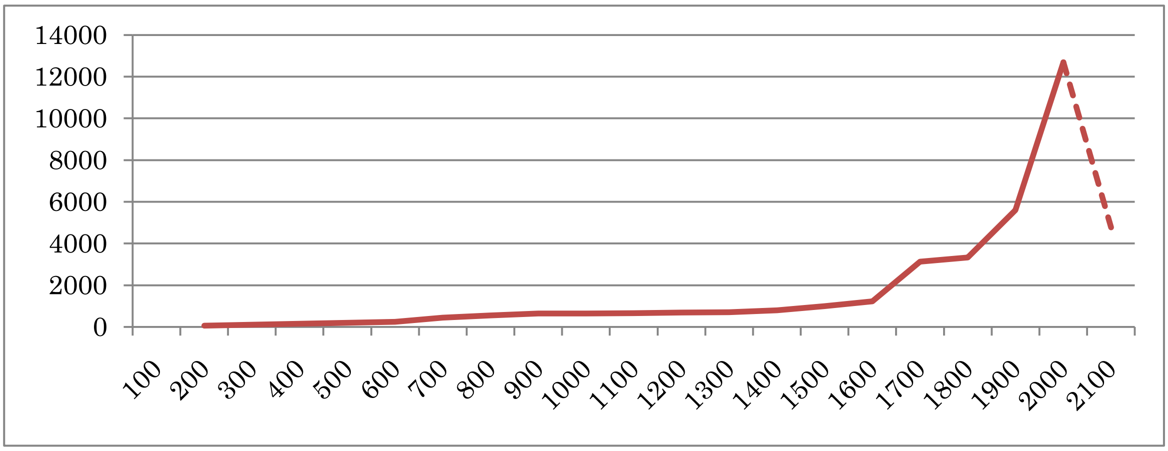
1 The issue

The fertility rate in Japan is rapidly falling and the aging society is a current big societal problem, causing major concern about future economic growth in Japan. Why does fertility continue to fall? When will it end? How should we cope with this phenomenon? After a generation-long discussion of these questions, the Japanese are still struggling to find the way. Some extreme opinions even mention that Japan is a new declining country, NDC, in contrast to emerging countries such as BRICs. The decline in the fertility rate also has indirect negative impacts on social policy. Pessimistic views on the future pension system and public debt create intergenerational conflicts between elderly and young cohorts. Radical ideologies against the current economical and political systems arise in poor strata, accusing the pursuit of economic growth to be the source of this vicious circle. Political instability might not be irrelevant to this societal confusion. Policymakers may have the opportunity to respond ahead of time. However, as the IMF report suggests remaining time is limited and the appropriate policy responses will inevitably involve difficult trade-offs, taking time to agree and implement[1].

As shown in Figure 1, Japan experienced major population growth in the late nineteenth century, which coincided with the dawn of the Japanese industrial revolution. The population has grown since the Meiji Restoration (the end of Samurai era) at an accelerated pace along with rapid growth of economy. However, the total fertility rate[2] started decreasing as early as the 1950s and it became less than the replacement level of 2.1 in the 1970s. The total population peaked off at 127 million in 2006 and is expected to decline to 95 million by 2050 according to OECD[3].

[1] IMF (2004), “World Economic Outlook - The Global Demographic Transition”
[2] The TFR; the number of children born to women aged 15 to 49
[3] OECD Factbook 2008

Figure 1 The population in Japan in the long run



Source: http://www2.ttcn.ne.jp/honkawa/1150.html[4]

In the case of Japan, the decrease in fertility is attributable to the higher education of women, the increase in the education cost, low mortality and other societal factors.

Oded Galor (2005) introduces unified growth theory as the first completed economic theory which incorporates the demographic transition. He states that if population growth is negative in the modern growth regime, then education and technological progress continue to fall. However, his model makes no firm prediction about what the growth rate of the population will be in the modern growth regime, other than that population growth will fall once the economy exits from the Malthusian region. Kazumasa Oguro (2007) emphasized the point which was originally postulated by Schultz (1964), that highly developed technology will accelerate the speed of obsolescence of human capital and raise the marginal revenue from rearing highly qualified children. Thus, further decline in fertility will be expected. He also argues that mortality is another factor affecting the fertility rate, by empirically testing panel data.

Based on these theories, this report primarily focuses on the determinants of population growth and explores the effects of related factors on population growth by testing

[4] Originally compiled by Hiroshi Kuroda in his book, “The Demographic History of Japan” (2000)

empirical data of Japan. The regressions are employed to test co-integrating relationships between variables and to develop an error-correction model.

2 Theories

2.1 Unified Growth Theory

The Malthusian era is characterized by the conflict between population growth and the limitations imposed by the carrying capacity, which have resulted in the tendency of oscillation in populations. Under the Malthusian trap, technological progress led to a larger population without altering the level of income, thus there was no transition to sustained growth of per capita GDP.

According to unified growth theory postulated by Galor, two central driving forces are missing for the transition to the sustained modern economy from such a pre-industrial revolution era; the demand for human capital and the demographic transition. He argues that the accelerated technological progress after the industrial revolution raised the demand for human capital. In other words, it raised the motivation to invest more in children. Highly qualified human capital, in return, enabled more technological progress, thus further acceleration of investment in human capital. During the course of the transitional cycle, the income effect increases fertility, but at the same time, the substitution effect between quantity of children and quality of children negatively affects the number of children. Therefore, the demographic transition would be fully achieved when population growth fell along with the increase in the average level of education. This enables sustained economic growth where per capita GDP is no longer constant, but exponentially grows.

2.2 The determinants of population growth[5]

The Galor Model is structured on an overlapping generation, general equilibrium model where fertility and the time cost for raising a child are endogenously determined through technological progress and accumulation of human capital. In each period t[6], members of a generation choose the number and quality of their children so as to maximize their inter-temporal utility function subject to the subsistence consumption constraint; mathematically this can be described as follows.

Production function is

$$Y_t = H_t^{\alpha}(A_tX)^{1-\alpha} \quad (1)$$

where H_t is the aggregated human capital, X represents land (exogenous), and A_t is the endogenously determined technological level in period t. (1) can be rewritten as output per worker at time t by dividing both sides of equation by L_t.

$$y_t = h_t^{\alpha}x_t^{1-\alpha} \quad (2)$$

Assuming that the wage per human capital is equal to the output per human capital, we get

$$w_t = (x_t/h_t)^{1-\alpha} \quad (3)$$

Under the life-cycle hypothesis, the generation-t is facing the following inter-temporal budget constraint, taking into account the potential income w_th_t, total consumption c_t, and the time cost for child rearing $\tau + e_{t+1}$, with n_t being number of children of generation-t.

$$w_th_t\, n_t\, (\tau + e_{t+1}) + c_t < w_th_t \quad (4)^{7}$$

τ is the fraction of the parent's unit time endowment required to raise a child regardless of quality. e_{t+1} is the fraction of the unit time invested in education of a child, expecting the

[5] For simplification, the explanation is limited to the case of modern sustained economies and thus the case of subsistence is omitted in this report.
[6] The model assumes that individual lives two time period, t and t+1, with t being childhood and t+1 being parenthood.
[7] Oguro extends the model to incorporate the probability of mortality, by taking into account the probability of p_t to die in the period t. Thus, his utility function is $w_th_t\, n_t\, (\tau + e_{t+1}) + (1- p_t)c_t < w_th_t$

raise in the potential rate of return to a child's human capital, h_{t+1}.

Parents are endowed one unit of time and they allocate it between child rearing and labor force participation. Thus, they choose the optimal combination of quality and quantity of children and supply their remaining time in the labor market. Assuming the Cobb-Douglas utility function with $\gamma \in (0,1)$, the parents' utility function is

$$u_t = (c_t)^{1-\gamma} (n_t h_{t+1})^{\gamma} \qquad (5)$$ [8]

Galor simply assumes that τ is sufficiently small so as to assure that population growth is positive; more specifically $\tau < \gamma$.

Further, whereas human capital is assumed as a positive function of the time cost, e_{t+1}, it is a negative function of technological progress, g_{t+1} ($g_{t+1} \equiv A_{t+1} - A_t$). The latter is called the 'erosion effect', which was stressed by Schultz (1964), that technological progress accelerates the obsolescence of existing human capital for the new technological environment. On the other hand, technological progress depends positively on the time cost and population level, L_t, in the previous period.

$$h_{t+1} = h(e_{t+1}, g_{t+1}) \qquad (6)$$

$$g_{t+1} = g(e_t, L_t) \qquad (7)$$

Solving the maximization problem of parents' utility function subject to the subsistence consumption constraint, the optimal choices of the number and quality of their children are given by a following equation;

$$n_t [\tau + e_{t+1}] = \gamma \qquad (8)$$ [9]

(8) can be rearranged as $n_t = \gamma / [\tau + e_{t+1}]$, which indicates that number of children born to a parent depends negatively on the time cost of education, concluding that the higher the

8 In the Oguro Model,the utility function is in the form of $E(u_t) = (1- p_t)(c_t)^{1-\gamma}+(1- p_t)(n_t h_{t+1})^{\gamma}$, by taking expectation of utility with the probability of p_t to die in the period t.

9 The solution to the Oguro Model is $n_t [\tau+ e_{t+1}] = \gamma (1- p_t)$. Accordingly, (9) is modified to $g_N = \gamma (1- p_t) / [\tau+ e_{t+1}] -1$

technological progress, the lesser the fertility. Empirically, preceding research [10] confirmed that the time cost in developed countries is high due to expensive tertiary education and the higher opportunity cost women face to rear children.

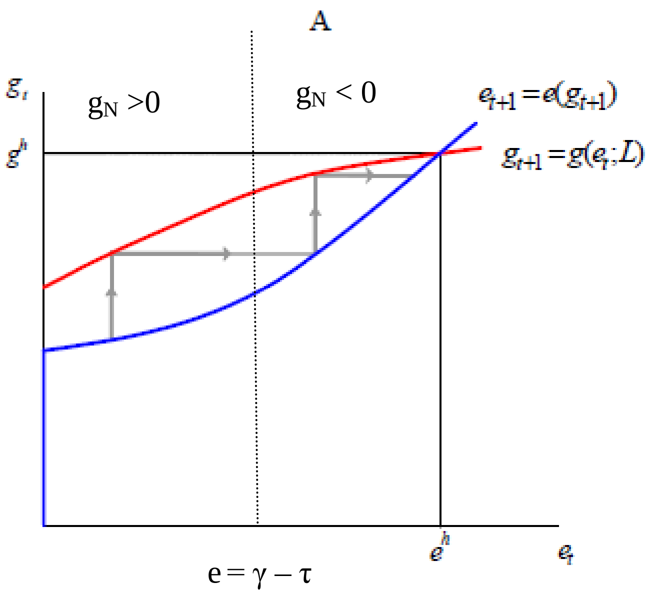
Further, from (8), to see how the dynamics of population, g_N, is affected by the time cost, we get,

$$g_N = n_t - 1 = \gamma / [\tau + e_{t+1}] - 1 \qquad (9)$$

The demographic change can be explained, conditioning on e_{t+1} as follows.

$$\begin{cases} \text{Decrease in population;} \quad g_N < 0 \leftrightarrow e_{t+1} > \gamma - \tau \\ \text{Increase in population;} \quad g_N > 0 \leftrightarrow e_{t+1} < \gamma - \tau \end{cases} \qquad (10)$$[11]

Figure 2 Phase diagram of evolution of technology, g_t, and the education cost, e_t[12]



As previously noted, Galor assumes that τ is sufficiently small such that population n_t per person is at least more than one. Thus, his model precludes the case when the population

[10] See "An Economic Analysis of Fertility, Demographic and Economic Change in Developed Countries" by Becker (1960) for further discussion on the quality and quantity trade-offs.

[11] The borderline of population growth can be written as $e_{t+1} > 1 - \gamma (1 - p_t) - \tau$ in the Oguro Model. Thus, if life expectancy is extended (in the case of lower p_t), the vertical line in Figure 2 shifts to the left, the equilibrium intersection being in the area where $g_N < 0$.

[12] A vertical line representing $e = \gamma - \tau$ is added to the original phase diagram.

declines, that is, τ is large enough to affect the level of population growth.[13]

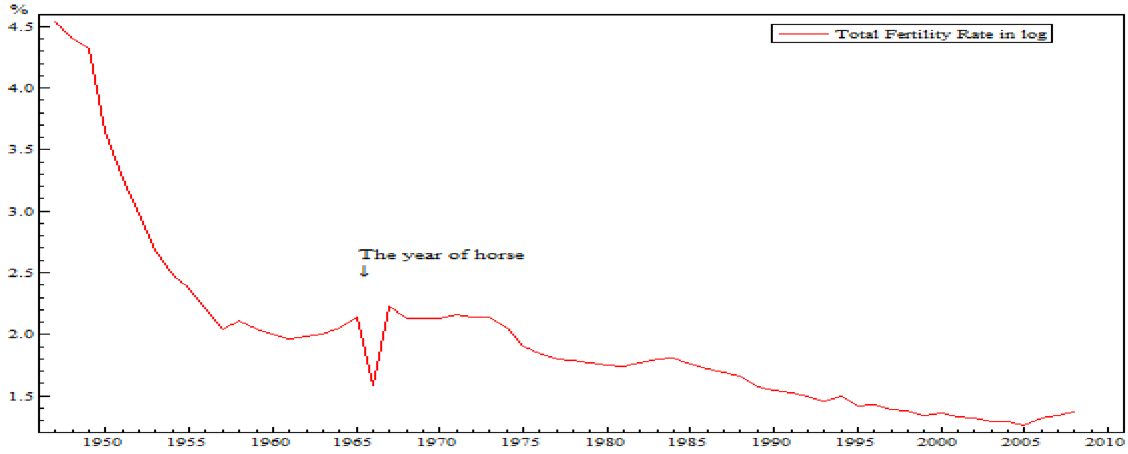
3 Empirical data analysis

3.1 Regressions

In this analysis, I focus on the determinants of population growth; more specifically I explore the links between fertility and the education cost by empirically testing time series data of Japan.

Figure 3 and 4 plot the Total Fertility Rate (the TFR) in the logarithm and percentage of the education cost in total household consumption from 1947 to 2008, respectively. Whereas the TFR constantly decreases over time (trend stationary variable[14]), the education cost fluctuates largely around a mean of 3% until late 1980 and then seems relatively constant during the last two decades at the 4.4% level (non stationary variable).

Figure 3 The Total Fertility Rate in Japan from 1946 to 2004

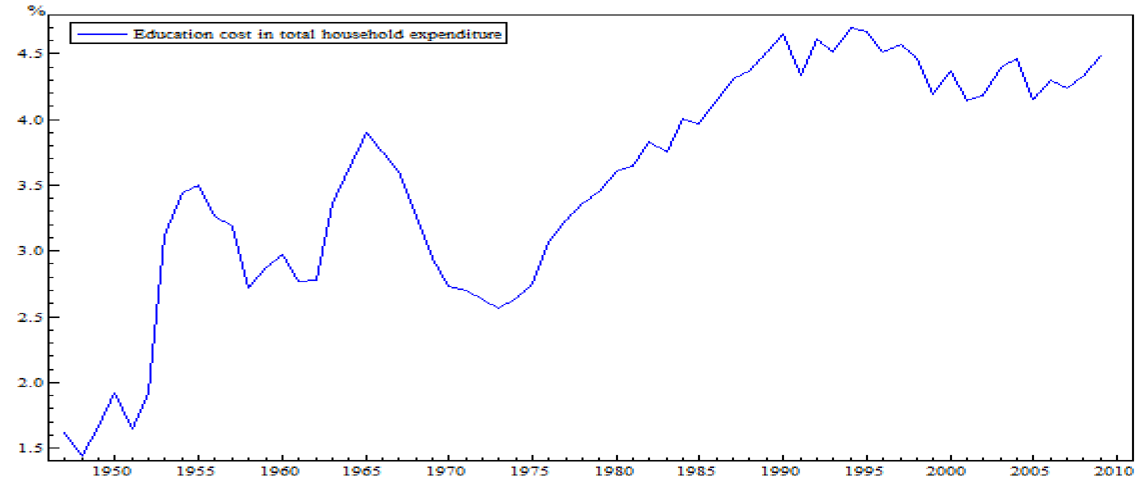


Source: Vital Statistics of Japan, Ministry of Health, Labor and Welfare (2009)

[13] Oguro asserts that fertility is lowered as a result of low mortality, thus a population decline is an inevitable outcome in an aging society and a decline in fertility continues as long as individuals expect longevity.

[14] The Dickey-Fuller unit-root test (5% significant level) was performed to test all variables.

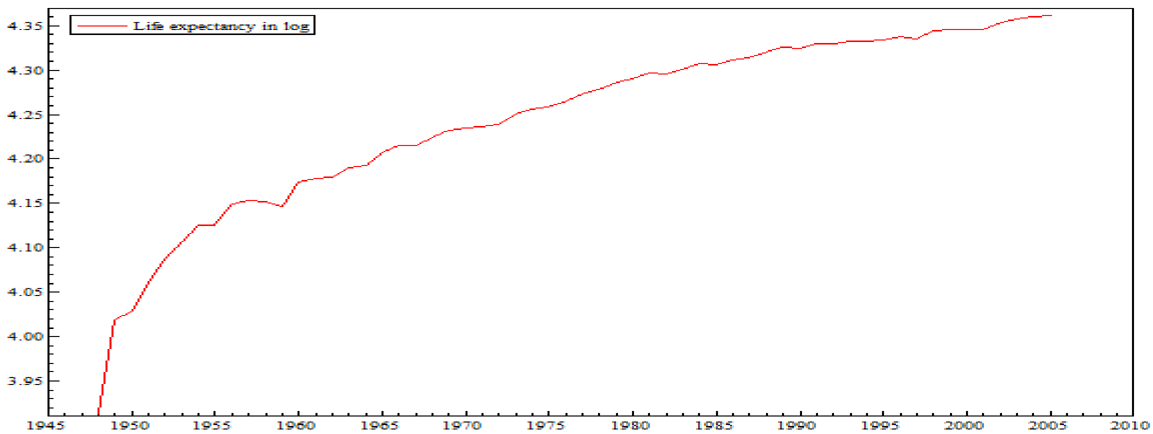
Figure 4 The education cost in total household expenditure from 1946 to 2008



Source: Statistics Bureau, Ministry of Internal Affairs and Communications (2009)

For the purpose of examining the hypothesis in the Oguro Model that mortality also affects fertility, I add average life expectancy (in logarithm) from 1947 to 2009 as another explanatory variable, noting that life expectancy is a non stationary variable.

Figure 5 Life expectancy



Source: Statistics Bureau, Ministry of Internal Affairs and Communications (2009)

Based on the theory, I would expect the TFR, the education cost and mortality to co-integrate. Thus, I estimate fertility as follows (Table 1) and test the null hypothesis of co-integration based on the Engle Granger two-step procedure.

$$n_t = \beta_1 + \beta_2 n_{t-1} + \beta_3 n_{t-2} + \beta_4 n_{t-3} + \beta_4 n_{t-5} + \beta_5 e_{t-4} + \beta_6 e_{t-5} + \beta_7 m_t + \beta_8 m_{t-4} + u_t \quad (11)$$

Using a test statistics in Table 2 with a 5% significance level, I can reject the null hypothesis that coefficients are statistically insignificant. Therefore I conclude that there is a strong statistical association between fertility, the education cost and mortality.

Table 1 The model selection

	Coefficient	Std.Error	t-value	t-prob
LTFR_1	0.393196	0.09639	4.08	0.0002
LTFR_2	0.361430	0.09038	4.00	0.0002
LTFR_3	0.142965	0.09539	1.50	0.1408
LTFR_5	-0.338327	0.07701	-4.39	0.0001
Constant	-2.20573	1.830	-1.21	0.2342
LLife	2.03399	1.014	2.01	0.0508
LLife_4	-1.40852	0.7311	-1.93	0.0602
Edu%_4	0.0383420	0.02320	1.65	0.1052
Edu%_5	-0.0364259	0.02164	-1.68	0.0992
dumm1966	-0.307070	0.03910	-7.85	0.0000
Trend	-0.00748776	0.002133	-3.51	0.0010

Table 2 Test statistics for co-integration of fertility, the education cost and mortality

	Coefficient	Std.Error	t-value	t-prob
residuals LRAUTO_1	-0.656752	0.1287	-5.10	0.0000

sigma	0.0303964	RSS	0.0461970988
log-likelihood	106.304		
no. of observations	51	no. of parameters	1
mean(Y)	0.00254418	se(Y)	0.0373999

However, the signs of coefficients are contrary to the prediction of the theories. The education cost affects both positively and negatively, depending on which time lags are considered, thus offsetting each other. I also note that for the education cost, t-values are not significant and coefficients are only showing $\pm$0.4%. Mortality has bigger impacts on fertility, with current life expectancy increasing the TFR by 2.0% while extended life expectancy in t-4 has a negative impact on fertility by 1.4%. Fertilities in the past also affect current fertility. They show positive trends, with an exception of fertility rate in t-5 having a negative coefficient.

From (11), I define an error correction model given by the estimated residuals from the first step.

$ecm_t = \hat{u}_t = n_t - (\beta_1 + \beta_2 n_{t-1} + \beta_3 n_{t-2} + \beta_4 n_{t-3} + \beta_4 n_{t-5} + \beta_5 e_{t-4} + \beta_6 e_{t-5} + \beta_7 m_t + \beta_8 m_{t-4})$

$$\Delta n_t = \alpha_0 \Delta n_{t-2} + \alpha_1 \Delta n_{t-5} + \alpha_2 \Delta m_{t-1} + \alpha_3 \Delta m_{t-2} + \alpha_4 ecm_{t-1} + \varepsilon_t \quad (12)$$

According to test statistics in Table 3, taking into account the outliers which distort fertility in specific years[15], the model indicates that fertility is restoring 44% of the deviation from the relation between fertility, the education cost and mortality in equilibrium, which occurred in the previous year.

Table 3 The error-correction Model for fertility, the education cost and mortality

	Coefficient	Std.Error	t-value	t-prob
DLTFR_2	0.149883	0.04035	3.71	0.0005
DLTFR_5	-0.107849	0.04088	-2.64	0.0112
DLLife_1	-1.44337	0.4013	-3.60	0.0008
DLLife_2	-1.41738	0.3825	-3.71	0.0005
dumm1966	-0.276947	0.02146	-12.9	0.0000
dumm1965	0.0595215	0.02156	2.76	0.0081
dumm1967	0.300641	0.02457	12.2	0.0000
residuals_(LR)	0.437489	0.1065	4.11	0.0002

sigma	0.0206749	RSS	0.020517575
log-likelihood	142.071		
no. of observations	56	no. of parameters	8
mean(DLTFR)	-0.013877	se(DLTFR)	0.0694209

ARCH 1-1 test:	F(1,54)	=	3.8535 [0.0548]
Normality test:	Chi^2(2)	=	0.23694 [0.8883]
Hetero test:	F(10,42)	=	0.77882 [0.6483]

Moreover, Figure 4 captures two different patterns in the fluctuation in the education cost over time. Therefore, I further explore the link between these variables, by separating

[15] In Japan, traditionally the year of horse (1966) see less fertility because of the myth that the girls born in the year of horse become obstreperous. It is often the case that the consequent year experiences a boost in baby born.

them into two different periods, one from 1950 to 1980 and another from 1981 to 2008.[16] The detailed test statistics are shown in Table 4a and 4b. In both cases, the co-integrating relationships between variables are confirmed by the Dickey Fuller test with a 5% significance.

In the first half of the period, the education cost affects positively even though the impact of one percent change in the education cost on fertility is 0.07%. Mortality has bigger impacts on fertility. One percent increase in life expectancy in the current year and the previous year will increase the TFR by 5.8% and 3.3%, respectively, while only life expectancy in t-5 negatively affects fertility by 1.6%. The relationship between variables in the first half of the period is analogous to the original model.

The signs of the coefficients in the second half differ from the first half, especially for those assigned to the education cost and mortality. The education costs lagged in t-1 and t-5 show negative impacts on fertility by 0.04% and 0.07%, respectively, the education cost in t-4 being the only one affecting positively. The current life expectancy now causes a 2.3% decline by one percent annual change. Still, life expectancy in t-4 has a positive impact on fertility.

Table 4 The model selection

a) The first half period (1950-1980)

	Coefficient	Std.Error	t-value	t-prob
LTFR_2	0.411832	0.09177	4.49	0.0002
LTFR_3	0.354718	0.09973	3.56	0.0020
Constant	-31.0210	6.538	-4.74	0.0001
LLife	5.85514	1.318	4.44	0.0002
LLife_1	3.31414	1.406	2.36	0.0288
LLife_5	-1.68508	0.5406	-3.12	0.0054
Edu%_4	0.0794843	0.01794	4.43	0.0003
dumm1966	-0.264719	0.03995	-6.63	0.0000
Trend	-0.0455582	0.009418	-4.84	0.0001

[16] Each time period corresponds to the first half of the period and the second half of the period.

b) The second half period (1981-2008)

	Coefficient	Std.Error	t-value	t-prob
LTFR_1	0.885173	0.04374	20.2	0.0000
LLife	-2.31659	1.040	-2.23	0.0365
LLife_4	2.38785	1.046	2.28	0.0324
Edu%_1	-0.0472651	0.01888	-2.50	0.0202
Edu%_4	0.0647691	0.02515	2.58	0.0173
Edu%_5	-0.0759191	0.02033	-3.73	0.0012

3.2 Conclusion

R squared and t-values indicate the significance of the model; however; the signs of the coefficients are not always consistent with the theories. It is only in the second half of the period that evidences are in accordance with theories, stating that the number of children depends on the education cost. However, the impact resulting from the increase in the education costs is not significant. Mortality has both positive and negative impacts on the fertility rate, offsetting each other in total. In fact, the recent three years from 2005 see a positive trend in fertility, which is not in line with the fact that both the education costs and life expectancy rise for those periods.

While the education cost and mortality are both important determinants of fertility, the relationship between these variables vary with time. This may be true when people's perception of longevity can be both positive and negative, depending on the circumstances and future prospects. Thus, the model can be improved if I take into account the forward-looking rational expectation in formulating the number of children and in assessing the expected return on investment in education of children. This can be the case where the time cost irrelevant to the quality of children, τ, can be large and γ is relatively small. If that is the case, lowering the education cost is not a sufficient measure to raise fertility, according to (10). There may be policies to keep τ lower and to enhance the social scheme where the young cohort benefits from the higher return to education.

References

M. C. Baddeley, D. V. Barrowclough (2009), "Running Regressions", Cambridge University Press

Rider, Christine (2007), "Encyclopedia of the Age of the Industrial Revolution, 1700-1920 - Vol. 1", Greenwood Press

Nakatani, Iwao (2007), "Introduction to Macroeconomics", Nihon Hyoronsha

Oguro, Masakazu (2007), "Consideration on Population based on the Demographic Transition Theory", PRI Discussion Paper Series (No.07A-18), Ministry of Finance of Japan

Galor, Oded (2005), “From Stagnation to Growth: Unified Growth Theory”, Minerva Center for Economic Growth Working Paper No. 2004-1

IMF (2004), "World Economic Outlook - The Global Demographic Transition"

Maddison, Angus (2001), "The World Economy - A Millenial Perspective", OECD

Schulz, T (1964), "Transforming Traditional Agriculture", Yale University Press