A social network analysis of psychological morbidity in an urban slum of Bangladesh: a cross-sectional study based on a community census

APPENDIX A: DETAILED ITEM ANALYSES OF GHQ-12

Here we present the detailed item-wise report from the Generalized Health Questionnaire we have implemented among our respondents (see Appendix Table 1). We have used a version of the GHQ-12 that has been previously translated and adopted in Bangladeshi context (Hossain, Siddique and Habib 2017, Islam and Iqbal 2008).

Appendix Table 1: GHQ-12 Responses by Each Item

	Reponses (fraction of total)				Mean	95% CI	
	Never	Sometimes	Often	Always			
	0	1	2	3			
Have you recently been able to; concentrate on what you are doing?	0.347	0.489	0.157	0.007	0.824	0.776	0.872
Have you recently lost much sleep over worry?	0.417	0.485	0.085	0.012	0.692	0.646	0.738
Have you recently felt you were playing important part in things?	0.369	0.468	0.159	0.004	0.797	0.749	0.846
Have you recently felt capable of making decisions about things?	0.214	0.567	0.211	0.008	1.015	0.968	1.061
Have you recently felt consistently under strain?	0.280	0.511	0.184	0.024	0.953	0.901	1.004
Have you recently felt you couldn't overcome your difficulties?	0.227	0.552	0.205	0.016	1.010	0.962	1.058
Have you recently been able to enjoy your normal day to day activity?	0.291	0.522	0.180	0.007	0.903	0.855	0.951
Have you recently been able to face up to your problems?	0.209	0.542	0.242	0.007	1.047	1.000	1.095
Have you recently been unhappy and depressed?	0.471	0.453	0.069	0.007	0.613	0.569	0.657
Have you recently been losing confidence in yourself?	0.715	0.221	0.028	0.036	0.386	0.337	0.435
Have you recently been thinking of yourself as a worthless person?	0.733	0.237	0.017	0.013	0.311	0.271	0.350
Have you recently been feeling reasonably happy, all things considered?	0.451	0.437	0.097	0.015	0.675	0.626	0.723
Overall GHQ-12					9.225	8.893	9.556

There are two suggested methods of scoring for GHQ-12. We have used the 'four point response scale' or Likert method, which should allow more variation in the scores (see Hankins 2008). GHQ-12 typically captures the unidimensional nature of unspecified psychological morbidity and commonly used in survey based instruments to measure the mental wellbeing in different populations.

APPENDIX B: CENTRALITY MEASURES

While intuitive, just focusing on the number of friendship ties can mask the deeper structure of social power or popularity within a network. We focus on a number of more sophisticated measures of centrality which gauge one's position in the entire network by analyzing not just the number of people they are connected to but also the type of people they are connected to and reveals to what extent that person is central/peripheral in his social network by analyzing their network positions (Freeman 1978). While 'node degree' shows the extent of connectedness, centrality shows how well and centrally each node is connected and we focus on a number of them.

Degree Centrality

Degree centrality is simply the number of degrees each person has. In-degree centrality is the number of referrals each person gets, out-degree centrality is the number of referrals each person gives and all-degree centrality is the number of total referrals (summing both the referrals he gives and the ones he gets). Hence, degree centrality is just the number of friendship ties each respondent has normalized by the possible total number of ties ($N-1$).

Closeness Centrality

Closeness centrality is the inverse of the average distance within a network. It measures how distant a node is from the rest of the nodes and how many times it has to be crossed by other nodes to reach some other node using the shortest path. Applying this in the context of our friendship network, we can measure how many stages a person requires to get connected to another random person or node in the network.

$$\text{Closeness Centrality}_i = \frac{n-1}{\sum_{j \neq i} l(i,j)}$$

where, $l(i,j)$ denotes the number of links node i needs to reach to node j using the shortest path. Input closeness centrality and output closeness centrality take into account of the direction of referral while all closeness centrality does not.

Betweenness Centrality

Betweenness centrality is a measure of centrality based on how well situated a person is in terms of the paths he lies on (see Freeman 1978, Jackson 2010). This takes into account the number of shortest links connecting each node to all other nodes that pass through a particular node.

Let $P_i(j,k)$ denote the number of shortest paths between any two nodes j and k that pass through node i and, let $P(j,k)$ represent the number of shortest paths between these two nodes . Then,

$$\text{Betweenness Centrality}_i = \sum_{k \neq j,k,j} \frac{P_i(k,j)/P(k,j)}{(n-1)(n-2)/2}$$

where, n is total number of nodes. So in short, betweenness centrality of a node is equal to the number of geodesics passed through that particular node divided by the number of all the geodesics of any two other nodes.

Eigenvector Centrality

Eigenvector centrality measures a person's centrality based on the centrality of his direct connections. Letting $C^e(g)$ denote the eigenvector centrality associated with a network g, then the centrality of a node is proportional to the sum of the centrality of its neighbors. So, eigenvector centrality, $\tau C_j e(g) = \sum_j g_{ij} C_j^e(g)$. And in terms of matrix, $\tau C^e(g) = gC^e(g)$ where $C^e(g)$ is an eigenvector of g and τ is the corresponding eigenvalue.

Eigenvector centrality is a better measure of social prestige as it takes account of the position of the direct friends of each person (Bonacich, 2007). As a result, a person having very few but centrally positioned friends will not be under-estimated to a person having a lot of almost isolated or peripherally positioned friends. Eigenvector centrality is closely related to Bonacich centrality and is a variant of Bonacich centrality. They are also used as a proxy for each other (Bonacich, 1987, Bonacich, 1991).

APPENDIX C: ROBUSTNESS CHECKS

To test the validity of our statistical findings, we carry out some additional robustness checks to see whether our estimates are sensitive to the models we have determined. The results are presented in Appendix Table 2. We first restrict our models by dropping the 267 isolated respondents. It is possible that our centrality measures can pick up the outcome differences between these two groups. However, results in row (1) of Appendix Table 2 suggest this is not the case. The estimate on the sub-sample is -0.098 (95% CI -0.151 to -0.044), which is very similar to the value we found in column (4) in Table 3. The estimated coefficient on betweenness centrality is not sensitive to excluding the isolated nodes. We also find that betweenness centrality has too many zeros, hence, we define a dummy for respondents with non zero values and re-estimate the model. We find negative association between mental health outcomes of the respondents and those with non-zero betweenness centrality (-0.163, 95% CI -0.321 to -0.004, see row [2]). The results are very similar for eigenvector centrality as well (see rows [3] and [4] in Appendix Table 1). We also use a new measure of being influential within a network namely input proximity prestige index. We find that one SD higher value in this index is associated with 0.06 SD lower GHQ score (95% CI -0.124 to 0.010, see row [5]), suggesting better mental health outcomes.

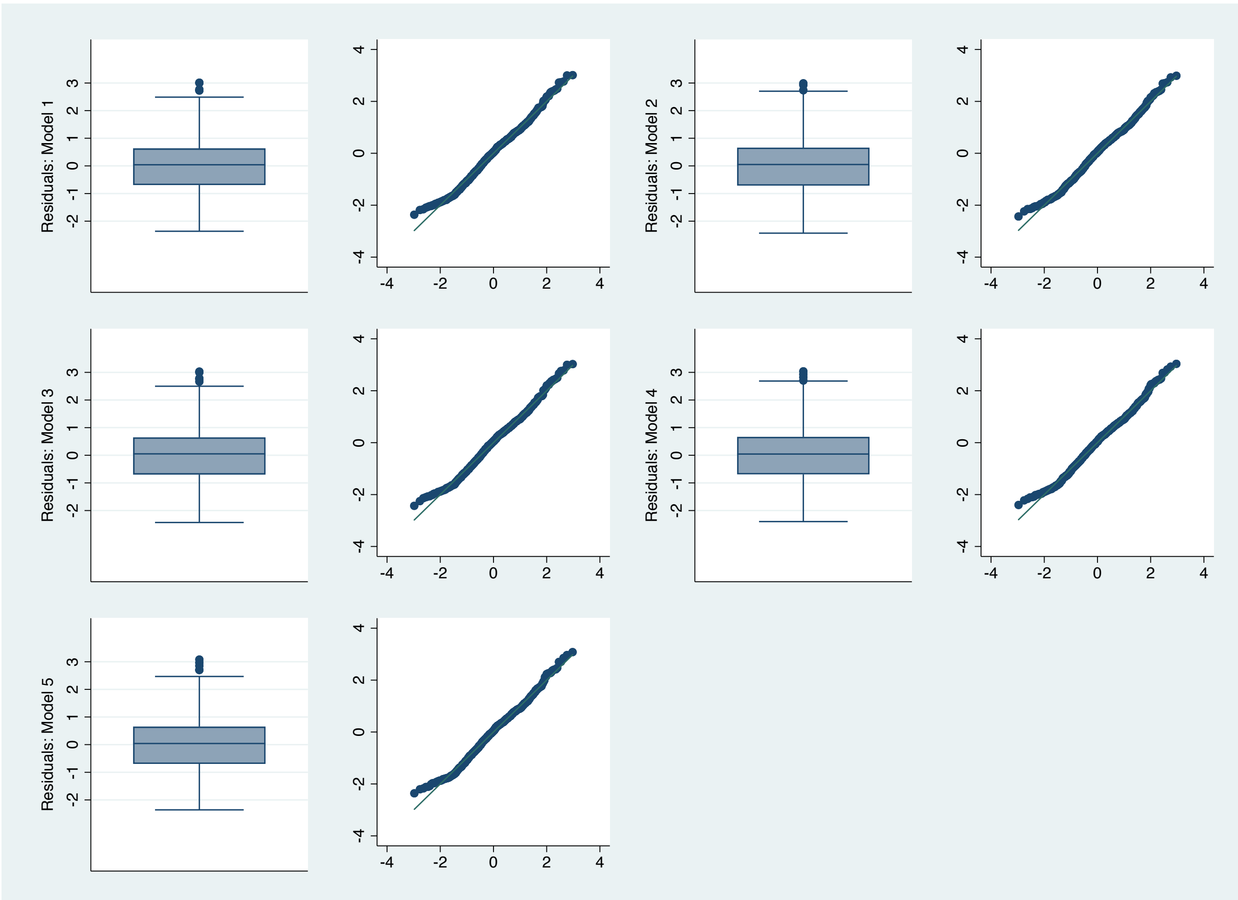
Appendix Table 2: Robustness Checks

		Coefficient	(95% CI)	N	R^2
(1)	Betweeness Centrality (standardized) excluding isolated respondents	-0.098***	(-0.151 to -0.044)	557	0.058
(2)	= 1 if Betweenness Centrality > 0	-0.163**	(-0.321 to -0.004)	824	0.038
(3)	Eigenvector Centrality (standardized) excluding isolated respondents	-0.060***	(-0.098 to -0.023)	557	0.051
(4)	= 1 if Eigenvector Centrality > 0	-0.117	(-0.257 to 0.023)	824	0.037
(5)	Input Proximity Prestige (standardized)	-0.057*	(-0.124 to 0.010)	824	0.036
Results from ordered probit models					
(6)	All closeness centrality (standardized)	-0.052	(-0.124 to 0.019)	824	
(7)	Betweenness centrality (standardized)	-0.106***	(-0.177 to -0.034)	824	
(8)	Eigenvalue centrality (standardized)	-0.064*	(-0.133 to 0.006)	824	

Note: The outcome variable is the standardized GHQ score in all specifications. In specifications (1) and (3), we drop the respondents who do not have any friendship tie. In specifications (2) and (4), we use an indicator variable for respondents with non-zero centrality values. In specifications (6-8), we use ordered probit models for the discrete standardized GHQ score as the outcome variables. In all specifications, we have retained the control variables that we include in Table 3. The robust p-values are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

As we noted earlier, GHQ scores are essentially discrete in nature and we could actually reject null hypothesis of normality distribution in GHQ scores. So we have re-estimated the models with three centrality scores using ordered probit models and relaxed the normality assumption in the outcome variables. The results are presented in rows (6-8). We find that both the point estimates and also the second moments are generally not sensitive to the alternative regression models.

Appendix Figure 1: Testing for Outliers in Residuals and QQ Plots



Note: In each panel, on the left we plot the box-plot for the residuals from each model reported in Table 3. On the right, we show the QQ plots for the same residuals.

APPENDIX D: DIAGNOSTIC TESTS FOR REGRESSION RESULTS IN TABLE 3

We present some diagnostic tests for the basic Gauss-Markov assumptions here (see Wooldridge 2002). Our outcome variable is discrete in nature so it is important test for normality. We also check for outliers in our models. We box plot the residuals for all five models from Table 3 and also plot the QQ chart to visually inspect the distributions for the residuals from the same models. We present the charts in different panels in Appendix Figure 1.

Simple visual inspections suggest there are few outliers in the residuals from all five models; however, the frequency does not warrant much concern. We also look at the quintile normal figures and residuals generally lie on the lines. While they may suggest that misspecifications may not be an issue we further use statistical tests to check the normality of the residuals. We show the results in Appendix Table 2.

Appendix Table 2: Normality Tests

	p-value	
Model	**Shapiro-Wilk**	**Shapiro –Francia**
1	0.00041	0.00121
2	0.00077	0.00213
3	0.00059	0.00163
4	0.00062	0.00172
5	0.00042	0.00119

Note. We report the p-values from Shapiro-Wilk and Shapiro-Francia tests for residuals from each model reported in Table 3.

The normality tests reported in Appendix Table 2 suggest that in all five models null of hypotheses of normality are rejected. Hence, we carry out further robustness checks with alternate specifications as reported in Appendix D below.

BIBLIOGRAPHY

Bonacich, Phillip. “Power and Centrality: A Family of Measures.” *American Journal of Sociology*, 1987: 1170-1182.

Bonacich, Phillip. “Simultaneous group and individual centralities.” *Social networks* 13, no. 2 (1991): 155-168.

Bonacich, Phillip. "Some unique properties of eigenvector centrality." *Social networks* 29, no. 4 (2007): 555-564.

Freeman, Linton C. "Centrality in social networks conceptual clarification." *Social Networks* 1, no. 3 (1978): 215-239.

Hossain, Md. Mobarak, Nur-E-Alam Siddique, and Murshida Ferdous Binte Habib. "Status of Marital Adjustment, Life Satisfaction and Mental Health of Tribal (Santal) and Non-Tribal Peoples in Bangladesh: A Comparative Study." *IOSR Journal Of Humanities And Social Science (IOSR-JHSS)* 22, no. 4 (2017): 5-12.

Islam, Md. Nurul, and Kazi Ferdous Iqbal. "Mental Health and Social Support." *The Chittagong Univ. J. B. Sci* 3, no. 1&2 (2008): 95-107.

Wooldridge, Jeffrey M. *Econometric analysis of cross section and panel data.* Cambridge, MA: The MIT Press, 2002.