The Fertility Transition in Egypt: Intraurban Patterns in Cairo

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Fertility transitions are historically thought to have started in cities and then spread to the rest of the country. This would suggest that in Egypt we would find that Cairo was well ahead of the rest of the nation in its fertility transition. The data suggest otherwise and highlight the fact that many parts of Cairo are still experiencing high levels of fertility. Population geographers have generally examined differences only between urban and nonurban areas, but incorporating census tract level data from the 1996 and 1986 censuses of Egypt into a geographic information system, we are able to show that there are substantial intraurban geographic variations in fertility within the greater Cairo area. These spatial patterns are indicative of underlying clusters of differences in human reproduction that have important implications for understanding the decline of fertility within Cairo and the spread of that decline throughout the remainder of Egypt. *Key Words: Fertility transition, geographic information systems (GIS), Spatial analysis, Cairo, Egypt.*

The history of fertility transitions is almost universally a picture of fertility declining first in cities, with a later spread to rural areas (Sharlin 1986). Cities are places where different bundles of ideas come together about how human society should be organized, and since humans are inherently social creatures, these ideas are more likely to be shared and acted upon when there are more rather than fewer people. It would not be unfair to apply a core–periphery framework to this pattern. The cities, as the dominant core regions, set the agenda, and the periphery eventually follows suit. Some of the reasons for this can perhaps be captured by the blended perspective on the fertility transition, which combines elements of the supply-demand framework and diffusion theory (see, for example, Cleland 2001; Lesthaeghe and Surkyn 1988). The higher densities and nonagricultural economies of urban places generally serve to reduce the demand for children, and with fewer children to deal with, women, in particular, are better able to improve their educational levels, participate more fully in the paid labor force, and become financially more independent, all of which provide additional incentives to limit the level of reproduction. Over time, the ideational changes that occur in the context of the shifting demand for children is theorized to spread outward from the city. Throughout the world, this can occur very quickly as a result of improved communication and transportation that allow the routine and rapid transfer of people and ideas between the urban core and the rural periphery.

A decline in mortality, especially among infants, has been a widespread, albeit not universal, precursor to a drop in the demand for children, since it increases the supply beyond that with which families can easily cope. This is the essence of Kingsley Davis's theory of demographic change and response (Davis 1963). Yet, we have to recognize that birth rates were low in cities even before mortality declined. In fact, when the now industrialized nations were beginning to urbanize, death rates were higher in the city than in the countryside (Landers 1993; Williams and Galley 1995). Davis (1973) estimated that in Stockholm in 1861–1870, the average life expectancy at birth was only 28 years, whereas for Sweden as a whole, at that time, life expectancy was 45 years. Despite the high mortality, fertility in European cities was lower than in rural areas, and lower than the death rate, so that cities would have depopulated without a constant influx of migrants from the countryside. John Graunt, in the seventeenth century, concluded that London marriages were less fruitful than those in the country because of "the intemperance in feeding, and especially the Adulteries and Fornications, supposed more frequent in London than elsewhere . . . and . . . the minds of men in London are more thoughtful and full of business than in the Country" (quoted by Eversley 1959, 38). In Paris in the 19th century, there was an increase in the percentage of women working outside the home (especially among middle class artisans and shopkeepers). A woman with a baby who wished to continue working had to hire a wet nurse, but most wet

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nurses were peasant women who lived in the countryside. Thus, a mother would have to give up the child for several months if she wished to keep working. Infant mortality was as high as 250 deaths per 1,000 infants among those placed with wet nurses (Sussman 1977), yet in the early 1800s nearly one fourth of all babies born in Paris were placed with wet nurses. Infants were a bother, and the risk was worth taking.

Cities are also the places where innovations of every kind are apt to be discovered and/or accepted and incorporated into society through the processes of diffusion. London has for centuries been the source of inspiration of fashion of all kinds for the rest of England (Wrigley 1987), and it was in New York City that Italian immigrant women found out how middle class American women kept their families small (Sanger 1938). Cities epitomize the environment in which elements of rational choice (the trade-off between the supply of and demand for children) intersect and interact with the diffusion of innovations (methods of fertility control) to keep fertility low. From this urban platform, the innovations of fertility regulation within marriage may diffuse to the rest of the population, especially, as in the past few decades, when mortality has been declining rapidly among both urban and rural populations and so the supply of children has been rapidly increasing, whereas the demand for children has not (Cleland 2001).

Cities in developing countries, especially in Africa and western Asia, have fertility levels that are probably higher than ever experienced in European cities. Data from Demographic and Health Surveys in developing countries in the 1990s show total fertility rates (TFRs) in urban areas in 16 surveys that are above 5.0 and an additional 14 surveys in which urban areas have TFRs between 4.0 and 4.9. Without exception, the countries with urban TFRs of 4.0 or above are in sub-Saharan Africa or western Asia. When we say that cities undergo a fertility transition, however, we must recognize that it is people, not cities, who bear children. Different cultural patterns may yield different levels of fertility between and, as we will see, within urban places. The overwhelming majority of studies in the literature that examine fertility by region do so on the basis of a simple urban–rural dichotomy, as though somehow there was spatial uniformity of fertility within urban areas and within rural areas and the differences between the two represented the only element of analytical interest. Yet, it has already been shown that there are important variations in fertility within rural areas in Egypt (Weeks et al. 2000), and in this paper we ask whether the urban areas also exhibit predictable patterns of spatial variation in this regard.

We cannot therefore understand the fertility transition in any country by simple reference to urban places as the source of low fertility (nor to rural areas as the source of high fertility). We have to ask why, and under what conditions, urban residents choose to limit their fertility. This calls for a perspective that is as much cultural in nature as it is economic. It is not enough to suggest, for example, that the participation of females in the paid labor force (an economic perspective) is typically associated with lower levels of fertility. We have to ask why this connection would exist—what would lead women to become involved in the paid labor force when they had not previously been so engaged (a cultural perspective) and then ask how that decision influences, or is influenced by, the number of children that they decide to have. Indeed, we even have to ask, as Coale did many years ago (Coale 1973), what it is that influences women to think of themselves as the decision makers with respect to human reproduction. These questions are at the heart of the concept of culture, which we define as the manifestation of the way in which we humans solve the problems of everyday life and transmit those solutions to other people and subsequent generations through the teaching/learning process. What do we eat and how do we eat it? How and with what do we protect ourselves from nature and predators? How do we organize our lives to minimize risk and maximize satisfaction?

If we accept this idea of culture, then we can see that culture is bound to be highly spatial in its nature because it is easier to copy than to invent (the essence of diffusion) and people are likely to copy solutions to their problems from neighbors: the fewer and the less diverse your neighbors, the fewer options you have from which to choose. The city is the fount of innovation, including that with respect to human reproduction, precisely because it brings together a greater diversity of people and their different solutions to life's problems than will typically exist in a small rural village. In the latter places, it is much more likely that a group's solutions will become reified—perhaps justified as having been derived from a supernatural power or thought of as having been inherited genetically. This promotes resistance to change, including change in family structure, gender relations, and reproductive behavior.

But even within a city, the social context will vary from place to place, in a pattern that might be called intraurban ecology, borrowing from a growing body of research in intraorganizational ecology (for a review, see Galunic and Weeks 2001; Weeks and Galunic 2003). This idea is also captured by the concept of environmental context, which suggests that the community within which you live will influence your behavior because we are social creatures who respond to the behavioral cues of people around us. Gladwell has called this the Power of Context, which powerfully shapes our lives: "the streets we walk down, the people we encounter—play a huge role in shaping who we are and how we act" (Gladwell 2000, 167).

If the fertility transition within cities is a cultural phenomenon, then places where fertility is clustered at low levels ought to represent those parts of the city that are most heavily modernized—places where women are delaying marriage, becoming more educated, and entering the labor force in greater numbers, in response to new ways of thinking about the world in a social environment that at least permits, if not encourages, these innovative approaches to the changing circumstances. As Kohler (2001, 183) has put it, "Demographic behavior is associated with externalities that renders the adoption of low fertility by one couple dependent on the contemporaneous fertility behavior of other community members. . . . [The externalities] arise because the adoption of low fertility by some parents contributes to the erosion of traditional norms or pressures to conform. They occur because the diffusion of information is a path-dependent process and the choices of early adopters influence the availability of information for later decision makers."

Women in more innovative areas may potentially be role models for those in other parts of the city where fertility remains high, unless of course there are relatively limited means of communications between areas or groups of people. If the communication and transportation infrastructure has not kept pace with urban population growth, an already large city can seem even larger due to the difficulty of traversing from one part of town to another. Furthermore, we might expect that areas populated by migrants from rural places, and/or areas with higher concentrations of people who hold more traditional religious perspectives will be places in which people may be actively discouraged from seeking new solutions to their problems. To the extent that this is so, these would be places where fertility would be expected to be highest and where women's participation in extrafamilial activities will be most limited. This perspective posits that the social and physical environment in which people live and work represents an important part of the broader matrix of networks by which change (e.g., the diffusion of innovations) is explained (see, for example, Kohler 2001; Kohler, Behrman, and Watkins 2001). Thus, one way to think about the spatial contextualization of reproductive decisions relates to the way in which social networks may help or hinder the spread of innovations—be they ideational (people's ideas about family size) or technological (people's ability to control family size). Carley (2001), in discussing the diffusion of ideas about family size and contraceptive behavior, has argued that spatial factors that influence who interacts with whom can give rise to locally consistent patterns of shared attitudes, meanings, and beliefs (194). Following Burt's (1992) concept of structural holes (built on Granovetter's [1973] notion of the strength of weak ties), we would expect that strong family structures, even within a city environment, would create fewer structural holes in the lives of family members, thus reducing the chance of having the kinds of weak ties that encourage innovation. From this perspective, we would hypothesize that neighborhoods dominated by dense and complex family relationships would be unlikely to be among the early participants in a city's fertility transition. We would expect this influence to operate especially through the mechanism of gender roles.

We argue then that spatial patterns are important because they offer clues to underlying causes and potential consequences of behavior. As Weeks (2003a) has noted, there is very little attention given in the literature to the social causes and consequences of fertility trends at the local level. It might be argued that these spatial patterns are obvious, but this is a testable hypothesis that has not, in fact, been tested in the literature. Rather, the emphasis in the literature has been on examining fertility at the individual level, using data from surveys that by and large do not permit a neighborhood analysis. These studies, of necessity, focus attention on national comparisons or on regional differences within a country. We suggest that the intraurban ecology—the local, within-city, place-to-place variations—may hold the key to understanding the fertility transitions that occur among urban populations, and thus to a better understanding of how it is that low fertility is accomplished beyond the city. There can be little doubt that national and regional events affect fertility levels regardless of where a person lives (see, for example, Fargues 1997) and that events outside an area can therefore be instrumental in producing change at the local level (Courbage 1994). These ideational changes may have less spatial dependence than other forms of influence, but the extent to which messages are heard and interpreted in a particular way, and thus the extent to which they ultimately affect behavior, may be closely related to the local environmental context. It is our view that the lack of literature on intraurban patterns of human reproduction is not due to a lack of interest in the subject, nor to the belief that somehow such results are trivial, but rather to the limited ability to conduct such an analysis prior to the recent technological developments in the field of geographic information science.

It is well known that cities may take on any of a wide variety of spatial patterns with respect to where people of differing social classes might live. (Knox 1994; Macionis and Parrillo 1998). In general, these patterns can be classified as being consistent with concentric zones, sectors, or multiple nuclei models. To the extent that (a) residential segregation exists by social class and (b) social class determines fertility, these residential patterns will define a city's spatial pattern of reproduction. It has been known for centuries that fertility tends to be lower in the higher social classes. Adam Smith observed in the *Wealth of Nations* that "Barrenness, so frequent among women of fashion, is very rare among those of inferior station. Luxury in the fair sex, while it inflames perhaps the passion for enjoyment, seems always to weaken, and frequently to destroy altogether, the powers of generation" (Smith 1776, Book 1, viii.37). If social class determines both where you live and how many children you have, then the spatial component of reproduction will be explained completely by social status. If social class does not determine residence, but does determine levels of reproduction, then we would not expect to find a spatial pattern to fertility. Similarly, if social class determines residence but is not predictive of fertility, then again we would not expect to find a spatial pattern to fertility, at least not one that was associated with social status per se.

Our hypothesis in this research is that fertility levels are determined partly by social class, measured by human capital variables such as education, labor force participation, and occupation. We expect that this determinant of fertility will have a spatial component, but that the spatial component will be explained by residential separation in terms of social class. However, we also hypothesize that there is a distinctly spatial component to fertility levels that is independent of social class or human capital variables. This is what has been called the neighborhood or environmental context effect on demographic behavior (Weeks 2003a). Because humans are inherently social creatures, we are influenced in our behavior by the people with whom we come into contact and with whom we interact. While much of that interaction may occur in places other than where we live, it is also likely that some of the most intensive and persuasive influences will in fact occur in the context of the local area in which we reside. This effect is a result of the networking and connectivity of humans, and of the diffusion of ideas and behavior (or the stifling of such innovation—social control) that occurs among people sharing the same physical space, regardless of their social class or human capital characteristics. We hypothesize that this influence on levels of reproduction will be spatially dependent and will index unmeasured attributes of the neighborhood that affect fertility independently of the social status of neighborhood inhabitants. More formally, the models that we test are as follows:

1. Fertility at time t = fn {social class + neighborhood context}
2. Fertility at time t + n = fn {social class + neighborhood context}
3. Δ Fertility from time t to t + n = fn{Δ social class + Δ neighborhood context}.

Within cities of developing nations, then, we expect to discover distinct spatial clusterings of high and low fertility, of declining and not declining fertility levels. A portion of this clustering will be due to the effect of residential patterns by social class, but another portion will be independent of human capital factors and will be due to what we have called neighborhood context. Changes in both of these sets of factors can be expected to influence the change in fertility over time. Furthermore, to the extent that cities differ in their fertility transition, their impact on the fertility transition in the peripheral areas, and on the nation as a whole, may also differ. In other words, the type of fertility transition taking place within an urban area is hypothesized to determine the influence that a given urban area will have on fertility levels beyond the metropolitan boundaries. This paper, then, tests hypotheses about spatial dependence in the levels of human reproduction within cities of developing countries. We test these hypotheses with data from Cairo, Egypt, and then discuss how this perspective helps us better to understand the broader patterns of the fertility transition in developing nations.

The Fertility Transition in Egypt and in Cairo

Egypt began the 20th century with 10 million people and ended it with almost 70 million. United Nations projections suggest that the population will exceed 127 million by 2050 (United Nations Population Division 2003). Most of the increase has taken place since the end of World War II, with a rapid decline in mortality, unaccompanied at first by any noticeable decline in fertility. Prior to World War II, more than 250 out of every 1,000 Egyptian infants died before reaching their first birthday (Bucht and El-Badry 1986; Fargues 2000), but since the late 1940s, the infant mortality rate has dropped quite steadily, down to the current level in which about 40 in 1,000 die before age one.

For at least 20 years this decline in mortality was not matched by a drop in birth rates. Data from the World Fertility Survey suggest that the total fertility rate for all of Egypt was 7.1 in the early 1960s, and even in the metropolitan areas (Cairo and Alexandria combined), the TFR in the 1960–1965 period was 5.9 (International Statistical Institute 1983). Abu-Lughod (1965) used data from the 1960 census to show that women in Cairo who had been married for 30 or more years had averaged 8.1 live births. At the same time, there was a clear negative relationship between education and fertility, so that illiterate women in Cairo averaged 8.4 live births after 30 or more years of marriage, compared to 3.9 live births for women who had at least completed high school. She concluded that the major proximate determinant of these differences was age at marriage, and this conclusion was echoed in the findings from the 1980 Egyptian Fertility Survey (the Egyptian implementation of the World Fertility Survey).

As of the 1960s, then, fertility was slightly lower in Cairo than elsewhere in the nation, and this was due at least in part to the effect of delayed marriage occasioned by higher levels of education among some women in Cairo. Between the mid-1960s and the mid-1980s the pattern of fertility change was difficult to ascertain in Egypt (Bucht and El-Badry, 1986; Zaky, Wong, and Sirageldin 1993), but in retrospect that period can be seen generally as representing the very early stages of the fertility transition. Table 1 shows the trend over time in the number of children ever born by age to women in Cairo governorate compared to the entire country for the fertility surveys of 1980, 1988, 1992, 1995, and 2000. In 1980 women in Cairo were completing childbearing (ages 45–49) having given birth to 6.14 children, compared to the 6.87 children for women in Egypt generally. By the year 2000, women in Cairo aged 45–49 had given birth to 4.07 children, a drop of 2.07 children during that two-decade period. Among all Egyptian women that age, the two-decade drop was only 1.33 children, but the gap between Cairo and all of Egypt was less at each successively younger age. Overall, an inspection of the data in Table 1 suggests that women in Egypt as a whole are about 12–15 years behind women in Cairo with respect to the number of children born at any given age. For example, in 1980 women in Cairo aged 25–29 had given birth to 2.56 children; and in 1995 women in all of Egypt reached that low level. At ages 30–34, women in Cairo in 1980 had given birth to 3.86 children, and it was sometime between the 1992 and 1995 surveys that all of Egypt reached that level.

We can see then that the onset of the fertility transition is nearly as recent in Cairo as it is in the rest of the nation, and so Cairo is not leading the nation by a very wide margin. As a result, there is a still a considerable distance for fertility to drop in Cairo before even approaching replacement level. That does not mean, however, that there are not pockets of very low fertility in Cairo; it just means that they are not yet the norm. Thus, if we accept the idea that urban places take the lead in fertility declines, then if we are to understand why fertility might drop to low levels throughout Egypt, it is critical that we understand how they have dropped within Cairo: to find out where fertility is high in Cairo and where it is low, where it is declining, and where it might even be increasing. Only with answers to these questions can we begin to decipher the likely underlying mechanisms of the Egyptian fertility transition.

Study Site and Methods

The study site is the Greater Cairo region of Egypt (see Figure 1). The urban area of Greater Cairo represents the governorate of Cairo on the east side of the Nile River as it travels north through the metropolitan region, the portion of the governorate of Giza that is along the west bank of the Nile River within the metropolitan region, and the

Table 1. Children Ever Born to Women by Age, Cairo and Egypt: 1980–2000

	Age group							
	15–19	20–24	25–29	30–34	35–39	40–44	45–49	Sample size
Cairo								
1980	0.79	1.60	2.56	3.86	4.78	5.45	6.14	1,593
1988	0.71	1.38	2.36	2.96	3.83	4.92	5.21	1,196
1992	0.76	1.17	2.30	3.14	3.88	4.27	5.24	1,078
1995	0.74	1.10	2.00	2.83	3.63	4.44	4.77	1,426
2000	0.74	1.30	1.93	2.67	3.19	3.86	4.07	1,129
1980 minus 2000	0.05	0.30	0.63	1.19	1.59	1.59	2.07	
Egypt								
1980	0.63	1.81	3.07	4.61	5.79	6.46	6.87	8,788
1988	0.65	1.70	2.94	3.96	5.28	5.88	6.25	8,911
1992	0.72	1.63	2.76	3.93	4.85	5.62	5.99	9,864
1995	0.62	1.52	2.59	3.63	4.57	5.25	6.02	14,779
2000	0.58	1.38	2.37	3.42	4.37	4.95	5.54	15,573
1980 minus 2000	0.05	0.43	0.70	1.19	1.42	1.51	1.33	

Sources: Calculated from 1980 Egyptian Fertility Survey, and Demographic and Health Surveys for 1988, 1992, 1995, and 2000.

Figure 1. The study site of Greater Cairo, Egypt.

southern portion of the governorate of Qalyubia, just to the north of Cairo. The United Nations estimates the population of the Cairo metropolitan area to have been 9.5 million as of the year 2000 (United Nations 2002). Our study area represents data for 299 *shiakhas* (equivalent to census tracts) in the Greater Cairo area. El-Batran (1997) notes that the shiakha has traditionally been viewed in Egypt as the equivalent of a neighborhood—a place with a social identity where services to the population were provided through local resources. The census is the only available source of population data at the local level of geography in Egypt, and the amount of information available from the census in Egypt is somewhat limited. However, we have been able to use spatial analytic techniques in conjunction with Demographic and Health Survey (DHS) data to improve the depth of our findings. We utilize data from the 1986 and 1996 censuses in Egypt, relying upon indirect measures of fertility derived from the age structure. Our study site had an unadjusted population count of 8.4 million in the 1996 census, so it represents most of the population within Greater Cairo.

The first question to be dealt with is with regard to the accuracy of the age and sex structure. We have used information from the 1995 Demographic and Health Survey in Egypt, as well as vital statistics for the years 1995–1997 for Greater Cairo as sources of data against which to compare the results of the 1996 census, especially at the youngest ages. The 1995 DHS included 1,613 households from 41 different shiakhas in our greater Cairo study site. From the household listing in the DHS we were able to reconstruct the age and sex structure as reported for each household, representing a sample household population in Cairo in the 1995 DHS of 7,721 persons. The age groups that are of importance for estimating fertility are children aged 0–4 and women of reproductive age (15–49), so we focused attention on those age and sex categories, but especially on the youngest age group, which is notoriously the least well enumerated. We assumed that the experienced interviewers of the DHS were likely to obtain more accurate information than would have been obtained by enumerators in the census, so we assumed that if the census age distribution showed a smaller percentage of children than the DHS, then that was evidence of underenumeration in the census.

We did not assume that underenumeration, if it exists, would be spatially uniform. The size of the DHS sample permitted us to disaggregate the household listings by governorate within Greater Cairo, of which there are three—Cairo, Giza, and Qalyubia. For smaller areal units, the sample size was too small to yield useful comparisons with the census. Comparing the DHS age distribution with the census age distribution led to the conclusion that in 1996 children aged 0–4 were 24 percent underenumerated in Cairo governorate, and 16 percent underenumerated in

Giza governorate. In Qalyubia governorate, there was not a statistically significant level of underenumeration.

We were also able to draw upon vital statistics data to evaluate underenumeration. We have data on the number of live births by *qism* (the aggregation of shiakhas) for Greater Cairo for the years 1995 through 1997. We took the average of those three years, multiplied it by five, and then applied survival ratios from life tables for Cairo (described below) to estimate the population aged 0–4 that would be implied by those data on live births, and then we compared that number with the data from the census. Again, we compared data at the governorate level within Greater Cairo. The results are nearly identical to the comparisons with the DHS data, in that we found a 24 underenumeration of children 0–4 in Cairo, a 19 percent underenumeration in Giza, and no statistically significant underenumeration in Qalyubia.

We have therefore adjusted the census figures in each shiakha in Cairo governorate to reflect a 24 percent underenumeration of children aged 0–4. For the shiakhas in Giza governorate, census data were adjusted upward at age 0–4 to reflect a 17.5 percent underenumeration (the average of the DHS and vital statistics estimates), and no adjustment was made for shiakhas in Qalyubia governorate. Our adjustment for underenumeration is consistent with the concern that existed on the part of the Egyptian government, which withheld release of data from the 1996 census for more than two years, at least in part because of concern about the apparent undercount (Sutton and Fahmi 2001).

We also conducted a similar comparison of the 1986 census data at the youngest ages with information drawn from the 1988 DHS. We ignored the two-year temporal mismatch since we had no way to account for it. In 1988 there were 24 shiakhas in our study area that were sampled for the DHS. They included a total of 1,451 households, from which we were able to extract age distributions based on a total of 6,638 persons. Again we separated the shiakhas into each of the three respective governorates. However, in this comparison we found that none of the differences in the percentage of the population that was aged 0–4 was statistically significant, and so no adjustment for underenumeration was made for the 1986 census. However, we did drop one shiakha—al-Mohammadi, which is in the Al-Waily qism, or district. In 1976 this was a slum area that was then torn down for the construction of the Ain Shams Hospital, essentially leaving no one to be counted in the 1986 census, and then the area was rebuilt and repopulated by 1996. Because of the lack of continuity of the population, it was dropped from the analysis.

In order to indirectly estimate the total fertility rate from the adjusted age data, we then rejuvenated the adjusted population of girls and boys aged 0–4 from the census by dividing by the respective sex-specific survivorship rates. We tested the issue of spatial variability in infant mortality rates by calculating infant mortality rates from the vital statistics. This comparison was restricted to the governorate level, since infant deaths, even more than live births, seem to be disproportionately numerous in those qism that had more hospitals, suggesting that infant deaths were often recorded at the address of the hospital, rather than the residence. The analysis did not suggest the existence of statistically significant differences in infant mortality rates among the three constituent governorates, so no spatial adjustment was made in survivorship rates. These rates were calculated from life tables derived from ${}_nM_x$ data compiled by the Cairo Demographic Center (2001). For females in 1996 the probability of survival from birth to age five was estimated to be 0.94350 and for males it was 0.94334. The population of females of reproductive age (15–49) was then rejuvenated using the same life table data, applying a five-year survival probability of 0.99035. From these estimates we calculated a five-year general fertility rate, and dividing that by five produced an estimate of the average single-year general fertility rate. This value was combined with data on the female population by five-year age groups in each shiakha to estimate the total fertility rate based on empirically derived relationships between the GFR, the female population, and age-specific fertility rates, using algorithms developed by Arriaga and his associates (Arriaga, Johnson, and Jamison 1994). For 1986, we rejuvenated the population of boys aged 0–4 with a survivorship ratio of .91266, and a rate of .92234 for girls. The survival rate applied to women aged 15–49 in 1986 was .97887.

Using this approach, the weighted TFR for Greater Cairo in 1996 was calculated to be 2.89. We were able to test the validity of this approach to measuring fertility by applying it to the data derived from the 1995 Demographic Health Survey for households in the Greater Cairo region. First, we used the DHS age data to indirectly estimate the total fertility rate for the DHS households following the algorithm described above, and we then compared that calculation with the TFR as measured directly by the responses that women gave to the question of births in the year preceding the DHS. Our indirect method of estimation, as described above, yielded a TFR of 2.92, whereas the TFR based on the DHS responses of women to the question of births in the past five years produced a value of 3.11. There is no direct way to evaluate the statistical significance of these observed differences, but we judged the three values to be sufficiently similar to give us confidence in the validity of the indirect method of measuring fertility that we are employing in our analysis.

Spatial Variability in Fertility in Cairo in 1986 and 1996

Our calculation of the TFR in Cairo for 1996 was, as indicated above, 2.89. This represented a decline from 3.47 in 1986, calculated in the same way as the data for 1996. This did not represent a substantial decline, of course, and it was a smaller decline than for the country as a whole. Overall, fertility in Cairo is still a considerable distance from replacement level, but there are pockets of below-replacement fertility, just as there are pockets of very high fertility. In 1986 the highest TFR registered within a shiakha was 7.40, whereas the highest in 1996 was 5.84. In 1986 the lowest TFR was 1.09, and the bottom dropped to 1.00 by 1996. Figure 2 illustrates the spatial variability in Cairo in 1996, while Figure 3 shows the pattern in 1986.

Fertility by shiakha shows an unmistakable pattern of lowest fertility in the center of Cairo in 1996 (Figure 2), with fertility increasing in a manner similar to that of concentric rings as one moves out from the center. From its lowest values near Tahrir and Talaat Harb Squares, fertility increases with distance from the center of the older part of the city. In a small section of the center of the city, fertility levels are at below-replacement levels, but at the suburban edge of the city, TFRs are routinely above 3.5 children per woman. If we assume that the wealthier, better-educated, elite residents live in the city center, that they have the lowest fertility, and that social status declines and thus fertility rises in a gradient out from the city center, then that is at least consistent with the pattern that can be observed in Figures 2 and 3.

On the other hand, anecdotal evidence suggests that the middle classes have been abandoning the center of the city as it becomes increasingly noisy, polluted, and degentrified (Rodenbeck 1999). These families have moved into many of the informal settlements (see below) on the edges of the older part of Cairo (El-Batran 1997), and so, to the extent that fertility levels are influenced by such residential shifts, the concentric ring pattern may not represent our expectations. We test these propositions in the analysis described below.

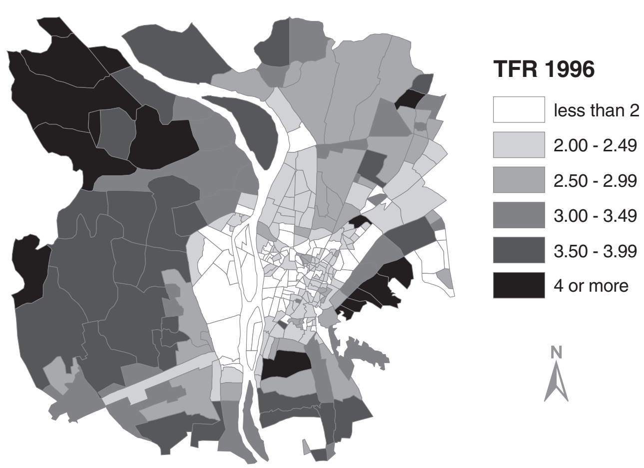

Figure 2. Spatial variability in fertility in Greater Cairo, 1996.

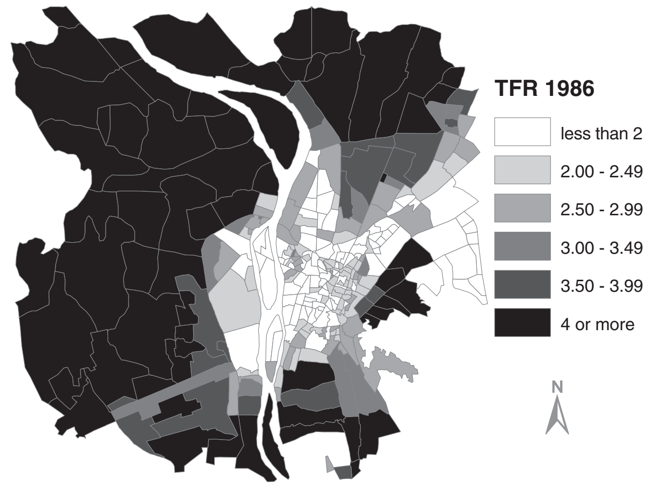

Figure 3. Spatial variability in fertility in Greater Cairo, 1986.

The pattern in 1986 (Figure 3) is similar to that in 1996, with a general replication of the concentric ring picture, but with higher fertility levels in most places in 1986 than in 1996. In 1986 there is a more obvious dichotomy between the lower fertility in the older parts of Cairo and the considerably higher levels of fertility in the newer suburbs, which are heavily characterized by informal settlements. The change in fertility between the two censuses can be anticipated by the patterns in Figures 2 and 3 and, indeed, Figure 4 shows that the most rapid rate of decline tended to be in the more suburban areas, whereas most of the older, central portion of Cairo was experiencing either no change or even a slight rise in fertility levels.

Without question, the fertility transition is taking place unevenly within the Cairo metropolitan area. The center of the city is where fertility remained low (typically below the replacement level) between 1986 and 1996. This area represents essentially an axis from the older parts of Giza (to the west of the Nile), through downtown Cairo, and out toward the airport (which is just beyond our study site in the northeast section). Scattered throughout this area, however, are neighborhoods that experienced rapid decline in fertility between 1986 and 1996. The area just beyond the city center tended to experience more rapid declines in fertility— keeping in mind that most of these areas nonetheless had fertility levels that were still well above replacement in 1996. These areas include the well-known popular quarters of Manshiat Nassir on the eastern

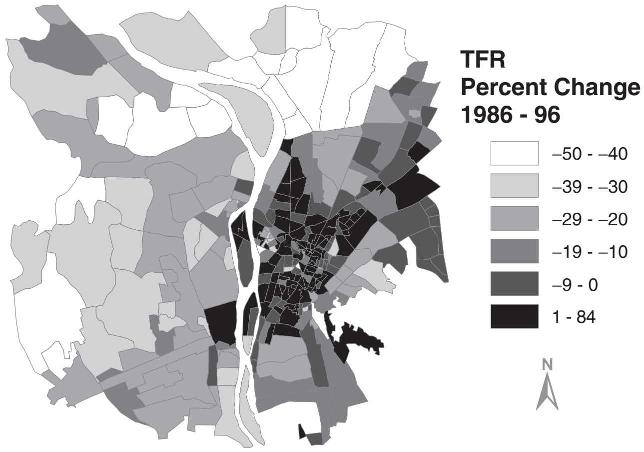

Figure 4. Changes in fertility in Greater Cairo, 1986 to 1996.

edge of the city, and the Imbaba slum area on the Giza side of the Nile to the northwest of downtown Cairo. As already noted, however, there were pockets in which fertility did not drop—in fact, increased—during that intercensal period. This pattern is especially noticeable in the Sayyida Zeiynab area which, although a well-established neighborhood, has taken on many characteristics of an informal area (Bayat 1997). Between 1986 and 1996, fertility levels increased in 12 of the 15 shiahkas that comprise the qism of Sayyida Zeiynab. The qism of Darb Al-Ahmar, which is adjacent and to the northeast of Sayyida Zeiynab, is the other major neighborhood experiencing an increase in fertility. Between 1986 and 1996 11 of Darb Al-Ahmar's 14 shiakhas increased their TFRs.

The pattern of change in fertility between 1986 and 1996 is consistent with the idea that the middle classes were vacating the inner areas (leading to a stop in the decline of fertility in those places) and moving into the more suburban areas (perhaps leading the fertility decline in those places). Furthermore, some of the areas near the center of Cairo have been increasingly transformed into informal settlements, with the potential for higher fertility. If these interpretations are correct, then any diffusion of low fertility norms in Cairo would have to be explained by relocation factors (lower fertility couples moving to different parts of the city) as well as by contagion factors (those couples influencing fertility norms in their new location and the couples left behind in the old location having a potentially opposite effect).

We can use the $G_i(d)$ statistic (Getis and Ord 1996, 1992; Ord and Getis 1995) to evaluate the contagion effect between 1986 and 1996 around those places that had the lowest fertility in Cairo in 1986. The $G_i(d)$ statistic indicates the extent to which a location (i) is surrounded by a cluster of high or low values. The statistic incorporates a symmetric one/zero spatial weight matrix, with ones for all links (j) defined as being within distance (d) of a given (i), excluding (i), and all other links are zero. Distance is measured between the centroids of the polygons (in this case the geographic center of each shiakha). In its original form (Getis and Ord 1992) the numerator of the statistic is the sum of all x(j) within (d) of (i), while the denominator is the sum of all x(j). The null hypothesis is that there is no association between the value found at site (i) and its neighbors within a specified distance (d). When the statistic is treated as a standard normal deviate, the expected value under the null hypothesis is 0, with a variance of 1 (Ord and Getis 1995). Positive values of $G_i(d)$ that exceed a *z*-score of 1.96 (the .05 level of statistical significance) indicate spatial association of high values, whereas negative values of $G_i(d)$ that are less than -1.96 indicate spatial association of low values. An increase between 1986 and 1996 in the distance at which $G_i(d)$ peaked around a site (i) would be consistent with a pattern of diffusion around that neighborhood.

We calculated this statistic for the lowest fertility shiakhas in 1986 to see if the distance at which clustering peaked changed between 1986 and 1996. Qasr al-Nil is the area (qism) at the heart of the elite portion of older Cairo, and in both 1986 and 1996 it registered the lowest levels of fertility in Greater Cairo. Its four shiakhas include Ismailiyya, Ma'ruf, Qasr al-Dubara, and Garden City, and institutions such as the American Embassy and the American University in Cairo are within this qism. In 1986 (and again in 1996) each of these four neighborhoods had TFRs that were below replacement level. In 1986 the value of $G_i(d)$ peaked at 5,000 meters for three of the four neighborhoods and at 6,000 for the fourth (Garden City). In 1996, the peak distance remained at 5,000 for two of the four, but actually declined for the other two, indicating no increase in the pattern of clustering between 1986 and 1996. We interpret this to mean that there is no evidence that low fertility norms were diffusing from the low fertility area of Qasr al-Nil to other parts of the city during this period of time.

Quantifying the Spatial Component in Fertility in Cairo

Our goal, analytically, is to decompose the variability in fertility in Greater Cairo across space and over time into that part that is attributable to human capital/social class factors that are only incidentally associated with locational attributes, and that part that is specifically spatial because it is associated with characteristics of the local neighborhood context. The variables in the analysis are listed in Table 2. From the census we are able to derive several variables that measure the human capital and social class characteristics of a shiakha. These include educational level, which we summarize by calculating the percentage of the population aged 15 and older that has at least an intermediate level of education (equivalent to at least some high school). We calculate these percentages separately for males and females. The participation of women in the paid labor force is a well-known correlate of lower fertility, and we are able to measure that for women aged 15 and older. Probably the single best measure of social status is the occupational status of the householder. The census does not ask for characteristics specific to the householder, but we know from other sources that in Cairo, as in most places, the householder tends to be male, and we are able to calculate the percentage of economically active males aged 15 and older whose occupation is in the highest occupational status categories, which include technical, professional, administrative, and managerial occupations.

Not surprisingly, all of these variables are highly intercorrelated. In 1996, for example, the lowest correlation coefficient among any two of these four variables was .851, and in 1986 it was .888. For this reason, we combined them into a single index using principal components analysis. This allowed us to maximize the usefulness of all four variables without detracting from the overall interpretability of the results. In both 1986 and 1996 the combined index weights each variable roughly equally into a measure that we call STATUS. This of course refers to a value for the shiakha (census tract), not individuals, and we are mindful of the way in which the results will need to be interpreted.

We want to measure the neighborhood context with a set of variables that are descriptive of the social environment in ways that are as independent as possible of the social status that we have attached to the area. One such candidate is the designation of a neighborhood as being an Ashawayat, which refers to settlements occurring outside the boundaries of planning and legitimacy. The term literally means disorganized and by implication it means unplanned (El-Batran 1997). Informal settlements are those that have been developed privately, outside the scope of government policy. As El-Batran and Arandel (1998) note, the growth of these areas in Cairo has occurred even in the face of housing vacancies in the older areas of the city because housing prices in that latter area have become too expensive for many families. This is partly a consequence of Egyptian government policies of removing some of the slum areas near the center of the city. This has had the effect of reducing population density and increasing the demand for (and thus the rent of) the places that remain or are built on the sites of the former slums. Thus, some families have been pushed out of the

Table 2. Variables Included in the Analysis

Category	Variable	Abbreviation*	Source
Dependent	Total Fertility Rate	TFR	Measured indirectly from census data
Social class/Human capital	Percent with intermediate education or more (separate for males and females)	EDUC_F EDUC_M	Census
	Percent of females 15+ in the labor force	FLFP	Census
	Percent of males with higher occupational statuses	HI_OCCUP	Census
	PCA index combining above 4 variables	STATUS	PCA
Neighborhood context	Informal or formal neighborhood	INFORMAL**	(El-Batran and Arandel 1998)
	Land cover metrics	VEG IMP*SHD (interaction term of IMP times SHD) SOIL TXTURE	RS imagery
Proximate determinants of fertility	Percent of women 15–29 who are not yet married	NOTMAR	Census
	Percent of nonpregnant married women of reproductive age using a modern method of contraception	CONTRA	DHS

*Each variable is also followed by an 86 or 96, indicating data for one of those two years, or 8696, indicating the change between those two years.
**Data are available only for one year that is closest in time to the 1996 census.

center into informal areas that tend to be on the edges of the older parts of Cairo. Almost by definition, they are not well served by infrastructure, leading to quality of life issues that will have an impact on all residents, regardless of social class. However, in the 1990s, the government embarked on a program of improving infrastructure in informal settlements in order to dampen complaint and tamp down the rise of Islamic fundamentalism. This has led to continuous increases in land prices, putting many of these places beyond the reach of the poor. As a result, the informal areas increasingly tend to house middle- and upper-income groups. Thus, informal does not necessarily mean poor, and although living in an informal settlement could be thought of as an indicator of social class, it is more a characteristic of a place rather than of the people who live there, and for that reason, properly belongs in the category of neighborhood context.

Another way to characterize the built environment is through the classification of data from remotely sensed imagery, and we were able to draw upon such analyses that have already been done for the Greater Cairo area from imagery for both 1986 and 1996. The details of the classification procedures are described elsewhere (Rashed et al. 2001; Weeks 2003b). We employed Ridd's (1995) V-I-S (vegetation, impervious surface, soil) model of urban ecology from remotely sensed data to guide a spectral mixture analysis (SMA) of medium-resolution, multi-spectral images for Greater Cairo for 1986 and 1996. The usefulness of this approach has been noted by Phinn and his associates (2002), Rashed and his associates (Rashed and Weeks 2003; Rashed et al. 2001; Rashed et al. 2003), and Wu and Murray (2003). We added another component to Ridd's physical model—shade/water—following the work of Ward, Phinn, and Murray (2000) indicating that the fourth physical component improves the model in settings outside of the United States. Spectral mixture analysis permits a soft classification of a pixel into the likely fraction of the pixel that is composed of each of the four physical elements (vegetation, impervious surface, soil, and shade). By summing up these fractions over all pixels contained within each census tract, we have a composite measure of the fraction of area in each census tract covered by each of the four land cover types. This provides us with a quantitative way of describing the built and natural environment in each neighborhood. For each shiakha we have a measure of the percentage of land cover that is characterized as vegetation, the percent that is impervious soil, bare soil, and shade.

Following the Ridd model, we expect that areas that are in the older part of Cairo will be characterized by higher fractions of impervious surface and lower fractions of vegetation. However, informal settlements are also expected to have a higher fraction of bare soil, since many of the buildings are made of local material and are thus potentially indistinguishable from bare ground. In the outer suburbs we expect to find a higher proportion of vegetation relative to all other types of land cover. Note that we will include only three of the four land-cover classes in the model in order to keep from overspecifying the model. We will exclude the vegetation fraction because it has the lowest variability and is the most highly skewed of the fractions, with only a few of the shiakhas having more than very low fractions of area covered by vegetation. Shade in our land cover classification is largely a proxy for the presence of multistory buildings, and in many areas the percentage of impervious surface and shade vary closely together. We used a rule of thumb that any variable with a variance inflation factor (VIF) greater than 10 would be excluded from the model (Montgomery and Peck 1992) or combined in an interaction term. On this basis, the fractions of both impervious surface and shade were replaced by an interaction term representing the product of the two. To those variables we have added a texture measure obtained by passing a moving window over the surface of a panchromatic image to measure the variability in brightness within the window compared to the average of windows surrounding that one. A high level of variability or contrast represents a heterogeneous surface, such as we would expect to find in the suburbs, whereas a low level of variability represents a more homogeneous surface, such as the older quarters of central Cairo.

The final set of variables represents the proximate determinants of fertility (Bongaarts 1978, 1982), those factors through which the previously listed variables must act in order to influence fertility. Education, for example, does not directly influence fertility; rather, it influences the timing of marriage and the likelihood of using means to prevent pregnancy. We do not have precise data on age at marriage, but we do have a proxy variable from the census, measured as the ratio of women 15 years of age and older who are not currently married to all women aged 15 to 29. The higher this ratio, the higher will be the average age at marriage in the neighborhood. We do not have data for each shiakha on contraceptive utilization, but we do have such data for women sampled in the 1995 and 1988 Demographic and Health Surveys. The 1995 DHS interviewed married women of reproductive age in 41 different shiakhas in Greater Cairo. For each of these 41 neighborhoods we have summarized the percentage of nonpregnant women who were currently using a modern method of contraception. Those data were then combined with the census data on the percentage of women who were single and with the total fertility rate in the neighborhood. We employed data from the 1988 DHS in a similar comparison with the 1986 census. For 1988, the DHS included 24 shiakhas in the Greater Cairo area, and so we used data for those places.

For 1996, the analysis shows that the combination of the percent of young women who are single and the number of women using modern contraceptives accounts for 70 percent of the variation in fertility in the 41 shiakhas that were included in the DHS. However, the respective beta coefficients of −.784 for the percent single and −.171 for the percent using modern contraceptives show (when squared) that variability in the delay in marriage is 20 times more important a predictor of fertility levels than is contraceptive utilization, which, in fact, was not a statistically significant predictor. We mentioned above that the delay in marriage has regularly been cited as an important factor in the Arab fertility transition (see also Rashad 2000), and these findings are consistent with that conclusion. Contraceptives tend to be far more available to married women than to single women, and single women tend to be much more heavily supervised in their relations with men than would be true in more Western countries. Thus, unlike in Europe and the United States, a delay in marriage is much more closely associated with a decline in fertility, rather than with a rise in out-of-wedlock births.

The data for 1986, combined with contraceptive use from the 1988 DHS, yielded comparable results. The combination of the percent of young women still single and the use of modern contraceptives by married women of childbearing age accounted for 96 percent of the variability in fertility in the 24 shiakhas from which respondents were drawn for the 1988 survey. Virtually all of that explanatory power resided in the marriage age variable (with a standardized beta coefficient of −.969) and the contraceptive use variable not only had a low, not statistically significant beta coefficient (.030), but it was also in the wrong direction. If we compare the weighted percentage of women using modern contraceptives in 1988 (55 percent) with that in 1995 (53 percent), we find that this difference is negligible and not statistically significant. On the other hand, the percent of young women remaining single went up from 44 percent in 1986 to 54 percent in 1996 in the neighborhoods included in the respective DHS samples. That difference is still not quite large enough to be statistically significant, given the relatively small number of shiakhas in the 1988 DHS, but it is in the expected direction. The important point to be taken from these analyses drawing upon the DHS data is that we can best understand the spatial patterns of fertility in Greater Cairo by reference to the percentage of young women who are not yet married (a delay in marriage), and so our lack of contraceptive use data for each shiakha seems unlikely to influence our results.

We know already from Figures 2 through 4 that fertility levels in both years are spatially autocorrelated and that the change over time is autocorrelated. Using Moran's I as the index of spatial correlation, with a weights matrix based on the inverse of squared distance between shiakha centroids, the *z*-normal value of I for fertility in both 1986 and 1996 was statistically significant, as it was also for the change between 1986 and 1996. The question is whether the predictor variables are able to account for that spatial pattern on their own, or whether there is a residual spatial component that is unmeasured in the initial model and must thus be accounted for.

Predictors of Fertility Levels in Cairo in 1996

Our first model looks at the first and most basic question that we posed in this research: Is the spatial variation in fertility in Cairo explained simply by the residential pattern of the population by socioeconomic status? We examined this question by calculating an OLS bivariate regression between TFR and STATUS and then examining the residuals of that model. In 1996, the resulting R^2 was only .30 and Moran's I, calculated for the residuals, was very high and statistically significant, signaling the presence of spatial autocorrelation in the residuals. From this we can conclude that (a) socioeconomic status is not the sole predictor of fertility rates in Cairo, and (b) there is a spatial pattern to fertility that is not accounted for by the socioeconomic status of neighborhoods. The residuals are mapped by neighborhood in Figure 5 where it can be seen that STATUS tends to overpredict the TFR in the central part of the city (where the predicted TFR tends to be higher than the actual values) and it underpredicts fertility in the suburbs, especially in Giza. (These patterns are very similar in 1986, and so we have not shown them here.)

Having determined that STATUS is not going to give us a full picture of fertility patterns in Cairo, we move to a more complete model in which we estimate TFR based on the combination of socioeconomic status, environmental context variables, and the proximate determinant of the proportion of young women who are single.

$$\begin{aligned} TFR = \beta_0 &+ \{\beta_1 STATUS\} + \{\beta_2 INFORMAL \\ &+ \beta_3 IMP^{*}SHD + \beta_5 SOIL + \beta_6 TEXTURE96\} \\ &+ \{\beta_7 NOTMAR\} + \varepsilon \end{aligned}$$

The results for 1996 are shown below, where the standardized beta coefficient and its associated t-score

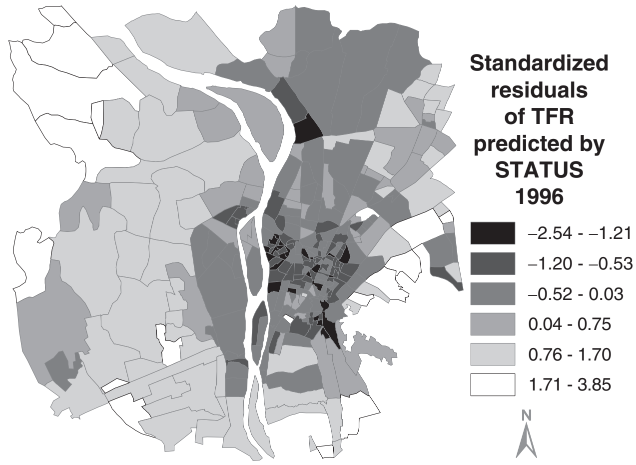

Figure 5. Map of residuals of predicted values of TFR based on socioeconomic level of neighborhoods, Cairo 1996.

(in parentheses) is shown for each variable in the equation (variables that are not significant at the .05 level are in italics):

$$\begin{aligned} TFR96 = \{ & -.020(-.451)\mathit{STATUS96}\} \\ & + \{-.060(-1.943)\mathit{INFORMAL} \\ & + -.139(-3.280)\mathrm{IMP^{*}SHD96} \\ & + -.121(-2.342)\mathrm{SOIL96} \\ & + -.124(-2.348)\mathrm{TXTURE96}\} \\ & + \{-.824(-15.141)\mathrm{NOTMAR96}\} \end{aligned}$$

The R^2 for 1996 was .763, indicating a good fit with the data. There was no evidence of strong multicollinearity, nor of heteroscedasticity. However, the residuals were spatially autocorrelated, measured by the *z*-normalized Moran's I. This indicates that the model is spatially misspecified and we will correct for that below. However, we can note at this point that the variable NOTMAR, representing the percentage of young women who are still single (our proxy for age at marriage), is by far the most important predictor of fertility. The higher this fraction, the lower is fertility. This, of course, is what we would expect. We anticipate that it is through this proximate determinant that fertility is influenced. Three of the environmental context variables (the interaction of impervious surface and shade, the soil fraction, and texture) are statistically significant, but the standardized beta coefficients indicate that they are only weakly predictive of fertility independently of the age at marriage variable. As impervious surface and shade increase together, fertility declines, which is what we expected. However, as texture increases, fertility declines, and that is contrary to our expectations. We expected that more texture would be associated with the outer areas where fertility is higher. The socioeconomic status variable is not significantly significant in combination with the other variables in the model, even though it does have a fairly high bivariate correlation with fertility, as we discussed above.

Spatially Filtered Regression

In order properly to specify our model, we must account for the spatial dependence that exists within the data. Anselin and Rey (1991) have differentiated between two forms of spatial dependence: that which is a nuisance and that which represents a substantive spatial process. As a nuisance, it can be controlled with a properly designed weights matrix within a spatially autoregressive model. However, when the spatial dependence is a subject of inquiry, as it is in this research, it is useful to be able to quantify the role that it plays within each of the predictor variables. Spatial filtering, based on the $G_i(d)$ statistic, offers a way of decomposing each variable into its spatial and nonspatial components and then reintroducing each component separately into the regression model. The final model fit has been shown to be comparable using spatial filtering and autoregressive models (Getis and Griffith 2002), but the spatial filtering technique has the advantage of giving us intermediate information about the effect of spatial dependence on the dependent variable that is not available within an autoregressive framework.

In this statistical approach, we first test for the presence of spatial dependence in each of the predictor variables by calculating Moran's I, using an inverse of squared distance weights matrix, where distance is measured between the centroids of shiakhas. For each spatially dependent independent variable, we use the $G_i(d)$ statistic as a spatial filter to extract the spatially autocorrelated portion of that variable. The difference between the original variable x_i and the filtered variable x_i^f is a new variable x_i^{sp}, that represents the spatial effects embedded in x_i (Getis 1995; Getis and Griffith 2002). These two variables, x_i^f and x_i^{sp} replace the original variable x_i in the regression equation to produce a spatially filtered regression model in which the contribution of the spatial and filtered (nonspatial) components of each variable can be determined by the beta coefficients in the resulting model. These techniques of spatial filtering have been programmed in Fortran by Scott (1999).

All of the predictor variables were spatially dependent (based on a statistically significant Moran's I), and all were filtered and then reintroduced into the respective regression models. If we use only the filtered (nonspatial) components of the variables to predict fertility in 1996, the

R^2 is only .407, suggesting that the spatial component is making a considerable contribution to the prediction of fertility levels. The two important predictor variables are the percent of women who are single (the higher this is, the lower is fertility), and texture (the more of it there is, the higher is fertility). Neither socioeconomic status of the neighborhood nor its status as an informal settlement was statistically significant.

Of course the model that includes only the filtered variables is not appropriate because it ignores the important spatial component. When we include both filtered and spatial components, the most parsimonious model is the one in which the two significant predictors of fertility levels in an area are the filtered and spatial components, respectively, of the percent of young women who are single. Together, those two variables combine to produce an R^2 of .748, nearly as high as the original model that included all of the unfiltered variables. The standardized beta coefficients of −.587 (t-score of −19.867) for the filtered component of NOTMAR96 and −.692 (t-score of −23.406) for the spatial component of the variable suggest that the filtered and spatial components of age at marriage are nearly equally important predictors of fertility in Cairo. Thus, the configuration of the neighborhoods (where they are vis-à-vis other neighborhoods) is as important as the actual percent of young women who are single in determining the fertility level within a neighborhood.

It is clear from the analysis thus far that if we can find the factors that are related to the percentage of young women who are still single (the proximate or direct determinant of fertility) and that explain the neighborhood configuration (the spatial component), then we will have a good understanding of the more distal or indirect factors that influence fertility. The most appropriate way to model this is with structural equation modeling (SEM). Figure 6 shows the path models produced by SEM. The top panel reflects the results for the original unfiltered model, based on experimentation to find the most parsimonious fit of the variables. Moving from left to right, the most powerful predictor of NOTMAR is an environmental variable, the interaction of the proportional abundance of impervious surface and shade; the second most important predictor is also an environmental context variable—the proportional abundance of bare soil. Status of the neighborhood is also an important predictor, although less so than the other variables, and it can also be seen that status is correlated with the abundance of bare soil. Together, these three variables explain 71 percent of the variation in the percent of young women who are not married, and that variable, in its turn, explains 71 percent of the variation in the neighborhood level of fertility.

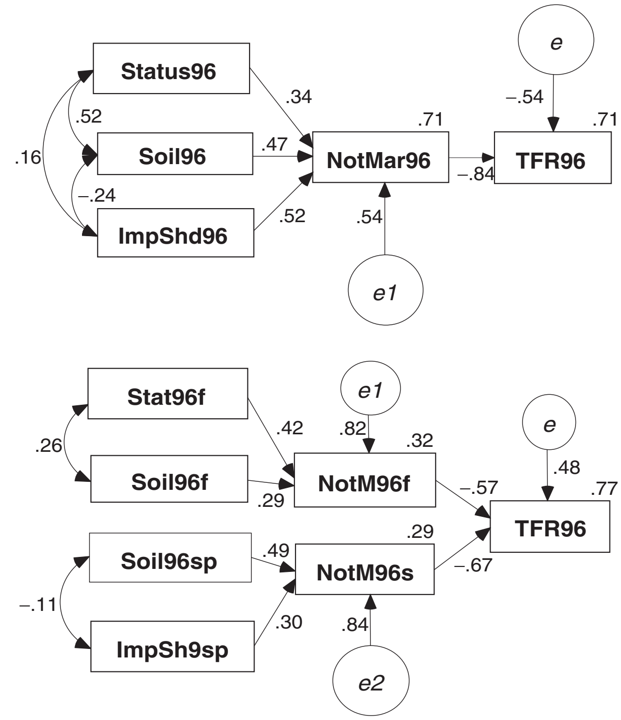

Figure 6. Path diagram for total fertility rate 1996.

A. Unfiltered model.
B. Filtered model.

The bottom panel of Figure 6 has the results for the filtered and spatial variables. In the upper left of the diagram are the two variables, STATUS and SOIL, which are the best filtered predictors of the filtered component of NOTMAR. Neighborhoods with a higher socioeconomic status have a higher percentage of young women who are single, regardless of where they are located spatially. Similarly, those neighborhoods with a high proportional abundance of bare soil have a higher percentage of single young women, regardless of their socioeconomic status. Our interpretation of the imagery suggests to us that this is a reflection (literally) of the building rooftops serving as a footprint of the density of buildings in those areas of the city where status is higher and fertility is lower. This is especially evident in places that are closer to the center of the city, but this filtered variable captures the nonclustered component of bare soil (e.g., rooftop material) abundance. Of the two predictors of the filtered component of NOTMAR, socioeconomic status is most important, as evidenced by the higher standardized beta coefficient (.42), and this is in line with our expectation that socioeconomic status would be an important predictor of fertility through its influence on the proximate determinants of fertility. However, it is also very clear that status is not the only predictor and, in fact, not even the most important one. That honor goes to the spatial component of bare soil, which embodies much of the spatial autocorrelation found in the data. In other words, the configuration of bare soil (probably the footprints of buildings) is a more important influence on the percentage of young women who are single than is socioeconomic status, per se, and thus it is reasonable to conclude that in Cairo in 1996, fertility levels were more influenced by where a neighborhood was located than by the socioeconomic status of that neighborhood. As we will discuss below, this is very important because it suggests a deepening shift in the status of women, as evidenced by a delay in marriage, that is not dependent necessarily on a rising standard of living, and this portends a broader change in social structure than simply a decline in fertility.

Predictors of Fertility Levels in Cairo in 1986

We turn now to the results for 1986, looking first at the prediction of the total fertility rate for that year based on the original (unfiltered) variables. The standardized beta coefficient and its associated t-score (in parentheses) is shown for each variable in the equation

$$\begin{aligned} TFR86 = &\{-.084(-2.657)STATUS86\} \\ &+ \{-.045(-2.211)INFORMAL \\ &+ -.107(-3.947)IMP^{*}SHD86 \\ &+ -.107(-4.911)SOIL86 \\ &+ .063(2.947)TXTURE86\} \\ &+ \{-.789(-20.298)NOTMAR86\} \end{aligned}$$

The R^2 for 1986 was .898, suggesting an even better fit to the data than in 1996. Once again, there was no strong evidence of multicollinearity, nor of heteroscedasticity, but the residuals were spatially autocorrelated, based on a z-normalized Moran's I. As was true in 1996, the status variable was a statistically significant predictor of fertility, but in fact all of the variables were statistically significant predictors of fertility, even if most were only weakly so. As was true for 1996, the percentage of young women who are still single was highly correlated with fertility at the shiakha level, and, as expected, it was by far the most important of the explanatory variables.

The top panel of Figure 7 shows the final path model for the 1986 data. In order to improve the overall fit of the data, the model was reduced to three variables (STATUS, SOIL, and IMP*SHD) as predictors of NOTMAR, with NOTMAR then being the proximate determinant of TFR. It can be seen that there are only modest correlations among the leftmost exogenous variables, and STATUS is a somewhat stronger predictor of NOTMAR than is

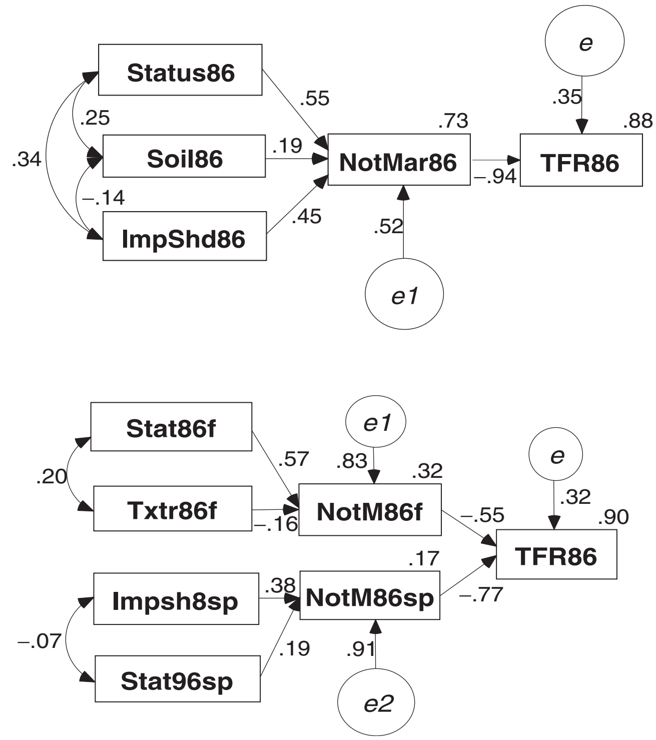

Figure 7. Path diagram for total fertility rate 1986.

A. Unfiltered model.
B. Filtered model.

IMP*SHD, but, in fact, the neighborhood environment variables of IMP*SHD and SOIL are important independent influences of the percentage of young women who are single, independent of the impact of the socioeconomic status of the neighborhood. The combination of those three variables explains 73% percent of the variation in NOTMAR, as can be seen in the figure.

In order to improve the specification of the model by controlling for the spatial autocorrelation, we once again undertook the filtering of variables. The R^2 for only the filtered variables as predictors of fertility was .604, suggesting again that the spatial component was a major contribution to the overall explanatory power. When both filtered and spatial components were introduced into the model, the overall R^2 jumped to .905, but now it is possible to see that the spatial component of NOTMAR was clearly the strongest predictor of fertility levels in 1986, followed closely by the filtered component of NOTMAR. Several of the other variables were statistically significant, but of the significant variables, the spatial and filtered components of NOTMAR alone had an R^2 of .883 as a predictor of total fertility rates. The other variables combined to add very little explanatory power. That is, of course, what we expect since the NOTMAR variable is the important proximate determinant of fertility.

Once again, then, the next interesting question relates to which of the distal or indirect variables best predict the proximate determinant of fertility. The bottom panel of Figure 7 shows the most parsimonious version of the filtered model for 1986. The filtered component of NOTMAR in 1986 is explained largely by the filtered component of neighborhood socioeconomic status—regardless of where a neighborhood is located, the higher the status, the higher the percent of young women who are single, and, then, of course, the lower is fertility. The spatial component of status is weakly predictive of the spatial component of NOTMAR, suggesting that the arrangements of neighborhoods by status does have an effect on age at marriage and fertility, regardless of the actual status level. The measures of neighborhood context derived from the remotely sensed imagery also have spatial and nonspatial components, which are predictors of marital status (and thus of fertility). Even when we control for status, the data show that the higher the fraction of an area that is covered by impervious surface and shade (the interaction of the two), the lower is the fertility in that area. Furthermore, the greater the amount of texture in the land cover describing the neighborhood, the lower is the age at marriage and thus the higher is fertility. This latter effect is embodied in the filtered component and is consistent with the idea that the suburbs are where fertility is highest, even controlling for social status of the neighborhoods. We interpret these findings to mean that the variability in age at marriage (and thus in fertility) is partly related to the status of the neighborhood, but it is also importantly influenced by the neighborhood context and the arrangement of neighborhoods within the city.

Informal settlements are not statistically significantly related to age at marriage or fertility, after controlling for the other variables in the model. This variable is, of course, a blunt instrument since we have only a binary classification, when, in fact, many neighborhoods almost certainly have a mix of informal and formal elements. At the bivariate level, we do know that the percent of women who are single is lower and fertility is higher in informal settlements. In both 1996 and 1986 fertility levels were statistically significantly higher in informal settlements than in other areas, but that relationship disappears when we take other factors into account.

Change in Fertility between 1986 and 1996

We turn now to an analysis of the change in fertility between 1986 and 1996 to see if the change in the significant predictor variables discussed above can explain the change in the age at marriage, and thus in fertility, between those two years. The initial model, comparable to the ones tested for each year individually, is as follows:

$$\Delta TFR = \beta_0 + \{\beta_1 \Delta STATUS\} + \{\beta_2 \Delta IMP^{*}SHD + \beta_3 \Delta SOIL + \beta_4 \Delta TEXTURE\} + \{\beta_5 \Delta NOTMAR\} + \varepsilon$$

Not unexpectedly, this model produces only one statistically significant predictor of the percent change in fertility—namely, the percent change in the proportion of young women who are single. The higher the rise in that proportion, the greater the drop in fertility, with an R^2 of .56. Underlying that relationship was the high negative correlation between the percent not married in 1986 and the relative change in that percentage between 1986 and 1996. Those neighborhoods with the lowest percentage of women who were not married in 1986 tended to be the places where the percentage increased most rapidly.

Figure 8 shows that the overall R^2 improved to .59 for the path model fitted to the unfiltered data. It can be seen that an increase in the age at marriage is able to explain a large fraction of the decline in fertility ($R^2 = .59$), but we have a more difficult time explaining the change in marital behavior ($R^2 = .27$). The best predictor of that change is the change in socioeconomic status—a more rapid increase in a neighborhood's status was associated with a more rapid rise in the percentage of young women who were single. Largely independent of that effect was the relationship between a neighborhood's status in 1986 and its change in the percent not married—the lower the status in 1986 the more rapid was the increase in the percent single between 1986 and 1996. Changes in the environmental context variables derived from the imagery were very modest in their effect. The bigger the change in the proportional abundance of soil, the slower was the increase in the age at marriage, but this was essentially offset by an increase in the pace of age at marriage as the rate of change increased in the interaction of impervious surfaces and shade. The low standardized beta coefficients

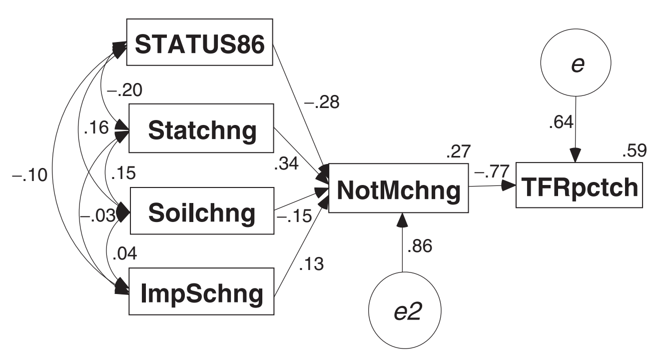

Figure 8. Path diagram for percent change in total fertility rate 1986–1996.

of these latter two variables, however, limit the value of these conclusions.

Keep in mind that the change in status of a neighborhood is positively correlated with the change in fertility, which is the opposite of what we would expect. It would be anticipated that a faster increase in status would be associated with a faster decline in fertility, but the results suggest the opposite pattern. This is, however, entirely consistent with the spatial pattern of fertility decline shown in Figure 4. Although fertility is lower toward the center of the city (in the higher socioeconomic areas) in both 1986 and 1996, it was in the lower-status outer suburbs where the decline in fertility was most rapid. This decline is largely a consequence of a delay in marriage on the part of young women in lower-status (probably more traditional) areas, which as noted above, is suggestive of a more fundamental shift in gender relations in Cairo that portend deeper social changes.

How might this process be taking place, despite the lack of evidence of a pattern of diffusion? One possibility is that social change is occurring more subtly than our statistics can detect. The demographics of Cairo have been influenced by the scarcity of housing, occasioned both by rent control in the center of the city, which has discouraged new construction, and by a decline in government spending on housing, as funding has been diverted instead to military resources (El-Batran and Arandel 1998). As a consequence, informal settlements beyond the city center have attracted both migrants to Cairo and native Cairenes who cannot afford to live in the older, more established parts of the city:

> Essentially, home-seekers lack access to rent-controlled accommodation even though these flats might not actually be occupied. The very low (controlled) rents encourage holders to retain these homes even if they do not occupy them. Beyond that, the unaffordable prices of newly built formal housing exclude the low-income groups from the housing market. Thus, there remains no other option for young people, in particular those intending to start a family, but to seek housing in the informal market. Hence, they venture out to join the outsiders who inhabit the large *ashwaiyyat*, the informal agglomerations surrounding metropolitan areas, some of which already accommodate groups of indigenous populations such as villagers or tribal people.
>
> —(Bayat and Denis 2000, 191–92)

Although these informal settlements have been assumed to essentially ruralize the urban environment, it is reasonable to expect that the intermixing of people of differing backgrounds will have the opposite effect of increasing the likelihood that migrants and other urban peasants will come into contact with more modern views about gender relations and about the tradeoff between the quantity and quality of children. Evidence of these types of social forces in Cairo are largely anecdotal (Obermeyer 1995), but it is consistent with the fact that informal settlements are believed to be an important element in the social structure of Cairo, even if they do not emerge on their own as statistically significant predictors of demographic patterns.

Conclusion

The Greater Cairo region has not necessarily been a strong leader in the fertility transition currently underway in Egypt. The trend data show that Cairo is only marginally ahead of the rest of the country in terms of its fertility decline and, more importantly, the greater Cairo region exhibits considerable intraurban variability in its own levels of fertility. Some areas of Cairo are much farther down the road toward low levels than are others. We have shown that, in general, fertility is lowest in the center of the city and highest in the suburbs. That is not too surprising on its own, but we have also shown that there is a very important spatial dependence to the bundling of fertility and its predictors in Cairo. Differences in reproductive behavior are often based upon differences in human capital, measured especially by education, and especially by female education (Bledsoe et al. 1999), which has had a strong history of relationship to fertility in Egypt (Abu-Lughod 1965; El Attar 1973; Gadalla 1978; Gadalla , McCarthy, and Kak 1987), as almost everywhere in the world. The economic or human capital theory of fertility makes no explicit claim about the role of place, but it is clear that some neighborhoods or social environments offer more economic opportunity than others, and some environmental contexts offer more opportunities for their residents to engage in innovative behavior. It does matter where you are. The socioeconomic status of neighborhoods is certainly related to fertility in Cairo, but it is not necessarily the most important factor influencing recent patterns of fertility change. Something about the spatial structure of the Greater Cairo area is clearly having an impact on fertility levels and changes. Such influences include the clearing of slums, rent control in the core of Cairo, and the rise of informal settlements throughout the suburban areas.

We have found no direct evidence of a spatial diffusion of innovative behavior, but we can observe very clearly that neighborhoods with an early age at marriage in 1986 were more likely to experience a delay in marriage and thus a drop in fertility in the subsequent decade. This has created flux in the fertility transition in Cairo, reflected in the fact that our models fit the data better in 1986, before these changes appeared to unfold, than in 1996. There is strong evidence that in Egypt, including its urban areas, traditional gender role attitudes are still prevalent (Mensch et al. 2003). Teenage girls (and boys) still accept the idea that when girls get married, they will give up their social freedom vis-à-vis the outside world and will accept a dominant role within the family in exchange for economic support from the husband. But, the data on the delay in marriage suggests that as girls in Cairo reach adulthood, they may be chafing at that traditional role set out for them by society, even if they do not openly object to it.

Young Egyptian women are dealing with traditional gender-role attitudes in a manner similar to women in northern Mediterranean countries such as Italy and Spain where fertility has dropped quickly because of a substantial delay in marriage and then a restriction of births within marriage. The current level of contraceptive use among married women in Cairo (53 percent) is consistent with Cairo's overall TFR of just less than 3 (Bongaarts 1986), so ultimately contraceptive use will have to rise if fertility in Cairo is to drop closer to replacement. The current delay in marriage is only marking time for that eventual occurrence, but in the meantime, it is almost certainly creating the context in which broader social changes in the lives of young women can occur, first at the neighborhood level, then regionally, and then eventually at national levels.

Regardless of the particular sociodemographic circumstances, behavior may well be influenced by the social pressures on offer within the neighborhood in which people live, and these local influences can have a powerful effect on both the quantum and the tempo of the fertility transition. Urban places represent a wide array of ecological settings in which a multiplicity and diversity of ideas about how to live life come together and influence behavior. Culture then builds on itself, and it does so in the fashion of Levi-Strauss's (1966, 17) *bricoleur* or handyman: making use of the materials at hand. Taking Levi-Strauss one step further, we suggest that these ingredients include ideational material (which has limited spatial dependence) and social material (which is much more spatially dependent). In sum, we have shown that intraurban variability exists in the fertility transition within Cairo, and we infer that an important component of this variability is the underlying spatial dependence of cultural phenomena.

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