Low Fertility in Japan: An Agent-Based Modeling Approach

Mary C. Brinton

Department of Sociology

Harvard University

Cambridge, MA, 02138

brinton@wjh.harvard.edu

Yun Zhou

Population Studies and Training Center

Brown University

Providence, RI, 02912

yun_zhou@brown.edu

Extended Abstract

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Introduction

Very low fertility rates became a common phenomenon across a range of postindustrial societies in the last few decades of the 20th century (Billari and Kohler 2004; Kohler et al. 2002). Among the countries characterized by lowest-low fertility, Japan stands out as an example where the fertility decline began relatively early—at the beginning of the 1970s—and has continued over time. A central question that has been raised in the low-fertility literature is whether below-replacement fertility such as Japan's represents a temporary equilibrium in which a society may be trapped (Kaneko et al. 2008; Lutz et al. 2006) or whether government policy efforts or more endogenous sources of change will move societies to an equilibrium characterized by population-replacement level fertility (Esping-Andersen and Billari 2012; Frejka et al. 2010; Lutz and Skirbekk 2005; Lutz et al. 2006; Myrsklä et al. 2009). Some demographers view below-replacement fertility as a temporary state from which societies will recover once cohort-specific trends towards higher age at marriage and fewer births slow down or reverse (Bongaarts 2002; Goldstein et al. 2009; Sobotka 2004) or as gender equity increases (Esping-Andersen and Billari 2012; Goldscheider et al. 2015; Myrsklä et al. 2009). Others are less optimistic about the ability of societies to return to a population-replacement fertility equilibrium, at least within the next several decades (Chesnais 2001; Kohler et al. 2006; McDonald 2006). While a number of countries in Europe that experienced lowest-low fertility in the 1990s and early 2000s exhibited some "recovery" beginning in 2003, this has not been the case in East Asia (Goldstein et al. 2003; Kaneko et al. 2008).

Agent-based modeling is uniquely equipped to investigate the *process* of individuals' fertility decision-making and the linkages and feedback between micro interactions, meso-level structural conditions that individuals face, and macro-level population outcomes. To explore the future of Japanese fertility, we propose an agent-based model that focuses on second birth transition for married Japanese women with one child. In the following sections, we outline the theoretical and empirical foundations of our model and describe its implementations. We conclude by presenting our preliminary simulation results.

Empirical Motivations for the Model Assumptions

Recognizing the low-fertility problem, the Japanese government has spent the past two decades proposing and implementing successively more generous policies to encourage higher parity births. Much of the English-language literature on family, work, and motherhood has focused on the strategies and adjustments women make with respect to their employment when facing stark incompatibility between work and family life (e.g. Stone 2007). In the context of Japan, with the population pyramid becoming increasingly top-heavy, Japanese government policy and discourse have changed course in the past several years. Rather than encouraging childbearing accompanied by women's retreat from the labor market, the government currently is encouraging Japanese married women to work full-time in the labor force and to have two children.

Empirical studies in multiple societies have examined the association between fathers' share of household work and the likelihood of second birth transition (e.g. Cooke 2004, 2009; Nagase & Brinton 2017; Olah 2003; Torr & Short 2004). For Japan, Nagase & Brinton (2017) have found that especially for dual-earner couples, husbands' housework hours is a significant positive predictor for second birth transition probability. In addition, scholars have also pointed to a generally positive relationship between husbands' (expected) housework share and fertility intentions in the Japanese context (Mizuochi 2010; Yamaguchi 2005). Since the early 2000s, as evident in a series of policy implementations, the Japanese government has become increasingly cognizant of the role that fathers' involvement in family life may play in achieving the goal of fertility recovery. With the passage of the "Act on Advancement of Measures to Support Raising the Next Generation of Children" in 2003, firms with more than 300 employees were mandated to construct work-family policies and to register a two-to-five-year action plan with the local Ministry of Health, Labor, and Welfare office (Nagase & Brinton 2017). Along with such governmental efforts, Japanese fathers' ideals about work and family too have gradually evolved, with an increasing number of fathers reporting (an ideal of) giving priority to family life. [1]

Based on these empirical findings and the policy context in Japan, we ask: If women's full-time employment is treated as a given, what are the adjustments and conditions that fathers need to fulfill in order to make second birth transition more likely for couples? To do so, in our model, we assume women will remain employed full-time throughout the simulated period. We also recognize that fertility decisions are made by socialized individuals deeply embedded in their social networks and are thus influenced by peer behavior and social norms (e.g. Diaz et al. 2011; Kohler 2000, 2001). Social interactions within one's network are integral for knowledge transmission and norm diffusion (Pollak & Watkins 1993; Watkins 1987). Social norms sanction what types of family forms are desirable. Peer behavior can provide a model and a reference point for individuals when they make

[1] Results based on the Survey on Child Rearing Support that surveyed fathers with preschool-age children. See Nagase & Brinton 2017.

their own family decisions. In addition to husbands' household work hours, we therefore highlight peer behavior as a second factor in agents' decision-making rules in second birth transition.

Model Implementation

We construct a one-sex model with each agent representing a full-time working mother who is married and has one child. Each agent has the following characteristics: age *a*, educational level *e* and husband's household work hours *h*, parity *p*, and a social network *nw*.

The Initial Population. Agents' age and education distributions are initialized using the subsample of married women with one child from the 2009 National Survey on Family and Economic Conditions (NSFEC) collected by the Keio University Center of Excellence (COE) program. The NSFEC provides a nationally representative sample of both men and women.

At initialization, all agents have a parity *p* equal to 1. Agents' age *a* ranges from 20 to 49. We further set the upper bound of agents' reproductive age to be 45. Agents older than 45 cannot give birth, but may influence other agents within their social networks.

Agents' educational level *e* has three possible values representing 1) high school or below, 2) junior college or two-year professional training, and 3) college or above. We assume that an agent's social network *nw* is formed primarily based on her education. After initialization, we rely on Schelling's (1971) model of segregation to separate agents based on their educational levels. To capture the dynamic nature of network formation and change, at each time step, an agent creates and/or drops a tie at varying probabilities (*pr*) with her neighbor within the radius *r*. Each agent has a network that consists primarily, but not exclusively, of her educational peers. In subsequent modeling, we vary the parameters of *pr* and *r* to test the effects of different configurations of agents' social network structure.

For each agent, husband's housework hours *h* is drawn from a log-normal distribution Log-N(μ_h, σ_h). In our model implementation, we start with empirical findings on Japanese husbands' housework participation for the initial parameterizations of μ_h and σ_h. We then vary the parameters of μ_h and σ_h to test how various levels of husbands' housework participation may shape second birth transition outcomes on the individual- and aggregate-level.

The Model Process. Each time step represents one year. We stop the simulation when all agents have surpassed the upper limit of the reproductive age. At each time step, agents have a small probability for death and/or divorce and will subsequently be dropped from their networks. At each time step, an agent decides whether to transition to a second birth based on her husband's housework hours and the peer behavior in her social network. Mathematically, we express this as the following:

$$\pi_i=\beta_i h_i+\xi_i\frac{\#\{j{:}p_j=2\wedge j\in nw\}}{s_i}+\varepsilon_i \qquad (1)$$

where π_i denotes the transition probability for agent i; h_i is husband's housework hours for agent i; and β_i captures the effect of husband's absolute household work hours on the probability of transition to second birth for each agent. We set the bounds of β_i following the empirical findings reported by Nagase & Brinton (2017). $\#\{j{:}\ pj = 2 \wedge j \in nw\}$ denotes the number of individuals within agent i's network *nw* who already have two children. Thus, $\frac{\#\{j{:}p_j=2\wedge j\in nw\}}{s_i}$ gives the proportion of mothers having made the transition to second birth within each agent's network. ξ_i is a scaling factor that regulates the intensity of the peer effect for each agent. Substantively, ξ shows how susceptible each agent is to the behavior of her peers; $\xi_i = 0$ means that peer behavior has no effect on an agent's transition probability. We draw ξ_i from a uniform distribution with the lower bound set at 0. In subsequent simulations, we test various strengths of peer effects by setting different upper bounds of the uniform distribution. ε_i denotes a time-variant baseline transition probability that is unique to each agent. Substantively, ε_i captures the heterogeneous and unobserved factors that influence individuals' decisions in second birth transition. We draw ε_i from a uniform distribution (0, 0.5). We assume that if an agent's husband performs zero amount of household work and there is no mother with two children in her social network, second birth transition is unlikely to happen, with a probability of 0.5 (i.e. a coin toss) at the most. To realistically capture declines in fecundity as agents age, ε_i is simulated to be time-variant, monotonically decreasing, and above zero at each time step. The size of the decrease at each time step is simulated from a uniform distribution (0, 0.01). Moreover, we fix ε_i to be close to zero for all agents aged 35 and above to reflect the sharp drop in female fecundity at that time.

Preliminary Simulation Results and Discussion

Husbands' Housework Hours. We start with 1000 agents with 10 runs for each scenario. Tsuya et al. (2000) have found that the average household work hours for Japanese husbands is 2.5 hours per week. We use this value as our starting point in the simulation. Here, we set agents' network radius *r* at 2 and the upper bound of the peer effect size ξ_i at 1. Based on the simplest model, we present the adoption rate (i.e. percentage of agents that have transitioned to a second birth) at different time points in the simulated period. Table 1 presents the findings.

Table 1. Transition Rate Based on Husband's Housework Hours

Mean housework hours of husband	Transition rate at year 2	Transition rate at year 4	Transition rate at year 6	Transition rate at year 8
2.5	0.44	0.59	0.66	0.70
	(0.01)	(0.02)	(0.02)	(0.02)
4	0.45	0.60	0.67	0.71
	(0.02)	(0.02)	(0.02)	(0.02)
8	0.47	0.61	0.67	0.70
	(0.03)	(0.03)	(0.02)	(0.02)
16	0.49	0.63	0.68	0.71
	(0.02)	(0.02)	(0.02)	(0.02)

*Standard deviations in parentheses.

At the end of year 8, the percentage of agents having made the transition to a second birth is similar across the four simulated scenarios, despite an eight-fold increase in husbands' household work hours. The effect of husbands' household work is more salient with respect to the slope of the curve. In other words, when a husband performs more housework hours, we see a more rapid increase in the transition rate within the first four years of the simulated period.

Network Structure and Peer Effect Strength. Next, we vary the radius *r* of agents' social network formation. Substantively, a larger radius means that agents make ties with a wider range of neighbors. On the aggregate level, a larger *r* corresponds to a more integrated population. We once again start with 1000 agents with 10 runs for each configuration. In this iteration, we fix the mean of husbands' housework hours at 2.5 and the upper bound of the peer effect size ξ_i at 1. Based on the simplest model, we present the transition rate at different time points in the simulated period. Table 2 presents the simulated transition rates at four different time points.

Table 2. Transition Rate Based on Size of Network Radius

Network radius	Transition rate at year 2	Transition rate at year 4	Transition rate at year 6	Transition rate at year 8
1	0.41	0.52	0.59	0.63
	(0.02)	(0.02)	(0.03)	(0.02)
2	0.44	0.59	0.66	0.70
	(0.01)	(0.02)	(0.02)	(0.02)
3	0.44	0.60	0.67	0.72
	(0.01)	(0.02)	(0.01)	(0.01)

*Standard deviations in parentheses.

Increasing the network radius from 1 to 2 corresponds to an increase in transition rates at all four time points. To put it differently, when agents form social ties from a wider range of neighbors and thereby create a more integrated population, the transition to second birth becomes more prevalent. As individual behavior is heavily influenced by social norms, a more integrated and closely connected population is much more conducive to norm diffusion and subsequently the diffusion of behavior. However, the caveat here is that when network radius is increased from 2 to 3, the transition rates across the simulated time points remain extremely close. This finding suggests that when considering the second birth transition rate at the group level, the network radius *r* at 2 may be the threshold value, after which point further increases in the group integration level do not lead to a higher probability of second birth transition behavior.

We now turn our attention to the strength of the peer effects and vary the upper bounds of the ξ_i parameter. We set the mean of husbands' housework hours at 2.5 hours and the network radius at 2. Table 3 presents the simulation results based on 1000 initial agents and 10 runs for each scenario.

Table 3. Transition Rate Based on Strength of Peer Effects

Peer effect strength	Transition rate at year 2	Transition rate at year 4	Transition rate at year 6	Transition rate at year 8
1	0.44 (0.01)	0.59 (0.02)	0.66 (0.02)	0.70 (0.02)
2	0.52 (0.02)	0.69 (0.02)	0.76 (0.02)	0.79 (0.02)

*Standard deviations in parentheses.

Unsurprisingly, a stronger peer effect is associated with higher transition rates across the simulated period. In addition, when we set agents' network radius at 1 and the upper bound of peer effects at 2, the prevalence of second birth transition across the simulated period is similar to when the network radius is set at 2 and the upper bound of the peer effect strength is set at 1. Table 4 presents these findings.

Table 4. Transition Rate with Given Peer Effect Strength and Network Radius

Peer effect strength	Network radius	Transition rate at year 2	Transition rate at year 4	Transition rate at year 6	Transition rate at year 8
2	1	0.48 (0.01)	0.60 (0.02)	0.66 (0.02)	0.70 (0.03)

*Standard deviations in parentheses.

In other words, a strong peer effect may make up for the absence of a closely connected and integrated population.

To summarize, findings from the simplest model suggest that husbands' household work hours matter more for the initial increase in second birth transition behavior. When husbands perform more household work, on the group level, we observe a sharper increase in the transition to second birth in the initial period. However, husbands' household work hours have a very small effect on the ultimate transition rates. Secondly, agents' network structure and the strength of peer effects jointly influence the transition rates across the simulated period. Stronger peer effects as well as a more integrated population produce a higher prevalence in second birth transition on the group level.

For our next steps, first, we will further incorporate additional scenarios of peer influence into the foregoing simplest model. As agents' social networks are made up by peers of both the same and different educational levels, in the extended model we assume agents are more susceptible to the behavior of other agents with the same educational level. In addition, as the Japanese policy is heavily centered on the twin goals of keeping women in the labor market and encouraging higher order birth transitions, we plan to re-introduce women's employment decision-making into the model process and further explore the feasibility of the Japanese policy.

References

Billari, Francesco, and Hans-Peter Kohler. 2004. "Patterns of Low and Very Low Fertility in Europe." Population Studies 48: 161-176.

Bongaarts, John. 2002. "The End of the Fertility Transition in the Developed World." *Population and Development Review* 28: 419-433.

Chesnais, J. C. 2001. "Comment: A March toward Population Recession." Pp. 255-259 in R. A. Bulatao and John B. Casterline, eds., *Global Fertility Transition*, supplement to *Population and Development Review* 27.

Cooke, Lynn Prince. 2004. "The Gendered Division of Labor and Family Outcomes in Germany." *Journal of Marriage and Family* 66:1243-1256.

----------------. 2009. "Gender Equity and Fertility in Italy and Spain." *Journal of Social Policy* 38:123-140.

Diaz, Belinda Aparicio, Thomas Fent, Alexia Prskawetz, and Laura Bernardi. 2011. "Transition to Parenthood: The Role of Social Interaction and Endogenous Networks." *Demography* 48(2): 559-579.

Esping-Andersen, Gosta, and Francesco Billari. 2012. "Re-theorizing Family Demographics." Working paper.

Frejka, Tomas, Gavin W. Jones, and Jean-Paul Sardon. 2010. "East Asian Childbearing Patterns and Policy Developments." *Population and Development Review* 36: 579-606.

Goldscheider, Frances, Eva Bernhardt, and Trude Lappegård. 2015. "The Gender Revolution: A Framework for Understanding Changing Family and Demographic Behavior." *Population and Development Review* 41 (2): 207–39.

Goldstein, Joshua, Wolfgang Lutz, and Maria Rita Testa. 2003. "The Emergence of Sub-Replacement Family Size Ideals in Europe." *Population Research and Policy Review* 22: 479-496.

Goldstein, Joshua R., Tomáš Sobotka, and Aiva Jasilioniene. 2009. "The End of 'Lowest-Low' Fertility?" *Population and Development Review* 35: 663-699.

Kaneko, R. et al. 2008. "Population Projections for Japan: 2006-2055: Outline of Results, Methods, and Assumptions." *The Japanese Journal of Population* 6: 76-114.

Kohler, Hans-Peter. 2000. "Social Interactions and Fluctuations in Birth Rates." *Population Studies 54*(2): 223-237.

-----------. 2001. Fertility and Social Interaction: A Economic Perspective. Oxford, UK: Oxford University Press.

Kohler, Hans-Peter, Francesco Billari, and J. A. Ortega. 2002. "The Emergence of Lowest-Low Fertility in Europe during the 1990s." *Population and Development Review* 28: 641-680.

Lutz, Wolfgang, and Vegard Skirbekk. 2005. "Policies Addressing the Tempo Effect in low-Fertility Countries." *Population and Development Review* 31: 699-720.

Lutz, Wolfgang, Vegard Skirbekk, and Maria Rita Testa. 2006. "The Low-Fertility Trap Hypothesis: Forces that May Lead to Further Postponement and Fewer Births in Europe." *Vienna Yearbook of Population Research* 4: 167-192.

McDonald, Peter. 2006. "Low Fertility and the State: The Efficacy of Policy." *Population and Development Review* 32: 485-510.

Mizuochi, Masaaki. 2010. "Husband's Childcare Time and Additional Births: A Comparative Analysis of Five Developed Countries." Journal of Population Studies (Jinkōgaku Kenkyū) 46:1-13. (In Japanese)

Myrskylä, Mikko, Hans-Peter Kohler, and Francesco C. Billari. 2009. "Advanced in Development Reverse Fertility Declines." *Nature* 460: 741-743.

Nagase, Nobuko, and Mary C. Brinton. 2017. "The Gender Division of Labor and Second Births: Labor Market Institutions and Fertility in Japan." *Demographic Research*, *36*, 339-370.

Oláh, Livia Sz. 2003. "Gendering Fertility: Second Births in Sweden and Hungary." *Population Research and Policy Review* 22:171-200.

Pollak, Robert A., and Susan Cotts Watkins. 1993. "Cultural and Economic Approaches to Fertility: Proper Marriage or Mesalliance?" *Population and Development Review*, 19: 467-496.

Sobotka, Tomáš. 2004. "Is Lowest-Low Fertility in Europe Explained by the Postponement of Childbearing?" *Population and Development Review* 30: 195-220.

Stone, Pamela. 2007. Opting Out? Why Women Really Quit Careers and Head Home. Berkeley: University of California Press.

Torr, Berna Miller and Susan E. Short. 2004. "Second Births and the Second Shift: A Research Note on Gender Equity and Fertility." *Population and Development Review* 30(1): 109-130.

Watkins, Susan. 1987. "The Fertility Transition: Europe and the Third World Compared." *Sociological Forum, 2:*645–673.