Working Paper Series (E)

No.30

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August 2019
http://www.ipss.go.jp/publication/e/WP/IPSS_WPE30.pdf

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Lowest-low fertility in Singapore: Current state and prospects[1]

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Abstract

By conducting a decomposition analysis on ethnicity-specific fertility changes since the 1970s, we show naptiality rather than marital fertility has been the main driving force for all major ethnic groups in Singapore. Using a micro-level data, we examine first marriage timings of Singaporean youths to show (1) gender differentials in the effects of ethnicity and managerial, professional, and special first occupations, and (2) gender indifferences in the effects of birth country and extended schooling. We discuss their consequences on population structures under prevalent phenomena of international and inter-ethnic marriages in Singapore.

The author thanks Christopher Gee Kok Aun, Mui Teng Yap, Noriko Tsuya, Shigesaburo Kabe, Shigeki Matsuda, and participants at the 2019 Population Association of Japan annual meeting for helpful comments and suggestions. This research is financially supported by Heath Labour Science Research Grant (Ministry of Health, Labour and Welfare, Japan Government) H27-Chikyukibo-Ippan-001 and H30-Chikyukibo-Ippan-002. Micro-data used in section 3 is collected by JSPS KAKENHI Grant Number JP26285122.

Introduction

We explore factors affecting the current state of lowest-low fertility in Singapore to empirically seek Singaporean prospects of population structures. We focus on ethnic diversity in Singapore society as a key aspect regulating evolution of Singaporean fertility. We also focus on rapid expansions of higher education as another key ingredient.

Our analyses combine both of macro- and micro-data to strength flexibility of latter and reliability of former each other. Macro data we demonstrate are derived from *Population Census* and *Vital statistics*, both of which are known to hold highest accuracy among population statistics in Singapore. We show recent developments of fertility and nuptiality since the 1970s. Specifically, we focus on ethnic differentials revealing in period fertility measures. Then, by conducting a decomposition analysis, we argue a relative importance of nuptiality's role on the fertility changes comparing with marital reproduction.

We analyze a micro-level data drawn from the 2016 survey, *Opinion Survey on Marriage, Family and Work*, for patterns and factors on first marriage timing of youths in contemporary Singapore. Our primary focus is gender differences in effects of extended schooling and managerial, professional, and special first occupations after the schooling on delaying first marriage. We also stress a gender difference in ethnicity effect of Non-Chinese marrying early, and a gender indifference in a birth-country effect by that both of Chinese and Non-Chinese native Singaporean (who were born in the city state) get married later than non-natives (who were born outside Singapore).

Next section reviews an ethnic stability of Singaporean youth population past two decades and shows the census data indicating rapid expansions of higher education after the establishment of the Republic of Singapore in 1965. Section three presents a decomposition analysis on fertility changes for contributions of marital status and marital fertility. Section four accounts the method and results of the event history analysis for first marriage timing. Final section discusses implications and prospects for a population structure in Singapore.

1. Brief reviews of demographic profiles of Singapore youths: Ethnicity and education

1.1. Population census and vital statistics in Singapore

Throughout this study, we use aggregate data taken from publicized statistical tables of decennial *Census of Population*, *General Household Survey*, annual *Report of Registration of Births and Deaths Statistics* and *Statistics on Marriages and Divorces*. All these statistics prevails high accuracy but requires a caution when combined. First population census after its independence was conducted in 1970. Since then, it continued to be undertaken by a ten-year interval until 2010. Beginning in 1995, the statistics department of the government initiated another decennial large-scale household survey to meet an increasing demand for accurate population statistics for economic and social planning. Population censuses on and before 1980 were conducted based on "*de facto*" concept in which all persons present in the country on the census date were counted. After 1990, both of statistics enumerates all populations residing in the territory on the reference date by the "*de jure*" (usual residence) concept. Most of statistical tables in these reports counted and included only Singapore residents, that is composed of citizens and permanent residents, but excluded foreigners. In fact, we only acquire total number of foreigners but not age and sex compositions, ethnicity and marital status, etc.

The establishment of vital statistics system in Singapore dated way back to the initiation of population census. Annual report of births and deaths registration has been compiled and published by the government's registrar general in a comparable format long time before the independence. It covers all incidence of births and deaths that were occurred in Singapore, irrespective of residential status. However, it does not report the births and deaths happened only to Singapore residents excluding those to foreigners. Hence, we only have resident populations as exposures to demographic events experienced by all populations including foreigners. This inconsistency between numerator (demographic events) and denominator (population at risk) induces an upward bias in calculation of demographic rates.

Because of intensive international migrations, the proportion of non-resident population among the total population has increased rapidly and has reached a considerable fraction after the 2000s: 5.5%(1980), 10.2%(1990), 18.7%(2000), 25.7%(2010), and 29.5%(2015). Interpretation of results for the macro analysis necessarily pertains a caution. As we discussed later in a case of fertility, ethnicity-specific statistics for Chinese and Malay are suffered by less severe biases.

1.2. Ethnic diversity

There are three major ethnic groups in Singapore population: Chinese, Malay, Indian, and others. The number and composition of ethnicity-specific population age 15-49 for 1960-2015 are shown in table 1. The data prior to 1980 refer total population including foreigners while the table shows Singapore residents on and after 1980 that are composed of citizens and permanent residents. The reproductive age population of all ethnic groups increased from 728.3 thousands in 1960 to 1,989.9 thousands in 2015 at an average annual growth rate of 1.8% and it has been nearly tripled in one half century. For overall of this period, youth population of all major ethnic groups grew by a similar pace at average annual growth rates of 1.8% for Chinese and Malay and 1.9% for Indian, though Chinese and Malay's increases were slow down after the late 1990s and Indian and Other's figures were boosted in the 2000s.

Table 1. Population of age 15-49 by ethnic group in Singapore: 1960-2015

	Ethnic composition of population (%)					Population by ethnic group (1,000)				
	Total	Malay	Chinese	Indian	Other	Total	Malay	Chinese	Indian	Other
1960	100.0	14.4	73.8	9.8	2.0	728	105	538	71	15
1965	100.0	14.2	75.9	8.2	1.7	841	120	638	69	15
1970	100.0	14.1	76.6	7.3	2.1	1,015	143	777	74	21
1975	100.0	14.1	77.2	6.6	2.1	1,225	173	946	81	25
1980	100.0	14.2	78.6	6.3	0.9	1,322	187	1,039	83	12
1985	100.0	14.0	78.4	6.7	0.9	1,478	207	1,158	98	14
1990	100.0	13.4	78.7	6.9	0.9	1,642	221	1,292	114	16
1995	100.0	13.2	78.8	7.0	1.1	1,790	236	1,410	125	19
2000	100.0	13.3	77.6	7.7	1.3	1,878	250	1,458	145	25
2005	100.0	13.8	75.4	8.7	2.1	1,923	265	1,451	167	41
2010	100.0	13.6	72.6	10.0	3.9	2,035	276	1,478	203	79
2015	100.0	13.8	72.6	9.8	3.8	1,990	274	1,445	196	76

Source: *Singapore Census of Population, 1970*. Department of Statistics Singapore, "SingStat Table Builder." <http://www.tablebuilder.singstat.gov.sg/> (accessed on 7th May 2018). Note: Data prior to 1980 refer to total population

which include foreigners, while data from 1980 onwards refer to Singapore residents which are composed of citizens and permanent residents.

Regardless of the rise in the number, ethnic compositions of Singapore youth population have been stable over the last half century: 73-79% for Chinese, 13-14% for Malay, and 6-10% for Indian. As we will discuss shortly, fertility rates have been distinguishably higher in Malay than those of Chinese and Indian during this period, Malay proportion in live births is higher than the population composition in Table 1. Instead, immigrants of Chinese, Indian and other ethnic groups are intensive and compensate for fertility differences as resulting in a stable ethnic composition for the decades. In the late 2000s, Singapore government exercised an excessive immigration adaptation policy. The policy last for a few years, however, Indian and other ethnic groups were quickly expanded, and they became to share Singapore youth population as Malay did by 2010.

1.3. Education developments

Education, or human capital accumulation, is assessed to perform as an engine of Singapore's economic growth (Sun 2012: p.56). Because of scarce natural resources, investing government budgets on human resources was one of the primary strategies for economic development. The education system of Singapore may be best characterized by a "streaming" or ranking students by their academic abilities through three examinations: the Primary School Leaving Examination (PSLE), the Singapore-Cambridge General Certificate of Education Ordinary Level (GCE O-Level) examination, and the Singapore-Cambridge General Certificate of Education Advanced Level (GCE A-Level) examination. Upon the completion of six-years compulsory primary education, all students are required to pass the PSLE. Based on results of the PSLE, students are placed in difference tracks ("streams") for four- or five-years secondary education: Express, Normal (Academic), and Normal (Technical). Students in the express path proceed to the GCE O-Level examination in the fourth year, while the normal(and academic/technical) students take the GCE N-Level examination in the fourth year with an opportunity of the fifth year leading to the GCE O-Level examination for the normal(or academic) path. Successful students in the GCE O-Level examination are admitted to two- or three-years pre-university programs after which they take the GCE A-Level examination. With the GCE A-Level certificate, students apply to four-year universities in Singapore or oversea for a degree. Otherwise, students with the GCE O-/N-Level certificates proceed to Polytechnic, or other technical or vocational education institutes to acquire a diploma. In the early 2010s, slightly less than one half of birth cohorts was admitted to Polytechnics and other diploma courses, and one third to one fourth of the cohorts succeeded to universities for degree courses (Singapore Ministry of Education 2016).

The government efforts are reflected in a rapid increase in higher education attained by cohorts born after 1960 who started primary education in the independent Republic of Singapore. Table 2 shows Singaporean resident population's education attainment distribution by birth cohorts. It is calculated by a statistical table for non-student populations by age and education qualifications in *Population Census 2010*. Except for the youngest age group who were born in 1980-1985 (age 25-29 in 2010), the schooling after the census do not enhance the figures much further and should be regarded as the cohort's final status. From the table, we see that the rates of populations with some diploma and a university degree was sharply increased between cohorts born in 1955-1960 and born in 1960-1965

from 20.6% to 30.2%, and the rates of higher education were uplifted dramatically to 44.9% (1965-1970 cohort), 59.5%(1975-1980 cohort), and 70.3%(1975-1980 cohort). At the same time, four-year university education became pervasive among the higher educations: university graduates accounted for 11.7% of 1955-1960 birth cohort and comprised 47.2% of 1975-1980 cohort. Furthermore, such prevalence of higher educations occurred quickly among women than men. Among 1955-1960 birth cohort, rates of a diploma/degree holder were 25.1% of male and 16.1% of female. This rate increased to 70.5% of male and 70.1% of female born in 1975-1980. In the pre-independence era, female Singaporeans were less likely received higher education than males did, however, females acquired at least as equivalent levels of higher educations as males did in a decade.

Table 2. Singapore resident's age-specific rate of educational attainment by sex: *Singapore Census of Population 2010*

Birth year	Highest qualification						
	Total	No Qualification	Primary	Secondary	Post-secondary (Non-Tertiary)	Polytechnic, Professional Qualification, Diploma	Univeristy
Total residents							
1980- 1985	100.0	0.8	1.0	14.9	11.9	25.5	45.8
1975- 1980	100.0	1.4	1.7	17.1	9.6	23.1	47.2
1970- 1975	100.0	2.8	2.8	22.9	12.0	19.6	39.9
1965- 1970	100.0	5.8	5.1	32.3	11.9	15.8	29.0
1960- 1965	100.0	9.7	8.8	41.0	10.2	11.3	18.9
1955- 1960	100.0	14.9	12.3	42.0	10.2	8.9	11.7
1950- 1955	100.0	19.5	13.0	43.1	8.7	6.8	8.8
1945- 1950	100.0	30.0	13.1	37.4	6.9	5.6	6.9
1940- 1945	100.0	45.7	12.3	26.7	5.9	4.3	5.1
1935- 1940	100.0	56.0	10.8	21.3	4.4	3.2	4.3
Male							
1980- 1985	100.0	0.6	0.9	15.1	15.0	26.4	42.0
1975- 1980	100.0	1.1	1.5	15.9	11.1	23.4	47.1
1970- 1975	100.0	2.4	2.3	20.1	12.5	19.3	43.4
1965- 1970	100.0	5.9	4.5	27.1	12.4	16.3	33.8
1960- 1965	100.0	9.3	8.3	36.9	10.7	12.2	22.6
1955- 1960	100.0	13.2	11.7	39.5	10.5	10.5	14.6
1950- 1955	100.0	14.8	11.5	43.2	9.8	9.0	11.6
1945- 1950	100.0	22.3	12.5	39.8	8.3	7.4	9.7
1940- 1945	100.0	34.7	13.6	31.2	7.2	5.7	7.6
1935- 1940	100.0	42.7	12.9	26.9	6.0	4.5	7.0
Female							
1980- 1985	100.0	1.0	1.1	14.8	9.2	24.7	49.3
1975- 1980	100.0	1.6	1.8	18.1	8.3	22.9	47.3
1970- 1975	100.0	3.2	3.2	25.5	11.5	19.9	36.7
1965- 1970	100.0	5.8	5.6	37.3	11.6	15.3	24.5
1960- 1965	100.0	10.2	9.3	45.1	9.7	10.4	15.2
1955- 1960	100.0	16.7	12.9	44.5	9.8	7.3	8.8
1950- 1955	100.0	24.3	14.4	43.0	7.6	4.6	6.0
1945- 1950	100.0	37.5	13.7	35.2	5.5	3.9	4.2

Source: Department of Statistics Singapore, *Singapore Census of Population, 2010*.

Table 3. Singapore resident's age-specific rate of educational attainment by ethnicity: *Singapore Census of Population 2010*

Birth year	Highest qualification						
	Total	No Qualification	Primary	Secondary	Post-secondary (Non-Tertiary)	Polytechnic, Professional Qualification, Diploma	Univeristy
Chinese							
1980- 1985	100.0	0.5	0.7	12.3	8.4	27.0	51.0
1975- 1980	100.0	1.0	1.4	16.3	8.2	25.1	48.0
1970- 1975	100.0	2.7	2.6	22.7	11.3	21.5	39.2
1965- 1970	100.0	5.8	4.9	32.2	11.4	17.2	28.6
1960- 1965	100.0	9.9	8.7	40.3	9.7	12.4	19.0
1955- 1960	100.0	15.3	12.3	41.2	10.0	9.6	11.6
1950- 1955	100.0	20.0	12.7	42.6	8.7	7.3	8.7
1945- 1950	100.0	30.7	12.8	36.9	7.0	5.9	6.8
Malay							
1980- 1985	100.0	1.8	2.2	29.1	30.8	25.1	11.0
1975- 1980	100.0	4.1	4.4	33.6	24.9	20.6	12.4
1970- 1975	100.0	5.9	5.7	39.9	23.5	14.5	10.5
1965- 1970	100.0	9.5	8.3	47.6	17.8	10.3	6.4
1960- 1965	100.0	11.7	11.8	54.1	13.5	5.8	3.2
1955- 1960	100.0	16.1	15.0	51.4	11.4	4.2	1.8
1950- 1955	100.0	21.4	16.1	50.2	8.7	2.1	1.6
1945- 1950	100.0	33.7	17.0	41.2	4.7	2.5	0.8
Indian							
1980- 1985	100.0	0.8	1.2	14.9	12.2	19.8	51.2
1975- 1980	100.0	0.9	1.5	13.0	7.6	19.2	57.7
1970- 1975	100.0	1.6	1.8	16.8	9.9	15.8	54.2
1965- 1970	100.0	3.4	4.0	24.5	11.5	13.8	42.8
1960- 1965	100.0	7.7	7.8	36.2	10.8	10.3	27.2
1955- 1960	100.0	12.6	10.9	40.9	10.2	8.0	17.5
1950- 1955	100.0	14.3	13.8	43.3	9.3	6.3	13.0
1945- 1950	100.0	21.7	14.1	39.3	8.5	5.6	10.9
Other							
1980- 1985	100.0	2.4	1.7	11.7	6.0	15.2	63.0
1975- 1980	100.0	1.8	0.9	7.2	5.1	11.9	73.2
1970- 1975	100.0	2.0	1.6	9.7	5.5	12.1	69.0
1965- 1970	100.0	2.7	2.3	13.0	7.6	12.4	62.0
1960- 1965	100.0	2.9	2.3	16.2	7.1	12.5	59.0
1955- 1960	100.0	3.9	2.9	20.6	10.2	13.5	48.8
1950- 1955	100.0	3.7	3.5	25.5	9.9	15.7	41.7
1945- 1950	100.0	3.5	2.9	37.0	9.5	11.8	35.3

Source: Department of Statistics Singapore, *Singapore Census of Population, 2010*.

Universality may well explain Singapore's phenomenon of rising higher education. In addition to the shrinking gender difference in the highest attainment level, Table 2 shows proportions without the secondary education have been virtually disappeared from both sexes' school year cohorts in the decade after the independence. In 1945-1950 birth cohort, females with primary or less educations accounted for 51.2% contrasting to male's proportion 34.9% that resulted in 16.3-percent-points gender difference. This gap in lower educations has

been quickly diminished to 2.0-percent-points difference (by male 19.5% and female 17.6%) in 1960-1965 cohort. In the 1945-1950 birth cohort (age 25-29 in 1975), 37.5% of females did have no education qualifications who would likely be illiterate. This figure dropped to 5.8% by 1965-1970 birth cohort (age 25-29 in 1995). Hence, uneducated women practically vanished from the prime reproductive of age 20s during the 1980s; the fact by which family planning program delivered contraception methods successfully.

Table 3 focuses racial differences in education attainment. Generally speaking, "Other ethnic group" is the best educated, followed by Indian and Chinese, and Malay's rate of higher education is the lowest among Singapore residents. At least two ethnic differentials are acknowledged. First, with a comparison between Chinese and Malay who have no education qualification, shrinking patterns are quite similar. Second, though Malay's rates of higher education increased considerably from 8.9% (1960-1965 cohort) to 36.1% (1980-1985 cohort), Malay is still behind of other ethnic groups in 1980-1985 cohort: the rates with some diplomas and above are 78.1%, 71.0% and 78.2% for Chinese, Indian and Other, respectively.

2. Decomposition analysis for nuptiality and marital fertility

2-1. Pro-natal policy developments and general patterns of fertility changes of the major ethnic groups in Singapore

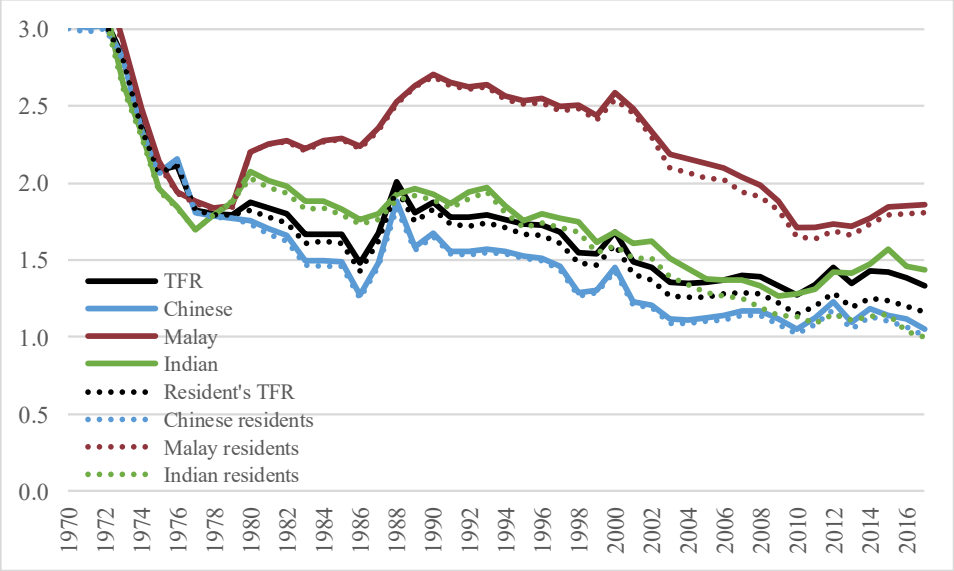
On its relationship to period fertility changes, pro-natal policy interventions in Singapore have been a demographer's concern. Pro-natal policy developments in Singapore were divided into several phases[2]. In the first phase, the Singapore government introduced a set of population control programs in the mid-1960s to achieve replacement reproduction by 1980, and this anti-natal policy remained effective throughout the early 1980s (Saw 2005: 35-39). These programs were so effective that Singapore's total fertility rate (TFR) reached 2.08 in 1975 and continued to decline until the mid-1980s. To respond to the prolonged decline, the Singapore government introduced policies in 1984 that aimed to raise the fertility of educated females (Phase II). These policies selectively targeting to the highly educated females did not remain, but the government 's attitude on population policies generally shifted from anti-natal to pro-natal. From 1987, the government started to support mothers who have the third and higher order children by adopting a set of pro-natal policy measures (Phase III). At the same time, eugenics policies and old anti-natalist policies were gradually abolished. While there were no major pro-natal policy developments from 1991 to 1999 (Phase IV), the government further emphasized the pro-natalist tone and enhanced supports for the first and second childbirths after 2000 (Phase V-VII).

Figure 1 shows that TFRs of all major ethnic groups achieved the replacement level by 1975. From the below replacement level, Malay TFR turned to increase in 1979 and stayed above the replacement level throughout the 1990s. However, Malay TFR is rapidly declining for 2000-2010. Chinese TFR stopped to decline in the early 1980s. It increased from 1986 to 1988 but declined steadily since the 1990s. Indian TFR increased from 1977 to recover the replacement level in 1980 but returned to follow a downward trend by slower pace than before. Indian TFR increased from 1986 to 1989 and stayed near the replacement level until 1993, however, it decreased more quickly than Chinese TFR throughout the mid-1990s and the 2000s. Nonetheless, all ethnicity specific TFRs seem

[2] See Saw(2005 and 2007), Wong and Yeoh(2003), Yap(2009), Straughan et al.(2009), Sun, Shirley Hsiao-Li (2012), and documents by Singapore National Population Secretariat among others for detailed pro-natal policy developments in Singapore.

to turn to increase (at least stop declining) from 2010.

Figure 1. Total fertility rate for the major ethnic group of resident population in Singapore: 1970-2017.



Source: For solid lines, Department of Statistics Singapore, "SingStat Table Builder," available on-line at http://www.tablebuilder.singstat.gov.sg/ (accessed on May 2018). For a set of dot lines, calculation by author.

Note: The TFRs calculated by author includes foreigner's births in the numerator, while resident populations are taken for the denominator. Ethnicity refers to those of mothers.

As we noted in Section 1-1, age-specific fertility rates are upward biased and so TFRs in figure 1 are, because the vital statistics reports all live births occurred in Singapore while no tabulations for age-specific female foreigners are released for decomposition analysis. Singapore department of statistics calculates Singapore resident's TFR after 1980, for which foreign women's births were subtracted. On the one hand, the difference of TFR calculated here from the official resident's TFR are expanding after the 2000s. The averages of the differences are 0.042 for 1970-2000 and 0.124 for 2000-2017, and this expansion of discrepancy causes a reduction in timeseries correlation coefficients from 0.999 (1970-2000) to 0.926 (2000-2017). On the other hand, sizes of the discrepancy significantly vary by ethnicity: averages (maximums in parentheses) of differences for 1980-2017 are 0.029(0.053), 0.038(0.097) and 0.120(0.434) for Chinese, Malay, and Indian, respectively. Timeseries correlation coefficients between the Singapore resident's TFR and own calculation for 2000-2017 are 0.993, 0.997, 0.673 for Chinese, Malay, and Indian, respectively. These patterns in the discrepancy seem to be consistent with the gender- and ethnicity-specific increase of immigration which would have brought international and inter-ethnic marriages(details omitted due to page restriction but see footnotes 3-4), we should be cautious in interpretation of decomposition results especially for Indian population after the 2000s. Because the marital statuses are those of residents taken from the census data and numerators of fertility rates are inflated, marital fertility effects rather than nuptiality effects would be upward biased. Other than that, we do not suspect serious biases in the decomposition analysis as far as risks attributable to foreigner's births were concerned.

2-2. Ethnic patterns of nuptiality by gender

To learn ethnic patterns of nuptiality, we focus not on marriage registrations released in the vital statistics (flow data) but on marital status surveyed in the population censuses (stock data). Table 4 shows ethnicity- and age-specific proportions of the never-married population and provides descriptive statistics to acquire insights for understanding decomposition results, because a change in the marital status distribution accounts for nuptiality in the decomposition analysis below. It is the rate of Singapore citizens and permanent residents (on and after 1990) so does not suffer foreigner's marriage registrations but incorporate naturalized immigrant's marriage history outside Singapore. As a summary measure, Hajnal's singulate mean age at marriage (SMAM in Hajnal 1953: pp.129-131) is computed and presented in the table.

Malay males and females marry earlier than Chinese males and females. Contrasting to the clear ethnic diversity of period fertility developments (Section 2.1), general tendency of delayed marriage is a common phenomenon among all ethnic groups of both sexes[3], and these ethnic differentials preserved for 1970-2015. In 1970, marriage in Singapore was early and universal: female's SMAM was below 25 and celibacy rate by the end of her reproductive ages was less than 4%. By 1990, the never-married rates increased in all age groups of both males and females. After remaining at around same levels during the 1990s, late marriages were accelerated after 2000.

Despite the general tendency of late marriage among ethnic groups, the extent of the delays differs between genders. Annual average growth rates of SMAMs show steeper rises for females: 0.78% (1970-1980), 0.06% (1980-2000), and 0.53% (2000-2015) for females; 0.36% (1970-1990), 0.03% (1990-2000), and 0.21% (2000-2015) for males. Further examination on the age-specific rates reveals that there was a surge between 1975-1980 birth cohort and younger (age 25-29 and below in 2005) from the former cohorts. These sudden rises were common among Chinese and Malay of both sexes but substantial among females: Chinese and Malay female's never-married rates of age 25-29 increased by 23.6 percent-points (from 44.5% to 68.0%) and 25.7 percent-points (from 25.6% to 51.3%) during 2000-2015, respectively; Male's rises for the same period were 16.3 percent-points and 15.4 percent-points for Chinese and Malay, respectively. Because of female's faster extensions in the never-married life, gender differences in the average age at marriage shrunk from 3.3 years (in 2000) and 4.5 years (in 2005) to 2.0 years and 2.4 years in 2015 for Chinese and Malay, respectively. It is interesting to notice that regardless of these age differentials between husbands and wives revealed in SMAM (husbands on average marring late by about three years), the never-married rates of age 45-49 were lower in male than those in female after the mid-1990s. These gender differences could be caused by intensive expansion of international and inter-ethnic marriage, in which proportion of foreign wife is double that of foreign husband[4].

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[3] There found to be an exception for Indian around year 2000 whose rates of the never married at age 20s dropped by unverifiable reasons. During the 1990-2000s, Indian immigration of age 25-44 was substantial: Indian resident's cohort change of age 5-39 to 15-49 (its ratio to cohort size at the beginning of period in parentheses) was 25,900 (28%) for 1990-2000 and 56,300 (39%) for 2000-2010, all of which were attributable to residents born outside of Singapore; proportions born outside Singapore among age 15-49 Indian residents (year in parenthesis) were 18%(1990), 29%(2000), and 47%(2010) (author's calculation based on *Census of Population, 1990, 2000, 2010*). Depending on marital status of immigrants and their marriage behavior, rate of never-married residents can change unpredictably.

[4] According to Singapore Department of Statistics

Table 4. Singapore resident men and women's rate of the never-married population by age for major ethnic groups: 1970-2015.

Ehnic group and year	Female										Male									
	15-49 total	15-19	20-24	25-29	30-34	35-39	40-44	45-49	50[1)]	SMAM[2]	15-49 total	15-19	20-24	25-29	30-34	35-39	40-44	45-49	50[1)]	SMAM[2)]
All																				
1970[3)]	39.4	95.2	64.6	22.6	9.6	5.1	3.3	3.1	3.6	24.2	49.8	99.5	88.5	48.0	21.5	10.8	7.2	5.9	5.7	27.8
1980[3)]	42.5	97.7	73.8	34.0	16.7	8.5	6.0	4.2	3.5	26.2	51.7	99.6	91.9	54.9	21.5	10.6	8.2	6.4	5.9	28.4
1990	37.3	98.6	78.5	39.3	20.9	14.8	11.5	7.3	6.5	27.0	46.9	99.8	94.2	64.1	34.0	18.1	10.9	8.5	7.9	29.9
1995	35.0	99.2	83.6	40.6	20.0	14.9	12.8	10.7	8.5	27.1	43.3	99.9	96.2	67.0	33.6	20.0	11.9	8.2	7.4	30.4
2000	33.1	99.0	83.8	40.2	19.5	15.1	13.6	12.5	11.4	26.5	39.8	99.9	95.2	64.2	30.7	19.7	14.8	10.5	8.9	30.0
2005	34.6	99.4	86.5	46.3	22.1	15.0	14.3	13.3	12.7	26.9	41.3	99.9	96.3	70.6	33.9	19.6	15.2	12.8	11.6	30.1
2010	37.6	99.6	91.8	54.0	25.1	17.1	14.1	12.8	12.9	27.9	43.8	99.9	97.6	74.6	37.1	20.4	15.3	13.2	12.7	30.4
2015	39.1	99.8	95.7	63.1	25.5	17.0	15.3	14.5	13.3	28.7	44.7	100.0	98.8	80.2	37.5	20.6	15.4	12.9	12.3	30.9
Chinese																				
1970[3)]	41.3	96.5	69.5	25.3	11.1	5.8	3.6	3.3	3.9	24.8	53.3	99.6	89.9	51.0	23.3	11.8	7.7	6.2	5.9	28.2
1980[3)]	43.2	98.4	77.0	35.8	17.8	9.3	6.7	4.6	3.9	26.6	52.3	99.7	93.3	57.0	22.6	11.4	8.8	7.0	6.5	28.6
1990	38.5	99.2	82.7	43.1	22.4	15.6	12.3	7.9	7.1	27.6	47.4	99.8	95.3	68.0	36.9	19.3	11.5	8.5	8.1	30.4
1995	36.3	99.6	86.7	44.1	21.8	15.8	13.7	11.6	9.2	27.6	44.3	99.9	96.7	69.6	35.7	22.0	13.0	8.8	7.7	30.8
2000	34.6	99.5	87.1	44.5	21.6	17.1	15.0	13.5	12.4	27.1	40.7	99.9	96.1	66.5	32.7	21.8	16.5	11.5	9.7	30.3
2005	36.1	99.6	90.7	51.3	25.6	17.0	16.0	14.4	13.8	27.6	42.4	100.0	97.3	72.7	36.8	21.5	16.9	14.5	12.9	30.5
2010	39.6	99.8	95.0	61.3	29.8	19.9	16.2	14.8	14.6	28.7	45.5	99.9	98.3	78.1	42.2	23.7	17.0	14.8	14.2	31.0
2015	40.8	99.8	97.9	68.0	29.3	20.1	17.4	16.4	15.1	29.3	46.0	100.0	99.1	82.8	40.5	23.6	17.4	14.3	13.8	31.3
Malay																				
1970[3)]	32.3	89.5	45.0	11.6	3.9	2.2	1.7	1.1	1.1	22.5	44.8	99.2	82.8	36.8	14.2	7.0	4.9	3.7	3.5	26.6
1980[3)]	40.7	95.1	60.4	25.4	12.7	5.6	2.6	1.7	1.4	24.8	53.1	99.3	86.2	43.7	16.3	7.6	5.2	3.9	3.7	27.3
1990	32.8	96.4	62.8	24.9	13.8	10.1	7.3	3.8	2.9	25.2	44.9	99.6	89.6	48.8	21.6	11.8	6.7	5.0	4.4	28.2
1995	29.7	96.9	71.1	25.6	13.4	11.6	8.9	6.1	5.4	25.3	40.1	99.7	93.8	54.4	25.1	12.3	7.7	5.0	5.0	28.8
2000	29.0	97.4	72.2	25.6	12.2	8.8	8.2	7.5	6.2	25.0	38.0	99.7	90.9	53.5	24.5	13.3	8.4	5.7	4.8	28.8
2005	33.0	98.4	76.4	32.9	11.8	9.1	8.1	9.2	8.1	25.3	42.0	99.7	92.0	62.1	29.8	17.3	10.9	6.9	5.6	29.8
2010	37.5	99.0	86.7	43.3	16.0	9.2	7.7	6.7	7.0	26.8	47.6	99.8	95.3	66.3	29.9	18.2	13.4	9.1	7.9	30.0
2015	40.3	100.0	88.8	51.3	19.8	12.7	8.3	7.7	7.5	27.8	50.1	100.0	97.8	68.9	33.1	14.0	15.8	12.7	9.8	30.2
Indian																				
1970[3)]	33.7	91.9	47.8	11.1	4.6	2.4	1.6	1.8	1.6	22.6	31.9	99.1	82.9	34.6	14.8	7.7	6.4	5.7	6.2	26.1
1980[3)]	41.3	96.8	66.6	30.7	12.8	4.7	3.5	2.6	2.3	25.3	47.1	99.6	90.0	54.4	18.8	7.2	5.7	4.7	4.4	28.1
1990	34.4	97.5	71.1	33.4	18.2	13.2	8.3	4.7	4.0	26.4	44.3	99.7	92.8	58.3	26.8	14.0	8.8	11.5	10.7	28.3
1995	31.3	99.2	74.6	36.3	15.5	11.5	8.7	5.7	4.7	26.5	38.6	99.8	95.0	65.3	28.1	12.6	5.1	6.9	6.9	29.2
2000	26.3	98.0	70.8	22.8	12.9	8.9	9.1	8.8	7.7	24.6	33.8	99.9	93.7	58.3	23.0	12.9	8.3	7.1	5.4	29.0
2005	26.9	99.3	72.5	23.2	8.8	9.4	9.6	8.1	8.9	24.3	33.2	99.9	94.7	63.6	19.3	10.6	7.8	7.6	7.8	28.5
2010	27.8	99.4	82.3	27.7	8.5	6.2	8.2	7.5	8.2	24.9	32.8	99.9	97.7	66.6	20.2	7.8	8.4	7.5	7.2	28.9
2015	29.3	100.0	90.1	52.4	11.4	4.6	5.4	11.6	9.1	26.7	33.6	100.0	99.0	80.7	26.7	8.0	5.7	5.1	5.8	30.1

Source: *Singapore Census of Population*, 1970-1990, 2000, 2010. *General Household Survey*, 1995, 2005, 2015. Data prior to 1990 refer to total population which include foreigners, while data from 1990 onwards refer to Singapore residents which are composed of citizens and permanent residents. Marital status was collected by sampling surveys in both of the censuses and GHS. The size of sample varies by survey year ranging from 20% for 1980-2000 to 3% in 2015. Notes: 1) Averages of age 45-49 and 50-54. 2) Singulate Mean Age at Marriage is calculated by $\Sigma(15+Sx-50*S_{50})/(1-S_{50})$ where Sx refers the rate of the never-married population at age x and the summation is taken over all reproductive ages. 3) Rates refer those of total population including foreigners for year 1970 and 1980.

2-3. A simple decomposition method suitable for Singapore

We would like to decompose the changes of the period TFRs into contributions of nuptiality and marital fertility. Seeking the simplest possible way, we apply a basic method, two-factor case for the rate as the product of factors (Das Gupta 1993: p.6-7). TFRs can be expressed in the equation 1:

(http://www.tablebuilder.singstat.gov.sg/publicfacing/mainMenu.action/ access on 11th November 2018), among marriages registered in Singapore during 1985-1990, residential status of husband and wife was composed of marriages 85.4% between resident husband and resident wife, 9.2% resident husband and non-resident wife, 3.9% non-resident husband and resident wife, and 1.5% non-resident spouses, implying that non-resident rates were 5.4% of husbands and 10.7% of wives. The non-resident rates of both spouses grew substantially: 7.0% (1995-2000) and 15.5% (2010-2015) for husbands; 21.2% (1995-2000) and 30.6% (2010-2015) for wives.

$$\mathrm{TFR} = \sum_{x=15-19}^{45-49} \left(\frac{B_x^{CM}}{F_x^{CM}} \frac{F_x^{CM}}{F_x} + \frac{B_x^{UM}}{F_x^{UM}} \frac{F_x^{UM}}{F_x} \right) \qquad \text{Equation. 1.}$$

where $F_x = F_x^{CM} + F_x^{UM}$, F_x^{CM} denotes age-specific currently married female population of age x, F_x^{UM} refers to those not currently married, and $\{B_x^{CM}, B_x^{UM}\}$ stands for births given by age x mother of corresponding marital status. To simplify the notation, we suppress ethnicity of mothers, however, equation 1 is calculated by ethnicity.

Equation 1 requires unavailable birth data disassembled by marital status of mother. However, under the strong norm of East Asian family tradition, childbearing and marriage are firmly tied especially in Chinese society. The percentage out-of-wedlock birth rates in Singapore during the 1990s-2010s accounted for around 1% (*the Report on the Registration of Births and Deaths Statistics, 2001,* and later). In addition, the out-of-wedlock birth rates do not show evident increasing or decreasing tendency for all ethnicity. We safely assume that the contribution of *change* in unmarried woman's birth $\left(B_x^{UM}/F_x\right)$ is negligible to period fertility changes and that ratios of illegitimate births to currently married women are unchanged over the analysis period. By these two assumptions, equation 1 reduces to equation 2 which decompose s-year change of the period TFRs into two components:

$$\begin{aligned} &\mathrm{TFR}(t) - \mathrm{TFR}(t-s) \\ &= \sum_{x=15-19}^{45-49} \left(\frac{B_x\ (t)}{F_x^{CM}(t)} - \frac{B_x\ (t-s)}{F_x^{CM}(t-s)} \right) \left(\frac{F_x^{CM}(t)}{F_x\ (t)} + \frac{F_x^{CM}(t-s)}{F_x\ (t-s)} \right) /2 \\ &+ \sum_{x=15-19}^{45-49} \left(\frac{B_x\ (t)}{F_x^{CM}(t)} + \frac{B_x\ (t-s)}{F_x^{CM}(t-s)} \right) \left(\frac{F_x^{CM}(t)}{F_x\ (t)} - \frac{F_x^{CM}(t-s)}{F_x\ (t-s)} \right) /2 \end{aligned} \qquad \text{Equation. 2.}$$

The first term corresponds with the contribution of marital fertility rates and the second term quantifies the contribution of currently married rates.

2-4. Decomposition results: Ethnic similarities and differentials in momentous role of nuptiality

There are ethnic similarities and differentials in nuptiality and marital fertility effects on period fertility changes in Singapore. Following the fall in the 1970s (and in the early 1980s for Chinese and Indian), TFRs of all major ethnic groups recovered in the late-1980s. Throughout the 1990s and the 2000s, the TFRs declined consistently. For 1990-2015 overall, late and less marriages account for all the fall of all major ethnic groups in Singapore. Moreover, if no change in nuptiality were occurred, marital fertility rates would make TFRs 20-30% higher. In fact, nuptiality effects lowered TFRs in all decennial (and quinquennial) periods during the 1970-2010 (and 1990-2015) of all major ethnic groups, except for the Indian late-1990s (detailed results omitted due to page restriction). Nuptiality is an essential determinant for lowest-low fertility in Singaporean ethnic societies.

Detail examinations by period reveal ethnic differentials in the nuptial and marital fertility effects on TFRs. In the 1970s, both nuptiality and marital fertility effects reduced TFRs of all major ethnic groups, however, the sizes differed: delaying marriage affected instrumentally for Indian, while limiting numbers of children among married couples lowed TFRs more in Chinese and Malay. In the 1980s, marital fertility effects turned to positive and nuptiality effects continued to be negative for all major ethnic groups, but again sizes differed: Malay TFR recovered above the replacement level as a result of substantial gains from marital fertility; Chinese and Indian marital fertility effects were positive but dominated by depressing marriage effects. In the 1990s, the marital fertility effect continued to be positive for Malay but became negative for Chinese and Indian. In this period, the

marital fertility effect dominated in the TFR declines for Chinese and Indian, Chinese TFR decreased due both to nuptiality and marital fertility, while marital fertility effect completely explained Indian's decline and nuptiality effect totally accounted for Malay's decline. For the 2000s, marital fertility effects became negative again for all three major ethnic groups. More importantly, the negative nuptiality effects were reinforced for all, though relative importance of the two effects differentiated: nuptiality was the main reason for Chinese and Malay; marital reproduction was relatively important for Indian[5]. In the early-2010s, marital fertility recovery was in common with steady nuptiality declines for all major ethnic groups. We must cautiously assess Indian results after the late 1990s, however, it should not ruin the fact that after the 1990s nuptiality was main driving force for TFR declines of all major ethnic groups with enforcing its power in the 2000s.

Table 5. Decompositions for changes in TFRs into contributions of marital fertility and nuptiality for the major ethnic group in Singapore.

Ethnic group	Period	TFR		Change in TFR (End - Begin)	Contributions of changes in		Percent distributions	
		Begin	End		Marital fertility	% Married	Marital fertility	% Married
Chinese	1970-1980	3.136	1.758	-1.378	-0.983	-0.395	-71.3	-28.7
	1980-1990	1.758	1.674	-0.084	0.155	-0.239	185.9	-285.9
	1990-2000	1.674	1.449	-0.225	-0.155	-0.070	-68.8	-31.2
	2000-2010	1.449	1.054	-0.395	-0.061	-0.334	-15.4	-84.6
	2010-2015	1.054	1.144	0.089	0.198	-0.108	221.2	-121.2
	1990-2015	1.674	1.144	-0.530	0.110	-0.641	20.8	-120.8
Malay	1970-1980	3.774	2.199	-1.575	-0.936	-0.639	-59.4	-40.6
	1980-1990	2.199	2.704	0.505	0.603	-0.099	119.6	-19.6
	1990-2000	2.704	2.583	-0.121	0.111	-0.231	91.4	-191.4
	2000-2010	2.583	1.714	-0.869	-0.183	-0.686	-21.1	-78.9
	2010-2015	1.714	1.842	0.128	0.320	-0.192	249.9	-149.9
	1990-2015	2.704	1.842	-0.862	0.256	-1.118	29.7	-129.7
Indian	1970-1980	3.354	2.077	-1.278	-0.475	-0.803	-37.2	-62.8
	1980-1990	2.077	1.929	-0.148	0.047	-0.195	31.8	-131.8
	1990-2000	1.929	1.680	-0.249	-0.398	0.149	-160.0	60.0
	2000-2010	1.680	1.282	-0.398	-0.213	-0.185	-53.5	-46.5
	2010-2015	1.282	1.567	0.285	0.600	-0.315	210.6	-110.6
	1990-2015	1.929	1.567	-0.361	0.078	-0.439	21.5	-121.5

Source: Author's calculation based on age-specific fertility rates summarized in Figure 1 and marital status used for Table 4.

3. Event history analysis for first marriage timing

3-1. Methodology and work data

We analyze the micro-data from the Opinion Survey on Marriage, Family, and Work (2016OSMFW hereafter). Conducted in February-March 2016 via computer assisted face-to-face interview, 2016OSMFW is a national representative sample of 800 men and women aged 20-49 of all marital statuses who lived in Singapore. The survey covered three of the four major official languages in Singapore: English, Chinese and Malay.

[5] Indian age-specific fertility rates used for analysis were upward biased due to foreigner's births but marital status data did not contain such discrepancies, if ignoring consequences of immigration (see footnote 3). Negative marital fertility effects were likely estimated larger than the reality (though the immigration complicates the direction of both effects).

Sampling of 2016OSMFW initially set simply randomly selected 800 addresses over the city state. If the interview in a selected point was not successful, the survey in another location was conducted for an address apart from a pre-specified interval in the list[6]. So, our sampling scheme entitled was a household sampling not a population sampling. Total of 803 usable questionnaire was collected and the response rate was 56.2%. Preliminary analysis for the representativeness of the sample shows in general good properties in terms of the age-sex distribution and the ethnic compositions by age or sex. With excluding 22 cases whose years of first marriage were unknown, work data include 781 Singapore residents (citizens and permanent residents) of all marital statuses.

We first conduct the Cox proportional hazard analysis (Cox 1972) on first marriage occurrences separately by genders[7]. Then, to test possible gender differences in the effects of covariates on first marriage timing, we pool male and female data and estimate models with adding one by one of demographic and socio-economic covariates with interactions to a dichotomous indicator for gender. In this pooled model, we specify baseline hazards stratified by genders, which is equivalent to fitting a separate relative risk model by genders under the constraint that the coefficients are equal while the baseline hazard functions are not. This specification formally tests gender differences in covariate's effects by allowing gender differences in the baseline hazards identified non-parametrically in the relative risk model framework[8].

The Cox proportional hazard model analysis which assumes a time-fixed coefficient, TFC, well established popularity by at least twofold: (1) summarizing covariate's effects in one single measure, the hazard ratio, and (2) flexibility by unspecified shapes of the baseline hazard curve over analysis time. However, the virtue mirrors limitations: (1) the hazard ratio can be seriously biased reporting a misleading result, and (2) inability to predict hazard schedules by covariates. To cope with these, we incorporate time-varying coefficients (TVC) into the models[9],. Specifically, we include covariates and their interactions with linear analysis time. In this TVC models, total effects of a covariate are composed sum of time-fixed parameter (main effect of the covariate that is constant over analysis time and proportionally lifts up/down baseline hazard functions) and time-varying parameter

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[6] Interview in the new candidate location was permitted if the living arrangement was similar to the initially sampled household. Only one respondent per one household was allowed to be interviewed.

[7] The Cox proportional hazard model specifies the hazard function by $h(t|x_i) = h_0(t)exp(x_i\beta)$ where $h_0(t)$ denotes the baseline hazard function of analysis time t, $x_i\beta$ expresses a covariate multiplied by a fixed parameter (i.e. covariate's effect is proportional to the baseline). $exp(\beta)$ is called hazard ratio of a (dichotomous) covariate x, because the hazard associating with the covariate is $exp(\beta)$-times bigger than the baseline hazard. Note that the baseline (reference) group should be deliberately chosen as is defined in the model by all covariates being zero.

[8] Stratified proportional hazard model by genders can be written mathematically in $h(t|x_i) = \left[h_{0,m}(t)exp(x_i\beta)\right]^{S_i} \cdot \left[h_{0,f}(t)exp(x_i\beta)\right]^{1-S_i}$, where S_i takes one for male and zero otherwise, $h_{0,m}(t)$ and $h_{0,f}(t)$ refer baseline hazards for male and female, respectively. Including an interaction term to gender in the model $h(t|x_i) = \left[h_{0,m}(t)exp(x_i\beta + S_i x_i\gamma)\right]^{S_i} \cdot \left[h_{0,f}(t)exp(x_i\beta + S_i x_i\gamma)\right]^{1-S_i}$ implies the following hazard functions: $h_{0,m}(t)exp\big(x_i(\beta+\gamma)\big)$ for male; $h_{0,f}(t)exp(x_i\beta)$for female. Then, gender differences in covariate's effects can be easily tested by $\gamma = 0$.

[9] A time-varying coefficient is a way to deal with non-proportionality. The specification works in bringing a time scale into the model. Note that the Cox proportional hazard with time-fixed coefficient model is identified only by the order of event occurrences (e.g. for the Cox model $h_0(t)exp(x_i\beta)$ in footnote 7, any increasing transformation $f(\cdot)$ of analysis time (as long as independent of covariates) gives the same parameter estimates as in $h(f(t)|x_i) = h_0\big(f(t)\big)exp(x_i\beta)$ where $h_0(\cdot)$ denotes the baseline hazard).

(interaction effect with analysis time that accounts for the change of the main effect as analysis time pasts). In order to improve comparability between estimation results by genders and of male and female pooled data, analysis time was centered at mean years of failure times by genders (28.6 for male; 26.2 for female) before taking interactions[10]. The change of coefficient as analysis time proceeds is hard to conceive by parameter estimates, so we report hazard ratios predicted by parameter estimates for several points in analysis time.

In the estimation, population at risk is the never-married males and females. The analysis time is age (measured in months). In macro analysis, we found the salient differentials in marriage timing by ethnic group under increasing phenomena of international and inter-ethnic marriage. In Singapore, never-married males and females can legally marry from age 16 or from age 18 according to their race[11], This difference in the marriage institution may regulate the length of duration under the marriage risk, with depending on an extent of an infrequent immigration after the age beginning the risk[12]. We incorporate delayed entry in the estimation (i.e. subjects become at risk for first marriage from age 16 or 18 by depending on their races). Additionally, in all estimation model we decided to include demographic covariates: dichotomous indicators of Non-Chinese and birth country whether born outside Singapore, together with birth cohort (minus 1980).

Socio-economic factors include (1) respondent's education attainment, and (2) a dichotomous indicator for managerial, professional and special first occupations after schooling. In 2016OSMFW, education attainment was collected by category (No formal education, GCE 'O' level or below, GCE 'A' level, Diploma, University or above). Because preliminary analysis shows equally consistent predictions for survival probability of higher education categories by linearity restriction and its gains in efficiency, we transform the categorical variable to a continuous schooling years (by assuming six years, ten years, twelve years, thirteen years, and sixteen years in the same order appeared in the previous parentheses) then subtract mean years (13.3) to set the baseline hazard for sensible interpretations.

3-2. Descriptive analysis

In Table 6, we made a simple tabulation for mean ages at first marriage and percentages ever-married males and females by demographic and socio-economic covariates. Stars in the table indicate significance levels of a covariate by testing null hypothesis that difference of the covariate-specific means from overall means by genders

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[10] Our TVC models is expressed mathematically in $h(t|x_i) = \left[h_{0,m}(t)exp\left(x_i\left(\beta + \theta(t-\mu_m)\right) + S_i x_i\left(\gamma + \lambda(t-\mu_m)\right)\right)\right]^{S_i} \cdot \left[h_{0,f}(t)exp\left(x_i\left(\beta + \theta\left(t-\mu_f\right)\right)\right)\right]^{1-S_i}$ where the same notation is employed as those in footnote 8, in addition to that $\{\theta, \lambda\}$ are fixed parameters and $\{\mu_m, \mu_f\}$ refer to mean years of analysis time only when some subjects fail. The statistical significance of a covariate's effects and its gender difference is jointly tested by $\{\beta, \theta\} = 0$ for males and females and $\{\gamma, \lambda\} = 0$, respectively.

[11] The Muslim Marriage Act permits to marry from age 16, while the Women's Charter prohibits a marriage of age under 18.

[12] We do not know when immigrating to Singapore if respondents born outside Singapore. It prohibits controlling the duration under risk onset of being in Singapore. Yet we measure an average risk ratio of immigrants relative to those born-in and grown-up. The difference in age beginning the risk could cause a non-proportionality in hazard functions by ethnicity and birth country. However, non-parametric identification of hazards seems unfeasible with given limited size of cases. Rather, we test a significance of time-varying coefficients to report the "average" risk ratios over time as quantifying and highlighting the effect.

equals to zero. Needless to say, respondents who were never married at the time of the survey did not know the age at first marriage. We were able to make simple tabulations only for ever-married respondents.

In general, we expect higher rates of never-married associating with late marriages or higher ages at first marriage. However, when a significant portion of population was never-married (i.e. right censored), estimates of mean age at first marriage only with ever-married (by a certain upper boundary age) would suffer from severe down-ward biases. It is not recommended that we argue marriage timing among population sub-groups solely based on the mean age at first marriage. Here, we descriptively tabulate our dependent variable to acquire a sense about work data, based on which we proceed to event history analysis to cope with such biases.

Table 6 shows that two third of females had ever married at least once, while only slightly more than half males did so by the time of survey, which resulted in the 13.5 percent-points difference in the never-married rates between genders. Moreover, male's mean age at first marriage was 28.6 years, while it was 26.2 for female resulting in two-and-a-half-year difference which was statistically significant at 1% level. Regarding other covariates overall of both sexes, we see that Chinese married later in terms both the never-married rate and the mean age at first marriage consistently. The late marriages of Chinese males and females are consistent with findings based on the census data. However, we should pay attentions to that Chinese never-married rates is slightly larger than one half, the disparities in mean ages would expand more than those in the table, if they finally married later in their life course. Contrarily, Table 6 also indicates that respondents born in Singapore and those whose first occupation were managerial, professional, and special married earlier on average (in terms of the mean ages of first marriage) associating with higher never-married rates. In these cases, disparities in the mean age would be reduced or the order among birth countries and first occupations would be possibly reversed.

Table 6. Rate of the ever-married and mean age at 1st marriage by demographic and socio-economic characteristics, accompanying with tests for the significance by gender: Singaporean of age 20-49 in 2016.

	Mean age at 1st marriage			%Rate of the ever-married			Total number of cases[(a)]		
	Total	Male	Female	Total	Male	Female	Total	Male	Female
Total	27.1 -	28.6 **	26.2 **	60.2 -	52.1 **	65.6 **	781	313	468
Born in Singapore	26.7 #	28.4	25.8 #	49.1 **	42.6 **	54.0 **	550	235	315
Born outside Singapore	27.5 #	29.1	26.7 #	86.6 **	80.8 **	89.5 **	231	78	153
Chinese	27.6 **	28.9	27.0 **	55.5 **	47.0 *	60.5 **	539	200	339
Malay, Indian & Other	26.1 **	28.3	24.7 **	70.7 **	61.1 *	79.1 **	242	113	129
Respondent's education									
University graduates	28.5 **	29.6 **	27.8 **	62.9	64.7 **	61.8	310	119	191
Other educational attainment	26.0 **	27.8 **	25.2 **	58.4	44.3 **	68.2	471	194	277
Occupation of 1st job									
Manager, Professional & Specialist	28.2 **	29.0	27.5 **	67.9 **	66.7 **	68.9	249	117	132
Other occupation	26.4 **	28.4	25.7 **	56.6 **	43.4 **	64.3	532	196	336

Note: Tabulation by author. Stars indicate statistical significance at ** 1% level, * 5% level, # 10% level under the null hypothesis: difference from gender-specific means (28.6 for males, 26.2 for females, and 27.1 overall for mean age at 1st marriage; 52.1% for males, 65.6% for females, and 60.2% overall for ever-married rates) equals to zero. (a) Exclude 22 cases (7 males and 15 females) of unknown age at 1st marriage.

When looking at the table by gender, we see that Chinese females married late in terms both the mean age at first marriage and the never-married rate, the results consistent with observation for overall males and females. Because of smaller tabulation cases by gender, results for other covariates showed discrepancies: focusing on male's birth place, race and the occupation for instance, the never-married rates were statistically significantly different between population sub-groups while mean ages at first marriage were not statistically significant for the same sub-groups (vice versa for female's education and occupation); the never-married rate of females born in Singapore was higher than those born outside Singapore, while Singapore origin females' mean age at first marriage was lower than their counterpart.

3-3. The Cox proportional hazard analysis by gender

Table 7 shows the hazard ratios (HRs) of demographic and socio-economic covariates in the relative risk models for first marriage timing of Singaporean males and females age 20-49 in 2016. Estimated separately by gender, it shows how large the hazard rates of population subgroups are on average through analysis time with a comparison to the gender-specific reference group(s). Time-fixed coefficient (TFC) specification model M1-0 in Table 7a shows statistically significant demographic effects at least 5% level for females: first marriage hazard at each age of women born outside Singapore were on average 29% larger than the reference group of those who were Chinese born in 1980 Singapore; Malay, Indian, and Other female's first marriage hazard was nearly twice as large as those of Chinese born in 1980 Singapore. The time-varying coefficient (TVC) models M1-1 – M1-2 report that these demographic effects are statistically significant and time-dependent: the hazard rates of women born outside Singapore increase more rapidly over their life courses and their hazard rates become higher than those born in Singapore from the early 20s (threshold age=22.3)[13]; Malay and other's hazard rates become smaller later in their life course and their hazard rates go below Chinese hazard rates from their early 30s (threshold age=31.7). Note carefully that the table shows the HRs relative to reference groups whose hazard rates exhibits reverse-U shape with peak ages in the late 20s, so the hazard rates of Malay and other women increase in the early 20s by a slower pace than the baseline does.

Table 7a (M1-3 – M1-6) also shows that, with demographic covariates held fixed, higher education and managerial, professional, and special first occupation cause female marriage delayed whose effects are time dependent and statistically significant at 1% level. In particular, the longer the schooling years than the average years, the higher the hazard rates after the age 30s while lower education encourages marriages in the 20s and discourages marriages after the 30s (threshold age=29.2), and special first occupations lower marriages in the 20s and accelerate those in the 30s and later (threshold age=31.6). Average schooling years (13.3) of our sample corresponds a little longer than those obtained some diplomas, so females whose marriages are delayed in comparison to the average schooling are university graduates, and with demographic covariates held fixed their

[13] Table 7a (M1-1) indicates that the hazard rate of women born outside Singapore changes as $h_0(age)\, exp(b_1 + b_2\, age)$ where $h_0(age)$ is the baseline hazard (of Chinese women born in 1980 Singapore), $\exp(b_1) = 0.240$ and $\exp(b_2) = 1.066$ constitute hazard ratios of time-fixed and time-varying parts, respectively. The hazard ratio $exp(b_1 + b_2\, age)$ equals to 1 when $age = 22.3$ (threshold age). This means that hazard rate of women born outside Singapore is, with other covariates controlled for, larger than the baseline before age 22 but smaller than the baseline after the age.

Table 7. Hazard ratios of relative risk model estimates for first marriage timing: Singaporean age 20-49 in 2016.

a) Female

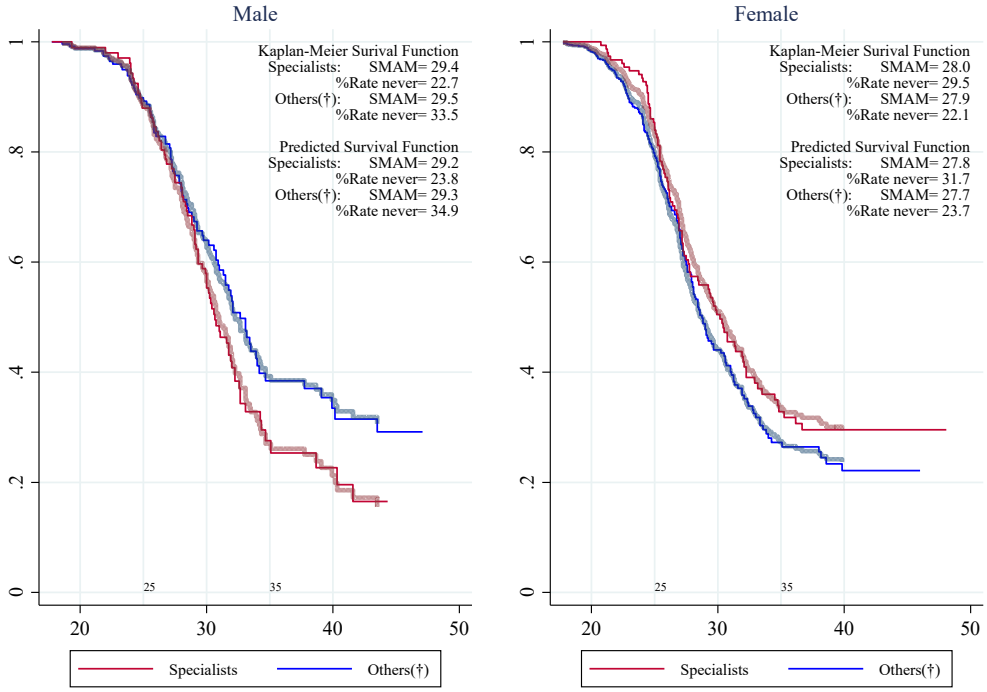
	M1-0	M1-1	M1-2	M1-3	M1-4	M1-5	M1-6	M1-7
Time proportional								
Born outside Singapore(=1)	1.290 *	1.288 *	1.307 *	1.372 **	1.395 **	1.337 *	1.352 *	1.438 **
Ethnic group								
Malay, Indian & Other Chinese[(a)]	1.904 **	1.894 **	1.782 **	1.814 **	1.818 **	1.933 **	1.935 **	1.707 **
Completed years of schooling[(b)]				0.906 **	0.916 **			0.929 **
1st Occupation								
Manager, Professional & Specialist Other occupations[(a)]						0.689 **	0.664 **	0.822
Birth year - 1980	0.971 **	0.971 **	0.973 **	0.981 *	0.983 #	0.972 **	0.973 **	0.982 *
Time-varing[(c)]								
Born outside Singapore (=1)		1.066 *						1.060 #
Malay, Indian & Other (=1)			0.901 **					0.903 **
Completed years of schooling[(b)]					1.030 **			1.027 **
Special 1st Occupation (=1)							1.080 **	1.010
#Subjects	468	468	468	468	468	468	468	468
Person-years at risk	5143.3	5143.3	5143.3	5143.3	5143.3	5143.3	5143.3	5143.3
Log likelihood	-1601.9	-1599.4	-1597.1	-1591.8	-1576.8	-1597.4	-1594.4	-1570.0
Chi-squared stat.	41.3	43.2	53.7	51.1	96.8	40.6	49.2	112.6
AIC	3209.8	3206.8	3202.1	3191.6	3163.5	3202.8	3198.7	3157.9
Joint test on H0: Time proportional coef.=0 and time-varying coef.=0								
Chi-squared stat.		10.9	33.4		51.9		15.0	
P-value		0.004	0.000		0.000		0.001	

b) Male

	M2-0	M2-1	M2-2	M2-3	M2-4	M2-5	M2-6	M2-7
Time proportional								
Born outside Singapore(=1)	1.438 *	1.432 #	1.438 *	1.516 *	1.514 *	1.418 #	1.470 *	1.559 *
Ethnic group								
Malay, Indian & Other Chinese[(a)]	1.338	1.347	1.343	1.327	1.347	1.333	1.325	1.286
Completed years of schooling[(b)]				0.971	0.964			0.941 #
1st Occupation								
Manager, Professional & Specialist Other occupations[(a)]						1.085	1.077	1.327
Birth year - 1980	0.989	0.987	0.989	0.990	0.990	0.989	0.988	0.989
Time-varing[(c)]								
Born outside Singapore (=1)		1.092 *						1.092 *
Malay, Indian & Other (=1)			1.012					0.995
Completed years of schooling[(b)]					1.017 *			1.011
Special 1st Occupation (=1)							1.068 #	1.046
#Subjects	313	313	313	313	313	313	313	313
Person-years at risk	3840.2	3840.2	3840.2	3840.2	3840.2	3840.2	3840.2	3840.2
Log likelihood	-766.6	-764.1	-766.6	-766.1	-762.4	-766.5	-764.9	-759.3
Chi-squared stat.	20.9	27.0	21.4	21.2	29.8	21.9	24.8	38.5
AIC	1539.2	1536.2	1541.1	1540.2	1534.7	1541.0	1539.8	1536.5
Joint test on H0: Time proportional coef.=0 and time-varying coef.=0								
Chi-squared stat.		8.8	2.6		7.4		3.7	
P-value		0.012	0.274		0.025		0.158	

Source: Calculation by author. Note: Statistically significant at ** 1% level, * 5% level, # 10% level, based on standard error clustered by subjects. (a) Reference category. (b) Difference from sample mean (=13.3) of all subjects. (c) Interactions with analysis time, which was centered at means of failure times by gender (28.6 for male; 26.2 for female) before taking interactions.

Figure 2. Model predictions and Kaplan-Meier estimates for never-married probabilities of Singaporean males and females age 20-49 in 2016



Source: Author's calculation. Notes: Thick lines indicate for model predicted survival functions by M1-7&M2-7 in Table 7. Thin lines correspond to the Kaplan-Meier estimates based on a TVC model where covariates and their interactions of M1-7&M2-7 other than first occupations are controlled (i.e. baseline hazard functions of models by gender that are stratified by first occupations in addition to the specification as of M1-7&M2-7).

HRs changes similarly to those special first occupations: HRs of sixteen-years education at exact ages 20, 30, and 40 are 0.48, 1.07, and 2.34, while they are 0.41, 0.89, and 1.91 for first special occupations. Because schooling years fit data better than the first occupations, the latter covariate loses statistical significance when putting them together (Table 7a M1-7). Despite being ready for instantaneous interpretation, because the effects of higher education and the special occupations are time dependent, the average HRs quantified by the TFC specifications should be viewed with a skepticism.

Generally speaking, the models for male Singaporeans show qualitatively similar effects of covariates as in female's results (Table 7b). However, because of relatively limited size of usable cases, male's models do not detect the statistical significance of covariate's effects except the birth country and the schooling years, both of which are time dependent. Male immigrants and highly educated males marry later in their life courses: the hazard rates of male born outside Singapore exceed those of Chinese born in Singapore 1980 after the mid-20s (threshold age=24.5 in M2-1); the hazard rates of male university graduates are smaller than the baseline in the 20s but become higher in the 30s and later (threshold age=30.8 in M2-4). Two remarks might attract an interest. One is that preliminary analysis found a statistically significant accelerating effect of Malay and other ethnic male, however, the ethnic effect became insignificant once the birth country effect was controlled for. Second, although it is

statistically insignificant by conventional levels, male's special first occupation associates with higher hazard rates over their life course (in the TFC specification) while the special occupation effect delays female's first marriage. These estimation results imply relatively stronger accelerating effect of special first occupation for males than one for females. Further examinations uncovered that male's survival probabilities predicted by the first occupations were little different in his 20s and predicted never-married probabilities for male specialist in his mid-30s were lower than those of other occupations (i.e. more male specialists had married by the 30s than male non-specialists), while predicted never-married probabilities for female specialist were higher (i.e. first special occupations depressed female marriage) especially after her mid-20s (Figure 2).

3-4. Gender differences and similarities in the demographic and socio-economic effects

Table 8 presents the HRs estimated by male and female pooled models that are consistent with models in Table 7. The table conducts statistical tests for the significance of gender differences in the effects of covariates. We found four statistically significant gender differences by conventional levels: TVC effects of ethnicity, TFC effects of higher education and special first occupations, and TVC effects of the special first occupations. When time-dependent characteristics of the education is modeled, the set of coefficient estimates looks qualitatively like first occupations. However, when putting all covariates together in M3-7, the gender differences in TVC ethnicity and special first occupation effects hold marginal significance (p-values are 0.065 and 0.099, respectively; not shown in the table) but the significance of TVC education effects does not remain(p value=0.217).

By showing predicted HRs by ethnicity, schooling years, and special first occupation at exact ages 20-40, Table 9 elaborates these effects. The table shows the HRs predicted by M3-7 (in table 8) that are the ratios relative to baseline age schedules of first marriage hazard. Since the baselines are stratified by genders, the reference groups correspond with male or female Chinese born in Singapore 1980 with average years of schooling and whose first occupation was other than manager, professional, and specialist. Note that the baseline hazard profiles are gender-specific and differ in their levels and shapes by genders, even when the HRs of both genders coincide.

The hazard rates of Malay, Indian and other ethnic males are higher over their life courses than the baseline, while the hazard rates of Non-Chinese females are larger in the 20s but lower after the early 30s than those of female Chinese born in Singapore 1980. Although the effects of schooling years are little steeper among females, the university education of both males and females suppresses marriages by the age 20s and stimulates those of the 30s and later, in comparisons with the gender-specific baseline hazards. Finally, the hazard rates of female specialists are lower over their life courses than the baseline hazard rates, while male specialist's hazard rates after the mid-20s exceed those of other first occupations.

These results conclude that in the class of TVC models the ethnicity and special first occupation effects, that quantify how the Chinese and specialists delay their marriage, are significantly gender different. Specifically, we found a gender difference in the way how the ethnicity effect was time dependent, in addition to the gender different first-occupation effect not only in TVC but also in TFC. At the same time, extensions in schooling years beyond the average years decelerate marriage timings similarly for males and females (indistinguishably time-dependent between genders).

Table 8. Hazard ratio estimates of the relative model stratified baseline by gender for first marriage timing: Singapore men and women of age 20-49 in 2016.

	M3-0	M3-1	M3-2	M3-3	M3-4	M3-5	M3-6	M3-7
Main								
Time proportional								
Born outside Singapore(=1)	1.293 *	1.315 *	1.339 **	1.390 **	1.407 **	1.335 **	1.359 **	1.440 **
Ethnic group								
Malay, Indian & Other	1.886 **	1.674 **	1.759 **	1.620 **	1.632 **	1.683 **	1.685 **	1.699 **
Chinese[(a)]								
Completed years of schooling[(b)]				0.903 **	0.913 **			0.928 **
1st Occupation								
Manager, Professional & Specialist						0.693 **	0.668 **	0.823
Other occupations[(a)]								
Birth year - 1980	0.977 **	0.976 **	0.978 **	0.985 *	0.986 *	0.978 **	0.978 **	0.985 *
Time-varing[(c)]								
Born outside Singapore (=1)		1.066 *						1.059 #
Malay, Indian & Other (=1)			0.899 **					0.903 **
Completed years of schooling[(b)]					1.030 **			1.027 **
Special 1st Occupation (=1)							1.080 **	1.011
Interaction with Male(=1)								
Time proportional								
Born outside Singapore (=1)	1.086	0.980						1.072
Malay, Indian & Other (=1)	0.708		0.777					0.757
Completed years of schooling[(b)]				1.078 *	1.057 #			1.016
Special 1st Occupation (=1)						1.534 *	1.586 *	1.606 *
Time-varing[(c)]								
Born outside Singapore (=1)		1.028						1.032
Malay, Indian & Other (=1)			1.125 *					1.100 #
Completed years of schooling[(b)]					0.988			0.984 #
Special 1st Occupation (=1)							0.990	1.036
#Subjects	781	781	781	781	781	781	781	781
Person-years at risk	8983.5	8983.5	8983.5	8983.5	8983.5	8983.5	8983.5	8983.5
Log likelihood	-2369.2	-2365.2	-2364.2	-2359.1	-2340.2	-2366.0	-2361.3	-2329.3
Chi-squared stat.	62.0	70.7	73.2	72.0	125.3	61.5	71.6	151.0
AIC	4748.4	4742.5	4740.5	4728.3	4694.4	4742.0	4736.7	4692.7
Joint test on H0: All gender-interaction coefficient=0								
Chi-squared stat.	2.4	0.4	6.6	4.2	4.5	4.8	5.3	15.8
P-value	0.299	0.836	0.037	0.040	0.106	0.028	0.072	0.045

Source: Calculation by author. Note: Statistically significant at ** 1% level, * 5% level, # 10% level, based on standard error clustered by subjects. (a) Reference category. (b) Difference from sample mean (=13.3) of all subjects. (c) Interactions with analysis time, which was centered at means of failure times by gender (28.6 for male; 26.2 for female) before taking interactions.

Table 9. Model predicted hazard ratios of ethnicity, schooling years and first special occupation by age and sex for first marriage timing: Singapore men and women of age 20-49 in 2016.

Age	Malay, Indian, and Other	Years of schooling			1st Special Occupation
		6 years (Primary)	10 years (Secondary)	16 years (University)	
			Male		
20	1.36	3.03	1.65	0.66	0.89
25	1.31	2.05	1.38	0.77	1.12
30	1.28	1.38	1.16	0.89	1.41
35	1.24	0.94	0.97	1.03	1.77
40	1.20	0.63	0.81	1.19	2.22
			Female		
20	3.20	5.85	2.22	0.52	0.77
25	1.92	2.20	1.43	0.75	0.81
30	1.16	0.82	0.92	1.07	0.86
35	0.69	0.31	0.59	1.55	0.90
40	0.42	0.12	0.38	2.22	0.95

Source: Calculation by author. Note: Hazard ratios are relative to reference groups: Chinese, average years of schooling (=13.3), and first occupations other than those managerial, professional, and special. HRs are predicted by estimates of M3-7 (in Table 8).

4. Future prospects and concluding remarks

By the event history analysis with using 2016OSMFW, we found a statistically significant gender difference in the ethnicity effects on Singaporean's first marriage timing (Section 3-4). As we noted in the Section 3-3, on the one hand, male Non-Chinese residents marry earlier than Chinese, however, this accelerating Non-Chinese effect lose statistical significance once controlling the immigration effects but not by schooling years nor special first occupations. On the other hand, there remains the promoting Non-Chinese effect for female Singaporeans after adjusting their birth country effects, while the birth countries outside of Singapore rise not only male hazard rates but also female first marriage rates similarly. We found these results after average marriage timings by gender (in baseline hazard functions of age as its argument) are adjusted with other covariates held fixed. In this sense, the ethnicity effects are gender specifics and the statistically significant gender difference in the ethnicity effect is genuine that is caused by noting other than ethnicity among covariates in the models. The genuine ethnicity effect may suggest a possible explanation by increasing phenomenon of inter-ethnic marriage. According to *Statistics on Marriages and Divorces*, Chinese males have more committed to inter-ethnic marriages than females did especially after the late-2000s: the proportions of Chinese husband who marry with Non-Chinese wife for 1965-1970, 1990-2000, and 2010-2015 are 0.7%, 3.8%, and 12.0%; the same proportions for female are 2.6%, 3.3%, and 6.8%, respectively. The surge of Chinese husband's inter-ethnic marriages must bring Non-Chinese wife's marriage and raises female's marriage rate. In the same period, international marriage increased substantially between a non-resident wife and a resident husband, which uplifted female's marriage rates. However, our estimation sample is consisted only of Singapore residents in addition to that the birth country effects were adjusted in the models, so possible explanations must resort to examining other factors than relying on international marriage that likely associates with immigration. In addition to the small size of usable cases, it limits

further investigations that spouse's ethnicity was not collected in 2016OSMFW. We call a rigorous sensitivity analysis by using another large-scale survey on these issues. Nonetheless, inter-ethnic and inter-national marriage may have become playing a significant role to determine future directions of Singapore marriage, fertility, and population structure.

In Singapore, extensions of schooling prevail among females more rapidly than among males, and female's proportions of higher education exceeded male's proportions in the youngest cohorts (Section 1-3). In the event history analysis, we found a gender equality in the education effects decelerating first marriage among male and female Singaporean (Section 3-4). By a composition effect, more female population attains higher education, female (crude) marriage rates suffer more than male ' s rates. It would be a rational reaction of Singaporeans to lowering female resident's naptiality that foreign wives increased more rapidly than foreign husbands. In addition, the increasing international marriage may reflect prevalent traditional gender role of females. We found an insignificant gender difference in education effect such that higher education gave opportunity for a high-income job and decelerated marriages both males and females. At the same time, we found significant gender difference in special first occupation effect by which male specialist's marriage was accelerated later in their life course. Male Singaporean may search an opportunity outside Singapore for comparative advantage in household production that induces female specializing in non-market goods production but male specializing in labor supply. This specialization is more likely beneficial for couples with large wage differentials such as unskilled foreign wife and skilled husband. In the traditional world, only highly educated female may feel to owe opportunity costs if not sharing dividends of the household productions. Presumably, having a child, which is permitted within a formal marriage by Singaporean society, accounts a significant portion of net revenue in household production. Meanwhile the immigration policy effectively functions as a population stabilizing policy by stimulating international marriage, it was not admitted remaining long, given limited land space and difficulties harmonizing immigrants. When promoting early marriages, policy responses need to examine how efficiently and effectively eliminate opportunity costs of childrearing that are perceived by female citizens and permanent residents who pursue both productive economic activities and the traditional gender role.

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