Childbearing Postponement, its Option Value, and the Biological Clock

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Motivation: Having a child is a risky project

Having a child is risky: future income, spending & utility flow more uncertain

Uncertain career cost

- atrophy of skills due to random interruptions [Adda et al., 2017]
- cases of lost earnings opportunities, lower wages [Miller, 2011]
- possibility of discrimination [Correll et al., 2007]
- Increase in sickness absences [Angelov et al., 2013]

→ **New notion**: risk opportunity cost

But also:

Childrearing reduces women's social network size and alters composition of men's network [Munch et al., 1997]

Long-term health consequences of childbearing (urinary incontinence, weight gain, etc.)

Having a baby causes substantial declines in the average couple's relationship [Doss et al., 2009]

Maternal mortality risk [Albanesi and Olivetti, 2016]

Pattern reinforced when children have special needs (such as visual or hearing impairment, mental retardation)

Research question

Literature: focus on first-order moments – effect of having a child on mean wage, on employment rate, etc.

Does not fully acknowledge the risk aspect. Stochastic models do not explicitly make risk depend on motherhood [Sheran, 2007]

One paper focuses on exogenous income risk and procreation timing [Sommer, 2016] but risk $\perp$ procreation

This paper: risk depends on procreation and it matters for optimal age at childbearing

Question: how to model increased risk? do we find it in the data? how big it is and does it matter for choices?

Idea: using option theory

Having a child is both irreversible and risky
$\rightarrow$ waiting has a value [Dixit and Pindyck, 1994]:

$$\text{option value} = (1)\ \text{option value for receiving information} + (2)\ \text{pure postponement value}$$

The riskier the project, the worthier it is to wait, even when $(1)=0$

The postponement value increases with risk.
It interacts with fecundity (the biological clock) & assisted procreation

What we do

1. A Theory where motherhood increases risk

   Parsimonious model – Can be solved explicitly
   Highlights how uncertainty & fecundity $\rightarrow$ timing of first birth
   Three types of childlessness: voluntary, natural, postponement

2. Quantitative analysis

   Identify structural parameters from NLSY79 data
   Mothers face higher income risk than childless
   Gap in risk between mothers and childless $\nearrow$ with education
   [explains why educated have children later]

3. Policy analysis

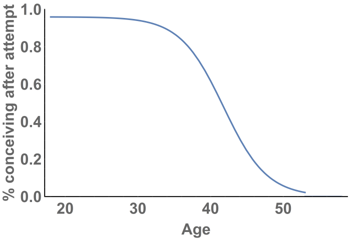
   Medically assisted procreation
   Hypothetical insurance against motherhood related risks

Model – Procreation technology

τ: age at pregnancy attempt (choice)

$\pi(\tau)$: probability to be mother

$\pi(\cdot)$ is decreasing in age τ and depends on medical technology.



Attempts succeed instantly or never (more than 75% of all pregnancies happen within a year of the attempt)

$$\text{Age at first birth: } \theta = \begin{cases} \tau & \text{with proba.} \pi(\tau) \\ +\infty & \text{with proba.} 1 - \pi(\tau) \end{cases} \tag{1}$$

Natural sterility rate: $1 - \pi(0)$

Menopause: age t^m such that $\pi(t) = 0$ for all $t \geq t^m$.

Model – Asset and goods

A representative household with one parent

Initial stock of composite asset: a_0

- Physical capital (house, financial)
- Experience capital

Composite consumption good c_t, including physical goods and leisure

Asset dynamics follow Itô's processes:

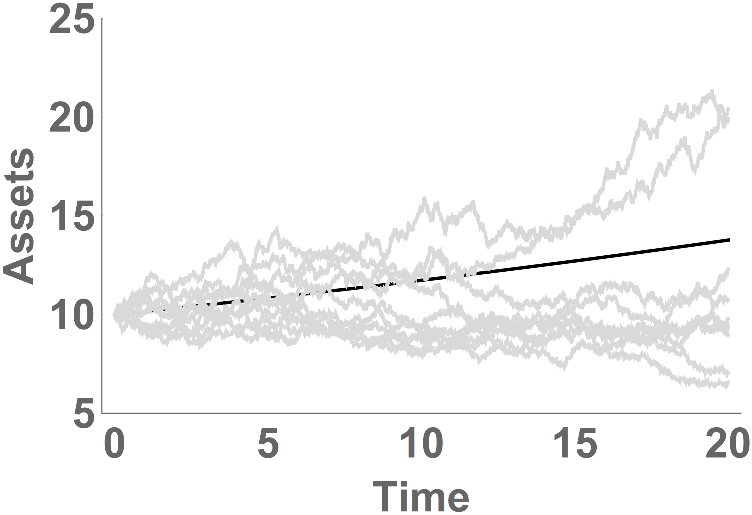
$$da_t = \begin{cases} (r_1 \, a_t - c_t)dt & \text{if } t \leq \theta \\ (r_2 \, a_t - c_t)dt + \sigma \, a_t \, dz_t & \text{otherwise} \end{cases} \tag{2}$$

σ: uncertainty from being a mother.

dz_t is a Wiener process (Brownian motion). $\mathbb{E}[dz_t] = 0$, $\mathrm{var}[dz_t] = dt$

Example of asset processes

Black: childless. Gray: mothers.



Model – Preferences

Utility:

$$\int_0^\infty u(c_t)\, e^{-\rho t} dt + e^{-\rho\theta}\omega$$

ω is the lump-sum utility (joy) of having children, and ρ is the psychological discount rate

CRRA utility function:

$$u(c_t) = \frac{c_t^{1-\varepsilon}}{1-\varepsilon}$$

$\varepsilon > 1$: the coefficient of relative risk aversion

Choices:

$$\underset{c_t, a_t, \tau}{\arg\max}\ \mathbb{E}\left[\int_0^\infty u(c_t)\, e^{-\rho t} dt + e^{-\rho\theta}\omega\right]$$

subject to (1), (2).

Model – Methodology

The problem has to be solved recursively:

[A] We first consider the post-birth program, once the pregnancy attempt has proven successful. (Stochastic optimal control [Turnovsky, 2000]) Consumption follows

$$c_t = qa_t, \ \ \forall t \geq \tau$$

with the propensity to consume out of wealth given by

$$q = \frac{\rho - (1-\varepsilon)\left(r_2 - \frac{\varepsilon}{2}\sigma^2\right)}{\varepsilon}$$

This delivers a utility $W_2(a_\tau)$ at a date τ with probability $\pi(\tau)$:

$$W_2(a_\tau) = q^{-\varepsilon}\frac{a_\tau^{1-\varepsilon}}{1-\varepsilon} + \omega.$$

[B] We also consider the case when the attempt turned unsuccessful. (Standard optimal control)
Consumption follows

$$c_t = pa_t,$$

where the propensity to consume p is

$$p = \frac{\rho - (1-\varepsilon)r_1}{\varepsilon}.$$

We have $p > q$ as $\varepsilon > 1$.
This delivers a utility $W_1(a_\tau)$ at a date τ with probability $1 - \pi(\tau)$:

$$W_1(a_\tau) = p^{-\varepsilon}\frac{a_\tau^{1-\varepsilon}}{1-\varepsilon}. \tag{3}$$

[C] Finally we study the program starting from the beginning of the adult life, which includes the optimal choice of τ.
(Optimal control with optimal regime switching [Boucekkine et al., 2013])

The full maximization program can be written as:

$$W(a_0) = \max_{\{c_t,\tau,a_t\}} \int_0^{\tau} u(c_t)e^{-\rho t}dt + \varphi(\tau, a_\tau)$$

$$\begin{aligned} \text{where } \varphi(\tau, a_\tau) &= e^{-\rho\tau}\left[\pi(\tau)W_2(a_\tau) + (1-\pi(\tau))W_1(a_\tau)\right] \\ \text{subject to } &: \dot{a}_t = r_1\ a_t - c_t \ \text{ and } \ a_0 \text{ given} \end{aligned}$$

This problem is time consistent (exponential discounting)

Part of the value $W(a_0)$ comes from the possibility of trying and giving birth. The value of having this possibility:

$$\text{value of giving birth} = W(a_0) - W_1(a_0),$$

$$\text{option value of giving birth} = \text{value of giving birth} - \pi(0)W_2(a_0),$$

Solving the full maximization program

Define the following Hamiltonian:

$$H(c, a, \mu) = U(c)e^{-\rho t} + \mu\,(r_1\; a - c)$$

The value-function $W(a_0)$ in terms of the Hamiltonian $H(\cdot)$:

$$W(a_0) = \int_0^{\tau} (H(c_t, a_t, \mu_t) - \mu_t\; \dot{a}_t)\, dt + \varphi(\tau, a_\tau)$$

First-Order Conditions

$$
\begin{aligned}
\frac{\partial H(c_t, a_t, \mu_t)}{\partial c_t} &= 0, \\
\frac{\partial H(c_t, a_t, \mu_t)}{\partial a_t} + \dot{\mu}_t &= 0, \\
H(c_\tau, a_\tau, \mu_\tau) + \frac{\partial \varphi(\tau, a_\tau)}{\partial \tau} &= 0, \\
\frac{\partial \varphi(\tau, a_\tau)}{\partial a_\tau} - \mu_\tau &= 0.
\end{aligned}
$$

The first two conditions are the standard Pontryagin conditions.

The third one equalizes the marginal benefit of waiting to the marginal cost of waiting.

The last one is a continuity condition.

These conditions are necessary but not sufficient for an interior maximum.

Result – asset accumulation in anticipation of birth

Marginal propensity to consume the asset before the pregnancy attempt at given τ:

$$s(\tau) = \left(\pi(\tau) q^{-\varepsilon} + (1 - \pi(\tau)) p^{-\varepsilon}\right)^{-1/\varepsilon}$$

Proposition

The higher the success rate $\pi(\tau)$ the lower $s(\tau)$.

Women planning to have a child accumulate more assets

- Smooth consumption facing future drop in income ($r_2 < r_1$)
- Precautionary motive: to ensure against shocks which follow birth.

Result – uncertainty and birth postponement

Proposition

High enough uncertainty leads to birth postponement:

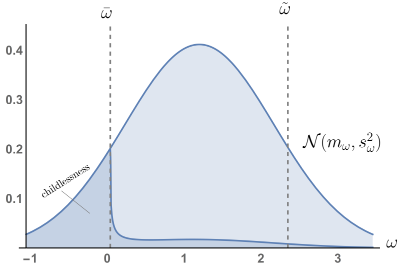
- ◇ *For* $r_2 = r_1$, $\omega > 0$ *and* $\sigma = 0$, *having a child has no cost.* $\tau^* = 0$ *i.e. it is then optimal to attempt to get pregnant as soon as possible.*
- ◇ *For* $r_2 = r_1$, *there exists a value* $\underline{\sigma} > 0$ *such that* $\sigma > \underline{\sigma} \Leftrightarrow \tau^* > 0$, *i.e. it is optimal to postpone birth.*
- ◇ *For* $r_2 = r_1$, *there exists a value* $\bar{\sigma} \geq 0$ *such that* $\sigma > \bar{\sigma} \Leftrightarrow \tau^* > t^m$, *i.e. it is optimal to postpone forever.*

Result – how to think about childlessness

Suppose $\omega \sim \mathcal{N}(m_\omega, s_\omega^2)$.

Three types of childlessness

1. voluntary childlessness $\tau \geq t^m$
2. natural sterility, because $\pi(0) < 1$
3. postponement childlessness: $[1 - \pi(\tau)] - [1 - \pi(0)] > 0$ for $\tau > 0$



Proposition

There exists a unique level $\bar{\omega}$ such that: $\omega \leq \bar{\omega} \Leftrightarrow \tau \geq t^m$

There exists a unique level $\tilde{\omega}$ such that: $\omega \geq \tilde{\omega} \Leftrightarrow \tau = 0$

These two levels are such that $\bar{\omega} < \tilde{\omega}$.


Let us move now to
the quantitative analysis

Quantitative analysis – Identification – Summary

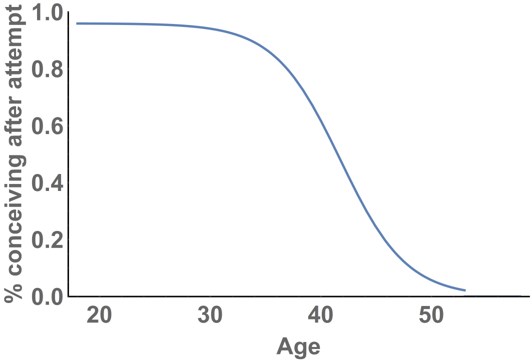
	Parameter	value	target
a_0	initial wealth	20	scaling factor
ρ	subjective time discount rate	2%	fixed *a priori*
ϵ	relative risk aversion	6	fixed *a priori*
$\pi(t)$	success rate of pregnancy attempt		[Léridon, 2005]
r_1	return on assets $\mid$ childless	Tab.1	income growth – NLSY79
r_2	return on assets $\mid$ mothers	Tab.1	income growth – NLSY79
σ	std. dev. of Wiener process	Tab.1	income range – NLSY79
m_ω	mean of the distribution of ω	2.143	mean age 1^{st} birth (cat. (7)) – NLSY79
s_ω	std. dev. of the distri. of ω	2.450	childlessness rate (cat. (7)) – NLSY79

Quantitative analysis - fecundity

Age 0 is age 18 in the data. $\pi(t) = 0$ for $t > t^m = 35$ (i.e. 53 years)

$$\pi(t) = \frac{a \exp(b - ct)}{d + \exp(b - ct)} \text{ for } t < t^m$$

We set a, b, c, d to minimize distance between theoretical function and data [Léridon, 2005] + assume infertility = 4% at 18.



Quantitative analysis - NLSY79

National Longitudinal Survey of Youth | 1979

Longitudinal project that follows the lives of a sample of American youth born between 1957-64.

The cohort originally included 12,686 respondents ages 14-22 when first interviewed in 1979.

Data are now available from Round 1 (1979 survey year) to Round 25 (2012 survey year).

We take all women with positive income, consider their income from age 39-45.

Quantitative analysis - education categories

Education category	Number of observations	Mean years of education	Mean age first birth	Percentage childless
Low education (1)	251	7.77	18.24	8.76
Less than high school (2)	300	10.52	19.34	7.00
High school compl. (3)	1868	12	21.70	12.15
Some college (4)	454	13	22.44	14.1
Some college (5)	469	14	24.38	20.04
Some college (6)	248	15	25.28	20.56
College completed (7)	551	16	27.64	24.32
More than college (8)	336	17.94	28.71	31.25
All	4477	13.08	22.93	16.04

Quantitative analysis - income growth

Calibrate r_1, r_2, σ, possibly different across education groups

Income is proportional to assets

Measure the growth rate of income between 39 and 45

Observe g_1 and g_2, infer r_1 and r_2 using:
for mothers:

$$g_2 + 1 \equiv \mathbb{E}\frac{a_t}{a_\tau} = e^{(r_2 - q)(t-\tau)}$$

For childless or sterile:

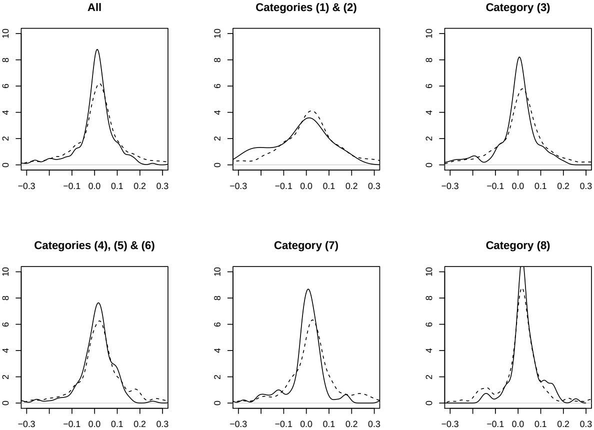
$$g_1 + 1 \equiv \frac{a_t}{a_\tau} = e^{(r_1 - p)(t-\tau)}$$

(this is all after the procreation attempt)

Need also σ

Quantitative analysis - income growth (2)

Infer σ from the additional dispersion in income growth among mothers



Kernel Density Estimations of income growth distribution. Childless Women (solid) and Mothers (dashed)

Quantile Regressions

In practice:
Quantile regressions with growth of income as dependent variable, and education, motherhood as independent variables

$\hat{g}_1 = Q(0.50) \mid \text{childless}$ $\qquad$ $\hat{\sigma}_1^2 = \frac{Q(0.93) - Q(0.07)}{3} \mid \text{childless}$

$\hat{g}_2 = Q(0.50) \mid \text{mother}$ $\qquad$ $\hat{\sigma}_2^2 = \frac{Q(0.93) - Q(0.07)}{3} \mid \text{mother}$

Quantile Regressions

	Dependent variable: income growth between 39 and 45			
	OLS	$Q(0.07)$	$Q(0.50)$	$Q(0.93)$
Mothers				
Constant	0.0720^{***}	-0.1891^{***}	0.0481^{***}	0.4757^{***}
	(0.0265)	(0.0580)	(0.0152)	(0.0652)
years of educ.	0.0005	0.0052	0.0000	-0.0063^{*}
	(0.0013)	(0.0034)	(0.0006)	(0.0034)
Observations	2,705	2,705	2,705	2,705
Childless women				
Constant	-0.0834^{*}	-0.5680^{***}	0.0259	0.1131^{*}
	(0.0491)	(0.0902)	(0.0429)	(0.0654)
years of educ.	0.0056^{***}	0.0191^{***}	0.0024^{***}	-0.00001
	(0.0020)	(0.0051)	(0.0009)	(0.0038)
Observations	530	530	530	530

Fixed effects for Race, Year of birth
for ever married, and for separated at 39

Quantile Regressions

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Education helps to reduce the occurrence of bad outcomes.
This "protecting" effect is stronger for childless than for mothers

Quantitative analysis - Calibration of r_1, r_2 and σ

Education	$\hat{\sigma}_2^2$	$\hat{\sigma}_1^2$	$\sigma = \sqrt{\hat{\sigma}_2^2 - \hat{\sigma}_1^2}$
$\vdots$			
3	0.01511	0.01157	0.059
$\vdots$			
7	0.01157	0.00674	0.069
$\vdots$			

Education	$\hat{g}_2$	$\hat{g}_1$	r_2	r_1
$\vdots$				
3	0.0212	0.00786	0.094	0.067
$\vdots$				
7	0.0212	0.01746	0.075	0.124
$\vdots$				

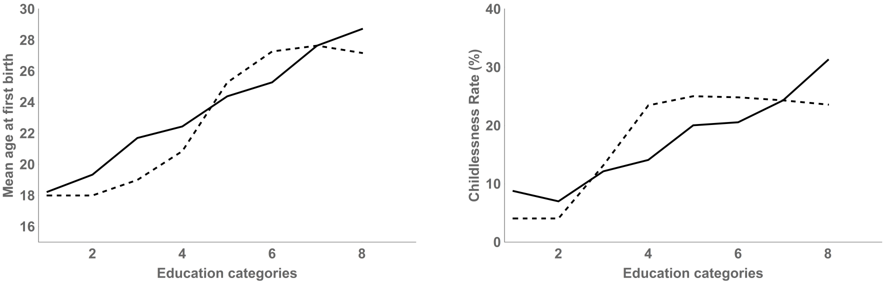
Quantitative analysis - Calibration of ω

Exact identification: Parameters of the normal distribution function $\mathcal{N}(m_\omega, s_\omega^2)$ set to match the mean age at first birth and the childlessness rate of the education category 7 (27.64 years and 24.32%).

It yields $m_\omega = 2.143$ and $s_\omega = 2.450$

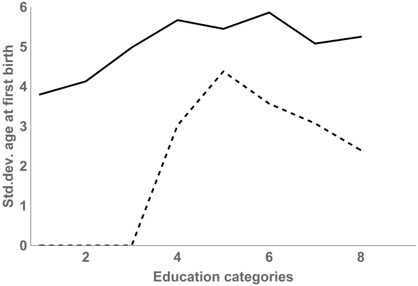
Quantitative analysis - Overidentification tests

Idea: check predictions about features not used to calibrate the model



Education Gradient - data:solid, simulated: dashed

Overidentification tests - more



Education Gradient - data:solid, simulated: dashed

Simulations - decomposition of childlessness

For High school completed (3). The total childlessness rate of 13.18% includes:

9.02% of voluntary childlessness,

3.52% of natural sterility,

0.16% of postponement childlessness,

and 0.48% of sterile women not wanting children.

For College completed (7). The total childlessness rate of 24.32% includes:

18.57% of voluntary childlessness,

3.07% of natural sterility,

1.75% of postponement childlessness,

and 0.93% of sterile women not wanting children.

Simulations

1) hypothetical insurance

We simulate optimal choices when $\sigma = 0$, i.e. become a mother does not entail higher risks

2) Medically assisted procreation

Making people 3 years younger: $\pi(t) = \pi(t-3)$

Strong changes - estimating upper bounds

Effect of policy on fertility timing choices, by education category

	education	perfect insurance	assisted procreation
Δ age at first birth	3	0.00	0.20
	7	-3.00	0.81
Δ childlessness rate	3	-0.96	-1.03
	7	-0.96	-1.86

Transfer policy

Wealth transfer to be received at motherhood to compensate the effect of uncertainty

$$W_2(a_\tau + T) = W_2(a_\tau)_{\sigma=0}.$$

Therefore,

$$T = a_\tau((q/q_{\sigma=0})^{\frac{\varepsilon}{1-\varepsilon}} - 1).$$

Normalizing the transfer in favor of the lowest education group to 1,
the transfer is equal to 2.89 for women with less than high school,
4.08 for high school graduates,
7.65 for college graduates,
and 9.03 for the highest group with more than college.

Strongly anti-redistributive.

Robustness to ρ and ε

Recalibration effect:
returns r_1 and r_2 as a function of observables depend on ε
$r_1 > r_2$ and $r_1 < r_2 + 0.06 \rightarrow \varepsilon \in (2.55, 6.42)$

Behavioral effect:

Parameters		Overidentifying tests: corr sim. with observed			Policy $\sigma = 0$		Policy $\pi^{\text{new}}(t) = \pi(t-3)$	
ρ	ε	E τ	cln	std. τ	Δ τ	Δ cln	Δ τ	Δ cln
0.02	4	0.96	0.83	0.75	-1.98	-0.99	+0.96	-1.95
0.02	5	0.95	0.82	0.83	-2.49	-1.14	+0.91	-2.04
0.02	**6**	**0.94**	**0.80**	**0.82**	**-3.00**	**-0.96**	**+0.81**	**-1.86**
0.02	7	0.94	0.76	0.86	-3.41	-1.10	+0.77	-1.96
0.01	6	0.94	0.79	0.84	-2.93	-0.97	+1.01	-1.91
0.02	**6**	**0.94**	**0.80**	**0.82**	**-3.00**	**-0.96**	**+0.81**	**-1.86**
0.04	6	0.94	0.79	0.82	-2.98	-1.70	+0.73	-2.18
0.06	6	0.94	0.79	0.84	-2.93	-0.97	+0.72	-2.54

Robustness to sample selection

Limit sample to married women

Remove from sample teenage mothers (to avoid endogeneity with education)

Control for number of kids

Sample		Overidentifying tests: corr sim. - observed			Policy $\sigma = 0$		$\pi^{\text{new}}(t) = \pi(t-3)$	
	Nobs	E τ	cln	std. τ	Δ τ	Δ cln	Δ τ	Δ cln
All	**4477**	**0.94**	**0.80**	**0.82**	**-3.00**	**-0.96**	**+0.81**	**-1.86**
Married	3761	0.94	0.89	0.59	-2.90	-1.83	+0.88	-1.67
No teenage mother	4304	0.90	0.74	0.84	-3.09	-1.12	+0.83	-1.33
Controlling # kids	4477	0.93	0.87	0.65	-2.44	-1.27	+0.95	-1.96

Note: 'cln' = childlessness rate

Fit slightly worse, but policy conclusions are robust

Non-married women and teenage mothers seem to be part of our story

Conclusion

A parsimonious model where giving birth increases income risk

all the more so for highly educated people

This may explain why highly educated postpone fertility more

Confirmed by quantitative analysis using NLSY79 data

Simulation shows assisted procreation cannot do much about it

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