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ORIGINAL RESEARCH

Targeting and Mistargeting of Family Policies in High-Income Pacific Asian Societies: A Review of Financial Incentives

Mengni Chen[1] · Stuart Gietel-Basten[2] · Paul S. F. Yip[3]

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Abstract

Very low fertility rates can be found in many high-income Pacific Asian societies, such as Hong Kong, South Korea, Japan, Singapore, and Taiwan. Governments in these territories have already taken pronatalist policies but with only modest effects, especially when measured by overall total fertility rate. Mistargeting has been cited as a potential explanation for this impact. To explore this notion in greater depth, we first identify the potential target groups that are most influential in changing the TFR for the five societies, based on a stochastic model and fertility elasticity analyses. Then we examine the targeting of current pronatalist policies, especially financial incentives and marriage policies. The analyses show that marriage rates, especially among women aged 25–29 are the most influential factor in shaping contemporary TFRs. Third and higher order births are insignificant in changing the fertility trajectories for all the five places. Besides, there are also territory-specific patterns. For Hong Kong, Taiwan and Singapore, first births (especially among women aged 30–34) are the second most influential factor; for South Korea, second births (especially among women aged 30–34) actually play a very important role, next only to marriage; for Japan, first- and second births are much less influential while marriage is an overwhelmingly essential factor of fertility. Furthermore, the review of financial incentives in these places reveals the mismatch between the targeting suggested by our analysis and the targeting implied by current policy measures. The mistargeting, piecemeal measures and the low level of financial support may be partly responsible for the ineffectiveness of the governmental action.

Keywords Pronatalist measures · Elasticity · Total fertility rate · Hong Kong · South Korea · Japan · Singapore · Taiwan

✉ Paul S. F. Yip
sfpyip@hku.hk

Extended author information available on the last page of the article

Introduction

Many high-income Asian societies are characterized by very low fertility. This has raised concerns about both the pace of population aging and, in some cases, of population decline. The narrative of low fertility and population aging has become very serious, with the issue being presented as a 'national security crisis' which will tick a 'demographic time bomb'(Pearce 2010; Vettori 2010; Khoo 2016). In response to this, governments have implemented a suite of policies which have sought to support parents (and prospective parents) in their reproductive decision-making. Some of these policies can be broadly characterized as being akin to 'family policies' designed to support working parents; while other policies are more explicitly pronatalist in nature (Chen et al. 2018b). Some of these pronatalist policies have included additional cash bonuses for parents of newborns, preference for home ownership application, parental leave, and so on (Yip and Chen 2016; Chen et al. 2018b).

There is, however, some concern about both the implementation and the success of these policies. Firstly, from a feminist standpoint, it has been argued that these policies have set out to utilize female wombs as the means to reach an (arbitrary) national target relating to fertility (Lee 2009; Lin and Yang 2009). In a similar vein, these policies have been criticized for stigmatizing childless couples, for fostering an intergenerational distrust, and for contributing to the idea of a 'social recession' among younger people eschewing their responsibilities (Turnbull et al. 2016). Secondly, the amount of money expended on some of these policies has raised concerns about their sustainability, especially in the context of high budget deficits (Guest 2007; Bradshaw 2012; Bradshaw and Tokoro 2014). For example, the South Korean Government has provided universal free childcare services to parents, and spent more than 61 trillion won (USD$54.3 billion) during 2011–2015, and is going to spend a further 108.4 trillion (USD$92.7 billion) over 2016–2020 (Yip 2017). Thirdly, there is concern about the (in) effectiveness of the policies in which so much money has been invested (Gauthier 2007; Atoh 2011; Jones and Hamid 2015). In South Korea, for example, the large-scale spending on childcare services has been well received in the population but the impact on raising fertility and working participating rate is very small. The impact upon TFR has largely been only modest. Over 2005–2010 when the family policies have been enhanced in Singapore and South Korea, the TFR declined from 1.26 to 1.15 in the former while increased from 1.08 to 1.23 in the latter (KOSIS 2015; Singstat 2017). Indeed, the fact that there has been relatively little overall change in TFR has been cited as a key indicator of the relative failure of these pronatalist policies in respect of one of their main motivators (Chen et al. 2018b).

While some studies have discussed the ways by which the policies may have been 'mistargeted' in terms of the substantive interventions (Lee 2009; Song et al. 2013; Gauthier 2016), much less attention has been given to the extent to which these policies could have succeeded in a much more narrower goal of increasing fertility among different subgroups. This is because policies and

reproductive decision-making decisions are often differentiated between parities. A recent study focusing on parity-specific pronatalist policies in Singapore (Chen et al. 2018b) suggested that policies which served to increase the marriage rate and first birth rate would likely be more important than the others. In other words, the *relative* impact of the policies as measured by TFR change is, in fact, highly skewed and dependent on the specificity of both parity and marriage status.

All the governments in high-income Asian societies (Japan, South Korea, Singapore, Hong Kong, Taiwan) have already taken some (explicit or implicit) pronatalist action, but the policy impact seems to be modest, with the TFRs still remaining at very low levels. Although it has been recognized that more efforts should be taken to increase fertility rates, "exactly what should be done remains elusive" (Straughan et al. 2008, p. 17). Apparently, "greater certainty about the issue of low fertility, however, is not matched by certainty about the appropriate range of policies to address low fertility" (McDonald 2002, p. 417).

In this study, we explore policies designed to support childbearing in Hong Kong, South Korea, Japan, Singapore, and Taiwan. The main focus here is on the financial benefits, while other policies (such as reconciliation of work and family life) that are equally important within the broader policy package are not covered in this paper. If policies are, indeed, designed, with a pronatalist intent, then, this study serves to demonstrate upon which subpopulations the investment of financial and political capital can most effectively be made to impact overall fertility in a parity-specific sense. By doing so, we can better understand why extant policies may have had relatively small impacts. Specifically, we first estimate marriage and fertility rates for subgroups of women—classified by their age, marital status, and the parity level (i.e., the number of children ever born) to demonstrate the current marriage and childbearing patterns. We then try to assess the roles of different subgroups of women in determining the TFR, based on a stochastic modeling and "fertility elasticity analysis". The elasticity analysis enables us to quantitatively identify the group(s) of women who are most influential in changing the fertility rate and can be targeted by policies for more significant impact. We perform the analysis for Hong Kong, South Korea, and Japan, and draw a comparison of our results together with Singapore and Taiwan which have already been investigated in the same method (Yip and Chen 2016; Chen et al. 2018b). By integrating the results from these fives societies, we demonstrate a more comprehensive picture, illustrate the cross-national similarities and differences in fertility dynamics in the high-income Asian societies, and provide empirical evidence for formulating more effective pronatalist policies in the future.

Currently, the five societies have similar demographic and socioeconomic profiles. As shown in Table 1, all of them have high income, and low fertility which is accompanied by delayed marriage and parenthood in the region. Interestingly, TFRs of first births in Hong Kong, Korea and Japan were at similar levels, a little higher than the rates in Singapore and Taiwan. The TFRs of second births are highest in Japan, while these rates in the other four places are lower and at almost the same level. The TFRs of third and higher order birth are relatively higher in Japan and Singapore. Besides, compared to Hong Kong, Japan, Singapore, and Taiwan, marriage in South Korea, though delayed, still seems to be more universal.

Table 1 Key demographic and socioeconomic characteristics in 2015. *Source* GDP per capital comes from World Bank Open Data; the other indicators are from Hong Kong Census and Statistics Department, Korean Statistical Information Service, Statistics Bureau of Japan, Singapore Department of Statistics, Statistical Bureau of Taiwan

	Hong Kong	South Korea	Japan	Singapore	Taiwan
GDP per capita (Constant 2010 US$)	36,173	25,023	47,150	53,785	23,318
TFR	1.20	1.24	1.45	1.24	1.18
TFR of 1st birth	0.65	0.65	0.69	0.59	0.61
TFR of 2st birth	0.44	0.47	0.52	0.44	0.45
TFR of 3rd and higher	0.11	0.12	0.24	0.22	0.13
Average age at first marriage	29.30	30.11	29.40	28.2	30.0
Average age at first birth	31.40	31.20	30.7	30.7	30.6
% of Never-married at age 45–49[a]	14.04	3.34	12.36	12.8	9.9

[a]The figures are for 2011 in Hong Kong, 2010 for South Korea, Japan, Singapore and Taiwan

But this should be interpreted carefully, as the percentage of never-married women in the 45–49 age group actually reflects the marriage situation of the 1961–1965 birth cohort. This statistics may not be able to predict the marriage trajectory of the younger generations, as their transition to marriage has declined significantly in South Korea, especially among women with no employment, which might be triggered by the 1997 Asian financial crisis (Ma et al. 2014). Moreover, in comparison to western countries, the proportion of births outside marriage is very low as non-marital childbearing is still not widely accepted. After all, it should be noted that the period TFRs (in Table 1) are often affected by the tempo effect due to changing timing of childbearing, and may fall well below the cohort TFRs. Therefore, the observed differences in the period TFRs across the five territories might be caused by some short-term fluctuations.

Data and Method

Data

To identify the potential target groups, we apply the method of stochastic modeling and fertility elasticity analysis to Hong Kong, Korea, and Japan, which have been used elsewhere to evaluate the targeting of pronatalist policies in Australia, Singapore, and Taiwan (Yip and Chen 2016; Chen et al. 2018a, b).

The data required for fertility elasticity analysis are the age-parity specific fertility rates of married women (APSFRs) and the age-specific marriage rates of unmarried women (ASMRs). The APSFRs are calculated by dividing the number of the $(j+1)$th births born to married women at age n and parity j by the number of married women at age n and parity j. As the denominator is the population of married women at real risk of having $(j+1)$th birth, the APSFR can be seen as an incidence rate. Since out-of-wedlock births are uncommon in these Asian societies (about 8%

in Hong Kong while about 2% in South Korea and Japan) (Gietel-Basten and Verropoulou 2018; Raymo et al. 2015), the APSFR can be a good proxy for the age-specific probability of parity transitions at the population level. Though the data on age-specific fertility rates (ASFRs) are publicly available, APSFRs are not, thus calling for self-estimation. Besides, the ASMRs are calculated by dividing the number of marriages (including first marriage and remarriages) in each age group by the number of unmarried women (including the never-married, divorced and widowed) in the same age group. This can also be seen as an incidence rate, reflecting the age-specific probability of getting married at the population level.

To compute the APSFRs, the data of married women and births broken down by age and parity are required. And to compute the ASMRs, the data of unmarried women and marriages broken down by age are required.

For Hong Kong, the data of women broken down by age, marital status, and parity levels (excluding foreign domestic helpers) were from the 2011 population census, provided by Census and Statistics Department of Hong Kong SAR Government (C&SD). The number of births broken down by women's age and parity in 2011 was tabulated based on the birth registration data, which again was provided by the C&SD. These birth data have excluded the babies born to non-local women from Mainland China, because most of these Chinese women would bring their children back to the Mainland after childbirth, which has caused some distortions in Hong Kong's fertility rate (Leung 2011; Gietel-Basten and Verropoulou 2013). The number of marriages (involving Hong Kong female residents) broken down by women's age was obtained from C&SD.

For South Korea, the data of women broken down by age, marital status and parity levels were tabulated based on the 2010 Population and Housing Census, available from the Statistics Korea (KOSTAT). The number of births by women's age and parity, and the number of marriages by women's age in 2010 were from the Korean Statistical Information Service (KOSIS).

For Japan, the data of women broken down by age and marital status were from the 2010th Population Census, provided by the Statistics Bureau, Ministry of Internal Affairs and Communications of Japan. However, as the 2010th census did not collect the parity information, the data of married women by age and parity were estimated based on the 14th Japanese National Fertility Survey in 2010 (IPSS 2010). The birth data broken down by women's age and parity, as well as the marriage data broken by the women's age in 2010, were from the Ministry of Health, Labor and Welfare. Some other detailed information on the socioeconomic status for these age-marital-parity specific groups are not available for further analysis.

The Stochastic Model and Fertility Elasticity

A stochastic model is constructed to simulate the dynamics of women's family formation and parity transitions over their reproductive years under several assumptions. For ease of illustration, it is assumed that (1) each woman can have a maximum of three children over her reproductive lifespan, as in contemporary high-income Pacific Asian societies births of the fourth and higher-orders are rare

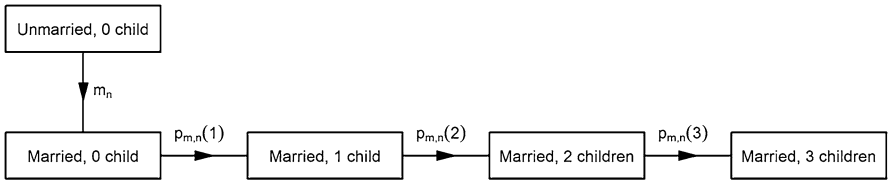

Fig. 1 Family formation and parity transitions of women

nowadays (for example, accounting for just 0.4% of the total births in Hong Kong in 2011, 1.3% in South Korea and 3.3% in Japan in 2010) (Statistics of Japan 2010; HKCSD 2012; KOSIS 2017); (2) one woman can give birth to one child at most each year; (3) marriage and childbirth cannot happen in the same year (that is, the time of marriage registration and the time of birth registration cannot be in the same year); (4) all births are born to married women, as out-of-wedlock births are very uncommon in these Asian societies.

Based on these assumptions, family formation and parity transitions of women can be visualized in Fig. 1. As shown, during a certain year, an unmarried woman either remains unmarried, or gets married; a married woman with no child either remains childless, or has the first child; similarly, women at parity 1 or 2 can either remain unchanged, or have another child. Hence, there are four probabilities governing all the transitions at age n: m_n denotes the probability of an unmarried woman getting married; $p_{m,n}(1)$, $p_{m,n}(2)$, and $p_{m,n}(3)$ denote the probabilities of married women with zero, one or two children making transitions to first, second or third births, respectively. Due to lack of data for 1-year age groups, we categorize women's age into 75-year age groups (covering the ages of 15–49) and assume that women in the same age group have the same probabilities of marriage or parity transitions. Hence, there are in total $4 \times 7 = 28$ parameters, and we use APSFRs and ASMRs as their realistic values. Let θ_i $(i = 1 \ldots 28)$ denote these 28 parameters, and mathematically, TFR can be regarded as a function of them, that is, $\mathrm{TFR} = \mathrm{f}(\theta_1 \ldots \theta_{28})$. For details of this function, see Appendix 1.

After establishing a mathematical function for TFR, we introduce the concept of fertility elasticity. Elasticity is originally an economic concept. In economics, price elasticity, for instance, measures the impact on the demand of a product when its price changes. It is often interpreted as the percentage change of demand per 1% change in the price (Gans et al. 2011). Analogously, we define the fertility elasticity as the percentage change of the TFR per 1% change in any of the 28 parameters (i.e., the ASMR and APSFR for seven age groups). The following formula is used to calculate the fertility elasticity with respect to θ_i:

$$\eta_{\theta_i} = \frac{\Delta(TFR)/TFR}{\Delta\theta_i/\theta_i} = \frac{\Delta(TFR)}{\Delta\theta_i} * \frac{\theta_i}{TFR} = \frac{\partial(TFR)}{\partial\theta_i} * \frac{\theta_i}{TFR}$$

The result can be interpreted as that given 1% change in θ_i, the TFR will change by $\eta_{\theta_i}\%$. The advantage of fertility elasticity is that it enables us to quantify the percentage impact on the TFR given a percentage change in the marriage or fertility

rate of any subgroup. More importantly, fertility elasticity can be compared across groups, times, and countries. The higher the elasticity, the more sensitive the TFR is to changes in the parameter, and the more influential the subgroup is in determining the country's fertility trend. Thus, by comparing the elasticities, we can identify the group(s) of women who are most influential in changing the TFR. If policies can aim at the influential groups with appropriate measures, a substantial increase in the fertility rate can be expected. It should be emphasized that considering percentage changes in the parameters would be more meaningful than considering a fixed amount of change. For example, in Hong Kong, the APSFR of parity 1 is about 0.214 in the 25–29 age group while 0.0004 in the 45–49 age group. So a fixed amount change of 0.01 in the former has a completely different meaning from that in the latter, as increasing the APSFR of parity 1 among women aged 45–49 by 0.01 is almost impossible.

Stochastic modeling and elasticity analyses were mainly performed using the Matlab software program. We first calculated the partial derivative of TFR with respect to each parameter (i.e., $\partial(TFR)/\partial\theta_i$). Then based on these partial derivatives, we estimated fertility elasticities with respect to the 28 parameters.

Results

Age-Specific Marriage Rates and Age-Parity Specific Fertility Rates

The ASMRs and APSFRs of Hong Kong, South Korea, and Japan for the year 2010/2011 are given in Table 2, with comparison to the rates for Taiwan and Singapore (Yip and Chen 2016; Chen et al. 2018b). Values of ASMRs and APSFRs are colored in their own scales respectively (highest = red and lowest = blue). The pattern of ASMRs is characterized by highest marriage rate in the age range of 25–34 in all the five societies. In South Korea and Singapore, the ASMRs of women in the 25–29 and 30–34 age groups are much higher than the counterparts in other three societies. Besides, the patterns of ASMRs for Hong Kong and Taiwan are very similar, with almost the same marriage rates of women aged 25 and above. Among the five societies, marriage seems more prevalent in South Korea as its ASMRs are much higher—not only in the 25–34 age groups but also in the 35–49 groups. However, the higher marriage rates of older groups may not be indicative to the behavior of the younger generations, as some scholars have implied that marriage rates for younger cohorts have reduced greatly after the Asian financial crisis in 1997 (Kim et al. 2015).

Regarding the APSFRs for parity 1, the common feature is that married women aged 15–24 have the highest APSFRs than other age groups in all the five Asian societies. This is probably related to the unintended premarital pregnancy which is often closely followed by marriage among the adolescents, as out-of-wedlock birth are still rarely practiced in these places (Raymo et al. 2015). Also, the number of married women aged 15–24 is actually very small, which makes the APSFRs very unstable. Besides, it shows that the South Korea's APSFRs for parity 1 are highest

Table 2 Age-specific marriage rates and age-parity specific fertility rates in 2010/2011. (Color table online)

Rate (per 1000)	15–19	20–24	25–29	30–34	35–39	40–44	45–49
ASMR							
Hong Kong	10	10	78	93	46	22	12
South Korea	13	13	120	139	71	42	31
Japan	18	18	96	80	46	21	10
Singapore	4	38	140	109	39	13	7
Taiwan	3	24	79	95	45	20	13
APSFR for parity 1							
Hong Kong	542	542	214	196	98	10	0
South Korea	815	815	664	644	283	54	4
Japan	972	972	459	297	189	45	1
Singapore	951	526	220	193	98	17	1
Taiwan	544	631	278	203	88	19	1
APSFR for parity 2							
Hong Kong	168	168	143	126	77	13	1
South Korea	145	145	154	176	69	8	0
Japan	226	226	218	208	122	22	1
Singapore	265	186	135	141	82	13	1
Taiwan	210	182	137	127	70	11	1
APSFR for parity 3+							
Hong Kong	83	83	67	44	31	13	2
South Korea	54	54	55	41	17	3	0
Japan	83	83	96	77	36	6	0
Singapore	136	154	92	64	39	7	0
Taiwan	140	84	47	29	15	3	0

Due to data limitation, the ASMRs and APSFRs for Hong Kong, South Korea, and Singapore can only be calculated for the 15–24 age group; the results for Hong Kong are based on the population census in 2011

(except for the 15–24 age groups), and next to it is Japan. Meanwhile, Hong Kong and Singapore have very similar patterns of APSFRs for parity 1.

The APSFRs for parity 2 of all age groups are lower than the APSFRs for parity 1. In Hong Kong, Japan, Singapore, and Taiwan, the rates for parity 2 decline with age, while in South Korea the rates show the peak level in the 30–34 age group. It is noteworthy that among these five societies, Japan has the highest APSFR for parity 2 in almost all age groups. This indicates that married women in Japan are more likely to have two children than in the other four societies, and the social norms for the two-child family are stronger in Japan.

In terms of the parity transition rates, in all the five societies the APSFRs of parity 3+ are the lowest and it is much lower than the rates for parity 1 and 2. This result is consistent with the pattern of parity transitions found by Yamaguchi and Youm (2012) which have estimated parity-duration-specific fertility rates based on panel surveys from Japan and South Korea. Moreover, Table 2 shows that Japan and Singapore have relatively higher APSFRs of parity 3+ than Hong Kong, South

Korea, and Taiwan. The case of Singapore might be related with its pronatalist policies which prioritize third and higher births (Chen et al. 2018b). The APSFRs of parity 3+ of Japan and South Korea are also very consistent with the transition rates of third marital childbirth calculated by Yamaguchi and Youm (2012).

Fertility Elasticity

Based on the ASMRs and APSFRs, we estimate the fertility elasticities. To reveal the patterns of fertility elasticities more clearly, we visualize the results in spider graphs in Fig. 2. The spider graphs have six (or seven for Taiwan and Singapore) axes representing different age groups with the lines representing the elasticities for different subgroups. The graphs look like a clock face with the longest arm pointing to the subgroup with the largest elasticity, which makes it easy for comparison. Table 3 shows the exact values of fertility elasticities for these five high-income Asian societies. The results for Taiwan and Singapore are extracted from the work by Chen et al. (Yip and Chen 2016; Chen et al. 2018b). As explained previously, the fertility elasticity can be interpreted as the percentage change of the TFR given 1% change in the ASMRs or APSFRs of a certain subgroup of women. For example, in Hong Kong, the fertility elasticity with respect to the ASMR of women aged 25–29 is 0.332, meaning that given 1% increase (or decrease) in the marriage rate of this group, the TFR will increase (or decrease) by 0.332%.

The spider graphs reveal some commonalities across the territories. First, in all the five Asian societies, the elasticities with respect to the ASMR in the 25–29 age group are largest and much higher than elasticities of other subgroups. Given 1% increase in the ASMR in the 25–29 age group, the TFR will increase by about 0.3% in Hong Kong, Japan, Singapore, and Taiwan, compared to about 0.24% in South Korea. This means that the increase (or decrease) of marriage rate in the 25–29 age group would lead to a relatively more significant increase (or decrease) in the TFRs. Second, compared to ASMR and APSFR of parity 1 and 2, the elasticities with respect to the APSFR of parity 3+ are lowest. This implies that the increase of third births (and hence a targeting of policies at this) would only result in a very minor change in the TFRs in these Pacific Asian societies.

Besides, the elasticity patterns also show some territory-specific characteristics. It is interesting to note that in Hong Kong, Singapore and Taiwan, next to marriage, first births are the second most influential factor in determining the TFR. Given 1% increase in the APSFR of parity 1 in the 30–34 age group, the TFR will increase by 0.18% in Hong Kong, 0.15% in Singapore, and 0.16% in Taiwan. This is because couples' transitions to first births are relatively slower (also see the APSFR of parity 1 in Table 2). With increasing proportions of married women remaining at parity 0, their decisions to have the first child have become very important to shape the countries' fertility rates (Chen et al. 2018b). Unlike these three societies, the second births—especially among women aged 30–34 in South Korea are much more influential than first births in changing the country's TFR. Given 1% change in the APSFR of parity 2 in this age group, South Korea's TFR will change by 0.11%, while given 1% change in the APSFR of parity 1 the TFR will change

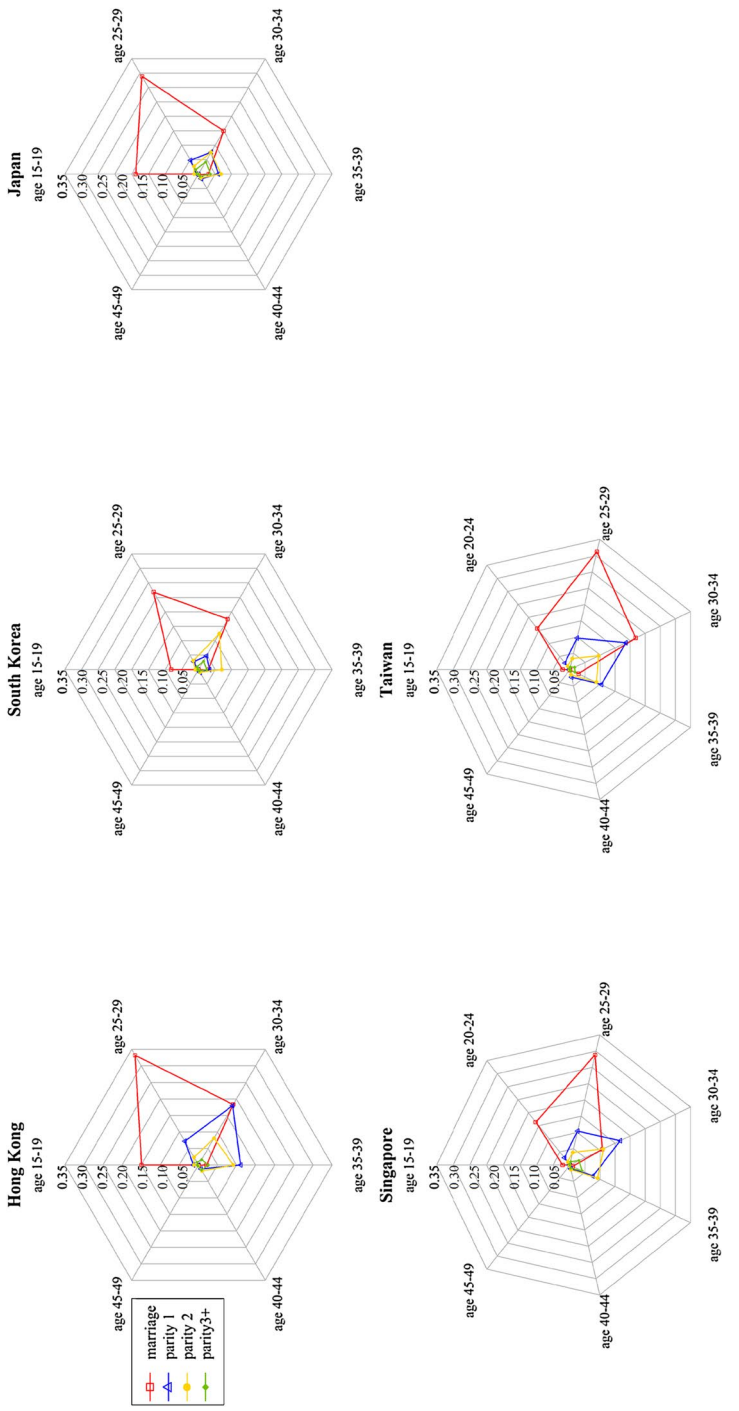

Fig. 2 Fertility elasticities in Hong Kong, South Korea, Japan, Singapore, and Taiwan

Table 3 Fertility elasticities in Hong Kong, South Korea, Japan, Singapore, and Taiwan

Age group	ASMR	APSFR of parity 1	APSFR of parity 2	APSFR of parity 3+
Hong Kong in 2011				
15–24	0.149	0.013	0.012	0.003
25–29	0.332	0.072	0.023	0.008
30–34	0.183	0.180	0.081	0.016
35–39	0.021	0.111	0.092	0.026
40–44	0.001	0.012	0.018	0.015
45–49	0.000	0.001	0.002	0.003
South Korea in 2010				
15–24	0.072	0.004	0.008	0.002
25–29	0.235	0.024	0.027	0.008
30–34	0.153	0.041	0.109	0.026
35–39	0.026	0.029	0.061	0.021
40–44	0.002	0.009	0.008	0.004
45–49	0.000	0.001	0.000	0.000
Japan in 2010				
15–24	0.164	0.005	0.011	0.004
25–29	0.296	0.042	0.024	0.014
30–34	0.131	0.067	0.066	0.037
35–39	0.026	0.052	0.059	0.032
40–44	0.002	0.014	0.012	0.007
45–49	0.000	0.000	0.000	0.000
Singapore in 2010				
15–19	0.020	0.001	0.001	0.000
20–24	0.144	0.024	0.010	0.002
25–29	0.296	0.091	0.034	0.009
30–34	0.094	0.146	0.097	0.026
35–39	0.008	0.067	0.080	0.035
40–44	0.000	0.010	0.013	0.008
45–49	0.000	0.000	0.001	0.000
Taiwan in 2010				
15–19	0.02	0.002	0.001	0.000
20–24	0.138	0.022	0.011	0.002
25–29	0.317	0.085	0.03	0.007
30–34	0.191	0.163	0.083	0.014
35–39	0.025	0.091	0.077	0.015
40–44	0.002	0.02	0.014	0.004
45–49	0.000	0.001	0.001	0.000

by 0.04%. This is because South Korean couples' transitions to second births are slower than the transition to first births, resulting in more women staying at parity 1 (see APSFRs of parity 1 and 2 in Table 2). Existing research has found that

women's employment after first birth may deter second births while those breadwinner-caregiver families may see faster transitions to a two-child household (Ma 2016). Besides, in South Korea the high financial investment in child education has made a second child unaffordable to parents (Anderson and Kohler 2013). Compared to the four Asian Tigers, Japan has a relatively unique pattern: the elasticities to ASMRs are overwhelmingly large, while elasticities with respect to APSFRs of parity 1, 2, and 3+ are rather small. This may be because in Japan many women are unmarried and marriage decisions often coincide with childbearing decisions; but once married, they are more likely to have two children. As marriage and childbearing are so closely linked, the merit of marriage cited most by those never-married is "having your own children and family" according to the Japanese National Fertility Survey in 2015 (IPSS 2015). The survey has also shown that the proportion of married women with two children has been quite stable across the last 30 year (about 55–57%), despite the rise of women with only one child while decline of those with three or more kids (IPSS 2015; Fukuda 2017), reflecting the deep-rooted two-child norm in Japan.

Targeting Implied by Current Pronatalist Measures

We further review the pronatalist measures adopted by these five governments with the main focus on financial incentives to examine targeting groups implied by the current policies. In South Korea, the policies mainly cover three aspects- enhancement in maternity and paternity leaves, *the childbirth benefits*, and subsidizing public childcare centers, with the first two most commonly used (Lee et al. 2016; Son 2018). In Taiwan, there are three policy pillars to raise fertility—"encouraging young people to get married, encouraging young people to give birth, and helping young people to raise children", with more consistent efforts of *financial support* in the third pillar (e.g., baby bonus, maternity leave pension, childcare allowance, etc.) (Yang 2019). In Japan, policies for low fertility are to provide *economical support* (especially in the form of child allowances), as well as to promote support for balancing work and child rearing (e.g., childcare leave, expansion of daycare service) (Kato 2016). In Singapore, the government has put forward a very comprehensive "Marriage & Parenthood" Package, which covers *cash benefits for newborns*, improving access to affordable housing, extending parental leave, more family-friendly working arrangement, subsidies for childcare, and so on (Heybaby 2019). In Hong Kong, as a laissez-faire society, the policies are more implicitly, focusing more on *tax allowances*, maternal leave, and financial assistance to low-income family in childcare and preprimary service (Yip et al. 2008). Seen from pronatalist measures across the five territories, the financial support through cash, tax reduction, or subsidies, remains an essential part of the toolbox. Though the five governments have not stated explicitly which group of people they are targeting in the current pronatalist measures, the review of the financial incentives indicates policy priorities of some subgroups over the others, while other measures covering parental leaves, working arrangements, and childcare service are often non-targeting in a parity-specific sense.

Table 4 Financial incentives in the five societies. *Sources* Yip and Chen (2016); Chen et al. (2018); Declining Birthrate White Paper from Cabinet Office of Japan; the official websites of governments in the five societies

Country/region	Child-related financial incentives
Hong Kong	Tax allowance HK$120,000 (US$15,000) for each of 1st to 9th child HK$120,000 (US$15,000) for each child born during the year
South Korea	Home care allowance 200,000 won (US$170)/month till age 1; 150,000 won (US$130)/month till age 2; 100,000 won (US$85)/month till age 7 Childbirth subsidy The amount varies across cities and regions Pregnancy bonus 500,000 won (US$430)
Japan	Child allowance for age 0–2, 15,000 yen (US$140)/month for age 3–12, 10,000 yen (US$90)/month for 1st & 2nd child and 15,000 yen (US$140)/month for 3rd and above for age 13–15, 10,000 yen (US$90)/month
Singapore	Baby bonus S$8,000 (US$5900) for 1st & 2nd child; S$10,000 (US$7400) for 3rd & higher Co-saving S$6000 (US$4400) for 1st & 2nd child; S$12,000 (US$8800) for 3rd & 4th child; S$18,000 (US$13,300) for 5th & higher Tax rebate S$5000 (US$3700) for 1st child; S$10,000 (US$7400) for 2nd; S$20,000 (US$14,800) for 3rd & higher Working mother tax relief 15% for 1st child; 20% for 2nd child; 25% for 3rd & higher
Taiwan	Childbirth allowance TW$6000–80,000 (US$190–2600) vary across cities and counties; six of 22 cities and counties in Taiwan have parity-progressive allowance and 16 are non-parity-targeted Childcare allowance TW$2000–5000 (US$60–160)/month for age 0–4 Parental benefits TW$2500–5000 (US$80–160)/month for parents not working with children aged 0–2

Financial incentives based on means tests are not included here. The names for the financial incentives are translated from the names in local language. "Home care allowance" in South Korea is a monthly cash benefit paid to parents for childcare if they raise children at home; if they send children to daycare, the allowance will be included in daycare fees. "Childbirth subsidy" in South Korea, "Baby bonus" in Singapore and "Childbirth allowance" in Taiwan are similar to each other, as a cash gift to the birth of a child. "Child allowance" in Japan is a cash benefit for people who are raising children up to their 15th birthday. "Childcare allowance" in Taiwan is a cash benefit for people with children aged 0–4, and the amount varies according to the family income. It is like the child allowance in Japan

Table 4 lists the latest financial incentives in the five places. As shown, compared to the other four societies, the government of Hong Kong provides limited financial support—only the tax allowance; however, the tax allowance has been increased greatly in the recent 5 years- from HKD63,000 (about USD8000) in 2013 to HKD120,000 (about USD15,000) in 2018. Except for Hong Kong, various financial benefits are available in South Korea, Japan, Singapore, and Taiwan, some of which

are lump-sum while some are installment. Among the four places, Taiwan provides the lowest amount of childbirth allowance: the lowest lump-sum payment in Taiwan is TWD6,000 (about USD190), while the highest payment is about TWD80,000 (about USD2,600) which is actually for the birth of third or higher order in Lienchiang county. In Taiwan, the childbirth allowances vary across different cities and counties, six of which are parity-progressive while 16 are non-parity-targeted. Japanese government offers child allowance for the longest period—from birth up to age 15, with the total amount of JPY1,710,000 (about USD15,000) for first and second child, and of JPY2,250,000 (about USD19,700) for the births of third or higher order. The government of South Korea provides childbirth subsidies and pregnancy bonus; in addition, a home care allowance from age 0 to 7, with the total amount of KRW10,200,000 (about USD9,000) is also available in South Korea to support child care. The Singapore government is very generous, especially to the third and higher order births. Babies born in Singapore enjoy not only the baby bonus but also the co-savings from the government (that is savings paid into a Child's Development Account by parents, which are matched dollar-for-dollar by the government). For instance, for a first child the government provides a total amount of SGD14,000 (USD10,300) (baby bonus + co-saving), while for a fifth child a total of SGD28,000 (about USD 20,700). Apart from these cash benefits, the Singapore government also offers very favorable tax rebates and reliefs for parents with three or more children. However, compared to the cost of raising a child, the financial support from these governments is actually very low. According to a rough estimation from Bauhinia Foundation Research Center in Hong Kong, the cost of raising a child up to age 22 is about HKD5.5 million (about USD700,000) (Gu 2014). In Singapore, it costs around 670,000 dollars to raise a child up to 22 (Lee 2018); and in this sense, even the most generous compensation of SGD28,000 in Singapore can only cover less than 3% of the cost.

Table 5 displays the explicit measures to encourage marriages in the five societies, most of which actually turns out to be directly aiming at marriage itself only. Except for Hong Kong where there is no specific measure, the other four governments have taken some efforts. It shows that the common approach is to support matchmaking, provide dating services, and offer trainings for relationship skills. Although these services have created more opportunities for singles to meet their future spouses, they have attracted some critiques about the government's intervention into the private affairs. Besides, the governments in Japan and Singapore have taken other measures with different emphases. In Japan, more efforts are devoted to increase the job security, help the young people find jobs—especially full-time and regular positions, as well as improve the working conditions for them. The latest Japanese National Fertility Survey (IPSS 2015) shows that "money for marriage" and "occupation and work" are the top obstacles to marriage for both women and men. Aware of the fact that many Japanese delay marriages because of employment insecurity and poor incomes, the Japanese government has listed "employment stabilization" in the *Declining Birthrate White Paper* (Cabinet Office 2018). In Singapore, the government focuses more on the housing issues. Currently, very favorable housing schemes with increased access and cheaper price are provided to the courting and newly married couples. For instance, the *Fiancé/Fiancée Scheme* allows courting couples to apply for a new or resale subsidized flat from

Table 5 Policy measures to encourage marriages in the five societies. *Sources* Yip and Chen (2016), Chen et al. (2018b); Declining Birthrate White Paper from Cabinet Office of Japan; the official websites of governments in the five societies

Country/region	Marriage policies
Hong Kong	No specific measures
South Korea	• Promote matchmaking services • Regional governments support volunteer meetings or cultural events to create opportunities for singles to meet future spouses
Japan	• Extend support for matchmaking by municipalities • Increase job security by providing public support for young people to look for jobs and facilitate their transition from irregular work to regular full-time positions
Singapore	• Establish the Social Development Network, which supports and coordinates with private matchmaking agencies to equip singles with relationship/dating skills • Provide attractive housing schemes for courting and married couples: newly married couples can enjoy the scheme "*Priority Allocation for First Timers*"; the courting couples can enjoy special housing access before the marriage registration through the "*Fiancé/Fiancée Scheme*"; support from the "*Staggered Down Payment*" and "*CPF Housing Grants*" to reduce the cost for couples' first homes
Taiwan	• In Taipei city, the government organizes matchmaking activities and offer free courses on handling relationships

Housing & Development Board (HDB) before the official marriage registration. Nowadays, a marriage proposal in Singapore is often interpreted as "do you want a flat?" (Strijbosch 2015). The HDB has also reserved a large part of estates and provided a series of housing grants for married couples to buy their first home through the *Priority Allocation for First-Timers Scheme*. Strijbosch (2015) has found that Singaporeans' marriage decisions are more affected by these housing schemes than by the governmental dating service.

From the comparison of financial incentives in the five Asian societies, three messages can be drawn. First, higher order births are often prioritized over lower-order births—particularly in Singapore, Japan, and some parts of Taiwan. And in some cases, there are quite large differences in financial support between first births and third and higher order births. Second, some incentives are non-targeting with the same payment for all births. Third, although the governments have been enhancing these measures, the level of financial support to families still seems very low in terms of the actual cost of bringing up a child. Furthermore, it seems that there is some mistargeting in the current policies. For example, third or higher births are very rare now and they have (structurally) limited impact on changing the TFRs, but they are actually prioritized by policies in these societies, while first and second birth that are much more influential are much less favored by the policies.

Conclusion and Discussion

This study has identified the most influential groups of women in determining the fertility rates in the five high-income Asian societies. Two important findings consistent across all the five societies should be singled out. First, fertility elasticities

with respect to APSFRs of parity 3+ are very small, indicating that policies explicitly targeting the increase of the number of third and higher order births would play only a very minor role in changing the TFRs of the five societies. This finding empirically supports McDonald's (2006) speculation that policies targeting higher order births are less likely to cause a large increase in the TFR. Second, marriage rates—especially among women aged 25–29—are the most influential factor in shaping the fertility trajectories in the five places. This finding also provides empirical evidence to Atoh's argument that marriage is the decisive factor of future fertility in East and Southeast Asian territories (Atoh et al. 2004). Increasing marriage rates of women in their late-20s would likely help to effectively reverse ultra-low fertility in these societies, *should that be a desired policy outcome*. Jones (2007, p. 473) has also emphasized that "efforts to facilitate marriage would need to be part of any set of policies to raise fertility", especially in Asia where childbearing out-of-wedlock is still uncommon.

Besides, the results have also shown some cross-country differences in the elasticity pattern. In Hong Kong, Taiwan, and Singapore, first births—especially among women aged 30–34—are the second most influential factor of their future fertility. A large proportion of women in these places still postpone the decision to have their first child even after getting married and the age of marriages is still continuously increasing. Therefore, if pronatalist measures can facilitate their transition to first births, it is supposed that an increase in the TFR may be possible. If policies targeting third or higher order births, form the bedrock of policy development, however, this would likely lead to a very modest change in the TFR given that it affects so few women. In South Korea, second births—especially among women aged 30–34—actually play a very important role. Choe and Retherford (2009) have shown that since 2000 there is an accelerated decline in the transition from first- to second birth among women across all education levels, which contributed to the lowest-low fertility in South Korea. In Japan, age-parity-specific fertility rates among the married women are rather insignificant while marriage rates are the dominant factor of its fertility trajectory. Compared to other four places, in Japan the transition rate to parity 1 and 2 are relatively high while the marriage rates remain at a low level. This indicates that many Japanese women are slow to enter marriage, while once they get married they are more likely to have two children.

Findings from our elasticity analysis highlight the roles of different subgroups of women (by age, parity, and marital status) in determining the future fertility trends. Our review of pronatalist measures implies that the ineffectiveness of the financial incentives in the five Asian societies is probably due to their mistargeting and the low level of support (relative to the actual cost of raising children). Therefore, if the government can enhance the policy targeting with appropriate measures and more input, the reversal of fertility can still be plausible. Meanwhile, it should be recognized that in different societies, to incentivize different subgroups may call for different specific measures. More knowledge about policy perceptions and understanding of the barriers faced by different subgroups are required, in order to improve the appropriateness of measures which can best match their needs. Table 6 shows the main reasons for not having a(nother) child (or perceived barriers in childbearing) in Hong Kong, South Korea, Japan and Taiwan (Singapore is excluded due to data

Table 6 Major difficulties/barriers to childbearing. *Source* The information for Hong Kong is from the 2012 Knowledge, Attitude and Practice survey comprised of 1518 married women aged 15–49. The information for Japan is from the 2010 National Fertility survey comprised of 7847 married women under age 50. The information for Taiwan is from the 11th Taiwan Fertility and Family Survey with the question answered by 4256 women aged 20–49. The information for South Korea is from the 2015 National Survey on Fertility, Family Health and Welfare, comprised of 11,006 ever-married women aged 15–49

No.	Hong Kong (2012)	South Korea (2015)	Japan (2010)	Taiwan (2012)
1	Increased economic burden (28.6%)	Being economically constrained (29.4%)	It costs too much to raise and educate children (60.4%)	A big economic burden to family (60.34%)
2	Big responsibility (24.7%)	Having economic difficulty in child care (21.4%)	Hate to bear children at older age (35.1%)	No freedom to do what you want (10.93%)
3	Children are rebellious and difficult to be taught today (11.6%)	Having children will reduce freedom (20.5%)	Want to have a child but cannot conceive (19.3%)	No confidence in being good parents (9.48%)

The difficulties/barriers here are predefined choice in the questionnaires for the surveys in the five territories

availability). As shown, the most cited reason in these societies is the cost of children. Particularly, in Hong Kong, existing research shows that increased economic burden is perceived to be the top difficulty by wives and husbands across all the parities (Chen and Yip 2017). This indicates that more financial support to reduce the cost of children would be most desired. In South Korea and Taiwan, people are very worried about the limited individual freedom after having children. In Japan, infertility and childbearing at older age are also very concerned. More medical assistance to infertile and old women would help them realize their fertility plans. Furthermore, "indeed what specific measures are preferred", though there are no policy perception data available for all the countries, surveys from Hong Kong and Singapore may provide us valuable information. According to Hong Kong's Knowledge, Attitude and Practice survey in 2012, among women who had not fulfilled their ideal parity, the top five measures which would encourage them to have a(nother) child are: (1) education subsidies; (2) medical subsidies; (3) free kindergarten education, (4) buy/change/rent house subsidies; and (5) milk subsidies. According to the Perception of Policies in Singapore Survey in 2014, the top five measures perceived to be influential by women are: (1) maternity leave; (2) parenthood tax rebate; (3) extended childcare leave; (4) government-paid maternity leave; and (5) medisave maternity package. Comparison of findings from Hong Kong and Singapore highlights the importance of tailor-made policies in each society.

From the analysis, it can be seen that mechanically, the marriage rate is the most influential factor to the fertility rates, confirming the close linkage between marriage and fertility in the five Pacific Asia societies. Then, what are the major barriers to marriage in this region? Indeed, some governments (e.g., Japan, Singapore) have been very active to support dating, housing, and employment security. The impact, however, seems to be very limited. Marriage is postponed as people nowadays spend more years in education and career advancement, due to the increasing job insecurity and fierce competition in the labor market. The rising education and labor participation of women have made marriage less economically attractive to women (Ono 2003). On the other hand, in Asian societies where hypergamous marriage is widely desired, the rapid improvement of women's socioeconomic status has created a marriage squeeze, especially towards highly educated women and low educated men (Raymo and Iwasawa 2005; Jones and Gubhaju 2009). Moreover, the heavy family obligations inside the "marriage package" imposing on women, as well as the declining marital stability (reflected by the rapidly rising divorce rates), have also made women more hesitant to marry (Bumpass et al. 2009; Jones 2007, 2012). Meanwhile, in these Asian societies where marriage is seen as the only acceptable setting for child bearing and rearing, fertility plans may lead to the marriage decision, in other words, pregnancy may trigger a marriage. Existing research reveals that marriage and childbearing decisions are often taken simultaneously, and that the timing of marriage and first births may be affected by common factors (Baizán et al. 2004). Intention to delay marriage may be driven by the intention to postpone childbearing. In this sense, marriage can be viewed as a milestone in the pathway to childbearing and an important proximate determinant of fertility. Therefore, a standalone 'marriage-only' policy may not be enough to raise fertility effectively" (Chen et al. 2018b); rather a portfolio of inclusive social policies to remove the common

obstacles to marriage and childbearing (e.g., costly housing, unstable employment, long working-hours) would be more helpful. Therefore, to formulate effective policies, a more holistic approach to understand the marriage and childbearing patterns as well as the linkage between them is very essential.

Then, under this context, will cohabitation and non-marital birth emerge in these Asian high-income societies, just like some Southern European countries which have seen rapid increase of these non-traditional family behaviors in the past five decades (Pereiro et al. 2014)? In South Korea, Japan, and Taiwan, the proportions of non-marital births were only about 1% in the 1960s—a similar level to Southern Europe at that time. But over the last 50 years, they have increased rather slightly, currently remaining less than 5%—a level much lower than some Southern European countries today (e.g., 29% in Italy and 43% in Spain) (OECD 2016). In Hong Kong, there seemed a noticeable increase of non-marital births from about 4% to 8–9% over the period of 1984–2014, and about 30% of conceptions among women in the 1990 + cohort occurred within a cohabiting union (Gietel-Basten and Verropoulou 2018). However, there is still much social stigma to children born out-of-wedlock and also many social welfare policies discriminate against these children and their parents in these Asian societies (Gietel-Basten and Verropoulou 2018). Despite some changes in attitudes towards cohabitation, the social and institutional context of childbearing in Asia is still heavily geared towards marriage. Under these circumstances, without great shifts in norms, work cultures, institutions and policies, it is still unlikely to see a significant rise of non-marital births in the near future. This implies that births inside marriage may continue to be mainstream in the future.

Though the analysis only considers the marriage and childbearing behavior of women, the role of men in these decisions should not be ignored. Men's participation in home production is found to contribute to higher fertility as well as higher female labor force participation (De Laat and Sevilla-Sanz 2011). Husbands' greater involvement in housework is positively associated with wives' fertility desire and intention (Chen and Yip 2017; Kan and Hertog 2017). The male-breadwinner and female-homemaker model has been challenged, as nowadays more women enter into the labor market and expect more contribution from men's in the family sphere. As shown in Japanese National Fertility Survey in 2015 (IPSS 2015), the proportion of single women expecting their potential spouse to have housework and parenting skills has been increasing and become the top criteria for mate selection. These indicate that promoting equal gender roles in the family, to some extent, would help to increase marriage and fertility.

This study has contributed to the literature by identifying the potential target groups for pronatalist actions and reveals some targeting mismatch in the current policies in Pacific Asian societies. To some extent, our study has reduced the elusiveness of pronatalist action regarding whom to target. Future studies can further explore what specific policy measures are appropriate and desired by different subpopulations. Policies such as "baby bonus", or "marriage promotion" alone cannot make a big difference, as obstacles to marriage and childbearing are various. They include small and expensive housing in urban areas, economic uncertainty, long working-hours and inflexible working arrangement, difficulties in combining work and family for women, gender inequality-especially in

the private sphere, high expectation, and cost of children's education. To remove these obstacles, indeed, a holistic and integrated portfolio of policy measures should be in place. Meanwhile, the decision to have children (no matter in terms of the timing or the number of children) is a reproductive right of women that should be respected. Government policies should not be formulated as a state intervention into the individual reproductive rights, but as efforts to create a more child- and family- friendly environment (Lin and Yang 2009).

However, there are still some limitations in this study. First, the elasticity analysis is based on several assumptions that are made to facilitate our computations, which consequently do not fully model the exact parity transitions in real life. For example, due to data limitations, we have not considered the childbearing behavior outside marriage. However, the omissions of the out-of-wedlock births are expected to have limited impact on the main findings as it is not common in Asian countries. We also assume that the time of marriage registration and the time of birth registration cannot be in the same year. The concurrent incidence rate of registering marriage and birth in the same year may not be very high, considering of 9–10 months of pregnancy. However, as the bridal pregnancy has increased, the modeling can be adjusted by removing this assumption in the future. If this assumption is relaxed, we can anticipate that the elasticity to marriage and first birth would become even larger than the present estimation, making their roles even more prominent in determining the TFR. Secondly, our analysis is based on cross-sectional 5-year age grouped data, which reflects the fertility dynamics from a "period" rather than "cohort" perspective. Therefore, the results should be interpreted with caution as it reveals the determinants of the period fertility rates in the 2010s rather than the cohort fertility rates. With very limited cohort data, we are unable to perform the cohort fertility elasticity analysis. In order to consider the rapid change in family behaviors across generations, in the following-up studies predictions of marriage and parity-specific fertility rates will be made for the younger cohorts to enhance our analysis. Thirdly, we have not incorporated the cross-border marriages into the elasticity analysis. In these Asian societies, cross-border marriages do help fulfill the family formation and childbearing aspirations of some people, especially men in low socioeconomic status. Fourth, we have not considered the selection effect. Specifically, women who marry at a younger age and have two or three children at a very young age may be a group of women with stronger preference for family formation and childbearing. Thus, the policy effect may not be as strong as expected; however, on the other hand, policies may affect the timing of marriage and childbearing, thus creating opportunities for a positive tempo-quantum interaction (just as postponement will depress the quantum of childbearing through a negative tempo-quantum interaction) (Lutz and Skirbekk 2005; Yip and Chen 2016). Finally, here we have only investigated subgroups specified by age, sex, and parity, and do not include subpopulations by socioeconomic status. Future research can assess roles of different socioeconomic subgroups in determining the fertility trajectories.

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Appendix 1

As shown in Fig. 1, a woman at age n may be in any of the five states: "unmarried with zero child", "married with zero child", "married with one child", "married with two children", or "married with three children". These five states are denoted as $U(0)$, $M(0)$, $M(1)$, $M(2)$, and $M(3)$, respectively. The stationary probability vector of these five states at age n (i.e., the distribution of a hypothetical cohort of women at age n) is denoted by:

$$\pi_{\mathrm{n}} = \left(\pi_{\mathrm{u,n}}(0), \pi_{\mathrm{m,n}}(0), \pi_{\mathrm{m,n}}(1), \pi_{\mathrm{m,n}}(2), \pi_{\mathrm{m,n}}(3)\right).$$

Initially, all women of a hypothetical cohort are in state $U(0)$, and so the stationary probability vector at the beginning is $\pi_{15} = (1, 0, 0, 0, 0)$. This means that all women are unmarried and with no children at age 15.

The matrix equation below is used to specify the dynamics in Fig. 1, as a hypothetical cohort of women move from age n to $n+1$,

$$\begin{pmatrix} \pi_{\mathrm{u,n+1}}(0) \\ \pi_{\mathrm{m,n+1}}(0) \\ \pi_{\mathrm{m,n+1}}(1) \\ \pi_{\mathrm{m,n+1}}(2) \\ \pi_{\mathrm{m,n+1}}(3) \end{pmatrix} = T_{\mathrm{n}} \begin{pmatrix} \pi_{\mathrm{u,n}}(0) \\ \pi_{\mathrm{m,n}}(0) \\ \pi_{\mathrm{m,n}}(1) \\ \pi_{\mathrm{m,n}}(2) \\ \pi_{\mathrm{m,n}}(3) \end{pmatrix}.$$

Here, T_{n}, the transition matrix at age n, is given by,

$$T_{\mathrm{n}} = \begin{pmatrix} 1-m_{\mathrm{n}} & 0 & 0 & 0 & 0 \\ m_{\mathrm{n}} & 1-p_{\mathrm{m,n}}(1) & 0 & 0 & 0 \\ 0 & p_{\mathrm{m,n}}(1) & 1-p_{\mathrm{m,n}}(2) & 0 & 0 \\ 0 & 0 & p_{\mathrm{m,n}}(2) & 1-p_{\mathrm{m,n}}(3) & 0 \\ 0 & 0 & 0 & p_{\mathrm{m,n}}(3) & 1 \end{pmatrix}$$

The TFR measures the expected number of children a hypothetical cohort of women would have, if they were subject to the ASFRs of a given year through their lifetime. Here, by assuming that the fertility rate of women aged 50 and over is negligible, TFR can be computed from the following equation:

$$TFR = 0 \times \pi_{\mathrm{u,50}}(0) + 0 \times \pi_{\mathrm{m,50}}(0) + 1 \times \pi_{\mathrm{m,50}}(1) + 2 \times \pi_{\mathrm{m,50}}(2) + 3 \times \pi_{\mathrm{m,50}}(3)$$

$$= \begin{pmatrix} 0 & 0 & 1 & 2 & 3 \end{pmatrix} T_{49} T_{48} \cdots T_{15} \begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}$$

To estimate the TFRs, the ASMRs and APSFRs were used as realistic values for the 28 parameters (i.e., m_n, $p_{m,n}(1)$, $p_{m,n}(2)$, and $p_{m,n}(3)$ for 75-year age groups, covering ages from 15 to 49). Since we only modeled transitions up to parity 3, to reduce potential underestimation, we used births of parity 3 and higher parities as the numerator while the number of married women with 2 children as the denominator to compute the ASPFR for parity 3.

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Affiliations

Mengni Chen[1] · Stuart Gietel-Basten[2] · Paul S. F. Yip[3]

Mengni Chen
mengni.chen@uclouvain.be

Stuart Gietel-Basten
sgb@ust.hk

[1] Center for Demographic Research, Université Catholique de Louvain, Place Montesquieu 1bte L2.08.03, 1348 Louvain-la-Neuve, Belgium

[2] Division of Social Science and Division of Public Policy, The Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong SAR, China

[3] Department of Social Work and Social Administration, The University of Hong Kong, Pokfulam, Hong Kong SAR, China