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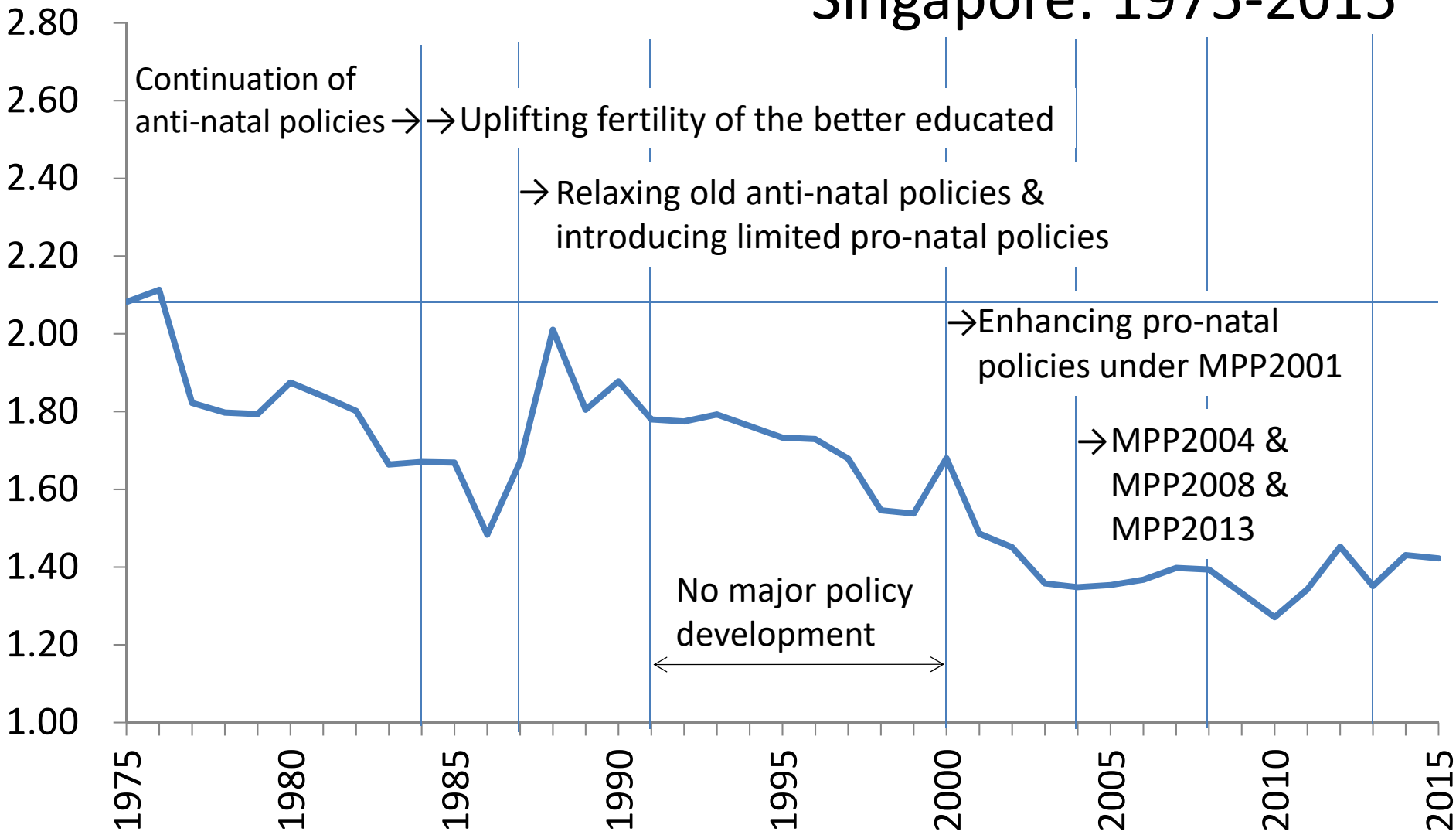
Ethnic differentials in effects of 1st marriage and marital fertility on below-replacement fertility in Singapore, 1980-2015: A lifetable analysis

Keita SUGA
（National Institute of Population and Social Security Research）

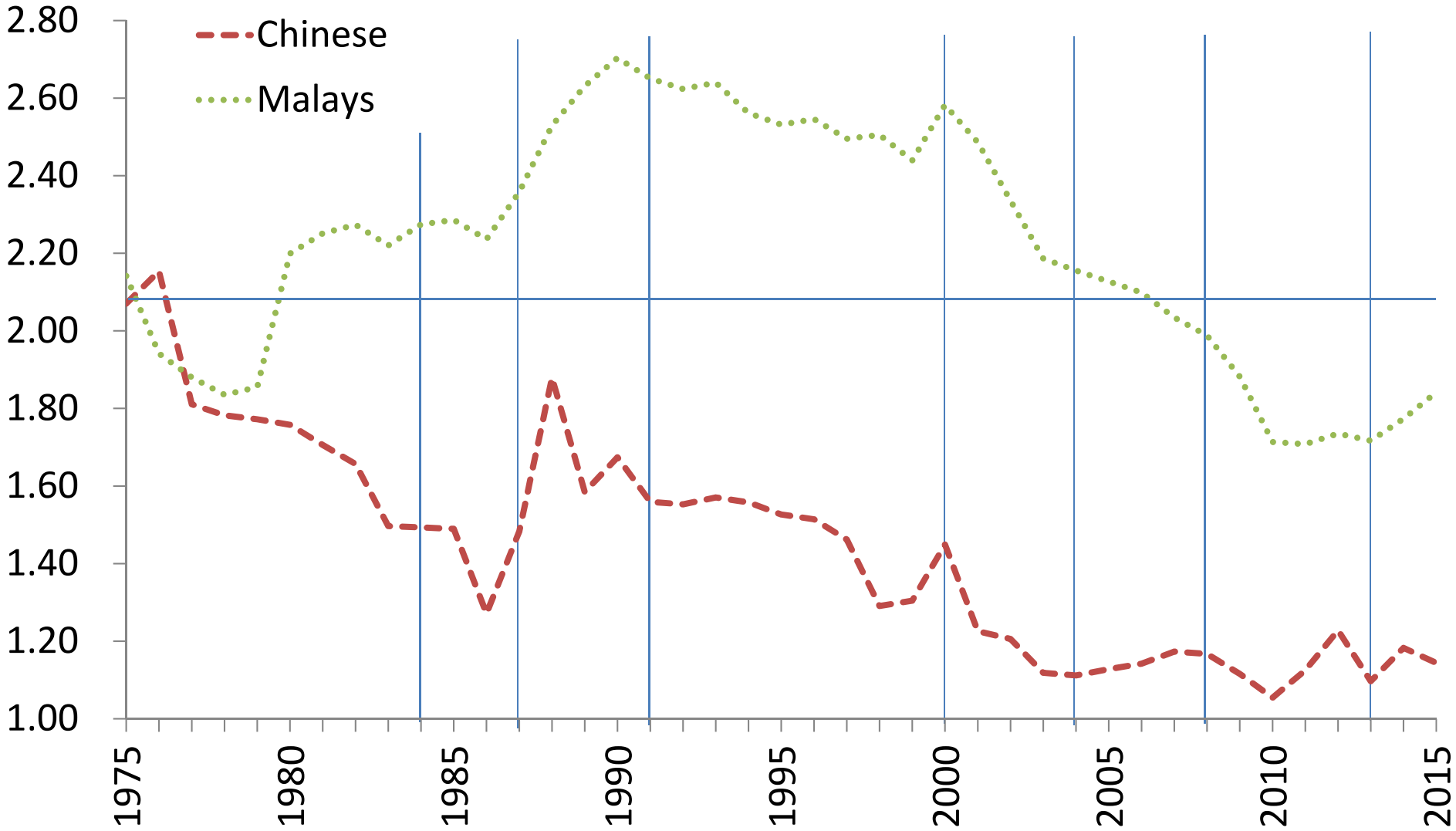
* E-mail: suga-keita@ipss.go.jp. This research was supported by Health and Labor Science Research Grants (H24-Chikyu kibo-Ippan-003, H27-Chikyu kibo-Ippan-001 , H30-Chikyu kibo-Ippan-002) from The Ministry of Health, Labor and Welfare.

Pro-natal policy development (& TFR) in Singapore: 1975-2015



Source: Author's calculation with *Registration of Birth and Death Statistics*, *Census of Population*, *Population Estimates*. Saw(2005), Wong and Yeoh(2003), Yap(2009), Straughan et al.(2009) and documents by Singapore National Population Secretariat for detailed policy development.

Period TFR by Ethnic group in Singapore: 1975-2015



Source: Author's calculation with *Registration of Birth and Death Statistics*, *Census of Population*, *Population Estimates*.

Objectives of the Study

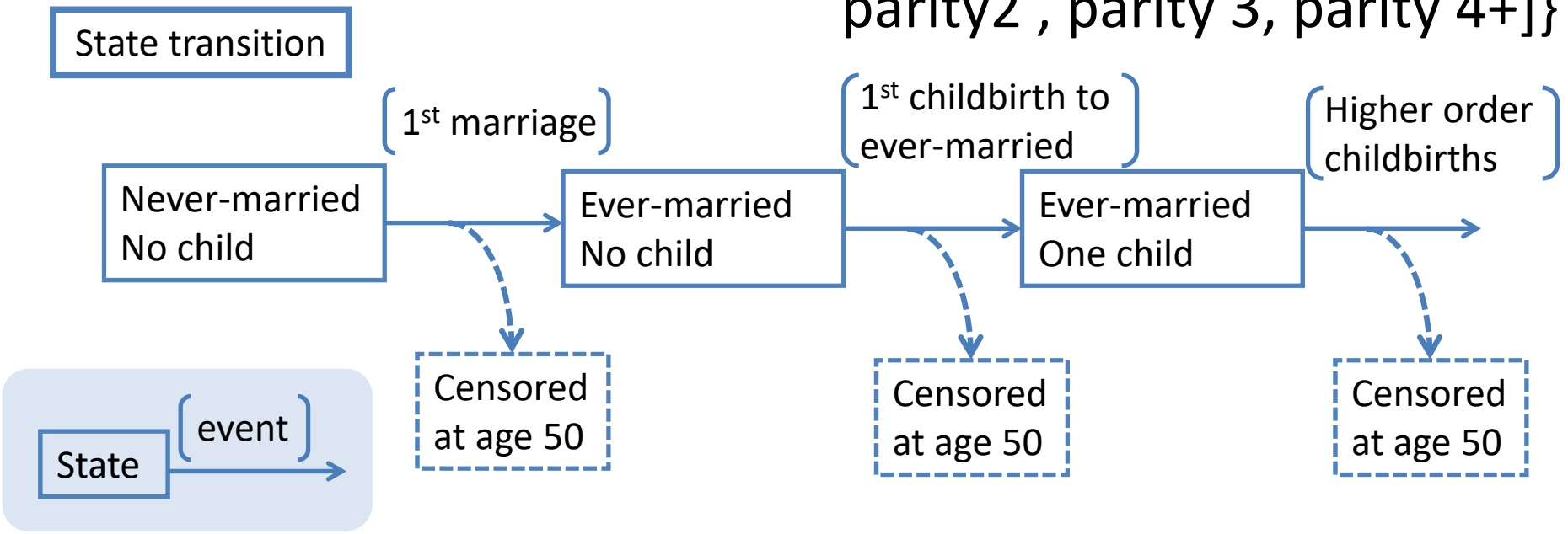
- Examine the patterns and demographic factors underlying the fertility changes in Singapore for 1980-2015, with focusing on the role of nuptiality in ethnic differentials of fertility changes.
- Construct multistate lifetables from 1980 to 2015 with **limited data** in order to decompose period fertility changes into contributions of the 1st marriage and marital childbirths.

II. Data and Methodology

(1) Multistate lifetable analysis of fertility

Multistate lifetable analysis of fertility (1)

State={Never-married, Ever-married&[No child, parity 1, parity2 , parity 3, parity 4+]}



—Initial state={Never-married & No child} at age 20.

—Transit from state i to state j at an age-specific **hazard rate** within the next one year (e.g. the 1st marriage hazard equals a rate of the 1st marriage occurrence among nevermarried females of age 20-24 in 1980).

—We will focus on a distribution over the state at age 50.

Multistate lifetable analysis of fertility (2)

Mathematical setup:

${}^{i}l_{x+1}^{j}$: The number of females who were in state i at exact age x and end up in state j by age $x+1$

${}_{1}M_{x}^{ij}$: Transition rates from state i to state j in an age interval $(x,x+1)$, which are the ratios of the number of transitions to the estimated midperiod population at risk

$$\mathbf{l_x} = \begin{pmatrix} {}^{1}l_x^1 & 0 & \cdots & 0 \\ 0 & {}^{2}l_x^2 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & {}^{6}l_x^6 \end{pmatrix}$$: State distribution at the beginning of an age interval $\mathbf{(x,x+1)}$

Multistate lifetable analysis of fertility (3)

$$\mathbf{E}_{\mathbf{x+1}} = \begin{pmatrix} {}^{1}l^{1}_{x+1} & {}^{1}l^{2}_{x+1} & \cdots & {}^{1}l^{6}_{x+1} \\ {}^{2}l^{1}_{x+1} & {}^{2}l^{2}_{x+1} & \cdots & {}^{2}l^{6}_{x+1} \\ \vdots & \vdots & \ddots & \vdots \\ {}^{6}l^{1}_{x+1} & {}^{6}l^{2}_{x+1} & \cdots & {}^{6}l^{6}_{x+1} \end{pmatrix}$$: State distribution at the end of an age interval **(x,x+1)**

Note that I_{x} is related with E_{x} as in Eq.[1]:

$$\mathbf{l}_{\mathbf{x}} = \begin{pmatrix} {}^{1}l^{1}_{x} & 0 & \cdots & 0 \\ 0 & {}^{2}l^{2}_{x} & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & {}^{6}l^{6}_{x} \end{pmatrix} = diag\left[(1,\cdots,1)\mathbf{E}_{x}\right] = \begin{pmatrix} \sum_{s=1}^{6} {}^{s}l^{1}_{x} & 0 & \cdots & 0 \\ 0 & \sum_{s=1}^{6} {}^{s}l^{2}_{x} & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & \sum_{s=1}^{6} {}^{s}l^{6}_{x} \end{pmatrix} \quad \text{Eq.[1]}$$

Construction follows a standard procedure in Palloni, Alberto(2001) “Increment-Decrement Life Tables.” Samuel H. Preston, Patrick Heuveline and Michel Guillot, *Demography Measuring and Modeling Population Processes*. MA, USA: Blackwell.

Multistate lifetable analysis of fertility (4)

Set state transition rates for an age interval $(x,x+1)$ in a matrix:

$$\mathbf{M_x} = \begin{pmatrix} {}_1M_x^{12} & -{}_1M_x^{12} & 0 & 0 & 0 & 0 \\ 0 & {}_1M_x^{23} & -{}_1M_x^{23} & 0 & 0 & 0 \\ 0 & 0 & {}_1M_x^{34} & -{}_1M_x^{34} & 0 & 0 \\ 0 & 0 & 0 & {}_1M_x^{45} & -{}_1M_x^{45} & 0 \\ 0 & 0 & 0 & 0 & {}_1M_x^{56} & -{}_1M_x^{56} \\ 0 & 0 & 0 & 0 & 0 & 0 \end{pmatrix}$$

Then, lifetable functions can be calculated by Eq.[2] with given radix I_{20}:

$$\mathbf{E_{x+1}} = \mathbf{l_x}\left[\mathbf{I} - \tfrac{1}{2}\mathbf{M_x}\right]\left[\mathbf{I} + \tfrac{1}{2}\mathbf{M_x}\right]^{-1} \qquad \text{Eq.[2]}$$

Multistate lifetable analysis of fertility (5)

Index examined:

$$TPAP = \sum_{i=3}^{6} (i-2)^{i} l_{50}^{i} \Big/ \sum_{i=1}^{6} {}^{i} l_{50}^{i}$$

Total Period Average Parity (TPAP)

A lifetable measure of a **completed fertility**; the total average number of births that a woman in a hypothetical cohort would have at the end of their reproduction year (i.e. age 50), if this hypothetical cohort experienced the age-specific transition rates of a given year.

II. Data and Methodology

(2) Data available to analyze ethnic differentials in fertility changes in Singapore

Necessary data for the multistate lifetable construction

Hazard rates (transition probability from state i to j)

Numerator: -1st marriages by age and ethnic group

-Live births by birth order, mother's age at that birth and mother's ethnic group

Denominator: Female population by the **marriage-birth state**, age and ethnic group

Data available to construct the multistate lifetables in Singapore

Numerators

- Live births by the order, age and ethnic group are available from the vital statistics.
- No data are available for 1st marriages by women's age and ethnic group, but the 1st marriages by women's age and registration system are available.

Denominators

- Female population by age and ethnic group are available annually from population estimate and population census.
- Female population by **marital status** and ever-married female by **parity**, age and ethnic group are available in the **decennial** population census.

Necessary data for the multistate lifetable construction

Hazard rates (transition probability from state i to j)

Numerator: -1st marriages by age and ethnic group

-Live births by birth order, mother's age at that birth and mother's ethnic group

Denominator: Female population by the **marriage-birth state**, age and ethnic group

(Female population by age and ethnic group) * (**State distribution** by age and ethnic group)

II. Data and Methodology

(4) Decomposition of TPAP change in the effects of first marriage and marital fertility

Decomposition of the effects of first marriage and marital fertility (1)

1. Generalized Kitagawa's decomposition method to a function (Kitagawa 1955; Das Gupta 1993)

$$\Delta TPAP_t \equiv TPAP_t - TPAP_{t-1} = \mathrm{A}_t + \mathrm{B}_t$$

Effect of a change in 1st marriage hazards

Effect of changes in child birth hazards between year t and t-1

Decomposition of the effects of first marriage and marital fertility (2)

2. Dynamic relationship of period measures:

$$TPAP_1 = TPAP_0 + \Delta TPAP_1 \quad \text{where} \quad \Delta TPAP_1 \equiv TPAP_1 - TPAP_0$$

$$TPAP_2 = TPAP_1 + \Delta TPAP_2$$

$$= \{TPAP_0 + \Delta TPAP_1\} + \Delta TPAP_2 = TPAP_0 + \sum_{\tau=1}^{2} \Delta TPAP_\tau$$

By recursive substitution until T,

$$TPAP_T = TPAP_0 + \sum_{\tau=1}^{T} \Delta TPAP_\tau \quad \text{Eq.[4]}$$

Keita SUGA. **2012**. "The Second Demographic Transition in Singapore: Policy Interventions and Ethnic Differentials," *Journal of Population Problems*, Vol68(4): pp.9-21.

Decomposition of the effects of first marriage and marital fertility (3)

3. Apply the orthogonal factor decomposition to single-year increments in Eq.[4]:

$$TPAP_T = TPAP_0 + \sum_{\tau=1}^{T} \mathrm{A}_\tau + \sum_{\tau=1}^{T} \mathrm{B}_\tau \qquad \text{Eq.[5]}$$

Cumulative effect of "first marriage"

Cumulative effect of "marital fertility"

Decomposition of the effects of first marriage and marital fertility (4)

- Define for all t

$$TPAP_t^{\alpha} = TPAP_0 + \sum_{\tau=1}^{t} \mathrm{A}_{\tau} \quad \text{Eq.[6]} \quad \textbf{(Cumulative effect of first marriage)}$$

$$TPAP_t^{\beta} = TPAP_0 + \sum_{\tau=1}^{t} \mathrm{B}_{\tau} \quad \text{Eq.[7]} \quad \textbf{(Cumulative effect of marital fertility)}$$

Decomposition of an annual average change of TPAP into first marriage- and marital fertility- contributions:

$$\frac{1}{T}\left(TPAP_T - TPAP_0\right) = \frac{1}{T}\left(TPAP_T^{\alpha} - TPAP_0\right) + \frac{1}{T}\left(TPAP_T^{\beta} - TPAP_0\right) \quad \text{Eq.[8]}$$

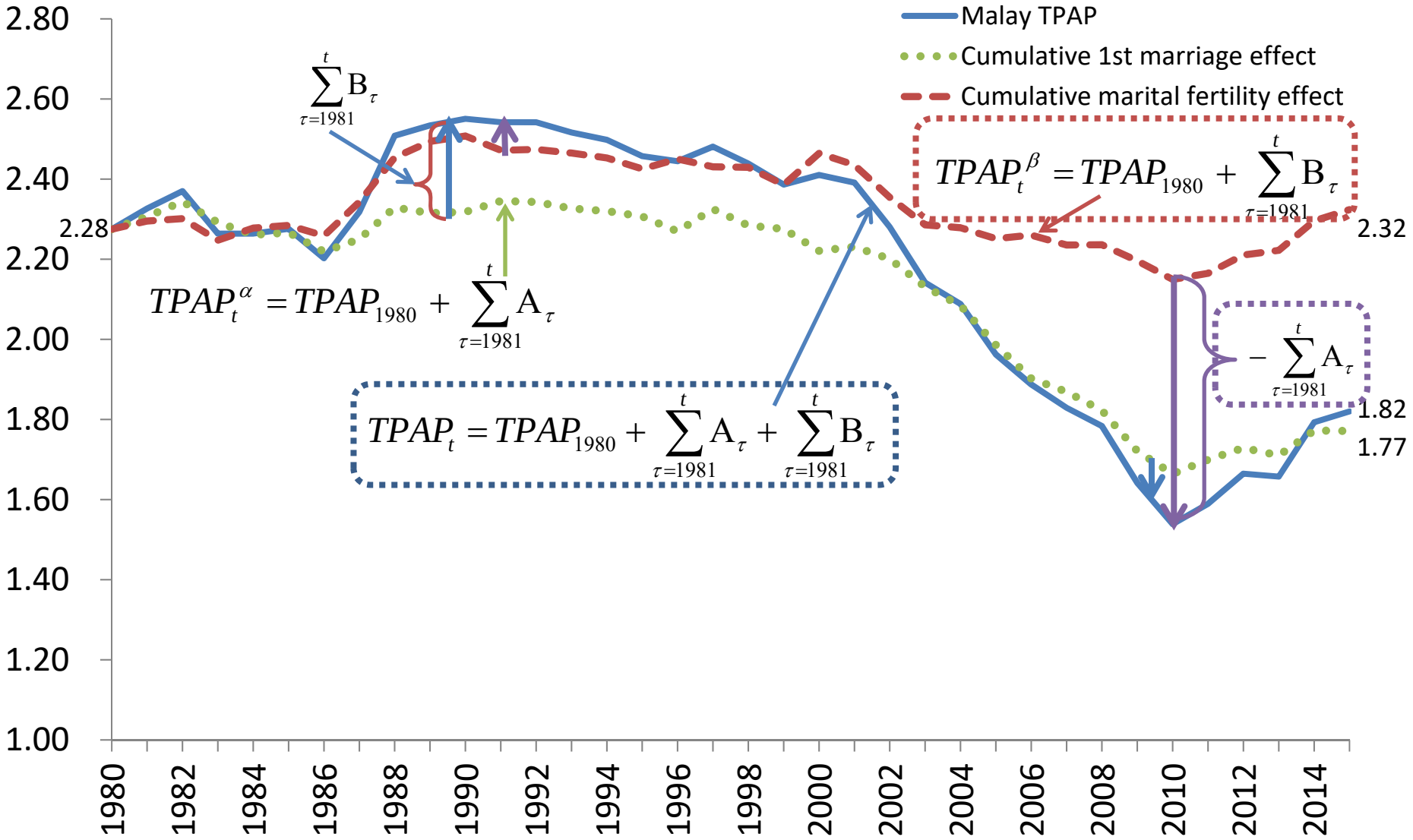
Change in a lifetable measure of completed fertility	Cumulative contribution of "**first marriage effect**"	Cumulative contribution of "**marital fertility effect**"

Decomposition of the effects of first marriage and marital fertility (5): Interpretations I

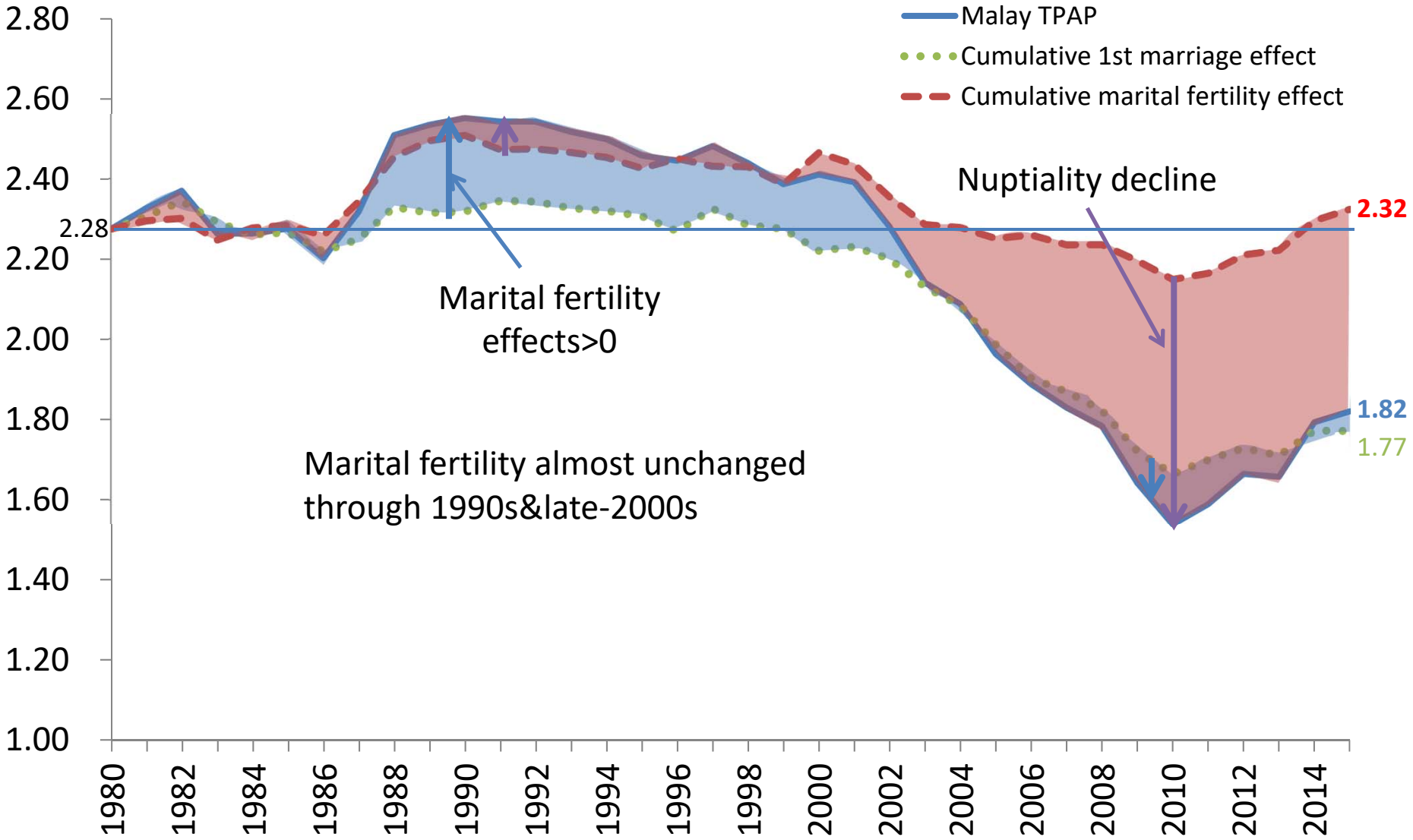
- **Cumulative first marriage effect** is a period measure which increases/decreases only in response to changes in the 1st marriage hazard. It corresponds with time series of **the total average number of births** that women in hypothetical cohorts would have, if **no change in childbirth hazards and shapes** of the age schedule from year 0 to year T.
- **Cumulative marital fertility effect** reveals time series of period total average parities with a fixed naptiality. It reflects a cumulative effect of changes in childbirth hazards of the ever-married from year 0 to year T, interpreted as **the number of births** of women in hypothetical cohorts under **a constant 1st- marriage hazard** at the level of year 0 with an **invariant shape** of age pattern.

III. Results

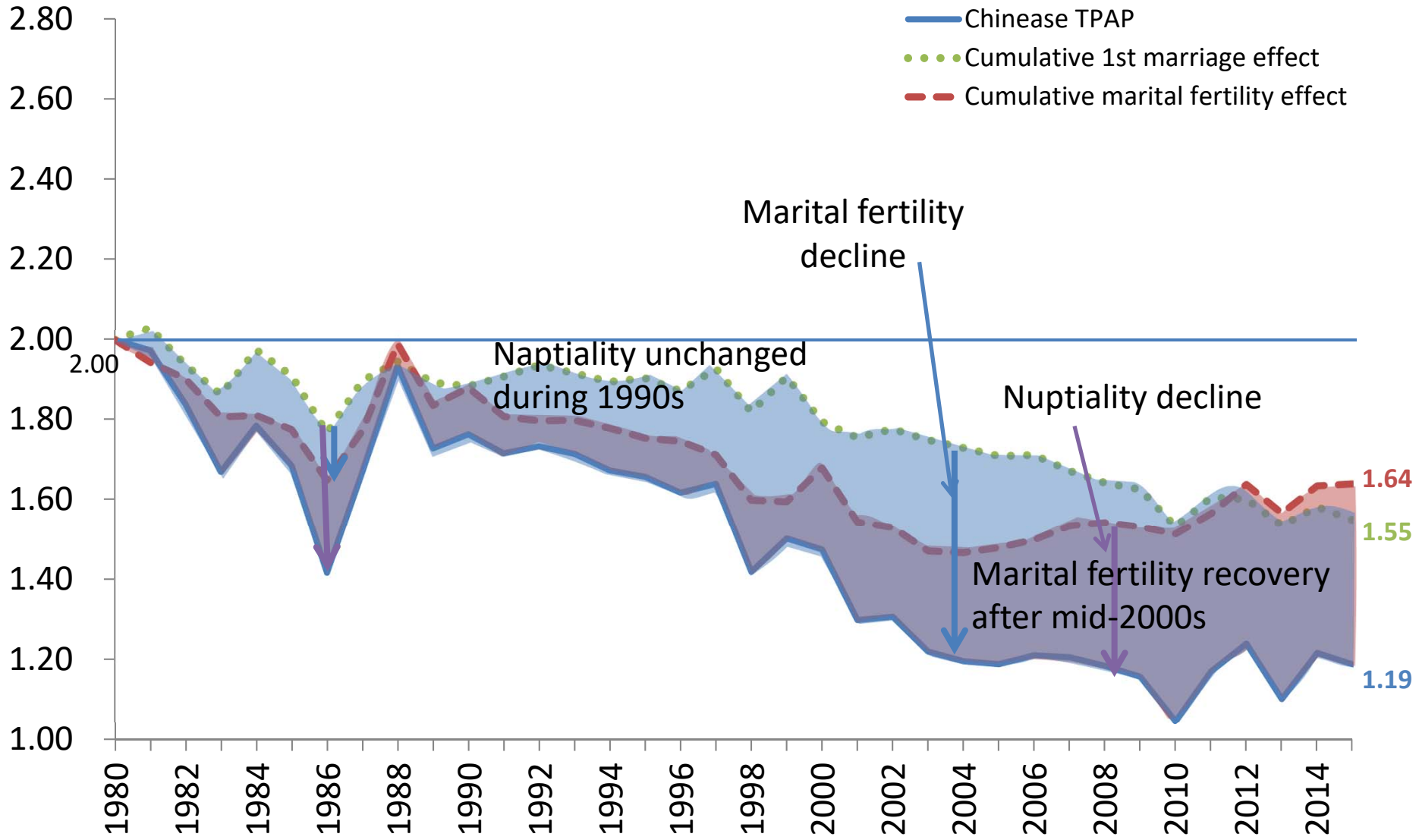
Decomposition result of TPAP into effects of nuptiality and marital childbirths in Singapore: Malay, 1980-2015



Decomposition result of TPAP into effects of nuptiality and marital childbirths in Singapore: Malay, 1980-2015



Decomposition result of TPAP into effects of nuptiality and marital childbirths in Singapore: Chinese, 1980-2015



Ethnic differentials and similarities in 1st marriage- and marital fertility- effects on fertility changes

Cumulative marital fertility effect

Period	Simirarity	Dissimilarity	
		Chinese	Malay
1986~1990	Increase*		
1990~2000		Decrease 1.88→1.68(-10.6%)	Almost constant 2.51→2.46(-1.7%)
1999~2000	Increase		
2000~2001		Sharp decline 1.68→1.64(-8.1%)	Decrease 2.46→2.44(-1.2%)
2001~2004	Decrease		
2004~2010		Slow increase 1.47→1.51(+3.2%)	Decrease 2.28→2.15(-5.7%)
2010~2015	Increase		

*Patterns differ.

Cumulative 1st marriage effect

Period	Simirarity	Dissimilarity	
		Chinese	Malay
1986~1990	Increase		
1990~2000	Little dicrease		
2000~2010		Decrease 1.79→1.53(-14.6%)	Rapid decline 2.22→1.66(-25.1%)
2010~2015		Stable 1.53→1.55(+1.1%)	Increase 1.66→1.77(+6.4%)

Concluding remarks

Results

- Ethnic differentials and similarities in 1st marriage and marital fertility effects

Methodological contributions

- Even when statistical tables for population at risk for a specific event (i.e. denominator for hazard rates) are not available in interim periods, we can construct multistate lifetables
  if the size of the total population and the number of demographic events until the year are known.

- If state distributions are observed in multiple years, we can improve state distribution estimates for the interim periods.