

# Networks, Peer Effects and Socioemotional Skills

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Very Preliminary

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- Interpersonal relationships has a vital role in many outcomes (education, crime, labor market, production, etc.).
- They can be formalized as direct links of agents. The collection of such links is called networks.
- The literature in economics has recognized the importance of social networks in structuring interaction among agents. (Jackson, 2009)
- The literature has also paid attention on the role of homophily on link formation (Fafcamp and Gubert, 2007; Mele, 2013; Goldsmith-Pinkham and Imbens, 2013; Dzemski, 2015; Graham, 2015)

- There is also a huge literature on evaluating peer effects on student achievement (Sacerdote, 2001; Hanusheck, 2003, Stinibricker and Stinibricker, 2006; Calvol-Armengol, 2009; Boucher et al, 2014; etc.).
- They look at both contextual and endogenous effect.
- The importance of socioemotional skills (SES) in several outcomes has been documented in the literature (crime, health, academic sucess, labor market, etc.) (Heckman, Stixrud, and Urzua, 2006; Almlund et. al., 2011; Fletcher, 2013)
- TTBOOK, no study has investigated the relationship between SES and networks nor the SES and peer effects.

- Networks and SES
  - Relationships (correlations) between SES and Networks Measures
    - Degree Heterogeneity; Density; Centrality; Clustering
  - The role (correlations again) of SES homophily on dyad formation
- Peer effects and SES
  - Contextual effect on Academic Achievement
  - Endogenous effect on SES

- Data on 3rd and 5th grade students of 30 elementary public municipal in Recife, PE, Brazil.
- The schools were randomly selected out of 120 schools.
- Two rounds of data were collected
- First round in July, 2014. Second round in December, 2014.
- We collected student-level data on cognitive skills, SES and social networks (friendship relationships)
- SAEPE (Basic Education Evaluation System of Pernambuco): proficiency on mathematics and language. The test is mandatory for all public schools from Pernambuco.

- **Verbal Logical Reasoning:** the extent and depth of verbal vocabulary knowledge and the ability to reason using concepts previously learned.
- **Abstract Reasoning:** the ability to think in new situations, create new concepts and understand implications.
- **Spatial Reasoning:** the ability to represent and manipulate mental images.
- **Numerical Reasoning:** the understanding of basic quantitative concepts such as addition, subtraction, multiplication and division and manipulation of numerical symbols.
- **Logical Reasoning:** items involving logical deductive reasoning questions similar to the child's daily life.

# Socioemotional Skills (SENNA Assessment: Big Five + Locus of Control)

- **Conscientiousness:** the tendency to be organized, responsible, and hardworking.
- **Extraversion:** an orientation of one's interests and energies toward the outer world rather than the inner world of subjective experience.
- **Emotional Stability:** predictability and consistency in emotional reactions, with absence of rapid mood changes.



# Socioemotional Skills (SENNA Assessment: Big Five + Locus of Control)

- **Agreeableness:** the tendency to act in a cooperative, unselfish manner.
- **Openness to Experience:** the tendency to be open to new cultural, or intellectual experiences.
- **External Locus of Control:** how individuals attribute experienced situations to chance or actions taken by third parties, as opposed to actions taken by themselves.

- Each student was asked to choose their closest classmates from a given list.
- The list had all the students enrolled in the class in the beginning of the year.
- The students could choose up to four classmates they enjoy doing each of the following activities with: playing, talking and studying.
- So far, we have looked at the three activities indistinctly.

# Sample size

Test	Test takers	Percentage
SAEPE	1643	50.3%
Cognitive	2697	82.6%
Socioemotional	1926	58.9%
Network	1982	60.7%

# Class Size

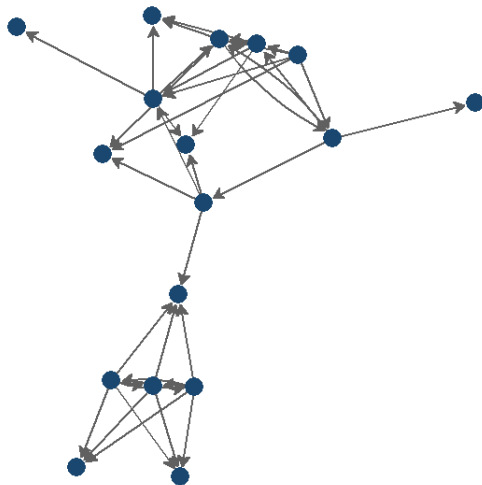
Students	Classes	Students	Classes
4	1	17	12
6	2	18	9
7	1	19	6
8	3	20	15
9	5	21	11
10	3	22	11
11	7	23	7
12	14	24	6
13	11	25	6
14	13	26	3
15	13	28	1
16	17		

# Test Takers

Test Takers	Classes	Test Takers	Classes
0	3	12	10
1	1	13	10
2	5	14	10
3	7	15	9
4	9	16	12
5	10	17	9
6	15	18	7
7	10	19	5
8	10	20	2
9	11	21	2
10	6	22	5
11	9		

- A node (or vertice) represents a student.  $N = 1, \dots, N$
- A link (or arc) represents a self-reported directed friendship (playing, talking or studying.)
- $G$  is the adjacency matrix. The element  $g_{ij} = 1$  if there is a relation between nodes  $i$  and  $j$ . (unweighted).
- In our case,  $G$  is asymmetric (directed).
- $G$  is block diagonal and each classroom also forms a different network ( $G_k$ ).
- There are 177  $G_k$ 's in our sample.

# Network Structure



- **Distance:** is the number of links in a shortest path (geodesics) connecting two nodes ( $D(ij)$ ).
- **Average Path:** is the average number of geodesics for all possible pairs of network nodes.
- **Density:** equals the frequency with which any randomly drawn dyad is linked.



- **Clustering:** Triple transitivity. If  $ij$  and  $ik$  are in the network, how often  $jk$  forms an arc.
- Overall clustering:

$$C^o = \frac{\sum_{i:j \neq i; k \neq j; k \neq i} g_{ij} g_{ik} g_{jk}}{\sum_{i:j \neq i; k \neq j; k \neq i} g_{ij} g_{ik}}$$

- **Centrality:** measures the importance of the location of a given node in a network.
  - **Degree:** is the total number of links that involves a node.
  - Directed networks: in-degree and out-degree.
  - **Closeness:** tracks how close a given node is to any other.
  - Inverse of average distance:

$$CL = \frac{n - 1}{\sum_{j \neq i} distance_{i,j}}$$

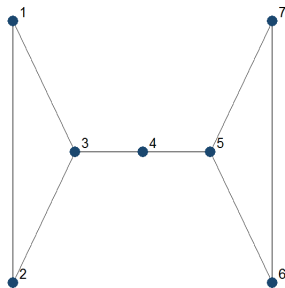
- For unconnected networks:

$$CL = \frac{\sum_{j \neq i} distance_{i,j}^{-1}}{n - 1}$$

- **Centrality:**

- **Betweenness centrality:** is an indicator of a node's centrality in a network. It is equal to the number of geodesics from all vertices to all others that pass through that node. Let  $D_i(jk)$  denote the number of geodesics between  $j$  and  $k$  that reaches  $i$ .

$$BW = \sum_{j \neq k: i \notin j, k} \frac{D_i(jk) / D(jk)}{(n-1)(n-2)/2}$$



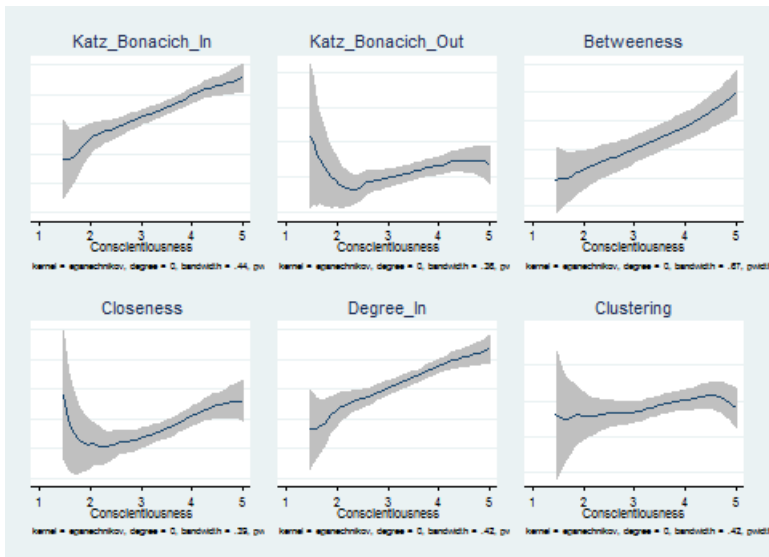
- **Centrality:**

- **Katz-Bonacich centrality:** (prestige centrality) is a weighted sum of the paths that starts from a node. Let a path of length 1 receives weight  $\lambda$ ; paths of length 2,  $\lambda^2$  and so on. Let  $\iota$  denote a vector of ones.  $G^k \iota$  is a vector with the number of paths of length  $k$  from each node.

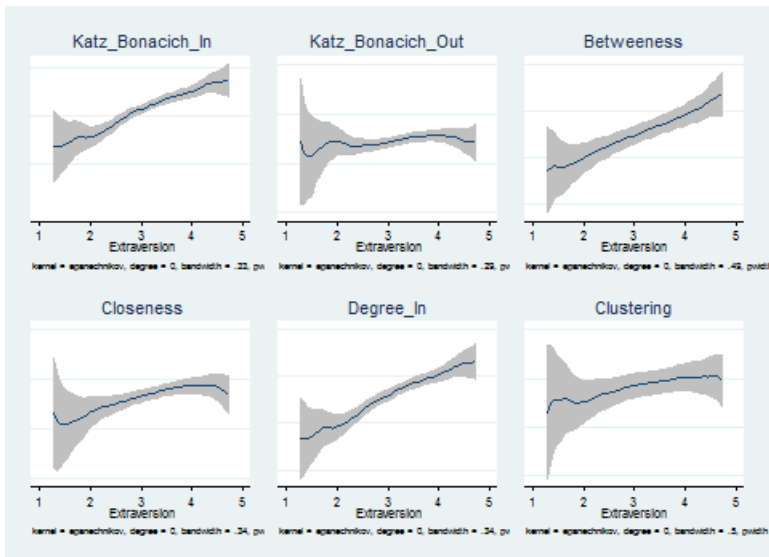
$$KB = \lambda G \iota + \lambda^2 G^2 \iota + \lambda^3 G^3 \iota + \dots$$

$$KB = (I - \lambda G)^{-1} G \iota$$

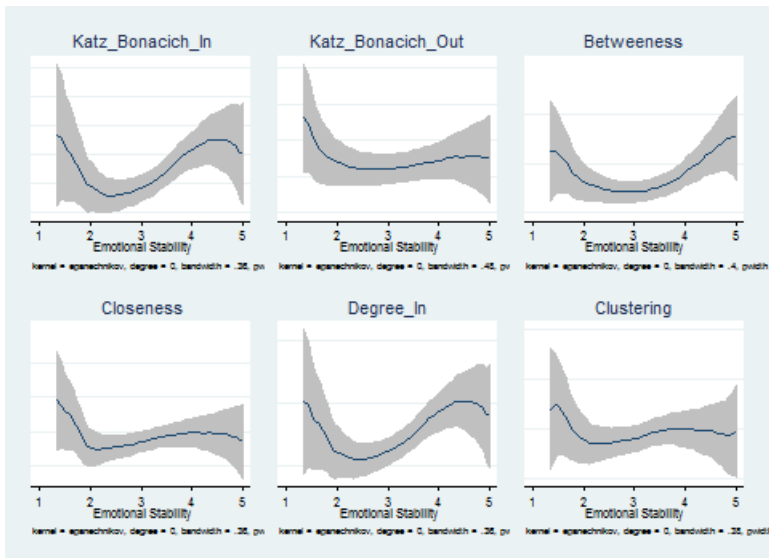
# Conscientiousness



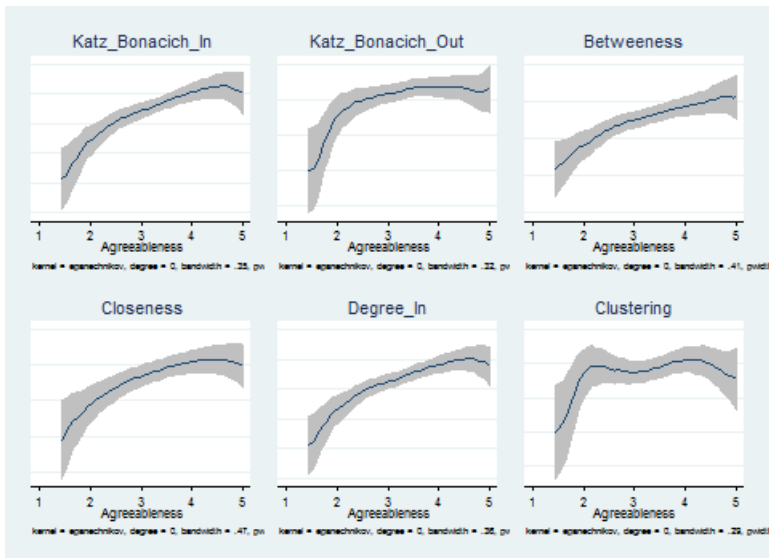
# Extraversion



# Emotional Stability

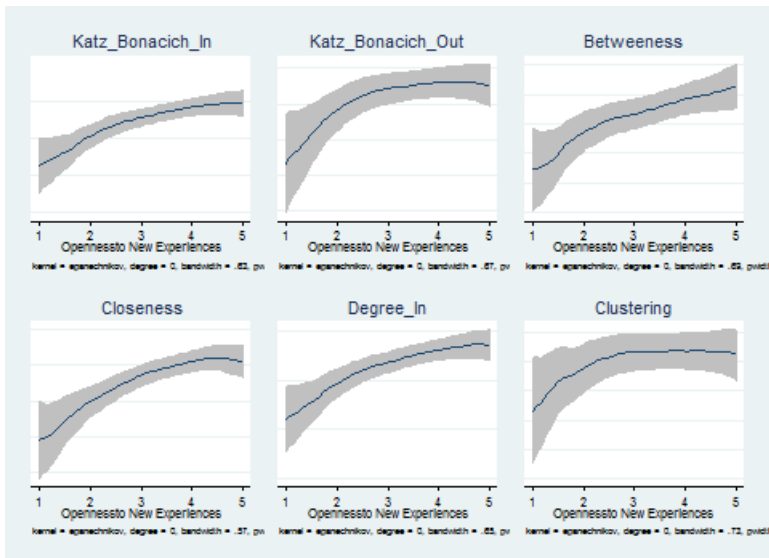


# Agreeableness

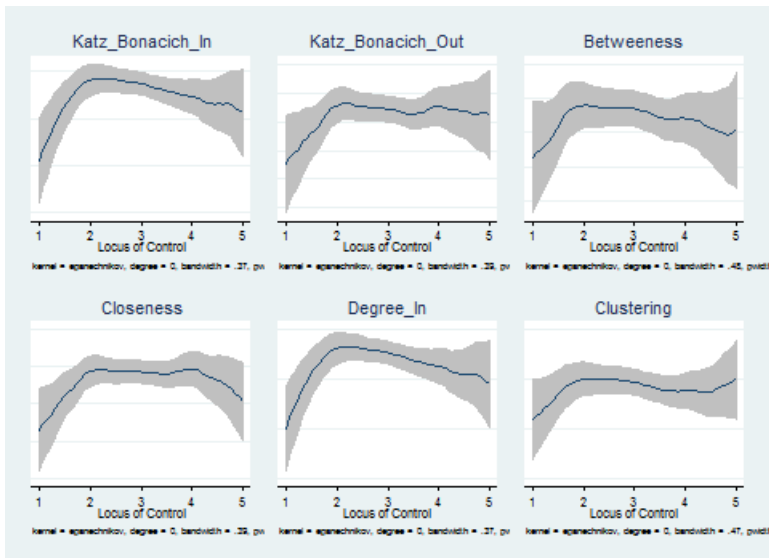




# Openness to New Experiences



# Locus of Control



# Summary - Correlations

	Katz In	Katz Out	Betweenness	Closeness
Conscient.	0.0215***	0.0189***	2.949***	0.0157**
Extraversion	0.0216***	0.0153***	0.636	0.0211**
Emot. Stab.	-0.000767	0.00888**	0.524	-0.00382
Agreeableness	0.0183***	0.0138***	1.691**	0.0136**
Openness	0.00926***	0.00988***	0.116	0.00770
Ext. Locus	0.00321	0.00521*	0.324	0.00868
	Out Degree	In Degree	Clustering	
Conscient.	0.449***	0.503***	0.0392***	
Extraversion	0.348***	0.502***	0.0511***	
Emot. Estab.	0.233**	-0.0145	0.0124	
Agreeableness	0.329***	0.435***	0.0207*	
Openness	0.229***	0.218***	0.0174*	
Ext. Locus	0.114	0.0736	0.00826	

# SES Homophily and Dyadic Formation

- Let  $Y_t(ij)$  denote an indicator whether there is a link between  $i$  and  $j$  at period  $t$
- $X$  includes gender, age, SES or cognitive skills.
- $\varepsilon(ij)$  has a logistic distribution

$$Y_t(ij) = 1(U_t(ij) > 0)$$

$$U_t(ij) = \alpha_0 + \alpha_i X_t(i) + \alpha_j X_t(j) + \underbrace{\sum_k \alpha_k |X_t(i) - X_t(j)|}_{\text{Homophily}} + \underbrace{\alpha_d Y_{t-1}(ij)}_{\text{previous link form.}} + \underbrace{\alpha_F F_{t-1}(ij)}_{\text{common previous friendship}} + \varepsilon(ij)$$

	Basic	Cognitive	Socioemotional
$Y_{t-1}$	1.638*** (0.098)	1.632*** (0.100)	1.617*** (0.100)
$F_{t-1}$	0.053 (0.093)	0.055 (0.090)	0.080 (0.093)
Gender(i)-Gender(j)	-1.121*** (0.132)	-1.127*** (0.133)	-1.146*** (0.131)
Age(i)-Age(j)	-0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
Verbal(i)-Verbal(j)		-0.015 (0.028)	
Abstract(i)-Abstract(j)		0.002 (0.029)	
Spatial(i)-Spatial(j)		-0.004 (0.030)	
Numerical(i)-Numerical(j)		-0.020 (0.013)	
Logical(i)-Logical(j)		-0.010 (0.010)	
Conscien.(i)-Conscien.(j)			-0.252*** (0.091)
Extraversion(i)-Extraversion(j)			-0.240** (0.115)
Emot. Stab.(i)-Emot. Stab.(j)			0.068 (0.107)
Agreeabl.(i)-Agreeabl.(j)			-0.095 (0.073)
Openness(i)-Openness(j)			0.023 (0.079)
Locus(i)-Locus(j)			-0.118 (0.082)
F (Skills Homophily)	-	0.529	0.006
N	6,376	6,376	6,376

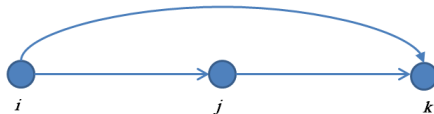
Note: (i) All regressions include control to level. (ii) Clusters in school level.

	Basic	Cognitive	Socioemotional
$Y_{t-1}$	1.676*** (0.102)	1.661*** (0.104)	1.643*** (0.105)
$F_{t-1}$	0.322*** (0.102)	0.305*** (0.104)	0.338*** (0.103)
Gender(i)-Gender(j)	-1.202*** (0.133)	-1.228*** (0.135)	-1.228*** (0.134)
Age(i)-Age(j)	-0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)
Verbal(i)-Verbal(j)		0.002 (0.035)	
Abstract(i)-Abstract(j)		-0.001 (0.035)	
Spatial(i)-Spatial(j)		-0.025 (0.034)	
Numerical(i)-Numerical(j)		-0.028** (0.013)	
Logical(i)-Logical(j)		-0.011 (0.009)	
Conscien.(i)-Conscien.(j)			-0.280** (0.109)
Extraversion(i)-Extraversion(j)			-0.159 (0.128)
Emot. Stab.(i)-Emot. Stab.(j)			0.073 (0.105)
Agreeabl.(i)-Agreeabl.(j)			-0.166** (0.080)
Openness(i)-Openness(j)			0.005 (0.087)
Locus(i)-Locus(j)			-0.148* (0.088)
F (Skills Homophily)		0.1096	0.0008
N	6,328	6,328	6,328

Note: (i) All regressions include control to level and class fixed effects. (ii) Clusters in school level

# Transitive Triads

- Transitive Triads are triples that have the following characteristics:



- The local structure test checks if the model is able to generate structures similar to the observed network.

- Test statistic (Dzanski, 2015):

$$T_n = \frac{(S_n - ES_n)}{n^3} \rightarrow N(0, V^s)$$

## ► Variance

- $S_n$  is the number of transitive triads in the observed network
- $ES_n$  is the expected number of transitive triads in the stochastic networks ( induced by the model);  $ES_n = \sum_{\beta \in B} \prod_{e \in \beta} F()$
- Model with homophily in cognitive skill:  $T_n = 3.90 \rightarrow p\text{-value} = 0\%$
- Model with homophily in SES:  $T_n = 1.86 \rightarrow p\text{-value} = 6.3\%$



# Peer - Effect (Lee's Approach)

- Main Idea: use variation in the class size to estimate peer effect
- There are  $N$  students indexed by  $i$  divided in  $K$  classes indexed by  $k$ .
- $n_k$  is the number of student at group  $k$ .
- $n_{ki}$  is the group of peers of student  $i$  of size  $n_k - 1$

$$y_{ki} = \alpha_k + \underbrace{\beta \frac{\sum_{j \in n_{ki}} y_{kj}}{n_k - 1}}_{\text{Endogenous effect}} + \gamma x_{ki} + \underbrace{\delta \frac{\sum_{j \in n_{ki}} x_{kj}}{n_k - 1}}_{\text{Contextual effect}} + \varepsilon_{ki}$$

- Within group reduced form:

$$y_{ki} - \bar{y}_k = \underbrace{\frac{\gamma - \frac{\delta}{n_k - 1}}{1 + \frac{\beta}{n_k - 1}} (x_{ki} - \bar{x}_k)}_{\text{Need at least 3 different class sizes}} + \frac{1}{1 + \frac{\beta}{n_k - 1}} (\varepsilon_{ki} - \bar{\varepsilon}_k)$$

$$JY = \beta \tilde{G}JY + JX\gamma + \tilde{G}JX\delta + J\varepsilon$$

- $Y$  is proficiency on SAEPE in Math or Language
- $X$  is a vector of contextual variables (gender, age and socioemotional skills)
- $\varepsilon$  is random error, clustered in the school level
- $\tilde{G}$  is a block diagonal matrix;  $g_{ij}=1$  if  $i$  and  $j$  are in the class.
- $J$  is a block diagonal matrix;  $J = \text{Diag}(J_1, J_2, \dots, J_K)$
- $J_k = (I - \frac{\iota_{N_k} \iota_{n_k}'}{n_k})$ ;  $\iota_{N_k}$  is a vector of ones with dimension  $n_k \times 1$
- The vector of instruments is given by  $S=[JX \ \tilde{G}JX \ \tilde{G}^2JX]$
- $|\beta| < 1$

# Proficiency - Math - Unweighted

	Individual (JX)	Contextual ( $\tilde{G}JX$ )
Female	0.0161 (0.0709)	0.450** (0.230)
Age	0.00 (0.000)	0.00 (0.0001)
Conscientiousness	0.188*** (0.0512)	0.571** (0.249)
Extraversion	0.0405 (0.0414)	-0.0357 (0.0997)
Emotional Stability	0.162*** (0.0530)	0.412** (0.189)
Agreeableness	0.162*** (0.0530)	-0.0962 (0.144)
Openness to Experience	-0.0553 (0.0590)	-0.0817 (0.165)
Locus of Control	-0.0492 (0.0515)	0.246* (0.136)
Endogeneous		-0.958 (0.608)

# Proficiency - Language - Unweighted

	Individual (JX)	Contextual ( $\tilde{G}JX$ )
Female	0.146** (0.0670)	0.545* (0.328)
Age	-0.0003*** (0)	0.0002 (0.00)
Conscientiousness	0.139*** (0.0421)	0.232 (0.215)
Extraversion	0.0785* (0.0409)	0.279 (0.176)
Emotional Stability	0.0562 (0.0363)	0.0657 (0.102)
Agreeableness	0.162*** (0.0488)	-0.0795 (0.128)
Openness to Experience	0.0422 (0.0501)	-0.097 (0.134)
Locus of Control	-0.171*** (0.0416)	-0.0501 (0.164)
Endogeneous ( $\tilde{G}JX$ )		-0.850 (0.874)

$$JY = \beta \tilde{G}JY + JX\gamma + \tilde{G}JX\delta + J\varepsilon$$

- Y is a socioemotional skill (Conscientiousness, Extraversion, Emotional Stability, Agreeableness, Openness to Experience or Locus of Control)
- X is a vector of contextual variables (gender and age)
- $\varepsilon$  is random error, clustered in the school level
- The vector of instruments is given by  $S=[JX \ \hat{G}JX \ \tilde{G}^2JX]$

# SES - Unweighted

		Consci.	Extr.	Emoti. Stab.
Endogeneous ( $\tilde{G}JY$ )		-0.245 (1.005)	-0.807 (0.622)	-0.961** (0.443)
Individual (JX)	Female	0.252*** (0.0491)	0.143*** (0.0454)	0.0167 (0.0470)
	Age	-0.0004*** (0)	-0.0001* (0)	-0.0002*** (0)
Contextual ( $\tilde{G}JX$ )	Female	0.205 (0.337)	0.422* (0.248)	0.138 (0.285)
	Age	0.0004*** (0.000108)	0.0001* 0.00	0.0002*** (0)

		Agreeabl.	Opns	Locus of Control
Endogeneous ( $\tilde{G}JY$ )		-0.642 (1.032)	-1.315 (1.588)	-7.029 (37.20)
Individual (JX)	Female	0.256*** (0.0493)	0.00863 (0.0528)	-0.165 (0.197)
	Age	0 (0)	-0.0003*** (7.01e-05)	0 (0)
Contextual ( $\tilde{G}JX$ )	Female	0.448* (0.258)	0.134 (0.389)	-1.472 (8.376)
	Age	0.00** (0)	0.0003*** (0)	0.0002 (0.001)

$$JY = \beta \hat{G}JY + JX\gamma + \hat{G}JX\delta + J\varepsilon$$

- Y is proficiency on SAEPE in Math or Language
- X is a vector of contextual variables (gender, age and socioemotional skills)
- $\varepsilon$  is random error, clustered in the school level
- $\hat{G}$  is a block diagonal matrix;  $g_{ij}=1$  if  $i$  and  $j$  are in the same class or  $g_{ij}=2$  if  $i$  and  $j$  are in the same class and if  $j$  chose  $i$  as a close friend.
- $J$  is a block diagonal matrix;  $J = \text{Diag}(J_1, J_2, \dots, J_K)$
- $J_k = (I - \frac{\iota_{N_k} \iota'_{n_k}}{n_k})$ ;  $\iota_{N_k}$  is a vector of ones with dimension  $n_k \times 1$
- The vector of instruments is given by  $S=[JX \ \hat{G}JX \ \hat{G}^2JX]$
- $|\beta| < 1$



# Proficiency - Math - Weighted

	Individual (JX)	Contextual ( $\hat{G}JX$ )
Female	-0.0369 (0.0621)	0.266 (0.277)
Age	-0.000138 (0.000104)	-0.000610** (0.000246)
Conscientiousness	0.238*** (0.0815)	0.374 (0.244)
Extraversion	0.0498 (0.0710)	-0.418 (0.294)
Emotional Stability	0.139** (0.0578)	0.223 (0.196)
Agreeableness	0.243** (0.0714)	0.236 (0.444)
Openness to Experience	0.243*** (0.0714)	0.236 (0.444)
Locus of Control	-0.151** (0.0624)	-0.542* (0.328)
Endogeneous ( $\hat{G}JY$ )		-1.388* (0.855)

# Proficiency - Language - Weighted

	Individual (JX)	Contextual ( $\hat{G}JX$ )
Female	0.0793 (0.0620)	0.424 (0.423)
Age	-0.000292*** (8.96e-05)	-0.000181 (0.000256)
Conscientiousness	0.157** (0.0658)	0.418 (0.704)
Extraversion	0.178** (0.0839)	0.294 (0.373)
Emotional Stability	0.110* (0.0614)	-0.358 (0.445)
Agreeableness	0.284*** (0.0662)	-0.166 (0.359)
Openness to Experience	0.0614 (0.0636)	0.118 (0.266)
Locus of Control	-0.271*** (0.0553)	-0.473 (0.470)
Endogeneous ( $\hat{G}JX$ )		-0.855 (1.081)

		Consci.	Extr.	Emoti. Stab.
Endogeneous ( $\hat{G}JY$ )		-0.951** (0.469)	-0.895 (0.780)	0.276 (0.802)
Individual (JX)	Female	0.259*** (0.0450)	0.120*** (0.0419)	0.00592 (0.0486)
	Age	-0.000280*** (0)	-0.000133* (0)	-0.000274*** (0)
Contextual ( $\hat{G}JX$ )	Female	0.604** (0.286)	0.452** (0.226)	0.0281 (0.140)
	Age	0.000175*** (0)	0 (0)	0.000270*** (0)

		Emot. Stab.	Agreeab.	Locus
Endogeneous ( $\hat{G}JY$ )		-0.602 (1.273)	-1.165 (1.410)	1.674 (2.300)
Individual (JX)	Female	0.225*** (0.0520)	0.000869 (0.0476)	-0.153*** (0.0509)
	Age	-0.000208*** (6.90e-05)	-0.000305*** (0)	0 (0.000151)
Contextual ( $\hat{G}JX$ )	Female	0.443 (0.379)	0.192 (0.350)	0.280 (0.501)
	Age	0.000127 (8.25e-05)	0.000282*** (0)	0 (0.000127)

- We find that SES are related to very classical network measures
- SES homophily seems important to explain link formation
- A model that includes SES homophily better replicates the behavior of observed networks compared to a model with cognitive homophily.
- SES of the peers induce important contextual effects on proficiency.
- We do not find that peers' SES are important to SES development (endogenous effect)

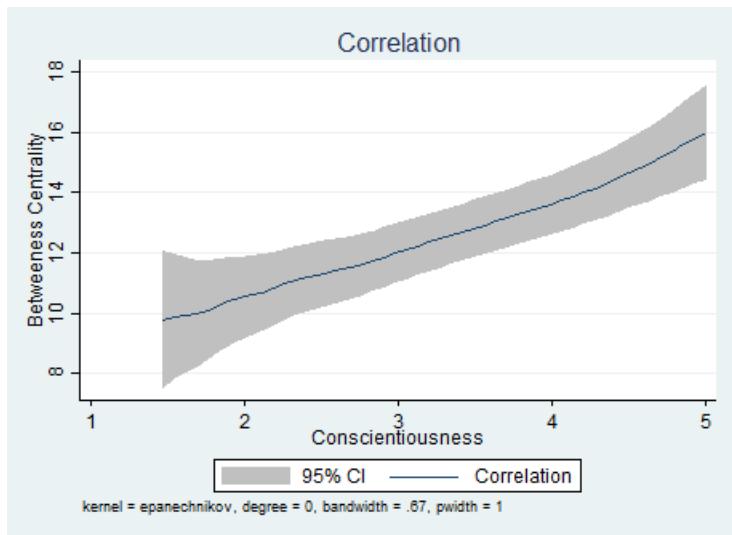
- For logit regression model:

$$V = \frac{1}{n^2} \sum_e F_e(1 - F_e)[\beta_e - RW^{-1}X]^2$$

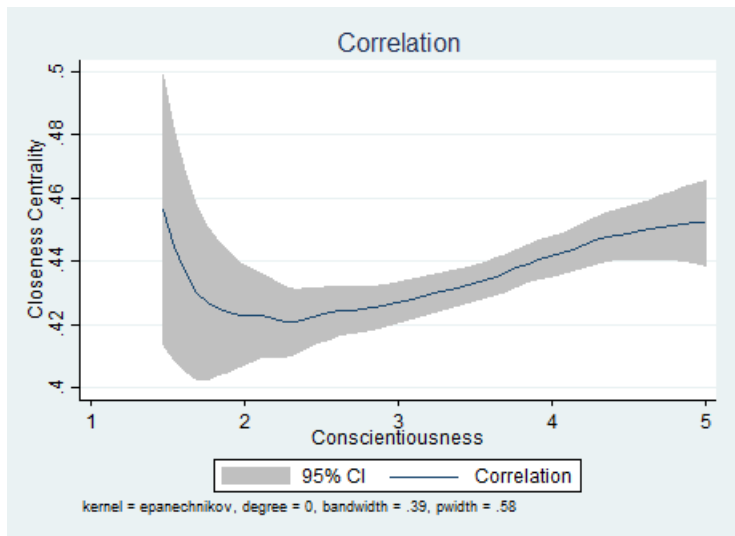
- $X$  is the matrix with covariates
- $F$  is the predicted probability of link
- $W = \frac{1}{n^2} \sum_e F_e(1 - F_e)XX'$
- $R = \frac{1}{n^2} \sum_e F_e(1 - F_e)\beta_e X$
- $\beta_e = \frac{1}{n} \sum_{k \notin \beta} F_{jk}F_{ik}$  is probability of a given dyad ( $e$ ) encompasses a transitive triad.

◀ Back

# Betweenness - Conscientiousness

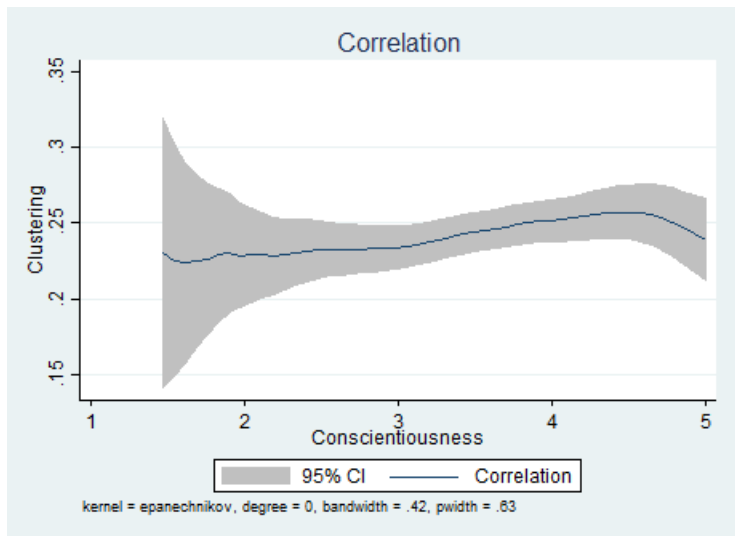


# Closeness - Conscientiousness

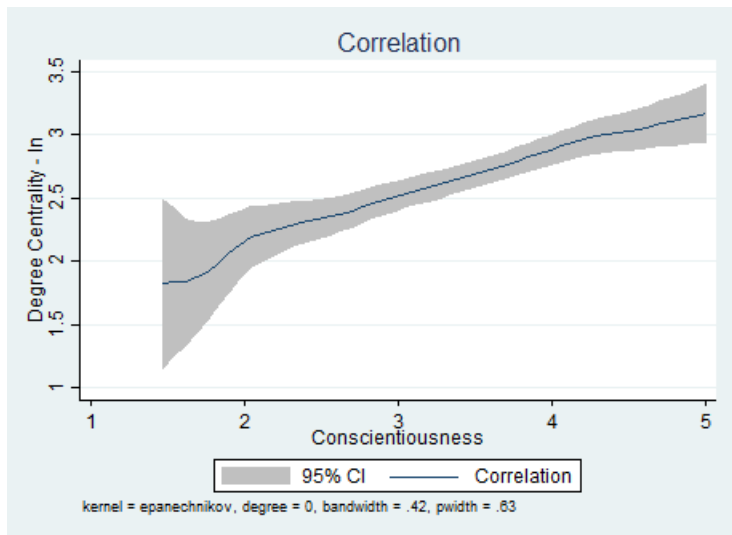




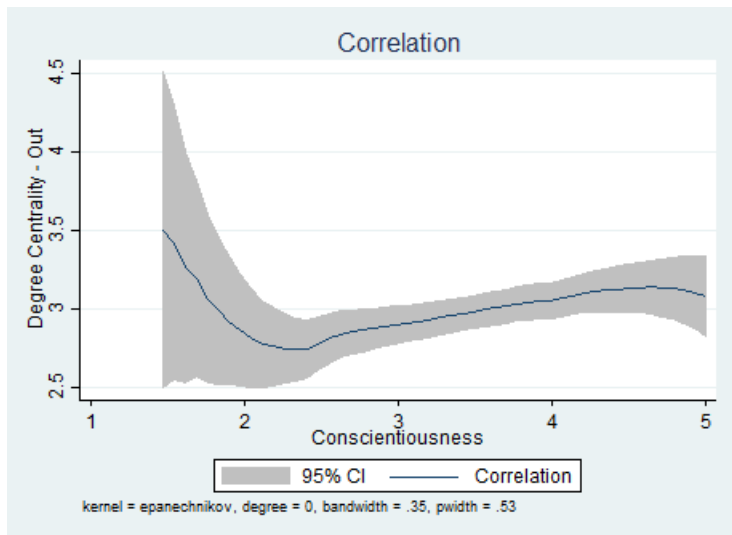
# Clustering - Conscientiousness



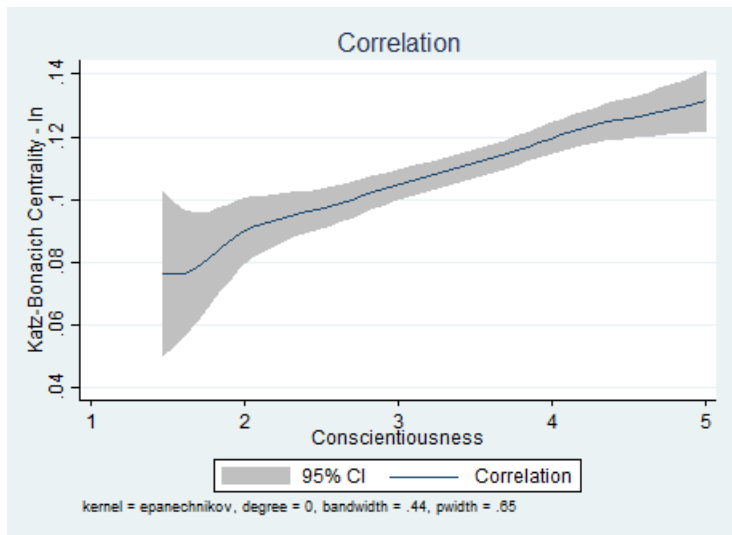
# In Degree - Conscientiousness



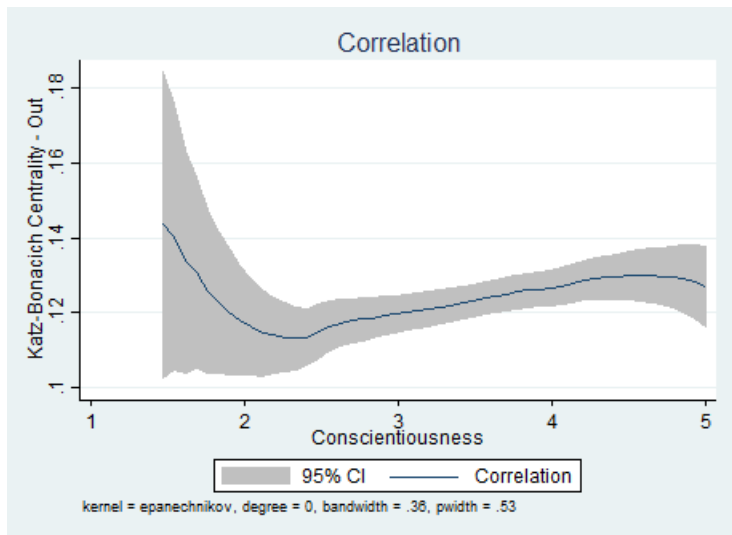
# Out Degree - Conscientiousness



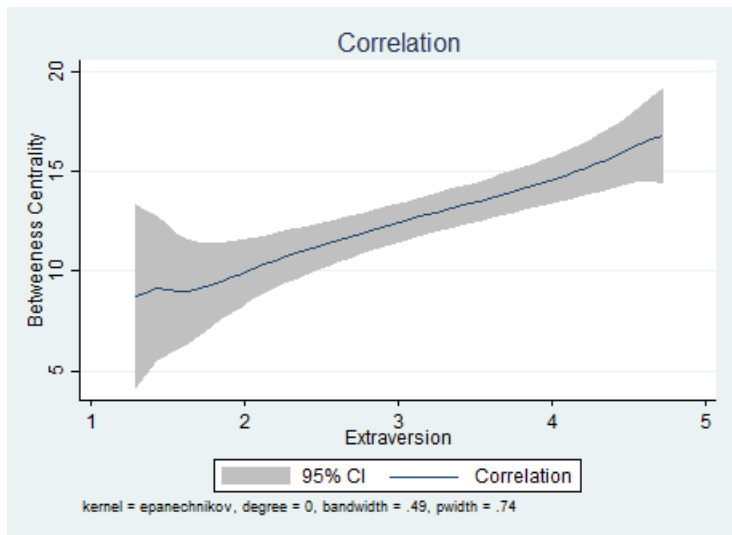
# Katz In - Conscientiousness



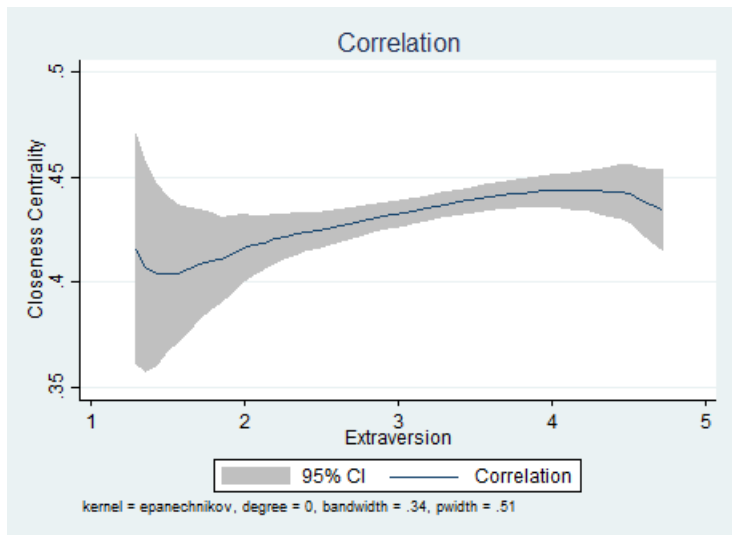
# Katz Out - Conscientiousness



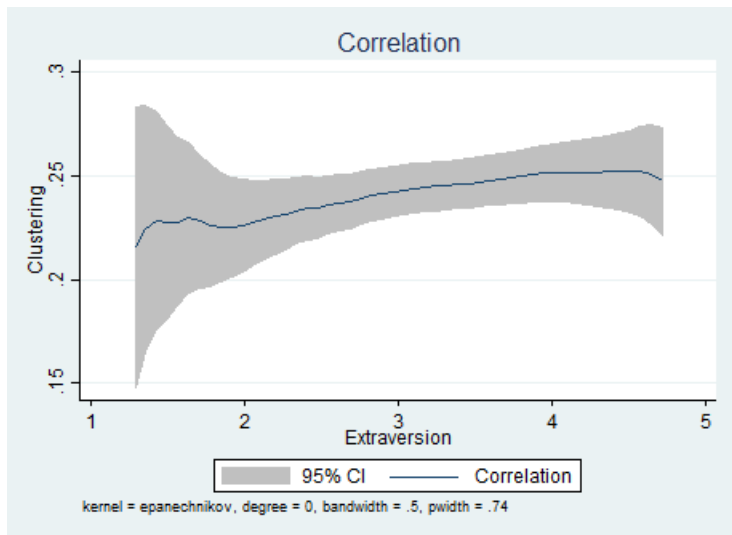
# Betweenness - Extraversion



# Closeness - Extraversion

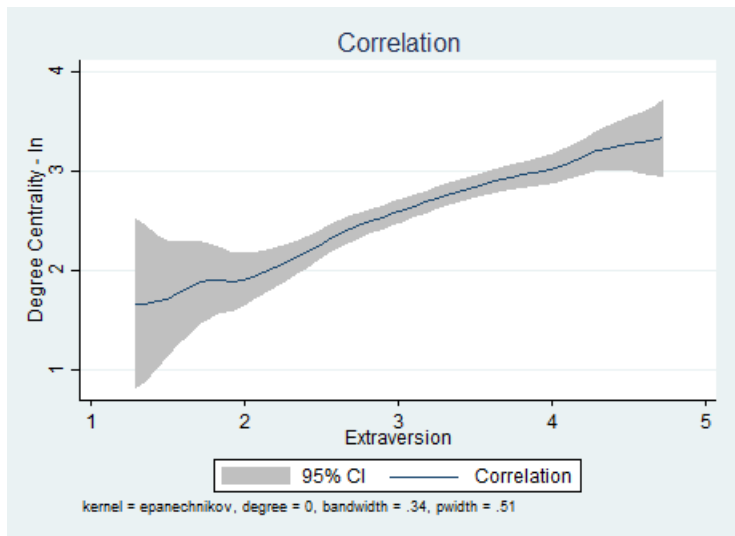


# Clustering - Extraversion

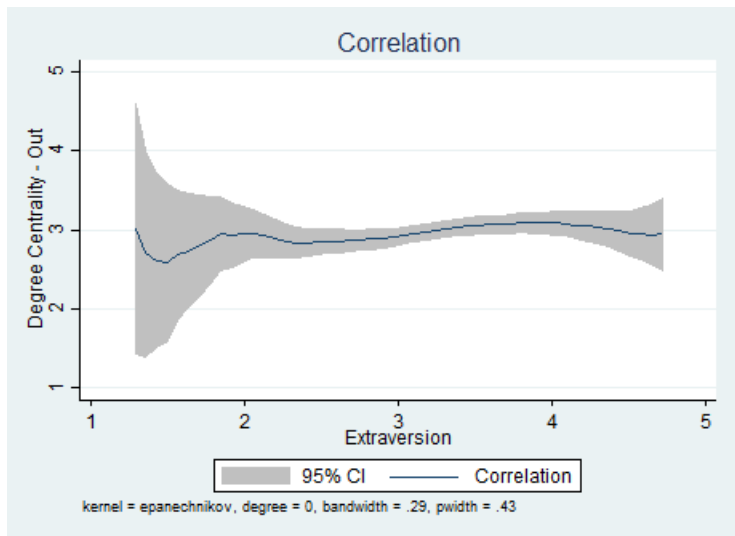




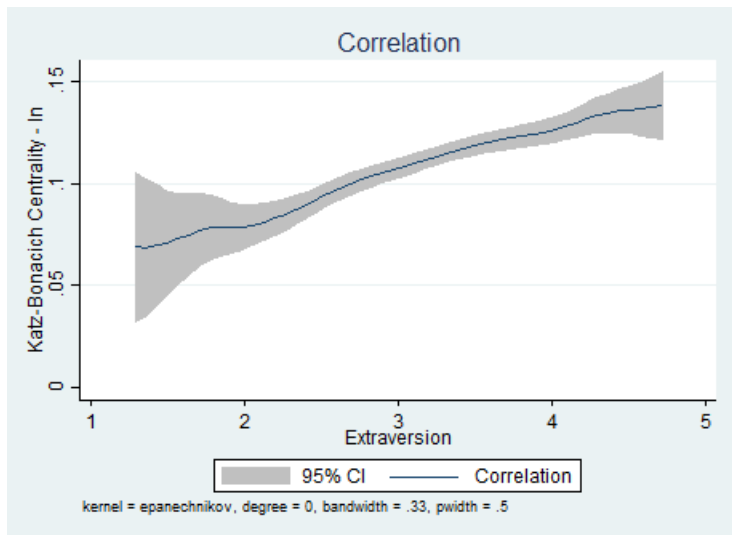
# In Degree - Extraversion



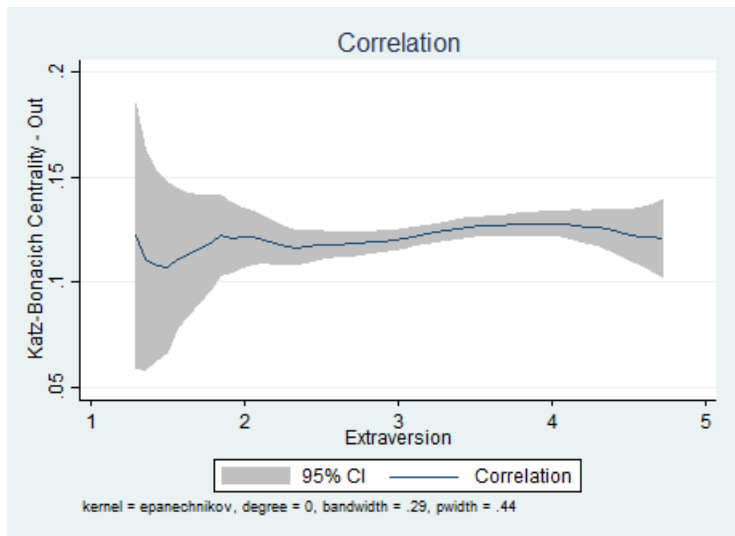
# Out Degree - Extraversion



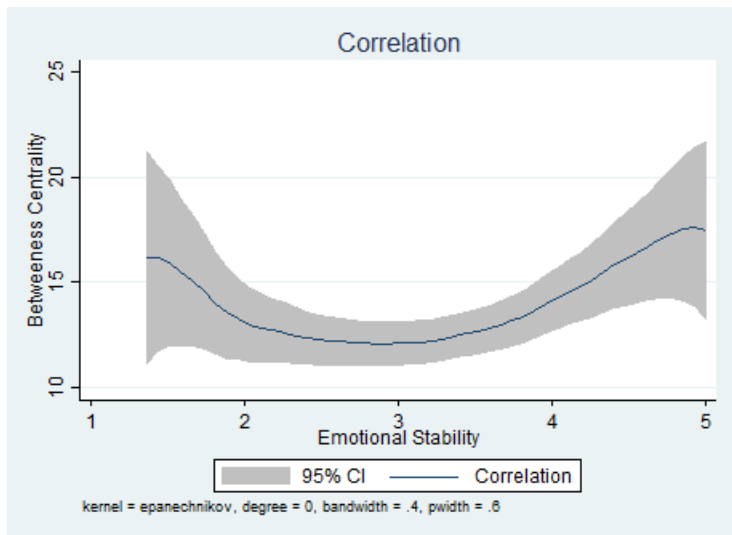
# Katz In - Extraversion



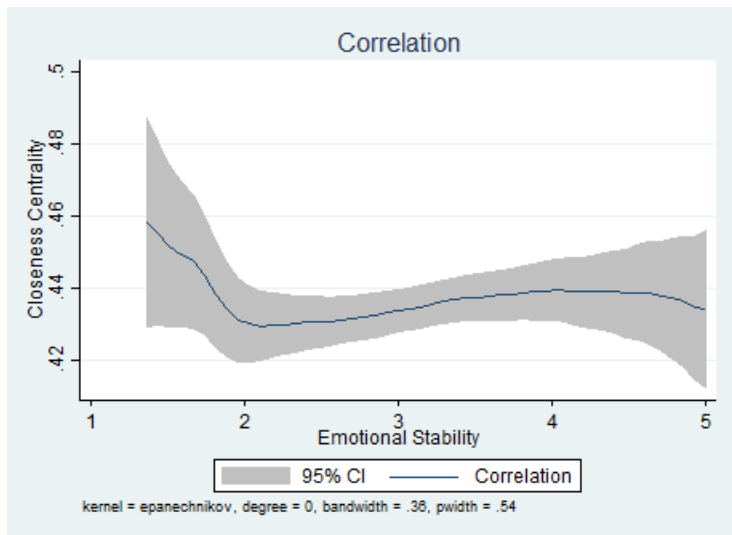
# Katz Out - Extraversion



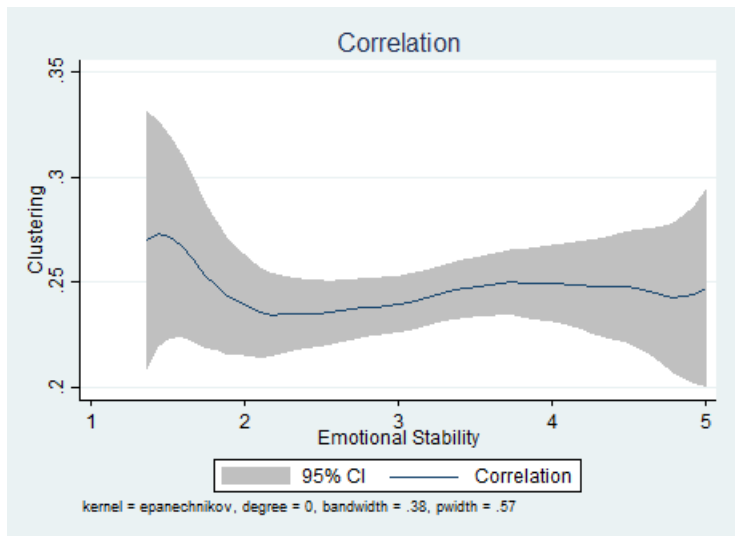
# Betweenness - Emotional Stability



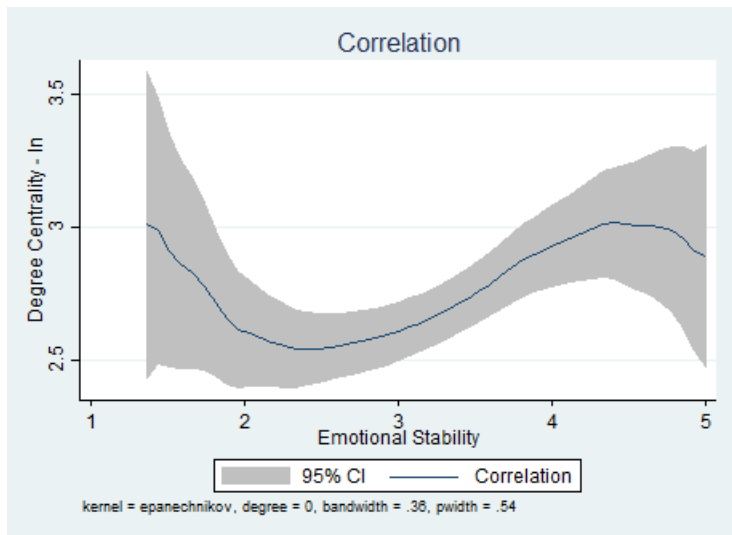
# Closeness - Emotional Stability



# Clustering - Emotional Stability

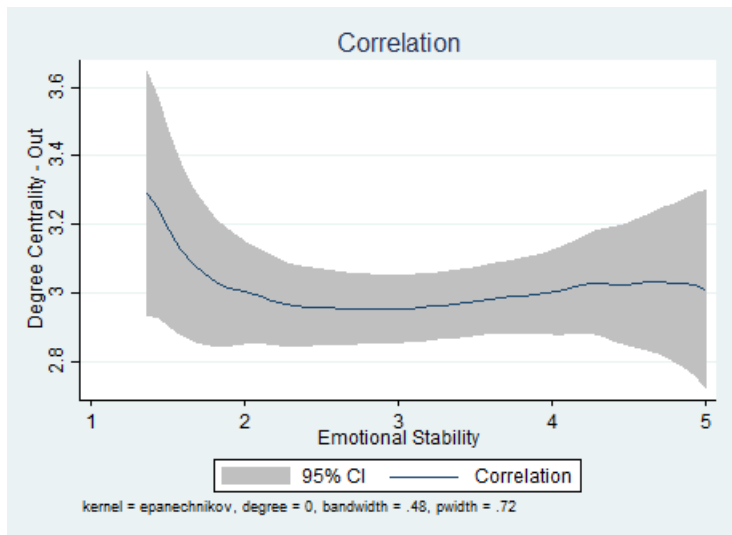


# In Degree - Emotional Stability

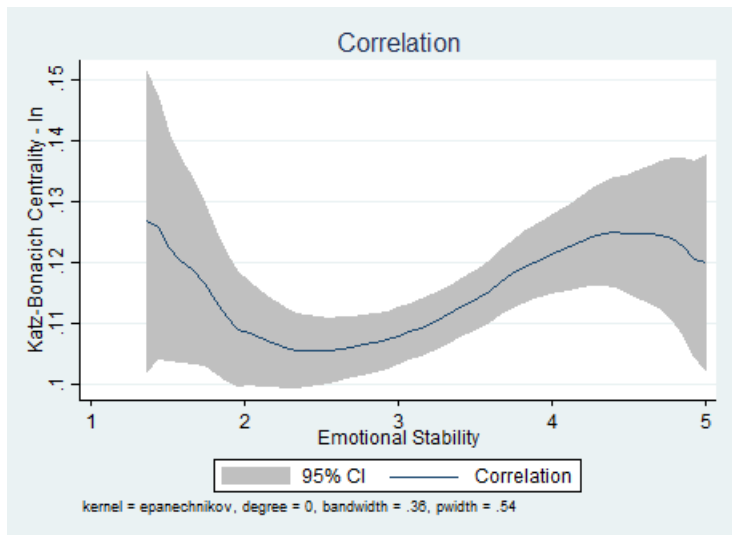




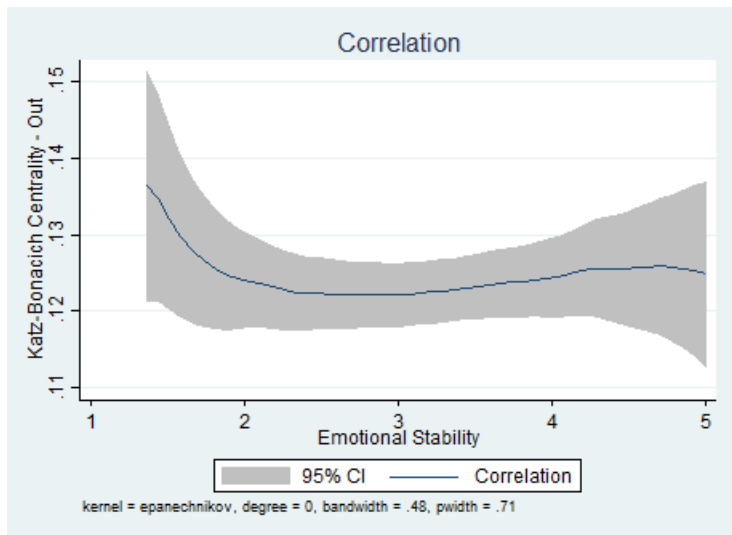
# Out Degree - Emotional Stability



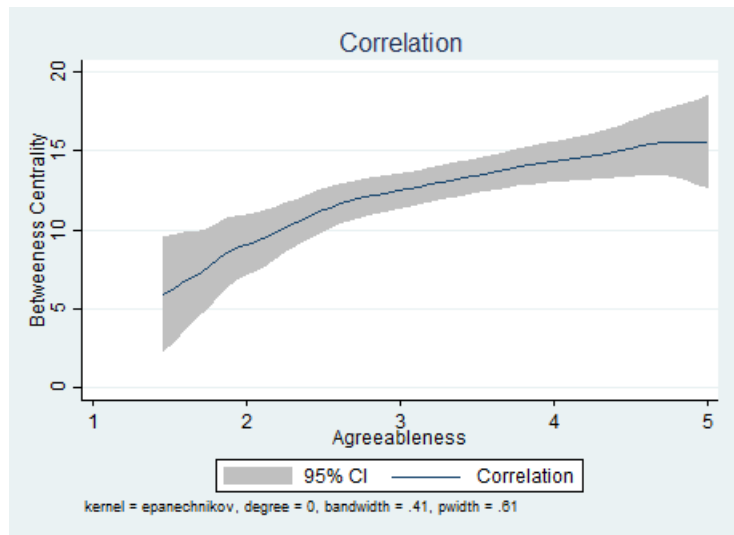
# Katz In - Emotional Stability



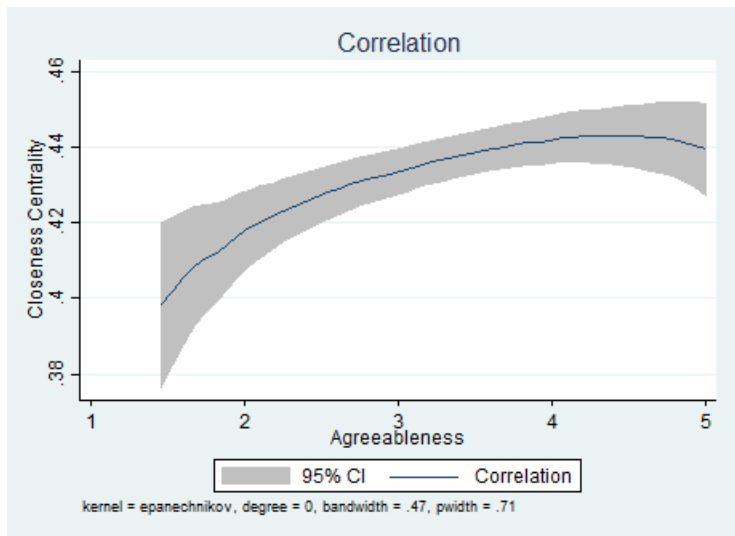
# Katz Out - Emotional Stability



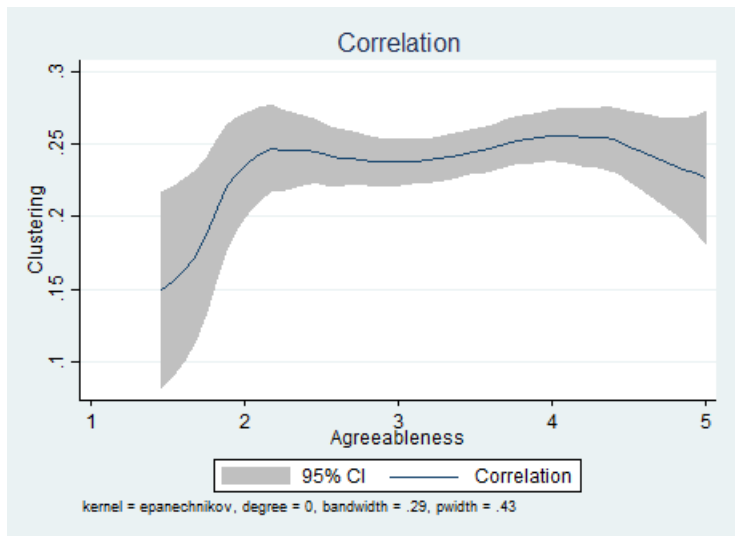
# Betweenness - Agreeableness



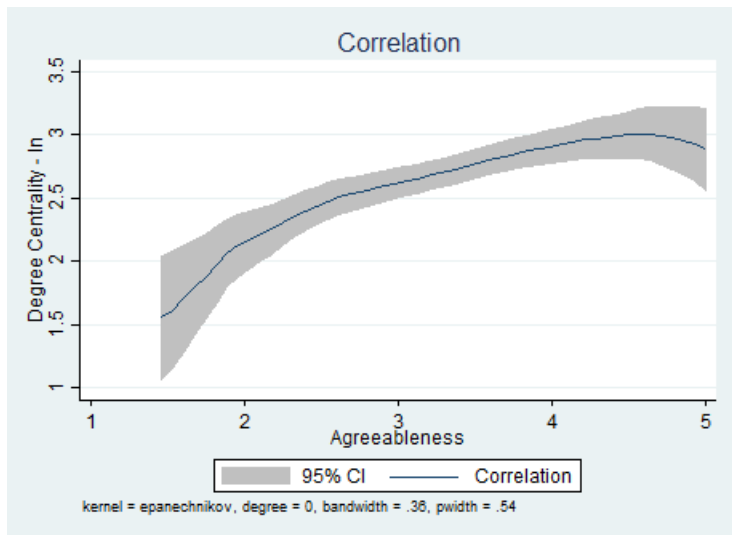
# Closeness - Agreeableness



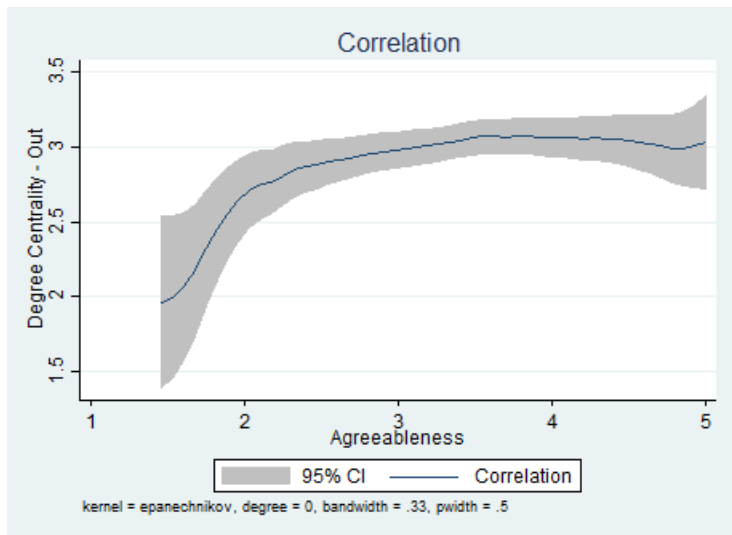
# Clustering - Agreeableness



# In Degree - Agreeableness

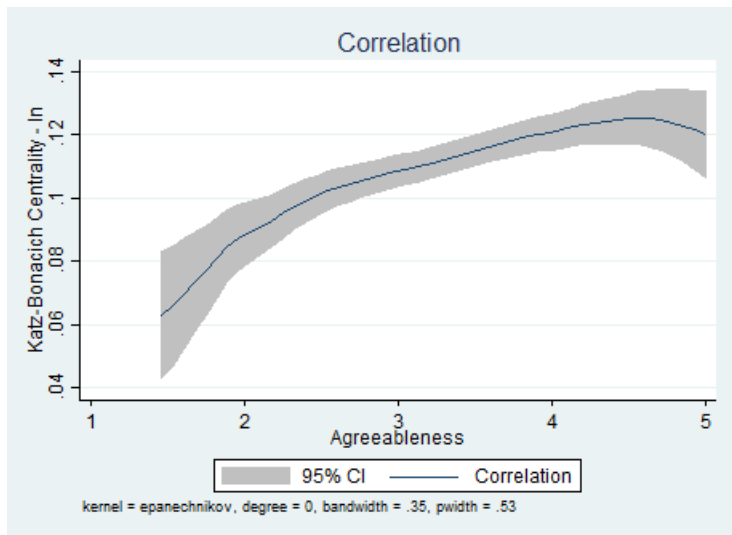


# Out Degree - Agreeableness

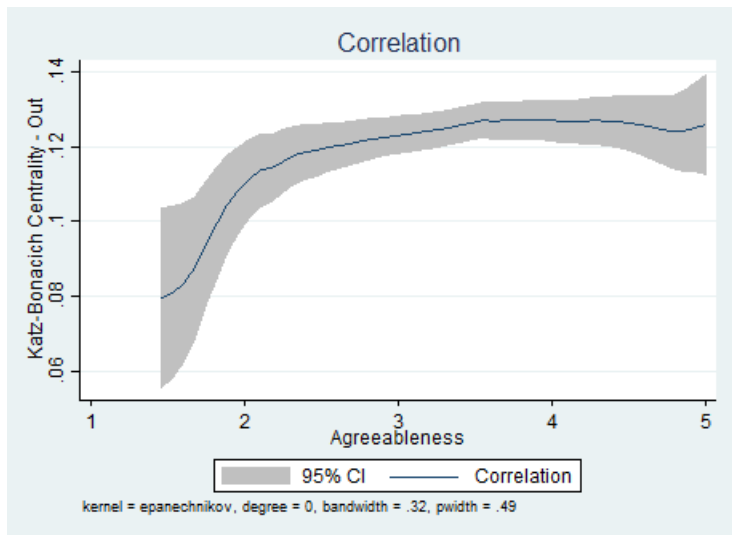




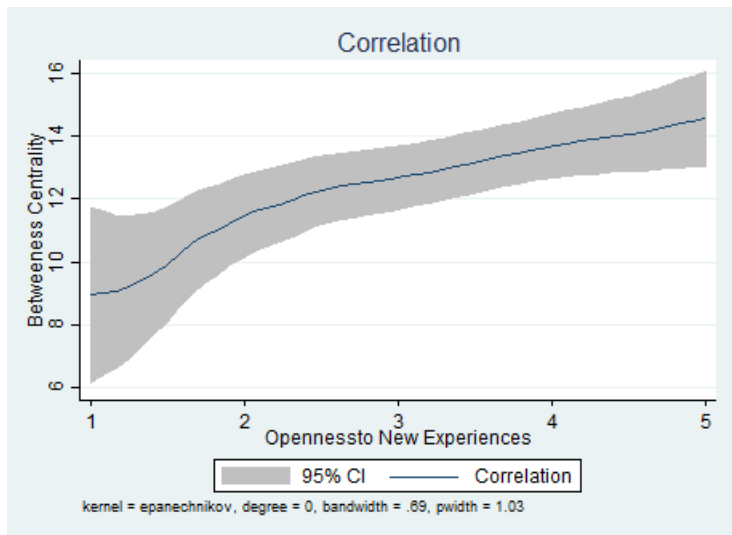
# Katz In - Agreeableness



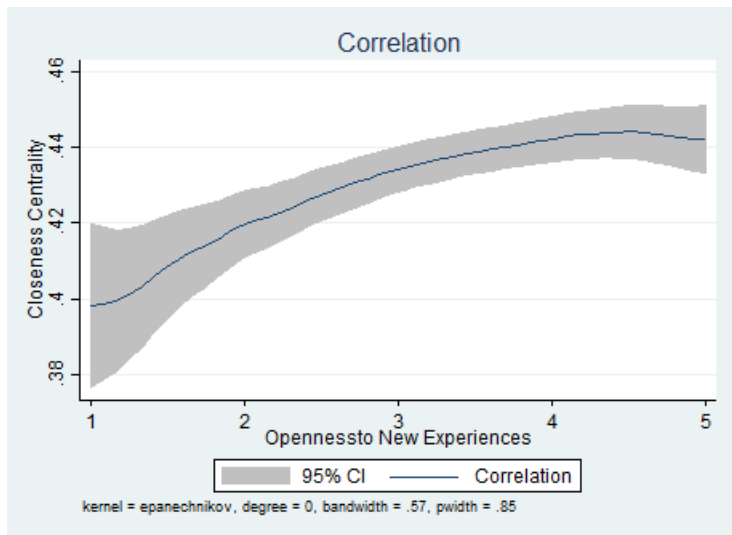
# Katz Out - Agreeableness



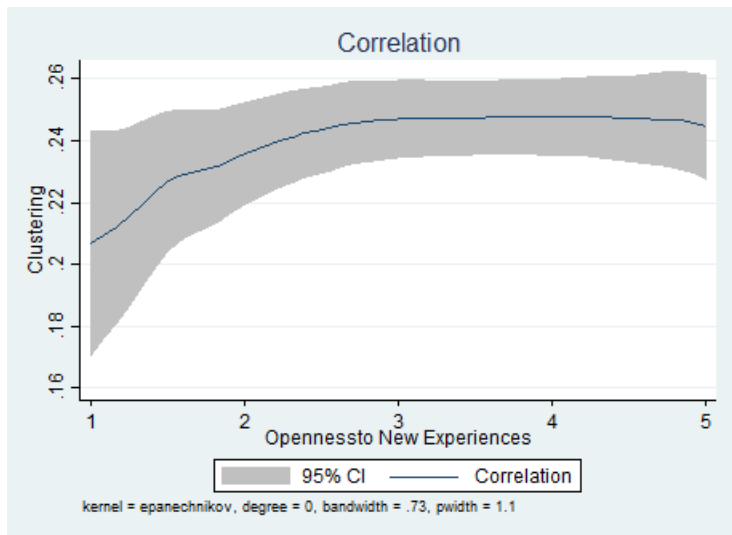
# Betweenness - Openness to Experience



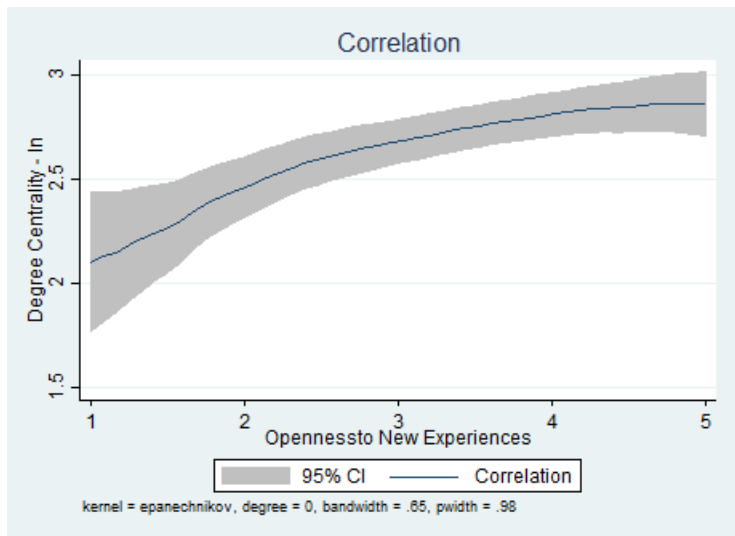
# Closeness - Openness to Experience



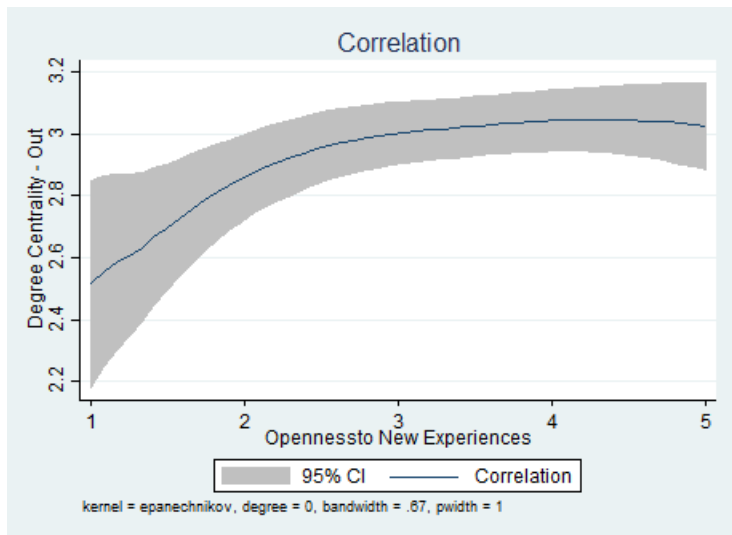
# Clustering - Openness to Experience



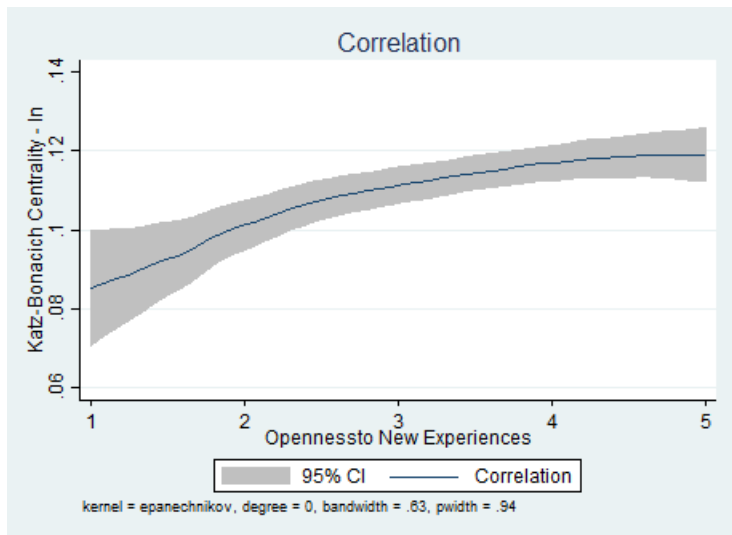
# In Degree - Openness to Experience



# Out Degree - Openness to Experience

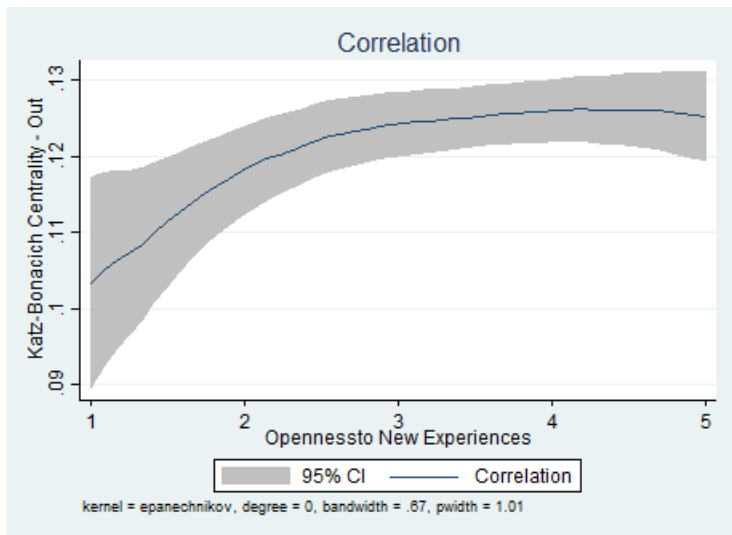


# Katz In - Openness to Experience

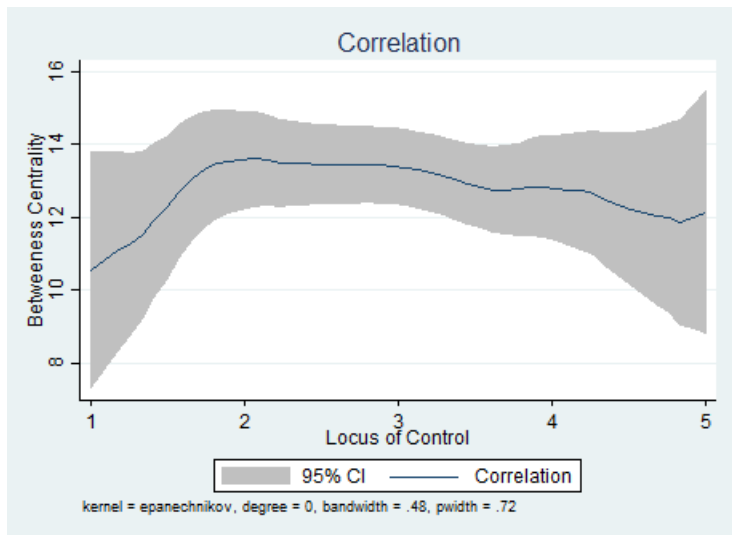




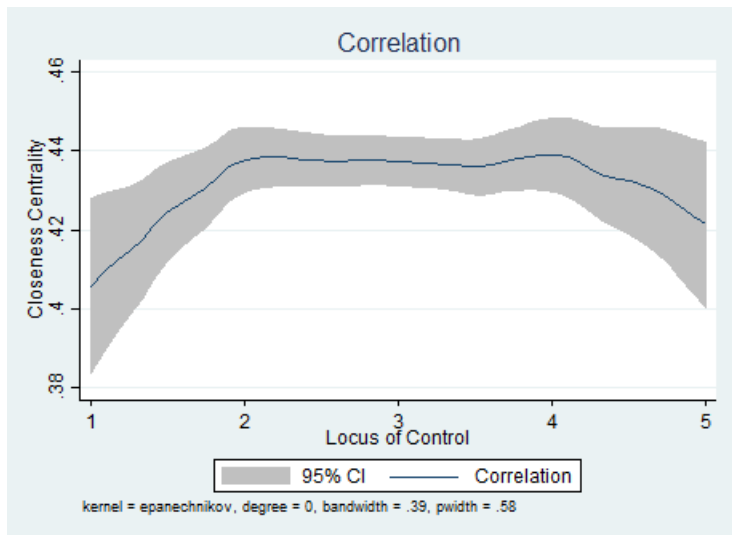
# Katz Out - Openness to Experience



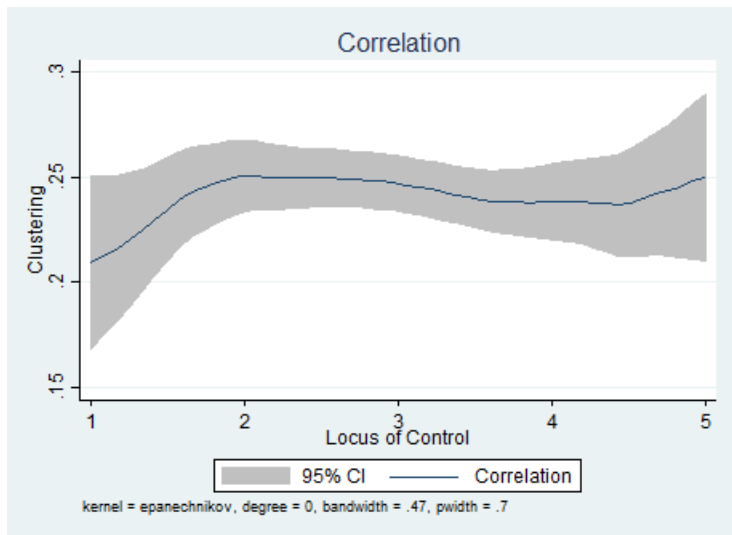
# Betweenness - External Locus of Control



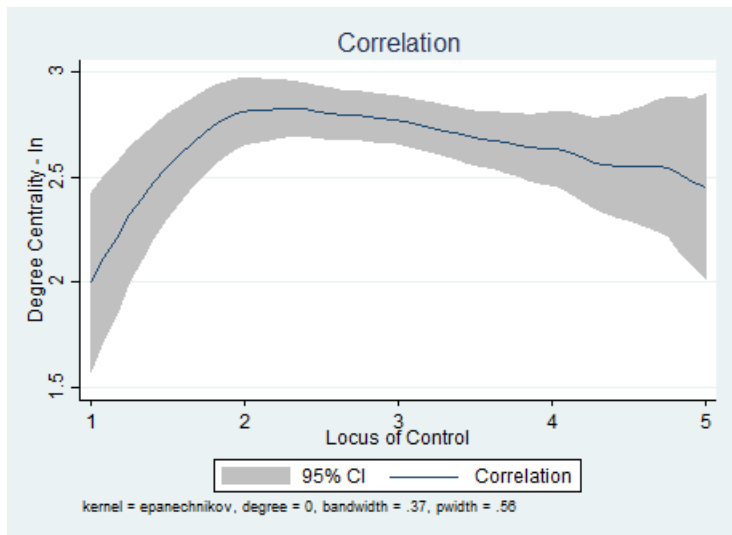
# Closeness - External Locus of Control



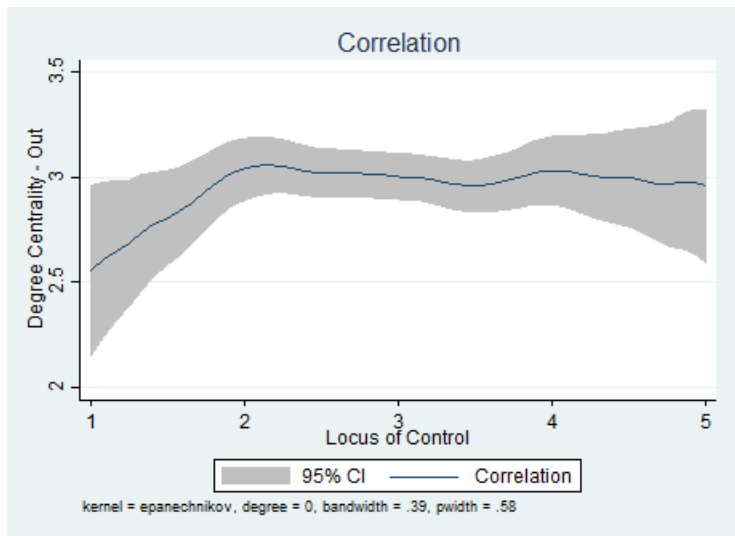
# Clustering - External Locus of Control



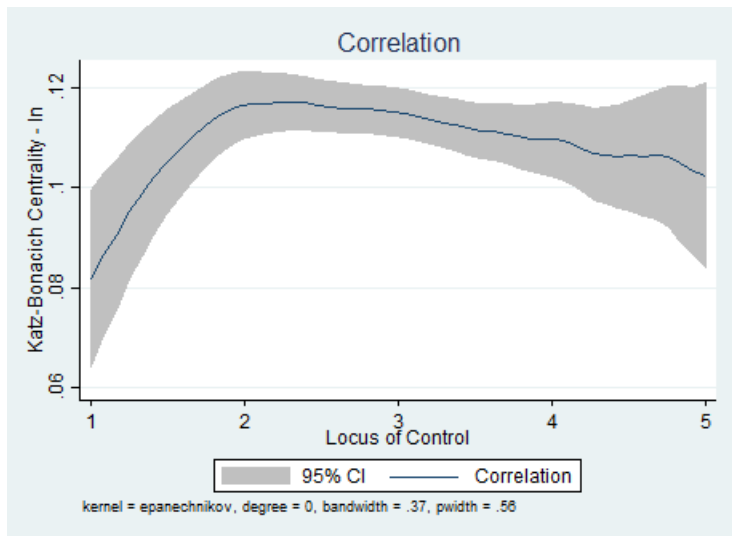
# In Degree - External Locus of Control



# Out Degree - External Locus of Control



# Katz In - External Locus of Control



# Katz Out - External Locus of Control

