Network Measures of Social Structure in a Historical Population

Julia A. Jennings
University at Albany, State University of New York

Abstract

The measurement of social structure in historical populations is complicated by data availability and completeness. Occupations were often only listed for working age males, while observations of wages or other measures of income, such as tax records, vary in coverage both between and within communities. Indicators of educational attainment and literacy can also be limited. This study develops a method to measure social structure in a historical demographic dataset that relies on a network approach. Position within marriage and servant networks are used as proxies for social status using data from 19th century Orkney, Scotland. To evaluate the use of this approach, network position is used as a predictor of child mortality and fertility timing responses to short term economic stress, two outcomes known to vary by social status in historical European populations.

Extended Abstract

Background

Measurement of social status in historical populations relies on a range of documentary evidence. In some communities, direct measures of income, wages, or wealth are available, while others rely on tax registers to infer economic standing. In many historical demographic documents, the most common indicator of social status is occupation. While important efforts have been made to standardize occupational status for comparative purposes (Schulz & Maas, 2010; Van de Putte & Miles, 2005; Van Leeuwen, Maas & Miles, 2002), not all communities have complete occupation listings, especially for women. Further, it is not clear how to classify multiple or by-employments accurately.

The reconstruction of social structure in nineteenth century Orkney is complicated by record availability and content in this specific social and economic context. Many commonly used historical demographic measures of socioeconomic status are unavailable or inappropriate for use in Orkney. Tax records are not available for individuals, but records of the taxable value of landholdings have been preserved and transcribed by the NOPH team. However, the interpretation of these land valuations is less clear in the case of large farms that hired many live-in agricultural servants and provided their workers with a dwelling and small parcel of land. The total valuation of the farm is listed, but not the portions assigned to each agricultural laborer, so the appropriate division of the total amount is unclear. Listings of occupations in the UK census and vital registers are often incomplete, especially for women. In addition, oral histories and documentary evidence from North Orkney indicate that it was common for individuals to hold multiple occupations at the same time, adding difficulty to classification efforts. There are few indicators of educational attainment or literacy available for the study period. Finally, the socioeconomic structure of the islands was somewhat flattened, as the landowning class was often absent from the islands, usually residing in Edinburgh or other locations to the south. Household position in labor and marriage networks may bridge this gap in our understanding of

the social structure of North Orkney and may have applications for other communities with comparable historical demographic data. The indicators derived from the proposed network approach are generated by the data rather than imposed by a classification scheme. This technique may be applicable to other historical populations with similar surviving demographic data sources. The network measures will be evaluated in event history models of the responses of child mortality and fertility timing to short term food price variation, which are known differ by social status both within historical Orkney and Europe (Bengtsson, Campbell, & Lee, 2004; Tsuya, Feng, Alter, & Lee, 2010).

Life-cycle servants, or servants in husbandry, were a common feature of preindustrial life throughout Europe. These servants worked as part of the household economy of the family that hired them in exchange for room, board, and wages (Kussmaul, 1981a 1981b, Whittle, 2000). Work in service was common for men and women and important driver of migration of young people out of their household of origin (Kussmaul, 1981a; Laslett, 1984; Laslett & Wall, 1974). This allowed young people some degree of independence from their parents before marriage and broadened their social contacts (Ewan, 2004). Social and kin networks were often essential to the hiring process as sources of information about available positions and the character of the individuals involved (Goldberg, 1992; Kitchen, 1981). The sending out of children as servants and the hiring of servants could therefore establish or reinforce economic and social ties among households.

Potential spouses made decisions about marriage in North Orkney, as in much of Northwest Europe, but family input was certainly important in forming opinions about the suitability of perspective partners and families could exert influence on decisions to marry and the timing of marriage. Marriage had significant economic consequences for the both the couple and their families of origin. Marriage ties could therefore unite families both socially and economically. Resources and information may be more likely to flow between households linked by marriage ties than those without such ties.

Marriage and labor networks could contribute to the social structure of rural society and the formation of social capital, especially in a region, such as North Orkney, where resources were limited and standard of living was low (Jennings, Quaranta, & Bengtsson, 2017). The techniques of social network analysis have proven useful in studying the formation of different kinds of social ties, as well as studying the relationships between network structure and social capital (Burt, 2005; Granovetter, 1973). A classic network study of wealthy Florentine families examined overlapping marriage and business ties (Padgett & Ansell, 1993). Kinship ties and social capital have been studied in a range of contexts, including colonial North America and pre-modern Prussia (Fertig, 2009; Morrissey, 2013).

In both marriage and labor networks, reputation, trust, and economic cooperation and interdependence may be influenced by network ties and structures (Kilduff & Krackhardt, 1994; Schweizer & White, 1998). These networks influence the deployment of resources in a remote community, and individuals and households that are favorably positioned in these two networks will have access to better flows of information, resources, and social capital. The systematic study of labor and marriage networks can advance our understanding of social structure in this rural, agrarian community.

Data and methods

The North Orkney Population History Project (NOPH) has collected and digitized historical demographic data including civil records of births, deaths, and marriages (1855-

present), and micro-level census data (1851-1911). These data have been linked to reconstruct individual life courses using the techniques of family reconstitution and nominal linkage. Demographic data are supplemental by detailed contextual information from grain price series, historic and modern maps, satellite imagery, archaeological surveys, and oral histories (Jennings, 2010; Sparks, 2007). The inhabitants practiced smallholder mixed agriculture supplemented by fishing and rural trades throughout the study period, and life-cycle servants were present in relatively high numbers, even in the early twentieth century.

The servant population of North Orkney during the study period ranged from 4.2 to 8.8 percent of the total population of the islands and 14.0 to 27.8 percent of the population aged 12-30. The vast majority (88 percent) of life-cycle servants were born in the study area, which allows us to track their life courses through the NOPH database. For servants from the study area, we can connect the individual to their household of birth and the household that hires them. 1578 marriages are recorded in the NOPH data between 1855 and 1911, and information on households of residence before marriage and parents' names allow for the reconstruction of marriage ties between the households and families of the bride and groom if they resided in the study area.

Ties of marriage and the sending and receiving of servants are be used to construct two sociomatrices, one for the marriage network and one for the servant network. Decennial census returns from 1851 to 1911 are used to create a sampling frame of households (N=814) so that isolates (households with no ties of marriage or service) could be included in the analysis. Incoming or outgoing ties from outside of the study area are excluded from the analytic sample, as household-level covariates cannot be identified.

The marriage network contains all brides and grooms with households of origin in the study area that could be identified in civil marriage records from 1855-1911. This period marks the beginning of civil registers of vital events in Scotland and the end of publically available census microdata. To construct the servant network, decennial census microdata (1851-1911) were used to identify the service household, and then nominal record linkage was used to find the household of origin for servants born and working in the study area. Thus, the census only captures snapshots (each ten years apart) of individuals who were servants at the time of enumeration. This sampling will miss some individuals who worked as servants, but there is no reason to believe that the sample would bias the network systematically. Rather, it would reduce its overall size and density.

Both networks are valued and directional. The value signifies the count of the number of ties that occurred between 1851 and 1911 (1 for one tie, 2 for two ties, and so on). Direction indicates the flow of servants from household of origin to household of service, while in the case of the marriage network, direction indicates the flow of grooms. While direction in a marriage network is less intuitive than in a servant network, and the choice of direction is arbitrary, directional ties are required for analysis of regular equivalence using the REGE algorithm (Borgatti, Everett, & Johnson, 2013).

Positional analysis is performed to uncover structure within North Orkney society using position within the marriage and servant networks as an indicator of social status. Regular equivalence is used as it relaxes the strict assumptions of structural equivalence, which would not allow for similarly positioned household on different islands to be grouped together (D. R. White & Reitz, 1983). Given the degree of spatial clustering in the networks, the assumptions of structural equivalence are too restrictive. In regular equivalence, actors are equivalent if they are tied to similar, but not exactly the same actors (Borgatti & Everett, 1992). The regular

equivalence algorithm REGE is used to partition the households based upon similar profiles of their position within the network. The REGE algorithm performs single-link hierarchical cluster analysis on the estimated equivalence matrix.

The analysis that follows uses clustering at the level of 6 groups, as it provided at least 20 observations in each group but allowed a sufficient number of groups to compare group-level characteristics using blockmodeling techniques. The choice of 6 groups is also supported by analysis of block membership, as it clustered isolates together, high-degree households together, and households of similar landholding size together (Faust & Wasserman, 1992). Blockmodeling is used to produce blocks of similarly positioned households (DiMaggio, 1986; H. C. White, Boorman, & Breiger, 1976). In blockmodeling, rows and columns of the adjacency matrix are arranged so that structurally similar actors are grouped together. The matrix is then reduced to represent these blocks of similar actors in what is known as an image matrix. Patterns in the reduced block model are compared to known structures in the data or actor attributes.

The blocks identified from the clustering of similarities using the REGE algorithm are used in an event-history analysis of the timing of child mortality and fertility between 1855 and 1911. Blockmodels identify households that are similarly connected in the marriage and servant networks. If network position confers advantages or disadvantages, one would expect that members of well-positioned blocks would enjoy a higher standard of living than members of more isolated blocks. In the event-history models (Cox proportional hazard models), the timing of mortality or fertility is predicted using time series of staple grain prices and control variables to explore whether this measure of network position is associated with vulnerability to short-term economic stress, proxied by annual variability in grain prices. In the interest of brevity in this work in progress, the construction of the person-year dataset and nature of the grain price data are described elsewhere (Jennings, Quaranta, & Bengtsson, 2017).

Preliminary Results

After descriptive analysis of the marriage and servant networks (Figure 1) was conducted (Table 1), positional analysis was conducted using regular equivalence (REGE algorithm, UCINET software). The REGE algorithm performed better than techniques using the automorphic definition of equivalence, which did not cluster high-degree households well. Using the results of the cluster analysis of measures of similarity produced by REGE, I chose a six-group level of clustering. While the choice in level of clustering is somewhat arbitrary in positional analysis, the six groups ensured at least 20 households were included in each group (Table 2). Further, this level of grouping clustered together isolates and high-degree households, and attributes of group members differed in ways that are sensible given the social structure of North Orkney during the study period. Blocks 3 and 5 contain some of the largest farms, which hired many servants and housed married servants in nearby cottages and unmarried servants in the main house or bothy, which is reflected in the average farm value, land held, and household size in these blocks. These blocks were also most central or popular in the network, as they had high degree, meaning more incoming and outgoing ties.

Positional analysis and blockmodeling is one approach to dimension reduction in large networks. When reduced to the identity matrices and visualized (Figure 2), some patterns emerge. Blocks 1 and 6 include the isolates from the marriage network (block 1) or both networks (block 6). Block 5 receives the most incoming ties and sends many outgoing ties in both networks, making it the most central group. Blocks 2, 3, and 4 are intermediate, but block 3

is the most prominent of these blocks. Two and 4 send more ties to other groups than they receive, while block 3 receives many ties, but not as many as block 5.

Given the results of positional analysis and blockmodeling, I hypothesize households in block 5 experience higher standard of living than those of the other blocks, as this block sends and receives many ties. If integration with the local community confers benefits and marriage and economic ties indicate trust, prestige, or the availability of social capital, then block 5 should be more advantaged than the rest, with the possible exception of block 3. The six block groups each have a mix of agricultural and non-agricultural households (Table 3), which were found to be affected differently by short-term economic stress (Jennings et al., 2017). Thus, the social structure revealed by the blockmodeling approach is different than what one would find using only occupation as an indicator of status.

To test this hypothesis, block 5 was compared with all other blocks in Cox proportional hazard model (Allison, 1984; Cox, 1972) of child mortality[1] from age 1 to age 15 and the timing of fertility in response to short-term economic stress, measured by variation in staple grain prices, in this case, oatmeal. This model is conceptually similar to a previous study that relied on occupation sector (agricultural vs. non-agricultural) as a measure of socioeconomic status (Jennings et al., 2017).

The results of these event-history models of mortality are shown in Table 4. For the high-status group (Block 5), there is no significant effect of grain price in the current or lagged year, indicating a high standard of living for the families of these children, as the risk of death was not affected by changes in food prices. For the lower-status group (all other blocks), there is a negative effect of high grain price, such that a 10% increase in grain price increases the risk of child mortality by 24.9% in the current year, but not the lagged year.[2] This reflects a rapid response to poor conditions, and low standard of living for this group, as even relatively small fluctuations in food prices increased the risk of death for their children.

The results of event-history models of fertility are shown in Table 5. For the high-status group (Block 5), the price of grain does not affect the timing of fertility in the current or lagged year, indicating that variation in economic conditions did not affect their fertility, which is taken to be an indication of high standard of living. For the lower-status group (all other blocks), a 10% increase in grain price decreased fertility by 13.6% in the lagged year, but not the current year.[3] This delayed fertility response is typically interpreted as a failure to anticipate poor conditions and adjust fertility behavior accordingly (Bengtsson & Dribe 2006). Fertility behavior changes in response to economic variation that can be anticipated tend to occur in the current year. The delayed response may be attributable to poor nutrition or the separation of spouses to seek employment and is an indicator of poor standard of living, as demographic behavior and plans were disrupted by food price fluctuations.

Discussion

The marriage and servant networks in North Orkney provide some insight into social structure and social processes in the islands. The blockmodel produced from these networks

[1] Models for infant mortality (ages 0-1) were also estimated, but the price effects were not statistically significant, possibly reflecting the practice of breastfeeding.

[2] These results are robust to including block 3 with block 5 in the high-status group, although the number of child deaths among the low-status group fell below 100 after moving block 3.

[3] These results are also robust to including block 3 with block 5 in the high-status group.

demonstrates that aspects of the social and economic relationships that are essential to well-being in a small, isolated society can be uncovered using marriage records and microlevel census data that identify life-cycle servants. These social and economic ties are associated with standard of living, as measured by child mortality and fertility responses to short-term fluctuations in grain prices. Ties within local networks may buffer or amplify the effects of short term economic stress, as demonstrated using non-network measures of social standing in comparative contexts (Bengtsson, Campbell, & Lee, 2004; Tsuya, Feng, Alter, & Lee, 2010). When indicators of social or economic standing, such as tax records, or detailed and reliable occupation, income, or landholding records are unavailable, network analysis may be a useful tool to provide insight into social structure in the past. Indeed, the blocks produced using this approach arrive at similar results in response to short term stress as occupation categories, even though the two methods of measuring social structure do not create fully overlapping groups, as the children of non-agricultural and agricultural workers are found in both high and lower status blocks (Table 3).

The techniques of position analysis and blockmodeling can be applied to other networks of interest to historical demographers, including position and roles within kin networks, and other outcome variables, such as mortality among other age groups. Further, the findings presented here suggest that these two networks, which are often available from historical records, can be employed as an indicator of social capital that is associated with health or wellbeing (Cattell, 2001; Lin, 1999).

Future Directions

Future directions for this work include examination of the blocks produced by each of the two networks in isolation, rather than as a joint network. A sensitivity analysis of the event-history models to of the level of clustering may provide additional insight into the robustness of the blockmodel approach. Other improvements to this approach include the parsing of agricultural servant households on large farms. In the present state of record linkage in the NOPH dataset, they are grouped together, as are the households in the one small village in the sample, Pierowall (excluded from the current analysis for this reason). This effort will help to increase the linkage rate and improve sample size. Finally, more in-depth comparison the results of positional analysis to other measures of socioeconomic standing are required, especially occupation and land valuation. While there are some weaknesses to these two measures, a rigorous comparison will assist in the assessment of the adequacy of the blockmodels.

Acknowledgements

I wish to thank Luciana Quaranta and Tommy Bengtsson, my collaborators on the first iteration of this project, the members of the NOPH team, and the people of North Orkney. My research is supported by the National Institutes of Health (1 K01 AG055664).

Tables and Figures

Figure 1. Network map of the joint marriage and servant network, 1851-1911. Color indicates island. Isolates removed. Source: NOPH database.

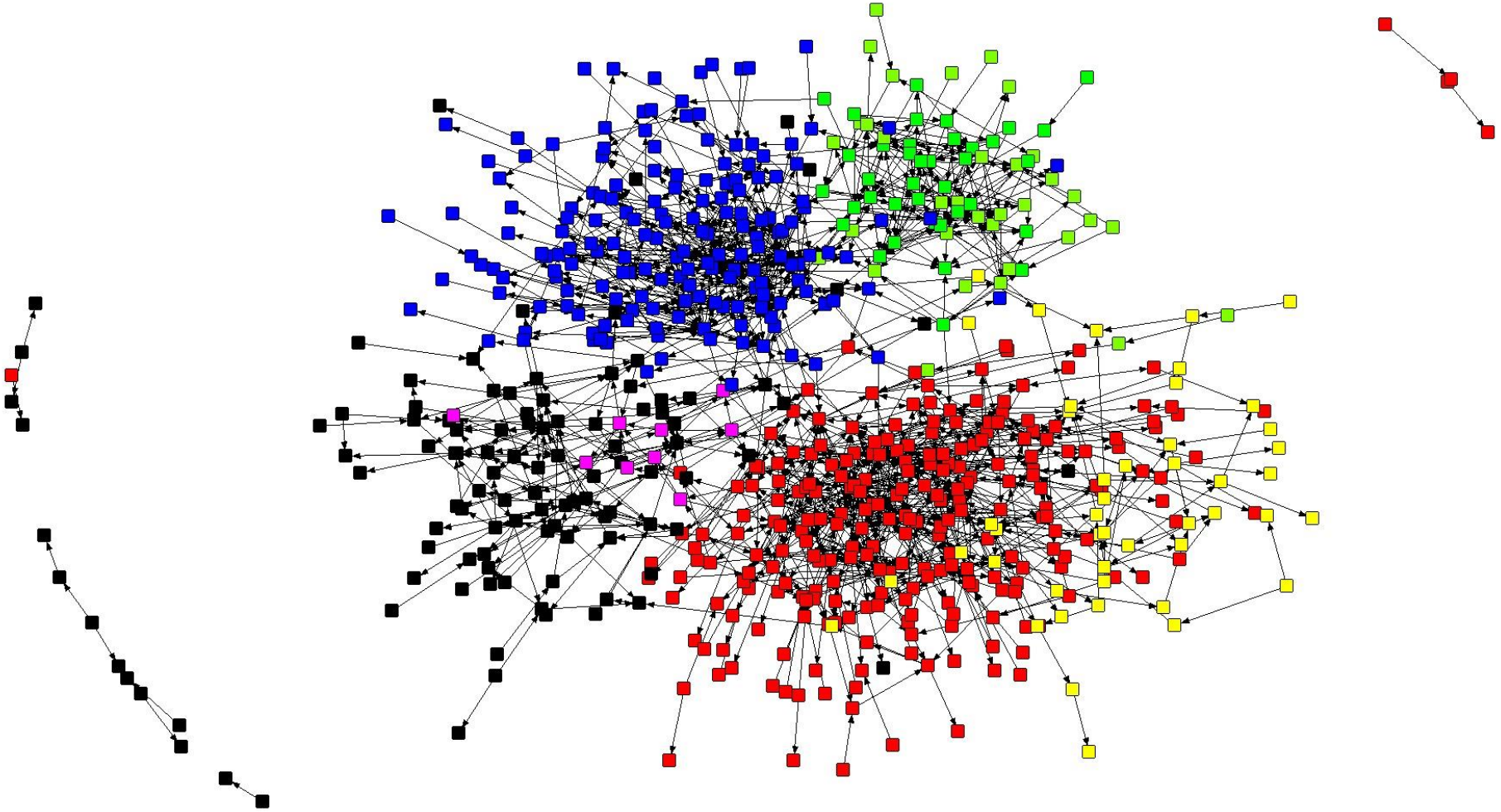

Table 1. Descriptive measures of the marriage and servant networks. Source: NOPH database.

	Marriage	Servant
Count of Nodes	814	814
Count of Ties	1088	396
Count of Isolates	208	450
Avg. Degree	1.337	0.486
Density	0.002	0.001
Avg. Distance	9.627	2.016
SD Distance	4.151	1.186
Diameter	27	6
Dyad Reciprocity	0.061	0.016
Island E-I index	-0.881	-0.752
Triad transitivity	0.022	0.029

Table 2. Selected attributes of the six blocks identified using cluster analysis of regular equivalence. Source: NOPH database.

Block	Count	Percent of sample	Average land value	Proportion female HH head
1	21	2.58	7.85	0.21
2	104	12.78	7.12	0.15
3	67	8.23	21.98	0.12
4	105	12.90	6.56	0.17
5	356	43.73	25.05	0.12
6	161	19.78	5.67	0.19

Figure 2. Reduced network map using the image matrix of the joint marriage and servant blockmodel. Source: NOPH database.

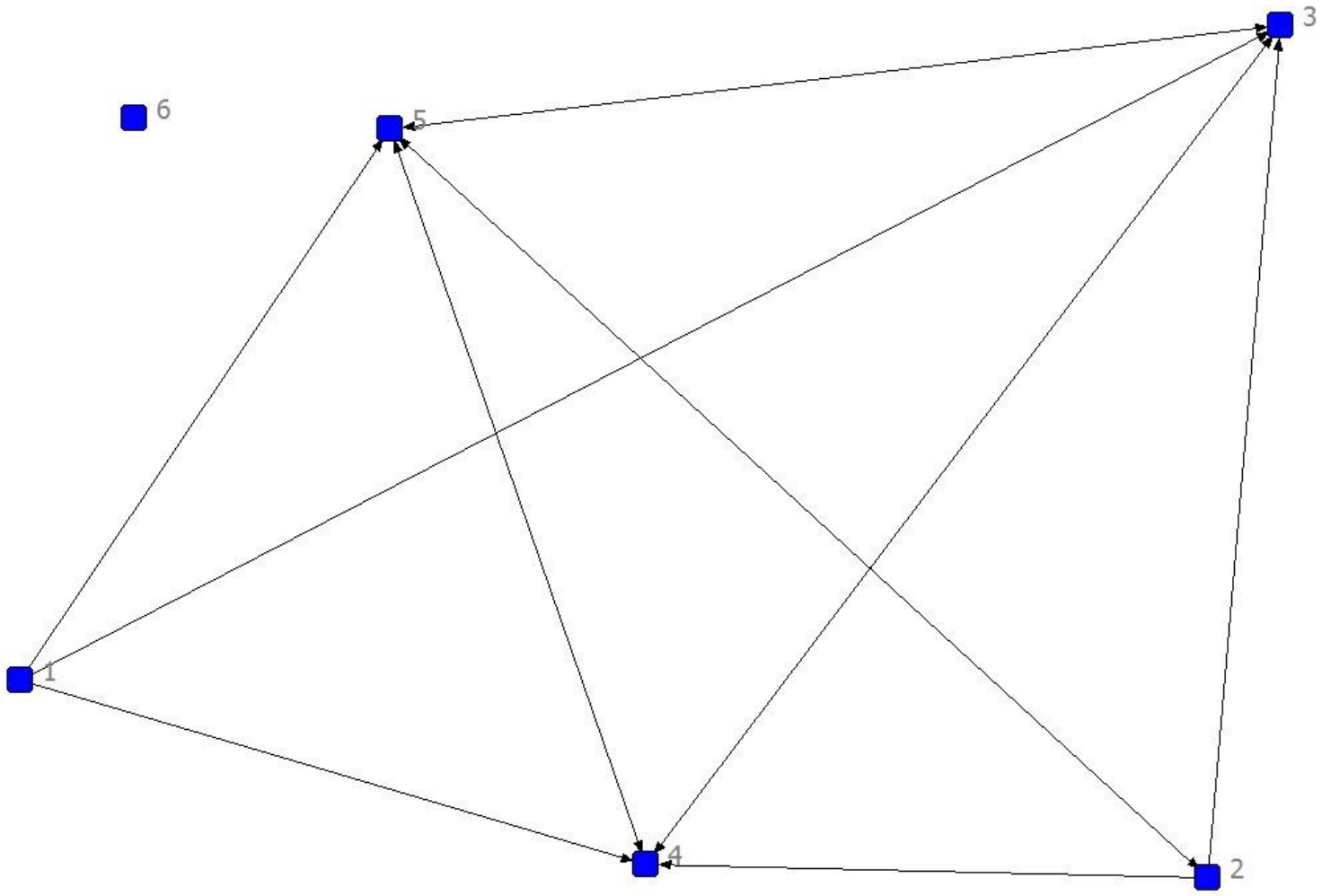

Table 3. Occupations represented in the six blocks. Farmers include owner-occupier and tenant farmers. Semi-landless includes agricultural laborers and servants. Non-agricultural occupations include artisans, general laborers, skilled trades, and fishing, among others. Source: NOPH database.

Block Number	Farmers	Semi-landless	Non-agricultural
1	0.41	0.33	0.26
2	0.58	0.15	0.28
3	0.50	0.27	0.24
4	0.39	0.25	0.36
5	0.43	0.24	0.33
6	0.28	0.30	0.42

Table 4. Cox proportional hazards models of mortality for children aged 1-14 years, North Orkney, 1855-1911: models for all children and for different block groups. Source: NOPH database.

	All children		High-status (block 5)		Lower-status (all other blocks)	
	Hazard ratio	p-value	Hazard ratio	p-value	Hazard ratio	p-value
Year	0.988	0.003	0.993	0.213	0.980	0.002
Male	0.897	0.385	0.926	0.637	0.853	0.414
female, ref.	1.000	--	1.000	--	1.000	--
High-status (block 5)	0.798	0.08	--	--	--	--
Lower-status (all other blocks), ref.	1.000	--	--	--	--	--
Percent change in mortality with 10% increase in current oat price	16.127	0.052	10.080	0.347	24.912	0.058
Percent change in mortality with 10% increase in lagged oat price	-2.213	0.764	-2.694	0.784	-2.532	0.821
N Children	4293		2583		1710	
N Deaths	248		142		106	

Table 5. Cox proportional hazards models of fertility, North Orkney, 1855-1911: models for all women and for different block groups. Source: NOPH database.

	All Women		High-status (block 5)		Lower-status (all other blocks)	
	Hazard ratio	p-value	Hazard ratio	p-value	Hazard ratio	p-value
Year	0.997	0.011	0.996	0.003	1.000	0.906
Previous child died (1=yes; 0=no)	1.737	<0.001	1.819	<0.001	1.532	0.045
High-status (block 5)	1.078	0.074	--	--	--	--
Lower-status (all other blocks), ref.	1.000	--	--	--	--	--
Percent change in fertility with 10% increase in current oat price	0.059	0.979	0.349	0.899	-0.198	0.963
Percent change in fertility with 10% increase in lagged oat price	-4.413	0.048	-0.099	0.972	-13.610	0.001
N Women	1020		734		395	
N Births	1572		1088		484	

Note: Controls for age of woman not shown

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