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Oded Stark

Menopause as a regulatory device for matching the demand for children with its supply: A hypothesis

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Abstract

Drawing on two assumptions: that menopause is an instrument for the efficient regulation of the duration of a biologically expensive state, and that people have children in order to obtain support from them in old age, we set out a new idea that seeks to explain both the occurrence of menopause and its timing. On the basis of the notion that the purpose of having children is to obtain support in old age, we perceive menopause as an upper limit to the fertile state, when a continued ability to give birth to children would not generate the desired support. The conjecture yields specific testable predictions, and can be assessed against the "reproductive conflict" hypothesis. Being supported by one's offspring is a distinctive feature of humans; in this context, we cannot rely on animal studies in evolutionary biology and related fields to help us to ascertain something that is specific to humans.

Keywords: Occurrence and timing of menopause; Support in old age; Demand for children; Supply of children

JEL classification: D64; D90; J13; J14

1. Introduction

There are many examples of how in the past prevailing preferences in general, and economic and social preferences in particular, were shaped by biological processes. Here are two examples. First, the taste for sweet food can be explained by irregular supply of calories in the past, and the fact that sweetness is a sign of both high calorie intake and of calorie- and protein-density. To scavenging primates, sweet natural foods, such as fruits which are high in sugars, provided valued energy. Second, a present-day desire for high status can be explained by a past environment in which food was scarce and its availability was unstable, and where high rank or status allowed for priority access to food that, in turn, conferred longevity. Another biology-based explanation that comes to mind is that nature processes promoted higher status as a path to greater reproductive success. There are not many cases of a reverse causality, namely cases in which economic and social preferences offer an explanation for biological processes. In this paper this lack is somewhat amended by a study of the menopause, which we perceive as an instrument that efficiently regulates the duration of a biologically expensive state.

Several studies in biology and evolutionary biology have sought to explain why women's ovulation ceases before they reach the end of their life (Williams, 1957; Shanley and Kirkwood, 2001; Hawkes, 2004; Lahdenperä et al., 2004; Cant and Johnstone, 2008; Lahdenperä et al., 2012; Levitis et al., 2013; Croft et al., 2015; and others). Here we outline a new conjecture that seeks to explain both the occurrence of menopause and its timing. Based on the idea that the purpose of giving birth to children is to obtain support in old age, we perceive menopause as an upper limit to the fertile state, a stop when a continued capability to give birth to children cannot produce the desired support. The conjecture yields specific testable predictions, and can be assessed against the intriguing "reproductive conflict" hypothesis (Cant and Johnstone, 2008; Croft et al., 2017).

At the core of the "reproductive conflict" hypothesis is the perception that menopause emerged because of competition between women for limited resources that are needed in the process of reproduction. The contested resources include communal goods (such as food) shared in the social groups to which the women belong, and help provided

by other adult members of the groups in the rearing of children. By means of the process of selection, menopause evolved so as to minimize the reproductive competition between generations within the same social group. Thus, it was older women who were selected by evolution for stopping reproduction midway through their life because in reproductive competition, younger women had a comparative advantage: by helping to rear the children of older women, younger women could not gain as much as older women could gain by helping to rear their grandchildren, where the gains are defined in terms of genetic relatedness.

The "reproductive conflict" hypothesis implies that menopause facilitates a substitution in the sense that instead of being able to give birth to children (or, for that matter, instead of being exposed to the "risk" of producing children), menopause allows a woman to *provide* support with rearing the children of her children. The conjecture presented in this paper is the complete opposite: when the purpose of giving birth to children is to *obtain* support in old age, menopause puts an end to a state that is biologically costly and futile.

2. A conjecture

In proposing a conjecture that is starkly different from the "reproductive conflict" hypothesis, that is, in postulating that menopause is driven by women's need to *obtain* support in their old age from their children rather than that menopause emerged in order to allow women to *provide* support to their children when they reproduce, we draw on two premises: that menopause is an instrument of efficient regulation of the duration of a biologically expensive state, and that people have children in order to obtain support from them in old age.[1] Being supported by offspring is a distinctive feature of humans; in this

[1] Leibenstein (1957) argues that the old age security motive is the most important motive for fertility. Nugent (1985) presents a wealth of evidence in support of the notion that the old age security motive is an important motive for fertility in developing countries, especially among women. Becker et al. (2016, p. S3) state that "Throughout history, most elderly parents received support from their children, either by having their children move in to live with them or by living with one of their children."

context, reliance on animal studies in evolutionary biology and related fields is not helpful in ascertaining what is specific to humans.

The wisdom and logic of nature and evolution require energy and resources to be conserved and retained for their most productive use. Being in the fertile state requires significant biological resources.[2] Obviously, biological resources are not free, and it is therefore important to allocate them efficiently between competing ends.

In economic parlance, being in a fertile state is a supply response to the demand for children. It is inefficient to provide (costly) supply when there is no demand, and it is equally frustrating to leave articulated demand not met. Here, supply takes the form of a woman in an age bracket in which she can give birth, and demand arises from an anticipated need for support from her children in her old age. In economics, the mechanism that enables transactions to be effected and markets to clear is the price scissors. Correspondingly, the idea postulated here is that in the domain of demand for and supply of children, menopause is a regulatory device when children are viewed as a source of support to their mother in her old age. Of course, people give birth to children not only in response to a desire for support and security in old age. Motivations for having children are many: they span from the joy of parenting, through preserving the family name, to the demand for grandchildren as elaborated in Cox and Stark (2005). However, as such, these reasons do not explain menopause. As shown below, the supply-demand reasoning outlined here links up with the occurrence and the timing of menopause.

If the desired outcome of fertility is to obtain support in old age from children, then for such support to be available there is not only a need to have children; there is also a

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[2] There is ample direct evidence (Harshman and Zera, 2007; Speakman, 2008) that maintaining the ability to reproduce entails considerable physiological costs (it taxes nutrition and drains energy). There is also interesting indirect evidence that being in a fertile state requires considerable nutritional resources. Such evidence comes from adverse experiences, as the one recently documented with regard to North Korean female soldiers. Lack of food and malnutrition are reported to have caused "many [to] stop menstruating;" "women missed their period for years while in the army." (A BBC World Service report "Rape and no periods in North Korea's army," November 21, 2017; https://www.bbc.com/news/stories-41778470.) Because the ability to remain fecund places demands on energy and nutrients then, when those supplies critically fall, and the retention of bodily functions other than being fecund is considered critical for survival, the body shuts off functions that in that regard are secondary in importance.

need for the children to be at such an age when their mother grows old to be able to provide the required support. There is, thus, a predictable link between a woman's life expectancy, the duration of her old-age infirmity and, consequently, the age beyond which her being fertile is superfluous. The latter consideration implies a rationale for an upper limit to the fertile state, which explains both the occurrence of menopause and its timing.[3] Suppose that a mother requires support during the last 10 years of her life and that if her life expectancy is 50, she will need support between the age of 40 and 50, and if her life expectancy is 60, support will be required between the age of 50 and 60. Suppose, in addition, that a child is capable of providing support on reaching the age of 15. Then, in the first case, it serves no purpose to give birth to a child beyond the age of 35, and in the second case, it is useless to give birth to a child beyond the age of 45. Because there is no sense in burdening a woman's body with fertility beyond the age of 35 (45) in the first (second) case, the age of menopause can be expected to track life expectancy, holding constant the number of years in which support in old age is needed. In other words, a positive correlation is expected between life expectancy and the age at which a woman's menopause occurs, conditional on the duration of a woman's frailty in old age. [4]

By the same logic, holding life expectancy constant, the age of menopause can be expected to be influenced negatively by the duration of the period of a woman's frailty. To see why, consider again the case in which a woman's life expectancy is 50, her period of frailty is the last 10 years of her life, and a child is capable of providing support from the age of 15. As already noted, there is no purpose in giving birth beyond the age of 35. But if the child's ability to provide support does not increase with age (except for reaching the ability to provide support at the age of 15), then there is no need for the woman to give birth prior to the age of 25 either. Thus, the efficient age bracket for fertility is 25-35. Now, holding life expectancy constant at 50, suppose instead that a woman's period of frailty is

[3] Indeed, the rationale helps explain why the reproductive function is terminated long before other physiological functions and long before mental impairment (if any), let alone well before life ends. Put differently, it helps explain why the timing of menopause does not coincide with the timing of death.

[4] Cooper and Sandler (1998) report a higher rate of mortality of women who experience menopause at a relatively young age. This finding translates into a positive correlation between the age of menopause and life expectancy.

the last 20 years of her life. As before, there is no purpose in giving birth to a child beyond the age of 35, and there is no need to give birth to a child prior to a maternal age of 15. The efficient age bracket of the state fertile is then 15-35, which, in terms of biological resources, is more demanding than the age bracket of 25-35. An evolutionary biological response to this (namely an adjustment as a means of "reducing the tax burden") is to reduce the length of the relatively broad age bracket of 15-35. A child born early within a fertility age bracket is available to provide support for more years than a child born late within a fertility age bracket. Therefore, if an older child is not less likely to be able to provide support than a younger child, then reducing the age bracket is not likely to take place at the more valuable lower boundary of the bracket but, rather, it will take place at the less valuable higher boundary.[5] This implies that when the period of a woman's frailty is expected to be long, menopause is likely to occur early in comparison with a situation in which the period of frailty is expected to be short. This is why, holding life expectancy constant, a negative correlation can be expected between the duration of the period of frailty and the age of menopause.

Given the life expectancy and the duration of the period of frailty, a logical corollary of the argument presented above is for the age of menopause to be influenced negatively by the age at which a child is capable of providing support to the mother. Thus, in economic environments in which the nature and technology of economic production render it possible for a child to become an effective support provider from a young age, menopause can be expected to set in later than in environments in which a child becomes an effective support provider at an older age.

The extent to which a woman's wellbeing in old age depends on support provided by her children can also be expected to impact on the age of menopause. For example, we can compare an environment in which girls and boys inherit equally with an environment in which only boys inherit. In the first environment, a woman's wellbeing will depend more on her own resources and less on support from her children than in the second

[5] If the cost of being in the state fertile is convex in age, the opportunity cost of not terminating this state rises with age.

environment. Because the need to bear children as a means of support in the first environment is lower, menopause in this environment will set in earlier, thereby eliminating the need for producing "marginal" children (the least valuable children whose overlap with the woman's years of old age is the shortest).

How can our proposed explanation of menopause be empirically distinguished from the explanation offered by the "reproductive conflict" hypothesis? A response can be provided by means of a numerical illustration. Let a woman's life expectancy be 50 and let a woman's fertility start at the age of 20. Assuming that her daughter too will be giving birth to children from the age of 20, then if the reason for the onset of menopause is the "reproductive conflict" hypothesis, the woman's state of being fertile will cease at 40. If children are needed to provide care when a woman is old, and if children can supply such care by the age of 20, then there will be no point giving birth to children past the age of 30. This calls for women's period of being fertile to cease at an age of up to 30. Thus, in the case of this illustration, predictions differ, and our proposed conjecture can be distinguished from the "reproductive conflict" hypothesis.

Comment. Given the reasoning above, one could question whether there is a selective advantage for a society to support elderly people simply to allow them to live on (unproductively) until they die. A response to this argument is that the notion of selective advantage for society should not override the individuals' own desire to live long. Individuals will be reluctant to enter a "deal" with their society by which as soon as they have completed the raising of their children to independence, their society will be "allowed" to dispose of them: "my bargain with you, society, is that I will contribute to your continued existence, to your preservation, by producing the next generation of children, and you will not dare to stop those children from supporting me" as it were.

3. Supplementary discussion

The need to obtain support in old age from children is common to women and men, while the constraint on fertility modeled in this paper is of women. The logic of the paper's hypothesis could in principle apply to men as well, thereby placing a similar constraint on their fertility. That this is not happening (men retain their fertility well into old age even if

at a reduced level, and with a hormonal change that is gradual and occurs over many years) is a consequence of the fact that unlike in the case of women, in the case of men being in a fertile state does not require significant biological resources.

An additional way to appreciate the physiological toll of maintaining fecundity (recall footnote 2) is to refer to recent assisted reproductive technologies (ARTs) applied to women in their 50s and beyond in countries such as India, where rural childless women are permitted to undergo the prescribed procedures. The ARTs make post-menopausal pregnancy physiologically possible. The quite high cost of administering the treatments further underscores the toll on a woman's body of being in the fertile, pre-menopause state.

If obtaining support in old age from children did not play the role described in this paper, then older individuals might have been abandoned when frail. Specifically, if we were to go back in time and study traditional societies such as hunter-gatherers and foragers who represent the type of ecology in which menopause could have evolved, we might reason that the need for frequent mobility to find new food and other resources would have imposed a burden in transporting elders. But that elders were not left behind to die of neglect helps support the idea that children care for their elders.

In line with the Comment presented at the end of the preceding section, an argument can be made that natural selection which promotes fitness and results in the propagation of one's genes in future generations implies that the flow of resources is down the generations, not up; in terms of the allocation of scarce resources, children will be better served by investing in the production of their own children than in administering care of an aging parent. But what this line of reasoning neglects is that the gene "file" also embeds a desire to live and to prolong life. Caring for the elderly requires ability (yielded, as argued before, by matching of the age spans, which in turn is facilitated by the timing of menopause) and willingness (served, for example, by the "demonstration effect" theory of Cox and Stark, 2005).[6] If there were no menopause, children could be produced with no ability to provide and demonstrate support, which in turn will not result in them

[6] Consult also Bergstrom and Stark (1993).

inculcating in their own children by means of example the trait of support of an aged parent. Seen this way, menopause defines an age bracket that at the same time both facilitates the ability to provide support and allows the instilling of an incentive to do so.

There is a complementarity between the literature on the "asset demand for children" (Stark, 1981) emanating from a desire to obtain support in old age and the hypothesis presented in this paper. The existing literature requires children to be born or else there will be no support available in old age, but it does not identify the time bracket in the life of a women when births should occur so as to result in an ability of a child to provide support when it is needed, nor when births should not occur because the availability of support will be useless if the mother is no longer alive. In other words, the emphasis in the existing literature is on an event, the emphasis in this paper is on timing. Menopause guards against "waste" in the sense of timing. In fairness to the existing literature, we should add that a reason given for births not to occur late in a woman's life is to guard against a woman's health being at risk.

At the core of this paper is the posting of a hypothesis that, in a sense, is the inverse of the "reproductive conflict" hypothesis. A reviewer of a preceding version of this paper raised the idea that because of its unusual linguistic elegance and aesthetic formulation is replicated here verbatim.

> "[T]he paper could be further strengthened by extending the discussion to the costs that occur after pregnancy. As mortality is a concept most people understand theoretically, it generally is hard to fully apply to oneself, as the self is only aware of itself as being alive, or, as supposedly said by Johann Wolfgang Goethe "It is quite impossible for a thinking being to imagine nonbeing, a cessation of thought and life." Women might hence be inclined to believe that they will be alive longer than would be expected statistically and, thus, be motivated to invest in childbearing to receive support in an improbable future. In a way, menopause can accordingly be interpreted as a "cunning of reason" to force women to forgo an investment that would not pay off."

On reflection, this intriguing idea can be taken as a support for this paper's hypothesis rather than as an alternative hypothesis. The *reason* why being fecund past a certain age is superfluous is that births at that time span cannot result in children providing old age support.

Taking the hypothesis to the data will not be easy. But some approaches could be sketched. For example, prolongation of life expectancy could permit a birth later in the course of a woman's lifespan that will produce a child able to provide support, given the age at which a child is able to provide it. The reason then for life expectancy to be positively correlated with the age of menopause is not that a state of better health invites a longer span of being fertile. In yet another example, if the demand for old age support is met by an alternative supply (an efficient intertemporal transfer of resources, a pension scheme), then the demand for support from a child will be reduced. But the effect will not be, as is often presumed, merely a lower fertility (Caldwell, 1982). Rather, the effect will be to bring forward in a women's lifespan a fertility stopping mechanism, holding constant the medical environment which can be "disturbingly" correlated with the introduction of means of old age support other than support by children. And as a third example, again as conjecture, given a woman's life expectancy and the duration of the period of her frailty, a shift upwards of the age at which a child could provide support (perhaps as a consequence of prohibition of child labor) will bring into the effective fertile span later births, thus affecting positively (delaying) the age of menopause. All three changes illustrated here will obviously take long to occur, and may well be marginal; after all, a sign is not a magnitude. Even though, detecting them will enrich the core idea presented in this paper.

4. Conclusion

In sum: if a daughter gives birth to a child at age t, and if this is the same age at which her mother gave birth to a child, then a mathematical representation of the "reproductive conflict" hypothesis is that the age of menopause, m, observes $m = 2t$. The conjecture presented in this paper implies a different mathematical representation in which m is a function of life expectancy, the duration of frailty in old age, and the age at which a child can provide an aging mother with care. While the "reproductive conflict" hypothesis can

usefully apply in non-human contexts, it may not fare well in the case of humans whose motives for bearing children are more varied. The examples presented above illustrate how one such motive, namely receiving support in old age, can be expected to influence the timing of menopause. How the long history of elderly people receiving support from their children interacts with the evolutionary processes that shape and modify biological aspects of human life is a fascinating field for theoretical and empirical inquiry.

Appendix: A graphical representation of distinctions between predictions of the "Reproductive conflict" hypothesis and the "Demand for children" hypothesis.

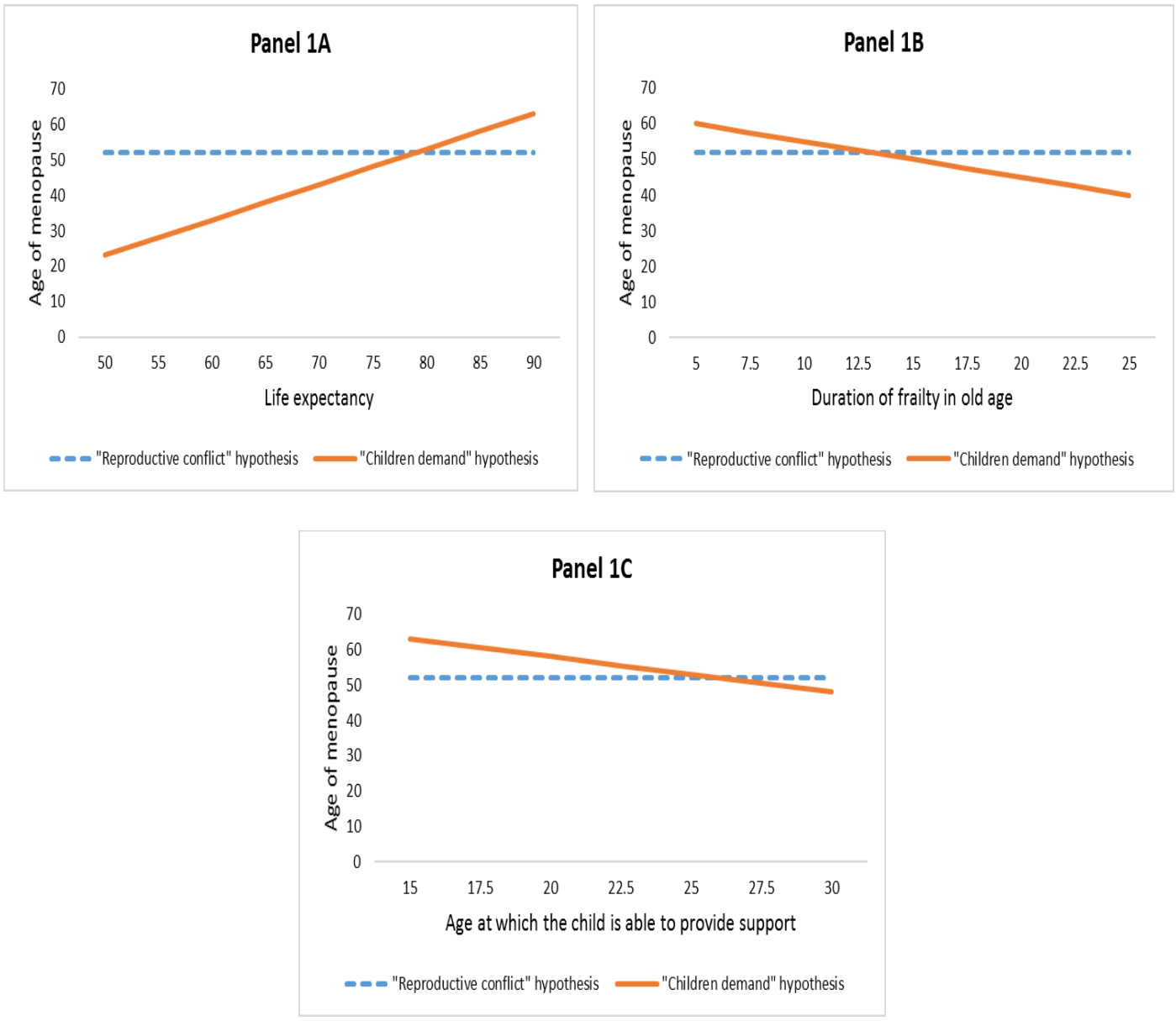

Figure 1. The implied relationship between the age of menopause and in Panel (1A) life expectancy; in Panel (1B) the duration of frailty in old age; and in Panel (1C) the age at which the child is able to provide support.

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