Analysis of the Biological Clock Decision

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The decisions of if and when to have a first child are very important for any woman or couple. This paper develops a model to examine when a woman should begin trying to conceive, which depends on the personal circumstances and values of each woman. The model incorporates separate objectives for a woman’s professional, social, and family aspects of life and integrates them into a quality-of-life function that includes the changing relative importance of these aspects with age over a woman’s life. Descriptions of the relative quality of each of these three aspects of a woman’s life are modeled over time for different cases. One case involves no child and other cases involve the woman giving birth at different ages from 21 to 50. The probabilities of conceiving when trying, as a function of a woman’s age, are included. The relative pros and cons of waiting until the late thirties to have a child to avoid perceived detrimental impacts on one’s career or social life are investigated. Several illustrations are included in the paper to demonstrate insights that can be generated using the model.

Key words: childbirth decisions; reproductive timing; reproductive decisions; conception decisions; child bearing; career-family trade-offs; baby decisions; biological clock time preference; personal decision making

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1. The Biological Clock Problem

The decisions of whether and when to have a first child are very important for many women or couples. For those who also plan to have a professional career, these decisions are very difficult for several reasons. First, there are multiple objectives to consider that concern the impact of a child on both the personal and professional aspects of one’s life. Second, the consequences on each of these aspects can be very different with and without a child. Third, given a child, such consequences can depend on both the ages of the child and of the mother. Fourth, the uncertainties about the chances of conceiving and giving birth to a healthy child are significant and change with the mother’s age. Fifth, the preferences for what one wants in life change with time.

It is obvious that there is much to consider in thinking about whether and when to have a child. Finding the optimal timing of the first child is too complex a decision to logically consider all the relevant aspects intuitively in one’s head. However, for many it is also too important and consequential to simply go with one’s feelings. Help in structuring one’s thoughts, gathering and organizing any relevant information, and incorporating one’s time-dependent preferences would be welcomed by some. These women would like their thinking and feelings to align.

However, to our knowledge there are no models that provide this help to complement intuition alone. Both the complexity and importance of the decision, and the fact that there were no tools to aid decision makers, were the motivation for the work in this paper.

This paper presents a general model of the biological clock decision, develops procedures to personalize the model to an individual woman or to a woman and her partner, and illustrates the use of and insights from the model in several situations. The output of the model is the relative desirability of a woman beginning to try to conceive a child at ages from her current age to age 49.

Natural circumstances concerning the timing of the decision to have a first child give rise to our phrase “biological clock decision.” The reproductive age starts with menarche around 12–13 years and ends with menopause around 51–52 years (Chumlea et al. 2003, Bromberger et al. 1997). From approximately 25 years of age onward, the probability that a
womancanconceiveachildbegins to decrease slowly, but at an increasing rate (Dunson et al. 2004). If this were the only issue affecting the timing of a first child, women should likely pursue having a first child in their early twenties. However, a woman interested in a professional career will typically finish her formal education between the ages of 25 and 32 (National Center for Education Statistics 2005). This includes doctors, engineers, scientists, academics, MBAs, and lawyers. Most must then immediately begin their career if they wish to achieve the professional influence and satisfaction that they desire, whereas having a child might disrupt or damage their professional life (Chartered Institute of Personnel and Development 2002). During this same period, they are often cultivating friendships and pursuing activities that will hone their life skills—including those needed to raise a family—and will finally define the adult they hope to be. These factors provide a logical and emotional push to have a first child later.

There is a great deal written in public literature on the biological clock problem. There is a literature on how the biological clock works (e.g., Birrittieri 2004). There are debates on how long a woman can wait to conceive a baby (e.g., Paulson and Sachs 1998). There are articles that speculate about whether there is an optimum age to conceive a child (e.g., Laurance 2006). However, all this literature fails to address the optimal age for a specific woman to have a child.

This paper develops a prescriptive framework to help people make the decision about the optimal timing to conceive a first child. We propose a model that addresses the complexities of the biological clock problem. There are several parameters to personalize the model to the factual reality (e.g., probability of conception as a function of a woman’s age and circumstances) and to the values (e.g., relative priorities of career, family, and social life) of each woman. Our model considers trade-offs between basic objectives and incorporates preferences for these objectives that can change over time. We illustrate the usage of the model with some examples and sensitivity analysis to demonstrate what types of insights might be made.1

The paper is organized as follows. Section 2 outlines our model. Section 3 discusses the assessments needed to personalize the model for a specific woman’s situation and values. Examples of the model usage are presented in §4, along with the insights they provide. Section 5 proposes several ways to extend the model, and §6 discusses the appropriate uses and usefulness of it.

2. The Biological Clock Model

Our model incorporates several major factors that should influence the best time to have a first child. It is built at a high level of aggregation to avoid being too unwieldy to generate any useful insights. The model has three objectives concerning what we refer to as professional life, social life, and family life. The time period that we consider is from a woman’s current age2 \( A_c \) to 75, where \( A_c \) can be from 20 to 49. The consequence describing her life with respect to each of the three objectives accrues annually and depends on the age of the woman, whether the woman has a child, and the age of the child if she has one. The contribution to quality of life from each objective, which depends on the consequence, is indicated by a utility that is subjectively assessed on a 0 to 100 scale. The overall quality of life in a given year depends on the utilities of the three objectives in that year and on the relative importance of the objectives in that year. A von Neumann and Morgenstern (1947) utility function aggregates the utilities over the woman’s life from \( A_c \) to 75 to indicate her overall quality of life.

A decision tree illustrating our model is shown in Figure 1. A woman of current age \( A_c \) is deciding whether to try to get pregnant, and if so, when. If she decides to try to get pregnant at age \( A_x \), she has a chance that a child will be born in each of the next four years.4 Otherwise, no child is born. For each set

1 Our biological clock model is available for anyone to use and can be found in the online supplement on the Decision Analysis journal’s website at http://da.pubs.informs.org/.

2 The average life expectancy for women in the United States is 82 years, and the healthy life expectancy is 70 (Crimmins and Saito 2001), so we take 75 as the end of time horizon in our model, which of course can be changed in each particular application of the model.

3 Although for demographic purposes reproductive age group is usually defined as 15–49 (Newell 1987), we use a 20–49 age group in our model, which can be easily modified in a particular model application.

4 See §2.4 for explanation on this “four years of trying only” assumption.
of decisions and sequence of events, there is an annual sequence of consequences for ages from $A_c$ to 75. For each series of consequences over this time period, the woman experiences a quality of life measured by the associated utility. She wishes to make her decision to maximize the expected utility of her choice. Thus, our model directly elicits the decision maker’s importance coefficients and utilities for each objective as functions of her age and circumstances (i.e., no child, child’s age). This results in a complete description of possible alternatives. The utilities of these alternatives are calculated using Microsoft Excel.

### 2.1. Objectives

The professional life objective includes everything related to professional activity, including education. This encompasses, for instance, the degree of professional self-realization, potential for self-development and gaining new knowledge, the satisfaction from work itself, the amount of money earned, the amount of hours spent at work, and the time spent on business trips.

The family life objective includes everything related to a child. This includes the joy of birth, the challenge of changing diapers, happiness from the first steps of a toddler, fun from camping in the Grand Canyon together with a teenager, stress from her being home too late after a first date, pride for a child’s accomplishments, and the adult relationship that eventually develops with one’s child.

The social life objective includes everything outside of family and work/school: meeting friends, dating,
climbing, traveling, hobbies, sports, and so forth. Note that these same activities when done with her child (like travel) are considered within family life quality.

We use the notation $P$, $S$, and $F$ to mean the professional, social, and family objectives. For each age $A$ of a woman (i.e., in each year), there will be a consequence denoted by $(p_A \mid t, s_A \mid t, f_A \mid t)$, where $p_A$ refers to the professional life in that year, and $s_A$ and $f_A$ refer to the corresponding social and family aspects of life, all given the child’s age $t$ in that year ($t =$ “No” will stand for no child). Instead of evaluating the consequences $p_A$, $s_A$, and $f_A$ and applying a utility function to them, we directly assess the correspondent utilities $u_p(p_A \mid t)$, $u_s(s_A \mid t)$, and $u_f(f_A \mid t)$. They are directly assessed as on a 0 to 100 scale, which corresponds to the worst and best that a woman might envision on the corresponding objective in any year, and are each a function of many factors in the woman’s life (e.g., success in career, a successful marriage, and her physical health).

2.2. Value Model

The quality of life in each year for a woman of age $A$ is evaluated using an additive utility function $U_A$ over the three objectives (Fishburn 1965), so

$$U_A(p_A, s_A, f_A \mid t) = k_p(A)u_p(p_A \mid t) + k_s(A)u_s(s_A \mid t) + k_f(A)u_f(f_A \mid t),$$

where $u_p$, $u_s$, and $u_f$ are the utilities defined above and $k_p$, $k_s$, and $k_f$ are age-dependent importance coefficients that sum to one in each year. The importance of the different aspects of life can change over the woman’s age. For instance, some women may place zero importance on family before age 25 ($k_f(A) = 0$ for $A < 25$), have $k_f(A)$ increasing in $A$ for $25 \leq A < 35$, and then place a constant importance on the family for the rest of her life ($35 \leq A$).\(^5\)

Overall life quality is measured using a value model that incorporates a woman’s annual quality of life in each year until age 75. Thus, the overall quality of her life is

$$U(p, s, f \mid B) = \sum_{A=1}^{B-1} U_A(p_A, s_A, f_A \mid No) + \sum_{A=B}^{75} U_A(p_A, s_A, f_A \mid A - B),$$

where $p$ is defined as $(p_A, p_{A+1}, \ldots, p_{T_5})$, $s$ and $f$ are analogously defined, $B$ is the woman’s age when she gives birth\(^6\) or $B$ is “Never” if she has no child, and $U_A$ is assessed using (1).

2.3. Component Utilities

The component utilities $u_p$, $u_s$, and $u_f$ for the three objectives must be specified for each age of a woman’s life from her current age $A_c$ to age 75. We illustrate the type of information required here and discuss how to assess this information in §3.

Consider a 22-year-old woman who has just graduated from college and begun working at a national firm. Suppose her plans are to work for four years until age 26 and then take two years to get an MBA. At 28, she plans to begin her first professional job in a major firm. Figure 2 illustrates how she may describe the component utilities of this situation for two outcomes\(^7\): either not having a child or having a child at age 32.

In the no-child case, she estimates the utility of her professional life to be 50 on her first job. She learns a lot and enjoys it, but relative to where she expects to be professionally in the future, it is a 50. The MBA

\(^5\) There is a great deal of empirical and theoretical literature on various decisions involving trade-offs among costs and benefits occurring at different times for a review, see Frederick et al. 2002. Most models evaluate alternatives by integrating them with existing plans rather than evaluate them in isolation. This is similar to choosing the optimal time to give birth, because the decision maker must account for the effect each alternative has on various aspects of her life. However, most existing literature on intertemporal choices does not account for the fact that the decision maker’s preferences for her states may change with time. Time-dependent changes in preferences have been studied in various areas of social sciences, including behavioral decision making (e.g., Benzon et al. 1989, Loewenstein 1987), but these are the descriptive models usually considering change in preference as some sort of a discounting process. In our model, the decision maker anticipates her different preferences at different future times and analyzes her decision in accordance with these preferences.

\(^6\) Child’s age $t$ used in $U_A$ is calculated as the difference between the woman’s age $A$ and her age when she gave birth: $t = A - B$.

\(^7\) For clarity purposes in this example, we provide the utility curves for two consequences only: no child and giving birth at 32. For a complete analysis, assessment of the utility curves for all the possible outcomes (child at 23, at 24, \ldots, at 50) is necessary.
program is a 60, mainly because her colleagues, both students and faculty, are more interesting. Then she gets a good job and begins to advance from a 70 to 80 between ages 28 and 34. At age 34, she anticipates a key advancement, so her professional life utility assessment jumps to 85 and then gradually increases to 95, which is maintained from age 45 to 55. Her utility of professional life then slowly decreases to 70 over the next 10 years until she retires at 65, when professional life quality becomes zero.

Suppose she would have become pregnant at age 31 and then had her child at age 32. Because of the time commitment to the child, she expects her professional life utility to drop from 75 at age 31 to 50, where it remains until the child begins school when the woman is 38. Her professional life utility improves over a few years to 75 and then follows a lower trajectory analogous to having no child. The social life utility curves in Figure 2 are constructed with a similar logic.
Regarding the utility of family life, it is 0 by definition prior to having a child. If the woman became pregnant at age 31 and has a child at age 32, she anticipates her family life utility to jump to 90, where it remains until the child is about 14, when the woman is 46. Then it drops to 50 during the years when the child is 16 to 18 and then improves to 80 after the child is 26.

The example above assumed that the timing of future events was well specified, such as when she gets the key promotion or when a teenager becomes somewhat unpleasant. The component utilities are intended to average over all of the possible conditions, so they may be smoother than those illustrated in Figure 2. By being specific in the discussion above, we could more clearly indicate the types of considerations that may influence the component utilities, and how to represent these considerations.

### 2.4. Uncertainties About Birth Date

If a woman decided to start trying to conceive at age $T$, it does not mean that a child will be born in nine months (i.e., at age $T + 1$ because we discretize life into one-year intervals). Medical research clearly shows that the probability of conceiving decreases as the potential mother becomes older. This major uncertainty is explicitly considered in our model.

The commonly used clinical definition of infertility is that a couple is unable to conceive within a year of unprotected intercourse. However, many infertile couples will conceive naturally in the second year of trying (Dunson et al. 2004). Beyond that, it is often recommended that a couple search for an assisted reproduction. For simplicity, we assume that a woman will try for some reasonably long period of time and then stop trying. We chose four years for this reasonable period of time. In §5 we discuss how our model can be modified to account for the possibility of assisted reproduction.

We denote the age-dependent probabilities to conceive during the first, second, third, and fourth year of trying as $q_1(T)$, $q_2(T)$, $q_3(T)$, and $q_4(T)$, respectively, where $T$ is the age when a woman starts trying. We use data from Dunson et al. (2004) to get $q_1(T)$ and $q_2(T)$ for $T \in [20, 39]$ and obtain the rest by extrapolation. The resulting probabilities are given in Table 1. Also shown is the probability of not conceiving after trying for four years beginning at age $T$, which we define as $q(T)$ and calculate using

$$ q(T) = \prod_{i=1}^{4} (1 - q_i(T)). \tag{3} $$

### 3. Assessments

There are three sets of assessments needed to use the biological clock model. These are the component utilities, the importance coefficients for the three objectives, and the probabilities of becoming pregnant. These will be discussed in order.

#### 3.1. Component Utilities

Specifying the component utilities for a woman is the most difficult assessment required for the model. On the other hand, the information embodied in these assessments are the essence of why the decision of whether and when to have a first child is so complex and important. Three component utility curves are required over a woman’s life for each age at which she could bear a child. Because we discretized the years

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Table 1 Probabilities of Conceiving Within a Certain Time Period When Starting at a Certain Age

<table>
<thead>
<tr>
<th>Age when a woman starts trying</th>
<th>20</th>
<th>25</th>
<th>30</th>
<th>35</th>
<th>40</th>
<th>45</th>
<th>49</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conception occurs during</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1–12 months</td>
<td>0.91877</td>
<td>0.90769</td>
<td>0.88078</td>
<td>0.83805</td>
<td>0.77949</td>
<td>0.70510</td>
<td>0.63419</td>
</tr>
<tr>
<td>12–24 months</td>
<td>0.63980</td>
<td>0.61714</td>
<td>0.56213</td>
<td>0.47475</td>
<td>0.35500</td>
<td>0.20290</td>
<td>0.05791</td>
</tr>
<tr>
<td>24–36 months</td>
<td>0.44553</td>
<td>0.41960</td>
<td>0.35875</td>
<td>0.26894</td>
<td>0.16168</td>
<td>0.05839</td>
<td>0.00529</td>
</tr>
<tr>
<td>36–48 months</td>
<td>0.31025</td>
<td>0.28529</td>
<td>0.22896</td>
<td>0.15235</td>
<td>0.07363</td>
<td>0.01680</td>
<td>0.00048</td>
</tr>
<tr>
<td>Conception does not occur</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>during 1–48 months</td>
<td>0.01119</td>
<td>0.01466</td>
<td>0.02581</td>
<td>0.05271</td>
<td>0.11045</td>
<td>0.21762</td>
<td>0.34263</td>
</tr>
</tbody>
</table>
and assumed a woman could get pregnant from age 20 to 49, she could either not have a child or conceive a child in 30 different years from ages 20 to 49. Thus there are at most 93 (i.e., 3 times 31) required component utility curves for a woman (fewer if a woman’s current age $A_c > 20$).

For a specific woman, she could provide estimates of all 93 component utility curves such as those illustrated in Figure 2. However, two specific techniques, scenarios and parameterization, should enhance thinking about the task and simplify it.

Scenarios may facilitate understanding an appropriate shape for the component utility curves. Consider a 25-year-old PhD student who plans to pursue a career in academia. Figure 3 depicts utilities for scenarios to construct her professional life utility curve assuming she has no child. She expects to be in school three more years until age 27 (flat on the graph), and then receive a tenure track position at a top university. Her professional life quality will increase (publications, experiences, salary, etc.) with possible tenure at age 35 (with probability 0.4). If she does not receive tenure, she will move to a different school, which decreases her professional life quality. At that school, she expects to get tenure with probability 0.7 in another five years. Overall, her expected professional life utility curve illustrated in Figure 3 is developed by weighting the three potential scenarios by their respective probabilities.

Now suppose the same decision maker estimates her professional life utility curve if she has a child at age 30, in her third year at the first university. The professional life utilities are the same until she gives birth. Then, because of time limitations and altered priorities, she believes her academic productivity will be less than without a child and so her professional life quality remains at the same level until the tenure decision. Now she feels that the probability of tenure has dropped to 0.2. If not tenured, she will get a job at a less prestigious university, but her judgment on receiving tenure there drops to 0.5. Figure 4 illustrates the overall expected professional life utility of this situation.

It is reasonable to assume that component utility curves for situations where the birth of a child changed by one year would be similar and that they would alter over time in a systematic manner. To capture these notions, one can use the technique of parameterizing the impact of having a child relative to having no child on each of the three sets of component utility curves. We can illustrate this idea as follows.

Recall that $u_{P|A}(p_A | No)$ is the professional life utility curve, given no child, where $A$ is the woman’s age. We will alter this curve based on a professional life adjustment function, denoted $g_P(t)$, for having a child of age $t$. Then the set of all professional life utility curves can be given by

$$u_p(p_A | t) = g_P(t)u_p(p_A | No), \quad \text{for } t \in \{0, 1, 2, \ldots\},$$  

(4)

where $g_p(t)$ is the proportion, scaled from zero to one, of the professional life utility without a child that the woman would experience with a child of age $t$. 

**Figure 3** Utilities for Professional Life Scenarios Without a Child and the Corresponding Expected Utilities
Figure 4  Example of the Impact of a Child Born by a 30-Year-Old Woman on Her Professional Life Utility

![Graph showing the impact of a child on professional life utility](image)

Figure 5 represents three types of professional life adjustment functions to present the concept in a concrete fashion. Collectively, these adjustments can be used to model many individuals’ beliefs about a child’s impact on one’s professional life quality.

Type 1 represents a case when having a child decreases the professional life to zero in the first year, and then it slowly grows back. Parameter $N$ defines the decrease in professional life in the second year of having a child; parameter $S$ defines for how many years the professional life utility is increasing afterwards. For example, some women may plan on taking maternity leave when their child is born. Then they will return to work, but spend less time in their career until the child is $S$ years old. During that period their professional life utility will be increasing from $N\%$ of what it would have been without a child to $I\%$, which may be $100\%$ or less than $100\%$.

Type 2 represents a case when a woman does not plan on taking a year-long maternity leave, so in the first year her professional life quality decreases to $M\%$ of what it would have been without a child at this age, and then it grows (with increasing annual improvements in professional life quality) until the child is $D$ years old. Then the professional life quality stays at $J\%$ of what it could have been at that woman’s age without a child.

Type 3, the most flexible case, represents a woman who will work part time for $T$ years after the child is born, so her professional life utility will be $L\%$ during this time period. Note that $L = 0\%$ corresponds to not working. Then she returns to full-time work and her professional life utility uniformly increases to the

![Graph showing three types of adjustment functions](image)
level $C\%$ by the time her child is $P$ years old. The case where $L = C$ corresponds to a woman's beliefs that having a child will have a constant effect (including possibly no effect) on her professional life quality. The same approach can be used to specify social life utility curves.

The assessment of family life utility given a child is handled in a slightly different manner. With no child, the family life utility is set at 0. With a child, the family life utility $u_f(f_A | t)$ of a woman of age $A$ having a child of age $t$ is given by

$$u_f(f_A | t) = g_e(A)u_c(t),$$

where $g_e(A)$ is the ability of a mother of age $A$ to enjoy a child measured on the 0 to 1 interval, where 1 stands for full ability and 0 stands for not being able to enjoy a child at all, and $u_c(t)$ is the relative utility of having a child of a certain age on a 0 to 100 scale.

Figure 6 describes $g_e(A)$ with a flexible parameterization. One would need to assess parameters $u_{20}$, $t_1$, and $t_2$ representing the relative ability to enjoy a child in her early twenties, the age at which she starts having an increased ability to enjoy a child, and the age when she has full ability to enjoy a child.

Figure 7 depicts a reasonable $u_c(t)$ function. In the figure, the woman is sure that she will have the best experience with a child between 4 and 11 years old, then there is a gap corresponding to the difficult teenage years, and the utility of her child aspects of family life stabilizes at 80. The curve can be flexibly parameterized to fit individual beliefs.

Figure 8 illustrates $u_f(f_A | t)$ as a combination of $g_e(A)$ and $u_c(t)$ for two outcomes: bearing a child at age 24 and at age 46. Note that in the case of a child born when the mother is 24, she never gets to enjoy him or her fully, because the best child’s age coincides with the mother’s age when she cannot fully enjoy the child.

For most women, the family life objective also concerns a wife-husband relationship. However, to focus the model on the professional, social, and child implications of when a woman should have a child, we choose not to complicate the model with adult male interactions. This is equivalent to assuming that the wife-husband expected family utility is constant over time without a child.

### 3.2. Importance Coefficients for the Three Objectives

The importance coefficients in (1) for the three objectives that describe life quality may change from year to year. Thus, age-dependent assessments for the woman’s ages from $A_c$ to 75 are necessary.

To appropriately assess importance coefficients for the life quality components, we must compare the ranges on the scales that measure those components (Keeney and Raiffa 1976). That is, for each age we compare three ranges: the range between no professional life and the best possible one, the range between no social life and the best possible social life, and the range between no child and the best possible experience with a child. For each age, the woman first ranks the relative importance to her of the differences between ranges on the three quality components. Next, the range most important to the woman can initially be assigned a value of 100. The importance coefficients of the two other ranges are assessed.
Relative to this 100. Then the three relative weights are normalized to sum to one in each year.

For example, at a given woman’s age, she may state that the range of professional life is most important, then the range of social life, and last family life. Subsequently, she may say the social range is 60% as important as the professional range, and the family range is 40% as important as the professional range. As a check, she may feel that the family range is about two-thirds as important as the social range. With these assessments the normalized importance coefficients for (1) on the professional, social, and family components are, respectively, \( k_p = 0.5 \), \( k_s = 0.3 \), and \( k_f = 0.2 \).

The importance coefficients can be drawn as shown in Figure 9, which facilitates understanding them. There, the relative importance of having a child between 25 and 35 is very low. The importance of social life initially is the highest and the importance of professional life is nearly half as great at age 25. Then the importance of the social life component decreases, whereas the importance of career grows. At age 35, the importance of professional life reaches a maximum of 50% and stays at this level until about the age of 55. At the same time, the importance of the family life component starts growing at the age of 35 and the social life importance consequently decreases even more. Between the ages of 44 and 60 the importance of the family component stays constant and then starts growing again, whereas the importance of professional life decreases sufficiently after the woman becomes 55 years old.

3.3. Expected Values of Decision Alternatives

A woman of current age \( A_c \) has a choice of alternatives: to start trying to conceive at age \( T = A_c \), or at
4. Analysis and Insight

This section contains several analyses using the biological clock decision model. They illustrate a range of circumstances that the model can address and the types of insights that can be gained by using the model.

4.1. Doctoral Student

Consider a 25-year-old female PhD student whose expected professional life utility curve without a child is represented in Figure 3. If she has a child, there will be an adjustment to her professional life utility represented by Type 1 in Figure 5. Whenever a baby is born, the woman plans to take a maternity leave so her professional life utility will be zero. The next year she plans to return to work and expects to start with $N = 65\%$ of what her professional life utility would be without a child at that age. The impact on her professional life decreases each year until the child is $S = 10$ years old. From then on she thinks she will always be somewhat behind ($I = 97\%$) of what her professional life utility would have been at that age without a child.

The professional life utility curves given a child at each age are constructed using (4), which is the product of childless professional life utility and the child’s effect on the professional life. Figure 10 illustrates these curves of our current doctoral student.\(^{10}\)

Social life utility without a child and with a child of different ages is constructed in a similar manner, although the effect of the child on social life may be different than that on professional life. The social life utility curves for our example are given in Figure 11.

The ability to enjoy a child as a function of the mother’s age, $g_c(A)$, is taken as in Figure 6, with parameters $u_{20} = .25$, $t_1 = 25$, $t_2 = 35$. Figure 12 displays the relative utility, $u_c(t)$, of having a child of different ages. Combining these using (5) yields the family life utility functions. Finally, the woman’s importance coefficients for the three objectives as a function of her age are taken as those in Figure 9.

All of this information, combined with age-dependent probabilities of getting pregnant, provides the total life quality for each age when a woman might start trying to conceive a baby. Figure 13 depicts the percentage of overall life quality for each age $T$, when the woman starts trying to conceive, relative to the optimal age ($EU(T) / \max_i [EU(i)]$). Given all the assumptions for our example, the optimal age for the woman to start trying to conceive is 35. If this woman decided to have no child, her expected overall life quality will be only $75.5\%$ of that if she decides to start trying to conceive at age 35. Also, a decision to start trying to conceive at any age prior to 35 leads to at most a $1\%$ loss of optimal life quality, whereas the decision to start trying to conceive after 35 years old leads to much larger decreases in life quality. The large change in the life quality due to trying to conceive at age 48 versus 49 is because she has two rather

\[^{9}\] In the model, we assume that the probabilities of giving birth are equal to the probabilities of conceiving. In §4.4 we show how one can additionally account for the probability of miscarriage.

\[^{10}\] Only the woman’s ages from 25 in Figures 10 and 11 apply to this base-case analysis. A subsequent analysis uses the range from age 20.
Figure 10. Professional Life Utility Curves for Doctorate Student Example Given Child Born at a Certain Woman's Age

Figure 11. Social Life Utility Curves for Doctorate Student Example Given Child Born at a Certain Woman's Age
then one year to conceive, as we assume that the probability of conception for age 50 and above is zero.

Note that in this example, the optimal age corresponds to when the woman expects the uncertainty about tenure in the best-case scenario to resolve (see Figure 3), when the importance of a child starts increasing, and she has full ability to enjoy the child. Using sensitivity analysis we can gain some insight about the relative importance of different factors.

Sensitivity analysis demonstrates that an increase in the woman’s ability to enjoy a child more at an earlier age does not change the optimal age (35 years old), but decreases the reduction of life quality from trying to conceive earlier. For example, if she can enjoy a child fully at any age (in which case $g_c(A) = 1$), the maximum loss in overall life quality corresponding to a decision to start trying to conceive at any age prior to 35 is at most 0.4% compared with 1% in the base case of Figure 13.

Variations in the importance coefficients of the three objectives can have a significant effect on the optimal age for the woman to have a child. Keeping the importance of professional life the same as in the base case, but increasing the importance of family life for her between ages 25 and 43 (compare Figure 14 with Figure 9), results in the optimal age to start trying to
conceive being 28 years old (see Figure 15). This is because now the weighted loss of social life quality caused by having a child at a younger age is smaller than the gain from having a child at that earlier age.

Now let us consider the same woman over an extended time horizon. Let us assume that she began thinking of her biological clock decision at age 20, when she was an undergraduate. She planned to enter the PhD program at age 25, and her expected utilities for social, professional, and family life starting at age 25 will be as in the example above (as in Figures 10 to 12). For simplicity, we also assume that her professional life utility and her social life utility at ages 20–24 are the same as at age 25. Finally, we keep the importance of family life as in the base case, but increase the importance of professional life so that it is constant for her for ages 20–45 and equal to 50%. For this woman, an interesting effect is that there are now two optimal points to begin trying to conceive, namely, ages 20 and 35 (see Figure 16). This might seem to be an unexpected result because most women who place high importance on their career prefer to postpone having a child. However, the optimum at age 20 is explained by the fact that weighted loss in the professional life utility is lower if the child is born while the woman is still in school versus if the maternity leave is to be taken when the woman is at the prime growth time of her career.

To study more thoroughly the effect of importance coefficients, we performed a detailed sensitivity analysis on the importance coefficients in a simple form: We assumed that the importance coefficients $k_F$, $k_P$, and $k_S$ in (1) were constant throughout the woman’s life. For the 20-year-old woman whose situation we just analyzed, we varied the importance coefficients and calculated the optimal age to begin trying to conceive. Because $k_F + k_P + k_S = 1$, the results are shown as a function of $k_F$ and $k_P$ in Table 2.

As expected, with very low importance placed on the family life component ($k_F = 0.05$), it is optimal not to have a child at all (optimal age = “No” means just that) except for the case when the importance of

---

**Figure 14** Importance Coefficients for Sensitivity Analysis in Doctorate Student Example with Higher Importance of Child at a Younger Age

**Figure 15** Percentage of Optimal Life Utility Given a Decision to Start Trying to Conceive at a Certain Age for Doctorate Student Example with Higher Importance of a Child at a Younger Age
social life is equal to zero. In this specific example, when social life and hence the detrimental impact on social life both become irrelevant, it becomes optimal to start trying to conceive at 20, 21, or 22, which is slightly better than having no child because of the 0.05 weight on family life. With $k_F$ equal to just 0.1, the woman should try to have a child in all cases, trying to conceive at either a late or an early age depending on the importance coefficient for her professional life. The reason is that without any child, there is almost a 10% drop in the utility of life after 50. As the importance of family life increases, the optimal age for trying to conceive decreases. If the importance of professional life is high enough, the optimal age becomes 20, which is explained by the fact that loss of the professional life utility is lower for birth at an earlier age.

4.2. Child Before or After the Promotion?

This is a common question that many professional women ask. What if our doctoral student believes that giving birth before she gets tenure (her key promotion) at the first university will decrease her probability of getting it? To analyze this, we assume that the woman has importance coefficients as shown in Figure 14, the three potential professional life utility curves as in Figure 3, and that she believes the child will not affect the probability of tenure at the second university if she happens to get there. We then varied the probability of getting tenure at the first university without a child from 0.1 to 1, and we varied the decreased probability of getting this tenure if the child is born before the tenure decision. For all cases, if having a child has no effect on the probability of getting tenure, the optimal age to start trying to conceive remains 28 years old, as indicated in Figure 15. If the woman believes that giving birth before the tenure decision decreases her probability of getting tenure, then the optimal age to start trying to conceive may change to age 34, so that no birth occurs before

Table 2  Optimal Age as a Function of the Importance Coefficients

<table>
<thead>
<tr>
<th>$k_p$</th>
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<th>0.10</th>
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</tr>
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the tenure uncertainty is resolved. For example, this occurs if the woman believes that the probability of getting tenure is 0.8 without a child and only 0.45 with a child. Figure 17 depicts the switching points from 28 to 34 years old for probabilities of tenure with and without a child prior to the tenure decision.

4.3. “I Don’t Want to Have a Child Until I’m 35!” and Its Consequences

Many young women have said something like “I definitely don’t want to have a child until I’m 35 years old.” The reasoning can vary. It could be a desire to live life fully while young, or it could be a decision to make an essential advance in career first. However, given that fertility decreases with age, is this best for the woman? In this section, we demonstrate that even if a woman feels that she does not want to have a child until a certain age, it might still be optimal for her—under not that rare of circumstances—to start trying to conceive earlier, sometimes even much earlier than this self-defined age constraint.

We model “I don’t want to have a child until I’m X years old” as a preference by assuming this means that $k_F = 0$ until the declared age $X$ and then $k_F > 0$ and increasing until $k_F = K$ at the age of 50. For simplicity, we assume that importance coefficients for professional and social life are equal and $k_F = k_S = (100 - k_F)/2$, as shown in Figure 18.

We consider a college student of current age 20, who expects to graduate and start her career at 23. Also, she expects that child’s impact on her professional life utility will be of type 3 in Figure 5 with parameters $L = 65\%$, $T = 0$, $P = 15$, $C = 97\%$. The expected professional life utility curves with no child, and given a child born at each age, are depicted in Figure 19. We assume she expects that a child will have similar impact on her social life.

We vary the age $X$, before which the woman does not want to have a child; and $K$, which is $k_F(A)$ for $A \geq 50$. Table 3 contains the optimal ages corresponding to all the combinations of $X$ and $K$. For some combinations, the results are not unexpected. For example, for $X = 35$ and $K = 0.6$ the optimal age to start trying to conceive is 34—i.e., exactly one year before the self-defined limit. For $X = 30$ and $K \geq 0.25$ the optimal age is 30. However, for some combinations the results are less obvious. For example, for $X = 40$ and $0.50 \geq K \geq 0.35$, it is optimal to start trying to conceive at the age of 38, and even earlier for $K > 0.50$. That is, even though the woman states that she does not want to have a child until she is 40, it is optimal for her to start trying to conceive earlier, so she might actually have a child before 40. This is explained by both the decreasing probability of conceiving with age and the growing importance of a child. The older she becomes, the higher is the chance to remain childless,
Figure 19  Expected Professional Life Utility Curves Given Child Born at a Certain Age for the “No Child Until 35” Example

in which case she loses a lot in terms of life utility, because the importance of having a child is high after age 50. Figure 20 depicts the case when $X = 40$ and $K/period or 50$, for which the optimal time to start trying is

38. If the decision maker starts trying earlier, she loses at most 1% of the optimal value (if she starts trying at age 24, her expected lifetime quality reduces only to 99% of the optimal, which is the minimum for ages 20–38). If she starts trying after age 38, her life quality decreases quickly, and at the age of 42 it is already equal to 97.88% of the optimal.

There are more surprising cases. For example, if the woman claims that she does not want a child until she is 45, but places $K ≥ 0.35$ importance on having a child after she is 50 years old, it is actually optimal for her to start trying to conceive at age 20. In this case there is almost a 100% chance that she will have a child before she is 45. The fact that it is optimal for her to start trying to conceive prior to 44 or 43 is explained by the increased probability of not conceiving at all if she starts trying at age 44. The reason that it is optimal for her to conceive so much earlier—at age 20—is explained by the fact that at this early age, her professional life utility is not that great, so losses are less in terms of the professional life utility than if she gives birth at a later age when her career quality is better. One might dismiss this case by saying that nobody would say they do not want a child until age 45. However, the recommendations are qualitatively the same if a woman said she did not want

<table>
<thead>
<tr>
<th>Family importance coefficient $k_f = K$ after age 50</th>
<th>Age $X$</th>
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<td>0.05</td>
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<tr>
<td>0.90</td>
<td>20</td>
</tr>
<tr>
<td>0.95</td>
<td>20</td>
</tr>
</tbody>
</table>
a child until age 37, because she expected important career accomplishments by then, and if she felt her age-dependent probabilities of conceiving at age 37 to 40 were less then our base-case probabilities for that age and similar to the 45–48 base-case probabilities in this case.

4.4. Later-Age Pregnancy: Increasing Infertility and Higher Miscarriage Odds

It is not uncommon for women to wait until they are in their late 30s or early 40s to have their first child (Ventura et al. 2001). Many women successfully conceive in their early 40s, but there are increased associated risks. The risks most often mentioned are infertility, greater risk of chromosomal abnormalities, and loss of pregnancy (Cleary-Goldman et al. 2005). In this section we analyze if and how some of these risks affect the optimal age to start trying to conceive.

Some women might find that our base-case age-dependent probabilities of conception (Dunson et al. 2004) are surprisingly high, and they may believe that their infertility probabilities are actually higher than this clinical research indicates. In addition, if it is suspected that a woman’s husband has, say, a 10% chance of being sterile, then the probabilities of becoming pregnant in each year should be reduced to 0.9 times its original value. Also, both paternal and maternal ages are risk factors for miscarriage (de La Rochebrochard and Thonneau 2002), which contributes to the decline of the probability to give a live birth at later ages.

We performed two types of modifications to see how these concerns might affect model recommendations. First, we decreased the probabilities of conception at each age to reflect possible health problems and known cases of sterility in the family. Second, we increased the rate at which fertility declines with age to reflect beliefs of those women who find the later-age probabilities indicated by the research to be unrealistically high or to account for miscarriages.

In the first case, we decreased the initial age-dependent probabilities a fixed percent for each year, using the initial doctoral student example (§4.1). Not surprisingly, Table 4 shows that the more we decrease the probability, the earlier it becomes optimal to start trying to conceive. Column 3 in Table 4 gives a reference point of the probability of conceiving at the age of 40 with this alteration. Thus, without any alterations (first line), the optimal age to start trying is 35 years old and the probability of conceiving within one year of trying at the age 40 is 0.78 (this is the base-case data). However, if all the probabilities of
Keeny and Vernik: Analysis of the Biological Clock Decision

Table 4 Sensitivity Analysis that Decreases the Medical-Research-Based Probabilities of Conceiving

<table>
<thead>
<tr>
<th>Percent of initial age-dependent probabilities of conceiving are decreased</th>
<th>Optimal age to start trying to conceive</th>
<th>Probability of conceiving within one year at the age of 40</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>35</td>
<td>0.78</td>
</tr>
<tr>
<td>5</td>
<td>35</td>
<td>0.74</td>
</tr>
<tr>
<td>10</td>
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<td>15</td>
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</tr>
<tr>
<td>20</td>
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<td>35</td>
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<td>75</td>
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<tr>
<td>80</td>
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<td>0.16</td>
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</tr>
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</table>

conceiving are uniformly decreased at, say, 50%, then it becomes optimal to start trying at 25, and the corresponding probability of conceiving within one year at age 40 becomes 0.39.

In the second case, we increased the rate of decline of later-age probabilities to conceive. Specifically, the initial probability decline with age is approximated with a quadratic parabola with coefficient $-0.031$. We modeled a faster decline of probabilities at later ages by decreasing this coefficient. The result is that the optimal age to start trying to conceive decreases somewhat. With the decline coefficient as low as $-0.046$ (which results in the probability of conceiving during the first year at age 40 being 0.72, which is 0.06 smaller than in the base case), the optimal age remains 35 years old. When the coefficient is decreased more, up to $-0.067$ (which results in the probability of conceiving during the first year at age 40 being only 0.62), then it is optimal to start trying at 33. When it is decreased to $-0.075$ (resulting in the probability of conceiving at 40 being the only 0.59), it is optimal to start trying at 32. Such small changes in the optimal birth age are explained by the fact that the changed probabilities mainly affect birth after age 30: Even with coefficient $-0.075$ the probability of conceiving at age 29 within one year of trying is only 0.03 less than in the base case. If the initial input information were such that the recommended age for a first child were higher, say 40 or 45 years old, then such a decrease in childbirth probabilities would likely have a greater influence on the model recommendations.

5. Model Extensions

There are several assumptions and simplifications made in constructing our model. Although some of the assumptions are strong, they allow us to achieve the main goal: to analyze the trade-offs among professional, social, and family life related to having a child. In this section we will demonstrate how the basic model can be extended to relax some of these assumptions. Using examples from this section for guidance, a decision maker can further explore and modify the model, customizing it to her particular case.

5.1. Risk of Chromosomal Abnormalities Increasing with Age

In this section we show how to account for a woman’s concerns about a child with chromosomal abnormalities and the effect of increasing age on the probability of those abnormalities. We will refer to a child with genetic abnormalities as a “handicapped child.”

Some women might undergo a prenatal diagnosis for chromosomal abnormalities such as Down syndrome (Thornton and Lilford 1990) and might choose not to keep the baby if an abnormality is found. To model this scenario, it suffices to decrease the probabilities of conception at a later age to reflect growing probabilities of chromosomal abnormalities, and this scenario is equivalent to the analysis in §4.4.

If the decision maker is going to keep a baby with a detected abnormality or if she plans not to undergo the prenatal testing, then the model can be modified to account for the possibility of a handicapped child. Having a healthy child and having a handicapped child might have different impacts on social life and career (for example, having a handicapped child might force a woman to quit her job) and most likely affect the quality of time with a child.

\[11\] Mathematically, this coefficient times the woman’s age gives the slope of the probability decline curve for this age. Thus, the decrease of this coefficient means steeper decline of the probability of conceiving at later ages.
To include this concern in our model, we introduce an additional coefficient into the basic model: relative joy of having a handicapped child $h \in [0, 1]$, which, multiplied times the utility of having a healthy child $u_T(f_h)$ will result in “utility from having a handicapped child” function $u_{Tb}(f_h) = h \cdot u_T(f_h)$. We also introduce age-dependent probabilities of a genetic abnormality (for data, see, for example, Hook 1981) in a newborn child $y(B)$ where $B$ is the mother’s age when the baby is born.\footnote{We use data from Hook (1981) to assess $y(T)$, $T \in [20, 45]$. We extrapolate this data to obtain $y(T)$ for $T \in [45, 49]$.} Hence, we construct a new family life utility curve as follows:

$$u_T(f_A|t) = (1 - y(A - t)) \cdot u_T(f_A|t) + y(A - t) \cdot u_{Tb}(f_A|t) = u_T(f_A|t) \cdot (1 - y(A - t) \cdot (1 - h)), \quad (7)$$

where the mother’s age when the baby is born is calculated as her age $A$ minus child’s age $t$: $B = A - t$. By replacing $u_T(f_h|t)$ with $u_T(f_A|t)$ in (1), we obtain a model that incorporates the possibility of genetic abnormalities in a child and can analyze its effect on the optimall age to start trying to conceive a child.

If one also wants to model the effect of a handicapped child on the professional or social life objectives, then in addition to eliciting utility curves corresponding to each of the outcomes when a healthy baby is born as a function of mother’s age, the correspondent utility curves for a handicapped child need to be elicited. Then, for each outcome (child born at current age $+1$, $+2$, etc.) and each objective, the expected (over the child’s health state) utility curves can be constructed for professional and social objectives and substituted into formula (1).

5.2. Assisted Reproduction

Although the base-case model is based on the probabilities of natural conception, it is easy to modify this to account for cases when this way is not available or desirable. For example, if artificial insemination or any other assisted reproduction method is considered as the only option or as a secondary option if natural conception does not occur within the first year or two, one needs to substitute the currently used probabilities to give birth through natural conception with age-dependent success rates for the particular method of no child over a woman’s life from her current age to 75. For all situations when a child is born, adjustments to the childless consequences are made based on the age of the child and the age of a woman in each year. The uncertainties of conceiving as a function of

5.3. More Then One Child

It is possible to extend the model so that it helps to make a decision about the optimal timing of a second or third child, and there are several ways to do so. For example, if the decision maker already has a child at her current age, then instead of childless utility curves for the objective components, the curve corresponding to “having only the existing child” must be elicited and other components (such as impact of a second child on social or professional life) are assessed so that they modify the “current child” base case. If the decision maker does not have a child, but is certain that she wants to have two or more children with more or less specific differences in ages, then utility components corresponding to all possible outcomes (first child at $A_c + 1$, second at $A_r + 2$; first child at $A_r + 1$, second at $A_c + 3$; etc.) must be assessed for each utility component and then combined into the expected value of each alternative using the conception probabilities. Parameterization and scenarios similar to the ones used in our base model might help to cope with a sufficiently increased number of outcomes. However, changes in information or in preferences will likely happen after a first child is born because a mother should have a better idea of her ability to enjoy children, her utility of having children, the child’s impact on her career and social life, etc. Thus, it seems reasonable to reconsider a decision of having a second baby after the first child is born.

6. Discussion

The model developed here explicitly addresses several major complexities of the biological clock decision. Three separate objectives concern the quality of the professional, social, and family aspects of a woman’s life. This quality is estimated for the case of no child over a woman’s life from her current age to 75. For all situations when a child is born, adjustments to the childless consequences are made based on the age of the child and the age of a woman in each year. The uncertainties of conceiving as a function of
A woman’s age are taken from the medical literature. A quality-of-life value model combines professional, social, and family components allowing for different relative importances assigned to these three aspects of a woman’s quality of life in each year.

An illustrative base-case analysis is presented that uses reasonable information for all required model inputs. For example, the average probabilities of conceiving for a woman of any specified age is taken from the medical literature. An individual woman can personalize this by changing the probabilities to reflect what she knows or believes are better estimates of the probabilities for herself. She can also adapt the model to include what she believes represents the relative quality of her professional career over time without a child, the impact of a child of different ages on her professional career, and her judgments about the relative importance of professional, social, and family aspects of her life over time. To facilitate adapting this information to an individual woman, the model parameterizes such information so that only a few parameters are needed to personalize the input.

The illustrative case considers a doctoral student aspiring to have an academic career. We demonstrate how the best age to start trying to conceive can change significantly depending on different inputs, such as the probability of becoming a tenured professor with and without a child, and as a function of changes in relative importance of professional and family life over time. We also examine implications of the statement “I don’t want to have a child before I am X years old.” It is shown that this preference may be inconsistent with other preferences that the woman may have. Separate analyses examine the implications of infertility being higher than average and the possibility of genetic abnormalities in children as a function of a mother’s age at conception.

With analyses that are personalized to each woman’s preferences and circumstances and having only run a limited number of analyses, it is difficult to make any general conclusions. However, recognizing those caveats, three preliminary findings may turn out to be reasonably robust. First, except in cases where the importance coefficient for having a child is very small (i.e., less than 0.10), it always appears better to have a child than not. Second, the relative loss of life utility for a woman first trying to conceive later than her optimal age appears to be much greater than trying earlier. Third, the decision not to have a child until one’s career is “fully established,” especially if this occurs in the mid-thirties or later, may be inconsistent with a woman’s circumstances and her fundamental preferences to balance her professional, social, and family aspects of her life.

Our model should be considered as a first-cut of a very important problem. However, it incorporates several factors that should be considered in the problem and tries to balance the effort needed to use the model and the insight that might be gathered from its use. We have also demonstrated how the first-cut model can be further extended to incorporate some additional concerns. The output of the model including the optimal age to begin trying to conceive is not the answer to any woman’s real-life decision. It is the answer to the model of that decision. Thus, the use of sensitivity analysis to understand what information and judgments are most important to a particular woman’s decision and how they affect the decision is what is meaningful. This understanding provides insights that can complement feelings and intuitive reasoning and lead to a more informed choice.

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