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論文内容の要旨
Summary of thesis contents

Evolutionary approaches to fertility decline in humans: case studies in Japan

Fertility directly affects one's reproductive fitness, so its decline (i.e., fertility decline, one of the main features of demographic transition) in modern societies is one of the most paradoxical phenomena in the evolution of human behavior. In my PhD thesis, I focus on the fertility decline in modern Japan (except a theoretical study in Chapter 5) and study various topics that are strongly related to fertility decline: the effect of socioeconomic status on the number of children and on the probability of childbirth, the effect of kin on fertility, a cultural norm for the preference for the number of children, sexual conflict between mother and father over reproductive decision-making within a couple, and the effect of peer competition and self-enhancement (i.e., options other than reproduction) on fertility decline. I conduct these studies by taking several approaches: statistical analysis of survey data, questionnaire survey at childcare facility to parents, and mathematical modeling.

Chapter 1 is General Introduction. I briefly review evolutionary approaches to fertility decline in humans. 18 years ago, Borgerhoff Mulder (1998) proposed various evolutionary hypotheses to explain low fertility rates. However, there has not been a unified consensus yet on why fertility decline occurs. In this chapter, I also summarize fertility trends in Japan. The fertility rate in Japan dramatically dropped after the World War II and it has been kept at a low level despite the economic growth and high resource availability. In addition, I explain the significance of analyzing Japanese data.

In Chapter 2, I study factors affecting the number of children. It is generally recognized that a notable feature of fertility decline is a non-positive relationship between one's socioeconomic status and the number of children. In this chapter, first, I review the existing literature that examined the relationship between them. Some studies reported positive relationships in men and negative ones in women. However, it is also reported that the positive relationship in men was often weakened when childless individuals were excluded from the analyses. It is because childless men tend to be at lower socioeconomic status and unmarried. I found that there was much variation in the effects of one's socioeconomic status on the number of offspring. Second, I analyze Japanese cross-sectional data in 2010 and studied how household income and education level, which are measures of one's socioeconomic status, affect the number of children. My conclusion is that when the effect of the age at first marriage was statistically controlled, socioeconomic status did not have significantly positive effects on the number of children. In the analyses, I found no sex-specific effects of one's socioeconomic status.

In Chapter 3, I study factors affecting the probability of childbirth. In order to

reveal the conditions that could facilitate childbirth, it is necessary to analyze not only cross-sectional surveys but also panel data that track the same person for a long period. In this study, I explore factors that influence the probability of childbirth. I analyze Japanese panel data by a statistical method called Cox proportional hazard model. Subjects of my analysis are married women and their childbirth records from 2004 to 2009. Contrary to the predictions based on the theory of behavioral ecology, I found no positive relationships between good parental conditions for childcare, such as high income, increase in income, or co-residence with parents (i.e., grandparents of children), and the occurrence of childbirth. I also found that the number of existing children had a significant impact on the probability of childbirth. The likelihood of further childbirth by couples with one child was nearly equal to that of childless ones. However, the corresponding likelihood of couples with two children was about five times lower than that of childless ones. The total fertility rates in modern developed societies are quite low and couples prefer having two children. This trend is known as the two-child norm, but it is a paradoxical phenomenon in terms of fitness maximization. My result provides new quantitative evidence of this norm.

In Chapter 4, I apply the perspective of sexual conflict between mother and father (her husband) to the fertility decline. It is predicted that, under serial monogamy that allows mate changes, the ideal number of children for women should be smaller than that for men, because the cost of reproduction for women should be higher than that for men. My reasoning is that if the cost of child-bearing and child-caring is higher in women than men, and if women, who want a smaller number of children than their husbands, have gained more power in reproductive decision-making within a couple owing to the modernization of the society, fertility decline should occur. Until now, few evolutionary studies have analyzed empirical data in modern developed societies with such a perspective. My questionnaire survey in an urban area in Japan revealed that mothers actually experienced greater cost during childcare than fathers. However, in contrast to my prediction, I found no sex differences in the ideal number of children within a couple in many cases. About 60% of parents wanted two children when they were childless. Moreover, my analysis showed that mothers and their husbands had equal power in their decision-making to bear children. My results suggest that men may not enjoy the advantage of serial monogamy in modern developed societies.

In Chapter 5, I study the effect of peer competition and self-enhancement on fertility decline. To understand fertility decline, it is necessary to explain how parents allocate their wealth to offspring/themselves and what environmental conditions lead to a decrease in fertility. In this study, I analyze a wealth-fertility relationship from the perspectives of peer competition among offspring and self-enhancement. In urban societies with competitive labor and mating markets, parental cost for childcare should be larger and fertility should consequently be lower than that in rural societies. Some examples of self-enhancement are dressing in designer clothing, acquiring luxury cars, and enjoying leisure activities. These may

be extreme examples, but it is reasonable to assume that, in modern life styles, people face attractive options that do not directly enhance their reproductive success. I assume that parents try to maximize *"Happiness"*, which is defined as the combination of biological fitness and self-enhancement. Note that this assumption is deviated from a purely evolutionary model. My mathematical models predict that high levels of investment in child quality and self-enhancement reduce fertility. These results would match the situations observed in modern low-fertility societies.

Chapter 6 is General Discussion. As I described above, I have obtained a number of results on fertility decline by taking a variety of approaches. I believe that I have contributed to providing a novel framework and pieces of evidence that are related to fertility decline. Based on these results, I discuss the relationship between socioeconomic success and reproductive success. It is expected that parents in modern developed societies keep high socioeconomic status in order to provide much parental investment for their children. It is because, in a competitive environment, lower-quality offspring tend to lose in peer competition in labor and mating markets, and to result in lower reproductive success. In such an environment, parents should set a high value on parental investment and would aim to produce a small number of high-quality children. I also discuss effects of various kinds of sexual conflict on fertility decline. There are various measures other than family size to study sexual conflict between parents. I provide new ideas of studies on sexual conflict over contraception and induced abortion. Additionally, I argue the relationship between evolutionary biology and social sciences. I believe that evolutionary thinking gives us a concise and rigid theoretical framework to study human behavior based on fitness maximization, which enables us to consider "why" questions (i.e., ultimate factors). Lastly, I give a perspective towards an integrated understanding of fertility decline and other evolutionarily (mal)adaptive behaviors in humans.

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博士論文の審査結果の要旨
Summary of the results of the doctoral thesis screening

博士論文の第１章では少子化を説明する三つの仮説が述べられ、また日本の少子化の現状がデータとともに述べられている。第２章からが本論であり、第２章では内閣府のデータを元に、ヒトの生涯繁殖成功に与える要因を一般化線形モデルにより解析している。特に出願者が注目したのは社会･経済的地位が繁殖成功に与える影響であるが､解析の結果、年収や最高学歴および家庭内の主婦の存在といった変数は子の数に有意な影響を与えておらず、初婚年齢のみが子の数に有意な影響を与えることが示された。また、子の数の分布はPoisson分布から有意に逸脱しており、特に親が子を２人持つことを殊更に選好する” two-child norm”の存在が示された。

第２章の討論部および第３章の序論では、第２章の方法論の問題に関する議論がある。第３章ではこの欠点を克服するため、長期に渡って同一人物を追跡したパネルデータを用い､Coxの比例ハザードモデルを用いて子の数に及ぼす要因を探った。このように適切な方法論を用いた点は大いに評価できる｡その結果､第２章とほぼ同様の結果が示唆されたが、特筆すべきは既存の子の数が新たな出産に及ぼす影響の分析であり、第２子の出生率は第１子の出生率と比べて遜色ないが、第３子の出生率は第１子の出生率の約５分の１であることが示された。これはtwo-child normに関する定量的な証拠を与えた重要な発見である。出願者は２という子の数の選好が生じている理由について、親が第３子を育てるコストを実際よりも非常に高く見積もってしまうからではないかと推測している。

第４章では出願者が自ら行った質問紙調査を元に、夫婦間の子の数に関する対立の有無が調べられた。出願者は現代日本の少子化の一因に妻の発言力の増大があるのではないかと着想し、子をもうける意思決定に夫と妻のどちらの意思がより反映されているかを調べた。これは、生物学的に見て男性よりも女性のほうが繁殖のコストが大きい為、女性の発言力の増加は少子化に繋がると考えたからである。しかし解析の結果、希望する子の数や子をもうける際の意思決定に、夫と妻の間で明確な力の偏りは見られなかった。論文中ではこの理由として、連続的一夫一妻制下では男性も離婚等のコストが大きく、従って男性が女性に比べて繁殖コストの面で優位に立っているとは必ずしも言えないからではないか、と述べられている。夫婦間の対立という視点は従来の人口問題研究には無かった点であり、” Evolutionary approaches” という論文表題にふさわしい分析で高く評価できる。

第５章では繁殖成功と心理的満足の積である” Happiness”を目的関数としたESSモデルが分析され、現代の競争的労働市場・婚姻市場、および多様化した自己充足のオプション（レジャー等）が少子化の要因であることが理論的に示されている。そして第６章では総合討論が展開されている。

博士論文の各章はいずれも出願者が主体的となって行った研究に基づくものであり、選定されたテーマおよび解析手法も適切である。得られた結果は少子化の要因に迫るものであり、内容の独創性および学術水準ともに、博士論文としてふさわしい。

博士論文を構成する主要な論文は、発表論文リスト内の[2,3,4]の三報である。これらについて主査は、論文[2]がLetters on Evolutionary Behavioral Science 誌に採録済みであり、論文[3]がAmerican Journal of Human Biology 誌のOnline 版に掲載済みであることを確認した。また、論文[3]とHuman Nature 誌に掲載予定の論文[4]に関しては、当該誌からの受理通知の電子メールを確認した。いずれの論文も出願者が第１著者である。また各論文の共著者から、これら論文を共著者が他の博士論文の基礎をなす論文として使用し

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ない旨の承諾書を得ていることを確認した。

公開論文発表会および口頭試問は平成２８年１月２２日に葉山キャンパスにて行われた。公開論文発表会における発表および討議の能力、および英語能力は博士の学位に相当する十分な水準に達していると判定した。口頭試問においても内容の基本的な理解は出来ていると判断し、審査委員４人の全員一致で、博士の学位を授与することを可と判定した。