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Research Article

Neighbors’ social attitudes predict variations in live births among the Amish of Holmes County, Ohio, United States

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Contents

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Abstract

BACKGROUND
Despite declining fertility rates in the West, high fertility rates persist among many North American ethnoreligious populations. Such populations often reside in cultural enclaves where pro-natalist norms are insulated from external influences, yet intra-enclave fertility rates vary. Internal community influences on fertility remain understudied.

OBJECTIVE
Using a diffusion framework, we examine how social and physical distances within an Amish enclave are associated with fertility patterns. We assess the relationship between household live births and proximity to others who have differing adherences to traditional pro-natalist attitudes.

METHODS
We use contemporary cross-sectional data on the rural Amish enclave of Holmes County, Ohio, United States. We test hypotheses for 5,706 Amish households and their proximity to households of ordained church leaders, strict adherents, and lenient adherents, and their proximity to villages.

RESULTS
Models demonstrate that spatial proximity predicts reproductive behaviors in uneven, identity-dependent ways. For example, among strict-denomination completed-fertility households and lenient-denomination households at high reproductive risk, living near ordained householders is associated with higher fertility, while there is no evidence for this effect among lenient completed-fertility or strict reproductive-risk households.

CONCLUSIONS
Findings reveal a complex relationship between socio-spatial factors and fertility behaviors. Within this high-fertility enclave, fertility patterns may operate through

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multiple pathways related to place and religious identity rather than through a unidirectional pathway with singular outcomes.

CONTRIBUTION
This study provides insights into how residential proximity relates to demographic behaviors, highlighting internal spatial processes that moderate high-fertility norms.

1. Introduction

Demographic transition theory predicts that multiple socioeconomic development processes upend social mechanisms supporting high fertility, leading to low fertility rates globally (Bongaarts 2009; Bongaarts and Watkins 1996). Yet multiple religious populations, such as Orthodox Jews, Fundamentalist Latter-Day Saints, and the Amish, have defied such mass demographic trends even as they are subjected to many of the same development processes. One shared characteristic across these populations is that they cluster in enclaves, where proximity may reinforce pro-natalist ideologies and structures (Anderton 1986; McAlister 2005). Nonetheless, within these religious populations, there is much household-to-household diversity in fertility behaviors. In this paper we ask: Could household differences in fertility result from the social and religious characteristics of neighbors?

This article advances our understanding of fertility diffusion by examining how enclave socio-spatial configurations predict variations in household fertility levels. Households within enclaves have both social and physical distances from other households, and we use these figurative and literal distances in tandem – socio-spatial configurations – to predict fertility. We employ a novel, contemporary dataset from the Amish, one of the largest high-fertility populations in the United States. The Amish case is particularly valuable for studying fertility diffusion processes because settlement patterns of the Amish create natural variation in household proximity to different social influences while their technological limitations heighten the importance of face-to-face interactions. We examine how geographical proximity to Amish co-adherents and local population centers predicts fertility outcomes, focusing specifically on residential proximity to ordained church leaders, households of varying religious strictness, and Amish-area village centers.

This is one of the first studies to examine how exposures within a community correspond to fertility behaviors at the household level. Our study demonstrates that spatial proximity among a population's adherents predicts variations in fertility levels. Although our cross-sectional data preclude causal inference, we find that the relationship between proximity and fertility behaviors varies by denominational identity and age.

These findings advance fertility diffusion theory by demonstrating that proximity effects are not uniform but rather are contingent upon religious identity within the enclave, suggesting that social identity mediates how spatial arrangements influence demographic behaviors. This research contributes to our understanding of the mechanisms driving fertility change and cultural persistence in high-fertility religious groups and more broadly contributes to debates about the role of local social ecologies in shaping demographic behaviors.

2. Background

2.1 Fertility decline theories

Across the 19th and 20th centuries, most Western populations completed a demographic transition, shifting from high to low mortality rates and then from high to low fertility rates (Bongaarts 2009; Reher 2004). While the decline in mortality rates has been attributed to public health developments, increased nutrition and hygiene, and modern medicine (Cutler and Miller 2005; Livi Bacci 2017; Omran 1971), explanations for fertility declines are more varied and complex.

While socioeconomic changes and mortality declines generally precede fertility declines globally (Hirschman 1994), scholars debate the proximate and direct determinants of fertility transitions, from economic factors to social shifts in marriage and contraception, child mortality, and women's education and labor force participation (Bongaarts 1978; Bryant 2007; Caldwell 2001; Dribe and Scalone 2014; Hacker and Roberts 2017; Klüsener, Dribe, and Scalone 2019; Mason 1997; Stover 1998). A number if not all of these processes are contributors to fertility declines; however, these processes remain understudied at a micro level.

Broadly construed, the determinants driving fertility decline can be classified as either adaptation or diffusion – adaptation capturing structural changes and diffusion capturing social interaction (Brown and Guinnane 2002; Carlsson 1966; Coale and Watkins 2017). For this study, we are interested in diffusion – that is, social interactions across space.

Diffusion theories posit that community ideas and materials influence fertility declines (Bongaarts and Watkins 1996; Casterline 2001). New ideas (such as fertility ideologies) and material objects (such as contraception) disseminate through networks, resulting in lower fertility rates. Much "diffusion of innovation" literature focuses on how diffusion processes – influence, learning, and contact through social structure, for example – were essential for reducing fertility levels in Western contexts (Bongaarts and Watkins 1996; Montgomery and Casterline 1993; Rogers 2003).

In addition to its social nature, diffusion is also a spatial phenomenon. Spatial proximity frequently facilitates or constrains diffusion processes. While ties can conceivably be made with individuals anywhere (especially given recent historic developments in technology and transportation), proximate individuals and households are still more likely to form ties than geographically distant individuals (Blau 1977; Festinger, Schachter, and Back 1950; Nahemow and Lawton 1975; Small and Adler 2019). Diffusion of fertility trends may act through proximity to and contact with others who may have different ideas and behaviors regarding childbearing (Bongaarts and Watkins 1996). The social character of ties also explains fertility behaviors (Cummins et al. 2007; Palloni 2001). Namely, socially close peers, family members, and coworkers have a demonstrable influence on fertility behaviors (Balbo and Barban 2014; Bernardi 2003; Hensvik and Nilsson 2010). Additionally, previous research finds that the spatial configurations of groups – whether through selection or socialization – are associated with individuals' attitudes and beliefs (Shetler and Yabiku 2023). Consequently, the spatial configuration of social networks may shape the spread of fertility behaviors. Physical proximity would seem to predict a greater likelihood of imitating and learning from each other's behaviors (Tolnay 1995), including fertility behaviors (Costa, Bocquier, and Eggerickx 2021; Goldstein and Klüsener 2014; Hedström 1994). This seems especially likely among populations that cluster in enclave-style neighborhoods.

Empirical studies have found evidence for the spatiality of fertility at various levels of aggregation – fertility behaviors spread among adjacent geographies and spatially proximate individuals (Costa, Bocquier, and Eggerickx 2021; Evans and Gray 2018; Goldstein and Klüsener 2014; González-Bailón and Murphy 2013; Jennings and Barber 2013). These studies provide evidence that spatial dependencies are necessary for understanding fertility, changes in fertility rates, and associated diffusion processes (Waldorf and Franklin 2002). However, a gap in the literature remains. Few studies have examined these dynamics at the individual or household level, in part due to the challenges of obtaining detailed data on both fertility outcomes and the spatial and social positioning of individuals within communities. In this article, we use household data to examine fertility diffusion at a more micro level.

2.2 High fertility religions and diffusion

Some Western populations maintain substantially higher fertility rates than national averages despite having their mortality rates being comparable to national levels. Notable among these are religious groups and ethnic sectarians, including the Amish (Anderson and Thiehoff In press; Colyer et al. 2017), Orthodox Jews (Pinker 2021), Hutterites (Evans and Peller 2015), Fundamentalist Latter-Day Saints/Mormons (Heaton 1986;

Morrison 2009), and more generally people who believe religion is important (Hayford and Morgan 2008). These populations grow primarily through high fertility and retention rather than conversion (Scheitle, Kane, and Van Hook 2011). Their persistently high yet varied fertility rates make them excellent cases for evaluating how socio-spatial dynamics shape fertility behaviors. The variation in fertility rates suggests that some segments are more influenced by the mechanisms driving fertility decline than others (Heaton 1986; Wasao, Anderson, and Mpody 2021; Wasao and Donnermeyer 1996).

While much research has identified religiosity as a key predictor of high fertility levels, less attention has been paid to the role of spatial context. Yet many religious groups cluster in neighborhoods or enclaves (McAlister 2005; Sinha et al. 2007; Stolzenberg and Myers 2022), suggesting a potential interplay between space and pro-natalist religious commitment. Indeed, secularization theory posits that maintaining strong religious beliefs within a population requires limited diversity in social contacts as well as the presence of institutions that reinforce the plausibility of religious worldviews (Berger 1990).

Building on these insights from both religious and spatial research on fertility, we ask: Is pro-natalist ideology among contemporary strict religions dependent on proximity to co-adherents? That is, do nearby households and institutions predict someone's fertility behaviors? In this article, we study the relationship between proximity, social identity, and fertility, assessing whether proximity to particular households and villages is associated with greater likelihood of adopting fertility-limiting behaviors or greater adherence to traditional pro-natalist behaviors.

2.3 The Amish

2.3.1 Historical and present-day situation

The Old Amish (also called the Old Order Amish; called just the Amish here) are an ideal population through which to study high fertility dynamics in a low fertility American context. Even though the Amish live among non-Amish with lower fertility rates, have experienced the same history as other Americans, and have experienced parallel declines in mortality, the Amish maintain unusually high – albeit varied – household fertility levels. Additionally, though numerous small populations have high birth rates in North America, practically no group compares to the Amish in size, fertility rates, and multigenerational presence.[3] Using newly compiled household data from a US Amish

[3] The Orthodox Jews are an exception, suggesting some potential advantages of comparative demographic study (Martino 2015; Neriya-Ben Shahar 2021, 2024; Neuberger and Tamam 2014; Rosenberg 2021).

enclave in Ohio, we are able to study the socio-spatial relationship between household proximity, identity, and fertility levels.

The Amish are Christians in the European Reformation-era Anabaptist tradition. Having migrated from Europe in the 1700s and early 1800s, the Amish have a long-standing presence in mid-American states such as Ohio, Pennsylvania, and Indiana (Beachy 2011). In-conversion has always remained low: No more than 200 people have joined from non-Amish settings since around 1930, and many of them eventually left (Anderson and Thiehoff In press). Since the 1950s, retention rates have been high, around 80% to nearly 100% depending on the group (Greksa and Korbin 2002; McConnell 2019; Meyers 1994). Consequently, Amish doubling time is now just over two decades; barring massive progressive schisms, the Amish will very likely have close to one million adherents by 2050 (Donnermeyer 2015). The Amish live exclusively in rural "settlements" that resemble ethnic enclaves (Anderson and Donnermeyer 2013). The smallest settlements have only several households while the largest two settlements number more than 40,000 adherents each. The Amish settlement in Holmes County, Ohio, begun in 1808, is one of these two and is the focus of this study.

Amish socio-religious ideology is pro-natalist, which motivates adherents to have large families (Anderson and Potts 2020). Routine religious teaching – delivered both in sermons and through socialization – underscores the desirability of marriage for young adults and the desirability of large families (Enninger and Raith 1982; Scott 1988; Škender 2020). Bible verses (Petrovich 2022b) such as "Be fruitful and multiply" (book of Genesis) are literally applied. The Amish role/status system reinforces this ideology. Marriage and birth of a first child are important rites of passage that infer role prestige on couples; singles and childless couples have no equivalent means to access this prestige (Enninger and Raith 1982; Enninger and Wandt 1979).

While household-level attributes clearly predict fertility outcomes in households among the Amish (Wasao, Anderson, and Mpody 2021), the Amish also receive structural and ideological reinforcement for their range of ethnic sectarian practices by residing in Amish-specific enclaves (Jeong 2013; Long and Moore 2014; Stein et al. 2020). For example, adherents visit one another routinely (Stein, Corcoran, and Colyer 2019), turn to one another for health advice (Anderson and Potts 2020), and attend church in rotation on one another's residential properties (Stoltzfus 1994). As sociological research has evidenced, geographical proximity encourages tie formation (Blau 1977; Small and Adler 2019) and is an important force in such enclaves.

Amish local networks seem even more important given certain church restrictions on communications and transportation technologies. While physical proximity has less importance in today's internet-connected societies, the early sociological directive that "all social interaction must take place in a physical space" is still salient for the Amish (Small and Adler 2019: 112). The Amish largely limit telecommunications, with stringency varying by denomination. More lenient Amish allow cell phones capable of calling and texting, while the strictest own no phones and limit phone use to just emergencies. Very few households openly have computers in the home (at least in 2015), though some use “Amish computers,” with filtered internet, in workplaces (Ems 2022; Neriya-Ben Shahar 2021, 2024; Petrovich 2014, 2017). So, though diffusion can occur across distances among the Amish, ideological traditions and technological restrictions elevate the influence of geographic proximity. Thus we assume that face-to-face communication remains vital to social life in Amish communities, including in diffusing fertility attitudes and behaviors. Therefore studying the Amish provides an opportunity to glean insight into long-asked questions about the proximate determinants of fertility and its potential decline.

2.3.2 The Amish and fertility

The Amish are characterized as a “near-natural fertility population,” maintaining six to eight live births per family over the past century (Anderson and Thiehoff In press; Colyer et al. 2017). While modest fertility decline may be occurring (Wasao, Anderson, and Mpody 2021), the substantial variation among households within Amish settlements is our primary interest, as it allows us to examine how fertility behaviors may be reinforced or moderated through social proximity, even in a high fertility population. Prior research on Amish fertility has found evidence that household-level attributes variously predict household fertility levels (Colyer et al. 2017). Given the inherently wider range of family sizes in pro-natalist settings, actual family size outcomes may be indicative of the extent to which households have internalized their religion’s pro-natalist ideology versus competing ideologies. Three household variables that reliably predict fertility levels are a farming (versus a non-farming) occupation, ordained leadership (versus layman status) in church, and denominational strictness (Wasao, Anderson, and Mpody 2021).

First, household mode of production has long been linked to higher fertility (Caldwell 1978; Macfarlane 1978; McQuillan 1984), and Amish households involved in farming similarly have large families. While the Amish have shifted to a farmer-minority population, farming remains the occupation most closely identified historically with Amish values. A family’s involvement in farming suggests that they are more ideologically committed to Amishness and thus to pro-natalism and larger families (Dorsten, Hotchkiss, and King 1999; Ericksen et al. 1979; Markle and Pasco 1977; Wasao, Anderson, and Mpody 2021; Wasao and Donnermeyer 1996).

Second, among the explicitly named prerequisites for ordained leadership is the perceived “orderliness” of a man’s family, which presumes that he is in fact married and has multiple children (Petrovich 2022a). Thus being a leader involves role-modeling the Amish pro-natalist family.

Third, the 20th-century Amish have experienced numerous internal schisms. The stricter, more traditional churches are likely to have higher fertility on average than the lenient denominations (Dorsten, Hotchkiss, and King 1999; Wasao, Anderson, and Mpody 2021; Wasao and Donnermeyer 1996).

In addition to these three influences on fertility, household proximity to enclave-internal villages may also be associated with fertility behaviors, as suggested by higher attrition rates of children (Meyers 1994) and broader findings regarding urbanization's impact on fertility (Connor 2021; Kulu 2011; Lerch 2019). Amish population centers – such as Holmes County's Walnut Creek, Mount Hope, and Charm – tend to be villages of up to several hundred residents and populated by people socially related to but moderately critical of the Amish, such as longtime residents, Amish-Mennonites and Mennonites, and ex-Amish. These population centers are traditionally undesirable places for the Amish to live, as Amish ideologies have long devalued "town living" in favor of more rural, agrarian contexts (Kollmorgen 1942). Villages also serve as important small-scale commercial hubs and social gathering spots for the Amish – in essence, small centers of economic power and idea diffusion.

2.4 This study

Cumulatively, the above studies suggest that in societies where low fertility is the norm, households of a pro-natalist, strict religious group will be responsive to the relative religious commitments of co-adherent neighbors, thus making the enclave a necessity for maintaining high fertility in low-fertility national contexts. The more committed one's co-adherent neighbors, the more a household's own pro-natalism will be reinforced. Likewise, the less religiously strict one's neighbors, the less one will be devoted to pro-natalist ideology, defaulting toward Western society's acceptance of regulating fertility, economic calculations favoring lower fertility, and the use of contraception to limit fertility.

We study fertility declines via a case study of the Holmes County Amish settlement – a high-fertility community in the United States. The Amish case is particularly well suited for this analysis, given the long history of Amish settlement in the United States, their clustering in rural enclaves, and the availability of detailed micro-level data on their households and communities (Anderson and Donnermeyer 2013). We examine whether Amish households living near those with pro-natalist social attributes have higher fertility rates and whether households closer to village centers – which represent social structures that do not support pro-natalism as strongly – have lower fertility rates. Specifically, we hypothesize that (1) households living closer to church leaders have higher fertility levels than households located farther away; (2) households living closer to strict-denomination households have higher fertility levels than households living farther away; (3) households living closer to lenient-denomination households have lower fertility than households living farther away; and (4) households living closer to village centers have lower fertility than households living farther away.

Although we present hypotheses, this study's cross-sectional design prevents causal inference. Rather our contribution lies in characterizing household-level fertility patterns within a pro-natalist population's spatial configuration, illuminating potential spatial and social micro-level diffusion processes. This study is also innovative in our analyses of contemporary data, as the majority of household-level research has employed historical data (Dribe and Scalone 2014; Hacker and Roberts 2017; Klüsener, Dribe, and Scalone 2019).

3. Methods

3.1 Data

Amish individuals – in collaboration with other Amish – commercially produce population registry books called directories. There are approximately 80 separate directory series, representing different Amish settlements, subgroupings, and regions, ranging in size from 10,759 households to as few as 20 (Anderson and Thiehoff In press). Population inclusion is basically complete, and directory accuracy is strong, as has been externally validated (Stone, Anderson, and Thiehoff 2025). Rarely do households opt out of directories, so a directory's information represents a census of the population. Because adherents provide information and because it is embarrassing for both the directory compiler and the household to have information printed incorrectly, directory data validity is high. This is especially true for directories that have gone through multiple editions.

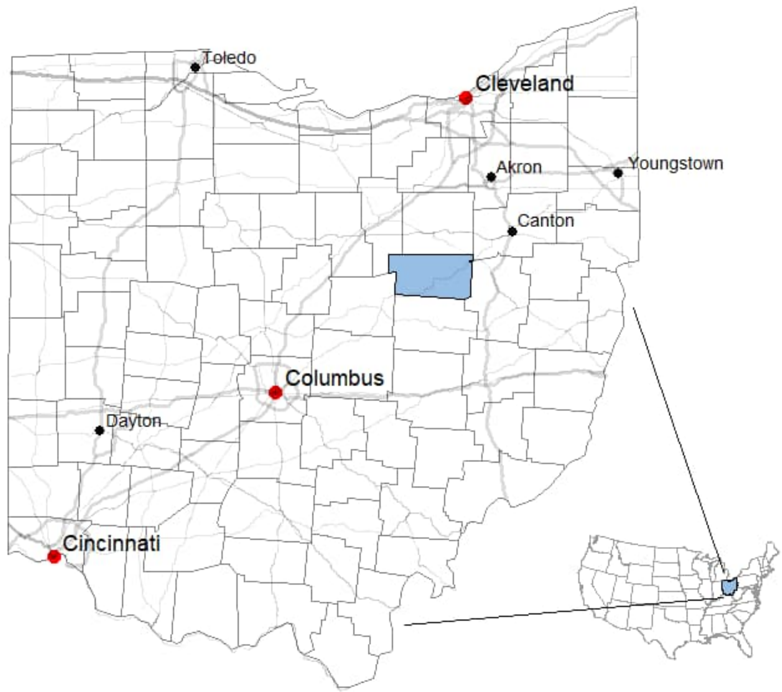
Directories include most vital statistics of Amish households, including all birth and marriage dates and most deaths dates, as well as social variables such as occupation of household head, individuals' given names, and church leadership status. For our study – and from the viewpoint of many Amish people (Petrovich 2022a) – the Amish population is conspicuously bounded no matter what definition of Amish people one applies (Anderson 2025), with few ambiguities between insiders and outsiders. Individuals who identify as ethnically Amish but are outsiders for sacramental purposes (Faulkner 2017) are not included in our study population.

For this study, we use the 2015 *Ohio Amish Directory, Holmes County* (ninth edition) (Cross 2023; Wengerd 2014), which is the second-largest Amish directory at 7,559 households. Holmes County, Ohio (see Figure 1), is one of only two Amish settlements with sizable populations spread across multiple Amish affiliations. Indeed, most major schisms in modern Amish history had their epicenter in Holmes County (Anderson 2019; Beachy 2011; Petrovich 2017; Sheets, Raber, and Anderson 2019b, 2019a). Denominations (listed from strictest to most lenient) include the Swartzentruber church (1910s), which later experienced a schism producing the similarly strict Stutzman-Troyer church (1940s); the 1955 Beschluß (aka Dan or Andy Weaver) church (1950s); the Old Order-mainline church; and the New Order church (1960s), which later had a New-New Order division (1980s) (Petrovich 2017, 2023; Sheets, Raber, and Anderson 2019b, 2019a; Waldrep 2008). Strictness is measured across several dimensions, including lifestyle restrictions (concerning dress patterns, for example), technology usage limitations, severity of excommunication practices, and theological orientations regarding salvation. See Table 1 in Petrovich (2017) for details.

Of further advantage for study, the Holmes County settlement is entirely rural, with a high concentration of Amish households (Hurst and McConnell 2010; Lowery and Noble 2000). While the region's rolling foothills shape social processes such as church district formation (Long and Moore 2014), unlike in Lancaster County, Pennsylvania – the other large Amish settlement – no major geographic features, such large rivers, cities, or limited-access highways, disrupt direct transects between households in Holmes County (see Figure 1).

The Holmes County directory is compiled by Amish adherents with experience in publishing and printing, suggesting high internal data validity. For an illustration of directory entries, see Colyer et al. 2017:Figure 1, which demonstrates the data format and explains what demographic information can be extracted from Amish directories. For this study, directory data were manually entered into a database by undergraduate students in an upper-level demography course, who then used the data for their own graded projects, suggesting personal investment in accurately inputting data. Furthermore, the dataset went through multiple tests for accuracy, including cross-referencing of dates to check for logical intervals between spouses' birth and marriage dates and between children's birth dates. The result is a highly accurate, census-level database of the Holmes County Amish population.

Figure 1: Ohio counties (outlined in black), major cities (large red points), and minor cities (small black points), with Holmes County highlighted in blue. Interstates and US highways are depicted as large gray lines and small gray lines, respectively. Inset map of the lower 48 US states highlights Ohio in blue.



The Holmes County directory includes most Holmes County Amish denominations and in-state daughter settlements. It does not include the strictest Swartzentruber Amish denominations, which around 2015 represented approximately 20 local congregations. For our analysis, we omitted the directory's daughter settlements (845 households) because they are small and geographically distanced from the main Holmes County settlement. After cleaning, the electronic database includes more than 30,000 people from 6,777 households. See "Sample criteria and missing data" for more on sample selection for this study.

The data for this study are cross-sectional. Hence an important limitation is that our analyses assume that reported distances to other households (and the makeup of those households) in 2014 were the same as those reported when households were making fertility decisions. Naturally, this assumes much more residential and social stability than exists for any population. For example, a current minister may not have been a minister when his neighbor was making fertility decisions. Still, given the high demand for limited land, high rates of landownership, geographic boundaries of Amish churches, and young couples' nearly universal desire to establish a home as quickly as possible, Amish families tend to reside in a single location over many decades. Thus residential mobility for the Amish is expected to be much lower compared to that of the general US population. Despite the limitations of a cross-sectional dataset, the present data represent an incredible compilation of spatial, social, and demographic information, making desirable even cautious conclusions from cross-sectional analyses.

3.2 Dependent variable

The dependent variable is the number of live births to the household through December 31, 2013. (The directory data were collected in mid- to late 2014, so we limit the data to all births prior to 2014.) Following prior Amish fertility studies (e.g., Wasao, Anderson, and Mpody 2021), we count all children ever born to the current household couple, regardless of children's current residence.

In Amish populations, household fertility typically represents the complete fertility of both spouses, as Amish generally marry once and bear children only within marriage. Households are predominately nuclear families, consisting of a householder, his wife, and their unmarried children. In this study we analyze married heterosexual households headed by men. We refer to their spouses as wives throughout. To simplify analysis, we exclude the few households representing blended families. (See "Sample criteria and missing data.")

Stratified analyses are conducted on subsamples of households by denomination and reproductive risk. Models for households that had completed fertility by 2014 (the wife was age 45 or older; 45 is a widely used age estimate for approximating menopause in demography [e.g., Tomkinson 2019]) and households at high reproductive risk (married for fewer than 15 years with the wife under age 45) are estimated to provide greater clarity on how age, in addition to denomination, contributes to results.

3.3 Independent variables

Independent variables consist of distances between coordinate pairs: among households and between households and village centers. Among households, distance variables include the shortest distances (in kilometers) to households of ordained leaders and to households of other denominations. The denominations are binomially aggregated into stricter denominations – Andy Weaver (1955 Beschluβ) and Stutzman-Troyer – and lenient denominations – Old Order-mainline, New Order, and New-New Order (Petrovich 2017). For simplicity in analyses, we use proximity to households – that is, we reverse the shortest distance variables. For example, in descriptive statistics, the shortest distance to an ordained household may be 0.20 km; this corresponds to a proximity of –0.20 km.

Households were geocoded using Esri ArcGIS 10. The first attempt to geocode resulted in a 99% match at the street address or land parcel level. All remaining addresses were either corrected and re-geocoded or (in the case of post office boxes, for example) removed from analysis due to insufficient information.

Village centers (n = 24) were determined by the second author based on his 15 years participating in the Holmes County community's socioeconomic life as a resident.[4] Villages are represented by a GPS coordinate pair at the village center. The distance variables were calculated using great circle distances in the *st_distance* function of the *sf* package in R (Pebesma 2018), which incorporates the spherical nature of Earth rather than providing Euclidean straight-line distances. The village centers (not to scale) are shown in Figure 2, with *o*'s representing the first class (see Footnote 2) and *x*'s representing the second class.

3.4 Covariates

Controls include household head's occupation, wife's cohort, denominational strictness, and average distance to all other households in the Holmes County Amish population.[5] While household heads reported a range of occupations, we collapse householder occupation into a binary variable of farming (1) versus non-farming (0). Among the

[4] Population centers are broken into two classes: (1) small commercial hubs well within the enclave – Kidron, Maysville, Fredericksburg, Mount Eaton, Mount Hope, Winesburg, Berlin, Walnut Creek, Shanesville, Sugarcreek, Charm, New Bedford, and Baltic; (2) small commercial hubs on the enclave's edges – Dalton, Apple Creek, Holmesville, Millersburg, Wilmot, and Dundee – and small mostly residential villages within the enclave – Farmerstown, Trail, Bunker Hill, Fryburg, and Benton. Neighboring population centers, such as Wooster and Dover, are commercial destinations on the edges of the Amish enclave but are not regarded as social or cultural centers of Amish life, nor are they places where Amish households reside.

[5] Educational attainment is commonly associated with fertility levels (Becker 1991; Lesthaeghe 2010). However, our data do not allow us to access educational attainment. We assume all householders have approximately the same educational attainment – eighth grade – which is the norm among the Amish, supplemented with only occasional vocational education for another one or two years (Bontrager 2022; King 2022). The Amish also have paths to informal educational attainment and intellectual enrichment, and while informal educational attainment beyond eighth grade will likely predict demographic outcomes such as fertility levels (Anderson and Potts 2022), we do not have the means to include an education variable in this study.

Amish, farming is the traditional household occupation and is linked to pro-natalist beliefs (Dorsten, Hotchkiss, and King 1999; Ericksen et al. 1979; Markle and Pasco 1977; Wasao, Anderson, and Mpody 2021; Wasao and Donnermeyer 1996).

We include the cohort of the wife to account for possible cohort declines in fertility and to account for the nonlinear association of fertility with age. The cohorts are pre-1940 (reference group; 8% of sample), 1940–1949 (9%), 1950–1959 (13%), 1960–1969 (17%), 1970–1979 (23%), 1980–1989 (26%), and post-1989 (4%). Due to high multicollinearity between cohort and wife's age (r = –0.98) and between cohort and years of marriage (–0.97), we include cohort only in our main models. A sensitivity analysis including cohort, age, and years of marriage estimates effect sizes similar to those of our main models (see "Sensitivity analyses" and Appendix B, Table A-3).

Strictness of household is based on the household's denomination; lenient households (Old Order-mainline, New Order, and New-New Order denominations) are coded as 0, and stricter households (1955 Beschluβ and Stutzman-Troyer denominations) are coded as 1. We operationalize strictness as a binary measure because while absolute strictness has become harder to assess in recent years (comparing New Order versus Old Order-mainline versus New-New Order, for example), the distinction between the two broad aggregates (lenient versus strict) remains unambiguous.

Finally, we acknowledge that edge effects – a potential bias that results from ignoring entities that are external yet adjacent to the study area – might be at play: Proximity to non-Amish households surrounding the Holmes County settlement may also be associated with Amish fertility outcomes. Accordingly, we control for average distance to all other households to account for households living on the edge of the settlement.

3.5 Sample criteria and missing data

Data for approximately 20 Swartzentruber Amish church districts, with an estimated 20 to 30 households per district, are not included in the directory. Of the 6,777 Amish households in the greater Holmes County settlement listed in the directory, we excluded households with invalid geocoded addresses (such as post office boxes; n = 72) and households outside the main Holmes County settlement (n = 2). We also removed households that married post-2013 (n = 71) to match the year constraints of the dependent variable. The excluded households were removed prior to calculating the independent variables because of their unknown locations of residence prior to 2014.

In addition, the analytical models also include sample restrictions. We excluded single householders who had never married from our models (n = 185 male householders; n = 365 female householders). Since these households (n = 550) do not include married couples, as a rule they do not include children. Householders who had been married for fewer than nine months by December 31, 2013 were also excluded because they were not at risk for reproduction (n = 187). We then excluded households that had a remarried householder (n = 110) due to the complexities in residential location and birth timing that cases of remarriage introduce. Finally, we excluded households where childbearing occurred only post-2013 (n = 34), households where women married after age 45 (n = 3), households with a missing year of marriage (n = 3), households with completed childbearing prior to marriage (n = 6), and households where either the husband or wife died before age 45 (n = 33). We retained households with widows/widowers when fertility was completed (women were over age 45) prior to either the husband's or the wife's death (n = 330). The distance-based independent variables were calculated with all analysis-excluded households (n = 926) because these households still constitute particular denominations and ordination statuses. The analytical models were estimated for the remaining 5,706 households.

Data are missing only for occupation (n = 459), with an additional 216 householders identifying as retired. For those who report retirement but have a known prior occupation, farming status is coded based upon their prior occupation (n = 69). For those without occupation data and those who report retirement but have an unknown prior occupation, farming status is imputed (n = 606). Based on the assumption that these data are missing at random (conditional on observed covariates), farming status of the householder is imputed for 25 replicate datasets using multivariate imputation by chained equations via the *mice* package in R (van Buuren and Groothuis-Oudshoorn 2011).

3.6 Analysis

We first calculate descriptives of the sample, including the spatial autocorrelation of all variables (Moran's *I* for continuous variables; join count analysis for binary variables). This provides an initial test of how Amish household fertility is spatially dependent on surrounding households. We expect that households in close proximity will have greater social influence than those farther away. We use k-nearest neighbors weight matrices to estimate autocorrelation. We report on results of the 15 nearest neighbors; sensitivity analyses using alternative k-nearest neighbor levels (8, 12, and 20) show comparable results. Other studies of households at a similar scale use similarly small values of k for such descriptive analyses (Hedefalk and Dribe 2020; Mitra and Buliung 2014; Song and Wang 2017). Additionally, for these analyses, for mapping, and to obscure household locations, we jitter household locations to separate households living at the same address. Moran's *I* and join count are calculated via *spdep* in R (Bivand 2022).

To test our hypotheses, we estimate models predicting fertility using independent variables individually and collectively. We estimate Poisson regression models predicting number of live births in R (version 4.5.0). There is no evidence of overdispersion, indicating preference for Poisson over negative binomial regression models. In addition to using proximity to households in our models (as described above in "Independent variables"), we exponentiate the regression coefficients to obtain incidence rate ratios (IRRs). So results can be interpreted in forms such as this: "If a household were to live 1 km closer to an ordained household, that household's number of live births would be expected to decrease/increase by a factor of IRR, holding all else constant."

3.7 Robustness checks

To have greater confidence in our results, we perform two robustness checks on subsamples of the population. We assess whether results are held when coresiding households are removed. In the Holmes County population, different households of the same family (such as a father's household and a son's household) are sometimes located on the same property and thus have the same geolocated address. To determine if results are driven by family proximity, we estimate models for (a) households with a greater than zero minimum distance to other households (n = 5,064) and (b) households with a minimum distance greater than 100 m (n = 2,171). These robustness checks are discussed in "Results" and included in Appendix A.

3.8 Sensitivity analyses

We differentiate sensitivity analyses from robustness checks. While robustness checks examine different subsamples of the population, sensitivity analyses evaluate different independent variables and controls. These analyses are summarized below and included in Appendix B.

First, as discussed in "Covariates," we estimate models including cohort, age, and years of marriage (Appendix B, Table A-3), finding effect sizes and significance levels similar to those in our main models.

Second, we assess quantity rather than proximity measures, calculating the number of ordained, strict, and lenient households and village centers within a 0.5 km radius and a 1 km radius of each household. These models (Appendix B, Tables A-3 and A-4) show that overall quantity of entities within these distances does not predict the number of live births; rather proximity itself matters, as shown in our main models. One exception is that as the number of village centers within 1 km increases, the expected number of live births decreases. However, this is extremely rare in reality: only one household among the 5,706 analyzed households had more than one village center within 1 km, so we do not place emphasis on this result.

Next, we test for threshold effects by binning the proximity variables, as spatial relationships may be nonlinear, with diminishing influence beyond certain distances (Quercia and Galster 2000). Using both tertile-based bins and defined distance bins (0.5 km and 1 km), we find that results do not depend on thresholds (Appendix B, Tables A-6 and A-5). That is, the binned variables do not provide evidence that households at medium distances or far distances have different results than households at close distances. Rather results depend upon linear proximity.

Finally, we examine proximity to ordained households in two ways: (a) measuring proximity to ordained households of the same strictness level and (b) measuring proximity to ordained households with householders over age 60, as these ordained groups may have greater or longer-established influence (Appendix B, Table A-8). We discuss these sensitivity checks in the first paragraph of "Poisson regression models," finding null results comparable to those of the main models.

4. Results

4.1 Descriptive statistics

A large majority (84.9%) of households report being Old Order-mainline, New Order, or New-New Order (lenient), while the remaining 15.1% report being part of the strict 1955 Beschluβ and Stutzman-Troyer denominations (Table 1). Households are 0.42 km (0.26 miles) on average from the nearest ordained leader, suggesting that most households live relatively close to a church leader. Households are generally farther from strict-denomination households, averaging 3.23 km (2.01 miles). As nearly all strict households are in the northern half of the settlement (Figure 2), southern households (primarily lenient households) disproportionately skew this mean. Alternatively, households are relatively close to lenient-denomination households (0.16 km/0.10 miles). Lastly, on average, households are 3.01 km (1.87 miles) from the closest village center.

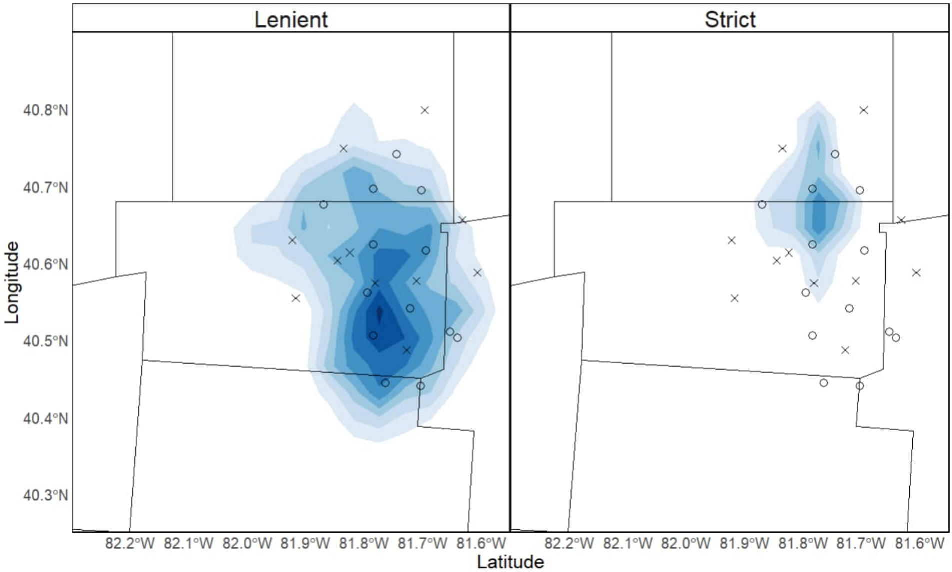
On average, couples have birthed five children and have been married for 25 years. Regarding occupation, following imputation, we expect that 85.1% of heads of households have a non-farming occupation. As reported in the directory data, most non-farming occupations are in woodworking, lumber, construction, carpentry, and related trades.

Table 1: Sample statistics (n = 5,706)

Variables	Mean or n (%)	SD	Min	Max	Missing n (%)	Moran's *I*
Independent variables						
Distance to nearest HH of ordained leaders (km)	0.42	0.41	0	8.52	0 (0)	0.35
Distance to nearest HH of strict denomination (km)	3.23	3.82	0	25.44	0 (0)	0.98
Distance to nearest HH of lenient denomination (km)	0.16	0.23	0	6.74	0 (0)	0.25
Distance to nearest village center (km)	3.01	1.71	0.01	17.11	0 (0)	0.92
Dependent variable						
Number of live births	5.03	2.95	0	18	0 (0)	0.03
Controls						
Average distance to other HHs (km)	15.70	3.18	11.44	33.49	0 (0)	0.97
HH marriage duration (years)	24.88	17.02	1	80	0 (0)	0.01
HH woman's age (years)	46.61	16.96	20	102	0 (0)	0.02
HH woman's cohort					0 (0)	0.02
< 1940	482 (8)					
1940–1949	490 (9)					
1950–1959	736 (13)					
1960–1969	988 (17)					
1970–1979	1317 (23)					
1980–1989	1475 (26)					
1990+	218 (4)					
Denominational strictness of HH					0 (0)	*
Lenient (0)	4842 (85)					
Strict (1)	864 (15)					
Occupation					606 (11)	*
Non-farming (0)	4282 (75)					
Farming (1)	818 (14)					

Notes: HH = household, * = indicates join count statistics discussed in manuscript text

Figure 2: Density plot of Amish households in the Holmes County settlement by denominational strictness



Notes: County boundaries are shown, with Holmes County centered in the image. Population (village) centers are shown (not to scale) in two classes: *o*'s, representing small commercial hubs well within the enclave, and *x*'s, representing residential villages within the enclave and small commercial hubs on the edges of the enclave.

4.2 Moran's *I* values and spatial autocorrelation

Moran's *I* values can range from –1 (high negative correlation) to 1 (high positive correlation). A value near –1 would indicate that dissimilar households are located next to each other while +1 would indicate that similar households are located next to each other, compared to 0, where households are randomly distributed. Moran's *I* values are calculated for each household characteristic. In our analysis, Moran's *I* values were high for the distance-based variables, particularly distance to strict households, meaning that these variables are more spatially clustered than would be expected at random. This is expected, as households in the settlement are clustered by denominational strictness (Figure 2). The Moran's *I* values are small for number of live births, marriage duration, and household woman's age, suggesting that households are more randomly distributed than clustered for these characteristics. For controls of farming occupation and denominational strictness of household, join count analyses were performed. The join count analyses – which calculate spatial autocorrelation for binary variables – strongly suggest spatial autocorrelation (clustering) of both farming occupation and strictness of household. For strict households, the join count statistic is 257.2 (expected = 65.3), and for lenient households it's 2246.5 (expected = 2054.3), both with p-values less than 0.001. For farming households, on average across the imputed datasets, the join count statistic is 92.2 (expected = 79.0), and for non-farming households it's 2013.8 (expected = 1982.2), both with p-values less than 0.001.

These descriptive findings suggest that the Amish may be selecting to live near similar others on occupation and denomination but selecting to live near dissimilar others on age and fertility, creating neighbor networks of fertility behavior heterophily. While fertility may not be spatially dependent on surrounding households at a solely geographical level (as measured by Moran's *I*), number of live births may be spatially dependent on surrounding households after accounting for the social attributes of surrounding households – which we explore in the following analyses.

4.3 Poisson regression models

First, using Poisson regression, we estimated the association between proximity to nearest household of ordained leaders and number of live births, controlling for average distance to all other households, cohort of the wife, the household's own denominational strictness, and farming occupation. We found no association between proximity to ordained households and number of live births (Table 2, Model 1; $p = 0.981$). As sensitivity analyses, shown in Appendix B, we find similar results when estimating models using distances from ordained households of the same denominational strictness (rather than any ordained household) and when estimating models using distances from ordained households where the ordained person is older than age 60 (Appendix B, Table A-8). These sensitivity analyses capture ordained households that may have more pro-natalist influence on neighbors but nonetheless have null results.

Second, we estimated the association between proximity to strict-denomination households and live births, with controls. If a household were to live 1 km closer to a strict household, that household's number of live births would be expected to decrease by a factor of 0.995, holding all else in the model constant (Table 2, Model 2; $p = 0.018$). In other words, those living closer to a strict household have fewer children than those who live farther away.

Third, we estimated the association between proximity to lenient households and live births, with controls. We cannot confidently say that the association between nearest lenient household and number of live births is different from zero (Table 2, Model 3; $p = 0.920$).

Fourth, we estimated the association between proximity to nearest village center and live births, with controls. Similar to Model 2, if a household were to live 1 km closer to a village center, that household's number of live births would be expected to decrease by a factor of 0.988 (Table 2, Model 4; p = 0.004); living closer to village centers is associated with having fewer children compared to living farther from village centers.

Table 2: Poisson regression predicting number of live births (n = 5,706)

	Model 1		Model 2		Model 3		Model 4		Model 5	
	Estimate	p-value	Estimate	p-value	Estimate	p-value	Estimate	p-value	Estimate	p-value
Intercept	5.238	0.000	5.433	0.000	5.240	0.000	5.337	0.000	5.508	0.000
Independent variables										
Proximity to nearest ordained HH	1.000	0.981							1.010	0.555
Proximity to nearest strict-denomination HH			0.995	0.018					0.995	0.029
Proximity to nearest lenient-denomination HH					0.997	0.920			0.998	0.937
Proximity to nearest village center							0.988	0.004	0.988	0.006
Controls										
Average distance to other HHs	1.013	0.000	1.009	0.000	1.013	0.000	1.009	0.000	1.007	0.014
HH strictness	1.290	0.000	1.311	0.000	1.289	0.000	1.284	0.000	1.302	0.000
Farming occupation	1.206	0.000	1.204	0.000	1.206	0.000	1.202	0.000	1.201	0.000
Cohorts										
< 1940	(Reference)		(Reference)		(Reference)		(Reference)		(Reference)	
1940–1949	0.993	0.770	0.993	0.789	0.993	0.770	0.993	0.782	0.994	0.807
1950–1959	0.932	0.002	0.931	0.002	0.932	0.002	0.932	0.002	0.931	0.002
1960–1969	0.847	0.000	0.847	0.000	0.847	0.000	0.845	0.000	0.846	0.000
1970–1979	0.765	0.000	0.766	0.000	0.765	0.000	0.764	0.000	0.765	0.000
1980–1989	0.427	0.000	0.427	0.000	0.427	0.000	0.426	0.000	0.426	0.000
1990+	0.139	0.000	0.139	0.000	0.139	0.000	0.139	0.000	0.139	0.000
AIC	25,256		25,250		25,256		25,248		25,248	

Notes: Exponentiated coefficients (IRRs). HH = household.

Next, in a comprehensive model – Model 5 – we estimated the associations of all above independent variables and live births, with controls, simultaneously. This combined model has a similar fit to Models 2 and 4 (as measured by AIC), and this final model reflects the findings of Models 1–4: Living closer to a strict household or to a village center is related to a lower expected number of live births, while there is no association for proximity to lenient or ordained households.

Additionally, throughout all models and as previous research has indicated, the controls of average distance to other households, household strictness, and occupation are strongly related to fertility. Holding all else constant, strict households are expected to have a live birth rate 1.302 times greater than that of lenient households (Model 5; $p <$ 0.001). The rate is 1.201 times greater for farming versus non-farming households (Model

5; $p < 0.001$). We also find that cohort is related to the number of live births: Compared to the pre-1940 cohort, recent cohorts are likely to have fewer live births.

The finding for proximity to strict households is counterintuitive. While we expected the IRR for proximity to nearest village center to be less than 1, we expected the IRR for proximity to nearest strict household to be greater than 1. That is, we hypothesized that living closer to a strict household would be associated with an increase in fertility (IRR > 1). Instead we found that fertility decreases (IRR < 1). To interrogate this unexpected relationship between proximity to strict households and fertility, we conducted additional analyses stratified by household denomination and reproductive risk (Table 3).

Table 3: Poisson regression predicting number of live births, by denominational strictness and reproductive risk

	Model 5a (lenient, completed-fertility HHs)		Model 5b (strict, completed-fertility HHs)		Model 5c (lenient HHs at reproductive risk)		Model 5d (strict HHs at reproductive risk)	
	n = 2,361		n = 335		n = 1,553		n = 372	
	Estimate	p-value	Estimate	p-value	Estimate	p-value	Estimate	p-value
Intercept	5.216	0.000	6.580	0.000	3.202	0.000	4.766	0.000
Independent variables								
Proximity to nearest ordained HH	0.982	0.444	1.152	0.024	1.084	0.045	1.025	0.799
Proximity to nearest strict-denomination HH	0.999	0.698	0.953	0.719	0.994	0.295	1.240	0.020
Proximity to nearest lenient-denomination HH	1.072	0.177	0.885	0.153	0.858	0.092	0.945	0.669
Proximity to nearest village center	0.984	0.005	0.977	0.259	0.986	0.151	1.023	0.430
Controls								
Average distance to other HHs	1.011	0.008	0.999	0.903	1.006	0.422	1.007	0.522
Farming occupation	1.207	0.000	1.267	0.000	1.209	0.000	1.101	0.262
Cohorts								
< 1940	(Reference)		(Reference)					
1940–1949	0.977	0.376	1.152	0.070				
1950–1959	0.911	0.000	1.111	0.116				
1960–1969	0.835	0.000	0.977	0.715				
1970–1979					(Reference)		(Reference)	
1980–1989					0.717	0.000	0.781	0.002
1990+					0.237	0.000	0.253	0.000
AIC	11,588		1,773		5,527		1,477	

Notes: Exponentiated coefficients (IRRs). HH = household. Completed-fertility households are those where women are 45 or older (n = 2,696). HHs at reproductive risk are a restricted sample of households where women are both younger than 45 and married fewer than 15 years (n = 1,925).

4.4 Stratified Poisson regression models

We estimate Model 5 for four different subsamples: lenient households (5a; n = 2,361) and strict households (5b; n = 335) with completed fertility (wife's age 45 or older), and lenient households (5c; n = 1,553) and strict households (5d; n = 372) at high reproductive risk (wife's age under 45 and married for fewer than 15 years).

Consistent with Model 5 (from Table 2), for lenient households with completed fertility, living closer to a village center is associated with fewer live births (Table 3, Model 5a; IRR = 0.984, $p = 0.005$). Put another way: Comparing two hypothetical lenient completed-fertility households, one located next door to a village and the other 15 km away, we would expect the next door household to have, on average, a 21.5% ($1 - 0.984^{15}$) decrease in the odds of live births. (For reference, the enclave area is approximately 40 km by 50 km.) If the 15 km away household has the average number of live births for the enclave (five), we would then expect the next door household to have just four live births. While this may not seem like a large difference for individual households, it may add up across the enclave. This stratified model shows that lenient households from older cohorts (pre-1970) appear to be driving the main model's results of village proximity and live births.

The other main finding from the aggregated model (Model 5) was that proximity to strict households is associated with fewer children. None of the stratified groups show evidence for this; indeed, the only association significantly different from zero is in the opposite direction. Model 5d estimates that, among strict households at reproductive risk, living closer to another strict household is associated with an increase in the expected number of live births (IRR = 1.240, $p = 0.020$).

Additionally, the stratified models reveal another key denominational and cohort difference. Among both strict completed-fertility households and lenient reproductive-risk households, for each 1 km increase in proximity to an ordained household, the expected number of live births increases by a factor of 1.152 (Model 5b; $p = 0.024$) and 1.084 (Model 5c; $p = 0.045$), respectively.

4.5 Robustness checks

Our robustness checks (Appendix A) support the main findings. (These checks are also discussed in the "Robustness checks" section. Models estimated on subsamples of non-coresiding households show similar effect sizes (Appendix A, Tables A-1 and A-2). These models, which remove households sharing property, underscore that the observed patterns reflect broader community influences rather than just family effects.

5. Discussion

This study is one of the first major investigations into how intra-community exposures predict household fertility levels. Leveraging a rich cross-sectional dataset about the Amish, a population where technological limitations heighten the importance of physical proximity, we produce new findings about fertility diffusion as a spatial process. We offer new contributions to theories of fertility by demonstrating that spatial proximity predicts reproductive behaviors in uneven, identity-dependent ways. Specifically, proximity to village centers predicts lower fertility only among lenient completed-fertility households; proximity to ordained households predicts higher fertility among both strict completed-fertility and lenient reproductive-risk households; and proximity to strict households predicts higher fertility only among strict reproductive-risk households. These patterns suggest that social influence operates through multiple diffusion pathways mediated by place, religious identity, and age rather than through unidirectional diffusion with singular outcomes.

5.1 Key findings and explanations

Contrary to expectations (Hypothesis 1), proximity to ordained church leaders was not associated with household fertility across all households. However, among two distinct stratified groups – strict completed-fertility households and lenient reproductive-risk households – proximity to the ordained is associated with fertility. For these groups, living closer to an ordained household is associated with more live births. This pattern suggests an association between proximity to religious authority and reproductive behaviors. It may be that church leaders monitor neighbors or role-model high fertility in proximity. Perhaps strict older households and lenient younger households were reinforced in pro-natalist norms when living near ordained households. Alternatively, for lenient older households and strict younger households, we find evidence that influence on reproductive behaviors may be limited to one's own household – that is, there is no association between proximity to the ordained and fertility. Another explanation for this null result is that church leaders vary in their enforcements and attitudes. Ordained leaders are not a monolith (Yeatman and Trinitapoli 2008) and may have little or contrasting influence on congregations. However, longitudinal analysis is necessary to fully scrutinize this hypothesis, especially because current leaders may have been laymen when neighboring households were making fertility decisions. Leaders are rarely ordained before their 30s.

We also find evidence that proximity to households of strict Amish denominations is associated with fertility levels (Hypothesis 2) for one specific group, not at a societal level. Strict households with high reproductive risk living near other strict households exhibit higher fertility than those living farther away. Additionally, proximity to lenient households is not associated with fertility across any of the denomination or reproductive-risk groups (Hypothesis 3). These are cross-sectional analyses, so these findings are merely descriptive. However, for discussion's sake, social identity may explain these findings. When similar but competing others occupy the same space, groups may increase the salience of group identity markers, accenting social distance and erecting barriers to diffusion across groups (Levine 1971; Stets and Burke 2000; Tafjel and Turner 1986). Following this explanation, strict households receive social and identity reinforcement when living close to other strict households.

Finally, consistent with prior research on fertility-suppressing effects of population centers (Connor 2021; Kulu 2011; Lerch 2019), we find that proximity to village centers corresponds with lower fertility among lenient completed-fertility Amish households (Hypothesis 4). This relationship between rural population centers and fertility patterns could reflect either diffusion processes via urbanization or residential selection, though longitudinal data would be necessary to distinguish between these mechanisms.

Our findings provide evidence of a modest but distinct spatial component to fertility patterns. Changes in fertility behaviors are not merely products of contact with low fertility populations; rather fertility behaviors are linked to internal community dynamics. Results suggest that Amish households' fertility patterns correspond to both their immediate social environment and their position within the settlement's broader socio-spatial landscape. Consistent with prior research (Hacker and Roberts 2017), we find that both socio-spatial and household factors predict fertility behavior, though household characteristics have greater predictive power than spatial measures, even within enclaves.

While our results are specific to the Holmes County Amish, the findings offer an important illustration of how proximity is associated with fertility behaviors in a spatially clustered high-fertility population. This relationship could conceivably apply to other North American religious enclaves – such as Orthodox Jews or Mormons – though studying other populations presents methodological challenges: Detailed household-level data for all individuals within an enclave are scarce. Further, geographical proximity to differing fertility behaviors or ideals may influence household fertility behaviors not just within enclaves but globally. Future research should study these phenomena among other communities or social networks. However, again, contemporary data including fertility and spatial proximity variables may be rare, limiting options for future research.

These findings take on additional significance as younger Amish cohorts increasingly engage with non-agricultural occupations and technology-mediated communication. While this study focuses on a period when face-to-face interaction continues to dominate social life, future cohorts may show different patterns of fertility diffusion as communication methods evolve, presenting important questions about how spatial influences on fertility might transform in groups communicating more rapidly across distances.

5.2 Limitations and future directions

This study has several limitations that future work should address. First, our cross-sectional data necessitate assumptions about the stability of household locations and neighborhood characteristics over time, limiting our ability to make causal claims about spatial contexts and fertility outcomes. Thus we are able to study only where individuals lived during data collection (mid- to late 2014), not where they were living at the time they were making fertility choices. Residential mobility among the Amish is relatively low; however, we cannot definitively say that residential mobility and selection do not contribute to these results. Simultaneously, while residential selection likely contributes to our findings, diffusion processes cannot be ruled out. Longitudinal data and additional research are needed to clarify the role of residential selection versus diffusion in this population.

Second, while our analysis includes the vast majority of Amish households in the Holmes County settlement, the omission of the strictest Swartzentruber Amish districts may affect our results, particularly if these groups exhibit distinctive fertility patterns or spatial distributions. (Although we do know that they are located solely in the north with the other strict denominations.)

Third, our measures of proximity may not fully capture the extent or quality of social interactions that shape fertility diffusion. Incorporating direct measures of social networks, like strength of neighbor ties, could provide a more complete understanding of these processes (Kohler, Behrman, and Watkins 2001; Zhang and Centola 2019).

Finally, while we control for household-level confounders and conduct robustness checks to assess the stability of our results, the potential for unobserved variables to influence both residential selection and fertility outcomes remains.

Nonetheless, we believe the associations between social influence, diffusion, and spatial proximity are important to document to advance research on diffusion of fertility behaviors. Our findings point to several promising avenues for future research. Longitudinal data collection – such as documenting where households lived at certain times, what occupations individuals previously held, and when individuals were ordained – would enable causal inferences and a more direct assessment of diffusion processes. Expanding data collection to include more robust measures of social network ties and cultural orientations could provide a more comprehensive understanding of the multiple influences shaping reproductive behaviors. Future research could examine couples' fertility desires and intentions, in addition to completed fertility behaviors, to understand fertility and space at a more holistic level (Miller 2011). Finally, comparative analyses that examine spatial and social diffusion processes across other high-fertility religious groups could assess the generalizability of our findings and identify the conditions under which local social ecologies are most likely to shape demographic outcomes.

6. Conclusion

Our study demonstrates the value of analyzing both spatial and social contexts to explain fertility patterns. We contribute to a better understanding of the contemporary influences supporting high fertility through analyses of an American high-fertility religious group. For the Amish in Holmes County, Ohio, while household-level factors such as occupation and denominational affiliation remain strong predictors of reproductive outcomes (Wasao, Anderson, and Mpody 2021), we find that proximity to particular types of neighbors and institutions also predicts fertility in complex ways. These findings highlight the importance of local social ecologies in structuring the diffusion of demographic behaviors.

More broadly, our study contributes to ongoing debates about the mechanisms driving fertility change and the role of spatial diffusion processes in shaping demographic behaviors. By leveraging unique micro-level data on a distinctive religious group, we are able to provide new insights into how individual, household, and contextual factors interact to shape reproductive outcomes. While our findings are specific to the Amish case, they have implications for understanding the reduction of fertility in certain ethnic religions and for the study of fertility decline more generally. This study underscores the need for future research that combines micro-level data on individuals and households with a spatial perspective on the social and institutional contexts that shape demographic behaviors.

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Appendix A – Robustness checks

Table A-1: Poisson regression predicting number of live births among non-coresiding households (n = 5,064)

	Model 1		Model 2		Model 3		Model 4		Model 5	
	Estimate	p-value	Estimate	p-value	Estimate	p-value	Estimate	p-value	Estimate	p-value
Intercept	5.148	0.000	5.406	0.000	5.156	0.000	5.262	0.000	5.492	0.000
Independent variables										
Proximity to nearest ordained HH	1.003	0.868							1.016	0.409
Proximity to nearest strict-denomination HH			0.994	0.006					0.994	0.011
Proximity to nearest lenient-denomination HH					0.995	0.863			0.990	0.752
Proximity to nearest village center							0.987	0.004	0.987	0.005
Controls										
Average distance to other HHs	1.013	0.000	1.008	0.003	1.013	0.000	1.009	0.000	1.005	0.082
HH strictness	1.294	0.000	1.320	0.000	1.293	0.000	1.287	0.000	1.309	0.000
Farming occupation	1.206	0.000	1.203	0.000	1.206	0.000	1.202	0.000	1.200	0.000
Cohorts										
< 1940	(Reference)		(Reference)		(Reference)		(Reference)		(Reference)	
1940–1949	0.993	0.806	0.996	0.876	0.993	0.807	0.993	0.805	0.996	0.876
1950–1959	0.940	0.019	0.941	0.019	0.940	0.018	0.939	0.017	0.940	0.018
1960–1969	0.868	0.000	0.870	0.000	0.868	0.000	0.866	0.000	0.868	0.000
1970–1979	0.782	0.000	0.784	0.000	0.782	0.000	0.780	0.000	0.782	0.000
1980–1989	0.437	0.000	0.437	0.000	0.437	0.000	0.435	0.000	0.436	0.000
1990+	0.144	0.000	0.144	0.000	0.144	0.000	0.144	0.000	0.144	0.000
AIC	22,238		22,231		22,238		22,229		22,228	

Notes: Exponentiated coefficients (IRRs). HH = household. Non-coresiding households are defined as households that have a greater than zero minimum distance to other households.

Table A-2: Poisson regression predicting number of live births among households with a greater than 100 m distance to other households (n = 2,171)

	Model 1		Model 2		Model 3		Model 4		Model 5	
	Estimate	p-value	Estimate	p-value	Estimate	p-value	Estimate	p-value	Estimate	p-value
Intercept	5.548	0.000	5.993	0.000	5.571	0.000	5.777	0.000	6.111	0.000
Independent variables										
Proximity to nearest ordained HH	1.022	0.315							1.031	0.264
Proximity to nearest strict-denomination HH			0.992	0.016					0.992	0.024
Proximity to nearest lenient-denomination HH					1.030	0.418			1.010	0.837
Proximity to nearest village center							0.984	0.012	0.982	0.008
Controls										
Average distance to other HHs	1.010	0.002	1.002	0.633	1.009	0.002	1.003	0.326	0.999	0.784
HH strictness	1.323	0.000	1.360	0.000	1.329	0.000	1.318	0.000	1.355	0.000
Farming occupation	1.160	0.000	1.156	0.000	1.160	0.000	1.155	0.000	1.154	0.000
Cohorts										
< 1940	(Reference)		(Reference)		(Reference)		(Reference)		(Reference)	
1940–1949	0.927	0.150	0.929	0.162	0.926	0.145	0.924	0.134	0.925	0.137
1950–1959	0.992	0.866	0.996	0.934	0.993	0.870	0.996	0.922	0.997	0.939
1960–1969	0.867	0.001	0.872	0.001	0.867	0.001	0.866	0.001	0.867	0.001
1970–1979	0.782	0.000	0.786	0.000	0.783	0.000	0.782	0.000	0.783	0.000
1980–1989	0.442	0.000	0.442	0.000	0.441	0.000	0.440	0.000	0.440	0.000
1990+	0.143	0.000	0.144	0.000	0.143	0.000	0.143	0.000	0.143	0.000
AIC	9,445		9,440		9,445		9,440		9,438	

Notes: Exponentiated coefficients (IRRs). HH = household.

Appendix B – Sensitivity analyses

Table A-3: Poisson regression predicting number of live births via cohort, age, and marriage duration (n = 5,706)

	Model 1		Model 2		Model 3		Model 4		Model 5	
	Estimate	p-value	Estimate	p-value	Estimate	p-value	Estimate	p-value	Estimate	p-value
Intercept	1.841	0.000	1.909	0.000	1.843	0.000	1.875	0.000	1.934	0.000
Independent variables										
Proximity to nearest ordained HH	0.997	0.819							1.011	0.519
Proximity to nearest strict-denomination HH			0.994	0.007					0.995	0.012
Proximity to nearest lenient-denomination HH					0.988	0.664			0.991	0.753
Proximity to nearest village center							0.985	0.000	0.986	0.001
Controls										
Average distance to other HHs	1.012	0.000	1.008	0.001	1.012	0.000	1.008	0.000	1.005	0.061
HH strictness	1.276	0.000	1.300	0.000	1.273	0.000	1.268	0.000	1.287	0.000
Farming occupation	1.200	0.000	1.198	0.000	1.201	0.000	1.197	0.000	1.195	0.000
Cohorts										
< 1940	(Reference)		(Reference)		(Reference)		(Reference)		(Reference)	
1940–1949	1.363	0.000	1.366	0.000	1.364	0.000	1.366	0.000	1.369	0.000
1950–1959	1.664	0.000	1.666	0.000	1.664	0.000	1.667	0.000	1.669	0.000
1960–1969	1.989	0.000	1.995	0.000	1.988	0.000	1.992	0.000	1.999	0.000
1970–1979	2.327	0.000	2.335	0.000	2.326	0.000	2.332	0.000	2.341	0.000
1980–1989	1.643	0.000	1.647	0.000	1.643	0.000	1.646	0.000	1.651	0.000
1990+	0.603	0.000	0.606	0.000	0.603	0.000	0.604	0.000	0.608	0.000
HH woman's age	0.977	0.000	0.977	0.000	0.977	0.000	0.977	0.000	0.977	0.000
HH marriage duration	1.051	0.000	1.051	0.000	1.051	0.000	1.051	0.000	1.051	0.000
AIC	24,603		24,595		24,602		24,590		24,590	

Notes: Exponentiated coefficients (IRRs). HH = household.

Table A-4: Poisson regression predicting number of live births via number of entities within 0.5 km (n = 5,706)

	Model 1		Model 2		Model 3		Model 4		Model 5	
	Estimate	p-value	Estimate	p-value	Estimate	p-value	Estimate	p-value	Estimate	p-value
Intercept	5.289	0.000	5.266	0.000	5.383	0.000	5.281	0.000	5.390	0.000
Independent variables										
Ordained HHs within 0.5 km	0.997	0.449							1.003	0.647
Strict-denomination HHs within 0.5 km			0.998	0.320					0.997	0.265
Lenient-denomination HHs within 0.5 km					0.998	0.142			0.999	0.354
Village centers within 0.5 km							0.940	0.068	0.953	0.201
Controls										
Average distance to other HHs	1.012	0.000	1.013	0.000	1.012	0.000	1.012	0.000	1.012	0.000
HH strictness	1.291	0.000	1.308	0.000	1.281	0.000	1.287	0.000	1.302	0.000
Farming occupation	1.205	0.000	1.205	0.000	1.202	0.000	1.203	0.000	1.201	0.000
Cohorts										
< 1940	(Reference)		(Reference)		(Reference)		(Reference)		(Reference)	
1940–1949	0.993	0.772	0.993	0.786	0.993	0.786	0.994	0.799	0.994	0.824
1950–1959	0.932	0.002	0.932	0.002	0.932	0.002	0.932	0.002	0.932	0.002
1960–1969	0.847	0.000	0.847	0.000	0.846	0.000	0.846	0.000	0.846	0.000
1970–1979	0.765	0.000	0.766	0.000	0.765	0.000	0.765	0.000	0.765	0.000
1980–1989	0.427	0.000	0.428	0.000	0.427	0.000	0.427	0.000	0.427	0.000
1990+	0.139	0.000	0.139	0.000	0.139	0.000	0.139	0.000	0.139	0.000
AIC	25,255		25,255		25,254		25,252		25,257	

Notes: Exponentiated coefficients (IRRs), HH = household.

Table A-5: Poisson regression predicting number of live births via number of entities within 1 km (n = 5,706)

	Model 1		Model 2		Model 3		Model 4		Model 5	
	Estimate	p-value	Estimate	p-value	Estimate	p-value	Estimate	p-value	Estimate	p-value
Intercept	5.259	0.000	5.250	0.000	5.190	0.000	5.313	0.000	5.143	0.000
Independent variables										
Ordained HHs within 1 km	1.000	0.847							0.999	0.661
Strict-denomination HHs within 1 km			1.000	0.755					1.000	0.962
Lenient-denomination HHs within 1 km					1.000	0.734			1.001	0.226
Village centers within 1 km							0.959	0.049	0.947	0.020
Controls										
Average distance to other HHs	1.013	0.000	1.013	0.000	1.013	0.000	1.012	0.000	1.013	0.000
HH strictness	1.290	0.000	1.296	0.000	1.292	0.000	1.285	0.000	1.297	0.000
Farming occupation	1.205	0.000	1.205	0.000	1.206	0.000	1.203	0.000	1.205	0.000
Cohorts										
< 1940	(Reference)		(Reference)		(Reference)		(Reference)		(Reference)	
1940–1949	0.993	0.771	0.993	0.773	0.993	0.767	0.993	0.786	0.993	0.780
1950–1959	0.932	0.002	0.932	0.002	0.932	0.002	0.932	0.002	0.932	0.002
1960–1969	0.847	0.000	0.847	0.000	0.847	0.000	0.846	0.000	0.846	0.000
1970–1979	0.765	0.000	0.766	0.000	0.766	0.000	0.764	0.000	0.765	0.000
1980–1989	0.427	0.000	0.427	0.000	0.428	0.000	0.427	0.000	0.427	0.000
1990+	0.139	0.000	0.139	0.000	0.139	0.000	0.139	0.000	0.139	0.000
AIC	25,256		25,256		25,256		25,252		25,256	

Notes: Exponentiated coefficients (IRRs). HH = household.

Table A-6: Poisson regression predicting number of live births via distance tertiles (n = 5,706)

	Model 1		Model 2		Model 3		Model 4		Model 5	
	Estimate	p-value	Estimate	p-value	Estimate	p-value	Estimate	p-value	Estimate	p-value
Intercept	5.195	0.000	5.483	0.000	5.209	0.000	5.268	0.000	5.429	0.000
Independent variables										
Proximity to nearest ordained HH										
First tertile (0–223 m)	(Reference)								(Reference)	
Second tertile (223–472 m)	1.018	0.223							1.014	0.365
Third tertile (472+ m)	1.011	0.461							1.008	0.581
Proximity to nearest strict-denomination HH										
First tertile (0–543 m)			(Reference)						(Reference)	
Second tertile (544–3,589 m)			0.970	0.072					0.973	0.104
Third tertile (3,590+ m)			1.019	0.316					1.018	0.330
Proximity to nearest lenient-denomination HH										
First tertile (0–44 m)					(Reference)				(Reference)	
Second tertile (44–157 m)					1.014	0.349			1.012	0.405
Third tertile (157+ m)					1.017	0.289			1.010	0.542
Proximity to nearest village center										
First tertile (0–2,690 m)							(Reference)		(Reference)	
Second tertile (2,690–4,176 m)							1.027	0.075	1.023	0.120
Third tertile (4176+ m)							1.035	0.030	1.030	0.064
Controls										
Average distance to other HHs	1.013	0.000	1.010	0.000	1.013	0.000	1.011	0.000	1.009	0.000
HH strictness	1.290	0.000	1.285	0.000	1.284	0.000	1.282	0.000	1.276	0.000
Farming occupation	1.205	0.000	1.203	0.000	1.207	0.000	1.204	0.000	1.203	0.000
Cohorts										
< 1940	(Reference)		(Reference)		(Reference)		(Reference)		(Reference)	
1940–1949	0.992	0.742	0.992	0.745	0.992	0.745	0.993	0.792	0.991	0.723
1950–1959	0.931	0.002	0.930	0.002	0.930	0.002	0.932	0.002	0.928	0.001
1960–1969	0.846	0.000	0.846	0.000	0.844	0.000	0.846	0.000	0.844	0.000
1970–1979	0.764	0.000	0.765	0.000	0.763	0.000	0.765	0.000	0.762	0.000
1980–1989	0.427	0.000	0.427	0.000	0.426	0.000	0.427	0.000	0.426	0.000
1990+	0.139	0.000	0.139	0.000	0.139	0.000	0.139	0.000	0.139	0.000
AIC	25,255		25,255		25,255		25,251		25,255	

Notes: Exponentiated coefficients (IRRs). HH = household.

Table A-7: Poisson regression predicting number of live births via defined distances (n = 5,706)

	Model 1		Model 2		Model 3		Model 4		Model 5	
	Estimate	p-value	Estimate	p-value	Estimate	p-value	Estimate	p-value	Estimate	p-value
Intercept	5.169	0.000	5.319	0.000	5.218	0.000	4.986	0.000	4.999	0.000
Independent variables										
Proximity to nearest ordained HH										
0–0.5 km	(Reference)								(Reference)	
0.5–1 km	1.018	0.200							1.017	0.242
1+ km	0.957	0.103							0.959	0.125
Proximity to nearest strict-denomination HH										
0–0.5 km			(Reference)						(Reference)	
0.5–1 km			0.962	0.077					0.964	0.095
1+ km			0.998	0.893					0.998	0.910
Proximity to nearest lenient-denomination HH										
0–0.5 km					(Reference)				(Reference)	
0.5–1 km					0.993	0.816			0.994	0.842
1+ km					0.971	0.631			0.987	0.829
Proximity to nearest village center										
0–0.5 km							(Reference)		(Reference)	
0.5–1 km							1.035	0.401	1.034	0.424
1+ km							1.066	0.058	1.062	0.072
Controls										
Average distance to other HHs	1.014	0.000	1.012	0.000	1.013	0.000	1.012	0.000	1.013	0.000
HH strictness	1.289	0.000	1.284	0.000	1.293	0.000	1.285	0.000	1.281	0.000
Farming occupation	1.206	0.000	1.206	0.000	1.206	0.000	1.203	0.000	1.203	0.000
Cohorts										
< 1940	(Reference)		(Reference)		(Reference)		(Reference)		(Reference)	
1940–1949	0.992	0.750	0.992	0.741	0.993	0.770	0.994	0.797	0.992	0.750
1950–1959	0.931	0.002	0.931	0.002	0.932	0.002	0.932	0.002	0.929	0.001
1960–1969	0.846	0.000	0.847	0.000	0.847	0.000	0.846	0.000	0.845	0.000
1970–1979	0.765	0.000	0.765	0.000	0.765	0.000	0.764	0.000	0.763	0.000
1980–1989	0.428	0.000	0.427	0.000	0.428	0.000	0.427	0.000	0.427	0.000
1990+	0.139	0.000	0.139	0.000	0.139	0.000	0.139	0.000	0.139	0.000
AIC	25,256		25,256		25,256		25,251		25,257	

Notes: Exponentiated coefficients (IRRs). HH = household.

Table A-8: Poisson regression predicting number of live births via within-strictness ordained and ordained aged over 60 (n = 5,706)

	Model 1		Model 2	
	Estimate	p-value	Estimate	p-value
Intercept	5.211	0.000	5.249	0.000
Independent variables				
Proximity to nearest within-strictness ordained HH	1.000	0.156		
Proximity to nearest ordained HH > 60 years old			1.000	0.629
Controls				
Average distance to other HHs	1.014	0.000	1.012	0.000
HH strictness	1.294	0.000	1.290	0.000
Farming occupation	1.207	0.000	1.206	0.000
Cohorts				
< 1940	(Reference)		(Reference)	
1940–1949	0.993	0.781	0.993	0.775
1950–1959	0.933	0.003	0.932	0.002
1960–1969	0.847	0.000	0.847	0.000
1970–1979	0.766	0.000	0.766	0.000
1980–1989	0.428	0.000	0.427	0.000
1990+	0.139	0.000	0.139	0.000
AIC	25,254		25,256	

Notes: Exponentiated coefficients (IRRs). HH = household.