WHEN TEMPO MEETS QUANTUM: INTEGRATING REPRODUCTIVE AGE LIMITS INTO DYNAMIC MICROSIMULATION MODELS OF FIRST BIRTH DELAY AND COHORT COMPLETED FERTILITY.

WITTGENSTEIN CENTRE CONFERENCE 2024
DELAYED REPRODUCTION: CHALLENGES AND PROSPECTS
21-22 NOVEMBER 2024

Karel NEELS
Centre for Population, Family & Health, University of Antwerp

Eva BEAUJOUAN
University of Vienna & Vienna Institute of Demography

BACKGROUND:
Fertility Postponement and cohort completed fertility

- In the **early stages** of the postponement transition, delayed entry into parenthood had **limited quantum implications**:
  - long time frame with high first birth probabilities remained
  - first probabilities at older ages initially increased as selectivity decreased

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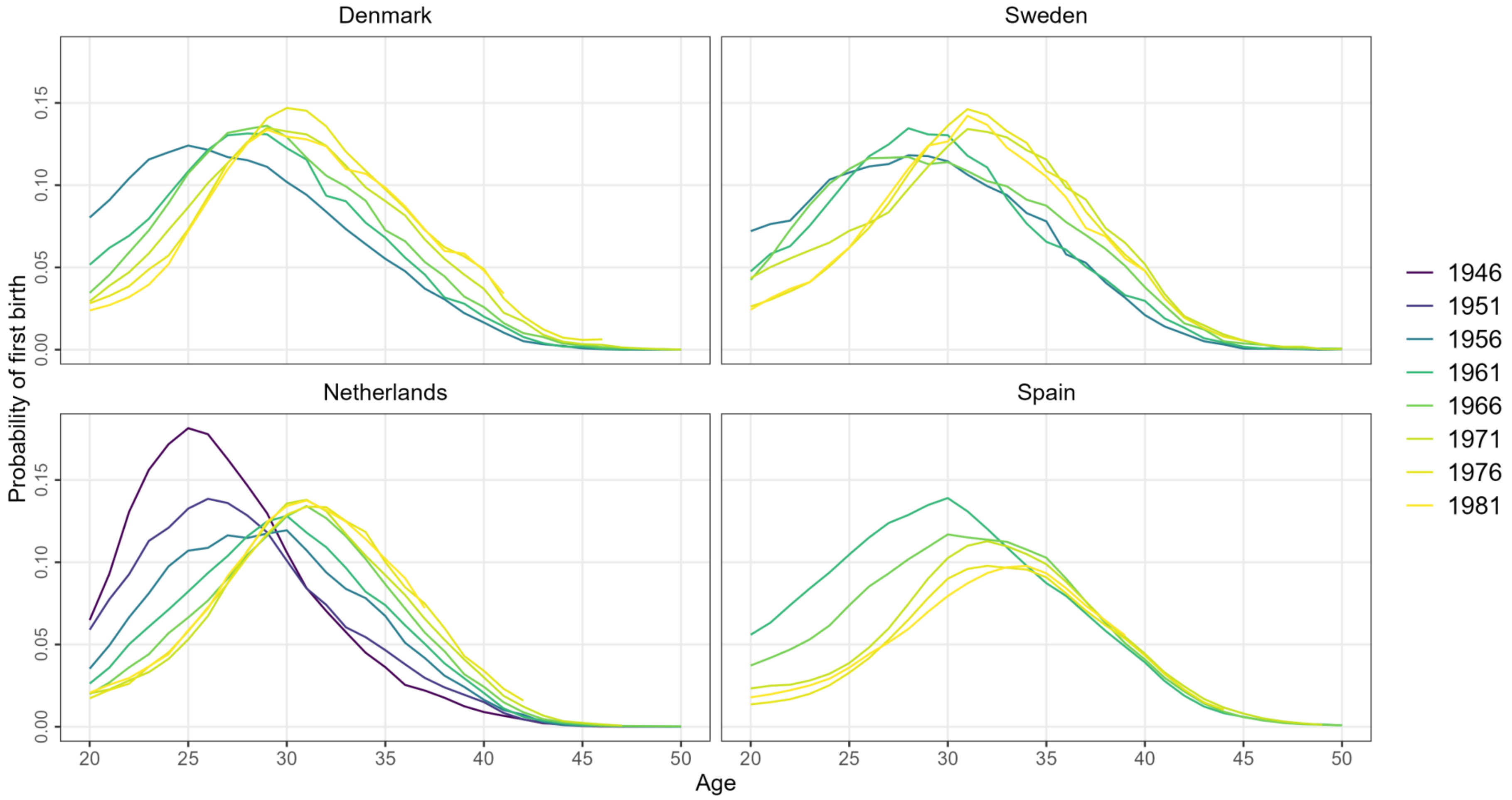
  - leaving **shorter time frame** with lower first birth probabilities
  - first birth probabilities of having a first child at older ages have now **stabilised**

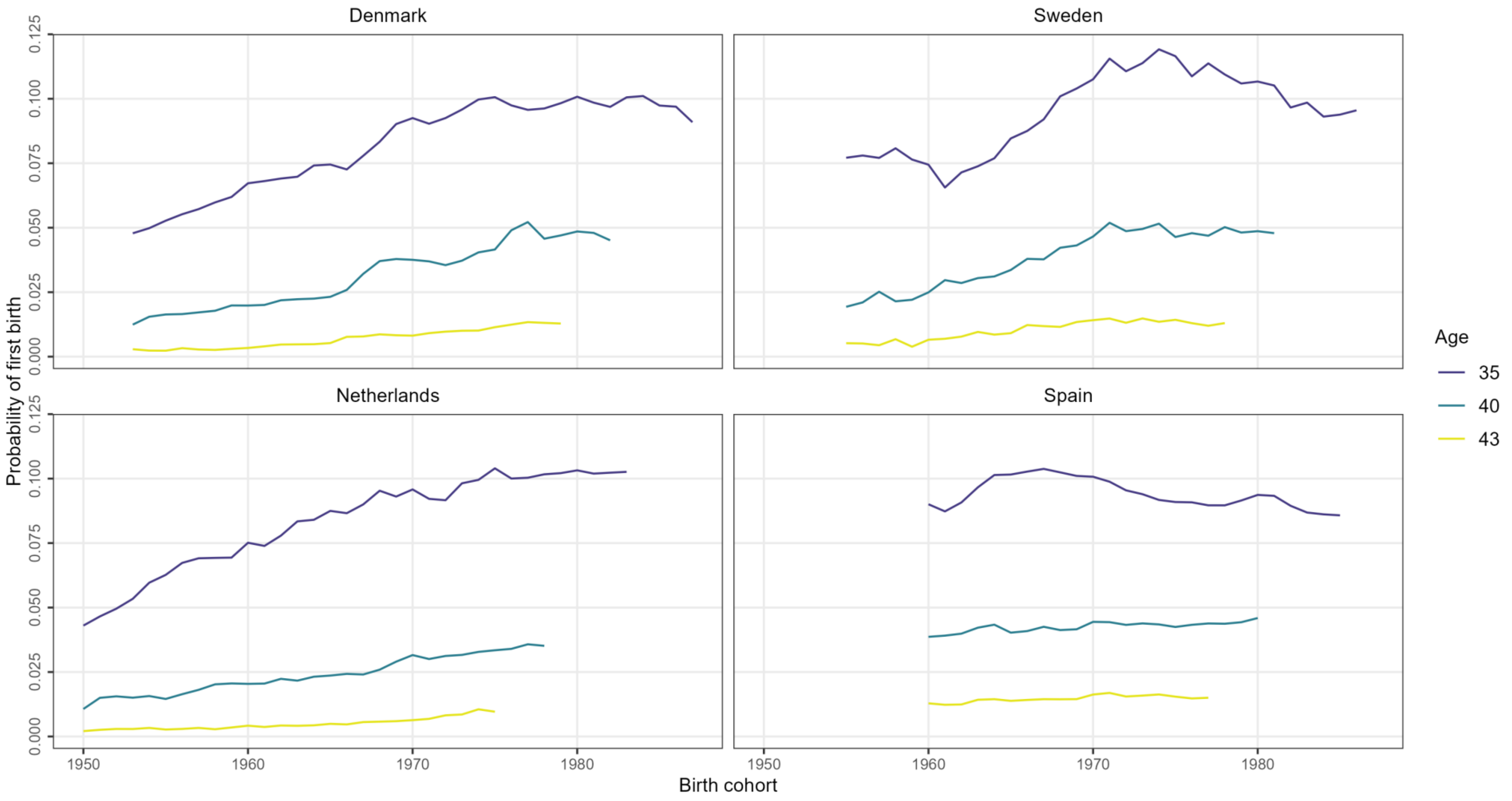
BACKGROUND:
Q1(x) schedules by age for birth cohorts 1946-1981 in selected countries



Source: Human Fertility Database

BACKGROUND:

Q1(x) at ages 35, 40 and 43 across birth cohorts



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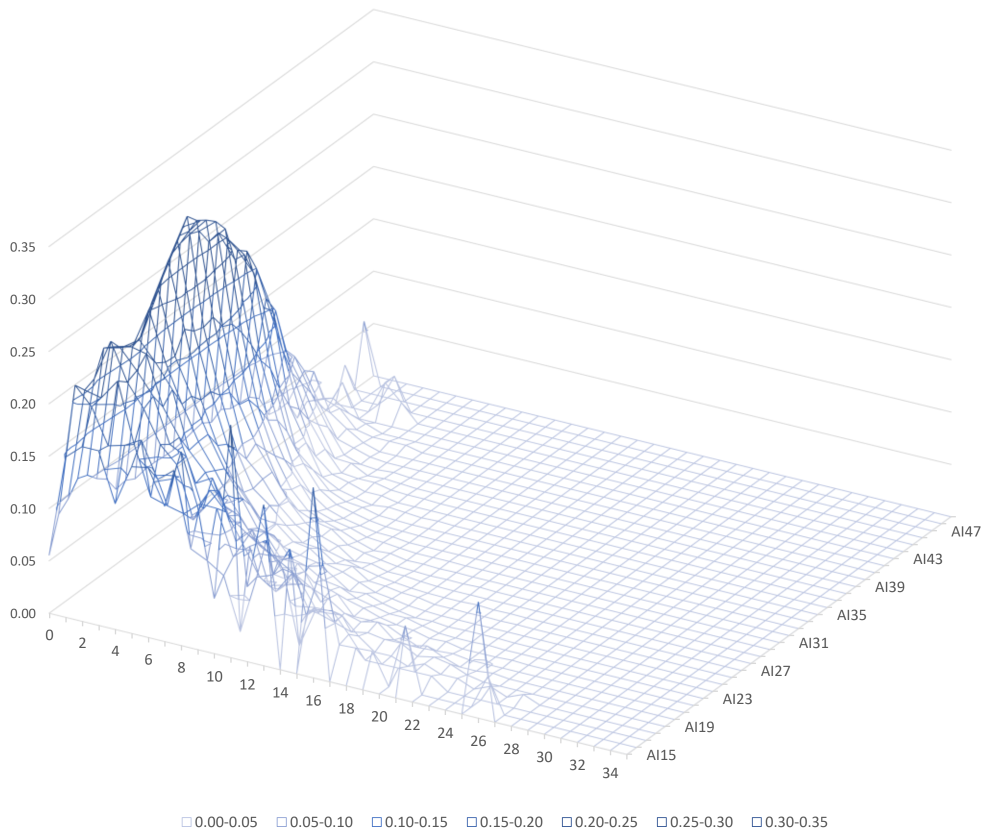
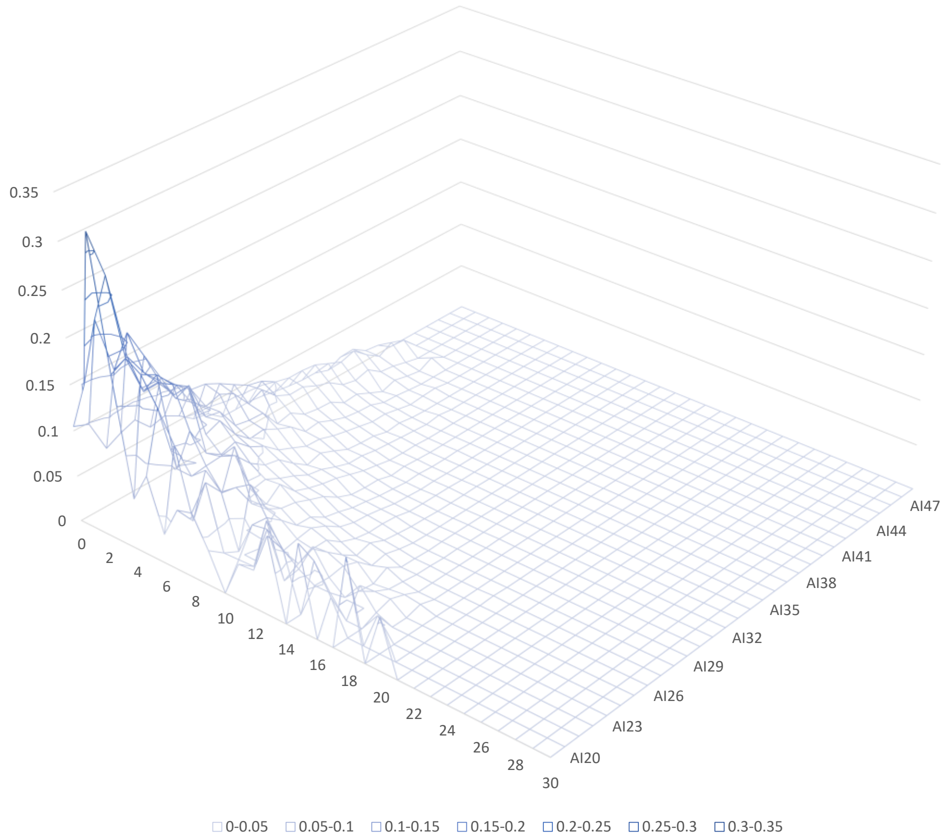
- In more recent cohorts the number of women postponing initiation of family formation until **late 20s or early 30s** has further increased:
  - leaving **shorter time frame** with lower first birth probabilities
  - first birth probabilities of having a first child at older ages have now **stabilised**
- Later ages at first birth affect probability of progression to higher-order births:
  - age at index birth affects mass and shape of q2+(x) schedules
  - margin to further compress birth intervals is limited at older ages

BACKGROUND:
Q2(x) and Q3(x) by age at index birth (AI) and duration since index birth





Source: 2011 Belgian Census & Population Register 1985-2022, Birth cohorts 1970-1972

RESEARCH QUESTION:

Quantifying effect of first birth delay on cohort completed fertility

1. A negative association between first birth delay on cohort completed fertility is generally accepted, but **quantifying the association is empirically challenging**:

   Change over time or spatial variation in timing of fertility typically coincides with variation in economic, social and cultural determinants also affecting cohort completed fertility

2. Aim is to estimate a compartimental hazard and microsimulation model which **quantifies the effects of age, parity, age at index birth, duration since index birth and interactions between these multiple clocks** for a single birth cohort

   Use the model to **simulate counterfactuals**: effect of further **translation of q1x schedule** on cohort completed fertility **under a reproductive age constraint**.

DATA AND METHODS:
Longitudinal Microdata from 2011 Census & Population Register 1985-2022

- **Birth cohort 1970-1972**:
  - observed to age 50 by December 31st 2022
  - completed fertility of 1.74 children per woman
  - Modal age of q1x schedule at 29 years
- **Omitting late entry/mortality** between ages 15-50 for model calibration
  - Limited impact on cohort completed fertility (-0.01 child/woman)
  - 176.537 women (307.904 births over 6.355.332 person-years)
  - Childlessness limited to 16.6 percent
  - Frequent progression to 2nd birth (CPPR2=0.728)
  - Lower progression to 3rd births (CPPR3=0.350) and higher-order births

DATA AND METHODS:

Compartmental hazard and microsimulation model

- **Compartmental hazard and microsimulation model** including parity dummy variables to (de)activate model compartments (demographic 'null' model):

$$
\begin{cases}
\text{P0:} & \displaystyle\int_t^{t+1} h(a)da = \begin{gathered} e^{\widehat{\alpha}}.\, e^{\widehat{\beta}.\mathrm{P0}_{ti}.\mathrm{CA}_{ti}^{1}}.\, e^{[\widehat{\beta}.P0_{ti}.CA_{ti}^{2}]}.\, e^{[\widehat{\beta}P(0)_{ti}CA_{ti}^{3}]}.\, e^{(\widehat{\beta}P(0)_{ti}CA_{ti}^{4})}. \\ .\, e^{(\widehat{\beta}P_0CA_{ti}^{5})}.\, e^{(\widehat{\beta}P_0CA_{ti}^{6})}.\, e^{(\widehat{\beta}P_0CA_{ti}^{7})}.\, e^{(\widehat{\beta}P_0CA_{ti}^{8})} \end{gathered} \\
\text{P1:} & \displaystyle\int_t^{t+1} h(a)da = \begin{gathered} e^{\widehat{\alpha}}.\, e^{\widehat{\beta}.\mathrm{P1}_{ti}}.\, e^{\sum\widehat{\beta}.\mathrm{P1}_{ti}.\mathrm{DI}_{ti}}.\, e^{\widehat{\beta}.\mathrm{P1}_{ti}.\mathrm{DI}_{ti}}.\, e^{\widehat{\beta}.\mathrm{P1}._{ti}.\mathrm{AI}_{i}^{1}}.\, e^{\widehat{\beta}.\mathrm{P1}_{ti}.\mathrm{AI}_{i}^{2}} \\ e^{\widehat{\beta}.\mathrm{P1}_{ti}.\mathrm{DI}_{ti}.\mathrm{AI}_{i}^{1}}.\, e^{\widehat{\beta}.\mathrm{P1}_{ti}.\mathrm{DI}_{ti}.\mathrm{AI}_{i}^{2}} \end{gathered} \\
 & \vdots \\
\text{P8+:} & \displaystyle\int_t^{t+1} h(a)da = \begin{gathered} e^{\widehat{\alpha}}.\, e^{\widehat{\beta}.\mathrm{P8+}_{ti}}.\, e^{\sum\widehat{\beta}.\mathrm{P4+}_{ti}.\mathrm{DI}_{ti}}.\, e^{\widehat{\beta}.\mathrm{P4+}_{ti}.\mathrm{DI}_{ti}}.\, e^{\widehat{\beta}.\mathrm{P4+}._{ti}.\mathrm{AI}_{i}^{1}}.\, e^{\widehat{\beta}.\mathrm{P4+}_{ti}.\mathrm{AI}_{i}^{2}} \\ e^{\widehat{\beta}.\mathrm{P4+}_{ti}.\mathrm{DI}_{ti}.\mathrm{AI}_{i}^{1}}.\, e^{\widehat{\beta}.\mathrm{P4+}_{ti}.\mathrm{DI}_{ti}.\mathrm{AI}_{i}^{2}} \end{gathered}
\end{cases}
$$

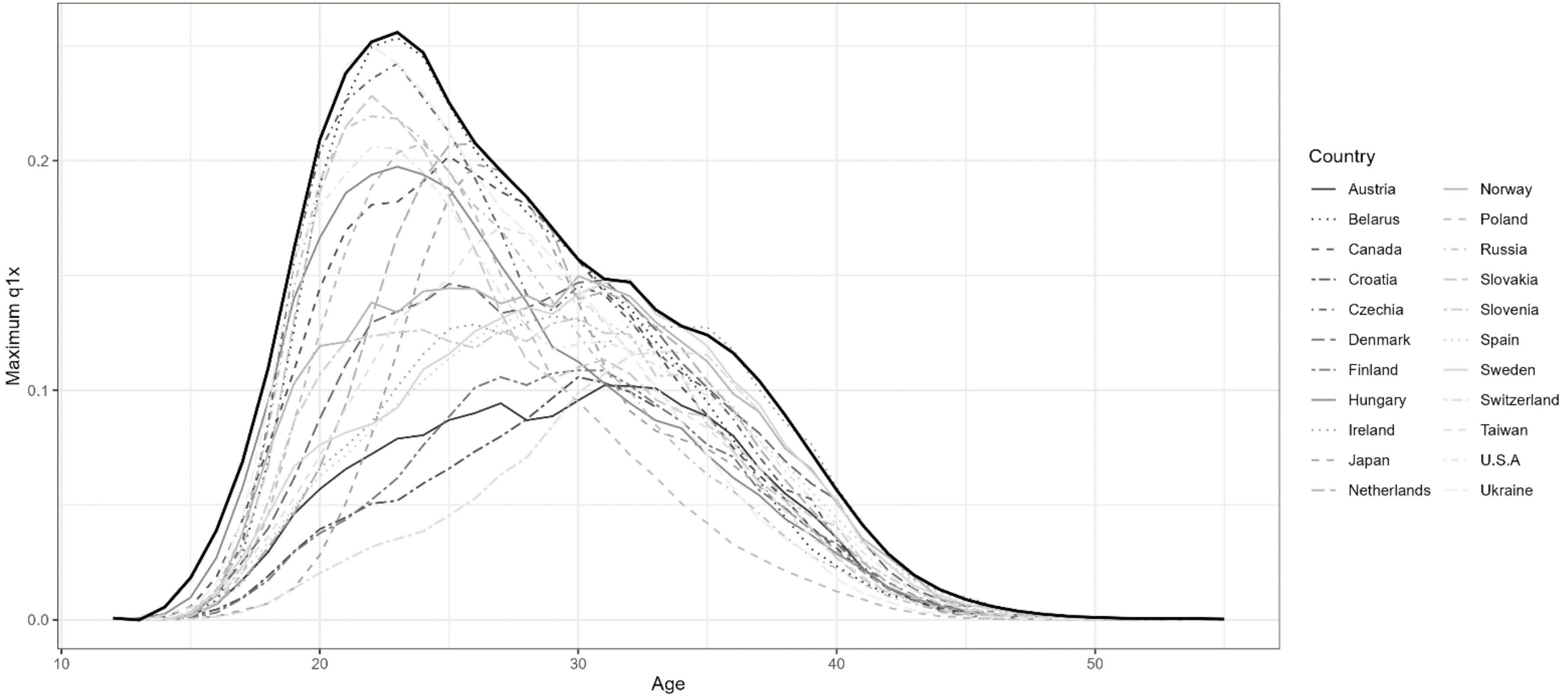
- **All parameters estimated from microdata**, without assumptions beyond model specification, and simulation outcomes are **validated** against observed patterns

DATA AND METHODS

Reproductive age-constraint based on HFD

- To assess importance of first birth delay for cohort completed fertility microsimulation model incorporates **maximum schedule of conditional first birth probabilities** drawn from cohort q1x schedules observed in **HFD**
- **Two-step derivation** of upper reproductive age:
  - Maximum of q1x across cohorts within countries (country lines)
  - Maximum q1(x) across countries (dark line)
- Maximum q1(x) schedule at later ages represents **current age constraints** on first births in **countries with advanced postponement**.
- Maximum q1(x) schedule at later ages mostly takes values from **recent cohorts**: (particularly DK, SE and IE above age 32; as well as ES, DK and NO above age 40).

DATA AND METHODS:
Reproductive age constraint

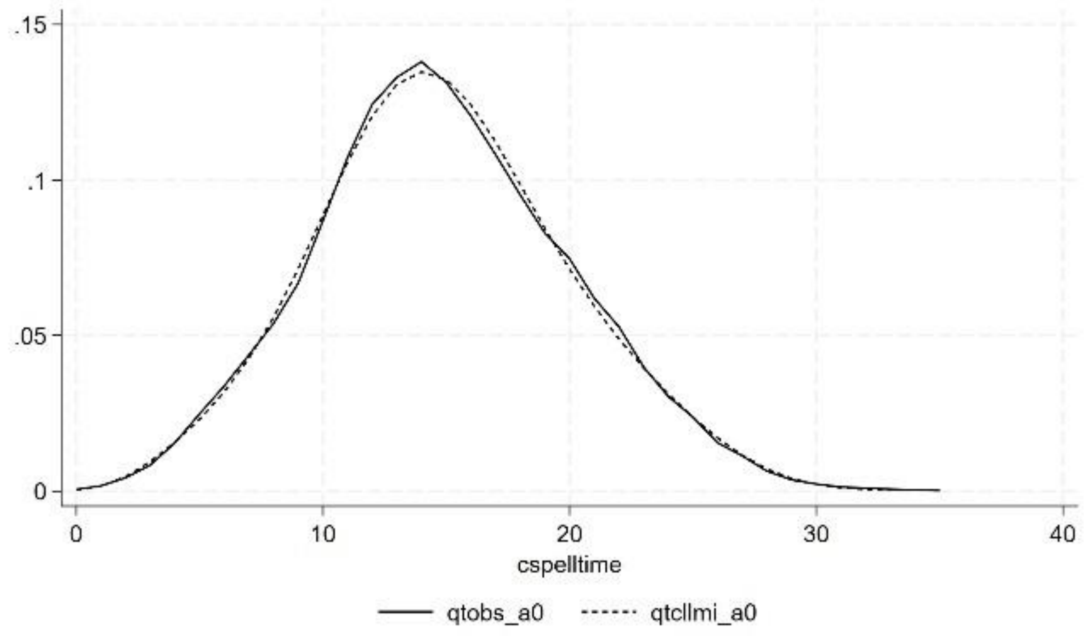


Source: Human Fertility Database

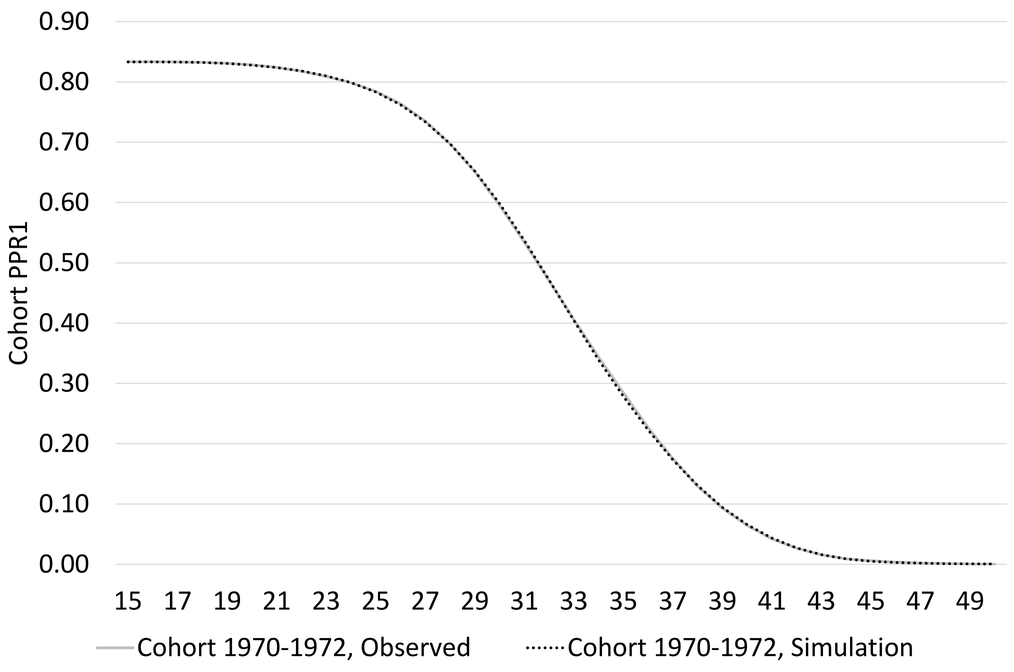
RESULTS:

Observed/Simulated q1(x) and Cohort PPR1 conditional on postponement up to age x

Observed and Simulated q1(x) schedules



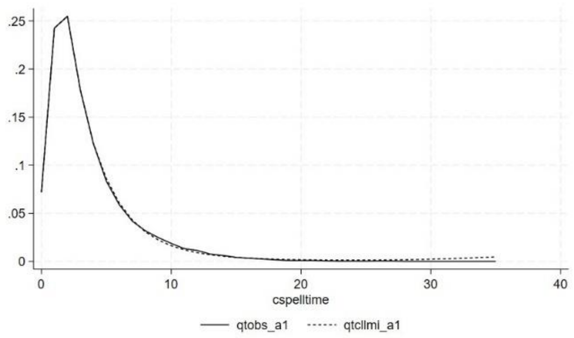
Cohort PPR1 conditional on postponement to age x



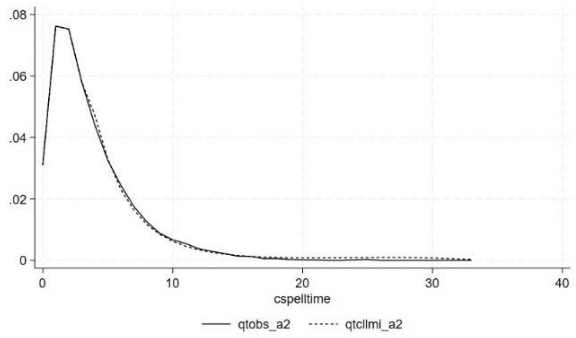
Source: 2011 Belgian Census & Population Register 2001-2022, Birth cohorts 1970-1972

RESULTS:
Observed/Simulated q1(x) to q7(x)

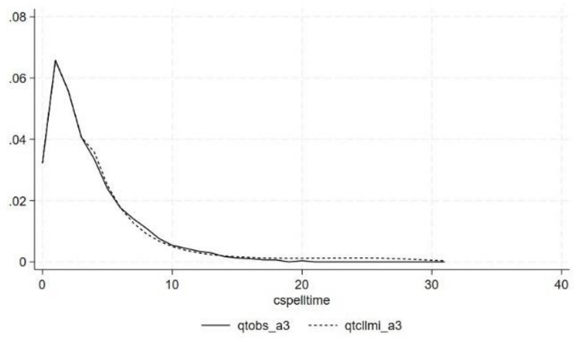
Observed and fitted q2x



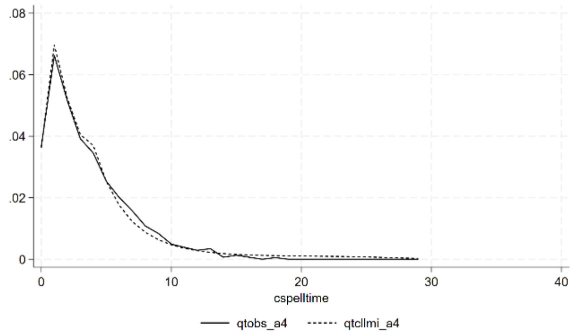
Observed and fitted q3x



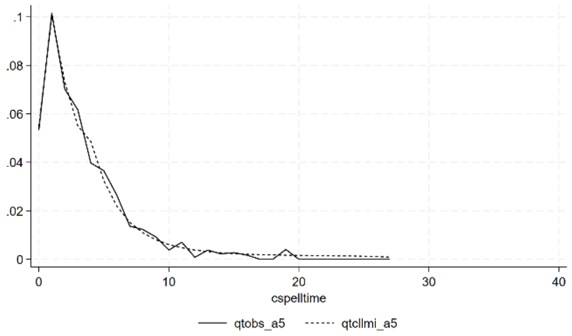
Observed and fitted q4x



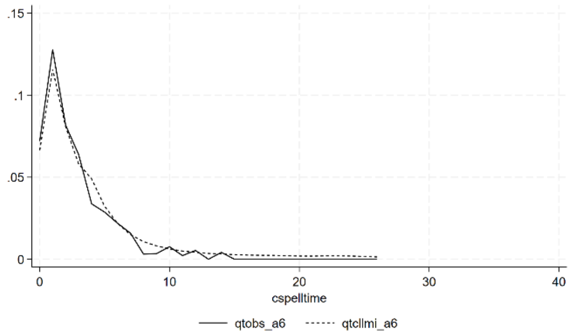
Observed and fitted q5x



Observed and fitted q6x

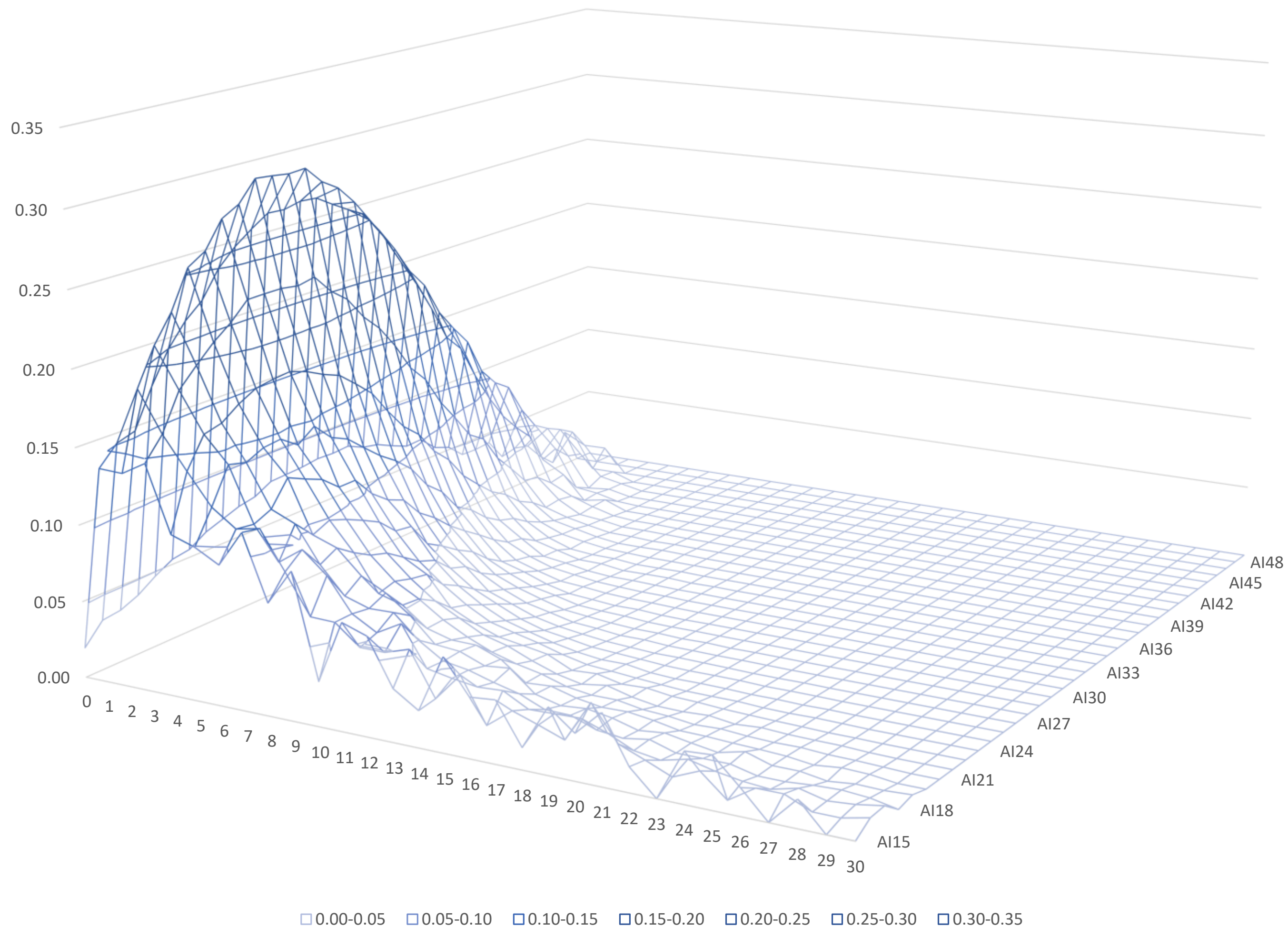


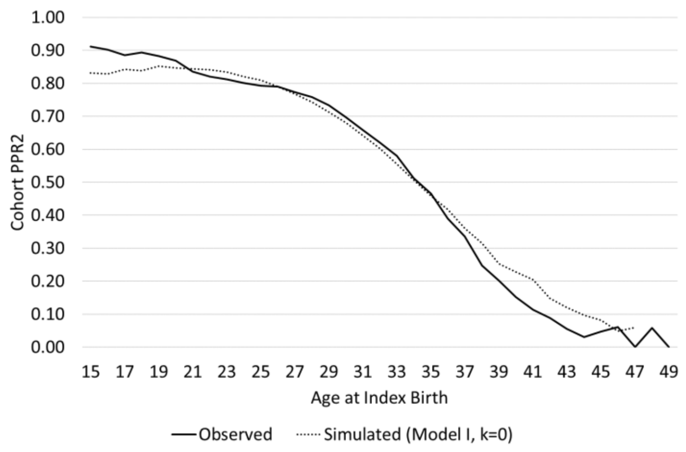
Observed and fitted q7x

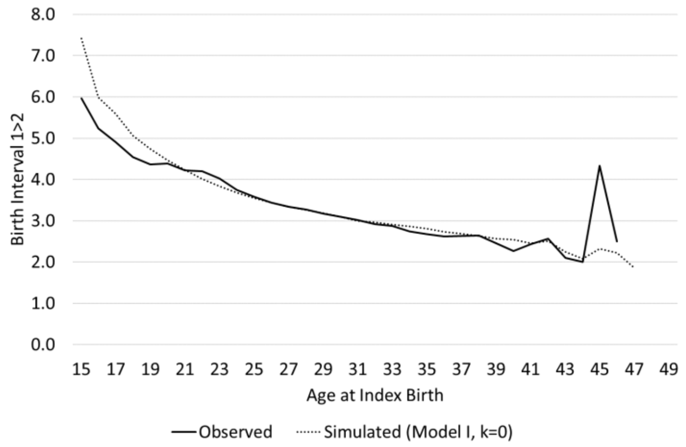


Source: 2011 Belgian Census & Population Register 2001-2022, Birth cohorts 1970-1972

RESULTS:
Cohort PPR2 and Birth Interval 1>2 by age at first birth



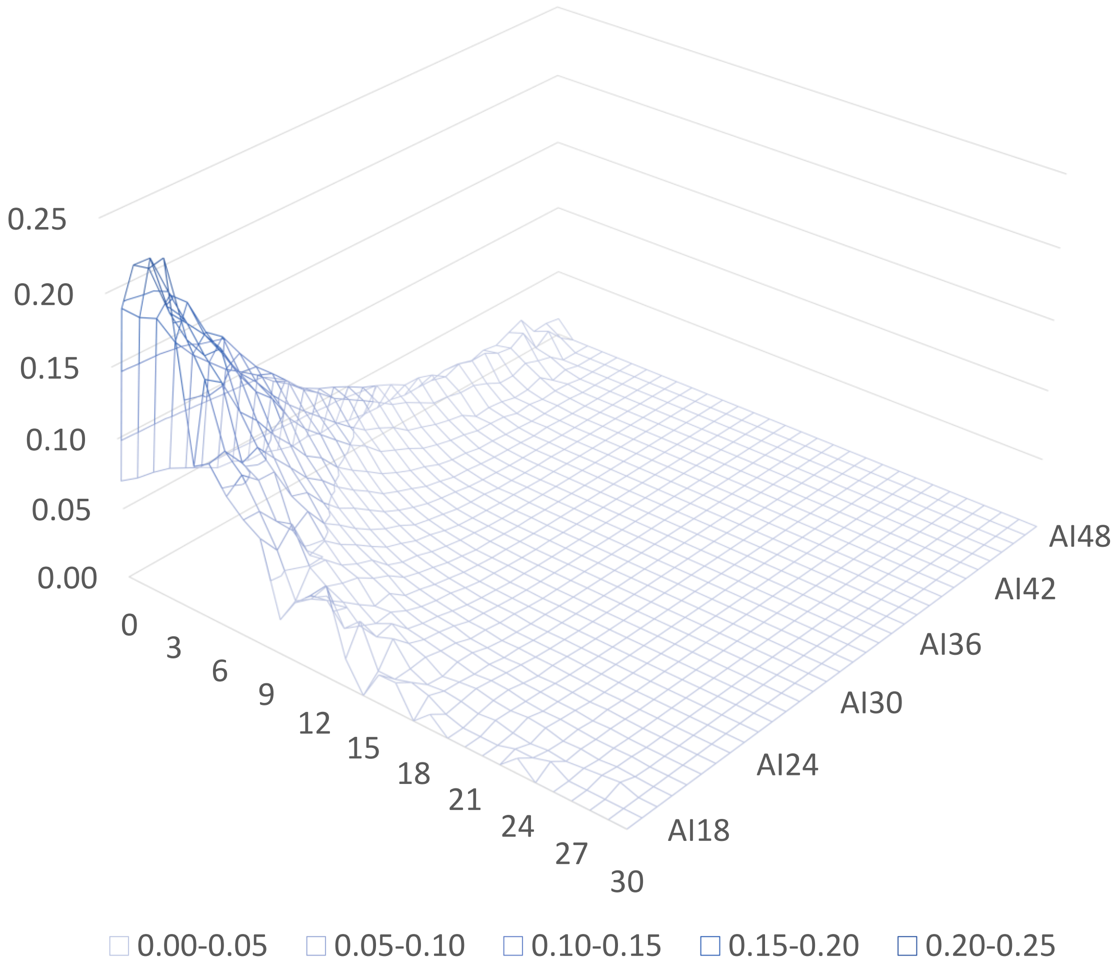


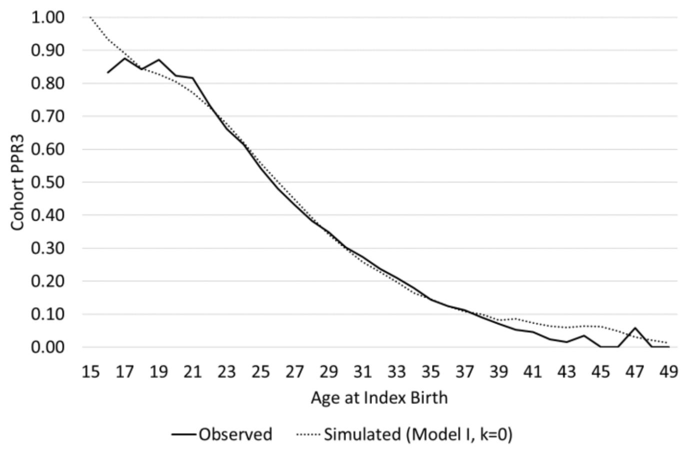


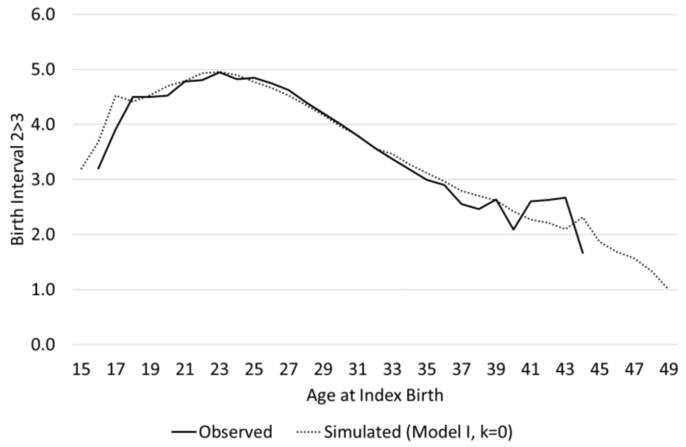
Source: 2011 Belgian Census & Population Register 2001-2022, Birth cohorts 1970-1972

RESULTS:

Cohort PPR3 and Birth Interval 2>3 by age at second birth



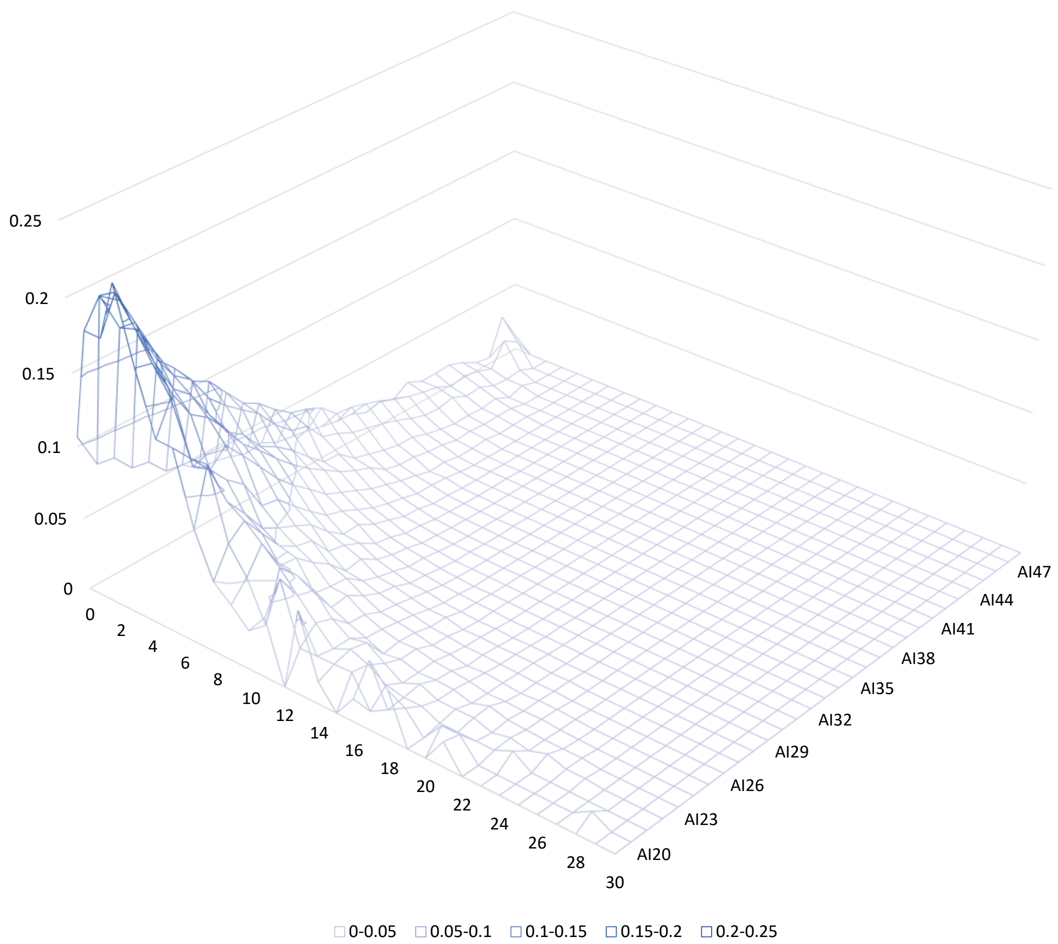


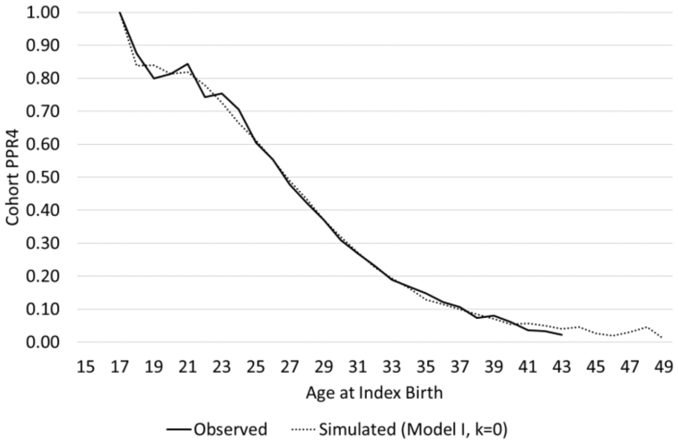


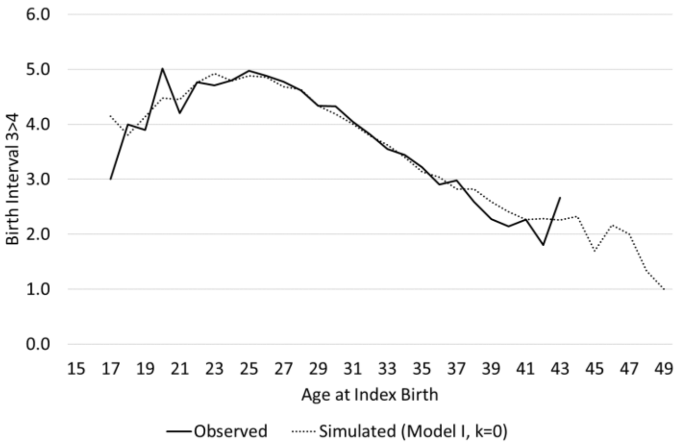
Source: 2011 Belgian Census & Population Register 2001-2022, Birth cohorts 1970-1972

RESULTS:

Cohort PPR4 and Birth Interval 3>4 by age at third birth







Source: 2011 Belgian Census & Population Register 2001-2022, Birth cohorts 1970-1972

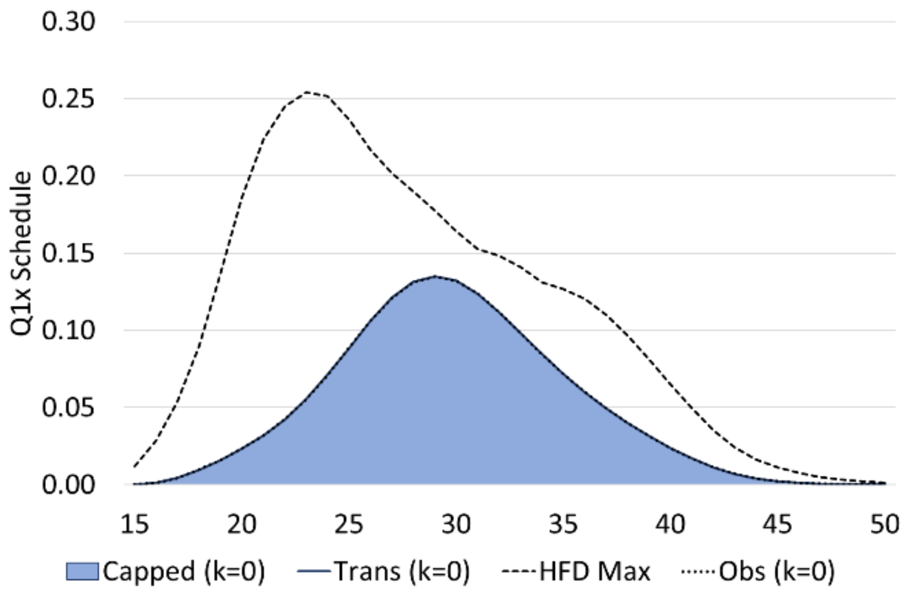
RESULTS

Continued postponement and completed fertility under reproductive age constraint

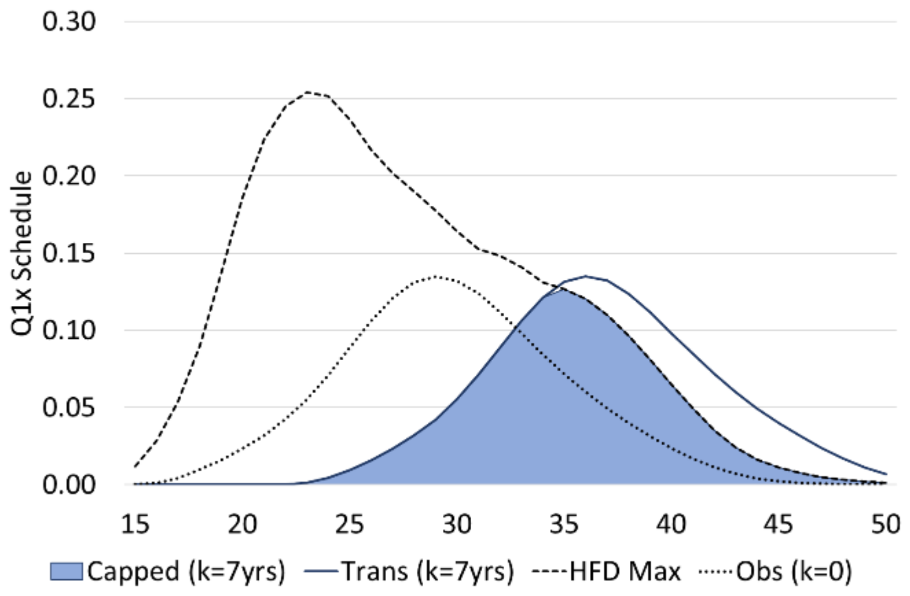
Translation of q1(x)-schedule to later ages by 1 to 10 years with q1(x)’ at later ages increasingly being capped to the values observed in the HFD maximum:

$$q1(x)' = q1(x-k) \leq max\ q1(x)_{HFD}$$

Observed q1(x) schedule



Translated/capped q1(x)’ schedule (k=7 yrs)



RESULTS

Continued postponement and completed fertility under reproductive age constraint

Cohort TFRi obtained by translation of observed q1(x)-schedule by 1-10 years with q1(x)' at later ages increasingly capped to values in maximum HFD-schedule:

	Obs	**1 yr**	**2 yrs**	**3 yrs**	**4 yrs**	**5 yrs**	**6 yrs**	**7 yrs**	**8 yrs**	**9 yrs**	**10 yrs**
CTFR1	0.833	0.833	0.833	0.833	0.827	0.811	0.783	0.750	0.714	0.674	0.630
CTFR2	0.604	0.583	0.560	0.534	0.505	0.471	0.433	0.393	0.353	0.314	0.275
CTFR3	0.213	0.188	0.164	0.142	0.122	0.104	0.087	0.073	0.060	0.049	0.040
CTFR4	0.063	0.050	0.040	0.031	0.024	0.019	0.014	0.011	0.008	0.006	0.004
CTFR5	0.019	0.014	0.010	0.007	0.005	0.004	0.003	0.002	0.001	0.001	0.001
CTFR6	0.006	0.005	0.003	0.002	0.001	0.001	0.001	0.000	0.000	0.000	0.000
CTFR7	0.003	0.002	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CTFR8	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CTFR9	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CTFR10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CTFR	1.742	1.676	1.612	1.551	1.486	1.409	1.320	1.228	1.136	1.044	0.949

Continued postponement and completed fertility under reproductive age constraint

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CTFR7	0.003	0.002	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CTFR8	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CTFR9	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CTFR10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
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CONCLUSIONS
Continued first birth dealy and cohort completed fertility

- Microsimulation model only considered **demographic variables** (age, parity, age at index birth, duration since index birth and interactions between these clocks) in tandem with a **reproductive age constraint** to simulate impact of continued first birth delay on childlessness, parity progression and cohort completed fertility
- Translation of cohort q1(x) schedule past modal age of 29 is associated with **strong reductions in cohort completed fertility** through **reduced parity progression** up to age 33 (-0.07 child/year), and further accelerates after age 34 as a result of **increasing childlessness** (-0.09 child/year)
- Modelling postponement through translation of q1(x) schedule preserves **population heterogeneity in ages at first birth**, resulting in slower reduction of cohort completed fertility with first birth delay than declines in cohort completed fertility **conditional on first birth delay up to given age**.

CONCLUSIONS

Continued first birth dealy and cohort completed fertility

- Results of first birth delay and cohort completed fertility cannot readily be transposed to **period mean ages at childbearing and period TFR** as the latter do not adequately control for parity structure and the interaction between multiple clocks, and are typically **deflated compared to cohort completed fertility** in case of postponement
- Compartmental hazard and microsimulation model allows to **consistently model cohort completed fertility** using a single equation, and **assess impact of economic, social and cultural determinants** on timing and/or intensity of entry into parenthood, progression to higher-order births, birth intervals and completed fertility

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Karel NEELS
Centre for Population, Family & Health, University of Antwerp

Eva BEAUJOUAN
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