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FAMILYSCAPE:
A SIMULATION MODEL OF FAMILY FORMATION

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Abstract. This paper describes FamilyScape, an agent-based simulation model of family formation. The model's phenomena of primary interest are the incidence of pregnancy and childbearing within and outside of marriage. We model the key antecedents of pregnancy – sexual activity, contraceptive use, and female fecundity – and many of its most important outcomes, including childbearing among married and unmarried parents, children's chances of being born into poverty, and abortion. Realistic variation is simulated in the model's behavioral inputs according to individuals' demographic characteristics. We present diagnostic results demonstrating that, especially for unmarried individuals, the model produces rates of pregnancy and childbearing that match their real-world equivalents when the simulation's inputs are carefully aligned to real-world data. The model readily lends itself to a wide range of policy applications, and we present illustrative results from a simulation that estimates the effects of an expansion in publicly-subsidized contraceptive services.

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In recent years, the topic of family formation has garnered ever-increasing attention among social scientists and policy makers. This heightened interest is motivated in large part by the well-established link between family structure and a range of different child outcomes. For example, children in single-parent families are more than four times as likely to be poor as children in two-parent families.[2] In addition, children who grow up in single-parent families have lower levels of educational attainment, are more likely to engage in risky behavior, and have higher levels of delinquency than their counterparts in two-parent families.[3] Family-formation patterns have also been evolving over time: the share of children living in single-parent families more than doubled between 1970 (12 percent) and the present (26 percent), and newly-released data indicate that the share of births occurring out of wedlock reached an all-time high of 40 percent in 2007.[4] It has been estimated that a majority of the children born in the last decade will spend at least part of their childhoods in single-parent households.[5]

Given the central role that family formation has assumed in discussions of child well-being and social policy, the Brookings Institution's Center on Children and Families has

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[2] Based on the authors' analysis of data from the 2007 Current Population Survey (CPS).

[3] Amato (2005), DeLeire and Kalil (2002a), Painter and Levine (1999). It is difficult, if not impossible, definitively to establish causality in the relationship between family structure and child well-being. However, Thomas and Sawhill's (2005) review of the literature on children's economic outcomes and Amato's (2005) review of the literature on their non-economic outcomes both conclude that such relationships often persist even after researchers attempt – however imperfectly – to account for other measurable and unmeasurable characteristics that are correlated with both living arrangements and child outcomes.

[4] For point-in-time estimates of the percent of children living in single-parent households, see United States Census Bureau (2009a). On the percent of births that are to unwed mothers, see Hamilton et al. (2009).

[5] DeLeire and Kalil (2002b).

developed FamilyScape, a cutting-edge model that simulates the effect of social policy on pregnancy and family formation. We model the key antecedents of pregnancy (sexual activity, contraceptive use, and female fecundity) and many of its most important outcomes (e.g., childbearing within and outside of marriage, children's chances of being born into poverty, and abortion). Our model serves several useful purposes. First, it enhances our understanding of the drivers of social change by shedding light on the mechanisms underlying family-formation patterns. Second, it helps to shape the agenda of the research community by identifying "soft spots" in our knowledge about these phenomena. And finally – and perhaps most importantly – it allows for the straightforward estimation of the effects of various policy changes on outcomes such as childbearing and child poverty.[6]

This paper documents the architecture of the FamilyScape model. It is divided into two parts. The first part provides a general and non-technical description of the way that the model works, the means by which its input parameters were estimated, and the results that it produces. The second part of the paper consists of a series of appendices that describe the simulation's subcomponents in more detail. In the next section, we provide a general overview of the model. We then present results from a series of baseline simulations and policy analyses.

OVERVIEW OF THE MODEL

FamilyScape is an agent-based simulation model (ABM). ABMs are powerful research tools that adopt a "bottom-up" approach to modeling: behaviors and outcomes of interest are simulated at the individual level and are then aggregated to produce population-wide estimates of the phenomena that the modeler wishes to study. The individuals (or "agents")

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[6] See Thomas (2008) for the results of a set of preliminary policy simulations that were generated using FamilyScape.

within the model are heterogeneous – each of them is assigned a set of demographic and behavioral characteristics that help to govern the various decisions that they will make over the course of the simulation. For the purposes of this project, we use a population of individuals whose gender, age, race, education, socioeconomic-status (SES), and marital-status profiles are consistent with the characteristics of the members of a nationally-representative dataset.

FamilyScape has a daily periodicity, which is to say that its behaviors and outcomes of interest are simulated on a daily basis. As is the case in the real world, individuals within the model behave autonomously and often inconsistently, and their behavioral attributes affect their interactions with each other. For example: a) some individuals in the simulation will be more inclined than others to have sex on a given day, b) a given individual will be more inclined to have sex on some days than he or she will on others, and c) a couple will have sex on a given day only if both members of the couple are inclined to do so at that point in time.

Each of the model's inputs (the formation of relationships, sexual activity, contraceptive use, etc.) is simulated in such a way as to ensure that aggregate measures of the resulting behaviors are consistent with demographically-specific benchmarks that were produced from extensive analysis of several different data sources.[7] We then validate the model by comparing its outputs (rates of pregnancy among teens and adults, the incidence of childbearing within and outside of marriage, the frequency of abortion, etc.) to the equivalent real-world data. We would argue, then, that the model's value depends in large

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[7] For example, each woman in the simulation is assigned a probability of using oral contraception based on her age, race, education level, and SES. These probabilities are derived from an analysis of data from the National Survey of Family Growth (NSFG).

part on whether or not, having carefully estimated its input parameters, we are able to "grow" aggregate-level outputs that are consistent with their real-world equivalents. As will be discussed later, the model generally performs quite well in this regard, especially for the unmarried population. Our model lends itself readily to policy simulations, since any of its inputs can be changed relatively easily under the assumption that a given intervention has a particular effect on individual behavior. For purposes of illustration, we present results in the next section from a simulation of an expansion in publicly-subsidized contraceptive services.

Before doing so, however, we describe the architecture of each of the model's components. Figure 1 diagrams the model's overall structure and delineates the various stages of the simulation. During the first stage, we populate the model with a group of individuals whose demographic characteristics match those of the members of a nationally-representative dataset. In the second stage, opposite-sex relationships of varying duration are formed among some individuals. In the third stage, sexual activity (or lack thereof) is simulated among married and unmarried couples, and contraceptive use (or lack thereof) is simulated among couples who have sex. In the fourth stage, some sexually-active couples become pregnant, and each pregnancy eventually results either in a birth, a fetal loss, or an abortion.[8] Because live births occur among married and unmarried couples, the model's fifth and final stage accounts for the fact that each birth is either to a married couple or to a single mother.

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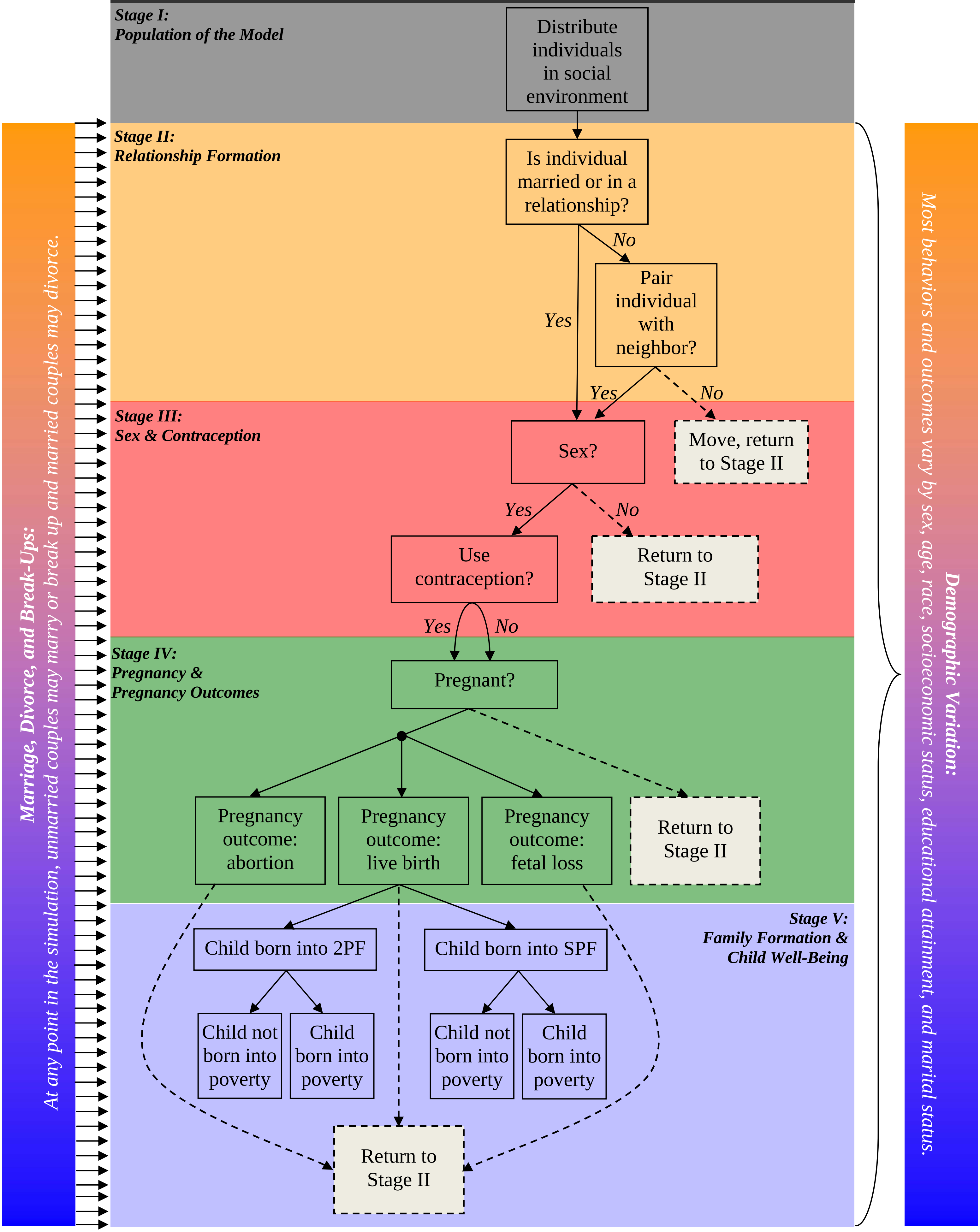
[8] Fetal losses are often referred to as "miscarriages," although this terminology is technically imprecise. We will use the term "fetal loss" to refer to pregnancies that fail to result in a live birth for reasons other than abortion. We should note that, after they become pregnant, couples within the simulation may continue to have sex, although they obviously cannot become pregnant again for the duration of the woman's pregnancy. We use data from a variety of different sources to define the lengths of the gestation periods in our simulation for the pregnancy outcomes described above. See Appendix IV for further discussion of this topic.

Largely as a function of the structure of the family into which each child is born, a poverty status is also assigned to each newborn child during the model's final stage.

All of the model's input dynamics are aligned to real-world data. Information from a wide range of sources is used to ensure that the model realistically simulates the share of people who are married; the share of unmarried people who are in relationships; the rate at which married and unmarried couples have sex; the frequency with which sexually-active couples use contraception; the types of contraception that they use; the frequency with which couples using various types of contraception become pregnant; the share of pregnancies that result in live births, fetal losses, and abortions; the typical gestation periods for each of these pregnancy outcomes; the share of live births that occur within and outside of marriage; and the share of births that occur within and outside of poverty. The model is designed to produce realistic variation in these dynamics according to individuals' demographic characteristics.

We would also emphasize that, because the model simulates these behaviors and outcomes on a daily basis, they may or may not occur anew on each new day. Thus, a single individual who did not enter into a relationship yesterday may do so today, a couple that does not have sex today may do so tomorrow, a sexually-active couple that will not become pregnant tomorrow may conceive on the day after that, and so forth. Figure 1 therefore only illustrates the broad contours of the model's stages. Figures 2 through 6 diagram these stages in more detail.

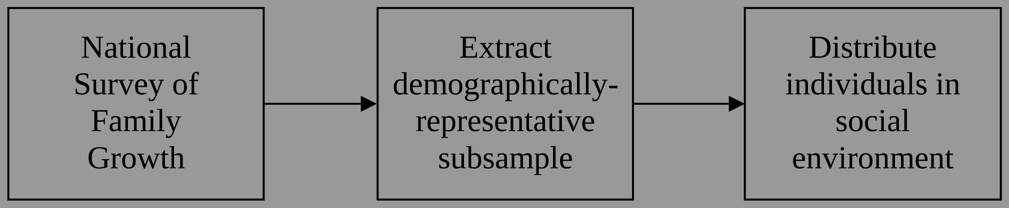
Figure 1: Summary Diagram of FamilyScape Simulation Model



Stage I: Population of the Model

Figure 2 shows the steps by which the model is populated. We start with the 2002 National Survey of Family Growth (NSFG), which is a nationally-representative sample of men and women who are between 15 and 44 years of age. Using the NSFG's demographic weights, we extract a subsample of 10,000 observations that are then imported into the model before the simulation is started.

Figure 2: Diagram of FamilyScape's Stage I Rules for Populating the Model



Because we use the NSFG's sampling weights to extract our subsample, the simulation population should have roughly the same demographic characteristics as both the weighted full NSFG dataset and the national population from which the NSFG's sample was drawn. Table 1 presents characteristics for three groups: the weighted full NSFG dataset, a weighted subset of the Census Bureau's Current Population Survey (CPS) containing all respondents who are between the ages of 15 and 44, and the population of individuals that was extracted from the NSFG and imported into the simulation model. These tabulations demonstrate that the population of individuals in our simulation is indeed nationally representative.

Table 1: Demographic Comparison of the CPS Subsample, the Full NSFG and the Simulation Population

	CPS Observations Aged 15 – 44 (weighted)	Full NSFG (weighted)	**Population for FamilyScape Simulation**
	Percent	Percent	**Percent**
15-19 (%)	16.4	16.3	**16.6**
20-24 (%)	16.1	16.1	**15.6**
25-29 (%)	15.2	15.1	**15.1**
30-44 (%)	52.4	52.5	**52.7**
Average age	29.9	29.9	**29.9**
White (%)	64.3	65.6	**66.1**
Black (%)	12.6	12.9	**12.9**
Hispanic (%)	16.3	15.7	**15.5**
Other (%)	6.8	5.8	**5.6**
Less than High School (%)	23.5	22.1	**22.5**
High School Degree (%)	27.3	29.7	**29.6**
More than High School (%)	49.2	48.1	**47.9**
Low SES (%)	--	22.6	**23.2**
High SES (%)	--	77.4	**76.8**
Unmarried (%)	53.9	53.8	**56.8**
Married (%)	46.1	46.2	**43.2**
Male (%)	49.9	49.1	**49.8**
Female (%)	50.1	50.9	**50.2**
N (unweighted)	93,784	12,568	**10,000**

Note: The CPS estimates were derived using the March 2003 Current Population Survey (CPS). In order to create a CPS subsample that is as comparable as possible to the NSFG, and since all NSFG respondents are between the ages of 15 and 44, demographic characteristics for CPS respondents are reported here only for respondents within this age range. Estimates of socioeconomic status are not available in the CPS. The "full NSFG" estimates were derived using the male and female respondent files from Cycle 6 of the National Survey of Family Growth (NSFG). The "simulation population" estimates were derived using a probabilistically-extracted subsample of the NSFG. Sampling weights were used to calculate summary statistics for the NSFG and the CPS but not for the simulation population.

We should note that no single dataset contains the breadth of information necessary to estimate all of the model's manifold input parameters. Thus, once these individuals are imported into the simulation, we use data from a variety of different sources to estimate the various parameters that govern their decisions about relationship formation, sexual activity, contraceptive use, etc. For reasons of internal consistency, we parameterize the model using data from calendar year 2002 whenever possible and, when 2002 data are not available, we use information from the closest available year. We use 2002 data because that is the most recent year for which NSFG data are currently available.[9] After the extracted subsample of the NSFG is imported into the model, these individuals are randomly arrayed within a physical space that can be thought of as representing the full range of schools, workplaces, bars, clubs, networking websites, and other social environments within which they might interact with each other.

Stage II: Relationship Formation

Figure 3 illustrates the process by which relationships are formed among members of the simulation population.[10] On each day, a single individual has a new opportunity to enter into a relationship if there is a member of the opposite sex who: a) is close to him or her in the model's social environment, b) shares his or her demographic characteristics, and c) is also single. If all three criteria are met, the pair of individuals will enter into a relationship if they are both willing to do so. Once they are paired up, a couple must decide on each day whether to end their relationship, to continue the relationship outside of marriage, or to marry. Thus, a relationship may last for as little as a single night, may continue indefinitely, or may develop into a marriage. Similarly, married couples must decide on each day whether to remain married or to get divorced. If, on a given day, an individual fails to enter into a relationship, ends a non-marital relationship, or becomes divorced, he or she will move to another location within the model's social environment on the next day in search of a partner.

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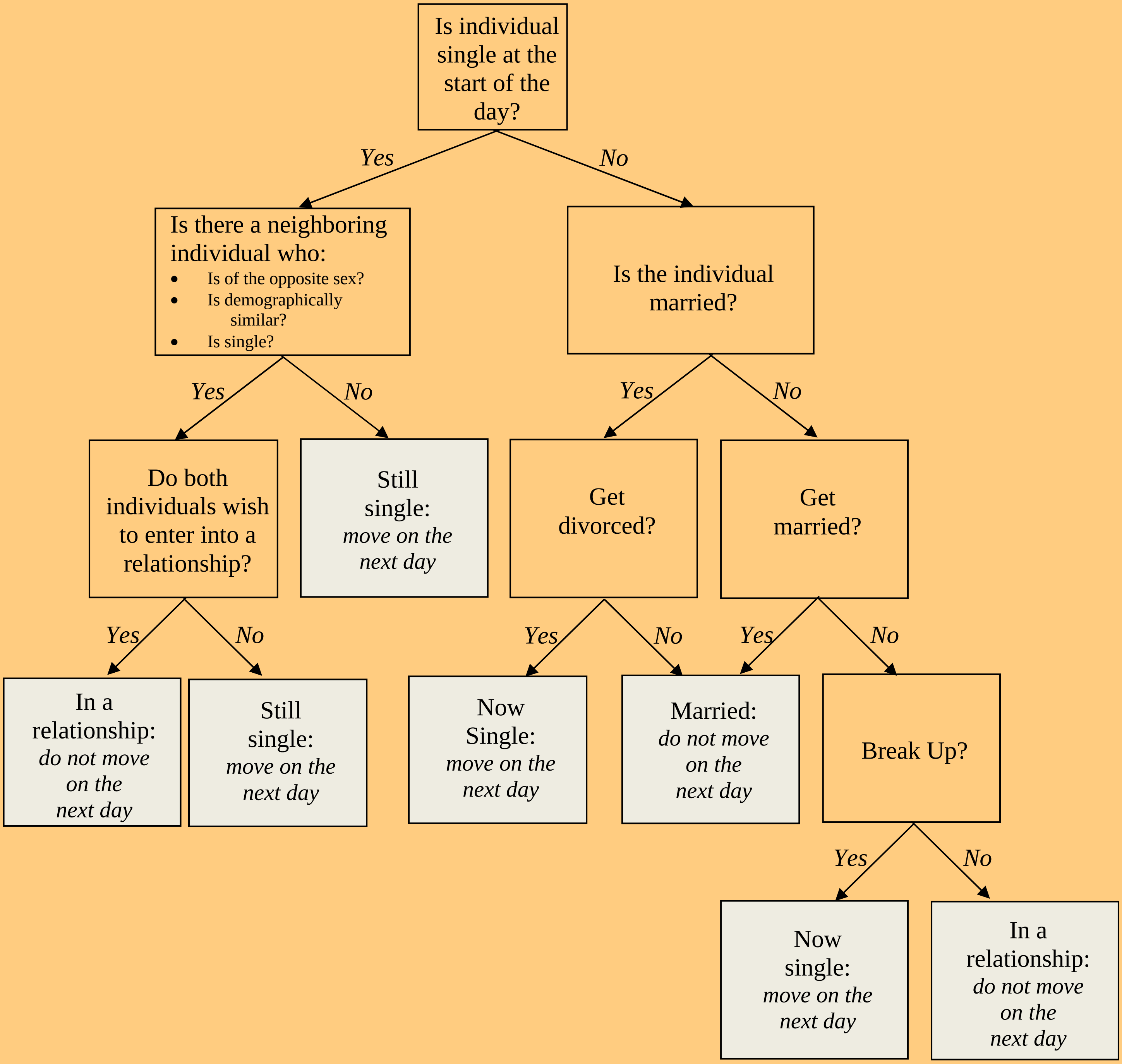
[9] The NSFG is the most reliable source of nationally-representative data on contraceptive use among sexually-active couples, and it also contains a wealth of information on sexual activity and pregnancy outcomes. Because the NSFG contains a sample of individuals rather than of households or families, respondents' spouses are not included in the dataset. Thus, before importing NSFG observations into our model, we create marital matches by pairing married women with married men who are demographically similar to them. Descriptions of our methods for creating the subsample of NSFG respondents that was imported into the model and for creating matches among married respondents can be found in Appendices I and II, respectively.

[10] See Appendix II for a more technical description of FamilyScape's relationship-formation module.

Figure 3: Diagram of FamilyScape's Stage II Rules Governing Relationship Formation on a Single Day



Some unmarried individuals in the simulation are more inclined than others to enter into new relationships, and some are more inclined than others to end relationships. Indeed, each individual is assigned a set of unique numerical values reflecting his or her proclivity to enter into a new relationship or to end an ongoing one. These values are assigned in such a way as to ensure that the share of couples within the model who are in relationships is consistent with the findings of our analysis of data from the General Social Survey (GSS), which suggest that, at any given time, about half of single people are in a relationship.

Individuals in the simulation are also assigned unique proclivities to marry and divorce. However, we are still in the process of refining the marriage and divorce components of our simulation. As such, the results presented here were generated from a version of the model that does not allow new marriages and divorces to occur. It is important to note, though, that the prevalence of marriage among the individuals that populate the model at the outset of the simulation is consistent with the share of individuals who are married in the population at large. Thus, while the version of the model that we use here does not account for the "flow" of individuals into and out of the married population, it does realistically capture the "stock" of married couples as reflected in the real-world data that were used to produce the model's baseline population.

Stage III: Sexual Activity & Contraceptive Use

Figure 4 shows the model's rules governing sexual activity and contraceptive use.[11] A couple's decision as to whether to have sex on a given day is made jointly by the man and the woman, and some individuals in the simulation are more inclined than others toward

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[11] See Appendix III for a thorough treatment of the technical details of FamilyScape's sexual-activity and contraceptive-use modules.

sexual activity. Our analysis of NSFG data suggests that a substantial share of individuals have little or no sex, that another large portion of the population have a moderate amount of sex, and that a small number of people have sex on an almost-daily (or even a more-than-daily) basis. We therefore place each individual into one of three sexual-proclivity categories: "highly active," "moderately active," or "inactive."[12]

Using the results of our analyses of NSFG data, we vary individuals' chances of being placed into each of these three groups by race, age, education level, and SES. We then calibrate the model's sexual-behavior component to ensure: a) that most of the individuals in the "inactive" category rarely or never have sex, b) that most of the individuals in the "highly-active" category have sex regularly, c) that most of the individuals in the "moderately-active" category have sex more often than those in the "inactive" group but less often than those in the "highly-active" group, and d) that the aggregate distribution of sexual frequency among the members of the simulation population approximates the equivalent real-world distribution as measured in the NSFG.[13] Because our preliminary analyses indicated that the married population tends to have more sex than the unmarried population, we calibrate this component of the model separately for these two groups.[14]

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[12] Because studies tend to show that survey respondents often over-report their rates of sexual activity – and because women in the NSFG report somewhat lower average levels of sexual frequency than do men – we use data on women's self-reported coital frequency to estimate the parameters for this module. For additional detail on this topic, see Appendix III.

[13] We should note that an individual's placement into a particular category does not guarantee that he or she will have a specific level of sexual activity in the simulation. For example, an individual who is placed into the "highly-active" category may in fact have little or no sex if he or she remains single for much of the simulation or is paired with a partner who has a low sexual proclivity. Thus, while an individual's sexual proclivity is strongly correlated with the amount of sex that he or she has, this correlation is by no means perfect.

[14] We also parameterize the model to ensure that the average annual number of sexual partners among unmarried individuals closely tracks its real-world target. See Appendices II and III for additional details as to how this aspect of the model was calibrated.

Among sexually-active couples, the model simulates contraceptive use. Our analysis of various sources of survey data and our review of the literature on contraception both suggest that surgical sterilization, condoms, and oral contraception (i.e., the pill) are each used by somewhat less than a third of contraceptors, and that the remaining share of contraceptors rely on one of a multitude of alternative options. We therefore simulate the use of only these three methods; the sub-set of contraceptors who report having used other methods are, for the purposes of this simulation, considered to have used the pill.[15] Using benchmark data on the method of contraception used at last intercourse among NSFG sample members, we assign a certain share of both the male and the female populations to be sterilized, a certain share of the non-sterilized male population to be condom users, and a certain share of the non-sterilized female population to be pill users.[16] With respect to condom use, we use NSFG data to assign non-sterilized men to one of three categories: consistent condom users, pill-conditioned condom users, and non-condom users. A consistent condom user always uses condoms when he has sex, a pill-conditioned user only uses condoms if his partner is not using oral contraception, and a non-condom user never uses condoms regardless of his partner's pill use.

As we do for sexual behavior, we use the results of our NSFG analyses to vary individuals' chances of using each of these methods by marital status, race, age, education level, and SES. We also vary contraceptive use by sexual-proclivity type. Thus, if individuals who report

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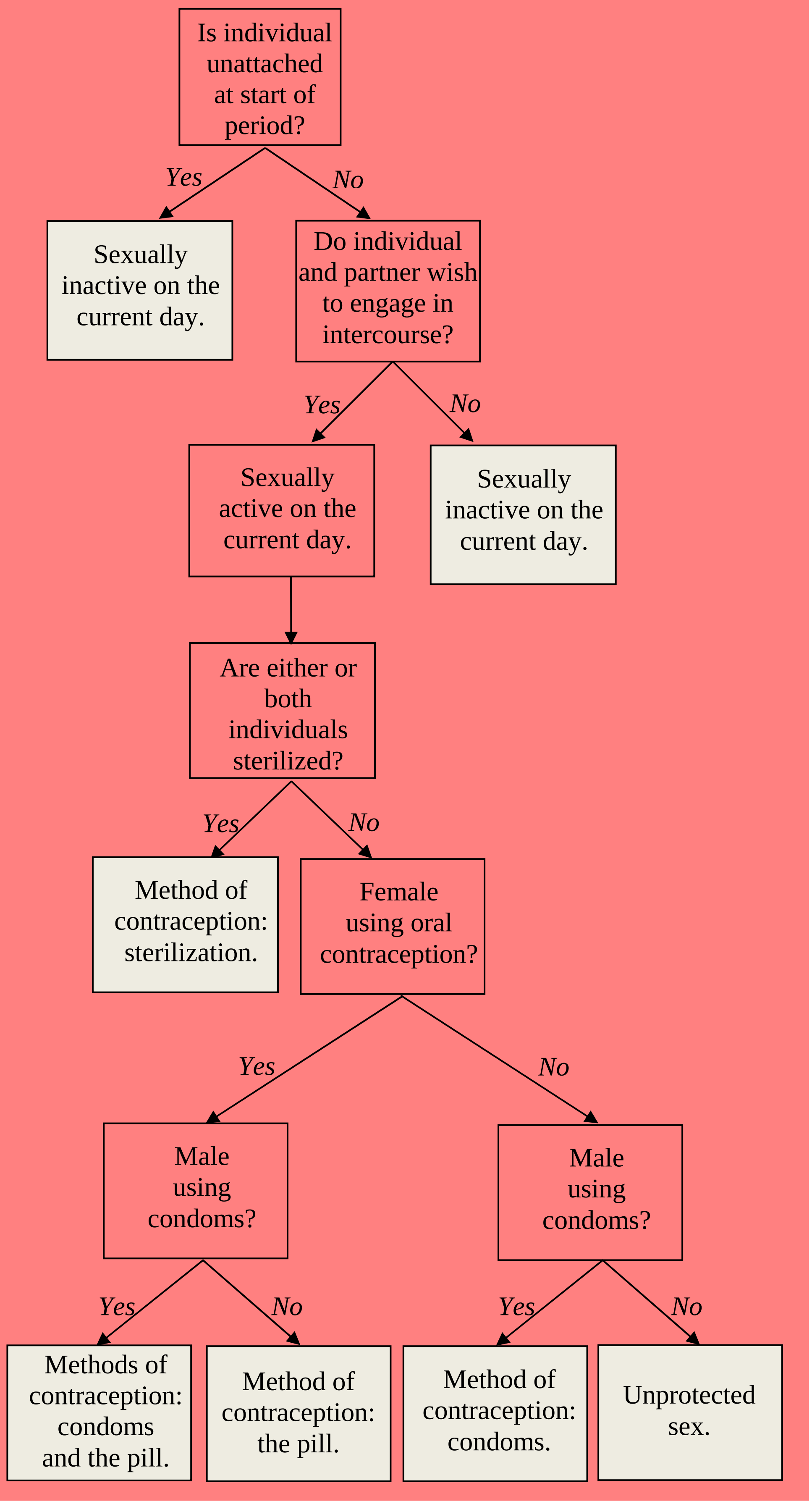
[15] See Thomas and Roessel (2008) for an extensive discussion of contraceptive use. Our tabulations of 2002 NSFG data show that about a tenth of sexually-active men and women report having used a method other than oral contraception, condoms, or sterilization at their most recent intercourse. Some of these users report having relied on relatively-ineffective methods such as periodic abstinence and withdrawal, while others report having used highly-effective methods such as Depo Provera and surgical implants. A crude weighted average of these methods' effectiveness suggests that, as a whole, they are about as effective as the pill.

[16] Throughout this discussion, we use the term "sterilization" to refer both to natural sterility and to surgical sterilization.

being relatively more (or less) sexually active in our real-world data also report being relatively more (or less) likely to use a particular type of contraception (or not to use any contraception at all), this dynamic is captured in the estimation of the model's input parameters.

Figure 4: Diagram of FamilyScape's Stage III Rules Governing Sexual Behavior and Contraceptive Use in a Single Day



Stage IV: Pregnancy & Pregnancy Outcomes

Figure 5 shows the model's procedures for simulating pregnancy and pregnancy outcomes. As is the case in the real world, a couple's chances of becoming pregnant after having sexual intercourse during the simulation depend on the woman's level of fecundity (i.e., her physiological capacity to become pregnant) and on the contraceptive method(s, if any) that the couple is using. FamilyScape allows for variation in a woman's level of fecundity as a function of her age and the day in her menstrual cycle. Thus, as the model advances from one day to the next, it also updates each woman's menstrual calendar and adjusts her fecundity level accordingly. We assign age- and day-specific fecundity estimates using the results of a published econometric analysis of the probability of becoming pregnant after intercourse.[17]

Regarding couples' contraceptive use, we assume that condoms are 85 percent effective, that the pill is 97 percent effective, that the simultaneous use of condoms and the pill is more than 99 percent effective, and that sterilization is 100 percent effective. Thus, couples in the simulation who have sex while using a condom are 85 percent less likely to become pregnant than couples who do not use any contraception, couples using the pill are 95 percent less likely to become pregnant, and so forth. See Appendix IV for a detailed discussion of the way in which we calculate these methods' levels of effectiveness.

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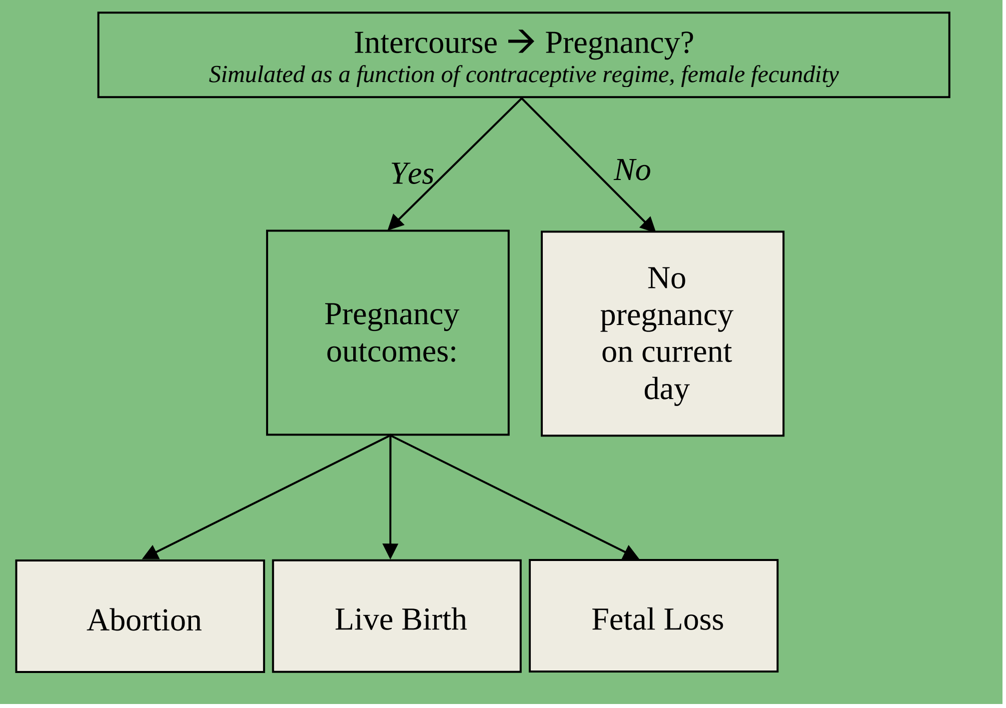
[17] A handful of studies have generated data capable of producing estimates of the probability of pregnancy from a single act of intercourse (e.g., Barrett and Marshall, 1969; Dixon et al., 1980; Royston, 1982; and Wilcox et al., 1995). All of these studies estimate pregnancy probabilities as a function of the day in the menstrual cycle. A common finding in this literature is that the probability of pregnancy is zero, or close to zero, for all days in the cycle outside of a roughly seven-day period that encompasses five or six days leading up to – and one or two days subsequent to – the point of ovulation. These studies' results consistently suggest that the probability of pregnancy from a single act of intercourse on an average day in the menstrual cycle is between three percent and five percent. For the purposes of our simulation, we use Royston's (1982) results because he models the probability of pregnancy as a function of both the woman's age and her menstrual calendar. See Appendix IV for additional details as to how fecundity is modeled.

After a couple in the simulation becomes pregnant, that pregnancy eventually results in a live birth, an abortion, or a fetal loss. We use information from the National Center for Health Statistics' National Vital Statistics System (NVSS), the Alan Guttmacher Institute's 2000 – 2001 Abortion Provider Survey (APS), and the NSFG to assign an outcome to each new pregnancy as a function of the mother's marital status and demographic characteristics.

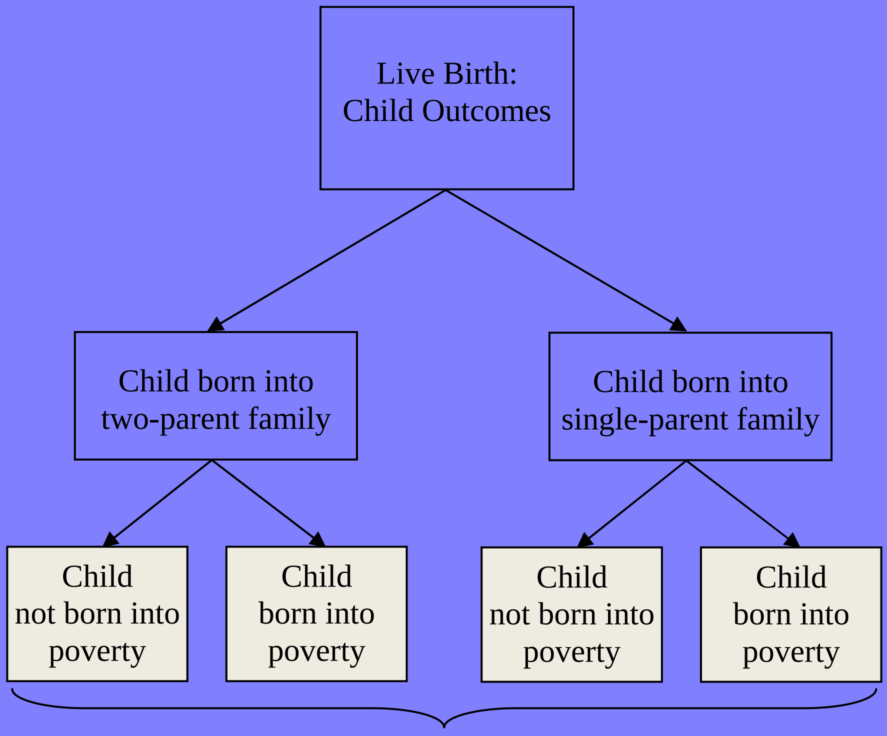
Figure 5: Diagram of FamilyScape's Stage IV Rules Governing Pregnancy Outcomes



Stage V: Family Formation & Child Well-Being

Figure 6 shows the model's procedures for simulating family formation and child well-being. Since the model tracks the marital status of each individual in the simulation, it therefore also automatically tracks the structures of the families – specifically, whether they are married-parent or single-parent – into which children are born. As is demonstrated in the next section, we almost always disaggregate our simulation results (e.g., rates of pregnancy, birth, abortion, etc.) by marital status.

Figure 6: Diagram of FamilyScape's Stage V Rules Governing Family Formation and Child Well-Being



Child poverty: modeled as a function of family structure and the mother's age, race, and educational attainment

For each new live birth, we also assign a poverty status to the newborn child. In order to provide the reader with a better sense of the process by which the model is typically parameterized, we explicate most aspects of FamilyScape's poverty-status module here rather than in an appendix. We do so, first, because it may be illuminating for us to describe in the main body of the paper a representative example of our procedures for estimating the model's parameters; second, because the poverty module is likely to be of particular interest to policy audiences; and, third, because it is quite a bit simpler – and therefore easier to describe concisely – than some of our other simulation modules. Thus, while the appendices contain the substantial bulk of the technical details about our simulation procedures, we describe the model's poverty-simulation component here for explanatory purposes.

This portion of the simulation is driven by the results of regression models that were estimated using data from the March 2003 CPS, which contains information on respondents' incomes for calendar year 2002. The coefficients from these regressions are imported into our simulation in order to impute, for each newborn child, the probability that he or she will be born into poverty. Because we are interested in the poverty statuses of newborn children in particular, we limit the CPS sample for our regressions to children who were under the age of one at the time that the survey was conducted. While the unit of analysis for these regressions is the child, the information for the models' demographic control variables is taken from the mother. Thus, we regress infants' poverty statuses on their mothers' demographic characteristics. Specifically, these regressions control for the mother's age, race, and education level. Because poverty rates are dramatically different between children in single-parent and two-parent families, separate regression models are estimated for children born to married and to unmarried mothers. See Table 2 for a complete set of poverty-status regression results.[18]

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[18] These regressions were weighted using the mother's individual weight. This is one of several simulation modules that are parameterized using the results of regression models that were estimated via Ordinary Least Squares (OLS). In all such instances, the dependent variable is binary rather than continuous. In many cases, we also estimated logit and probit models using the same dependent variable(s). The results of these analyses were qualitatively similar to the corresponding OLS results. When regression coefficients are required to parameterize a particular aspect of the simulation, we therefore always use OLS models to generate them. Since the individuals that populate the model were taken from the NSFG, and for the sake of consistency, we considered the possibility of using the pregnancy file of the NSFG rather than the CPS to perform our poverty regressions. However, we opted not to do so because: a) the CPS is widely considered to be the most reliable dataset for the measurement of poverty, and b) poverty rates among children under the age of one in the NSFG are considerably higher than in the CPS. (In order to create comparable samples between the NSFG and the March 2003 CPS – and because children under the age of one in the March CPS were born between April of 2002 and March of 2003 – the NSFG sample was limited for the purposes of this comparison to children who were born during the same period. The poverty rate among such children in the NSFG – 25.7

Table 2: Regression Results for Poverty Status at Birth

	Unmarried Women	Married Women
	Coefficient *t-value*	Coefficient *t-value*
Age Dummy: 20-24	0.089 *54.27****	-0.036 *-28.05****
Age Dummy: 25-29	0.205 *104.39****	-0.086 *-68.11****
Age Dummy: 30-44	0.270 *126.79****	-0.088 *-69.95****
Education Dummy: High School Degree	-0.158 *-110.61****	-0.215 *-303.23****
Education Dummy: More than High School	-0.298 *-177.94****	-0.304 *-435.53****
Race Dummy: Black	0.192 *140.42****	0.056 *72.19****
Race Dummy: Hispanic	0.088 *52.61****	0.041 *73.77****
Race Dummy: Other	0.193 *69.17****	0.000 *0.50*
Constant	0.448 *284.55****	0.423 *324.68****
P-Value for Joint Test of Age Covariates	0.000	0.000
P-Value for Joint Test of Education Covariates	0.000	0.000
P-Value for Joint Test of Race Covariates	0.000	0.000
N *(unweighted)*	529	2,081

Notes: All parameters were estimated using data on observations in the March 2003 Current Population Survey (CPS) who were under the age of one at the time that their families' interviews were conducted. While the unit of analysis is the child, the demographic information used here reflects the characteristics of the mother. Socioeconomic status is not included as a covariate here because the necessary data are not available in the CPS. The excluded age, education, and race categories are as follows: age group 15-19, an educational attainment of less than a high school degree, and the white race category. One asterisk (*) indicates that the parameter estimate is significant at or beyond the .1 level, two asterisks (**) indicate that the parameter estimate is significant at or beyond the .05 level, and three asterisks (***) indicate that the parameter estimate is significant at or beyond the .01 level.

Each time that a new birth is simulated, the coefficients from these regressions are used to calculate a probability that the child in question will be born into poverty as a function of the mother's marital status and demographic characteristics. A random draw is then taken from a uniform (0,1) distribution in order to assign a poverty status to the child. For example, assume that – given his mother's characteristics – a newborn boy's chances of being born

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percent – was substantially higher than the equivalent rate from the CPS – 19.9 percent.) These regressions do not include controls for SES because the necessary data are lacking in the CPS.

into poverty are calculated to be 20 percent. If the relevant draw from the uniform distribution were, say, .13 (or any number less than .2), then the child would be assumed to have been born into poverty; if the draw were, say, .58 (or any number greater than .2), then he would be assumed not to have been born into poverty. Diagnostic results from multiple simulation runs show that demographically-specific poverty rates among the members of our simulation population are generally quite comparable to their real-world equivalents.[19]

SIMULATION RESULTS

Having described the model's architecture, we now present results from a series of diagnostic runs. We begin by briefly describing the model's visualizations. For ease of exposition, the visualizations shown here are from a version of the model that contains only 500 individuals; the results presented subsequently are from a series of simulations that contain 10,000 individuals. Figure 7 shows a visualization of the simulation just after the beginning of a representative run of the model. Males are represented using squares, and females are represented using circles. Color is used here to indicate age: the "lighter" an individual is, the older he or she is. Recall that the individuals in the simulation are between the ages of 15 and 44. Thus, squares that are shaded dark blue represent teenaged boys, circles that are nearly transparent represent women who are in their late thirties or early forties, etc.

Although the model also accounts for race, education level, and SES, we do not incorporate these characteristics into its visualizations because doing so would cause excessive clutter. We do, however, distinguish visually between marital and non-marital relationships. Some

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[19] See Table A12 in Appendix V for a complete set of diagnostic poverty results.

of the individuals in the model are connected to one another by black lines. These individuals are part of either a marriage or a non-marital relationship; black tips at either end of a line indicate that the couple in question is married. In Figure 7, we identify one of the couples that is married and one of the couples that is unmarried during the early part of the simulation. Note that women who are "dark blue" tend to be paired up with men who are "dark red" while women who are of a paler color tend to be paired up with men who are of a similar hue, which is to say that male and female individuals tend to enter into relationships with members of the opposite sex who are demographically similar to them. Figure 7 also identifies one of the couples that is having sex, which is represented visually by having the couple flash yellow on the day(s) on which they have intercourse.

Figure 7: Overhead View of FamilyScape Model After 2 Days

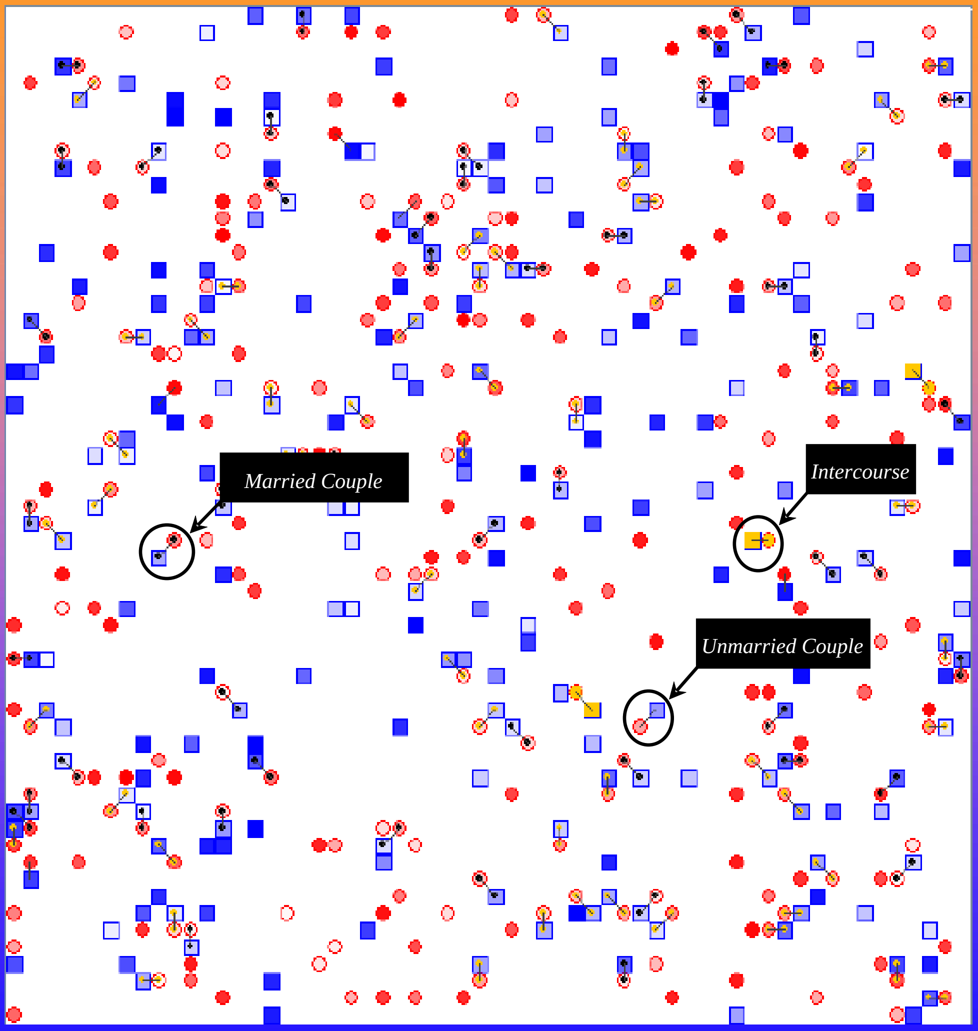

Figure 8 shows a visualization from the 14th day of the same run of the model. The model is still reaching the point of approximating the real world as relationships continue to be formed, sexual activity increases, and pregnancies begin to occur. As single individuals move through the model's social environment in search of potential relationship partners, increasing numbers of them are successful in their searches during this early phase of the simulation.[20] Thus, more unmarried people are participating in relationships in Figure 8 than in Figure 7. We are also beginning to see the first occurrences of pregnancy in the model. A pregnancy is represented by shading the pregnant woman green. Figure 8 highlights a pregnancy for a relatively-young woman in the model (we know that she is young because she is paired up with a dark blue – i.e., a young – man, and because the model creates matches between individuals who are demographically similar to each other).

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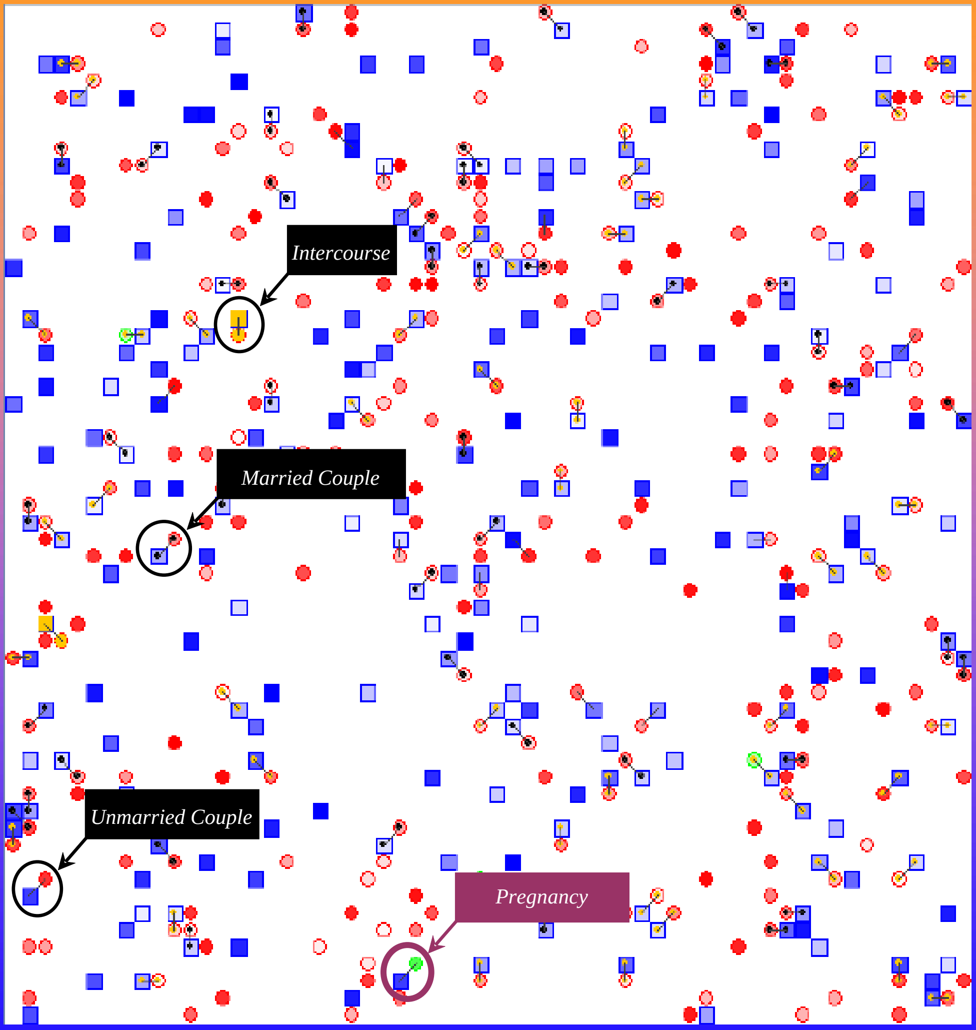
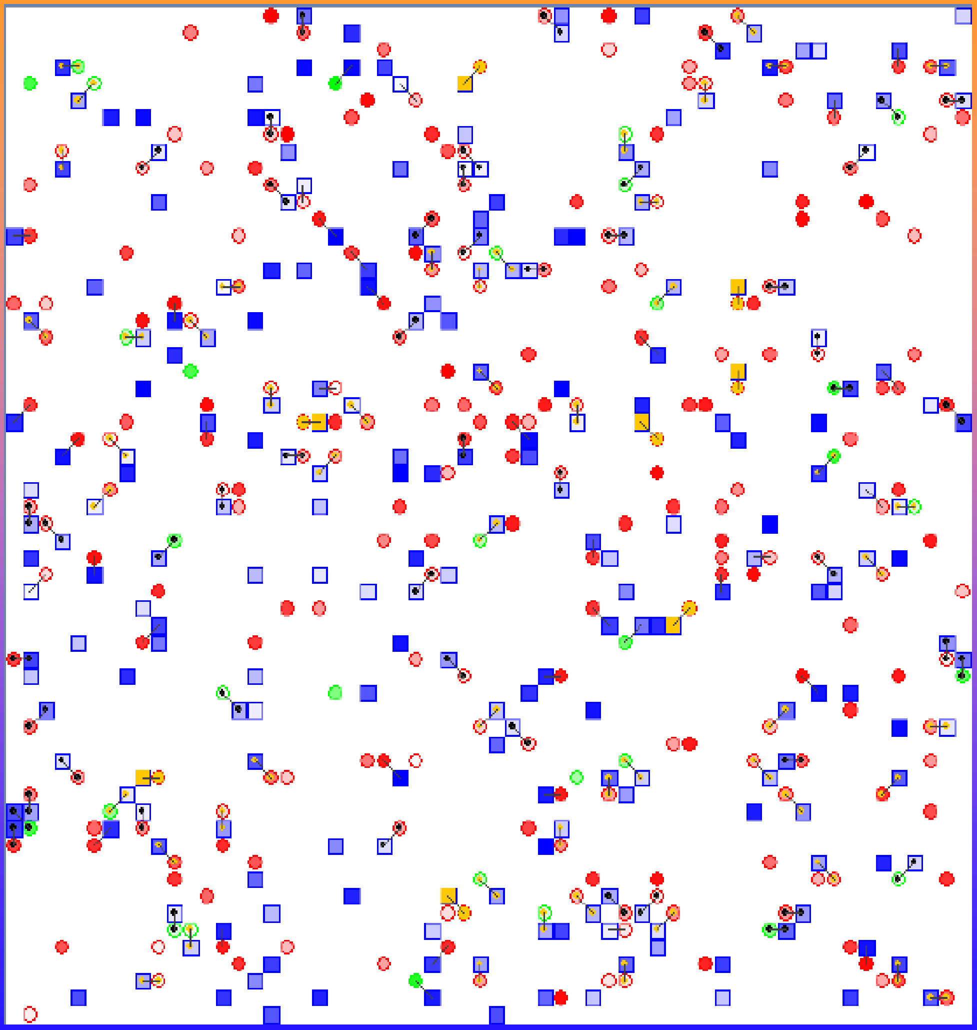
[20] During the first several months of analysis time, the number of people who are entering into relationships exceeds the number of people who are exiting them. Thus, the overall percentage of single people who are in a relationship continues to increase throughout the first year or so of the simulation and then levels off at about 50 percent. See Appendix II for more information on this topic.

Figure 8: Overhead View of FamilyScape Model After 14 Days



Finally, Figure 9 shows a visualization after a year has passed within the simulation. By this time – as we will see in a moment – the model does a good job of approximating the real-world outcomes in which we are interested, especially for unmarried couples. Thus, we see substantially more sexual activity, and many more pregnancies, than was the case in the prior two figures.

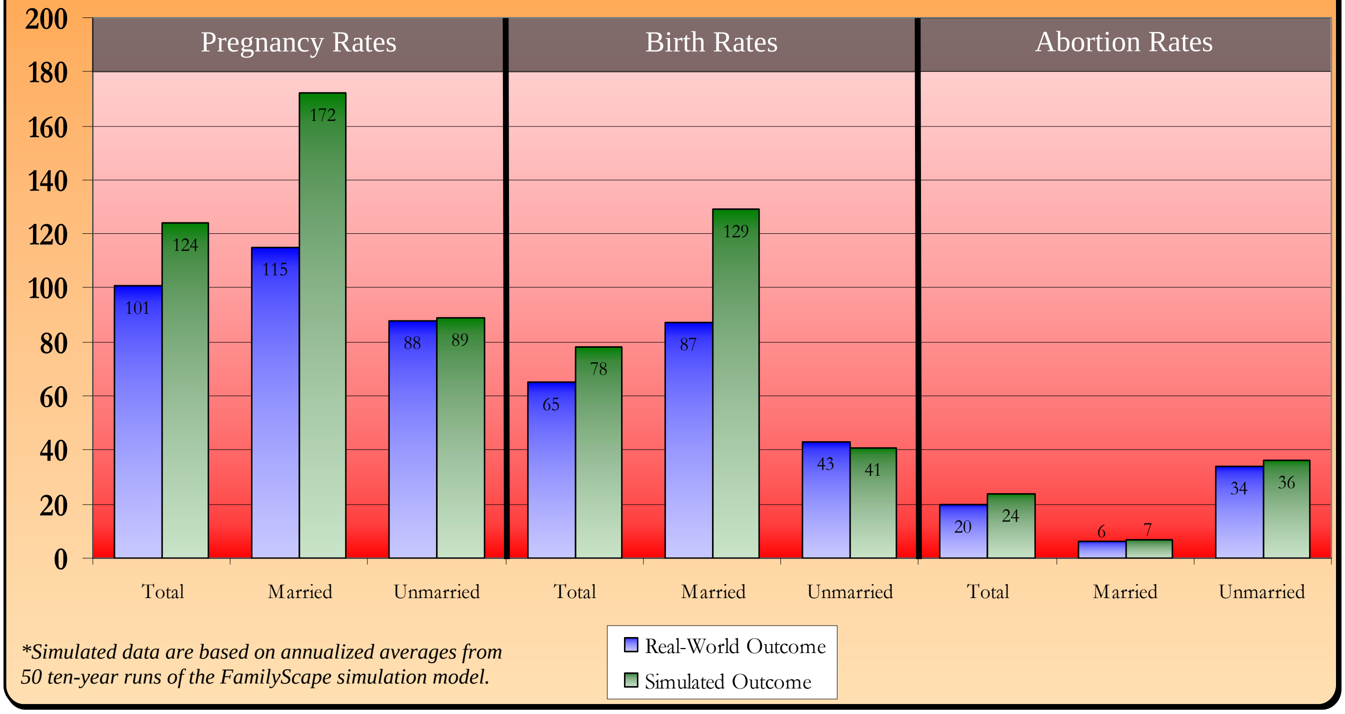
Figure 9: Overhead View of FamilyScape Model After 365 Days



As was discussed at the beginning of the paper, FamilyScape's usefulness is determined in large part by how well it approximates the real world in terms of the policy-relevant outcomes that it tracks. None of the model's components that have been described thus far was manipulated to ensure that the simulation produces the "right result." Rather, we have attempted to be as careful as possible in formulating the model's inputs, such as relationship formation, sexual activity, contraceptive use, contraceptive effectiveness, and female fecundity. We now turn to the question of whether the model can be validated by comparing its outputs to their real-world equivalents. Figure 10 shows a comparison of annual pregnancy, birth, and abortion rates from our simulation to the equivalent statistics in real-world data. For unmarried couples, the model approximates all three real-world outcomes remarkably well. The rate of pregnancy in the model is within about one percent of its target, and the rates of birth and abortion are both within about five percent of their targets. Among married couples, however, our simulated rates of birth and pregnancy are about 50 percent above their targets.

Since we are most interested in out-of-wedlock pregnancy and childbearing, our first priority is that FamilyScape produce realistic results for the unmarried population, and that goal has been achieved. However, we would ideally like for the model to match its targets for the married population as well. We continue to explore various theories as to why the model might be over-simulating pregnancies for married couples. One such theory is that married respondents may have a stronger tendency than unmarried respondents to over-report sexual activity on surveys such as the NSFG. We noted in the previous section that, according to our analysis of survey data, married couples have more sex on average than do unmarried couples. We implement an alternative specification of the simulation in which sexual activity among married couples is reduced. Specifically, we adjust the parameters governing married sexual behavior so that the rate of coital frequency among married couples matches the (lower) real-world benchmarks for unmarried individuals. In this specification, then, we take up the following question: what would be the effect on the over-simulation of pregnancies and births among married couples if we were to assume that they only had sex as frequently as members of the unmarried population do?

Figure 10:
Real-World and Simulated Pregnancy, Birth, and Abortion Rates*
Per 1,000 Women



**Simulated data are based on annualized averages from 50 ten-year runs of the FamilyScape simulation model.*

Figure 11 shows the results of this specification. Once the model's parameters are adjusted in order to bring the rate of married sexual activity down to the level that is reported among unmarried individuals, the model performs considerably better: the rates of pregnancy and childbearing among married couples are now within ten percent of their real-world targets. In an important sense, this result is simply a mechanical one; we set a new and lower benchmark for married sexual behavior, and the resulting diminution in sexual activity depressed the incidence of pregnancy and childbearing among married couples. However, one can construct a plausible argument as to why married couples might be more inclined than unmarried individuals to over-report their rates of sexual activity.[21] To the extent that this is the case, the alternative specification described here might in fact be a sensible one. More importantly, however, we show in the next section that the model produces essentially the same results for an illustrative policy simulation regardless of whether married sexual behavior is calibrated in its original fashion or is instead calibrated to produce a lower level of sexual activity.

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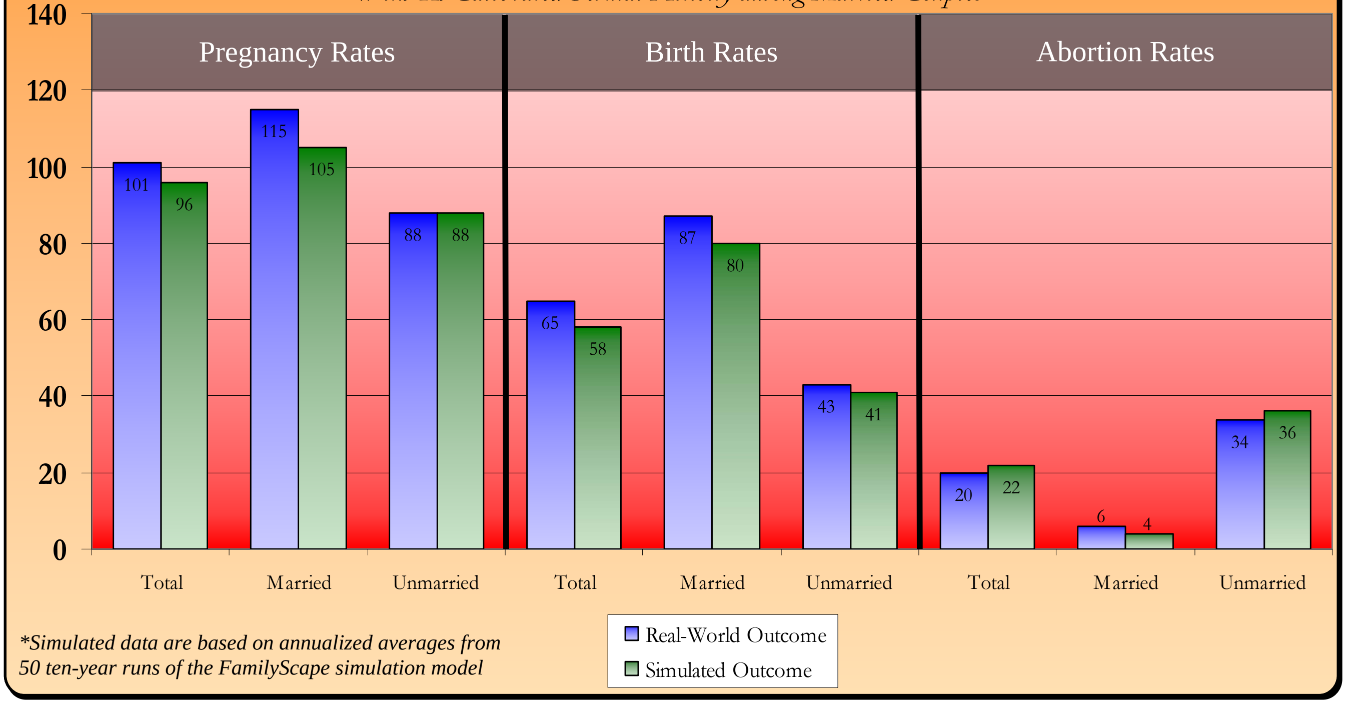
[21] Indeed, some small-scale studies of married women find that they tend to overstate the frequency of their sexual activity on surveys (Clark and Wallin, 1964; Hornsby and Wilcox, 2003). These findings suggest the possibility that our model's sexual-behavior component – which is calibrated using women's responses to questions about coital frequency in the NSFG – may be relying on self-reports that sometimes overstate the true frequency of sex among married couples. However, there is also evidence of the same phenomenon among unmarried women (Jaccard et al., 2002). In order for this hypothesis to explain why the model produces a more realistic rate of pregnancy within the unmarried population than within the married population, it would have to be the case that married women are more likely than unmarried women to over-report their rates of sexual activity. We are unaware of any study that includes both groups and disaggregates its results by marital status.

Figure 11:
Real-World and Simulated Pregnancy, Birth, and Abortion Rates*
Per 1,000 Women;
With Re-Calibrated Sexual Activity among Married Couples



**Simulated data are based on annualized averages from 50 ten-year runs of the FamilyScape simulation model*

Policy Simulation: Expanded Eligibility for Family-Planning Services under Medicaid

The federal Medicaid system provides contraceptive services to pregnant women and to mothers whose incomes fall below a relatively low threshold. However, about half of states have been granted federal waivers in recent years that allow them to serve all income-eligible women – regardless of whether they are or have been pregnant – and, in most cases, to raise their income-eligibility thresholds as well. Congress has considered (but has not yet passed) legislation that would permit the remaining states similar latitude in setting their eligibility criteria.[22] In a recent paper, Melissa Kearney and Phillip Levine (2007) estimate that, in the states in which it was implemented, this policy resulted in about a five percent reduction in the number of non-teenaged women who failed to use contraception at their last

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[22] For more information on the recently-considered legislation that included this provision, see Thomas and Sawhill (2009).

intercourse.[23] Their corresponding estimates for teenagers were not precise enough to allow them to reach any firm conclusions for that group.

In order to illustrate the potential applications of our model, we simulate the effects of implementing such a proposal in the states that have not yet relaxed their income-eligibility criteria. For the purposes of this exercise, we assume that the policy will engender an increase in contraceptive use among both teenagers and non-teenagers and among both married and unmarried women. We assume more specifically that the proposal will result in a five-percent reduction in the share of women who have unprotected sex, and we assume that these newly-contracepting women will use the pill. We therefore conduct a set of simulations in which we assign sufficient numbers of previously-non-contracepting women to the "pill-use" category to reduce the number of non-contraceptors by five percent. Specifically, two such simulations are conducted: in the first, we do not make any changes to the parameters governing married couples' sexual behavior, and, in the second, we adjust the model to reduce married couples' sexual frequency in the manner described above. The projected effects of the policy are then estimated by comparing the results from these simulations to the baseline results presented in Figures 10 and 11, respectively. Thus, we calculate two sets of effects: one under the assumption that married couples have as much sex as survey data suggest is the case, and another under the assumption that they have about as much sex as unmarried individuals.

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[23] The authors attempt to identify the effect of the waiver policy by comparing changes in contraceptive use over time between women in states that implemented a waiver and women in states that did not. Among women in states that received waivers, they also compare changes in contraceptive use between those who were and were not eligible to take advantage of the expanded eligibility rules.

Figure 12 presents the results of these simulations. We find: a) that the policy would reduce pregnancy rates by between eight and nine percent among married women and by between about four and five percent among unmarried women; b) that the policy would reduce birth rates by about eight and a half percent among married women and by between about three and a half and four and a half percent among unmarried women; c) that the policy would reduce the number of children born into poverty by about five percent; and d) that the assumption that one makes about married couples' sexual behavior has only a negligible effect on the results of the policy simulation.[24]

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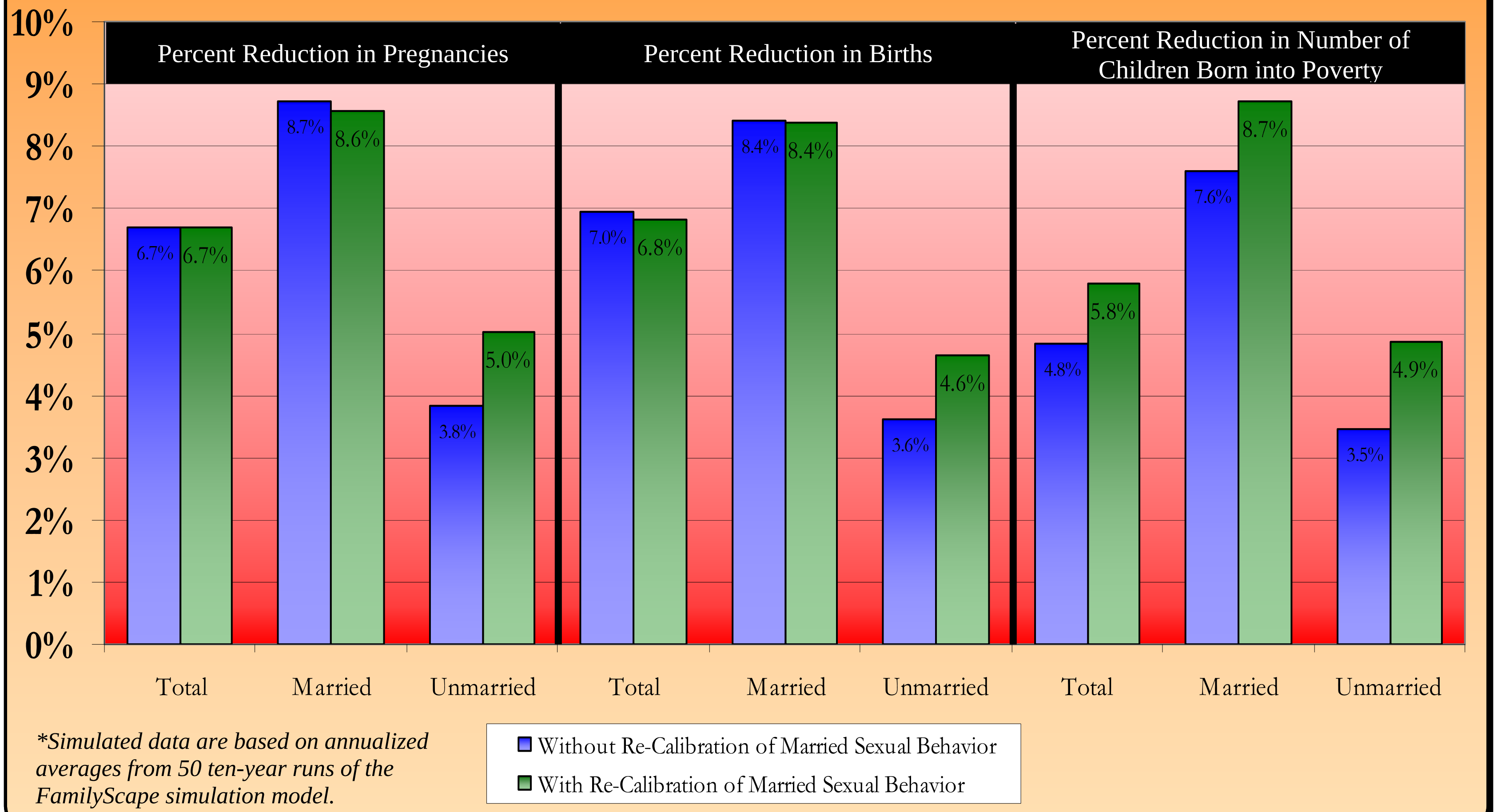
[24] The reader may have noticed that the change in the parameters governing the sexual behavior of married couples appears to have had an effect on the number of pregnancies and births to unmarried couples. However, this is not actually the case. The difference in the number of pregnancies and births to unmarried women is a function of the fact that: a) each run of the model produces slightly different results because of random variation across runs in relationship formation, sexual activity, etc., and b) the number of pregnancies and births among the 2,928 unmarried women in the model's population is relatively small in a single year. In fact, the differences reported here correspond with a total reduction in the annual number of simulated pregnancies and births to unmarried women of about three and two, respectively. These small absolute differences translate into moderately-large proportional differences, but they are driven entirely by random variation in the model's results from run to run.

Figure 12:
Simulated Effects of Medicaid Waiver Expansion*

With and Without Re-Calibrated Married Sexual Behavior



**Simulated data are based on annualized averages from 50 ten-year runs of the FamilyScape simulation model.*

SUMMARY & NEXT STEPS

The FamilyScape model realistically simulates many of the most important antecedents of pregnancy, including sexual activity, contraceptive use, and female fecundity. Especially within the unmarried population, the model generates rates of pregnancy, abortion, and childbearing within and outside of poverty that closely match their real-world equivalents. Data from a variety of sources are incorporated into the simulation in order to ensure that these behaviors and outcomes vary realistically according to demographic characteristics such as marital status, gender, age, race, educational attainment, and SES. See the appendices at the end of this paper for additional technical details regarding the way that each of the model's components functions.

Policy simulations may be conducted by changing any of the model's inputs under the assumption that a given policy has a particular impact on individual behavior. The model also lends itself to examinations of the determinants of various trends in pregnancy and childbearing. By exploring alternative parameterizations of the model, for example, one might be able to help to explain what drove the reduction in the incidence of teen and out-of-wedlock births in the 1990's and early 2000's, and what has driven the recent increase in these same indicators. Thus, FamilyScape is already a useful tool for research and policy analysis. However, we continue to refine the model and to enhance its capabilities in a number of different ways. First, we will complete the instillation of the marriage and divorce modules in order to allow for married individuals to become divorced and for single individuals to become married over the course of the simulation. Second, we will continue to explore various hypotheses as to why the model is over-simulating pregnancies among married couples. We will do so by studying the results of alternative specifications of the model, and by continuing to canvass the literature and the available sources of data in order to determine whether there are factors that we have neglected to address in the model and that might have an effect on pregnancy rates among married couples.

Third, we are considering a number of potential long-term projects that may enhance the model's usefulness and realism. The next version of the model – one might think of it as "FamilyScape 2.0" – may incorporate some or all of the following improvements:

- **Modeling inconsistent contraceptive use**. Because it uses NSFG data on individuals' recent contraceptive use, FamilyScape probably assumes, first, that a smaller number of individuals use contraception than is actually the case; and, second, that those who use contraception do so with more consistency than is true in the real world. It is possible that these two sources of error effectively cancel each other out in the aggregate, but it is difficult to know with certainty whether or not this is the case. In its current conception, the model is therefore not ideally-suited to policy simulations in which inconsistent contraceptors are induced to switch to long-acting methods. Thus, we are considering the possibility of allowing for more inconsistent contraceptive use among a greater number of individuals in the model.
- **Exploring peer effects and social norms.** Agent-based models have the capacity to allow individuals to learn and change by observing and imitating their peers. Under such circumstances, norms of behavior may emerge from the simulation as the natural result of social interactions between individuals. Since it seems likely that norms and peers are important determinants of sexual activity and contraceptive behavior – and therefore of pregnancy and family formation – we may add a component to the model that attempts to capture these dynamics

- **Modeling changes over time.** At present, the model is designed to reproduce the conditions observed in 2002 repeatedly over the course of the simulation. Thus, when the model is run in perpetuity, data on any single sliver of 365 days should be roughly reflective of the conditions that prevailed in 2002. We are considering allowing the population of individuals in our model to age and to change their behavior over time. This would allow us to model the relationships between one's fertility and marital history and one's subsequent sexual activity, contraceptive use, childbearing decisions, etc. It would also allow us to account for whether a given birth is a first or a higher-order birth.

Given that FamilyScape is a work in progress, we would welcome any comments that the reader might have on this project. Our hope is that, as we continue to augment it, our model will become an increasingly-powerful tool for explaining the drivers of family structure and for estimating the effects that changes in policy might have on family-formation patterns and child well-being.

TECHNICAL APPENDICES

APPENDIX I: GENERAL CHARACTERISTICS OF THE MODEL

This appendix addresses several cross-cutting issues that have relevance for all of FamilyScape's modules. Specifically, we discuss the periodicity of the model, the data sources that were used to produce its population of agents and to derive its various parameters, our reasons for selecting the demographic covariates that are included in the simulation, the distinction between causation and correlation in our simulation procedures, and the random variation that is produced in the model's outcomes across runs.

Periodicity

FamilyScape has a daily periodicity. We chose to denominate analysis time in this way because the key antecedents of pregnancy – namely, sexual intercourse and contraceptive use – can occur on a daily basis, if not more frequently.[25] Moreover, sexual pairings in the real world are often of very short duration.[26] Defining the model's periodicity on an annual, monthly, or even weekly basis could therefore obscure potentially-important variation in the behaviors that help to determine the incidence of pregnancy and childbearing. Thus, the model allows individuals to engage anew in these behaviors on each new day.

Data Sources

We populate the simulation model using data from the combined adult male and female files of Cycle 6 of the National Survey of Family Growth (NSFG), which was administered in 2002. When its weights are applied, the sample's joint age-gender-race-ethnicity distribution is consistent

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[25] Only a very small portion of the population – 1 percent of all NSFG respondents, and 1.7 percent of sexually-active respondents – report having sex on more than a daily basis. Thus, for the purposes of our simulation, we only allow sexual intercourse and our other behaviors of interest to occur once per day, at most.

[26] Our tabulations of data from the 2002 General Social Survey (GSS) indicate that, among those aged 15 to 44, almost 45 percent of men and more than a quarter of women report having had sex with at least one "casual date" in the past year.

with the equivalent distribution for the national population from which it was drawn.[27] NSFG respondents were between the ages of 15 and 44 when the survey was conducted.[28] Sample members were asked a wide range of questions pertaining to their sexual activity, contraceptive use, and pregnancy outcomes.

Since the NSFG is only nationally representative when its individual sampling weights are applied, it would not be appropriate for us simply to populate the model with the unweighted sample. Instead, we create a simulation population by probabilistically selecting 10,000 observations using the dataset's individual weights.[29] As was discussed in the main body of the paper, our simulation population's demographic characteristics are similar to those of the full weighted NSFG sample and of the national population of 15-to-44-year-olds as measured by the Census Bureau's Current Population Survey (CPS). We considered the possibility of populating our model using an extract from the CPS rather than from the NSFG. However, we chose not to do so for two reasons. First, we estimate a large number of the model's input parameters using the NSFG, so populating

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[27] Lepowski et al. (2006).

[28] In fact, three male members of the sample were 45 years old. These observations were dropped from the dataset before it was used to populate the model.

[29] In order to produce our simulation population, we first sorted the NSFG dataset by the values of respondents' individual sampling weights. Next, we generated a variable – call it X_1 – representing the cumulative sum of the individual weights up to and including a given individual's own weight. We then created a second variable – call it X_2 – representing each observation's position in the cumulative weighted probability distribution of the sample. This variable was calculated as the ratio of each observation's X_1 value to the sum of the sampling weights across all observations. Thus, if the *i*th individual has a value of, say, .65 for this variable, then 65 percent of the total probability reflected in the sampling weights would be contained in the observations up to and including individual *i*. After creating these variables, we probabilistically selected observations by taking random draws from a uniform (0,1) distribution and identifying, for each draw, the observation whose X_2 value is as close as possible to the value of that draw without exceeding it. So, for example, if: a) individual *i* has an X_2 value of .65, b) individual $i+1$ has a value of .655, c) individual $i+2$ has a value of .672, and d) a given random draw yields a value of, say, .658, then individual $i+1$ would be selected. Had the random draw yielded a value of .651, observation *i* would have been selected, and so forth. Observations were selected from the NSFG with replacement, and this process was repeated 10,000 times in order to produce a simulation population of the appropriate size. We chose to create a population of this size because: a) the larger the simulation population, the greater the amount of computing resources that are required to conduct a single run of the simulation; b) in order to produce reliable results for a given specification of the model, it is necessary to run the simulation many times over; and c) a sample of size 10,000 is relatively large, but it is not so large as to prevent us from achieving our goal of conducting several runs for a given model specification. After the simulation population is created, the model is initialized by randomly arraying these individuals within the model's social environment, which consists of a 225*225 matrix of square cells.

the model with individuals from the same data source allows for a greater degree of internal consistency. And second, our simulation varies individual behavior by socioeconomic status (SES), among other demographic characteristics. A common proxy for SES is maternal educational attainment, which is measured in the NSFG but not in the CPS.[30]

The most recent year for which NSFG data are available is 2002. Thus, the model is designed to reproduce the conditions observed in 2002 repeatedly over the course of the simulation. Output data on any single sliver of 365 days should therefore be roughly reflective of the conditions that prevailed in 2002.[31] The NSFG contains much – but certainly not all – of the information necessary to parameterize the model. We therefore use data from other sources as necessary to estimate the model's parameters. We use 2002 data for this purpose whenever possible and, when 2002 data are not available, we use information from the closest available year.[32]

Choice of Demographic Covariates

As we import individual observations into the model, we retain information on many of their demographic characteristics. Specifically, we retain individual-level information on gender, age, race, educational attainment, SES, and marital status. We then simulate variation in the model's behavioral inputs and key outcomes according to these characteristics.

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[30] On the use of maternal education as a proxy for SES, see Bornstein et al. (2003).

[31] This is actually true only after the model reaches a quasi-steady state. At the outset of the simulation, relationships have yet to be formed among unmarried individuals, and – once married and unmarried couples become pregnant – births do not occur until about nine months after the day of conception. After about two years of analysis time, the model produces reasonably realistic rates of relationship formation, sexual activity, pregnancy, and childbearing for both the married and unmarried populations. In the interest of caution, we therefore only use the model's output data from day 1,000 and beyond to measure our outcomes of interest. Thus, the model's aggregate outcomes between days 1,000 and 1,365 (or between days 1,100 and 1,465, or between days 1,365 and 1,730, etc.) should be reflective of the real-world outcomes that obtained in 2002.

[32] The other data sources that are used to parameterize the model include (but are not limited to) the 2003 CPS; the 1998 and 2002 General Social Surveys; the Guttmacher Institute's Abortion Provider Survey from various years; the National Health and Social Life Survey, which was conducted in 1992; and the 2002 version of the National Center for Health Statistics' National Vital Statistics System.

Some of these demographic covariates were chosen for substantive reasons, while others were chosen primarily for policy reasons. As is shown in the results reported in other appendices, there is often enormous variation in the model's behaviors and outcomes of interest by age. For example, older women are much more likely than younger women to be sterilized, and pregnancies among younger women are much more likely to result in an abortion than are pregnancies among older women. There is less such variation with respect to some of the simulation's other covariates. Indeed, we suspect – although we have yet to test this theory – that the model's aggregate outcomes would be about the same if it accounted only for age, gender, and marital status as when it accounts for the full complement of characteristics enumerated above. However, we were encouraged by several knowledgeable experts to include race, educational attainment, and SES in the model in order to ensure that its results are useful to policy makers and to other interested audiences.

We usually rely on the results of regression analyses to parameterize the model's behaviors and outcomes of interest. Because some of the simulation's covariates are included more for policy reasons than for substantive ones, many of the relevant regression coefficients are very small in magnitude and/or are statistically insignificant. For the sake of internal consistency, however, we account for all of these characteristics wherever possible, regardless of the magnitude or significance level of the relevant coefficients.[33] Table A1 shows the categorical specifications that

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[33] It is relatively benign for us to include coefficients in the simulation that are both small in magnitude and statistically insignificant, since doing so has little or no effect on our results. It would, however, be problematic if we were to include coefficients that were *large* in magnitude and insignificant, since doing so might result in our modeling relationships that do not exist in the real world but that have a meaningful impact on our findings. We have carefully examined our regression results and have concluded that there are no such coefficients incorporated into the simulation. We considered the possibility of accounting for a variety of other covariates, but we decided not to do so for three reasons. First, the simulation already contains about 400 input parameters, and we wanted to achieve some measure of modeling parsimony. Adding more covariates to the model would substantially increase the number of

were chosen for each demographic characteristic. We selected these specifications either based on the results of econometric analyses or because we were compelled to do so by the limitations of data that were available to us. They are also quite consistent with the categorical definitions that are typically used in the broader literature on population studies and family formation.[34]

Table A1: Specification of Covariates

	Age Group	Race	Educational Attainment	SES	Marital Status
Categories	15-19	White	Less than high school	Mother had less than a high school degree	Unmarried
	20-24	Black	High school degree	Mother had at least a high school degree	Married
	25-29	Hispanic	More than high school		
	30-44	Other			

Note: Individuals who are separated are considered to be married. Individuals who are cohabiting are considered to be unmarried.

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parameters that we would be required to estimate. Second, the results of various econometric analyses suggested that the model would not be meaningfully enhanced by the inclusion of these additional covariates. For example, we considered the possibility of accounting for religious affiliation and/or religiosity, but we found that – regardless of how these characteristics were measured – the relevant coefficients were almost always extremely small in magnitude and were usually also statistically insignificant. And third, the general consensus among the experts advising us on our project was that the characteristics listed in the text above were the most important for us to include on policy grounds.

[34] Our specification for race was somewhat obvious, although we could have chosen instead to use a white/non-white dummy variable. Primarily for policy reasons, we concluded that it would be preferable for us to be able to disaggregate our race-specific results in more of a fine-grained fashion. We parameterize the model's coital-frequency and contraceptive-use modules using the results of regression models that were estimated using NSFG data. In exploratory work, we considered the possibility of using several alternate specifications of education and age for these regressions. (For education, we also considered models using a continuous variable. For age, we considered models using a continuous variable; continuous and squared variables; and continuous, squared, and cubed variables.) According to the results of various significance tests, the variable specifications described in Table A1 usually performed at least as well as – if not better than – these alternate specifications. Following standard convention, we use maternal education as a proxy for SES. We considered several alternate specifications of SES in our coital-frequency and contraceptive-use regressions. Specifically, we considered a continuous variable, a four-category variable (less than high school, high-school degree, some college, and a college degree or more), and a tripartite variable (less than high school, high-school degree, and more than high school). Significance-test results indicated that a dummied version of this variable was preferable, although it was not obvious whether the variable's breakpoint should be at "less than a high-school degree/at least a high school degree" or at "high school degree or less/some college." We chose to use the high-school breakpoint, which has the advantage of producing a slightly more balanced distribution between the two categories. In our pregnancy-outcomes analyses, we were compelled to rely heavily on published data – and we were unable to control for educational attainment or SES – for reasons that are discussed in Appendix IV. The specifications of the race, age, and marital-status variables described in Table A1 are consistent with the equivalent specifications in the published data that were used for these analyses. With respect to marital status, we adopt the Census Bureau's practice of coding separated couples as married (United States Census Bureau, 2009b).

We considered the question of whether to account for interactions between these variables in our regression analyses. However, we were explicitly prevented from doing so for our pregnancy-outcomes module because – as will be described in Appendix IV – we were compelled to parameterize this portion of the simulation using published data. For our coital-frequency and contraception analyses, we compared several different significance-test results and goodness-of-fit measures for models that did and did not include interaction terms.[35] We estimated a large number of models – some included interaction terms only for race and SES, some only included interactions for education and age, some included a full set of interaction terms, and so forth. The results of these analyses generally suggested that the inclusion of interaction terms was unnecessary.

However, perhaps the most instructive set of results in this regard – although, admittedly, they were also the least econometrically sophisticated – were from a series of figures showing the predicted values of our various dependent variables from models with and without interaction terms. To the extent that the predicted values from these two sets of regressions were roughly comparable, one could conclude that interaction terms do not enhance the models' ability to capture demographic variation in our behaviors and outcomes of interest. As was the case for the econometric analyses described in the previous paragraph, we created a large volume of such figures to account for the many possible interactions that might be included in our various regressions. These figures consistently showed, first, that there were rarely meaningful differences between the predictions of these two sets of models; and, second, that – in the few cases in which such differences did exist – they pertained only to very small groups of individuals.

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[35] Specifically, we examined Bayesian Information Criteria, Oaxaca decompositions results, various R^2 measures, and individual and joint tests of statistical significance.

We include two such figures below as representative examples of our complete set of results. Figure A1 compares predicted values from two different regressions of the probability of having used contraception at last intercourse. Both models contain a full set of age, race, education, and SES control variables. However, one model also contains age-race interaction terms, while the other one only contains the "main-effect" variables. Similarly, Figure A2 compares the results of coital-frequency models with and without education-SES interaction terms. The predicted values reported in these charts are quite similar for the models with and without interaction terms; the only notable difference is in the probability of using contraception among teenaged Hispanics, but – as is indicated by the dotted line in the bottom portion of the chart – this group only contains a handful of observations, which suggests that the results for this group are potentially unreliable and are unlikely to affect the simulation's aggregate results.

Figure A1: Predicted Probability of Having Used Contraception at Last Intercourse

from Regressions With and Without Age-Race Interaction Terms

(Among Unmarried Individuals)

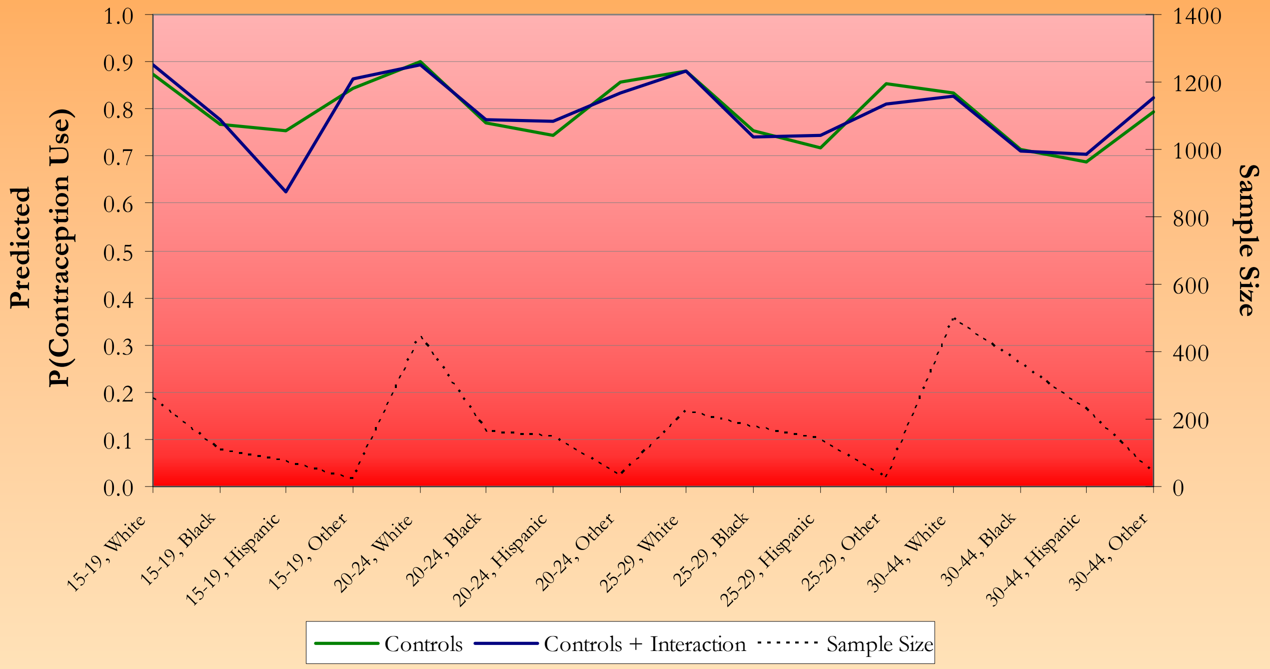
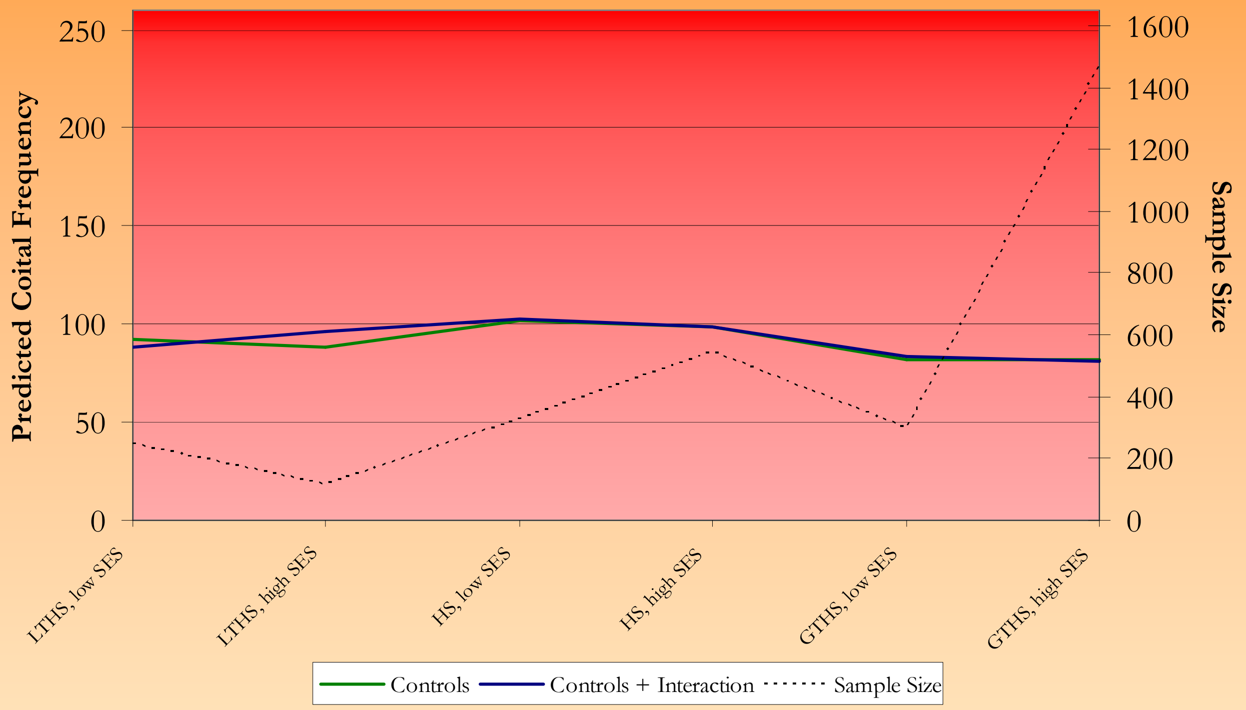


Figure A2: Predicted Coital Frequency

from Regressions with and Without Education-SES Interaction Terms

(Among Married Individuals)



The take-away conclusion from these figures (and from the findings of our other visual analyses) is consistent with the implications of our econometric results: the inclusion of interaction terms in the regressions used to parameterize the simulation would add little to its ability to capture real-world demographic variation in our outcomes of interest. Thus – and in the interest of parsimony – we do not allow for interactions between demographic characteristics in the simulation.

Causality

Some of the statistical associations modeled within FamilyScape – the relationship between age and fecundity, for example – are explicitly causal. Others – for instance, the relationship between age and the probability of being sterilized – are probably only partially causal. And a large portion of these relationships are likely to be primarily correlational in nature. This does not threaten the model's ability to replicate real-world conditions at a given point in time. In other words, to the extent that we were interested solely in mimicking such real-world dynamics as the measured covariance between (say) education and coital frequency, our primary task would be to ensure that the incidence of intercourse varies with education among the members of the simulation population in a manner that is comparable to what is observed in real-world data.

The distinction between correlational and causal relationships becomes considerably more important, however, when simulations are conducted in which changes are made to the model's baseline assumptions. Thus, if we were to implement an alternative parameterization of the model in which (say) individuals were assumed to have higher levels of educational attainment than is the case under our baseline specification, it would be important for us to consider the question of whether the observed (and simulated) relationship between (say) education and sexual activity is correlational or causal. One should also bear in mind that any number of potentially-important assumptions about causality are implicitly incorporated into FamilyScape by virtue of the wide range of possible relationships that the model does *not* account for. For instance: in the policy simulation discussed in the main body of the paper, an increase was modeled in the share of women who use contraception, but a corresponding change was not simulated in the sexual behavior of newly-contracepting women. The implicit assumption underlying this particular simulation, then, is that contraceptive use does not affect sexual frequency.[36]

For purposes of simplicity, we will generally assume that, after a given parameter(s) is (are) changed, all subsequent elements of the FamilyScape's implicit "causal chain" will continue to operate as initially specified unless there is compelling evidence to suggest that we should assume otherwise. Recall, for example, that the policy simulation described above drew on Kearney and Levine's (2007) finding that an expansion in access to publicly-subsidized contraceptive services under Medicaid results in an increase of about five percent in the number of women who use contraception. The authors also find that the Medicaid expansion had little, if any, effect on women's sexual behavior. We are therefore comfortable with the policy simulation's implicit assumption that a change in contraceptive use does not affect sexual frequency. More generally, we will attempt to be as clear as possible about the assumptions that drive our policy-simulation results, and we will make decisions on a case-by-case basis as to how best to handle questions related to causality when changes are made to the model's baseline parameterization.

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[36] We would emphasize that, in fact, FamilyScape does account for the correlation between sexual frequency and contraceptive use. However, it does so by using coital-frequency type as a covariate in the equations that model the probability of using contraception, rather than by using the latter as a covariate for the former (see Appendix III for additional discussion of this topic). Within the simulation, then, a change in the model's sexual-frequency parameters has implications for the distribution of contraceptive use, but a change in contraceptive use does not affect the distribution of coital frequency.

Variation in Outcomes Across Runs

As is made clear in the remaining appendices, FamilyScape – like most agent-based models – relies heavily on random variation. As the simulation proceeds, various random processes govern the movement of individuals throughout the social environment, the pool of potential partners with whom a given individual might enter into a new relationship, the probability that he or she will in fact enter into a relationship, the likelihood that a given married or unmarried couple will have sex on a given day, the probability that a couple will use contraception when they have sex, and so forth. Thus, no two runs of the model are exactly alike.

We therefore report simulation results using data that are averaged over multiple runs of the model. Specifically, the results reported here are for 50 ten-year simulation runs. In other words, each time that a simulation is performed, the model is first allowed to reach a quasi-steady state, and outcomes are then tracked for ten full years of analysis time. This process is repeated 50 times in order to produce 500 years' worth of data. This approach allows us to "average out" random variation across years (since, for example, the simulation may produce a slightly different rate of pregnancy in the fourth year of a given run of the model than in the fifth year) and across runs (since the random values used to initialize the model and to govern the way that the simulation unfolds differ slightly from run to run).

Figures A3 through A12 show distributions for the rates of childbearing and pregnancy generated by the model across runs. As the number of distinct runs approaches infinity, these figures should begin to approximate normal distributions. The distributions shown here are for 50 distinct runs, and some – but not all – of them are roughly normal. In all cases, however, the bulk of the results are clustered near the means of the distributions. Thus, by calculating average values across several multi-year simulation runs for our outcomes of interest, we mitigate the possibility that our reported results will simply represent outliers in the distribution of possible results produced by the model.

Figure A3:
Distribution of Ten-Year Averages of Annual Birth Rates

From 50 Runs of the FamilyScape Simulation Model,
Among All Women & with Re-Calibrated Sexual Activity among Married Women

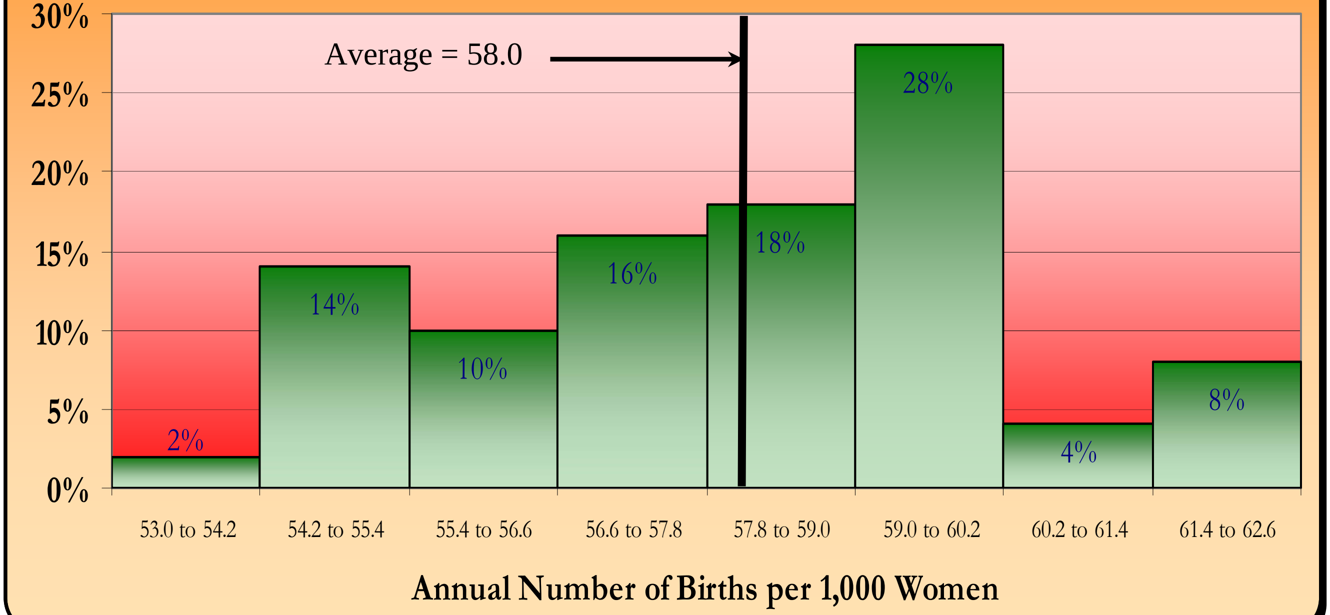


Figure A4:
Distribution of Ten-Year Averages of Annual Birth Rates

From 50 Runs of the FamilyScape Simulation Model,
Among Married Women & with Re-Calibrated Sexual Activity

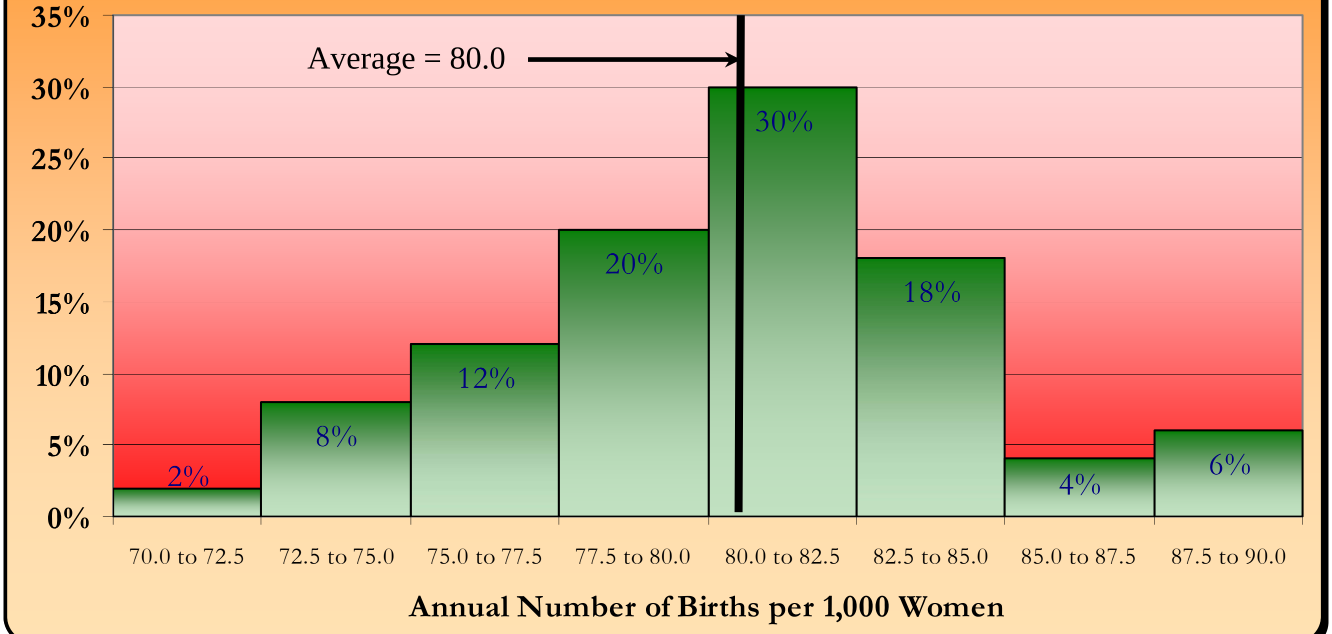


Figure A5:

Distribution of Ten-Year Averages of Annual Birth Rates

From 50 Runs of the FamilyScape Simulation Model,
Among all Women

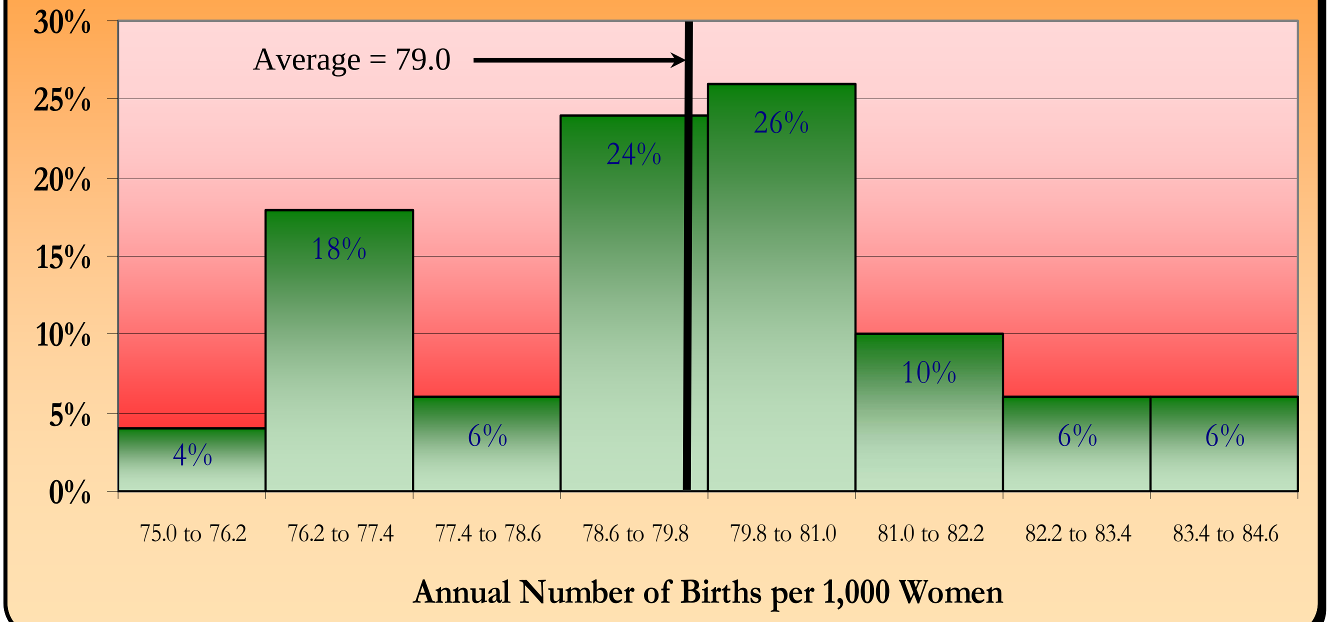


Figure A6:

Distribution of Ten-Year Averages of Annual Birth Rates

From 50 Runs of the FamilyScape Simulation Model,
Among Married Women

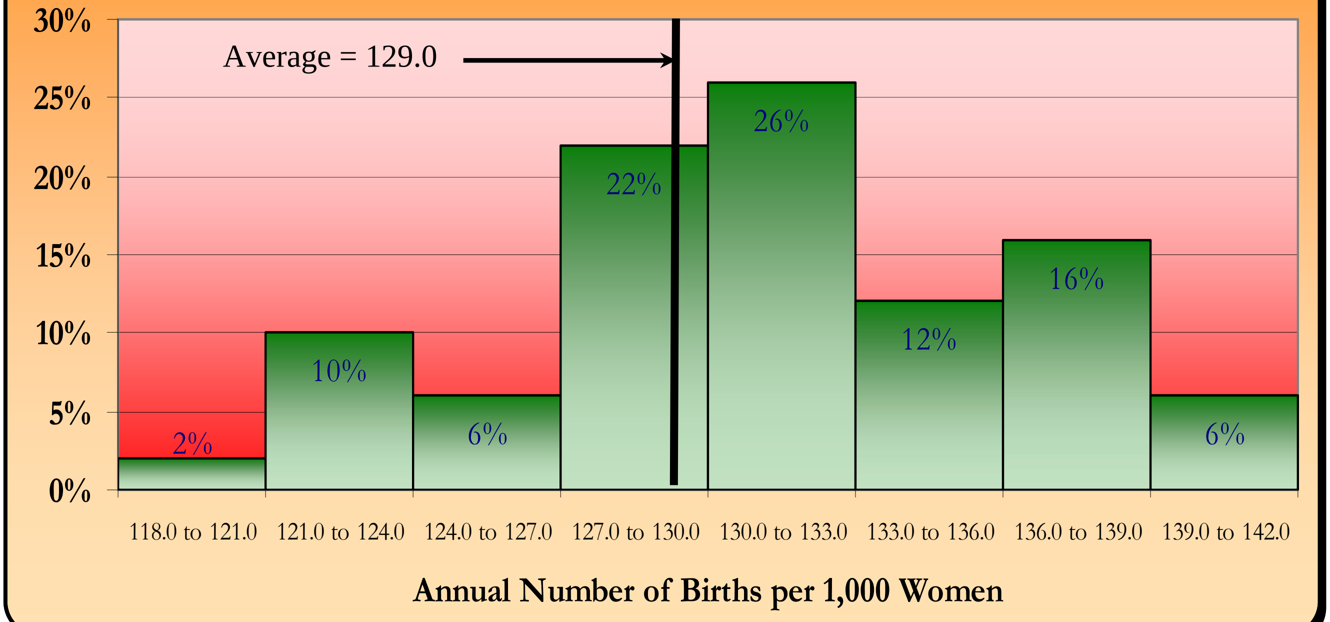


Figure A7:

Distribution of Ten-Year Averages of Annual Birth Rates

From 50 Runs of the FamilyScape Simulation Model,
Among Unmarried Women

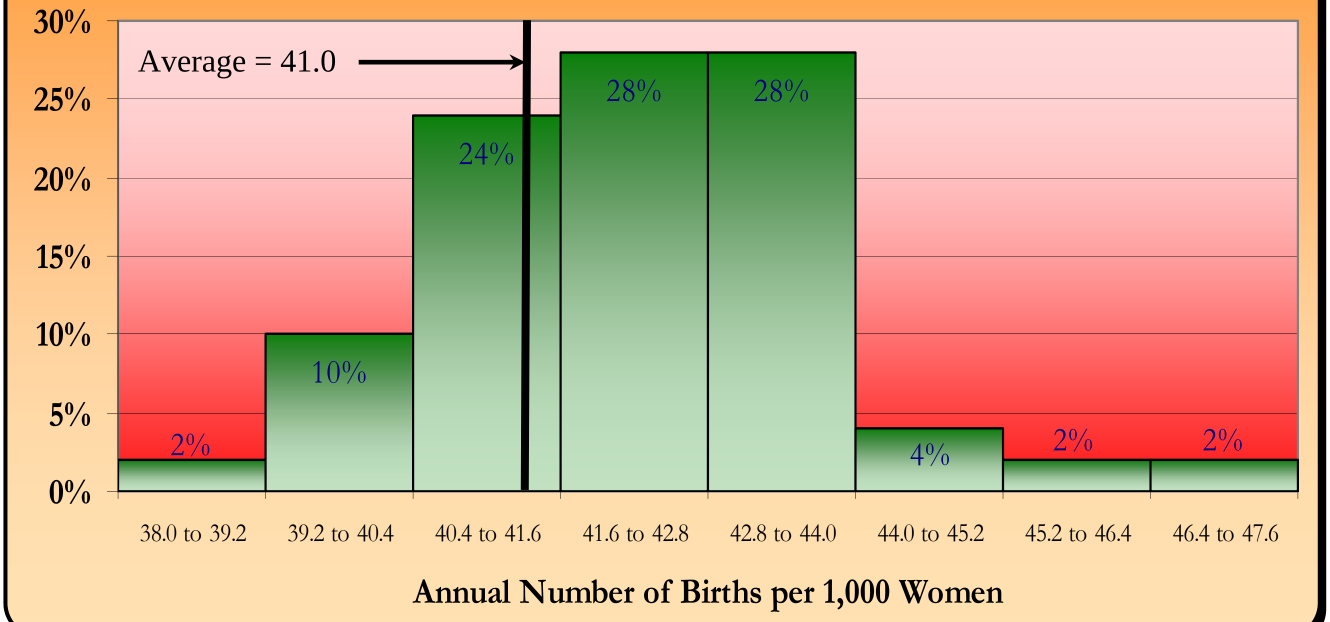


Figure A8:

Distribution of Ten-Year Averages of Annual Pregnancy Rates

From 50 Runs of the FamilyScape Simulation Model,
Among all Women & with Re-Calibrated Sexual Activity among Married Women

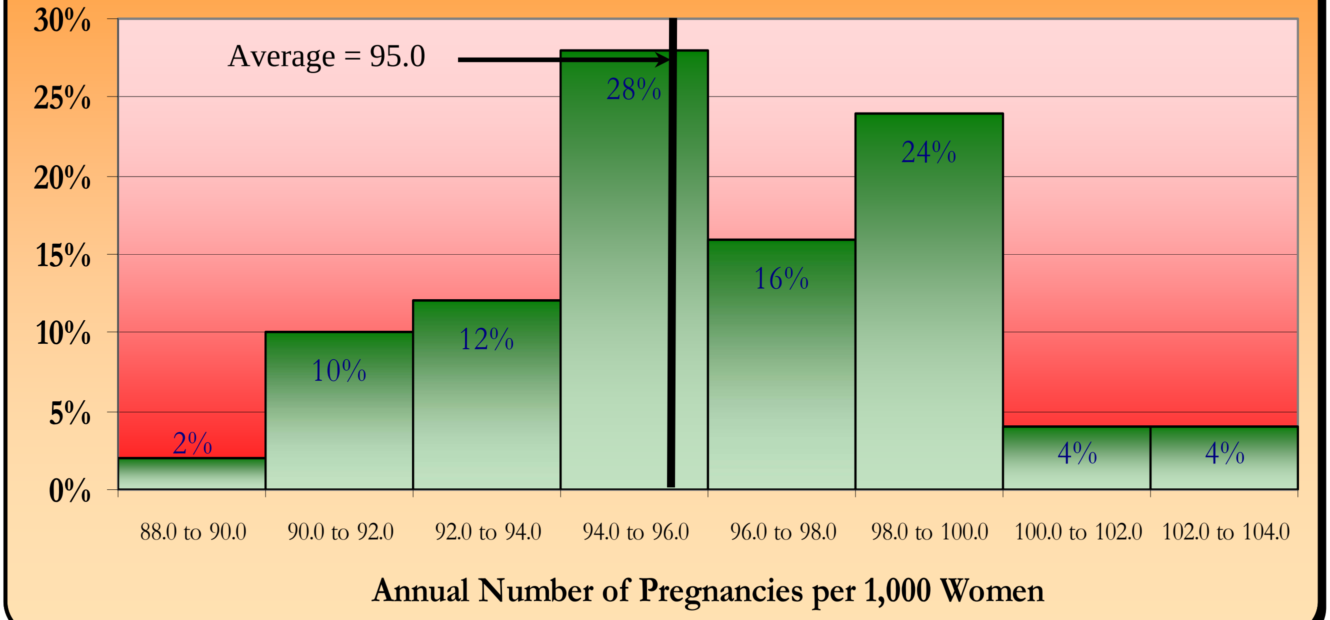


Figure A9:

Distribution of Ten-Year Averages of Annual Pregnancy Rates

From 50 Runs of the FamilyScape Simulation Model,
Among Married Women & with Re-Calibrated Sexual Activity

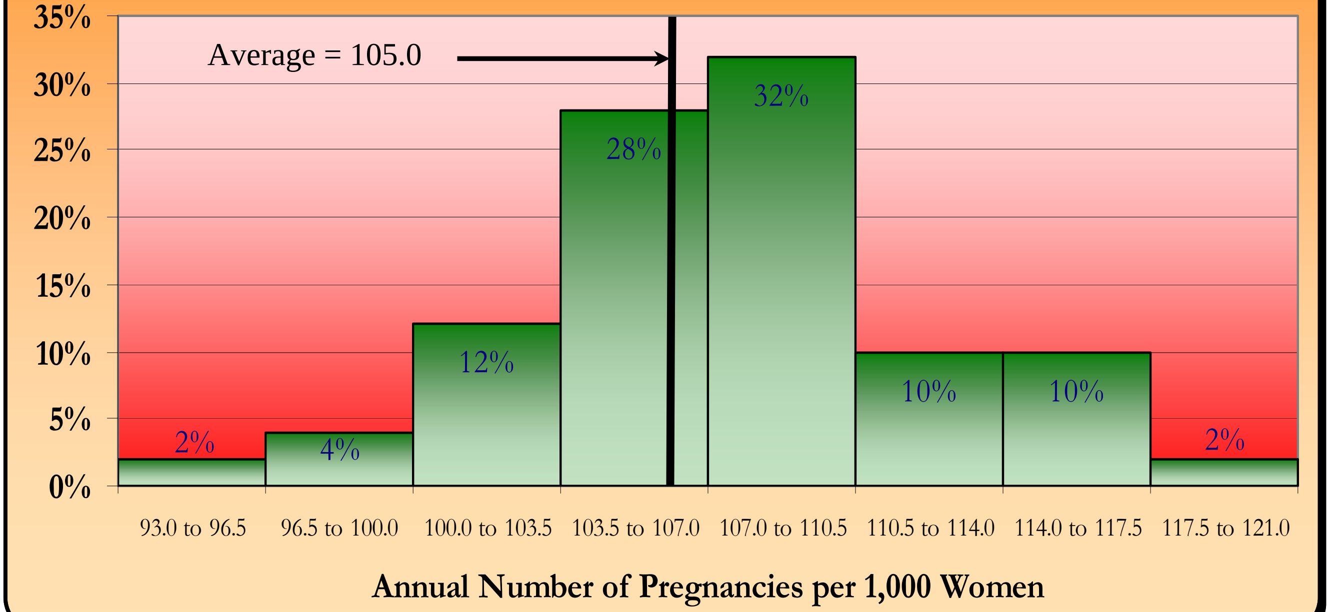


Figure A10:

Distribution of Ten-Year Averages of Annual Pregnancy Rates

From 50 Runs of the FamilyScape Simulation Model,
Among all Women

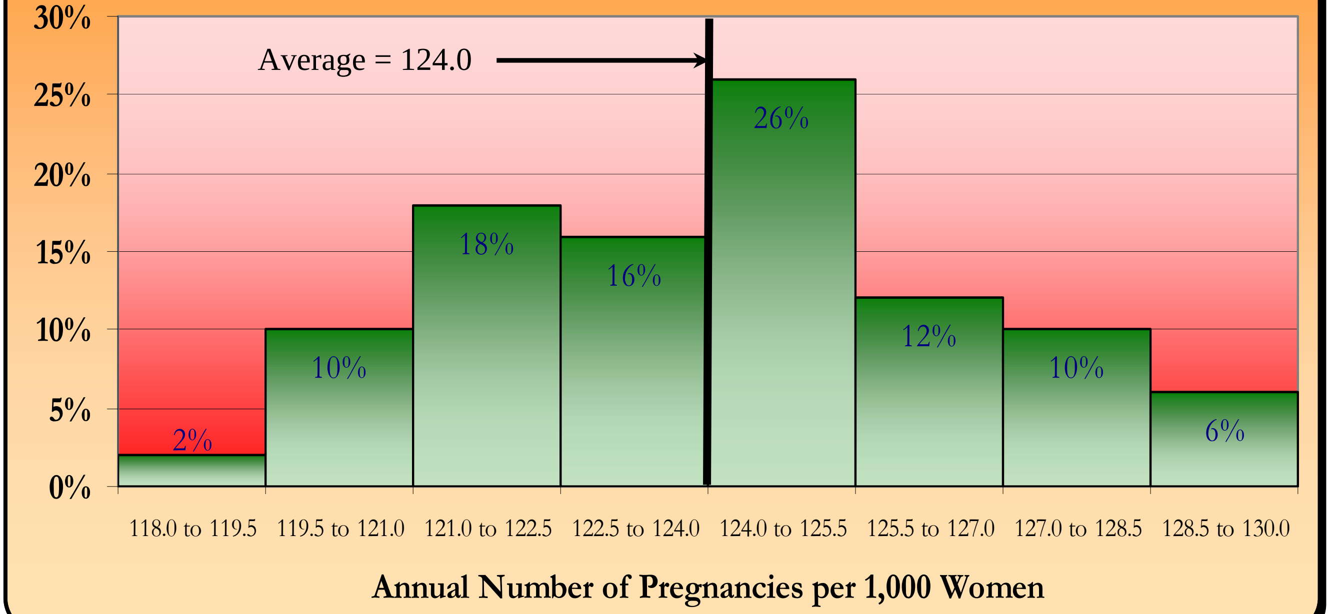


Figure A11:

Distribution of Ten-Year Averages of Annual Pregnancy Rates

From 50 Runs of the FamilyScape Simulation Model,
Among Married Women

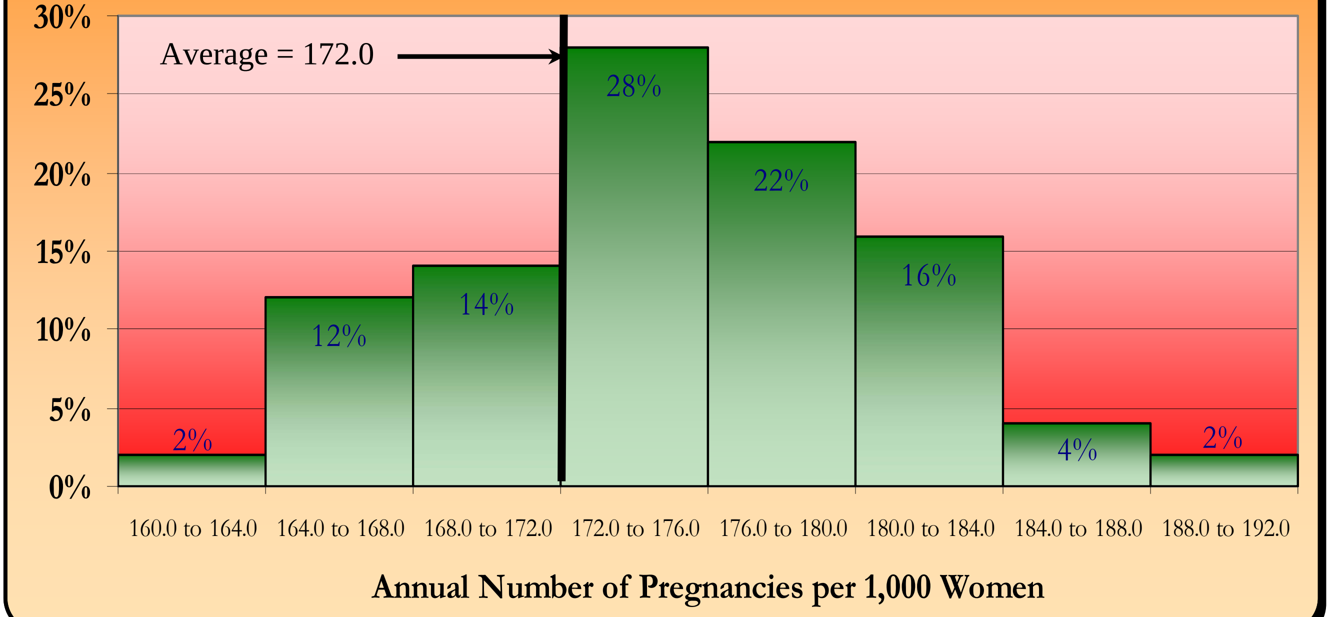
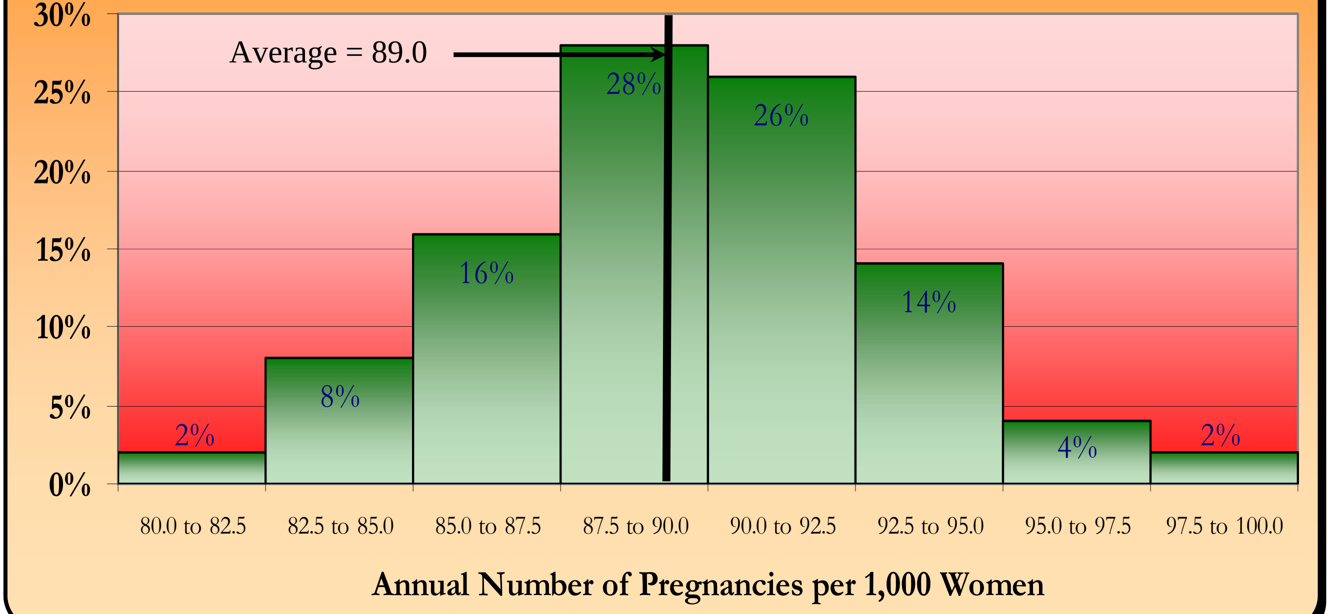


Figure A12:

Distribution of Ten-Year Averages of Annual Pregnancy Rates

From 50 Runs of the FamilyScape Simulation Model,
Among Unmarried Women



APPENDIX II: RELATIONSHIP FORMATION

This appendix describes FamilyScape's procedures for modeling the creation and dissolution of opposite-sex relationships. We begin by discussing the simulation of non-marital relationships among single individuals. We then describe the process by which marital matches are created among the married individuals that are imported into the model.

The Simulation of Non-Marital Relationships

At the beginning of the simulation, all unmarried individuals are single. However, as analysis time passes, opposite-sex relationships begin to be formed by some single individuals.[37] On each day, a single individual has a new opportunity to enter into a relationship if there is a member of the opposite sex who: a) is near to him or her in the model's social environment, b) shares his or her demographic characteristics, and c) is also single.[38] If all three criteria are met, these individuals will enter into a relationship if they are both willing to do so.

An individual's generic willingness to enter into a relationship is represented by a unique "relationship-proclivity" threshold that is randomly assigned to him or her at the beginning of the simulation. These proclivities vary across individuals but are fixed over time. For a given pair of potential relationship partners on a given day, separate random draws are taken from a uniform

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[37] Since we are interested primarily in the incidence of pregnancy and childbearing, we do not model same-sex relationships. A simulated relationship may last indefinitely, or it may be terminated after as little as a single day. These "relationships" should therefore not be thought of as automatically corresponding with stable romantic pairings. Rather, they simply function as necessary pre-requisites for sexual intercourse (in fact, they are often quite durable, but that need not be the case in order for a couple to have sex in the short term). We use the term "relationship" to describe all such arrangements for ease of exposition. However, the reader should bear in mind that this term is being used rather loosely.

[38] Specifically, two individuals of the opposite sex are considered to be potential relationship partners if and only if they are positioned in neighboring cells within the model's social environment. A given cell's neighbors are defined using the rules of a Moore neighborhood. Thus, two cells are considered to be neighboring if they share a common border or corner. Individuals are considered to have common demographic characteristics if they fall into the same age, race, education, and SES categories. See Table A1 in Appendix I for an overview of the ways in which these categories are defined.

(0,1) distribution. If the value of a particular individual's draw exceeds his or her threshold, then that individual is considered to be willing to enter into a relationship with his or her potential partner. Thus, those with relatively low relationship thresholds are generically more willing to enter into relationships than are those with relatively high thresholds. A couple will form a relationship only if and only if both potential partners wish to do so.

Each individual is also assigned a unique (and fixed) threshold that represents his or her likelihood of exiting a relationship. On every day that a pair of individuals are in a relationship, separate random draws are taken from a uniform (0,1) distribution, and, if either individual's draw exceeds his or her "breakup-proclivity" threshold (or if both of them do), then the relationship comes to an end. Depending both on the specific thresholds of the members of a given couple and on the values of the random draws that are taken over time to determine whether they break up, their relationship may be dissolved after as little as a single day, or it may last indefinitely.

Our tabulations of data from the 1998 General Social Survey (GSS) indicate that slightly more than 50 percent of unmarried women between the ages of 15 and 44 – and slightly less than 50 percent of men in the same age range – report that they are currently "romantically involved." We therefore calibrate the relationship-formation module of the model in such a way as to ensure that about half of individuals in the simulation are participating in relationships at any given point in time.[39] We do so using a set of parameters that define the ranges of values from which

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[39] GSS respondents were asked specifically whether they had a "main romantic involvement." For our purposes, it would be ideal if respondents had answered in the affirmative even if they only had a casual sexual partner(s). It is likely, however, that some casual sexual relationships were not captured in responses to this question. As is discussed below, we compensate for this potential drawback by parameterizing the model to ensure that both the distribution of annual coital frequency and individuals' average annual number of sexual partners closely track their real-world targets.

individuals' relationship-proclivity and breakup-proclivity thresholds are randomly assigned at the beginning of the simulation.

The share of unmarried individuals who participate in relationships and the durations of those relationships both depend on the specification of these ranges. For example, if the average relationship-proclivity threshold across all individuals is quite low and the average breakup-proclivity threshold is quite high, then substantial numbers of unmarried individuals will be participating in long-term relationships. Similarly, if relationship and breakup thresholds are both low, then a large share of the population will be participating in short-term relationships; if relationship thresholds are high and breakup thresholds are low, then a relatively small number of people will be participating in relationships, and these relationships will tend not to last for very long; and so forth.

Thus, there are a number of different parameterizations of the model's relationship-formation module that would produce the desired result of ensuring that about half of the unmarried population is participating in a relationship at any given point in time. Some of these parameterizations correspond with a norm of relatively shorter-term relationships, while others correspond with a norm of relatively longer-term relationships. We calibrate this component of the model in order to ensure both that the appropriate share of individuals are participating in relationships and that the simulated average annual number of sexual partners is consistent with the results of our tabulations of 2002 GSS data. Our tabulations suggest that, among unmarried individuals aged 15 to 44, the average number of sexual partners per year is about 2.4. In exploring the model's parameter space, we found that the unmarried members of the simulation population have an average of about 2.3 sexual partners per year – and that about half of them are participating in relationships at any given time – when: 1) the model's coital-frequency module is fully calibrated, 2) individuals' relationship-proclivity thresholds are assigned by taking random draws from a uniform (0,.5) distribution, and 3) their breakup-proclivity thresholds are assigned by taking random draws from a uniform (.975,1) distribution.[40] These are therefore the distributions from which individuals' thresholds are assigned.

Figure A13 presents relationship-participation results from a representative run of the model when it is parameterized in this fashion. After about a year, the model reaches a quasi-steady state in which slightly less than half of unmarried individuals are participating in a relationship.

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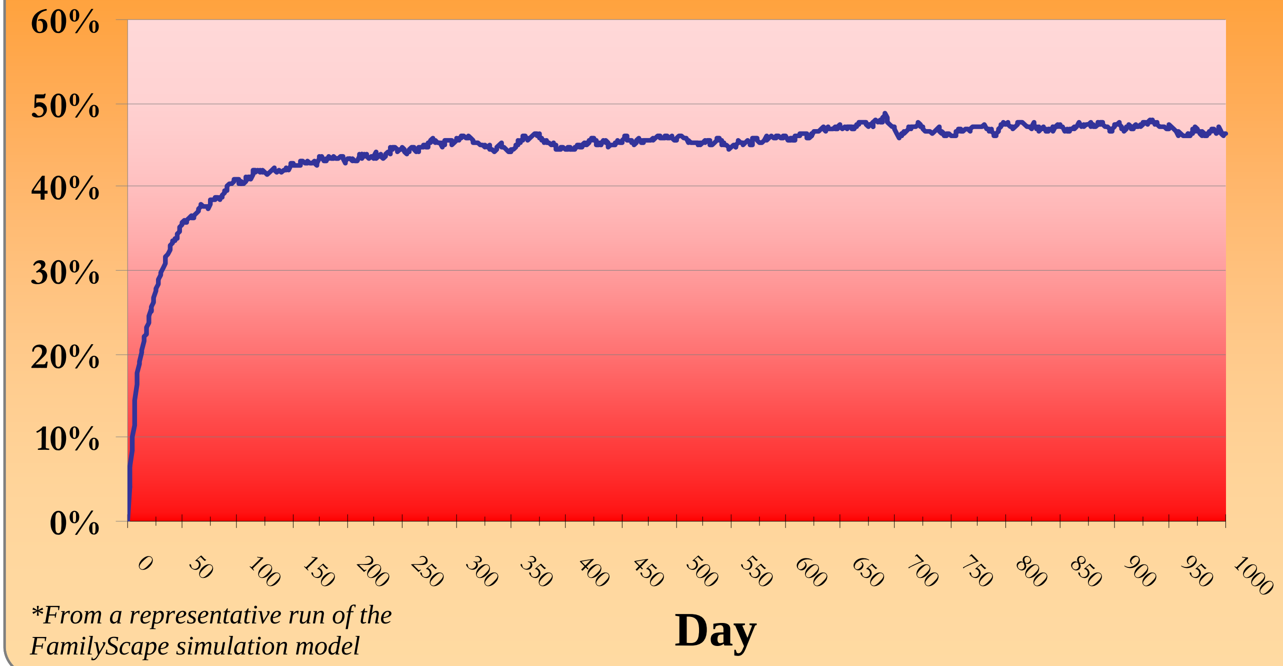
[40] We considered the possibility of varying individuals' relationship- and breakup-proclivity thresholds by their demographic characteristics. However, since the simulation of relationships within FamilyScape functions primarily as a necessary prerequisite for sex – and because the model does in fact vary sexual proclivity by individual characteristics – we concluded that also allowing for demographic variation in relationship formation would complicate the model unnecessarily. See Appendix III for a discussion of the method by which coital frequency is conditioned on individual demographic characteristics.

Figure A13: Percent of Unmarried Adults In the FamilyScape Simulation Who are in a Relationship*



*From a representative run of the FamilyScape simulation model

An “attached” couple will remain in a fixed location within the model’s social environment for the duration of their relationship. A single individual who fails to enter into a relationship on a given day will move to a neighboring location in a continuing search for a suitable partner. Such individuals tend to move in the direction of others who are demographically similar to them.[41]

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[41] Specifically, an individual who moves between rounds will search for another, demographically-similar individual within a Moore neighborhood of range six (which is to say that the relevant neighborhood is a square whose corners are defined by moving six cells diagonally in all four directions from the cell in which the individual is presently situated). If such an individual is identified, the agent will move one cell closer to his or her location. This rule does not take gender into account. Thus, men are just as likely to move in the direction of demographically-similar females as they are to move in the direction of demographically-similar males, and the same is true of women.

The Simulation of Marriages

Somewhat less than half of the NSFG's sample members – and thus, somewhat less than half of the individuals imported into the simulation – are married. However, because the NSFG is a sample of individuals rather than of households or families, respondents' spouses are not included in the dataset. Before importing our extracted subsample into the model, we therefore simulate marital matches between demographically-similar individuals who are coded as married. In the first phase of the marriage simulation, we create random matches between individuals who fall into the same age, race, education, and SES categories. We then begin gradually to relax our matching criteria by allowing as-yet-unmatched individuals to marry if they are similar along most (or some), but not all, of these demographic dimensions. We continue this process until we have created as many matches as possible among the members of the simulation population who were coded as married in the NSFG.[42]

After this process is completed, the proportion married within the simulation population (43 percent) is roughly equivalent to the proportion married among the national population of 15-to-44-year-olds as measured in the 2003 CPS (46 percent). Table A2 compares the extent of marital homogamy among the members of our simulated marriages and among married CPS respondents. Due in large part to the premium placed on match quality in our marriage simulation, the simulated marriages are somewhat more homogamous than are their real-world equivalents.[43]

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[42] There are somewhat fewer married men than married women in the subsample of individuals that were extracted from the NSFG to populate the simulation model. As a result, we are left at the end of the matching process with a handful of women who reported being married in the NSFG, but for whom we were unable to identify a spouse from among the available pool of married men. For the purposes of the simulation, we switch the marital statuses of the members of this group from married to unmarried.

[43] The comparison of age-specific match quality is somewhat awkward, since the men and women participating in simulated marriages are all between the ages of 15 and 44. This restriction artificially inflates the extent of age-specific homogamy within the simulated marriages. In order to create a comparison group that is as similar as possible to the married members of the simulation population, the CPS sample is limited to couples in which the wife falls into this age range.

Table A2: Comparison of Match Quality Among Real-World Marriages in the CPS and Simulated Marriages in the FamilyScape Simulation Population

	Marriages in the CPS	Simulated Marriages in the FamilyScape Simulation Population
Same age (%)	12.5	9.8
Wife older than husband (%)	18.3	44.2
Husband older than wife (%)	69.3	46.0
Mean age difference, in years (wife - husband)	-2.88	-0.18
Same level of education (%)	39.4	48.6
Wife has more education than husband (%)	31.3	24.6
Husband has more education than wife (%)	29.3	26.8
Same race (%)	91.8	97.6

Note: Simulated marriages were created using observations from a weighted subsample of Cycle 6 of the National Survey of Family Growth's (NSFG) male and female respondent files. The data reported here on real-world marriages were taken from the March 2003 Current Population Survey (CPS). In order to create a CPS subsample that is as comparable as possible to the group among whom marriages were simulated using the NSFG, and since all NSFG respondents are between the ages of 15 and 44, demographic characteristics for married CPS respondents are reported here only for couples in which the wife is within this age range.

When the model is initialized by randomly arraying the simulation population within FamilyScape's social environment, married couples are placed in adjoining cells. As is the case with individuals participating in non-marital relationships, married couples remain in their fixed locations for the duration of their marriages. We are still in the process of refining and calibrating the components of the simulation that model divorces among married couples and new marriages among unmarried couples. Thus, marriages in the current version of the model persist in perpetuity. The next iteration of the model will contain a completed module accounting for the "flow" of individuals into and out of the married population.

The reader should bear in mind, however, that the current version of FamilyScape already realistically models the "stock" of marriages within the simulation population. Moreover, in a given year, only about one percent of marital unions are dissolved, and new marriages make up only about two percent of the total number of existing marriages.[44] Thus, the inclusion of a module accounting for new marriages and divorces will have a negligible effect on the overall

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[44] Based on the authors' analysis of data from Bramlett and Mosher (2002) and Munson and Sutton (2004).

annualized distribution of marriage within the simulation population. However, given the interest among many members of the policy community in pursuing initiatives designed to incentivize marriage, the completion of FamilyScape's divorce and new-marriage modules remains a high priority for the next iteration of the model.

APPENDIX III: SEXUAL ACTIVITY & CONTRACEPTIVE USE

The first section of this appendix describes FamilyScape's methods for modeling coital frequency among married and unmarried individuals. The second section describes our procedures for simulating contraceptive use (or lack thereof) among sexually-active couples.

Coital Frequency

In order to engage in sexual activity, an individual in the simulation must be part of a marriage or a non-marital relationship. A couple will have sex on a given day if both the man and the woman are willing to do so, and an individual's willingness to have sex is governed by a "sexual-proclivity" threshold that is assigned to him or her at the outset of the simulation. These thresholds vary across individuals but are fixed over time. On each day that an individual is married or in a relationship, a draw is taken from a random uniform (0,1) distribution and compared with his or her threshold. If the value of that draw exceeds the individual's threshold, then he or she is considered to be willing to have sex on that day. Thus, individuals with relatively low thresholds are more likely to be willing to have sex on a given day than are individuals with relatively high thresholds.

These thresholds are assigned in such a way as to produce a simulated distribution of sexual activity that approximates its real-world equivalent.[45] Figure A14 shows the distribution of coital

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[45] In earlier versions of the model, we calibrated the sexual-behavior module simply by pegging the average aggregate level of coital frequency – rather than the entire distribution – to the appropriate real-world target. However, we discovered that this approach was inducing a substantial over-simulation of the number of pregnancies relative to real-world pregnancy rates. This phenomenon was largely attributable to the fact that there was considerably more sexual abstinence in the real world than in our simulation. We therefore restructured the model so that it is able to approximate the entire real-world distribution of sexual activity. Once this enhancement was implemented, the model produced pregnancy rates that were almost identical to their relevant real-world targets among unmarried individuals and were much closer to the relevant targets among married couples.

frequency over a 28-day period among married and unmarried individuals in the 2002 NSFG.[46] About half of unmarried people – and nearly a fifth of married people – report having had no sex in the four weeks prior to their interview. Among both groups, a small share of the population experience what are, in relative terms, very high rates of sexual activity. And a large portion of both married and unmarried individuals fall between these two extremes.

In order to reproduce these distributions within our simulation, we first assign each individual to one of three sexual-proclivity groups: "highly active," "moderately active," or "inactive." Individuals are assigned to groups using the results of three different sets of regressions. Each regression has a dummied dependent variable indicating whether or not respondents fall into a particular category.[47] These regressions are conducted using NSFG data, separate models are estimated for married and unmarried respondents, and a full set of demographic covariates are included in each one. See Table A3 for a complete set of regression estimates. These estimates are incorporated into the simulation and are used to impute individuals' probabilities of falling

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[46] NSFG respondents provide information on their coital frequency over the four-week period preceding the day on which the survey was administered. The survey distinguishes between heterosexual and homosexual sex, and between vaginal intercourse and other forms of sexual activity. Since we are principally interested in the incidence of pregnancy and childbearing, we limit our definition of sexual activity to heterosexual vaginal intercourse. Men tend to report higher levels of sexual activity than do women. Since the aggregate amount of heterosexual intercourse experienced by men and by women should theoretically be the same, it seems likely that that one or both of the two sexes have a systematic tendency to misreport their true level of sexual activity. Small-scale studies of sexual behavior generally find that respondents are more likely to over-report the amount of sex that they have than they are to under-report it (Jaccard et al., 2002; Graham et al., 2003). Thus – and since women tend to report having less sex than men – we make the assumption that women's self-reports of sexual activity are more reliable than are men's. We therefore calibrate the model's coital-frequency module using only data on women's sexual activity. As such, the real-world distributions of coital frequency discussed here and the regression results presented in Table A3 are estimated using data only on women's self-reported coital frequency.

[47] Since there are substantial differences between the coital-frequency distributions of the married and unmarried populations, we specify the breakpoints that define their coital-frequency categories differently. Specifically: unmarried NSFG respondents were deemed to be in the "inactive" category if they had no sex in during the previous 28 days; they were considered to be in the "highly-active" category if they had sex 20 times or more during this period; and they were considered to be in the "moderately-active" category if their level of sexual activity fell in between these two thresholds. Married respondents were considered to be in the "inactive" category if they had sex less than four times during the previous 28 days; they were considered to be in the "highly-active" category if they had sex 19 times or more; and they were considered to be in the "moderately-active" category otherwise. Sensitivity-test results suggest that FamilyScape's key outcomes (i.e., rates of pregnancy and childbearing) are insensitive to reasonable changes in values of these breakpoints.

into each of the three sexual-proclivity groups. A given individual's probabilities are then compared with the results of a random draw from a uniform (0,1) distribution in order to assign him or her to a particular sexual-proclivity category.[48]

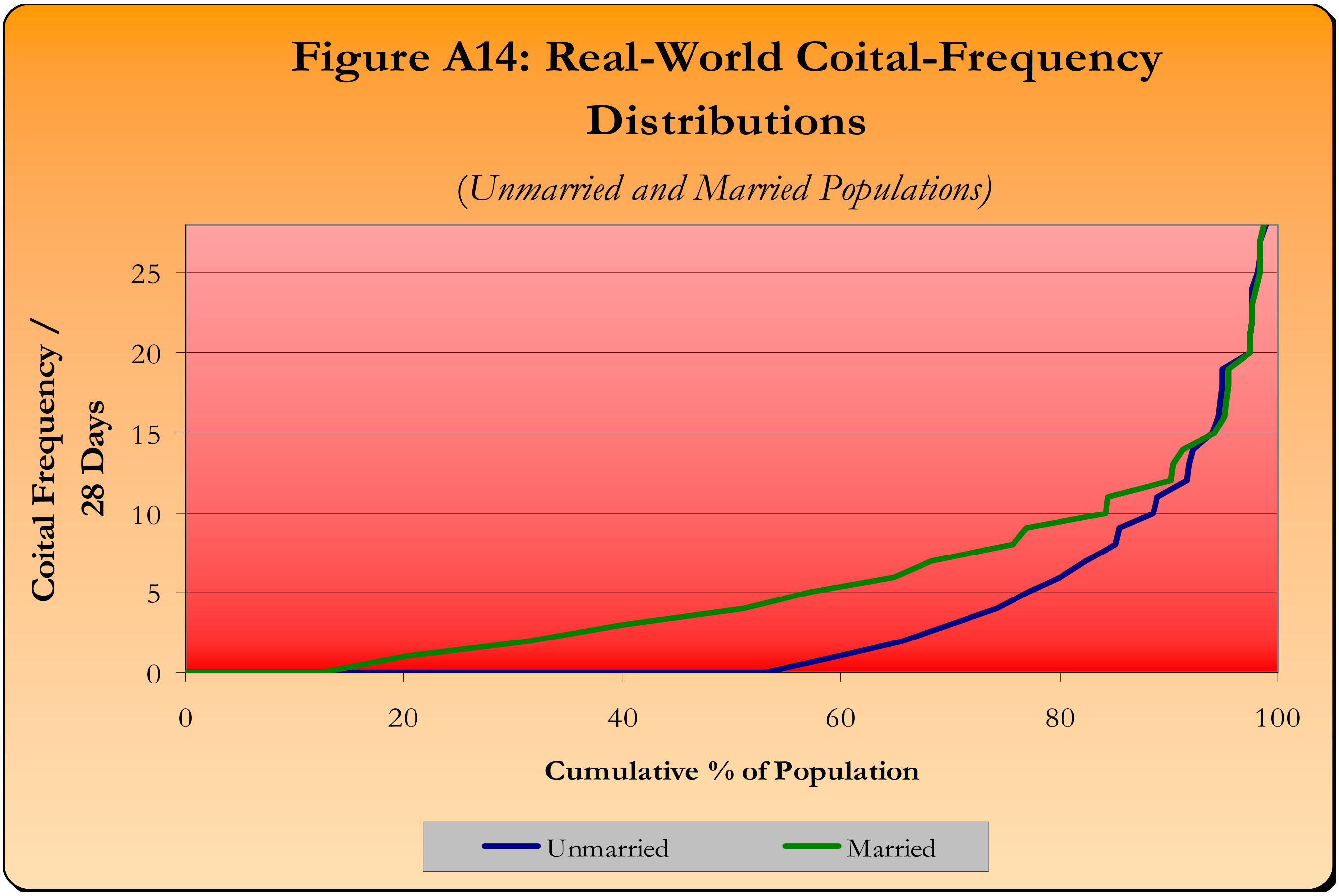

Figure A14: Real-World Coital-Frequency Distributions

(Unmarried and Married Populations)

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[48] In fact, because our three sexual-proclivity categories are exhaustive and mutually exclusive, only two sets of regression coefficients are required to calculate an individual's relative chances of falling into each of these three groups. Thus, we actually only incorporate the "inactive" and "moderately-active" regression results into the simulation model. Assume, then, that an individual in the simulation were calculated to have an "inactive probability" of .2 and a "moderately-active" probability of .6. A random draw between 0 and .2 would result in his being placed into the "inactive" category, a draw between .2 and (.2 + .6) = .8 would result in his being placed into the "moderately-active" category, and a draw between .8 and 1 would result in his being placed into the "highly-active" category.

Table A3: Sexual-Proclivity Regression Results

	Low Proclivity		**Moderate Proclivity**		**High Proclivity**	
	Unmarried Women	Married Women	Unmarried Women	Married Women	Unmarried Women	Married Women
	Coefficient *t-value*	Coefficient *t-value*	Coefficient *t-value*	Coefficient *t-value*	Coefficient *t-value*	Coefficient *t-value*
Age Dummy: 20-24	-0.340	0.027	0.284	0.066	0.056	-0.093
	*-11.18****	*0.25*	*9.28****	*0.55*	*3.37****	*-0.98*
Age Dummy: 25-29	-0.389	0.072	0.356	0.039	0.033	-0.111
	*-11.84****	*0.66*	*10.64****	*0.33*	*1.77**	*-1.17*
Age Dummy: 30-44	-0.252	0.135	0.228	-0.001	0.024	-0.134
	*-8.51****	*1.25*	*7.75****	*-0.01*	*1.40*	*-1.42*
Education Dummy: High School Degree	-0.099	-0.090	0.067	0.066	0.032	0.025
	*-3.56****	*-2.31***	*2.44***	*1.69*	*1.85**	*1.28*
Education Dummy: More than High School	0.017	-0.013	-0.010	0.008	-0.006	0.005
	0.59	*-0.35*	*-0.37*	*0.22*	*-0.40*	*0.29*
Race Dummy: Black	-0.012	0.043	0.042	-0.071	-0.030	0.028
	-0.49	*1.26*	*1.73**	*-2.11***	*-2.60****	*1.64**
Race Dummy: Hispanic	0.010	-0.051	0.007	0.019	-0.017	0.032
	0.36	*-1.69**	*0.27*	*0.64*	*-1.18*	*1.96***
Race Dummy: Other	0.083	0.114	-0.062	-0.095	-0.021	-0.019
	*1.87**	*2.03***	*-1.39*	*-1.71**	*-1.21*	*-1.34*
SES Dummy	0.028	-0.075	-0.015	0.112	-0.013	-0.036
	1.11	*-2.49***	*-0.58*	*3.78****	*-0.95*	*-2.22***
Constant	0.712	0.466	0.239	0.346	0.049	0.188
	*24.44****	*4.17****	*8.35****	*2.93****	*2.84****	*2.02***
P-Value for Joint Test of Age Covariates	0.000	0.005	0.000	0.202	0.005	0.016
P-Value for Joint Test of Education Covariates	0.000	0.014	0.005	0.105	0.019	0.016
P-Value for Joint Test of Race Covariates	0.237	0.014	0.126	0.034	0.073	0.018
N (unweighted)	4,224	3,286	4,224	3,286	4,224	3,286

Notes: All parameters were estimated using the male and female respondent files from Cycle 6 of the National Survey of Family Growth (NSFG). An unmarried respondent is coded as having a low sexual proclivity if he/she had not had sexual intercourse in the four weeks prior to his/her interview; as having a moderate proclivity if he/she had sex at least once but less than twenty times during this period; and as having a high proclivity if he/she had sex twenty or more times during this period. A married respondents is coded as having a low sexual proclivity if he/she had sex less than five times in the four weeks prior to his/her interview; as having a moderate proclivity if he/she had sex between five and eighteen times during this period; and as having a high proclivity if he/she had sex more than eighteen times during this period. The excluded age, education, and race categories are as follows: age group 15-19, an educational attainment of less than a high school degree, and the white race category. The SES dummy is set equal to one if the respondent's mother had an educational attainment equal to or greater than a high school degree and zero otherwise. While results for all three sexual-proclivity analyses are shown here, only two sets of results are necessary to assign sexual-proclivity status in the simulation model, since the three proclivity categories are exhaustive and mutually exclusive. We therefore incorporate only the results for the low- and moderate-sexual-proclivity regressions into the model. One asterisk (*) indicates that the parameter estimate is significant at or beyond the .1 level, two asterisks (**) indicate that the parameter estimate is significant at or beyond the .05 level, and three asterisks (***) indicate that the parameter estimate is significant at or beyond the .01 level.

At the outset of the simulation, each individual is assigned a fixed sexual-proclivity threshold by taking a random draw from one of several different uniform distributions. The ranges of these distributions are defined differently, and the particular distribution from which an individual's draw is taken depends upon his or her marital status and sexual-proclivity type.[49] These ranges are specified such that, among individuals who are of the same marital status, the thresholds of those in the "highly-active" category are at least as low as the thresholds of those in the "moderately-active" category, and that the thresholds of those in the "moderately-active" category are at least as low as the thresholds of those in the "inactive" category (since relatively lower thresholds reflect a relatively greater willingness to have sex).

After extensive exploration of the model's parameter space, we identified a set of threshold ranges that produce distributions of married and unmarried coital frequency that roughly approximate their real-world equivalents.[50] Figure A15 compares the 28-day distribution of coital frequency among unmarried NSFG respondents with the equivalent unmarried distribution from a representative run of the model after it has been parameterized in this fashion. Figure A16 shows the same comparison for married couples. In both figures, the simulated and real-world distributions are roughly comparable.[51]

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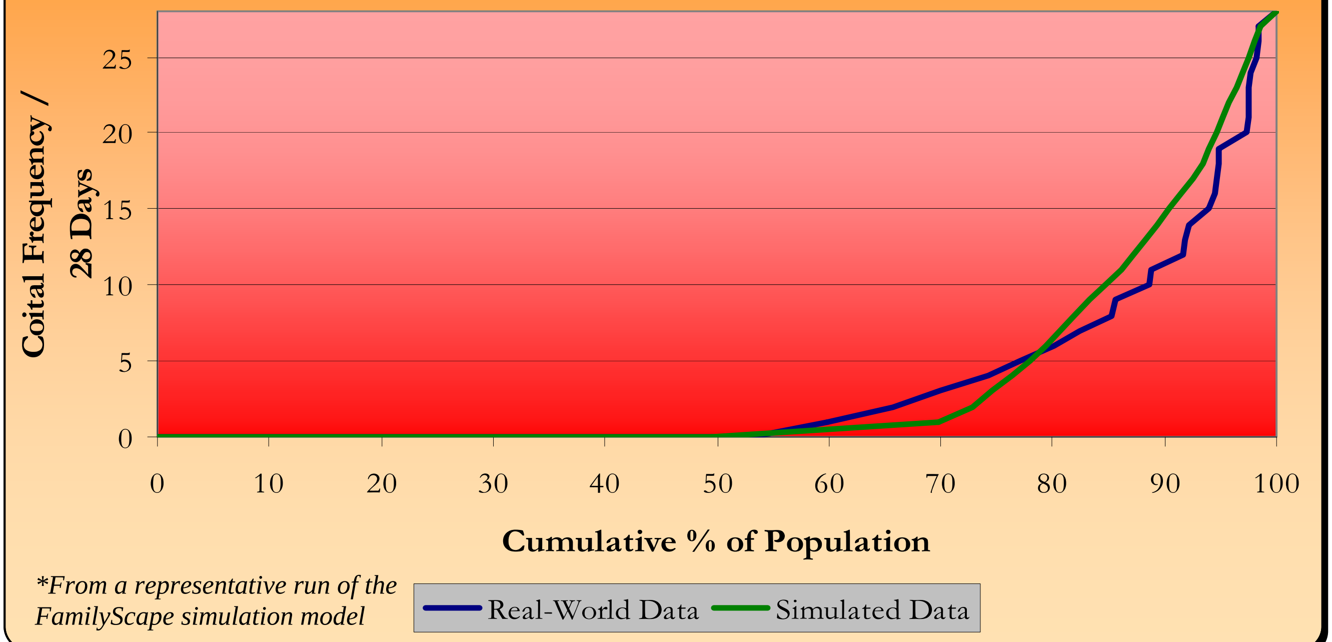
[49] Since there are three sexual-proclivity types and two marital statuses, there are 2*3 = 6 possible distributions from which an individual's threshold might be assigned.

[50] This parameterization is as follows: among unmarried individuals, those in the "inactive" category are randomly assigned thresholds from a (.93,1) distribution; those in the "moderately-active" category are randomly assigned thresholds from a (0,.93) distribution; and those in the "highly-active" category are all assigned thresholds equal to zero. Among married individuals, those in the "inactive" category are randomly assigned thresholds from a (.82,1) distribution; those in the "moderately-active" category are randomly assigned thresholds from a (0,.82) distribution; and those in the "highly-active" category are all assigned thresholds of zero.

[51] These figures show distributions of coital frequency as measured over a four-week period. We would also note that the average *annual* rate of sexual frequency in the simulation is consistent with the results of our tabulations of the 2002 GSS, and with estimates reported in Laumann et al.'s (1994) landmark analysis of data from National Health and Social Life Survey. The real-world and simulated 28-day distributions shown in Figures A15 and A16 are similar, but they certainly are not identical to each other. The differences between the two sets of distributions are driven largely by the fact that, in the simulation, an individual's sexual-proclivity threshold is strongly correlated with – but is far from perfectly predictive of – the frequency with which he or she will have sex. For example, an individual who is

Figure A15: Coital-Frequency Distributions in Real-World and Simulated Data*

(Unmarried Population)



**From a representative run of the FamilySscape simulation model*

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placed into the "highly-active" category may in fact have little or no sex if he or she remains single for much of the simulation or is paired with a partner who has a low sexual proclivity. Thus, the mixing of sexual-proclivity types in the formation of relationships and the random variation that is inherent to the simulation process prevent us from being able to replicate perfectly the real-world distribution of sexual activity. However, we have become convinced by the results of a series of sensitivity analyses that the modest distributional differences shown here are too small to have a meaningful impact on the simulation's results.

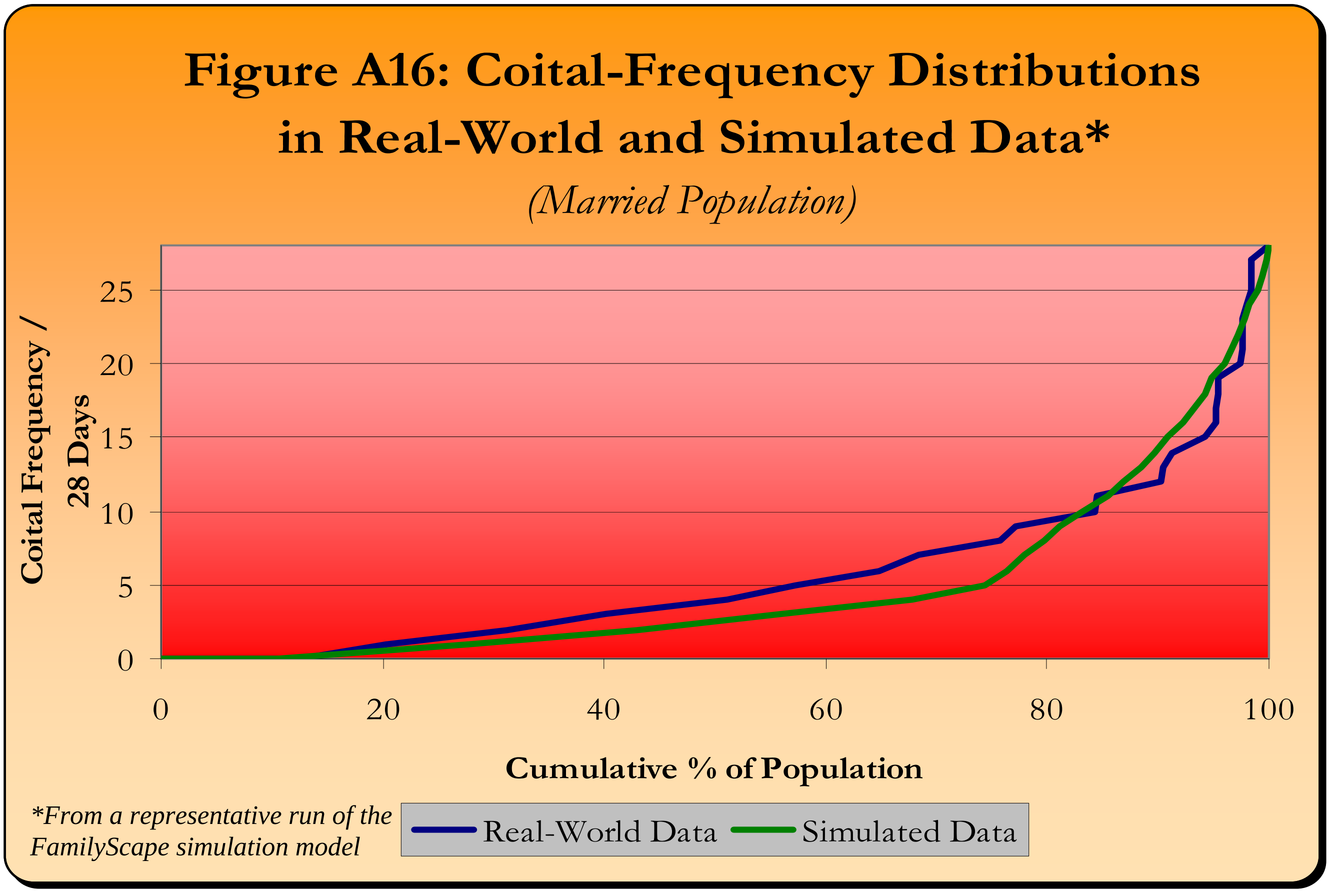


Figure A16: Coital-Frequency Distributions in Real-World and Simulated Data*

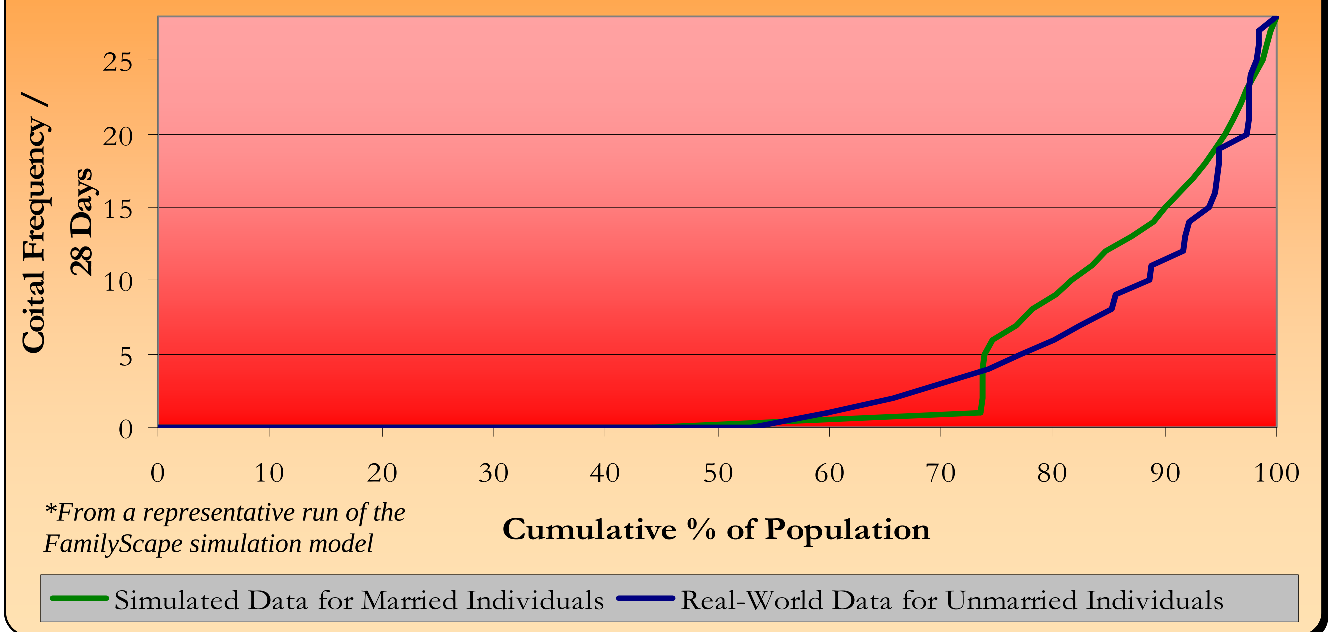
(Married Population)

**From a representative run of the FamilyScape simulation model*

As is discussed in the main body of the paper, the model's baseline specification produces rates of unmarried pregnancy and childbearing that are extremely close to their real-world equivalents. Among married couples, however, the model's key outcomes initially exceed their targets by about 50 percent. We therefore explore an alternate specification in which married couples are assumed to have sex about as infrequently as unmarried individuals do. Figure A17 compares the real-world distribution of coital frequency among unmarried individuals with the simulated distribution among married individuals after the implementation of this new specification.[52]

Figure A17: Coital-Frequency Distributions in Real-World and Simulated Data*

(Simulated Sexual Behavior for Married Individuals Calibrated to Match Unmarried Real-World Target)



**From a representative run of the FamilyScape simulation model*

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[52] Under this specification, married individuals are randomly assigned sexual-proclivity thresholds from a uniform (.96,1) distribution if they are in the "inactive" category and from a (0,.79) distribution if they are in the "moderate" category, and they are assigned a threshold equal to zero if they are in the "highly-active" category.

Contraceptive Use

FamilyScape simulates contraceptive use (or a lack thereof) among sexually-active couples. This module is parameterized with coefficients from regression analyses of the probability of using various types of contraception among NSFG respondents.[53] These coefficients are used to permanently assign each individual in the simulation population to the use of a particular method (or of no method at all) at t=0 as a function of their demographic characteristics. Choice of contraceptive regime (if any) thus varies across individuals but is fixed over time.

As is described in the main body of the paper, our literature review and our original analyses of various data sources suggest that surgical sterilization, condoms, and oral contraception are each used by somewhat less than a third of contracepors, and that the remaining share of users rely on a variety other options. In the interest of parsimony, we simulate the use of only these three methods in the model's baseline specification. Thus, the subset of contraceptors who report having used other methods are, for our purposes, assumed to have used the pill.[54] We begin by simulating sterilization among a certain share of the male and female populations. We then assign a certain share of the non-sterilized male population to be condom users and a certain share of the non-sterilized female population to be pill users. Individuals who are not sterilized and who use neither condoms nor the pill are non-contraceptors. We describe our procedures for simulating the use of each of these methods below.

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[53] These regressions rely primarily on a series of variables that were created by asking NSFG respondents to list up to four of the methods that they used at their last sexual encounter. The universe of respondents for this question was limited by the survey's administrators to men and women who report having had sex at least once in the past twelve months.

[54] See Thomas and Roessel (2008) for an extensive discussion of contraceptive use. A crude weighted average of the effectiveness of methods other than condoms, sterilization, and the pill implies that, as a whole, they are about as efficacious as oral contraception.

Sterilization

At t=0, we impute a probability of being sterilized to each individual in the simulation population using the results of regressions that were performed with NSFG data.[55] Sterilization is much more common among women than among men, and it is more common among married individuals than among unmarried individuals. We therefore estimate separate regressions by gender and marital status. All four equations include a full complement of demographic covariates. In addition, these regression models – and, indeed, all of our contraceptive-use regressions – control for sexual-proclivity status in order to ensure that the simulation accounts for any correlations that might exist between the frequency with which individuals have sex and their likelihood of using contraception when doing so. The equation for married men also contains a covariate accounting for their wives' sterilization statuses in order to ensure that the model properly simulates the distribution of sterilization both at the individual level and at the couple level.[56] See Table A4 for a complete set of sterilization regression results.

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[55] The NSFG distinguishes between respondents who are surgically sterilized and those who are naturally sterile. For the purposes of our simulation, it is unimportant whether an individual is sterile for surgical or for natural reasons. When conducting analyses of NSFG data in order to parameterize the simulation model, we therefore code respondents as being "sterilized" even if they are sterile for natural reasons. Thus, throughout this discussion, we use the term "sterilization" to refer both to natural sterility and to surgical sterilization. NSFG respondents may indicate that they are sterilized either in one of the four contraceptive-method variables described in the previous footnote or in a stand-alone question that asks them about their sterilization status. For the purposes of these regressions, we assume that respondents are sterilized if they indicate on any of these questions that this is the case.

[56] Our procedure for determining the sterilization status of a respondent's partner – in terms of the types of variables used and the way in which we define sterilization – are similar to the procedures described in the previous footnote for determining a respondent's own sterilization status. We control for wives' sterilization in the married men's equation in order to ensure that the simulation properly models the couple-level distribution of contraceptive use. Consider a scenario in which 20 percent of married men and 20 percent of married women are sterilized. One extreme possibility is that only 20 percent of married couples are sterilized (if all sterilized men are married to sterilized women), and the other is that 40 percent of couples are sterilized (if it is never the case that sterilized people are married to each other). Our analysis of NSFG data suggests, first, that the real world is closer to the latter extreme than to the former one; and, second, that the failure to account for this dynamic in our regression models would result in a substantial under-simulation of the percent of FamilyScape's married couples in which at least one member is sterilized. As is discussed later in this section, we also condition married men's condom use and married women's pill use on their spouses' sterilization statuses. However, we do not implement an equivalent provision for unmarried couples. We elected not to do so in the interest of parsimony, and because it seems intuitively likely that

Table A4: Sterilization Regression Results

	Unmarried Women	Married Women	Unmarried Men	Married Men
	Coefficient *t-value*	Coefficient *t-value*	Coefficient *t-value*	Coefficient *t-value*
Age Dummy: 20-24	0.074 *4.64****	0.147 *4.99****	-0.006 *-0.50*	0.011 *0.34*
Age Dummy: 25-29	0.141 *6.01****	0.257 *8.27****	0.026 *1.35*	0.065 *1.92*
Age Dummy: 30-44	0.438 *16.94****	0.434 *13.99****	0.060 *3.68****	0.241 *5.94****
Education Dummy: High School Degree	-0.041 *-1.53****	-0.100 *-2.62****	-0.008 *-0.52*	-0.026 *-0.51*
Education Dummy: More than High School	-0.144 *-5.77*	-0.224 *-6.02****	-0.013 *-0.73*	-0.092 *-1.73**
Race Dummy: Black	-0.004 *-0.16*	0.151 *4.55****	0.018 *1.26*	-0.104 *-2.92****
Race Dummy: Hispanic	-0.039 *-1.53*	-0.026 *-0.89*	0.024 *1.35*	-0.107 *-2.69****
Race Dummy: Other	0.008 *0.15*	-0.113 *-3.68****	0.028 *0.92*	0.078 *1.01*
SES Dummy	-0.064 *-2.31***	-0.117 *-4.04****	-0.004 *-0.23*	0.001 *0.03*
Moderate Sexual Proclivity Dummy	0.024 *1.18*	0.021 *1.02*	-0.008 *-0.52*	0.060 *1.89**
High Sexual Proclivity Dummy	0.064 *1.79**	0.141 *3.08****	-0.020 *-0.99*	0.114 *1.70**
Partner's Sterility Dummy	--	--	--	-0.095 *-2.84****
Constant	0.091 *2.83****	0.113 *2.67****	0.036 *1.64*	0.034 *0.63*
P-Value for Joint Test of Age Covariates	0.000	0.000	0.000	0.000
P-Value for Joint Test of Education Covariates	0.000	0.000	0.762	0.114
P-Value for Joint Test of Race Covariates	0.446	0.000	0.292	0.006
N (unweighted)	2,783	3,115	2,241	1,273

Notes: All parameters were estimated using the male and female respondent files from Cycle 6 of the National Survey of Family Growth (NSFG). Sterilization status is defined using information on both natural sterility and surgical sterilization. The excluded age, education, and race categories are as follows: age group 15-19, an educational attainment of less than a high school degree, and the white race category. The SES dummy is set equal to one if the respondent's mother had an educational attainment equal to or greater than a high school degree and zero otherwise. Unmarried respondents are coded as having a moderate sexual proclivity if they report having had sexual intercourse between one and nineteen times in the four weeks prior to their interview and as having a high sexual proclivity if they report having had sex more than nineteen times during that period. The equivalent thresholds for married respondents are five and eighteen times. Partner's sterility was included as a control variable only in the male married analysis for two reasons: first, it is unlikely that large numbers of unmarried men and women would condition their sterilization decisions on the sterility status of their sexual partners; and second, for married respondents, we need only condition on partner's sterility for one of the two sexes. One asterisk (*) indicates that the parameter estimate is significant at or beyond the .1 level, two asterisks (**) indicate that the parameter estimate is significant at or beyond the .05 level, and three asterisks (***) indicate that the parameter estimate is significant at or beyond the .01 level.

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married individuals would be more prone than unmarried individuals to consider their partners' sterilization statuses when deciding what method(s, if any) of contraception they themselves should use.

The coefficients from these regressions are used to impute sterilization probabilities for the members of the simulation population. At the outset of the simulation, we take a random draw from a uniform (0,1) distribution for each individual and, if the value of that draw falls below the individual's probability, then he or she is considered to be permanently sterilized.

Oral Contraception

We assign a share of non-sterilized women to the use of oral contraception. We generate the parameters for this portion of the simulation via a set of regressions that were performed using the NSFG. Recall, first, that a relatively small portion of contraceptors use a method other than condoms, the pill, and sterilization; and, second, that we make the simplifying assumption for the purposes of this simulation that these individuals are in fact oral contraceptors. Thus, we collapse all contraceptive methods other than condoms and sterilization into the "oral-contraception" category.[57] For our pill-use regressions, we therefore assume that a female NSFG respondent is an oral contraceptor if she: a) is not sterilized, b) does not list condoms as her only method of contraception, c) does not list her partner's sterilization as her only method of contraception, and d) states that she used some form of birth control at her last sexual encounter. We regress the probability of pill use on respondents' demographic characteristics, sexual-proclivity types, and – for married women – their spouses' sterilization statuses. Separate models are estimated for married and unmarried women. See Table A6 for a complete set of results from these regressions.

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[57] See Centers for Disease Control (2009) for a full inventory of the different contraceptive methods that NSFG respondents were allowed to list. About a third of individuals whom we code as "pill users" actually reported having used a method other than the pill. This group represents about ten percent of contraceptors overall.

The coefficients presented in the table are used to calculate pill-use probabilities for all non-sterilized female members of FamilyScape's simulation population. For each such individual, a random draw is taken from a uniform (0,1) distribution at the outset of the simulation, and the value of that draw is compared with her pill-use probability. If the value is below the woman's threshold, then she is assigned to the use of oral contraception for the duration of the simulation. If the value exceeds her probability, then she is considered to be a non-contraceptor for the duration of the simulation.

Condoms

We also use regression coefficients to assign non-sterilized men in the simulation population to one of three condom-use categories: consistent condom users (i.e., men who use condoms whenever they have sex), pill-conditioned condom users (i.e., men who use condoms only if their current sexual partner is not on the pill), and non-condom users (i.e., men who never use condoms, regardless of whether their current partner is on the pill). As was the case with our simulations of sterilization and pill use, we rely here on a series of contraceptive-use variables in the NSFG indicating what method(s, if any) respondents used the last time that they had sex. If a respondent reports that he used a condom and that his partner used oral contraception at his last sexual encounter, he is considered to be a consistent condom user.[58] Similarly, if a respondent reports that, the last time he had sex, he did not use a condom and his partner did not use oral contraception, he is considered to be a non-condom user. However, if a respondent reports that he used a condom and that his partner did not use the pill, it is not obvious whether he is a consistent or a pill-conditioned condom user; similarly, if he reports that he did not use a condom

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[58] We continue to make the simplifying assumption that all contraceptive methods other than condoms and sterilization are equivalent to oral contraception. Thus, if a respondent indicates that, at last sex, he used a condom and his partner used, say, an IUD, he is considered for our purposes to be a consistent condom user (which is to say that he is assigned to a condom-use category as though his partner had used oral contraception).

but that his partner used the pill, it is not obvious whether he is a pill-conditioned condom user or a non-condom user. Table A5 summarizes these scenarios.

Table A5: Condom-Use Types

	Did male respondent use a condom at last intercourse?	
Did partner use the pill at last intercourse?	*Yes*	*No*
Yes	Consistent Condom User	Non-Condom User *or* Pill-Conditioned Condom User
No	Pill-Conditioned Condom User *or* Consistent Condom User	Non-Condom User

More information is required if we are to assign men in the upper-right-hand and lower-left-hand boxes to the appropriate condom-use category. In addition to the "method used at last sex" variable, the NSFG also contains a variable indicating the number of times that a respondent reports having used a condom in the last four weeks, which – together with the variable on coital frequency over the same period – can be used to estimate the percentage of recent sexual encounters in which respondents report having used a condom. We use these estimates to assign men in the two ambiguous scenarios described above to a usage category.

Specifically, for men who report that they did not use condoms the last time they had sex but that their partners used oral contraception, we assume that they are non-condom users if they are estimated never to have used condoms, and we assume that they are pill-conditioned condom users if they are estimated to have used condoms at least some of the time. For men who report that they used condoms the last time they had sex and that their partners did not use oral contraception, we assume that they are consistent condom users if they are estimated to have used condoms every time that they had sex, and we assume that they are pill-conditioned condom users if they are estimated to have used condoms only some of the time.[59]

Having assigned NSFG respondents to condom-use groups, we regress the probability of their falling into each of these three categories on their demographic characteristics, their sexual-proclivity types, and – for married men – their wives' sterilization statuses. Separate models are estimated for married and unmarried men. See Table A6 for a complete set of condom-use regression results. We use the coefficients from these regressions to impute probabilities for the members of the simulation population of falling into each of the three condom-use groups. For each individual in the simulation, we then take a random draw from a uniform (0,1) distribution at t=0 and compare the results of that draw to his condom-use probabilities in order to assign him to one of the three categories.[60] Individuals retain their contraceptive-use types for the duration of the simulation.

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[59] About 53 percent of the 3,272 non-sterilized men in our NSFG sample fell into one of the two "ambiguous" categories described above. Our calculations indicate that roughly ninety percent of the members of this group either used condoms every time they had sex or never used condoms. These men were categorized as consistent condom users and non-condom users, respectively. The remaining share of individuals are estimated to have used condoms during some, but not all, of their sexual encounters. These men were coded as pill-conditioned condom users.

[60] Because our condom-use categories are exhaustive and mutually exclusive, only two sets of regression coefficients are required to estimate an individual's relative chances of falling into each of these three groups. Thus, we actually only incorporate the "consistent use" and "pill-conditioned use" regression results into the simulation model. Assume, then, that an individual in the simulation were calculated to have a "consistent-use" probability of .5 and a "pill-conditioned-use" probability of .1. A random draw between 0 and .5 would result in his being placed into the "consistent-use" category, a draw between .5 and (.5 + .1) = .6 would result in his being placed into the "pill-conditioned use" category, and a draw between .6 and 1 would result in his being placed into the "non-use" category.

Table A6: Pill-Use and Condom-Use Regression Results

	Pill Use		Non-Condom Use		Pill-Conditioned Condom Use		Consistent Condom Use	
	Unmarried Women	Married Women	Unmarried Men	Married Men	Unmarried Men	Married Men	Unmarried Men	Married Men
	Coefficient *t-value*	Coefficient *t-value*	Coefficient *t-value*	Coefficient *t-value*	Coefficient *t-value*	Coefficient *t-value*	Coefficient *t-value*	Coefficient *t-value*
Age Dummy: 20-24	-0.025	-0.067	0.158	0.240	0.102	0.085	-0.260	-0.324
	-0.65	*-0.56*	*4.05****	*1.33*	*3.62****	*2.71****	*-6.43****	*-1.78**
Age Dummy: 25-29	-0.015	-0.005	0.308	0.278	0.132	0.045	-0.440	-0.323
	-0.37	*-0.04*	*5.70****	*1.58*	*3.48****	*2.29***	*-9.46****	*-1.82**
Age Dummy: 30-44	-0.131	-0.033	0.410	0.316	0.082	0.048	-0.492	-0.364
	*-3.23****	*-0.28*	*10.59****	*1.82**	*3.18****	*3.59****	*-12.99****	*-2.06***
Education Dummy: High School Degree	0.012	-0.009	0.017	-0.025	0.026	-0.009	-0.043	0.034
	0.32	*-0.18*	*0.46*	*-0.77*	*0.93*	*-0.51*	*-1.25*	*1.23*
Education Dummy: More than High School	0.185	-0.016	-0.098	-0.068	0.000	0.026	0.097	0.043
	*4.85****	*-0.34*	*-2.45***	*-1.97***	*0.01*	*1.37*	*2.53***	*1.38*
Race Dummy: Black	-0.136	-0.094	-0.131	-0.085	-0.036	0.036	0.166	0.048
	*-4.23****	*-2.35***	*-3.86****	*-2.19***	*-1.72**	*1.58*	*5.13****	*1.45*
Race Dummy: Hispanic	-0.129	0.005	-0.002	-0.068	0.025	0.030	-0.023	0.038
	*-3.68****	*0.15*	*-0.04*	*-2.00***	*0.95*	*1.69**	*-0.7*	*1.27*
Race Dummy: Other	-0.202	-0.090	-0.044	-0.158	0.122	0.032	-0.078	0.126
	*-3.22****	*-1.78**	*-0.45*	*-2.21***	*1.64*	*0.80*	*-1.35*	*1.91**
SES Dummy	0.017	0.039	-0.051	0.013	0.016	-0.005	0.035	-0.009
	0.48	*1.16*	*-1.34*	*0.44*	*0.64*	*-0.33*	*1.06*	*-0.31*
Moderate Sexual Proclivity Dummy	0.144	0.089	0.184	0.026	-0.224	-0.003	0.041	-0.023
	*4.94****	*3.18****	*5.95****	*0.96*	*-7.86****	*-0.23*	*1.51*	*-0.93*
High Sexual Proclivity Dummy	0.157	0.057	0.400	0.051	-0.172	-0.001	-0.229	-0.050
	*3.15****	*1.21*	*5.92****	*0.97*	*-3.35****	*-0.03*	*-4.87****	*-1.25*
Partner's Sterility Dummy	--	-0.473	--	0.163	--	-0.041	--	-0.122
		*-19.42****		*7.48****		*-3.96****		*-6.23****
Constant	0.416	0.460	0.172	0.540	0.180	-0.008	0.648	0.467
	*8.53****	*3.67****	*3.60****	*3.07****	*4.9****	*-0.42*	*14.44****	*2.62****
P-Value for Joint Test of Age Covariates	0.019	0.506	0.000	0.146	0.000	0.000	0.000	0.128
P-Value for Joint Test of Education Covariates	0.000	0.942	0.024	0.127	0.391	0.023	0.000	0.327
P-Value for Joint Test of Race Covariates	0.000	0.032	0.001	0.013	0.018	0.182	0.000	0.109
N (unweighted)	2,327	2,311	2,118	1,113	2,118	1,113	2,118	1,113

Notes: All parameters were estimated using the male and female respondent files from Cycle 6 of the National Survey of Family Growth (NSFG). The excluded age, education, and race categories are as follows: age group 15-19, an educational attainment of less than a high school degree, and the white race category. The SES dummy is set equal to one if the respondent's mother had an educational attainment equal to or greater than a high school degree and zero otherwise. Unmarried respondents are coded as having a moderate sexual proclivity if they report having had sexual intercourse between one and nineteen times in the four weeks prior to their interview and as having a high sexual proclivity if they report having had sex more than nineteen times during that period. The equivalent thresholds for married respondents are five and eighteen times. While results for all three condom-use analyses are presented here, only two sets of results are necessary to assign condom-use status in the simulation model, since the three usage categories are exhaustive and mutually exclusive. We therefore incorporate only the results for the medium- and high-condom-use regressions into the model. One asterisk (*) indicates that the parameter estimate is significant at or beyond the .1 level, two asterisks (**) indicate that the parameter estimate is significant at or beyond the .05 level, and three asterisks (***) indicate that the parameter estimate is significant at or beyond the .01 level.

As can be seen in Table A7, the patterns of contraceptive use among individuals in FamilyScape closely match the corresponding patterns in the real world.

Table A7: Distribution of Real-World and Simulated Contraceptive Use, by Gender and Marital Status

Men

	Unmarried		Married		All	
	Real World	Simulation	Real World	Simulation	Real World	Simulation
Sterilized (%)	5.2	5.6	16.0	13.7	11.0	9.2
Consistent Condom User (%)	38.8	41.4	9.9	9.9	23.1	27.6
Pill-Conditioned Condom User (%)	12.9	15.8	4.4	4.3	8.3	10.8
Non-Contraceptor (%)	43.1	37.1	69.7	72.1	57.6	52.5

Women

	Unmarried		Married		All	
	Real World	Simulation	Real World	Simulation	Real World	Simulation
Sterilized (%)	17.8	15.8	26.1	28.0	22.7	21.0
Oral Contraceptor (%)	43.9	41.8	30.0	30.5	35.7	37.0
Non-Contraceptor (%)	38.3	42.4	43.9	41.5	41.6	42.0

Note: A consistent condom user always uses a condom, and a pill-conditioned condom user only uses a condom if his partner is not a pill user. A woman is considered to be an oral contraceptor (i.e., a pill user) if she uses a form of birth control other than sterilization or condoms alone. See the text of this appendix for a more detailed explanation of the definition of the process by which individuals in the simulation are assigned to the use of a specific method of contraception. Real-world results were produced using the male and female respondent files from Cycle 6 of the National Survey of Family Growth (NSFG). Simulation results were generated using data from fifty ten-year runs of the FamilyScape model.

Consistency of Contraceptive Use

We assign members of the simulation population to a contraceptive regime using NSFG data on the method(s, if any) that respondents used at their last sexual encounter. Since individuals' contraceptive-use types are fixed over the course of the simulation, we are implicitly assuming: 1) that NSFG respondents rely on the method(s) of contraception that they used at their last sexual encounter every time that they have sex, and 2) that respondents who did not use contraception at last intercourse will never use contraception. These assumptions are almost certainly at least somewhat incorrect.[61] The NSFG also contains data on respondents' longer-term patterns of contraceptive behavior, and we are considering

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[61] In their canvass of the literature on the consistency of contraceptive use, Thomas and Roessel (2008) review findings suggesting that about half of oral contraceptors miss at least one pill per month, that about a quarter of them miss at least two pills per month, and that oral contraceptors as a whole miss an average of about one and a half pills per month. While findings from studies of condom use are less reliable, the authors cite results indicating that condoms are at least sometimes used incorrectly and/or are used inconsistently by the majority of users.

the possibility of incorporating these data into the model in order to simulate the inconsistent use of contraception.

The implementation of this change would boost the number of people who use contraception at least intermittently over the course of the simulation. It is possible that, if we were to make this change to the model, the resulting increase in the number of contraceptors and the resulting decrease in the consistency of contraceptive use would effectively cancel each other out in the aggregate. However, it is difficult to know with certainty whether or not this would be the case. Moreover, adding an inconsistent-use module would allow us to conduct more realistic simulations of the effects of inducing inconsistent users of a given method to switch to longer-acting forms of contraception.

APPENDIX IV: PREGNANCY & PREGNANCY OUTCOMES

This appendix is divided into three sections. In the first section, we detail our methods for estimating female fecundity and contraceptive effectiveness, which jointly determine the probability of pregnancy among sexually-active couples. In the second section, we describe FamilyScape's procedures for determining whether each new pregnancy results in a live birth, an abortion, or a fetal loss. And in the final section, we discuss the means by which the model's gestation-period module is parameterized.

Pregnancy

Each time that a couple has sex during the simulation, there is some probability that they will become pregnant. The occurrence of pregnancy is simulated by taking a random draw from a uniform (0,1) distribution whenever a couple has sex and comparing the value of that draw to the woman's probability of conceiving from a single act of intercourse. If the value of the draw is less than the woman's conception probability, then she becomes pregnant. A woman's conception probability is determined by two factors: 1) her level of fecundity (i.e., her physiological capacity to become pregnant), and 2) the effectiveness of the contraceptive method(s, if any) that she and her partner are using. A small number of studies have generated data capable of producing estimates of the probability of conceiving from a single act of unprotected sex.[62] Most of these studies allow their conception-probability estimates to vary as a function of the day in a woman's menstrual cycle on which she has sex, but Royston's (1982) model has the added benefit of also allowing for variation in the probability

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[62] See, for example, Barrett and Marshall (1969), Dixon et al. (1980), Royston (1982), and Wilcox et al. (1995). A common finding in this literature is that the probability of pregnancy is zero, or close to zero, for all days in the menstrual cycle outside of a roughly seven-day period that encompasses five or six days leading up to – and one or two days subsequent to – the point of ovulation. These studies consistently find that the probability of conceiving from a single act of intercourse on a randomly-selected day in the menstrual cycle is between three and five percent.

of conception as a function of the woman's age. We therefore simulate female fecundity using Royston's results. He estimates the following model:

$$\mathrm{p(conception)}_{i,t} = \{\varkappa_0 - \varkappa_1(\mathrm{A}_i - \overline{\mathrm{A}})\}\alpha_t,$$

where $\mathrm{p(conception)}_{i,t}$ is the probability that individual *i* will conceive if she has unprotected sex on day *t*, A_i is the age of individual *i*, $\overline{\mathrm{A}}$ is the mean age of all of the women in the sample, $\varkappa_0$ and $\varkappa_1$ are econometrically-estimated parameters, and α_t is a vector of generic probabilities of ovular fertilization that vary by the day in the menstrual cycle.[63] The results of Royston's analysis imply that the (unweighted) average probability of conception across years of age on a randomly-selected day in the menstrual cycle is about 4.5 percent.

At t=0, every woman in the simulation population is randomly assigned to one of the 28 days in the normal menstrual cycle, and their menstrual calendars are updated daily as the simulation proceeds. The model assumes that all women will have regular 28-day cycles, and that they will always ovulate on the 14th day of their cycles. Each time a couple has sex, Royston's estimates are used to calculate an initial conception probability as a function of the woman's age and the day in her cycle. We then calculate a final probability of conception by taking the product of this initial probability and the "failure rate" of the contraceptive method(s, if any) that the couple is using.

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[63] Specifically, $a_{f,t}$ is modeled using the following functional form: $\alpha_{f,t} = \exp\{-(t_{ov} - t)/\lambda_s\}$ for all $t < t_{ov}$; $\alpha_{f,t} = 1$ for $t = t_{ov}$; and $\alpha_{f,t} = \exp\{-(t - t_{ov})/\lambda_e\}$ for all $t > t_{ov}$, where *t* is an index for the day in the menstrual cycle, t_{ov} is the day of ovulation, λ_e is the average life of the egg in days, and λ_s is the average life of the sperm in days. The author estimates the value of λ_s to be 1.47, and he estimates the value of λ_e to be .7. The mean age of the participants in the author's sample was 32, and he estimates the values of $\varkappa_0$ and $\varkappa_1$ to be .48 and .022, respectively.

The effectiveness of a given method is difficult to measure accurately because practical and ethical concerns preclude researchers from pursuing the sorts of randomized controlled trials that would allow them to identify a causal relationship between the use of that method and the risk of pregnancy. There are, however, several studies that simply measure the incidence of pregnancy among users of a particular method. Some studies estimate pregnancy rates using survey data, while others use data generated by clinical trials. We perform back-of-the-envelope calculations of contraceptive effectiveness using data from various clinical trials.

Virtually all contraceptive methods are more efficacious if they are used perfectly (i.e., if they are used correctly and are used every time that an individual has sex) than if they are used imperfectly (i.e., if they are used incorrectly and/or inconsistently). Because FamilyScape does not explicitly account for inconsistent or incorrect contraceptive use, we impose an implicit assumption that some of the contraceptors in the model will use their methods more imperfectly than others. For the purposes of our simulation, we therefore estimate rates of contraceptive effectiveness that are roughly averaged across data on perfect and imperfect users. Although our estimates are calculated using data from clinical trials, they are reasonably consistent with an equivalent set of published results that were calculated using survey data.

In order to make rough calculations of contraceptive effectiveness using clinical-trial results, one must compare the pregnancy rate that is observed among individuals who use a particular method with a plausible estimate of the counterfactual rate of pregnancy that would have obtained had those same individuals not been using contraception. With respect to the first of these two quantities: among typical condom users, estimates of pregnancy rates over a period of six menstrual cycles range from about three percent to about eleven percent; among all oral contraceptors, the estimated one-year pregnancy rate is generally between about two and three percent; and, among sterilized individuals, the rate of pregnancy over several years is typically found to be less than one percent.[64]

Published estimates and our own analysis of survey data both suggest that unmarried adults have sex between about 60 and 70 times per year on average, and studies of female fecundity consistently find that the mean probability of pregnancy from a single act of intercourse on an average day in the menstrual cycle is between three percent and five percent.[65] If one were to assume: a) that the participants in the contraceptive trials described above engaged in sex with a similar frequency – say, 65 times per year; and b) that their probability of pregnancy from a typical act of unprotected intercourse was, say, 0.045 (which is roughly consistent with Royston's results); then their average annual rate of pregnancy without the use of contraception would have been expected to be $[1 - (1 - .045)^{65}] \approx .95$.

The observed annual rate of pregnancy among all users of oral contraception in the findings cited above was two to three percent. We therefore estimate an effectiveness rate for the pill of $[1 - (.025/.95)] \approx .97$. For condoms, the midpoint of the six-cycle typical-use pregnancy rates cited above is roughly seven percent. Thus, one might infer that a full-year pregnancy

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[64] See Thomas and Roessel (2008) for an extensive review of this literature. In the nomenclature of population studies, "typical condom use" encompasses both perfect use and imperfect use. Some studies separately report typical-use and perfect-use pregnancy rates among condom users. However, for the reasons discussed above, typical-use rates are better-suited to our needs. Pregnancy rates are often expressed as the number of pregnancies that occur per 1,000 women in the population at large. However, for the purposes of the discussion in this section, we follow the standard practice within the contraceptive-efficacy literature of defining pregnancy rates as percentages.

[65] On the probability of conceiving from a single act of intercourse, see the studies listed in footnote 60. On the annual rate of coital frequency, see the estimates cited in Laumann et al. (1994). These coital-frequency estimates are based on the authors' analysis of data from the 1992 National Health and Social Life Survey, and they are broadly consistent with the results of our analysis of the 2002 GSS and of the 2002 NSFG.

rate among typical users would be about twice this amount, or 14 percent.[66] Under such an assumption, the implied effectiveness rate for condoms would be [1 - (.14/.95)] ≈ .85. And finally, for purposes of simplicity, we assume that sterilization is 100 percent effective.

One can use this information to estimate "failure rates" for every possible regime of contraceptive use in the model. These rates reflect the number of pregnancies that occur when a particular method is used as a proportion of the number of pregnancies that *would have occurred* absent the use of that method:[67]

- If a couple is using only condoms, the failure rate of their contraceptive regime is assumed to be 1 – .85 = .15.
- If a couple is using only the pill, the failure rate of their contraceptive regime is assumed to be 1 – .97 = .03.
- If a couple is using both condoms and the pill, the failure rate of their contraceptive regime is assumed to be [(1 – .97)* (1 – .85)] = .0045.[68]
- If either member of a couple is sterilized, the failure rate of their contraceptive regime is assumed to be zero.

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[66] As is discussed in Thomas and Roessel (2008), the most reliable clinical studies of the male condom report six-cycle – rather than annual – rates of pregnancy. In fact, the annual pregnancy rate among the participants in a given clinical trial could be somewhat less than twice the six-cycle rate, since some individuals – namely, those who are relatively more fecund, who have higher rates of coital frequency, and/or who are relatively less conscientious about taking contraception – are relatively more likely to become pregnant during the early stages of the study. To the extent that this is true, one would expect pregnancy rates among a study's pool of participants to decline steadily over time. However: a) we believe that this phenomenon is unlikely to be so pronounced as to have a strong effect on the proportional difference between a sample's cumulative short-term and medium-term pregnancy rates; and b) six menstrual cycles actually constitute slightly less than half of a year. We therefore make the simplifying assumption that the twelve-month rate will, in fact, simply be equal to twice the six-cycle rate.

[67] This definition of "contraceptive failure" is somewhat different than the one that is generally implied when the term is used within the demography and public-health literatures. Researchers in those fields often use the term to refer simply to the rate of pregnancy that obtains among the users of a particular method over a specified period of time. We find our definition both to be somewhat more intuitive and to be better-suited to our purposes.

[68] Trussell et al. (1990) argue that the efficacies of independently-operating methods of contraception interact multiplicatively.

These estimates are within a few percentage points of the failure rates calculated by Kost et al. (2008), who use data on contraceptive use and pregnancy rates from the NSFG rather than relying on information from clinical trials.[69]

In order to calculate a woman's final probability of conception after a given act of intercourse, we multiply her initial conception probability by the failure rate of the contraceptive method(s) that she and her partner are using. So, for example, our fecundity equation suggests that, if a 25-year-old woman has sex on the 10th day of her menstrual cycle, she has an initial conception probability of .0417. If she is an oral contraceptor, and if her partner does not use a condom, her probability of conceiving as a result of having sex on this particular day would be estimated to be $.0417*.03 \approx .00125$. Each time that a couple has sex, a random draw is taken from a uniform (0,1) distribution, and the value of that draw is compared with the woman's final conception probability for the day in question. If this value is less than this probability, then she will become pregnant – which is to say, in the case of the example described above, that she would become pregnant if the value of the random draw were less than .00125.

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[69] The authors estimate annual pregnancy rates among condom and pill users of .17 and .09, respectively. If one were to assume (as we do for the purposes of our calculations above) that individuals would be slightly less than 100 percent likely to become pregnant over the course of a year without using contraception, then the estimated "failure rates" for these methods would be negligibly higher than the pregnancy rates reported here. Our extensive explorations of FamilyScape's parameter space suggest that the differences between our contraceptive-failure estimates and those implied by Kost and her coauthors are not large enough in magnitude to have a meaningful impact on our simulation results.

Pregnancy Outcomes

In order to assign an outcome for a given simulated pregnancy, we must first specify a set of parameters reflecting the relative probabilities that the pregnancy will result in a birth, and abortion, or a fetal loss. These probabilities should, ideally, vary as a function of the pregnant woman's demographic characteristics. However, due to extensive data limitations, the specification of these probabilities in a logistically-feasible manner within our simulation proved to be challenging. The limitations of the pregnancy-outcomes data are severalfold:

- First, no single dataset contains all of the information needed to estimate the incidence of pregnancy. In fact, the most reliable data on births, abortions, and fetal losses all come from different sources. Thus, pregnancy rates are typically calculated by aggregating information from three or four different datasets.
- Second, these data are not all disaggregated in the same way. For example, one can produce estimates that are simultaneously disaggregated by race and marital status for births and fetal losses, but not for abortions.
- Third – and perhaps most vexingly, from our perspective – because pregnancy-outcome data come from several different sources and are usually available only at the aggregate level, there is no single, individual-level dataset that can readily be used to estimate regression models of the probability that a pregnancy will result in a given outcome as a function of individuals' demographic characteristics.

We would place special emphasis on the third of these items. We simulate demographic variation in the rest of FamilyScape's behaviors and outcomes using the results of regression analyses, rather than explicitly defining separate probabilities for each cell in the joint age-race-education-SES-marital-status distribution. This approach has enormous benefits in terms of reduced requirements for programming time, computing power, model parameterization, etc.[70] As we developed this module, we therefore placed a high priority on the goal of ensuring that it could be parameterized using regression results rather than explicit probabilities.

More specifically, our goal was to be able to perform three different regressions, each of them estimated at the individual level and containing as many of our standard demographic covariates as possible: one modeling the probability that a pregnancy will result in a live birth, a second modeling the probability that a pregnancy will result in an abortion, and a third modeling the probability that a pregnancy will result in a fetal loss. Our solution is as follows:

- **Step #1:** We collect demographically-specific data on the incidence of all three pregnancy outcomes.
- **Step #2:** We combine these data in order to estimate demographically-specific probabilities that a pregnancy will result in each outcome.

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[70] As is described in Appendix I, FamilyScape's demographic covariates are defined such that there are four different race categories, four age categories, three education categories, two SES categories, and two marital-status categories. If we were required to specify separate, demographically-specific probabilities to simulate each behavior and outcome that is included in the simulation, we would have to estimate 4*4*3*2*2 = 192 separate parameters for each one. We rely instead on regression results, and – as is also discussed in Appendix I – we are able to avoid the use of interaction terms in our estimation of these regressions. Because we typically estimate separate regression models by demographic status, we parameterize most demographically-specific dimensions of the simulation using 2*(4+4+3+2) = 26 separate parameters. Thus, the use of regression models rather than demographically-specific probabilities reduces by a factor of more than seven the number of estimated values that are needed to parameterize the model. This is, in practical terms, an important consideration for any number of reasons. For example, we have implemented a rigorous "unit-testing" quality-control procedure in order to ensure that all of the parameters in the model function as expected. Substantially increasing the number of parameters included in the model would, in turn, proportionally increase the number of unit tests that are required to vet the model fully. While this is not necessarily a prohibitive concern, it serves as a useful example of the kinds of concerns that must be taken into account when assessing the wisdom of increasing the parametric complexity of the model.

- **Step #3:** We create three new variables within the 2002 pregnancy file of the NSFG: one reflecting the share of pregnancies that result in live births, another reflecting the share of pregnancies that result in abortions, and a third reflecting the share of pregnancies that result in fetal losses.[71] The values of these three variables differ depending upon observations' demographic characteristics. For example, our estimates suggest that 57.5 percent of pregnancies among unmarried white teenaged girls result in live births. Thus, all observations in the NSFG who have this demographic profile are assigned a value of .575 for the newly-created "live-birth-probability" variable.
- **Step #4:** We conduct regressions for which the dependent variables are these pregnancy-outcome probabilities. Separate regressions are estimated by marital status, and – due to data limitations that are detailed below – each of them controls for age and race, but not for education and SES.

We present evidence below demonstrating that the predicted values from these regressions are almost always very similar to the equivalent demographically-specific pregnancy-outcome proportions that are observed in real-world data. The coefficients from these regressions are imported into the model and are used to impute pregnancy-outcome probabilities for each simulated pregnancy. These probabilities are then used in turn to assign an outcome for each simulated pregnancy. This process allows us to simulate realistic demographic variation in pregnancy outcomes in a way that is logistically feasible within the constraints of the simulation-modeling process. The next three subsections detail our procedures for

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[71] The NSFG's pregnancy file is distinct from its adult male and female files. Its level of observation is – as the name would suggest – the pregnancy, and it contains information on up to 19 pregnancies for each female respondent. Thus, there is a record in the file corresponding to each pregnancy that occurred to a female member of the NSFG's 2002 sample, although most of those pregnancies ended before calendar year 2002.

collecting demographically-specific pregnancy-outcome data, as per the first step of the process described above. The subsequent three subsections then discuss the means by which steps two through four of this process were carried out.

Step #1a: Collection of Data on the Incidence of Live Births

The most reliable and comprehensive source of information on the national number of births in a given year is the National Vital Statistics System (NVSS), which is maintained by the National Center for Health Statistics (NCHS). The NCHS website allows users to generate tabulations of NVSS birth data that are simultaneously broken down by a variety of different demographic characteristics. We use this tool to produce estimates of the number of births that occurred in 2002. We are able to disaggregate these estimates by all of FamilyScape's demographic covariates except SES.[72] Because we are also unable to disaggregate our abortion and fetal-loss estimates by SES, this covariate was eliminated from the pregnancy-outcomes analysis.

Step #1b: Collection of Data on the Incidence of Induced Abortion

There are two major sources of data on induced abortions in the United States: the Alan Guttmacher Institute's Abortion Provider Survey (APS) and the Centers for Disease Control and Prevention's (CDC) Abortion Surveillance System.[73] The CDC has collected data on the incidence of abortion every year since 1969, and the Guttmacher Institute has done the same on a quadrennial basis since 1974. While the CDC relies on the voluntary reporting of

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[72] See National Center for Health Statistics (2009) for additional information about the online tool that was used to generate these estimates.

[73] The term "induced abortion" implies a distinction between pregnancy terminations that are intentional and those that occur spontaneously (i.e., naturally). The latter category is considered to reflect a type of fetal loss. The discussion in this subsection is specific to abortions that fall into the former category.

data from state health departments, the Guttmacher Institute directly surveys all known abortion providers.[74] As such, the APS tends to produce higher abortions counts than does the CDC survey and is generally considered to be the more reliable of the two data sources in this regard.[75] We therefore use data from the Guttmacher Institute rather than the CDC to measure the overall incidence of abortion.

However, the CDC collects detailed demographic data on abortion patients more often than does the Guttmacher Institute. Indeed, Guttmacher sometimes applies the demographic distribution of the CDC's sample to its own raw counts of abortions in order to produce demographically-specific estimates of the incidence of abortion.[76] Thus, we rely on tabulations of CDC data in order to measure the demographic characteristics of women who have abortions.[77] In other words, we produce demographically-specific tabulations of the incidence of abortion by taking the products of a set of distributional percentages that are estimated using CDC data (e.g., the percent of abortions that are to black women, to white women, to Hispanic women, etc.) and an overall count of abortions that is generated using AGI data.

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[74] Henshaw and Kost (2008). The APS collects information on the total number of abortions performed in the year of the survey and interpolates data for years in which the survey was not conducted. See Finer and Henshaw (2003) and Jones et al. (2008) for additional detail on the APS's survey procedures. The Guttmacher Institute has performed underreporting surveys in order to determine the extent to which the APS may underestimate the incidence of abortion. They have found: 1) that their sample may exclude as many as half of the providers who perform fewer than 30 abortions per year; and 2) that the actual annual number of abortions may therefore be three to four percent higher than is implied by the provider survey (Finer and Henshaw, 2003).

[75] The Guttmacher Institute (1997), Saul (1998).

[76] See Henshaw and Kost (2008) for a description of the means by which these two data sources are combined to produce demographically-disaggregated abortion estimates.

[77] The Guttmacher Institute also collects demographically-specific data on abortion patients, but they do so much less frequently than does the CDC. Since the CDC collected such information for 2002 and AGI did not, we use the former's data to measure demographic variation in the incidence of abortion.

Neither of these datasets is available for public use. We are therefore constrained to use published tabulations of them for the purposes of informing our data-collection process.[78] Since we are able to produce birth tabulations that are simultaneously broken down by age, race, education, and marital status, it would be ideal if we were able to obtain abortion estimates that are similarly disaggregated. However, most publicly-available tabulations of the CDC's demographic data are broken down by these characteristics separately but not simultaneously.[79] We have been able to identify a single exception to this rule: Ventura et al. (2008) use 2004 CDC data to cross tabulate the age and race characteristics of women obtaining abortions. The authors do not, however, include educational attainment in this analysis. Thus – and since, as is described in the next subsection, we are also unable to produce reliable fetal-loss tabulations that are appropriately disaggregated by the mother's educational attainment – we eliminate education from our pregnancy-outcomes analysis altogether, and we use Ventura et al.'s cross tabulations to measure the relationship between age, race, and the incidence of abortion.[80]

We are unaware of any publicly-available estimates that disaggregate the incidence of abortion simultaneously by age, and race, and marital status. However, Henshaw and Kost (2008) use 2004 CDC data to produce tabulations of the overall percent of abortions that are to married and unmarried women. Specifically, the authors find that about 14 percent of

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[78] The NSFG also contains self-reported abortion data. However, abortions have found to be dramatically underreported in the survey (Jones and Kost, 2007). Thus, we do not consider the NSFG to be a plausible alternative for estimating the incidence of abortion.

[79] See, for example, Henshaw and Kost (2008).

[80] See Ventura et al. (2008), Table 3. The categorizations of age and race in this report are identical to our own specifications of these variables, with one exception: the oldest age category in FamilyScape contains women who are between the ages of 30 and 44, while the equivalent category in Ventura et al. (2008) includes all women who are above the age of 30. However, since we use this estimate specifically to measure the proportion of abortions that are to older women – and because abortions (and pregnancies more generally) are quite rare among women who are over the age of 44 – this difference is of little importance for our purposes.

abortions are to married women and that 86 percent are to unmarried women. Since rates of marital and non-marital pregnancy are of central interest for our simulation, we apply these marginal percentages to Ventura et al.'s age-race cross tabulation in order to generate a distribution of abortions that is simultaneously disaggregated by these three characteristics. We are forced to assume, then, that the age-race distribution of abortion does not differ by marital status. Although we would prefer not to have to impose this admittedly-heroic assumption, we are compelled to do so by the limited data that are available to us.

Having estimated the percent of abortions that are to women of various ages, races, and marital statuses, we multiply these proportions by the total number of abortions that are estimated to have occurred in 2002 (126.9 million) in order to produce demographically-specific estimates of the incidence of abortion in that year.[81]

Step #1c: Collection of Data on the Incidence of Fetal Loss

The NVSS and the NSFG are the two most commonly-used sources of data on fetal losses. However, the NVSS generally only records information on the small share of fetal losses that occur at gestations of 20 weeks or more, whereas the NSFG contains data on fetal losses at all gestation periods.[82] Ventura et al. (2008) note that even fetal losses occurring at 20 weeks and beyond are underreported in the NVSS. Thus, we use the NSFG rather than the NVSS to estimate the incidence of fetal loss.

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[81] The estimate of the total number of abortions in 2002 was reported in Jones et al. (2008) and was produced by the Guttmacher Institute, which conducted Abortion Provider Surveys in 1999-2001 and in 2004-2005. Thus, the 2002 estimate is an interpolation. The age-race cross tabulation from Ventura et al. (2008) and the distribution of abortions by marital status from Henshaw and Kost (2008) were both for 2004. Thus, by applying these distributions to the abortion tally for 2002, we are implicitly assuming that the age-race-marital status distribution of abortions remained unchanged between 2002 and 2004.

[82] Ventura et al. (2008).

There are two possible ways in which we might use the NSFG to measure fetal loss. The first would entail our conducting independent analyses of the 2002 dataset in order to produce demographically-specific estimates of the frequency with which women with different characteristics experience a fetal loss. After having conducted an extensive series of analyses, we concluded that this option was impractical because: 1) the number of pregnancies occurring to NSFG respondents in a single year is relatively small; 2) less than a fifth of pregnancies result in a fetal loss; and 3) our simulation accounts for a number of different demographic characteristics. As a result, we were often compelled to estimate the incidence of fetal loss using data on an extremely small number of cases. Our estimates for many demographic subgroups were therefore either implausibly large or implausibly small and/or were highly inconsistent with the results of published analyses.[83] As a result, we opted not to pursue this option.

The second option was to rely on a set of estimates from Ventura et al. (2008) that were produced using many years' worth of NSFG data. Because they used data from several different survey years, Ventura and her coauthors were able to mitigate the cell-size problems that we encountered in our analysis of the 2002 sample. The authors estimate the incidence of fetal loss by calculating the ratio of fetal losses to live births in the NSFG and then applying this ratio to the count of births in the NVSS. Underlying this approach is an assumption that the NSFG produces the correct fetal-loss-to-live-birth ratio, but that it does not capture the full number of pregnancies that occur in a given year. Since the NVSS is

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[83] We explored a variety of different potential solutions for this problem. For example, we considered the possibility of eliminating one or more of our demographic covariates from the analysis (indeed, we automatically eliminated SES, since we were unable to produce live-birth or abortion estimates that were disaggregated by this characteristic). We also attempted to collapse the categories of one or more of our covariates. Even after having done so, however, we were still confronted with the problem of having to produce estimates based on very small sample sizes, and our estimates therefore remained implausible in many cases.

widely accepted to be the most reliable source of data for live births, this approach is presumed to produce a more accurate estimate than would a simple tally of fetal losses in the NSFG.

Ventura et al.'s fetal-loss and live-birth estimates are disaggregated by age and race simultaneously.[84] Since their results are not broken down by education – and given the fact that we also encountered problems in our attempts to produce abortion estimates that are broken down by education – we elected to eliminate this covariate from our pregnancy-outcomes analysis altogether.[85] Ventura and her coauthors also neglect to account for marital status in their age-race disaggregations. We therefore make the simplifying assumption that fetal-loss-to-live-birth ratios do not vary by marital status within age-race groups. In other words, we transform Ventura et al.'s joint age-race distribution into a joint age-race-marital-status distribution by assuming that groups of married and unmarried women who have the same age-race characteristics will also have identical fetal-loss ratios. In light of the results presented in Table A8, this would seem to be a reasonable assumption. The table shows estimates reported by Ventura et al. of fetal-loss ratios that are disaggregated simultaneously by marital status and race.[86] These results suggest that there is little difference between the race-specific ratios of married and unmarried women.[87]

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[84] See Ventura et al. (2008), Table 3.

[85] This decision was bolstered by the results of our own analyses of the 2002 NSFG as described in a previous footnote. In our attempts to determine which covariates could most sensibly be removed from the analysis, we estimated a multitude of different regression models of the probability that a pregnancy would result in a fetal loss. We found that – especially for unmarried couples – the removal of education from these regressions usually had little, if any, effect on their predictive power.

[86] The authors do not present estimates of fetal-loss ratios that are similarly disaggregated by age and marital status.

[87] More intuitively, there would seem to be little reason to expect that a woman's marital status would affect the likelihood that her pregnancy will result in a fetal loss, since this dynamic is presumably physiological in nature.

Table A8: Variation in Fetal Loss-to-Live-Birth Ratio by Marital Status

	Unmarried Women			**Married Women**		
	Live Birth Rates	Fetal Loss Rates	Fetal Loss-to-Live-Birth Ratio	Live Birth Rates	Fetal Loss Rates	Fetal Loss-to-Live-Birth Ratio
White	43.7	11.2	0.256	88.2	22.5	0.255
Non-Hispanic White	38.9	9.9	0.255	84.4	22.3	0.264
Black	27.8	7.3	0.263	64.9	19.6	0.302
Hispanic	66.2	20.0	0.302	100.1	20.5	0.205
All	87.9	18.0	0.205	86.3	22.1	0.256

Source: Ventura et al. (2008). Rates are per 1,000 women aged 15-44.

We multiply each (demographically-specific) fetal-loss-to-live-birth ratio by the appropriate (demographically-specific) NVSS-based count of live births in 2002 in order to produce estimates of the incidence of fetal loss in 2002 for every age-race-marital status subgroup.[88]

Step #2: Estimation of Pregnancy-Outcome Probabilities

Upon completion of step #1, we have produced estimates of the incidence of childbearing, abortion, and fetal loss for each of our age-race-marital status subgroups. In step #2, we transform these raw counts into demographically-specific pregnancy-outcome probabilities. We accomplish this objective by: 1) summing the numbers of live births, abortions, and fetal losses for each subgroup in order to produce estimates of the incidence of pregnancy; and 2) using these estimates to produce, for each group, the probabilities that a pregnancy will result in each of the three outcomes. The top three panels of Table A9 detail our estimated pregnancy-outcome probabilities by age and race for unmarried women, married women, and all women. The bottom panel of the table shows the equivalent estimates for all women

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[88] The age-race cross tabulation from Ventura et al. (2008) was generated using NSFG data on births and fetal losses that occurred between 1976 and 2002 among teens and between 1991 and 2002 among adults. By applying this distribution to the count of live births from 2002, we are implicitly assuming that the age-race distribution of fetal loss-to-live-birth ratios remained unchanged between these years and 2002. This appears to be a safe assumption: Ventura and her coauthors find that the demographic distribution of these ratios has remained relatively unchanged from the mid-1970s to the present day.

as reported in Ventura et al. (2008). (Recall that Ventura and her coauthors do not present results that are simultaneously disaggregated by age, race, and marital status.) Our estimated pregnancy-outcome probabilities for all women are quite comparable to the equivalent results reported by Ventura et al.

Table A9: Live-Birth, Induced-Abortion, and Fetal-loss Probabilities

Estimates for FamilyScape Model;
Year = 2002

	Live Births					Induced Abortions					Fetal Losses				
						Unmarried Women									
	White	Black	Hispanic	Other	All	White	Black	Hispanic	Other	All	White	Black	Hispanic	Other	All
15-19	0.575	0.519	0.594	0.507	0.560	0.270	0.338	0.241	0.337	0.286	0.155	0.143	0.165	0.156	0.154
20-24	0.555	0.481	0.574	0.422	0.530	0.317	0.397	0.340	0.423	0.355	0.127	0.122	0.086	0.154	0.115
25-29	0.497	0.399	0.541	0.393	0.469	0.394	0.503	0.374	0.526	0.433	0.109	0.098	0.085	0.081	0.097
30-44	0.394	0.329	0.465	0.307	0.387	0.482	0.531	0.410	0.608	0.492	0.124	0.141	0.124	0.085	0.121
All	0.512	0.436	0.549	0.405	0.491	0.352	0.433	0.339	0.486	0.383	0.136	0.132	0.113	0.110	0.126
						Married Women									
	White	Black	Hispanic	Other	All	White	Black	Hispanic	Other	All	White	Black	Hispanic	Other	All
15-19	0.667	0.271	0.684	0.586	0.625	0.153	0.654	0.125	0.234	0.204	0.179	0.075	0.190	0.180	0.172
20-24	0.773	0.545	0.800	0.666	0.751	0.050	0.317	0.080	0.090	0.086	0.177	0.138	0.120	0.244	0.163
25-29	0.805	0.653	0.821	0.800	0.795	0.019	0.187	0.049	0.035	0.040	0.177	0.160	0.129	0.164	0.165
30-44	0.751	0.621	0.758	0.763	0.742	0.014	0.113	0.039	0.026	0.026	0.235	0.266	0.203	0.211	0.232
All	0.771	0.608	0.781	0.751	0.757	0.025	0.208	0.059	0.042	0.048	0.204	0.184	0.160	0.207	0.194
						All									
	White	Black	Hispanic	Other	All	White	Black	Hispanic	Other	All	White	Black	Hispanic	Other	All
15-19	0.595	0.500	0.615	0.522	0.572	0.244	0.363	0.214	0.317	0.271	0.160	0.138	0.171	0.161	0.157
20-24	0.665	0.492	0.665	0.527	0.618	0.182	0.384	0.235	0.280	0.248	0.153	0.124	0.100	0.193	0.134
25-29	0.735	0.476	0.695	0.681	0.676	0.104	0.408	0.196	0.180	0.183	0.161	0.116	0.109	0.140	0.140
30-44	0.698	0.454	0.649	0.667	0.653	0.083	0.351	0.177	0.148	0.143	0.219	0.194	0.173	0.184	0.204
All	0.691	0.479	0.660	0.631	0.640	0.126	0.377	0.205	0.197	0.196	0.183	0.145	0.135	0.171	0.164
						From Ventura et al. (2008); Year = 2004									
	White	Black	Hispanic	Other	All	White	Black	Hispanic	Other	All	White	Black	Hispanic	Other	All
15-19	0.590	0.495	0.621	0.481	0.569	0.252	0.369	0.206	0.370	0.274	0.159	0.136	0.173	0.148	0.156
20-24	0.667	0.491	0.675	0.519	0.621	0.180	0.385	0.224	0.291	0.244	0.153	0.124	0.101	0.190	0.135
25-29	0.738	0.486	0.706	0.676	0.682	0.100	0.395	0.183	0.185	0.176	0.162	0.119	0.111	0.139	0.142
30+	0.699	0.458	0.664	0.673	0.657	0.082	0.346	0.158	0.141	0.138	0.219	0.196	0.177	0.186	0.206
All	0.693	0.481	0.672	0.627	0.644	0.124	0.373	0.191	0.197	0.191	0.183	0.145	0.137	0.175	0.165

Note: Real-world data were taken from Ventura et al. (2008) and from the National Center for Health Statistics' NVSS data resource for fetal losses; from Ventura et al. (2008), Henshaw and Kost (2008), and Jones et al. (2002) for abortions; and from the National Center for Health Statistics' NVSS data source for live births. See the text of this paper for a detailed explanation of the means by which these data were used to produce the estimates reported here.

Step #3: Creation of Pregnancy-Outcome Variables in the NSFG

In step #3, we create new variables in the NSFG's pregnancy file using the pregnancy-outcome probabilities reported in Table A9. We create three new variables, one of them containing demographically-specific information on live-birth probabilities; a second containing information on induced-abortion probabilities; and a third containing information on fetal-loss probabilities. So, for example, all unmarried white NSFG respondents who are between the ages of 15 and 19 are assigned a value of .575 for the "live-birth-probability" variable; all married black respondents who are between the ages of 20 and 24 are assigned a value of .317 for the "induced-abortion-probability" variable; and so forth. These variables serve as the dependent variables for the regressions that are performed in step #4, and, within each demographic subgroup, their values sum to one.

Step #4: Estimation of Pregnancy-Outcome Regressions

In the fourth and final step of this process, we estimate three sets of regressions: one for fetal losses, one for abortions, and one for live births. The unit of observation for these regressions is the pregnancy, and the covariates included in the equations reflect the mother's characteristics. Thus, we regress the probability that a pregnancy will result in, say, a fetal loss on the demographic characteristics of the pregnant woman. As per the discussions in previous subsections, these regressions control for the mother's age and race (but not for her educational attainment or her SES), and separate models are estimated for married and unmarried women. See Table A10 for a complete set of regression results.[89]

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[89] As was mentioned in a previous footnote, the pregnancy file from Cycle 6 of the NSFG contains a record for every pregnancy that was experienced by a female member of the 2002 sample. A substantial majority of the pregnancies for which a record exists occurred before 2002. If we were to limit the dataset for this analysis to those pregnancies that occurred in 2002, there would be literally no observations in some age-race-marital-status cells. We therefore use all pregnancies in the file for purposes of practicality. To the extent that the results of the analyses of 2002 pregnancies are

Table A10: Pregnancy-Outcome Regression Results

	Fetal Loss		Abortion		Live Birth	
	Unmarried Women	Married Women	Unmarried Women	Married Women	Unmarried Women	Married Women
	Coefficient t-value	Coefficient t-value	Coefficient t-value	Coefficient t-value	Coefficient t-value	Coefficient t-value
Mother's Age Dummy: 20-24	-0.033 -79.52***	-0.013 -9.08***	0.062 138.26***	-0.101 -35.16***	-0.029 -68.07***	0.114 58.74***
Mother's Age Dummy: 25-29	-0.053 -119.91***	-0.013 -10.02***	0.141 199.98***	-0.142 -50.83***	-0.087 -140.17***	0.155 84.20***
Mother's Age Dummy: 30-44	-0.027 -34.19***	0.050 37.45***	0.204 157.14***	-0.152 -53.96***	-0.177 -220.14***	0.102 54.64***
Mother's Race Dummy: Black	-0.007 -26.22***	-0.018 -11.88***	0.076 188.38***	0.205 52.01***	-0.070 -214.90***	-0.188 -74.23***
Mother's Race Dummy: Hispanic	-0.014 -20.53***	-0.040 -69.83***	-0.014 -17.70***	0.019 27.24***	0.028 53.23***	0.021 48.92***
Mother's Race Dummy: Other	0.005 2.25**	0.012 3.55***	0.096 50.70***	0.029 21.35***	-0.100 -39.95***	-0.040 -10.76***
Constant	0.158 663.52***	0.188 151.04***	0.263 767.42***	0.159 61.30***	0.579 2106.74***	0.653 375.57***
P-Value for Joint Test of Age Covariates	0.000	0.000	0.000	0.000	0.000	0.000
P-Value for Joint Test of Race Covariates	0.000	0.000	0.000	0.000	0.000	0.000
N (unweighted)	6,710	6,531	6,710	6,531	6,710	6,531

Notes: All parameters were estimated using the pregnancy file from Cycle 6 of the National Survey of Family Growth (NSFG). Thus, the unit of analysis for these regressions is the pregnancy, and each regression can be interpreted as reflecting the controlled correlations that exist between the model's covariates and the probability that a pregnancy will result in a particular outcome (say, an abortion) rather than in either of the other two possible outcomes (say, a birth or a fetal loss). Demographically-specific probabilities for each outcome were assigned to each observation in order to create the individual-level data necessary to perform these regressions. These probabilities vary by the age, race, and marital status of the female respondent and were calculated using data that are external to the NSFG. Most of the data on fetal losses were taken from Ventura et al. (2008) and the National Center for Health Statistics' NVSS data resource; most of the data on abortions were taken from Ventura et al. (2008), Henshaw and Kost (2008), and Jones et al. (2002); and most of the data on live births were taken from the National Center for Health Statistics' NVSS data resource. See the text of this paper for a detailed discussion of how these data were used and of the manipulations that were applied to them in order to create the pregnancy-probability dataset used here. The excluded age and race variables are, respectively, age group 15-19 and the white race dummy. While results for all three pregnancy-outcome analyses are presented here, only two sets of results are necessary to assign an outcome to each pregnancy, since the three outcome categories are exhaustive and mutually exclusive. We therefore incorporate only the results for the fetal-loss and abortion regressions into the model. One asterisk (*) indicates that the parameter estimate is significant at or beyond the .1 level, two asterisks (**) indicate that the parameter estimate is significant at or beyond the .05 level, and three asterisks (***) indicate that the parameter estimate is significant at or beyond the .01 level.

For reasons of parsimony, these regressions do not include interaction terms to account for potential covariance between age and race in their relationship with our pregnancy-outcome probabilities. It is possible that, as a result of our failure to include interactions, these regressions are producing unrealistic predictions. However, Figure A18 shows that this is rarely the case. This figure shows, for each regression, the percentage-point difference between the prediction of the model for each demographic subgroup and the actual corresponding pregnancy-outcome proportion. For example, recall that 57.5 percent of pregnancies to white unmarried teenaged girls

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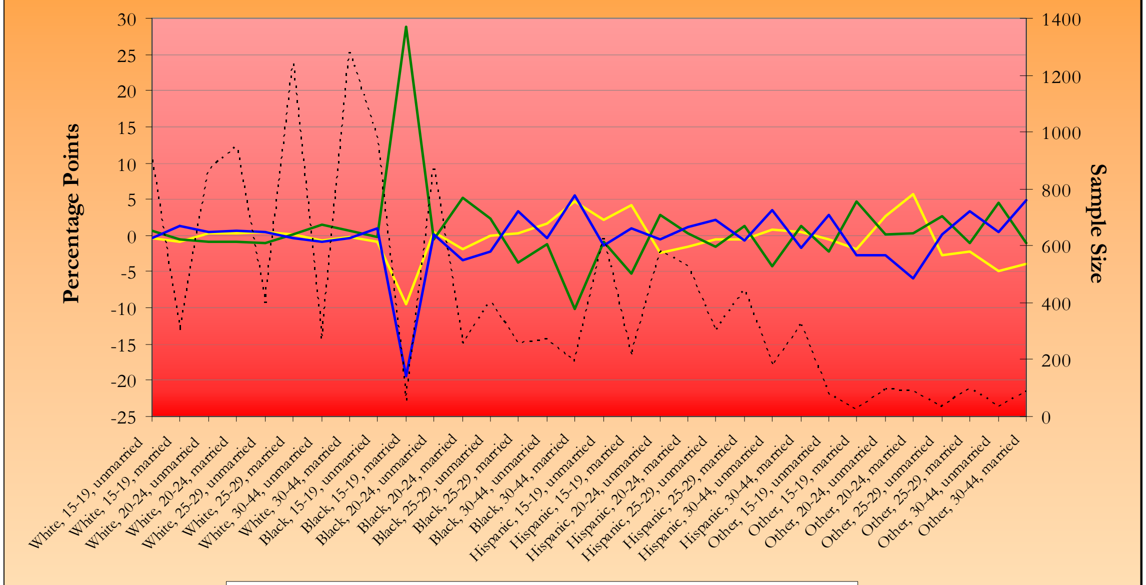
comparable to the results of the analyses using data on pregnancies across multiple years, these two sets of results are quite similar, both with respect to the coefficients presented in Table A10 and the performance of the model in reproducing real-world outcomes as reported in Figure A18 below.

result in a live birth. Assume that the regression model predicted a live-birth probability of .875 for this group. That prediction would be 30 percentage points too high (since .875 – .575 = .3). Thus, the smaller the differences reported in this figure, the better the performance of the regressions at modeling our three pregnancy outcomes.

Figure A18 shows that the models' predictions are almost always within five percentage points of the actual values of their dependent variables. The few exceptions to this rule are for extremely small groups. For instance, the abortion equation's predicted value is about 30 percentage points too high for black married teenagers, but – as is reflected by the black dotted line – this group only contains a handful of observations (which also implies that there are very few members of this group within the simulation population). On the whole, then, these results suggest, first, that our failure to include interaction terms has relatively little effect on the regressions' ability to capture realistic demographic variation in the pregnancy outcomes that they are modeling, and, more importantly, that our overall approach has allowed us to model the desired level of demographic variation in pregnancy outcomes without making potentially-costly sacrifices in the parsimony of the simulation model.

Figure A18: Differences between Actual and Predicted Pregnancy-Outcome Probabilities



The coefficients from these regressions are incorporated into the simulation model and are used to determine, for each simulated pregnancy, the probability that it will result in each of our three possible outcomes. On the day on which the pregnancy occurs, a random draw is taken from a uniform (0,1) distribution, and the value of that draw is compared to these probabilities in order to determine the pregnancy's outcome.[90]

Pregnancy-Outcome Results

Table A11 presents detailed pregnancy-outcome results from the simulation model. The table reports annual rates of pregnancy, birth, and abortion per 1,000 women as a function of their race,

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[90] Since our pregnancy-outcome categories are exhaustive and mutually exclusive, only two sets of regression coefficients are required to estimate the relative probabilities that a pregnancy will result in each of these outcomes. We therefore only incorporate the abortion and fetal-loss regression results into the simulation model. Assume that a simulated pregnancy was assigned an abortion probability of .25 and a fetal-loss probability of .35. A random draw between 0 and .25 would result in the pregnancy being simulated as ending in an abortion, a draw between .25 and (.25 + .35) = .6 would result in the pregnancy being simulated as ending in a fetal loss, and a draw between .6 and 1 would result in the pregnancy being simulated as ending in a live birth.

age, and marital status. The top panel of the table shows results from 50 ten-year runs of the model under its baseline specification. The middle panel shows results from the alternative specification in which married couples are assumed to have sex about as infrequently as unmarried individuals. And the bottom panel of the table shows real-world pregnancy-outcome estimates as measured using the data described in earlier subsections of this appendix. For most demographic subgroups among unmarried couples, the model approximates real-world outcomes relatively well in both specifications. Among married couples, the model's results are substantially closer to their real-world targets in the alternative specification than in the baseline specification.

Table A11: Comparison of Real-World and Simulated Pregnancy Outcomes by Age and Race

	Annual Pregnancy Rate (number per 1,000 women)			**Annual Fetal-Loss Rate (number per 1,000 women)**			**Annual Abortion Rate (number per 1,000 women)**			**Annual Live-Birth Rate (number per 1,000 women)**		
	Unmarried Women	Married Women	All	Unmarried Women	Married Women	All	Unmarried Women	Married Women	All	Unmarried Women	Married Women	All
Simulated Data *(no Re-calibration of Sexual Activity for Married Couples)*												
15-19	43.7	283.7	47.1	6.6	48.7	7.2	12.3	48.8	12.8	24.6	187.7	26.9
20-24	112.3	318.0	147.4	13.8	52.9	20.5	38.8	26.5	36.7	59.9	238.8	90.5
25-29	119.3	244.9	176.3	11.5	40.6	24.7	51.0	10.4	32.6	56.6	194.3	119.1
30-44	97.8	143.9	126.4	12.1	33.6	25.5	48.3	3.8	20.7	37.1	106.6	80.3
White	76.4	170.2	119.3	9.5	37.4	22.3	29.5	2.6	17.2	37.4	130.5	79.9
Black	115.3	177.5	130.1	13.9	33.8	18.6	54.7	39.3	51.1	46.5	104.2	60.2
Hispanic	101.3	171.7	133.1	11.5	29.2	19.5	37.4	7.3	23.8	52.4	135.3	89.8
Other	105.2	179.1	137.5	14.2	39.8	25.4	49.1	8.9	31.6	42.3	130.9	81.0
All	88.6	171.5	123.8	10.9	36.0	21.5	36.3	6.5	23.6	41.4	129.2	78.7
Simulated Data *(with Re-calibration of Sexual Activity for Married Couples)*												
15-19	42.9	197.7	45.1	6.7	33.2	7.1	12.0	33.5	12.3	24.0	131.3	25.6
20-24	113.9	217.5	131.6	13.8	36.8	17.7	39.6	17.3	35.8	60.4	163.9	78.1
25-29	117.8	160.5	137.1	11.7	26.3	18.3	49.9	6.9	30.4	56.1	127.6	88.6
30-44	96.9	84.3	89.1	12.4	19.5	16.8	47.8	2.1	19.4	36.6	62.8	52.9
White	76.8	105.4	89.9	9.9	22.9	15.8	29.6	1.6	16.8	37.3	81.0	57.2
Black	113.5	100.7	110.5	14.0	18.8	15.2	53.4	22.3	46.0	46.0	59.6	49.2
Hispanic	101.7	109.9	105.4	11.2	18.3	14.4	37.9	4.9	23.0	52.5	87.0	68.1
Other	99.5	97.1	98.4	13.2	20.5	16.4	46.5	4.9	28.3	40.0	71.6	53.8
All	88.2	105.3	95.5	11.0	21.7	15.6	36.0	3.9	22.4	41.1	79.7	57.5
Real-World Data												
15-19	62.7	536.2	74.9	9.7	92.0	11.8	18.0	109.3	20.3	35.1	334.9	42.8
20-24	130.4	289.4	166.9	15.0	47.3	22.4	46.2	24.8	41.3	69.1	217.3	103.1
25-29	132.7	198.0	167.9	12.9	32.7	23.6	57.5	7.9	30.8	62.3	157.4	113.5
30-44	58.2	75.6	70.3	7.0	17.6	14.4	28.7	2.0	10.0	22.5	56.0	45.9
White	53.5	111.8	83.6	7.3	22.8	15.3	18.8	2.8	10.6	27.4	86.2	57.8
Black	158.0	112.5	143.5	20.8	20.7	20.8	68.4	23.4	54.0	68.8	68.4	68.7
Hispanic	156.0	125.4	139.7	17.6	20.0	18.9	52.8	7.4	28.6	85.6	98.0	92.2
Other	68.9	127.4	98.0	7.5	26.4	16.8	33.5	5.3	19.4	27.9	95.7	61.9
All	87.8	115.2	101.3	11.1	22.4	16.6	33.6	5.6	19.8	43.1	87.3	64.8

Notes: Real-world data were taken from Ventura et al. (2008) and the National Center for Health Statistics' NVSS data resource for fetal losses; from Ventura et al. (2008), Henshaw and Kost (2008), and Jones et al. (2002) for abortions; and from the National Center for Health Statistics' NVSS data resource for live births. See the text of this paper for a detailed discussion of how these data were used to produce the estimates reported here. Pregnancy rates are calculated as the sum of fetal-loss, abortion, and live-birth rates. While the unit of analysis for these estimates is the pregnancy, the demographic information used here reflects the characteristics of the female respondent. The population denominators required to produce pregnancy, birth, abortion, and fetal-loss rates were taken from the 2003 CPS. The two sets of simulated results were generated using data from fifty ten-year runs of the FamilyScape model.

Gestation Periods

On the day on which a simulated pregnancy occurs, FamilyScape assigns both an outcome for the pregnancy and a gestation period for that outcome. Women within the simulation are unable to become pregnant again for the duration of their pregnancy's gestation period. After canvassing the relevant literature, we have concluded that the typical gestation period for a live birth lasts for between 245 and 273 days subsequent to the day of conception; that the typical gestation period for an abortion is between 14 and 90 days; and that the typical gestation period for a fetal loss is between 28 and 70 days.[91]

Since women are also typically unable to become pregnant again for a period of time after their pregnancy ends, we extend these gestation periods somewhat in order to model the proper duration of time during which women are infertile as the result of a pregnancy. Our literature review suggests that the average period of postpartum infertility lasts for between ten and eleven weeks; that the average period of post-abortion infertility is about ten days; and that there is little or no period of infertility after a fetal loss. When it is determined that a pregnancy will result in a live birth, a random draw is therefore taken from a uniform (315,350) distribution in order to determine the length of the pregnancy's simulated gestation period. For abortions and miscarriages, equivalent draws are taken from uniform (24,100) and (28,70) distributions, respectively.[92]

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[91] Information on gestation periods for live births was taken from the NVSS. For more information on gestation periods for induced abortions, see Finer and Henshaw (2003), Gamble et al. (2008), the Guttmacher Institute (2008), Jones et al. (2008), Jones and Kost (2007), and Physicians for Reproductive Choice and Health (2008); and, for more information on gestation periods for fetal losses, see Brown (2008), Everett (1997), MacDorman et al. (2007), Nybo Anderson et al. (2000), Ventura et al. (2008), and Wilcox et al. (1988).

[92] The ranges of these distributions are calculated by taking the sum of the relevant gestation-period and post-pregnancy-infertility-period durations. For instance: since the typical gestation period for a live birth lasts for between 245 and 273 days, and since the typical period of post-partum infertility lasts for between 70 and 77 days, gestation periods for live births are simulated by taking a random draw from a uniform distribution whose lower bound is equal to 245 + 70 = 315 and whose upper bound is 273 + 77 = 350. For additional

APPENDIX V: FAMILY FORMATION & CHILD WELL-BEING

This fifth and final appendix is quite brief for two reasons. First, the processes leading up to the occurrence of childbearing inside and outside of marriage are woven throughout the simulation modules that have already been explicated in the previous four appendices. For example, Appendix III explains the way in which we differentiate between married and unmarried individuals in simulating sexual activity and contraceptive use. These dynamics represent the two most important proximal causes of pregnancy, which in turn is a necessary prerequisite for childbearing. Appendix IV then describes our methods for simulating childbearing (among other pregnancy outcomes) among married and unmarried mothers. Thus, the prior sections of this paper collectively serve as an overview of the way in which we model family formation, since they describe our methods for simulating the antecedents of pregnancy, the occurrence of pregnancy, and the incidence of childbearing within and outside of marriage. See Table A11 in the preceding appendix for a summary of FamilyScape's simulated rates of marital and non-marital childbearing among various demographic subgroups.

The second reason for the brevity of this appendix is the fact that the main body of the paper already contains an explanation of our procedures for modeling the poverty statuses of newly-born children. We do not restate that explanation here. We do, however, present results in Table A12 comparing the poverty rates of newborn children in our simulation with their real-world equivalents. Since our child-poverty regressions control for the mother's

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information on postpartum infertility, see Hatcher et al. (2004); for additional information on post-abortion infertility, see Boyd and Holstrom (1972), Hatcher et al. (2004), Lahteenmaki (1993), Vorherr (1973), and World Health Organization (2009); for additional information on post-fetal-loss infertility, see Miscarriage Support Auckland Inc. (2009) and Perloe (2008). Due to a quirk in the specification of the model, simulated gestation periods for fetal losses last for longer than they should. We will address this issue in the next version of FamilyScape.

age, race, education level, and marital status, the results shown here are disaggregated by the same set of characteristics. We also report poverty rates both for the model's baseline specification and for the alternative specification in which the frequency of intercourse is assumed to be lower for married couples. In both specifications and for most demographic subgroups, FamilyScape approximates real-world child-poverty rates quite well.

Table A12: Comparison of Real-World and Simulated Poverty Rates Among Newborn Children by Age, Race, and Education

	Unmarried Women	Married Women	All
	Percent	Percent	Percent
Real-World Data			
15-19	46.4	32.3	42.0
20-24	47.9	21.1	33.1
25-29	58.1	10.5	18.0
30-44	58.5	8.0	11.7
White	40.9	7.4	12.6
Black	60.8	15.8	41.8
Hispanic	55.5	24.8	31.0
Other	65.3	7.6	15.5
Less than High School	62.7	39.2	48.9
High School Degree	50.6	15.2	26.3
More than High School	38.8	4.4	8.0
All	51.2	11.3	19.9
Simulated Data *(no Re-calibration of Sexual Activity for Married Couples)*			
15-19	46.3	34.7	45.1
20-24	39.5	18.8	30.1
25-29	49.7	10.7	20.8
30-44	56.9	8.9	17.3
White	39.7	7.8	15.9
Black	63.3	14.7	43.3
Hispanic	53.3	22.9	32.6
Other	58.8	8.9	23.6
Less than High School	58.8	37.9	47.6
High School Degree	52.7	13.7	26.8
More than High School	39.1	4.3	12.8
All	48.0	10.7	22.0
Simulated Data *(with Re-calibration of Sexual Activity for Married Couples)*			
15-19	45.7	35.7	45.0
20-24	39.5	19.0	32.2
25-29	49.3	10.7	24.1
30-44	57.7	9.1	21.9
White	40.0	8.2	19.5
Black	62.4	12.9	48.2
Hispanic	53.6	23.1	36.0
Other	59.6	9.1	30.2
Less than High School	58.5	38.1	49.9
High School Degree	53.1	14.2	31.3
More than High School	38.7	4.4	16.2
All	48.1	11.1	26.3

Notes: Real-world child-poverty estimates were calculated using data on observations in the March 2003 Current Population Survey (CPS) who were under the age of one at the time that their families' interviews were conducted. While the unit of analysis for these estimates is the child, the demographic information used here reflects the characteristics of the mother. Simulation results were generated using data from fifty ten-year runs of the FamilyScape model.

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