Social Networks and the Diffusion of Fertility Control

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1 Overview

Theories of the fertility transition now routinely reserve a place for diffusion effects (Mason 1997). Such effects arise because individuals are themselves members of larger groups. The information that is held by group members, the choices they make, and the outcomes that flow from them—all these can exert a powerful influence on individual incentives to innovate. In settings in which fertility has been high, such innovation may take the form of modern contraceptive adoption and fertility limitation. Under certain conditions, the individual-to-group connections establish pathways along which such innovative demographic behavior can diffuse.

What empirical evidence supports the view that diffusion matters to fertility decline? As we will show, proponents can find in the fertility literature numerous hints and indirect suggestions of a role for diffusion. Until very recently, however, the available data were insufficient to withstand rigorous scientific scrutiny. Over the past several years, several groups of researchers have initiated longitudinal studies that promise to better illuminate the contribution of diffusion.[1]

With the study of diffusion effects about to enter a new phase, this is an appropriate moment to take stock of what has been learned and to describe the new research directions that lie ahead. Our aim in this paper is threefold: to assemble the disparate concepts of the diffusion perspective into a coherent whole; to review the literature in and outside demography in the light of these concepts; and to present simulations and new data on the role of social networks, which we take to be one of the key mechanisms in diffusion processes. Throughout the paper, we illustrate the issues with applications to Ghana, one of the sites being explored in new longitudinal research. The effort to understand the specifics of the Ghanaian case requires that concepts and illustrations be drawn from the broader literature in social science and fertility change.

In our view, diffusion modeling can be regarded as a special case of multi-level modeling. It is distinctive in two respects: first, consideration of diffusion emphasizes a particular set of individual-to-group

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[1] Research in Ghana involves John Casterline, James Phillips, and Mark Montgomery at the Population Council; in Ghana, Fred Binka and Alex Nazzar of the Navrongo Health Research Centre and in a parallel research program in the south, Dominic Agyeman of the University of Cape Coast. Preliminary findings are presented in Phillips et al. (1997b) and Agyeman et al. (1996). Similar research is being conducted by Susan Watkins and colleagues in Kenya and Malawi (see Watkins et al. (1995) for preliminary results) and by Entwisle and Godley (1998)in northeastern Thailand.

connections, those associated with information exchange and innovation; and second, it focuses attention on dynamic implications. If they are appropriately structured, the channels by which individuals are connected to groups can permit and even facilitate wholesale behavioral change—the dynamics can take the form of "cascade," "contagion," and "tipping point" phenomena. That diffusion effects have the potential to accelerate social change is well recognized; but it is less well understood that, depending on social setting, diffusion dynamics may also stifle innovation and bind individuals more tightly to the status quo.

In other work (Montgomery and Casterline 1996), we have argued that diffusion is best analyzed in terms of its two defining features, social learning and social influence. The concept of social learning is pertinent to environments that are characterized by flux and uncertainty, in which new choice options are coming to the fore with associated costs and benefits that have yet to be fully understood. The choices could be entirely novel, as in the case of a new technology, or socially novel in the sense of being uncommon in an individual's own social circles. In either case, information about the new choices might be sought from an individual's reference groups, the set of other persons with whom information is exchanged or who provide models illustrating the links between choice and outcome. Below we will describe the various reference groups and linkages as "social networks." The phrase social learning thus encompasses both the social aspects of information acquisition and the filtering or distillation of that information into terms that are meaningful to individual choice.

Social influence is a rather different concept. It refers to the collective power of institutions, structures of authority, and social groups to establish the larger context within which individuals must evaluate their private decisions. As individuals learn about the nature of the new choices, they may find that various groups, institutions, or local elites are positioned either to facilitate those choices or to constrain them. But such social structures are themselves rarely immutable or impervious to influence, and their nature may well change with the prevalence of innovation. For instance, social norms favoring high fertility may dissolve or be reconfigured as modern contraceptive use spreads.

Contraceptive adoption

For a number of reasons, the adoption of modern contraception may be strongly influenced by diffusion effects. Where modern contraception is still new, social learning may help to establish the properties of contraceptive methods themselves—their levels of efficacy, where they may be obtained, the associated monetary and social costs, and the potential side effects of use. These are doubtless central concerns in settings where few people have used contraception. Even in high-prevalence settings, however, the distribution of contraceptive knowledge will be uneven and in certain groups, at least, social learning can continue to play an important role. The life-cycle aspect of learning also warrants study. Whatever the prevalence of contraception among adults, adolescents will have much left to learn about the nature and consequences of method use. They will often refer to the behavior of peers and others for guidance; and adolescents may find themselves constrained by peer group norms or by the institutionalized service delivery practices of family planning programs.

The scope for social learning is much broader than this focus on methods and means would suggest. In developing countries, where many society-wide transformations are underway, individuals may need to rely on social learning in order to extract the meaning for themselves of the larger forces. For example, social learning may be much involved in individual perceptions of mortality decline (Montgomery 1998, 2000) and in the effort to understand the risks and benefits of heavy investments in children's education. Learning in these dimensions involves issues distinct from the properties of contraceptive methods, but such learning could ultimately be expressed through contraceptive use.

Thus, there is merit in thinking broadly about the roles of diffusion and social influence. By no means does the adoption of a diffusionist perspective require one to abandon concern for socioeconomic determinants. Quite to the contrary—the diffusion perspective helps to enrich understanding of the full force of

these determinants. It draws attention to their role in forming the local social structure; and it introduces a distinction between their direct impacts and their spillover or social multiplier effects.

Social multipliers and programs

When seen from the viewpoint of reproductive health programs, the recognition of diffusion effects opens a new window on program evaluation. The essence of a diffusion dynamic is that the information or behavior of one person—let us say, a contraceptive adopter—can have spillover effects on the motivations of another—say, a potential adopter. This spillover effect, or informational externality, can be either positive or negative in character. That is, when considered by the potential adopter, the experience of an earlier user can help to tip the balance toward contraceptive use or can serve to dissuade the potential adopter.

Consider a case in which a family planning program reaches one person directly with services and information. If this person uses contraception, the program can rightly claim a portion of the credit. The diffusion perspective suggests that second-round, social multiplier effects also need consideration. When the example of the first contraceptive user persuades another person to adopt, the program might legitimately claim a measure of credit for the second adoption. Although it would be difficult to properly apportion this credit, the basic principle is that program effects extend beyond those individuals who are directly affected by the program.

Once this principle is accepted, it implies the need to reconsider not only the social dimension of program effects, but also the geographic dimension. When different geographic areas are linked by social network ties, program efforts directed at one area can exert a spillover influence on contraceptive use in another. By emphasizing pathways such as these, the consideration of diffusion dynamics forces a rethinking of the conventional evaluation framework.

This much has long been known. Indeed, one of the earliest experimental interventions in family planning—the Taichung experiment, reviewed below—underscored the significance of social multiplier and geographic spillover effects in contraceptive knowledge and adoption. The difficulty has been to properly estimate the size of these effects, and thereby understand the practical implications for evaluation. This task requires both rich longitudinal data and an appropriate conceptual and statistical apparatus. One longitudinal analysis (Montgomery and Casterline 1993) has found that in the case of Taiwan, estimates of family planning program effectiveness were greatly modified by consideration of diffusion dynamics. A conventional analysis of program impact, which ignored diffusion, suggested that no more than 5 to 20 percent of marital fertility decline could be attributed to program efforts. When the social multiplier effects of diffusion were taken into account, however, the estimates of program impact rose to over 30 percent.

Does the diffusion perspective also provide clear lessons for program design? The 1993 National Academy of Sciences report, *Factors Affecting Contraceptive Use in sub-Saharan Africa*, linked social networks to the prospects for increases in contraception,

> The challenge for policy...is how to seize on the themes and motivations brought out by economic stagnation and crisis in a cost-efficient way, recognizing that initially the appeal of family limitation will not be in evidence across the full socioeconomic spectrum, and even the appeal of birth spacing via modern contraception may be resisted in some traditional quarters. One proposal, advanced by Lesthaeghe, is to exploit the concept of diffusion and the potential presented by sub-Saharan forms of local social organization.
>
> It is clear that the provision of information and the social legitimation of modern contraception will be crucial to the prospects for service delivery. Given the budgetary constraints and limitations of personnel with which sub-Saharan governments must cope, national delivery strategies must tap a variety of local social networks ....
>
> (Bertrand and Jolly 1993:122–123)

The report went on to discuss the possible roles of local women's groups, marketing associations, local political associations, mutual aid and rotating credit groups, and traditional birth attendants, as well as various church and youth associations. This theme was echoed in Bongaarts and Bruce (1995), who asked how local African social structures and traditional community institutions might become involved in efforts to reduce "unmet need" for birth spacing. They envisioned a role for such institutions in the organization of service delivery and in the diffusion of information.

Although the potential exists, it is too soon to say whether the diffusion perspective will have a major impact on program design. In the Navrongo experiment, a large-scale family planning intervention set in northern Ghana (Nazzar et al. 1995), local social, religious, and political institutions have been enlisted in support of an innovative program of doorstep delivery of modern contraception. A longitudinal evaluation of diffusion dynamics is also underway.

Organization of the paper

With the preceding overview serving as background, we have organized the next sections of the paper as follows. In Section 2, we provide a more formal definition of the concepts of social learning and influence, the two fundamental components of diffusion theory. Section 3 reviews the demographic and related social science literature on diffusion modelling. Section 4 presents results from an analytical simulation model of diffusion, with emphasis on the contribution of social networks. Section 5 then provides empirical data from Ghana on social networks and contraceptive use in that context. Our conclusions are set out in Section 6.

2 Key Concepts

In developing countries, most adults are keenly aware of the flux and new uncertainties of their social environments. Mortality decline is underway, although its extent may be only dimly perceived; the prospects for wresting a living from agriculture may be threatened or undergoing radical change; new forms of human capital investments in children must be considered; and the perceived costs of children are often shifting in ways that might motivate lower fertility. In addition to this, most adults understand that new technologies are available for the control of fertility, with the new methods often being promoted by information and education campaigns and provided through government and private health services. Each of the new decision options presents social and economic risks as well as potential benefits. In consequence, individuals will make use of information drawn from many sources to help resolve the uncertainties facing them and to clarify the benefits and costs associated with their private decisions.

In such environments, *social learning* may be described as follows. Consider an individual i at time t. In weighing alternatives and making decisions, this person refers to an information set $\mathcal{I}_{it}$, which summarizes his or her knowledge of all factors that might bear on decisions. Some aspects of the decision environment are not known with certainty, and these must be represented in terms of subjective expectations and measures of uncertainty. Such knowledge may have been created by the mingling of different sources of information, some of it being impersonal, such as knowledge gleaned from the mass media, and some personal in the sense of being inferred from the experiences or views of others with whom the individual interacts.

Particularly relevant for innovation is the individual's knowledge regarding what economists call "equations of motion." These equations represent an individual's perceptions of the link between an action or choice undertaken at time t, let us say c_t, and the distribution of possible consequences, say y_{t+1}. Consider the case of the IUD, which has only recently been introduced to Ghana. One equation of motion might describe the long-term effects of adopting the IUD on a woman's future state of health; associated with it

would be her expectations and subjective uncertainties regarding these consequences. A Ghanaian woman who has heard of the IUD might wish to know about such health implications, and might be concerned with how her husband might react and what strategies she can draw upon in spousal negotiations. On these matters, rumors or confidences imparted by friends about the IUD might be distinguished from the information that the woman has distilled from media campaigns.

The information set $\mathcal{I}_{it}$ thus includes a listing and description of other individuals $\mathcal{N}_{i,t}$, a set of persons whose actions, communications, or perceived traits might help person i to resolve uncertainties. The various members of $\mathcal{N}_{i,t}$ may be sorted into groups (which themselves may overlap), some of which can be described as personal social networks. Social learning takes place *interpersonally* when the other actors in $\mathcal{N}_{i,t}$ supply information that shapes person i's subjective beliefs about the equations of motion or other decision parameters. These actors may also function as resources to be sampled when person i wishes to gather additional data.

Learning can be said to take place *impersonally* when, for example, knowledge is gleaned from the media. The boundary between interpersonal and impersonal sources is admittedly indistinct. Information obtained from the media is often passed on and evaluated through further social interaction (Hornik and McAnany 1998). Contacts with family planning programs often have both an interpersonal and an impersonal character.

The concept of *social influence* overlaps, to a degree, with the concepts of social learning and information sets, but is in many ways distinct. The term refers to the effects of interpersonal interactions that derive their power from factors that are intrinsically "social" and that are expressed in individuals' preferences and constraints as well as in their information sets. A vast literature in social psychology demonstrates the power of pressure toward social conformity in groups; see the comprehensive reviews by Moscovici (1985) and Cialdini and Trost (1988). A rather different form of social influence is expressed in concepts such as authority, power, and deference. In Ghana, men often exercise authority over women and define for them the limits of appropriate behavior. Senior women living in a household compound, such as the wife of a compound head, may exercise control over junior women. Senior men and women together may function as "gate-keepers," who restrict the movements of younger women (and to some degree, younger men) outside of the compound (see the description of northern Ghana by Adongo et al. (1997)). In terms of our conceptual model, these hierarchical and power-based influences can be interpreted as additional constraints on individual behavior, or as a set of (psychic) costs facing the junior woman who contemplates innovative but deviant behavior.

In short, the reference groups and social networks embedded in $\mathcal{N}_{i,t}$ can influence fertility through several distinct behavioral mechanisms. First, the information they provide may expand the set of reproductive choices known to the woman. Second, behavior within $\mathcal{N}_{i,t}$ can provide empirical demonstrations of the range of consequences that can follow from the adoption of a particular reproductive choice c_t, and may thereby shape the woman's subjective probability distributions and equations of motion. The third way in which $\mathcal{N}_{i,t}$ enters is through effects on preferences, that is, through social influence effects, conformity pressures, and so on.

Suppose that woman i, having weighed the options and the attendant uncertainties, decides that she will adopt contraception at time t. Then, at time $t+1$, woman i may play a new role as a reference point in the social networks of all other women, $\mathcal{N}_{j,t+1}$, to which she belongs. For such women, i's experience may add to the accumulation of evidence in favor of modern contraceptive use. Whether this occurs depends on the degree to which woman i's contraceptive use is public knowledge, or is shielded by a screen of privacy that is lifted only when she decides to do so (Phillips et al. 1997a). The informational content of her experience also depends on how woman i herself perceives the experience: she may find a newly adopted contraceptive method disagreeable or its health side effects disturbing and be willing to broadcast this view to others.

There should be no presumption that social effects must reinforce innovation. One gets the impression from research in developing countries that conversation about modern contraception is far more often

negative than positive, with stories about extreme negative health repercussions of contraceptives often dominating the discussion (for Senegal, see Ngom (1995)). Even in the contemporary United States, views regarding the potential health risks posed by contraceptive methods such as the pill or IUD have included considerable misperception, and this may well have resulted in long-term changes in the U.S. contraceptive method mix. Similar misconceptions are widespread in Ghana, as has been documented by Adibo (1992), Adongo et al. (1997), and Agyeman et al. (1996). Health scares, backlashes, the disapproval of local elites, the public failure of innovators—all these social effects can frustrate rather than encourage innovation.

A social effects model emphasizing the role of networks $\mathcal{N}_{i,t}$ is incomplete unless it addresses the issue of how such networks are formed and inter-linked, and whether network membership is constant over time or varies with the life-cycle stage of the individual or other circumstances. Indeed, as will be demonstrated in Section 4, the dynamics implied by a diffusion model cannot be described unless that model can explain who is connected to whom. There are clearly linguistic and geographic boundaries on network formation, but there must also be other social and economic factors that determine $\mathcal{N}_{i,t}$.

The content of learning

To this point, our discussion has emphasized the properties of contraceptive methods as the subject of information exchange, but social learning with respect to other issues may be equally or more important. One sees in Ghana the beginnings of a quantity-quality transition, whereby some families are having fewer children and investing more heavily in the education of each child. This innovation is more characteristic of urban than of rural areas, but even rural areas have begun to participate. To a rural couple, however, surrounded by family elders and living in what remains a largely traditional environment, the full implications of the new schooling and fertility strategies must seem uncertain indeed. How can they persuade themselves of the wisdom of this new course, if not by reference to the experiences and views of others who have already embarked on it?

In considering these two arenas of choice, one concerned with the costs of fertility regulation and the other with the long-term benefits, we see that the time spans required for outcome y to be revealed may be very different. The health implications of using the pill or the IUD might be known in a matter of months or a few years; the risks and rewards of educating one's children, however, might not be known for decades. In the latter case, family i might have to rely on the experiences of the very early adopters of the lower-fertility, higher-schooling strategy, and these adopters might be found in socioeconomic circumstances very different from its own. Family i might also solicit the views and opinions of the other couples in its networks in an effort to better understand the educational "equations of motion." No one might have any direct experience to recount, but each couple in the network might relate stories heard at second-hand, and offer its predictions as to the likely outcomes of educating children.

The costs of sampling and network formation are also different in the two cases. Where contraception is concerned, there is always an element of privacy and potential embarrassment to consider. To engage in a discussion about such intimate matters, or even to broach the subject, may risk exposure to criticism or to social sanctions (Phillips et al. 1997a). We might distinguish between the fixed costs that person i anticipates in first opening the subject with person j, and the costs of any subsequent discussion, which would presumably be lower. Costs probably assume less importance in obtaining information about schooling, this being a neutral subject open to free discussion. Knowledge about schooling might therefore have the character of a local public good, with information being exchanged easily among members of networks or wider social groups. Information about contraception, however, would more closely resemble a private good, available to the interested woman or couple only at an (implicit) price.

Whether it is information about schooling or about contraceptive methods that diffuses, new reproductive ideas will often be expressed through changes in contraceptive use. Trends in use, however, do not in themselves shed light on the nature of the information that has been exchanged. Offsetting positive and

negative messages about contraception may both be exchanged, so that the net change in the prevalence of use is not revealing of the salience of the information that was communicated. Moreover, contraceptive use may serve only as a *signal* of the diffusion of more fundamental messages on the motivations for childrearing, and these messages need not have any direct connection to the properties of contraceptive methods themselves.

The foregoing discussion may help to clarify the differences between social learning regarding reproductive strategies, on the one hand, and learning in the context of agricultural innovation, on the other. As discussed in the next section, there is a long tradition of research on why farmers adopt or fail to adopt new agricultural practices, and this literature can be a rich source of insights and analogies. In the agricultural case, the treatment or choice c_t made by one farmer (e.g., the adoption of a new high-yielding seed) can be easily observed by others, and one need wait only until the end of an agricultural season to know the outcome y_{t+1}. The village or some other geographically defined area can serve as the natural sample frame for each farmer, and within this frame a farmer can update his subjective beliefs without much consideration of sampling costs (Besley and Case 1993). By contrast, in settings such as northern Ghana, where modern contraception is thought to be socially threatening to men and women take pains to guard their privacy, the costs of information-gathering on contraception are probably high.

In both the agricultural and reproductive spheres, a problem arises in how to draw lessons from other actors who are situated in circumstances very different from one's own.[2] Presumably what is relevant about the experiences of others is the link between their choices c_t and their outcomes y_{t+1}. If the connections between choice and outcome are situation-specific, then it is difficult to know precisely how one family's experiments with a new reproductive strategy may prove relevant to another's. This may explain the apparent failure of fertility regulation practices to diffuse for many generations in some settings—for example, from European colonizers to native Africans, and from the upper to the lower social strata in Latin America (Rosero-Bixby and Casterline 1993). The value of information gained through network $\mathcal{N}_{i,t}$ may therefore depend on the socioeconomic circumstances of network members relative to i's own circumstances.

Taken to the extreme, this would suggest that family i should populate its networks with peers, i.e., with those most like itself in respect to the socioeconomic factors that affect the equations of motion. The difficulty, however, is that the homogeneous groups formed by this sampling strategy may not generate sufficient diversity of information. There may also be an advantage to sampling the experiences of non-peers, whose choices c_t and outcomes y_{t+1} may better reveal the full range of possible behaviors and consequences. Depending on the innovation in question, then, network $\mathcal{N}_{i,t}$ may be composed both of peers and of non-peers drawn from different social groups or strata. Again, the costs of forming network contacts must be taken into consideration, as it may be more difficult to forge a direct connection with another person who is distant in a socioeconomic or geographic sense.

Extending the analysis somewhat, we might consider the information on new reproductive strategies that is provided by impersonal and even fictional contacts, such as characters found on television (Faria and Potter 1999) or in the movies. These characters often embody new ideas and exemplify in their actions the conflicts between the old and new ways of thinking and behaving. They can provide models of new forms of consumption behavior, which may stimulate individual i's aspirations for various consumer goods. They also show how conflicts might be resolved and what negotiating tactics among spouses or relatives might prove successful.

Summary

We have sketched a view of diffusion that takes, as its starting-point, a set of rational individual decision-makers who must make choices in new and uncertain environments. We have argued that they are likely to

[2] Manski (1993a) has developed an interesting model of social learning from peers, but a key assumption is that individuals are identical in all dimensions affecting the equations of motion.

proceed on the basis of information drawn from their personal social networks, local social organizations, influential elites, the mass media, and program personnel. Having made their own judgments as to the best reproductive strategy open to them, individuals contemplating innovative choices may find that others are positioned either to constrain or to facilitate such choices, acting on authority derived from roles such as spouse, compound gate-keeper, political or religious leader, or the like. The social dynamics of innovative behavior are therefore complex. Theory alone cannot provide clear guidance on the magnitude—or even the direction—of such social effects.

3 An Overview of the Literature

With these concepts in mind, we turn to the literature on diffusion modeling. A notable development in contemporary social science is the parallel evolution, across a number of disciplines, of ways of thinking about change that can be described in terms of diffusion. In other work (Montgomery and Casterline 1996), we have reviewed research in the fields of sociology, economics, and psychology; taken collectively, these fields have much to offer to the demographer and program evaluator. In what follows, we will summarize the demographic research on diffusion and then, more briefly, review recent contributions from economics and sociology.

The demographic literature

Within demography, much of the current interest in diffusion effects can be traced to two influential studies: the family planning experiments conducted in 1964 in Taichung, Taiwan (see Palmore and Freedman (1969); Lu et al. (1967)) and the European Fertility Study (see Knodel and van de Walle (1979); Watkins (1987)). Curiously, of these two, the Taichung research is more persuasive on scientific grounds, but it is the European results that seem to have captured the imagination of the current generation of demographers.

The Taichung study, based on a randomized experiment and longitudinal follow-up, showed how direct program interventions targeted to some individuals can affect others who were not directly contacted. These effects clearly illustrate how program impacts can be magnified by transmission through personal social networks. Retherford and Palmore (1983) provide a comprehensive review of the Taichung and other early Asian studies, emphasizing the role of such informal networks.

In contrast to the individual-level observations that formed the basis for the Taichung experiment, the European studies were based on aggregated areal data with a time-series dimension. Creatively using maps and other illustrative devices, Leasure (1962) and Lesthaeghe (1977) detected remarkable spatial, ethnic, and linguistic patterns in the fertility transitions of Spain and Belgium. The Belgian case (Lesthaeghe 1977) is particularly interesting, in that it documents clear linguistic boundaries to fertility change separating adjacent urban neighborhoods, this being suggestive of social barriers to information transmission. Other scholars (Knodel and van de Walle 1979; Cleland and Wilson 1987; Watkins 1987) put emphasis on the apparent simultaneity of fertility declines across Europe and on the rapid pace of demographic change once the transitions were engaged.[3] The European studies suggest that the links between fertility decline and conventional measures of socioeconomic development are weak—a much-disputed position (Galloway et al. 1994; Richards 1977)—thereby arriving at diffusion processes and "ideational change" as residual explanations for fertility decline.

The European evidence, although intriguing, is far from conclusive. Rapid and discontinuous change in fertility is consistent with a diffusion dynamic, but it is also consistent with conventional, individualistic fertility models incorporating thresholds or nonlinearities (Retherford 1985). The fact that fertility change observes linguistic or cultural boundaries is likewise consistent both with diffusion and with alternative

[3] Bongaarts and Watkins (1996) see similar patterns in contemporary developing countries.

perspectives. Furthermore, as we established above, a well-formulated diffusion model must reserve a place for conventional social and economic factors. The notion that diffusion constitutes a wholly distinct class of explanation does not stand scrutiny.

Recent empirical research has continued to add findings supportive of diffusion hypotheses. In the longitudinal analysis mentioned above, Montgomery and Casterline (1993) present suggestive results for Taiwan based on a set of aggregate cross-sectional and time-series data. Similar approaches were followed by Rosero-Bixby and Casterline (1994), Tolnay (1995), Land and Deane (1991), and Munshi and Myaux (1998). These authors acknowledge a discomfort with aggregate data and argue that proper tests require multi-level data on individuals and their social networks.

Until very recently, only one effort had been made to assemble such data: the pioneering work of Everett Rogers and colleagues (summarized in Rogers and Kincaid (1981)) on social networks and contraceptive use in rural Korea.[4] The Korean data, although rich in network detail, are cross-sectional and therefore cannot furnish the basis for tests of diffusion. Subsequent research by Valente and colleagues in Cameroon (Valente et al. 1997), by Entwisle and colleagues in Thailand (Entwisle and Godley 1998), by Watkins and colleagues (Watkins et al. 1995) in Kenya, coupled with our own efforts in Ghana (summarized briefly in Section 5 and in Montgomery and Zhao (1998)), have contributed new cross-sectional studies of social networks and contraceptive use. Until the longitudinal dimension of these new studies can be filled in, they too must be regarded as making suggestive rather than definitive contributions.

Other research traditions

Social effects, broadly defined, have long been at the center of sociological theory and research. See, for example, the review of research in social psychology in Cialdini and Trost (1988) and the theoretical essays in Hedström and Swedberg (1998). More directly relevant to the research agenda described here is the study of social networks, which in itself is a well-developed subfield of sociology. It is the domain of two journals, *Social Networks* and *Connections*, and the central preoccupation of a literature too vast to summarize here. Recent articles that draw out the implications for diffusion are Marsden and Friedkin (1993) and Strang (1991); a recent summary is Marsden (1998). Granovetter and Soong (1983, 1986) developed analytic methods that Valente (1995) later adapted to the study of contraceptive use. Branches of social and cognitive psychology (Carley 1998; Nowak et al. 1990) have also been concerned with social learning processes.

The literature on diffusion in agricultural economics has likewise been a source of hypotheses and analogies (see Griliches (1957) for an early contribution and Feder et al. (1985) for an insightful review). As noted above, one can see common elements in the situations of poor farmers considering adoption of high-yielding seeds and of poor men and women considering the adoption of contraception. The analogies are sometimes superficial or inexact, but they often merit serious consideration. Besley and Case (1993), Munshi (1994), and Foster and Rosenzweig (1994) have analyzed agricultural decisions in a manner that has clear applicability to demographic innovation.

In other fields of economics, however, interest in diffusion and related social effects is a comparatively recent phenomenon. In the 1990s, such research has belatedly flourished as a number of economists pursued analyses of social learning, information cascades, social interaction, and diffusion, often in models in which individuals are assumed to be identical apart from the information they possess.[5] Much of this literature is theoretical, a notable exception being McFadden and Train (1996).

[4] These data were later reanalyzed by Montgomery and Chung (1999) and Valente (1995)

[5] See, among others, Arrow (1994), Arthur and Lane (1992), Banerjee (1992, 1993), Besley and Case (1993), Bikhchandani et al. (1992), Conlisk (1980, 1996), Ellison and Fudenberg (1993, 1995), Foster and Rosenzweig (1994), Kohler (1997), Manski (1993a,b), McFadden and Train (1996), Munshi (1994); Munshi and Myaux (1998), and Shiller (1995).

A closely related literature is that concerned with "interdependent preferences," see Pollak (1976), Alessie and Kapteyn (1991) and Kapteyn et al. (1997). The theme pursued by these authors is the interconnection among individuals of demands for consumer goods. In making decisions about consumption, individuals are assumed to be influenced by the consumption behavior exhibited in their reference groups. This is a potentially fruitful area for demographic research, in the sense that consumption aspirations may have an indirect yet fundamental influence on the demand for children.

4 Dynamic Simulation Models

Having highlighted the central roles of social networks and information exchange in the theory of diffusion processes, we now ask how these roles might be revealed in empirical data. The key question is whether the effects of diffusion can be identified and the magnitudes estimated. Formidable difficulties confront this task. Indeed, in the view of some skeptics, the effort to estimate diffusion models is likely to founder on one key problem, how to separate the effects of diffusion from the influence of unmeasured, persistent individual attitudes and motivations. There is cause for concern on this score, because diffusion models are akin to regression models with lagged dependent variables, and unmeasured heterogeneity presents problems of a similar nature. If the skeptics are right and there is little hope of estimating proper causal models, then the diffusion hypothesis will likely remain no more than a tantalizing theoretical possibility.

The skeptics have powerful arguments on their side—see Durlauf and Walker (1998) for an insightful presentation—but it would be premature to cede the field to them. The essence of the problem is that when a diffusion model is specified in full generality, it admits too many possibilities and lacks sufficient structure for diffusion effects to be precisely and confidently identified. Additional social-structural assumptions are therefore needed; but, of course, these assumptions cannot be imposed arbitrarily. The structural assumptions must be grounded in detailed, specific knowledge of the local social context. The need for local detail then precludes certain types of empirical investigation, for example, large national samples involving hundreds of heterogeneous clusters and communities. It implies a rather different mode of research, one that is based in well-understood communities or regions.

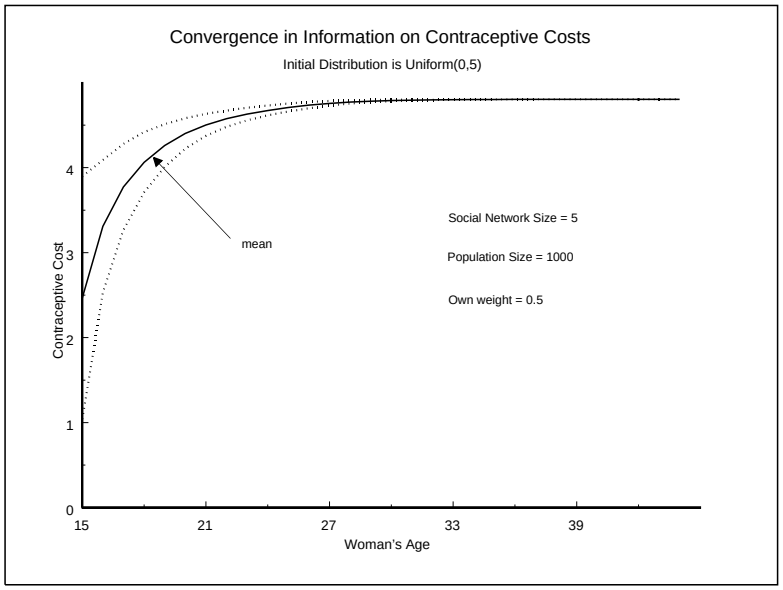
Given research designs such as these, three related modes of inquiry are required. First, careful, demographically realistic analytic simulations are needed to draw out the data needs of diffusion modeling and to highlight the empirical regularities that require closest attention. Second, since so little is known about social networks in developing countries, rich descriptive information is needed on these networks in the local context. Third, the properties of newly developed econometric techniques need to be carefully assessed, first through application to simulated data and then to actual data from the study communities.

With these long-term aims in mind, in what follows we present the early returns from a set of analytic simulation models. The models are constructed so as to expose the dynamic implications of different social network configurations. By using simulation methods, one can manipulate the key parameters describing these networks and then investigate the effects on such outcome measures as contraceptive use or knowledge. This approach is useful in understanding the data that will be required for effective empirical work.

Information exchange in social networks

We begin by abstracting from demographic decisions so as to focus on some of the implications of information exchange in social networks. We will show that both *network structure* and the *content of information* affect the evolution of beliefs in the population. Having sketched some of the possibilities in this section, we will proceed in the next section to embed a dynamic individual decision model in a social network con-

Figure 1: Information updating by averaging of own views with highest-cost views in the network



text, and explore how information exchange affects demographic decisions, which then feed back into the system to alter future information exchanges.

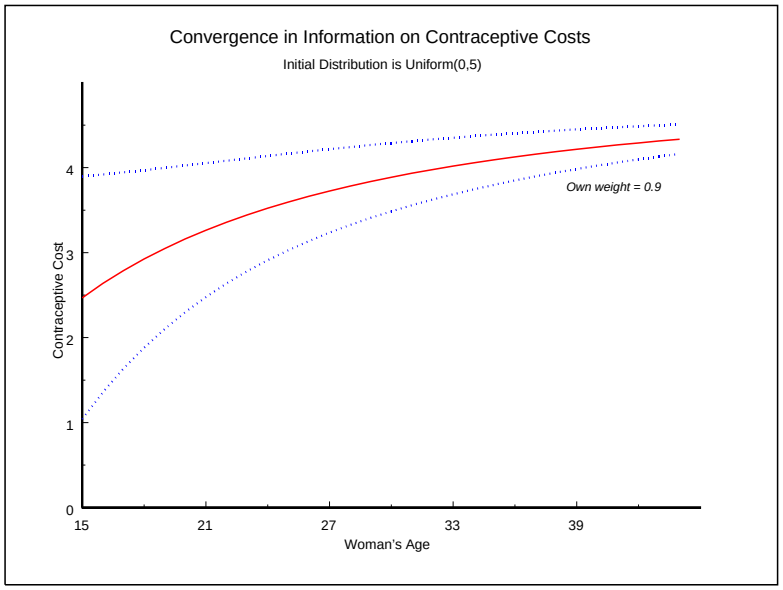
Imagine that each woman i begins her reproductive career with an initial belief about contraceptive costs. Also imagine that each woman is endowed with a fixed reference group of five other women, selected randomly from the population, each of whom has her own initial belief regarding costs. Denote this reference group or information network by $\mathcal{N}_i$. Woman i may be a reference point for other women, who can gather information from her, but she herself refers only to the members of $\mathcal{N}_i$. At intervals, woman i collects information about contraception from her reference group $\mathcal{N}_i$ and, on the basis of this, updates her own views of costs.

Consider now one way in which views of contraceptive costs might be revised. A substantial literature in psychology (Montgomery 1998, 2000) suggests that negative information is often given disproportionate weight in the formation of perceptions and the evaluation of risks. How might such a notion be relevant to the diffusion of contraceptive use? We might think of negative information about contraceptive costs as being summarized, for woman i, in the most extreme view of costs that is held by a member of her reference group. Suppose that woman i adjusts her perceived costs by averaging her own beliefs and the worst (maximum cost) belief that happens to be found in her network.

Figure 1 shows how with successive rounds of updating (we assume that updating takes place on a yearly basis), negative views of contraception come to dominate in the population. The solid line in the figure shows the mean perceived costs in the population of women, and the dotted lines show the range of views from one standard deviation below the mean to one standard deviation above. Our simple model of information exchange produces a near-consensus about the high costs of contraceptive use.

To understand this figure, it is useful to know that the initial contraceptive cost is represented by a number randomly drawn for each woman from an uniform(0,5) distribution with mean 2.5. The mean and standard deviation bounds are the left-most values indicated in Figure 1. At the first round of updating,

Figure 2: Increasing the weight placed on own views



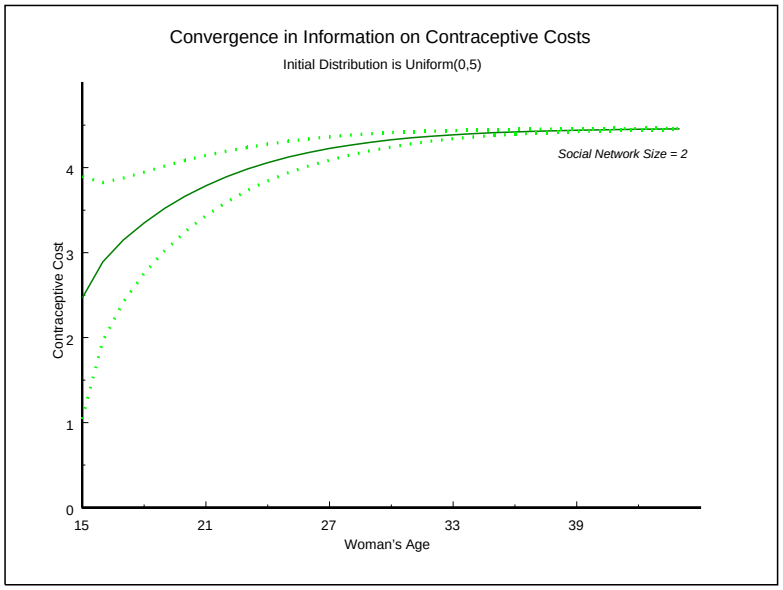
the woman focuses on the most extreme information about contraceptive costs that can be found in her reference group. The expected value of this maximum in a reference group of size n is $5n/(n+1)$, and with $n = 5$, this is obviously greater than the overall mean of 2.5. We should therefore expect that perceptions of contraceptive costs will tend to display an upward trend as information is exchanged. Note that as each woman i revises her own views of contraceptive costs based on her own reference group $\mathcal{N}_i$, other women for whom woman i is a reference point will revise their views, in part with reference to her. The consequence is that in the population as a whole, there is a decreasing variance in perceptions of contraceptive costs, as indicated in the convergence of the standard deviation bounds about the mean.

To continue with the example, Figure 2 shows the influence of the weight that women place on their own views as against the negative testimony of their reference groups. In the previous figure, women gave equal weight to their personal views and the most extreme view found in their reference group. In Figure 2, by contrast, women pay systematically less attention to the beliefs of their reference groups. This difference is evident in the slower upward revision of views about costs and in the persistent of variation in the population.

Figure 3 shows how network size might influence the distribution of views. (We return here to the assumption of equal weights.) Suppose that reference groups were composed of only two instead of five women. The expected value of the most negative view found in the smaller reference group would necessarily be lower than the expected value in a larger reference group. As a result, there is again a slower increase in the mean perception of costs than was true in Figure 1, as well as somewhat more persistence of variation in views.

As can be seen in these simple examples, network size—one aspect of social network structure—makes a difference to the evolution of views in the population. So, too, does the nature of information exchanged within the networks. Had we focused on the average view of contraception within i's networks, rather than the maximum-cost view, the convergence behavior seen in Figure 1 would have reappeared, but in this case

Figure 3: Reducing social network size



the population distribution would have converged to the expected value of contraceptive costs (this is 2.5 in our simulation). Both network structure and information content make a difference.

The Individual Model

Following Montgomery and Zhao (1998), we now proceed to embed a dynamic individual decision model in a social structure in which individuals are connected by networks. Individual reproductive decisions are rational and forward-looking and are made with respect to an evolving set of information. As in the simple mixing models above, information is allowed to circulate among decisionmakers through their network ties. Each decisionmaker is endowed with an initial set of information, but revises that information in the light of such information exchange. This approach respects the multi-level and dynamic nature of diffusion processes.

The individual decision model is invested with features that are broadly similar to those of Ghanaian reproductive decisionmaking. The full reproductive span for a woman ranges from age t_0 to T, where we take t_0 to be age 15 and T to be age 45. Within this reproductive span, age t is indexed in months. The terminal age T is defined to be the oldest age at which conception probabilities are non-zero. Women first marry at age t_m, an age that is randomly drawn from a first marriage age schedule for Ghana. We assume that no reproduction takes place before t_m and also assume that all marriages remain intact until the terminal reproductive age T. (We hope to generalize future versions of the model to accommodate marriage dissolution and remarriage.) Each woman possesses an *ideal family size* $\tilde{s}$, which can be regarded as a target number of surviving children. Beginning in month t_m, she strives to reach $\tilde{s}$ in an optimal fashion over the course of her reproductive career.

Because reproductive outcomes cannot be perfectly controlled, a woman may either fall short in her attempt to meet the target $\tilde{s}$ or exceed the target. She may be prevented from reaching $\tilde{s}$ by infant or child

mortality, which remains high in Ghana. The risk of such mortality is expressed in an age schedule of mortality hazards m_a for a child of age a, with the values of m_a drawn from life tables based on Demographic and Health Survey data (Ghana Statistical Service and Macro International 1994). The woman can also overshoot $\tilde{s}$ through unintended conceptions, or she can fail to conceive and thereby undershoot $\tilde{s}$.

The woman also has preferences with regard to the spacing of births. A birth occuring within 36 months of a previous birth is assumed to reduce the woman's utility. Within this interval, the penalty declines with the length of the birth interval. We assume that the spacing penalty decreases linearly in the duration since the last birth—duration is denoted by a_t—and (in the current specification) does not depend on whether the previous birth is alive.[6]

In striving to reach $\tilde{s}$ and maintain her desired birth spacing, the woman makes use of a single *control variable*, denoted by c_t, which indicates use of modern contraception in month t. Contraceptive use promises utility benefits in that it reduces the probability of conception. The age schedule of fecundability is denoted by fn_t, and a woman who uses modern contraception faces reduced risks of conception, as expressed in the schedule $fc_t = \beta \cdot fn_t$ with $\beta < 1$. If she conceives, there is a 9-month gestation period to be endured (months of pregnancy are indexed by g_t) and, following birth, a 17-month period of postpartum amenorrhea and sexual abstinence.

Regulating fertility through contraception entails two sorts of costs. First, each month of use exacts a penalty cc, the level of which is expressed in terms of the woman's utility. Second, contraceptive use also exposes the woman to the risk of health side effects. Having such health problems (a situation expressed by $h_t = 1$) reduces the woman's monthly utility by an amount hc. If she uses contraception, she faces the probability ph of contracting such a side effect. A woman who has such a side effect can abandon contraceptive use; if she does, her monthly probability of recovery from the side effect is given by rn. If she continues to use contraception, however, the monthly probability of recovery is given by $rc < rn$.

To summarize, the *control variable* of the decision model is contraceptive use, with $c_t = 1$ indicating use of a method and $c_t = 0$ indicating no method use. The *state variables* for the model are as follows. The number of surviving children, as of mother's age t, is denoted by s_t. The number of months since her last birth is given by a_t and the survival status of the last birth is indicated by l_t, where $l_t = 1$ means that the child is still alive. (These two state variables are assigned default values for women who have not yet had any births.) The indicator h_t expresses the woman's health status at age t, with $h_t = 1$ meaning that she has a health side effect that is traceable to contraceptive use. Non-pregnant women have gestation indicator $g_t = 0$, whereas g_t indexes the month of pregnancy for pregnant women.

Given the state and control variables, women are assumed to behave in an optimal fashion. By this, we mean that they are assumed to act so as to maximize their expected utility over the reproductive lifetime. Lifetime utility is given by the summation of a sequence of age-specific utility functions $u_t(s_t, a_t, l_t, h_t, g_t, \theta)$, and a terminal value function $U(s_T, a_T, l_T, h_T, g_T, \theta)$, with θ a vector of decision parameters. Let the full state vector be given by $y_t = (s_t, a_t, l_t, h_t, g_t)$. In this notation, the expected utility derived over a reproductive career is

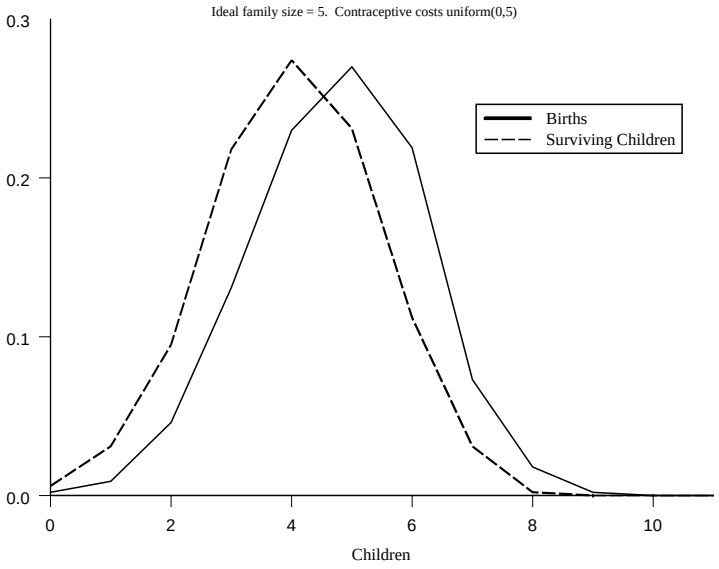
$$E_{t_m}\left(\sum_{t=t_m}^{T-1} u_t(y_t, c_t, \theta) + U(y_T, \theta)\right)$$

where E_{t_m} denotes expectations formulated as of the woman's age at marriage t_m. The functional forms we use for $u_t(\cdot)$ and $U(\cdot)$ are discussed in the appendix, along with other modelling details.

Since the decision horizon is finite, ending at T, the states are discrete-valued, and the (single) control variable is also discrete, optimal contraceptive decisions are readily determined by the method of backwards recursion. Montgomery (1989) develops a number of demographic models in this vein; also see Wolpin (1998) for a simple example involving child mortality, and Rust (1994) for a review of the related econometric literature.

[6] We will revise this in future work.

Figure 4: Births and surviving children in benchmark model



Using a baseline set of parameter values and demographic schedules, we have simulated contraceptive decisions and reproductive outcomes for a birth cohort of women whose ideal family size is $\tilde{s}\epsilon\{4,5,6\}$ children. Women differ in their initial views of the direct costs of contraception, such that they are distributed uniformly across the range of possible costs from low to high. The model assumes that for each woman i, the parameter cc_i is drawn randomly from a uniform distribution with range [0,5]. The mean value of cc_i is thus 2.5. In the benchmark model, we assume that each woman retains her initial view of costs (the value of cc_i) throughout her reproductive career. In this benchmark model, then, no information exchange or learning about contraceptive costs takes place.

Figure 4 shows the simulated distributions of births and surviving children under the benchmark assumptions. (The figure summarizes a simulation of the reproductive careers of 1000 women.) Under this extreme assumption of no interaction, the simulated total fertility rate of 4.75, and the age-specific birth rates (not shown) fall towards the lower end of the range of reasonable values in the Ghanaian context.

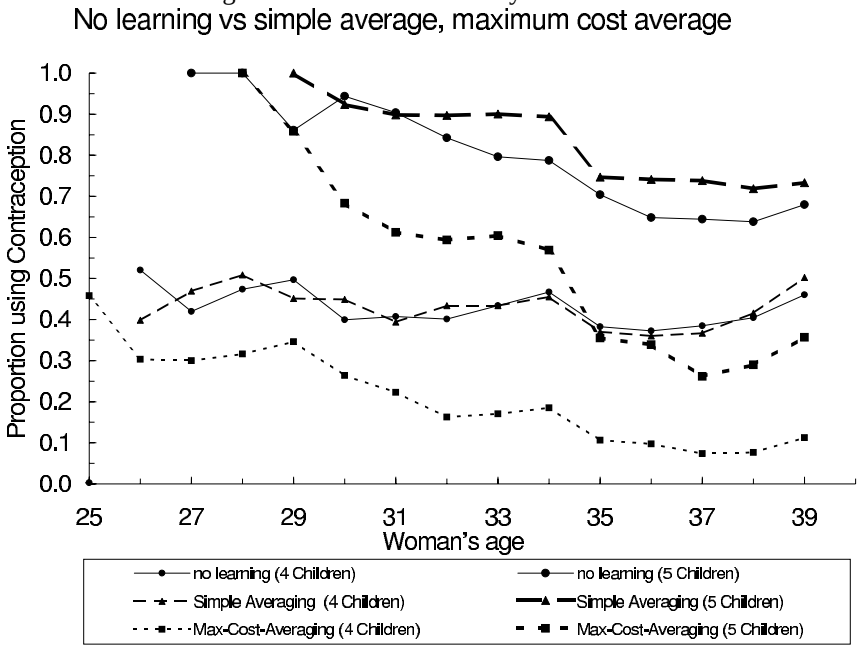
Learning through social networks

Imagine that each woman i is endowed with an initial value for cc_i just as above. At intervals, woman i draws information about contraception from her reference group $\mathcal{N}_i$ and, on the basis of this, updates her own views of costs, generating a new value of cc_i. For example, having first updated her cost view (cc_i) at age t_1, she proceeds to solve again the dynamic decision problem, which is to maximize

$$E_{t_1}\left(\sum_{t=t_1}^{T-1} u_t(y_t, c_t, \theta) + U(y_T, \theta)\right)$$

taking as given the value of the state vector y_{t_1}. The procedure is repeated upon the next infusion of information at $t_1 + \Delta$. In the interim between t_1 and $t_1 + \Delta$, woman i acts according to the revised

Figure 5: Simulations from dynamic model



dynamic decision rules that are based, in part, on her revised views of contraceptive costs. We assume for simplicity that in the interim, woman i behaves myopically in the sense that she ignores the possibility of all future changes in such costs.

How might these differences in information transmission affect contraceptive use? In Figure 5, we plot simulated contraceptive prevalence under three scenarios: (1) the benchmark case, in which women are randomly allocated their views of contraceptive costs and do not learn or revise those views over their reproductive careers; (2) the "simple averaging" case in which women annually revise their views by equally weighting their views and those of their network members; and (3) what we might term "maximum cost-averaging,", in which beliefs are updated by equally weighting the woman's own views and the most extreme view held by a network partner.

The contraceptive use schedules implied by the model are shown in Figure 5, match the empirical data better than those without learning. For all levels of ideal family sizes, the use of modern contraception starts to increase again after its peaks at the ideal number of children. In addition, the peak probability of use for women exposed to conception risk is about 0.4 with maximum-cost-averaging, compared to 0.7, and 0.33, respectively, for the baseline scenario and for DHS data. The intuition for the result is clear. Since the woman revises her perceived cost based on negative information only, contraceptive costs will increase over time, which in turn decreases the likelihood of contraceptive use. Note that the total fertility rate must be larger under this type of learning. In fact for the ideal family size of 5 surviving children, the predicted TFR is 5.3, a reasonable value in the Ghanaian context.

All women with five surviving children, the ideal in this simulation, use contraception at ages 28 and younger; but contraceptive prevalence remains highest in the case of revisions based on the simple average of own views and those of the reference group. If attention is paid solely to the most pessimistic view shared by the reference group members then for both parity levels the proportion using contraception declines appreciably faster than in the case of no learning or "simple averaging".

Summary

The simulation model is clearly illustrative, its main point being to demonstrate the subtleties of the diffusion perspective. Evidently, the details of behavior and social organization will matter: that is, precisely how individual social networks are formed, how extensive they are, and what information is exchanged within them can decisively shape aggregate trajectories of innovation. These critical modeling issues cannot be decided on the basis of theory alone. What is required is dedicated empirical work.

5 Ghanaian Social Networks

No one data collection exercise could hope to gather all relevant elements of individual information sets, the social structure in which individuals are embedded, the messages communicated along their social networks, and the new thinking stimulated by the operation of programs and the media. It is feasible, however, to concentrate research attention on a few of the dimensions believed to be critical to reproductive change. In 1995, our research team gathered data in four sites in the Central and Greater Accra regions of southern Ghana (Agyeman et al. 1996). The purpose was twofold: to develop a portrait of the social organization of these sites, and to measure both formal and informal social interaction concerning modern contraception. Multiple data collection methodologies were employed, including semi-structured interviews, focus group discussions, surveys, and ethnographic methods. Here we provide glimpses of these data, in order to demonstrate that measurement of social interaction is feasible and that the measures are associated with contraceptive use in ways that are consistent with the diffusion perspective.

Contraceptive use is still uncommon in these study sites. Although a majority of reproductive-age adults have heard of modern methods such as the pill, injectables and the condom, only about one-quarter of women report having used a modern method and only 10 percent report using at the time of the survey. As is often the case in West Africa, the corresponding fractions are higher for men.

In regard to local social structure, Table 1 summarizes the main elements of political, social, and religious organization. (Additional discussion and detailed community profiles are presented in Agyeman et al. (1996).) A striking feature is the large number of organizations in rather small communities. These organizations include various church fellowships and associations, Town Development Committees, the 31st December Women's Movement, PTAs, Youth Associations, and Women's Welfare Associations. Several of these organizations are national in character. In the ethnically Akan sites (Frami and Dutch Komenda), there is in addition an Asafo Company, a traditional military organization for men. Some of these organizations are gender-based, and their objectives center around improving the socioeconomic status of community members. All sites save Tubaman have a bewildering variety of religious associations, from Orthodox Protestant groups to Roman Catholics to all manner of syncretic churches and traditional religions. Some of the organizations listed in Table 1 also facilitate extra-community interaction. The Football Club in Amanfro and the 31st December Women's Movement, for example, bring their members into contact with people from all over Ghana. And all of the religious organizations, including the Muslim organizations in Tubaman, influence information flow to and from the communities. Finally, in all the sites exposure to the influence of radio and, to a lesser extent, television, is pervasive.

The novel aspect of this exploratory research was the collection of social network data at both the individual and the community level. Our strategy was to collect data from each respondent on the characteristics of each of his or her network members. We first inquired about outside-compound contacts, using responses to the question "With whom do you talk most often?" to identify up to four network contacts. [7] Our intention was to emphasize interactions other than those with spouses and near kin, who are likely to

[7] In earlier pilot research, we allowed for more than four network partners. The decision to truncate the list at four is the product of a compromise: the lower the truncation point, the greater the potential bias, but the greater the number of network partners considered, the greater the risk of respondent fatigue and perfunctory replies. In the longitudinal research currently in the field, we first obtain a

Table 1: Study communities and local influentials

	Frami	**Tubaman**	**Amanfro**	**Dutch Komenda**
Community Characteristics				
Ethnicity	Denkyira	Adangbe	Ga	Fante
Lineage Type	matrilineal	patrilineal	patrilineal	matrilineal
Ecology	Inland, rural	Inland, rural	Inland, peri-urban	Coastal, rural
Local Influentials				
Chief(s)	4	1	1	2
Queen Mother(s)	3			1
Linguists	4		1	1
Chief Fisherman or Farmer	1	1	2	2
Asafo	1			1
Religious Leaders	3	5	5	5
Heads of Basic Education	1	2	2	2
Town Development Committee	1	1	1	1
Unit Chairmen	1	1	1	1
31st December Women's Movement Leaders	1	1	1	1
Assemblyman	1		1	1
PTA Chairman	1	1	1	1
Other influentials		2	4	2
Health and Family Planning	Clinic	Nurse-Midwife	Clinic, Pharmacy	PPAG, monthly

Table 2: Number of network members, by sex of respondent

	Men (N=288)	*Women* (N=312)	*Total* (N=600)
Those "with whom you talk most often outside this compound"	Percentages		
No One	2	3	2
1 Person	3	12	7
2 People	20	20	20
3 People	26	15	21
4 People	49	50	50
Mean Network Size	3.2	3.0	3.1

reside in the respondent's compound. (No doubt these near-at-hand daily interactions are also important; we will examine them more intensively in the upcoming longitudinal research.) The general demographic characteristics of each network member were determined (from the respondent's report) and we then probed to learn of conversations and other exchanges regarding contraception. In a second segment of the questionnaire, we asked about any other persons with whom modern contraception had been discussed; persons co-residing in the compound were eligible to be included in this second battery of questions.

We were not aware of any equivalent efforts to gather social network data in southern Ghana and, at the outset, could not rule out the possibility that respondents would be reluctant to report on network members. In the event, such fears proved to be unfounded. The respondents reported on a relatively large number of network members (see Table 2): an average of about three persons in the first block of questions (those outside the compound "with whom you talk most often") and an average of about four persons (results not shown) in the two blocks of questions combined. Virtually no one failed to identify network members, and over 90 percent volunteered information on two or more network members. Some 50 percent of the respondents reported on the maximum of four network members permitted in the first block of questions (those outside the compound "with whom you talk most often"). Overall, this must be regarded as confirmation that this strategy of inquiry can succeed in southern Ghana, at least to the extent of respondents cooperating in the basic task of reporting on their fellow network members. A final point about Table 2 is that men reported on slightly more network members than did women.

Respondents were asked about a selected set of demographic and socioeconomic characteristics of their network members. Table 3 shows the characteristics of outside-compound network members, with attention to the differences between network members and the respondents. Of course we expect to find a good deal of homogeneity in personal networks, but we were also interested to see what degree of heterogeneity characterizes them for men and women. The table indicates that outside-compound social networks are: (1) heterogeneous with respect to age, with high proportions of respondent reporting both older and younger network contacts; (2) almost entirely same-sex in character; (3) composed of both kin and non-kin, the latter being more prevalent; and (4) heterogeneous with respect to schooling and, to some degree, with respect to residence as well. There are surprisingly few male-female differences in these networks, with perhaps the most interesting finding being the higher proportions of outside-village contacts among women. We suspect that these contacts may be the result of women's roles in trading and marketing.

full list of network partners and then make detailed inquiries for four of these. This alternative approach will permit (limited) analyses of truncation bias.

Table 3: Characteristics of network members in relation to respondent (R), by sex of respondent. Figures presented are percentage distributions.

	Men	*Women*	*Total*
Age			
Younger than R	44	38	41
Same age	11	9	10
Older than R	45	53	49
Sex			
Male	94	7	51
Female	5	93	49
Relationship			
Kin	20	38	29
Non-Kin	80	62	71
Schooling			
Less than R	28	31	29
Same as R	51	47	49
More than R	20	20	20
Residence			
Same village	87	76	81
Other village	5	10	8
Town or city	7	13	10
Most Recent Conversation			
Today	45	50	48
Yesterday	27	20	24
This week	14	11	12
Previously	13	19	16

For schooling, 2 percent of observations are missing.

Table 4: Discussion of contraception with network members, by ever-use of contraception, sex of respondent, and number of network members

	Never Used Modern Contraception		**Ever Used Modern Contraception**		**Total**	
	Men	*Women*	*Men*	*Women*	*Men*	*Women*
Number of Members With Whom Discussed Contraception						
			One Network Member			
Discussed with one (percent)	25	23	33	50	29	27
			Two Network Members			
No discussion	61	71	18	35	45	61
Discussed with one	8	11	27	35	15	18
Discussed with both	31	18	55	30	40	21
			Three Network Members			
No discussion	68	61	29	36	46	55
Discussed with one	12	11	17	9	14	11
Discussed with two	9	11	12	36	11	17
Discussed with all	12	17	43	18	29	17
			Four Network Members			
No discussion	64	53	13	23	37	43
Discussed with one	10	23	13	23	12	23
Discussed with two	6	8	20	18	13	11
Discussed with three	7	8	20	18	14	11
Discussed with all	12	8	34	18	23	11

Table 5: Summary of contraceptive discussion with network members, by ever-use of contraception and respondent's sex

	Never Used Modern Contraception		**Ever Used Modern Contraception**		**Total**	
	Men	*Women*	*Men*	*Women*	*Men*	*Women*
Mean Number with whom discussed	0.8	0.7	2.0	1.5	1.4	0.9
Mean Percentage with whom discussed	26	24	61	46	43	31

The conversations about contraception that occur in these personal networks are described in Table 4. This table is stratified according to the number of network members reported by the respondent. The reason for stratifying is that, with everything else being equal, a respondent who identifies more network members is more likely to have discussed contraception with at least one of those members. Consider the "Total" columns and those respondents who mentioned one network contact. Among these respondents, 29 percent of men and 27 percent of women reported having had a discussion with that person about modern contraception. Among those mentioning two network contacts, 40 percent of men reported having had a conversation with both persons and 55 percent (40 + 15) with at least one person. Considering the majority of respondents, those who reported on two to four network members, over one-half report conversations about contraception with at least one person. Interestingly, men were somewhat more likely than women to report conversations about contraception with at least one of their network partners. For both sexes, however, such conversations are relatively common. It seems that there is a good deal of interpersonal interaction about contraception in these villages.

Table 4 also examines the association between interpersonal interaction regarding contraception and use of modern contraception. Analysis of precisely this linkage is the long-term goal of the research program, motivated by the theory and other research described earlier. The materials at hand are limited to a single cross-section snapshot of a dynamic relationship; we cannot hope to identify the causal impact of network interaction on contraceptive behavior on this basis. Until we have gathered the appropriate prospective data, analysis of the sort presented in Table 4 is nevertheless of interest, for two reasons. First, it contributes to our evaluation of the validity of this data collection strategy: we assume that those who have used modern contraception are more likely to have discussed it with friends and relatives, and therefore we would question the validity of the reports of conversations about modern contraception if these were not reported to be more common among ever-users. Second, the figures in Table 4 give a rough indication of the direction and strength of interpersonal diffusion.

Almost without exception, respondents who have ever used modern contraception are much more likely to report having conversations about contraception with fellow network members. The association between interpersonal interaction and use is strongly positive. Table 5 distills the findings in two summary indicators: for contraceptive users and non-users, the mean number and the mean percentage of persons with whom conversations have occurred. For example, among men, ever-users have discussed modern contraception with 2.0 network members on average, as against 0.8 network members among never-users. These results are strikingly similar to the findings of Valente et al. (1997) and Watkins et al. (1995).

Further details on the likelihood of conversations about modern contraception occurring are given in Table 6. The probability (expressed as a percentage) that contraception is discussed is shown according to characteristics of the network members (as well as the sex and contraceptive use status of the respondent). This table offers rich material for addressing a host of questions about social interaction and contraception. One can, for example, ask questions about the association between network heterogeneity and discussions

Table 6: Contraceptive discussion with types of network members, by ever-use of contraception and respondent's sex

	Never Used Modern Contraception		**Ever Used Modern Contraception**		**Total**	
	Men	*Women*	*Men*	*Women*	*Men*	*Women*
Age						
Younger than R	20	24	67	55	44	33
About same age	27	26	47	57	36	34
Older than R	28	25	58	38	44	29
Sex						
Male	25	16	60	47	43	25
Female	19	25	64	46	48	31
Relationship to R						
Kin	21	19	59	44	42	34
Non-Kin	26	28	61	47	44	27
Schooling						
Less than R	15	28	56	44	40	34
Same as R	28	23	64	47	44	30
More than R	25	24	62	48	44	29
Residence						
Same village	24	26	61	50	43	33
Other village	17	16	52	29	33	19
Town or city	37	27	63	31	52	28
Most Recent Conversation						
Today	24	27	66	48	46	34
Yesterday	25	26	56	47	40	31
Previous	26	19	56	42	42	26
All Network Members	24	25	61	46	43	31

of contraception. The Granovetter (1973) argument that "weak ties" are more conducive to the diffusion of innovative ideas implies that information about contraception is more likely to be exchanged in outside-village network contacts and among non-kin. The figures in Table 6 do not show such limits on contraceptive information exchange; it seems to occur with outside contacts and those inside the village, between kin and non-kin, among those with greater schooling than the respondent and with less, and so on. Socioeconomic factors may well facilitate or constrain discussion of contraception, but identifying the precise patterns will require further research.

6 Conclusions

The term "diffusion" has appeared in the literature on fertility transition with increasing frequency during the past two decades. This paper has provided a more precise definition of diffusion than is the norm in the literature, and considered how diffusion effects might be expressed and what they might imply for the timing and pace of fertility change.

As used here, diffusion refers to a process in which individuals' decisions—in this instance, decisions bearing on reproduction—are affected by the knowledge, attitudes, and behaviors of others with whom they come in contact. This contact might occur through face-to-face social interaction with kin, friends, and neighbors or, at the other extreme, through interactions at a distance through the mass media. Two fundamental behavioral mechanisms account for such diffusion effects: social learning and social influence. Social learning refers to the acquisition of information from others. The information might have to do with a new technology, or with the health, social, and economic consequences of decisions. In the case of fertility, individuals might learn from others about the availability of a new contraceptive, or about health side effects of certain contraceptives, or about the apparent gains and losses from having fewer children and investing in their schooling. Social influence refers to the power that individuals exercise over each other through authority, deference, and pressures for social conformity. In the case of fertility, spouses and other kin may forbid practice of contraception (and have the means to enforce this prohibition), or individuals may be reluctant to depart from community reproductive practices out of fears of social marginalization.

Although social learning and social influence undoubtedly operate in every setting, it is likely that their effects are more powerful in environments of uncertainty, where the costs and benefits of decisions are poorly understood. The uncertainty can be induced by forces such as demographic changes (reductions in mortality), rapid introduction of technological innovations, transformations in the economy, the improvement of transportation and communication infrastructure, and the expanded provision of public services by government and private agencies. Such forces, often perceived by individuals as being out of their control, leave them both bewildered and insecure about appropriate behavioral responses. In such environments, it is natural to seek guidance from others, whether as sources of essential information or as models of how to respond to the changes that are underway.

This paper has emphasized the role of individual networks and local social structure, but as others have argued (e.g., Bongaarts and Watkins 1996), national and even international networks should also be considered. The political and bureaucratic commitments needed to sustain delivery of family planning and health services are no doubt strengthened by an interlocking series of networks. These serve to link, at one end, international donors and providers of technical assistance with groups of in-country policymakers and program managers, at the other end. Such connections are brought to the fore in Watkins' analysis of the development of population policy in Kenya (Watkins and Hodgson 1998).

It has been a common practice in the research literature of the past two decades on fertility transition to set diffusionist theory against conventional theory. This opposition is incompatible with the model developed in this paper, in which diffusion effects and the effects of demographic, social, and economic

factors are inseparable. Diffusion dynamics—the expression of social learning and social influence—are one means through which the fundamental factors operate.

This is a central point of the argument we have developed, and perhaps can be made clearer by illustration. Consider the response of fertility to mortality decline. According to the argument developed here, the magnitude of the population-level response depends in part on what individuals conclude from their own observations and from their discussions with others about improvements in survival chances. Similarly, emerging employment opportunities for women will alter reproductive strategies only to the extent that households are made aware of these opportunities through mass media channels and informal social interaction, and to the extent that social constraints do not prevent women from pursuing these opportunities. Much the same logic can be applied to many conventional explanatory variables.

If the causal process leading to fertility decline operates in this way, then clearly it makes little sense to impose a conceptual boundary between diffusion effects and the effects of exogenous economic and social variables; and there can be no support for the view that the two sets of effects are alternative and competing explanations for fertility decline. Rather, diffusion dynamics occupy a position of a different character in the causal model for fertility decline: they condition or mediate the effects of other variables, either dampening or amplifying these effects. Diffusion and conventional explanatory variables can coexist comfortably in a well-specified theory of social change.

If one accepts this view, then the research challenge is to make an accurate and balanced assessment of the nature and magnitude of diffusion effects. Two strategies for carrying out such an assessment are presented in this paper. The first strategy uses micro-simulations in which an individual woman's contraceptive practice is responsive to the knowledge and practice of contraception in her social network. Despite the simple structure of the simulation model employed here, it clearly illustrates the subtleties of the diffusion perspective.

In the simulation model, the likelihood of using contraception is influenced by contact with other persons. The simulations illustrate how the magnitude of the influence depends on the size of a womans social network and on the weight she attaches to the information she receives from network partners. Evidently, the details of behavior and social organization matter: how individual social networks are formed, how extensive they are, and what information is exchanged within them can decisively shape aggregate trajectories of innovation.

These parameters are inputs to the simulations and, given the present state of knowledge, the choice of values is arbitrary. The simulations will become more informative to the extent that the parameters correctly describe social processes in specific settings. The key information is not yet known for societies that are now undergoing transition from high to low fertility, and hence the social network and related parameters must be measured through dedicated empirical studies.

The second strategy involves collection of the necessary primary data, here through fieldwork initiated in Ghana in 1995. Descriptive results from our first attempts to measure social networks and link them to contraception were presented. The exercise provides considerable encouragement that empirical work on this topic is feasible. In the focused inquiry about social networks, virtually none of the Ghanaian respondents failed to identify a network member, and over 90 percent volunteered information on two or more members. The reported characteristics of these network relationships seem reasonable, in particular showing male-female differences that are plausible in Ghanaian society. The data also reveal that conversations about contraception are relatively common in the sampled communities, having occurred in roughly one-half of the network relationships (and, interestingly, more frequently for men than women). Finally, a strong positive association is apparent between such conversations about contraception and the likelihood of having used modern contraception.

This empirical association is consistent with the theory developed in the first part of this paper, but it would be premature to claim empirical verification of the theory. If the decision to use contraception can be attributed in part to social diffusion effects, then contraceptive users should report more social

interaction about contraception than non-users, just as observed in the Ghanaian data. But this association can also be explained by a process in which individuals make a decision to use contraception in isolation, uninfluenced by the contraceptive attitudes and behaviors of members of their social network, and then, having adopted contraception, proceed to discuss it with those members. Individuals might even decide to affiliate themselves with others who are known to have made the same innovative choice. That is, the presence of contraceptors in an individuals social network, and the discussion of contraception with friends and neighbors, might follow from, rather than precede, the decision to use contraception. Either causal process is compatible with the Ghanaian data.

With reflection, it becomes clear that this matter cannot be resolved with a single cross-section study measuring social interaction patterns and contraceptive attitudes and behaviors. Indeed, short of pure experimental design, no strategy will yield an unambiguous portrait of the causal structure. But if social interaction patterns and contraceptive use are jointly tracked over time, the analytical capacity to disentangle stimulus from response is significantly strengthened. Building on the exploratory materials described here, we have established such a longitudinal research program in Ghana. The over-arching aim of this program is to make an empirical assessment of the scope and scale of diffusion effects on reproductive behavior, with particular attention to the practice of contraception. The design will also permit a host of corollary issues to be addressed, including: the density and composition of social networks and how these vary by sex, age, schooling, ethnicity, social organization of the community, and other variables; the content of discussion about modern contraception and, in particular, the relative weight of positive and negative messages; the effect of local health and family planning services on the prevalence and content of discussion about contraception and related issues; and the prevalence of discussion about modern contraception per se as against discussion of broader issues concerning the costs and benefits of childbearing and childrearing. Each of these issues can have considerable bearing on the direction and magnitude of diffusion effects on fertility.

The significance of this work for the design and evaluation of programs is clear. If diffusion dynamics have substantial effects on reproductive decisions, then surely the design of programs should be sensitive to this fact and, indeed, exploit it to the extent possible. Programs should nurture positive diffusion effects and deliberately counter negative diffusion effects. In a similar vein, efforts to evaluate program impact will be biased if they ignore the "spillover" and "multiplier" effects that social diffusion dynamics produce; hence, practicable methods for accounting for diffusion effects in program evaluation must be developed.

Appendix: Details of the dynamic model

To implement the model described in the text, we require functional forms for the period utility function $u_t(y_t, \theta)$ and the terminal value function $U(y_T, \theta)$. For simplicity, we define the period utility function to be

$$u_t = -\Omega(S_t, s_t \mid \tilde{s}, \tau_1, \tau_2) + \min\{-\phi_1 + a_t \cdot \phi_2, 0\} - h_t \cdot hc - c_t \cdot cc,$$

with penalty function

$$\Omega = S_t \cdot \tau_1 \cdot \mid s_t - \tilde{s} \mid + (1 - S_t) \cdot \tau_2 \cdot \mid s_t - \tilde{s} \mid = (s_t - \tilde{s}) \cdot ((1 - S_t) \cdot \tau_2 - S_t \cdot \tau_1)$$

where S_t is an indicator for the current number of surviving children relative to the ideal family size: it is equal to one if the number of surviving children is smaller or equal to the ideal family size and equals zero otherwise. Deviations from the family size ideal $\tilde{s}$ are penalized in a linear and asymmetric fashion if $\tau_1 \neq \tau_2$ ($\tau_1, \tau_2 > 0$). One might expect smaller penalties for exceeding $\tilde{s}$ in societies like Ghana's that have been organized to manage high fertility, implying that $\tau_1 < \tau_2$.

The second part of the utility function, $\min\{-\phi_1 + a_t \cdot \phi_2, 0\}$, represents the utility costs associated with short birth intervals. The intercept and slope parameter of this penalty function are denoted by $\phi_1 > 0$

and $\phi_2 \equiv \phi_1/36 > 0$, respectively. To ensure that the penalty does not apply until the first birth, we set a_t to its maximum value of 60 months by default. The period utility u_t is not discounted in this formulation, although doing so would be an easy generalization.

As for the terminal value function,

$$U = -\kappa\, E_T \Omega(S_T, s_T \mid \tilde{s}, \tau_1, \tau_2) - E_T(\sum_{v=T}^{\infty} h_v \cdot hc \mid c_T = 0).$$

The factor $\kappa > 1$ is employed to inflate the value of U in relation to period utility u_t. Expectations are required in defining U because women may be pregnant ($g_T > 0$) upon entering period T and the ensuing birth may or may not survive. In addition, women can enter T with a health condition ($h_T = 1$) that was the result of prior contraceptive use and this condition may persist for some time even in the absence of contraceptive use. The expected health cost can be summarized as equal to hc/rn if $h_T = 1$ and equal to zero otherwise.

We must also select a schedule of fecundability by age, fn_t, choose a value for contraceptive efficacy β, and specify the trio of transition probabilities that are associated with health, (ph, rc, rn). The utility parameters hc, cc, κ, τ_1, τ_2, and ϕ_1 must also be specified.

The chosen parameter values are as follows for the baseline runs. The direct contraceptive cost parameter $cc = 2.5$; the health cost parameter $hc = 1.5$; the monthly probability of contracting a health side effect if using contraception is $ph = .25$; and the monthly probability of recovery is $rc = .1$ when contraception continues to be used and $rn = .9$ if it is not used. The weighting factor κ for the terminal value function is set to $\kappa = 10$. The weighting factors τ_1 and τ_2 for the ideal family size penalty function are set to $\tau_1 = 1$ and $\tau_2 = 0.75$ implying that exceeding the ideal parity level is less costly than falling short of it. The spacing parameter ϕ_1 is $\phi_1 = 12$. Contraceptive efficacy $\beta = .05$, and the mortality schedule is chosen so that ${}_5q_0$ matches the values for the Central region of Ghana. See Montgomery and Zhao (1998) for further discussion.

The fertility rates produced by the model and the profiles of contraceptive use implied by the model are encouragingly similar to those reported in the Ghana DHS. Given the ideal family sizes, the model predicts the following: essentially contraceptive use increases with the number of surviving children before the ideal family size is reached, and declines thereafter at a decreasing rate. The result is driven by two incentives, first, the incentive to space births, and second, the incentive to avoid over− and under−shooting the ideal family size targets. In the latter case, contraceptive use is "precautionary" (see Montgomery (1989) for a discussion of the precautionary motive in dynamic models of target fertility). Furthermore, at the ideal number of surviving children, contraceptive use is universal, at least initially. Holding the number of surviving children constant at four or more, contraceptive use declines with the woman's age, this being a consequence of declining fecundability, which reduces the risks of non-use. The benchmark model's predictions are consistent with the Ghana DHS data in two respects. First, the data shows appreciable contraceptive use among women with fewer surviving children than their expressed ideal. The model captures this behavior that reflects motives for birth spacing. The DHS data essentially also shows that contraceptive use peaks around the number of surviving children that is considered the ideal family size. However, the model without learning fails to predict that the use of contraception begins to rise again soon afterwards. Moreover, at no parity is contraceptive use universal; rather, the peak probability of use for women exposed to conception risk is about .33 compared to .7 according to the baseline simulation.

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