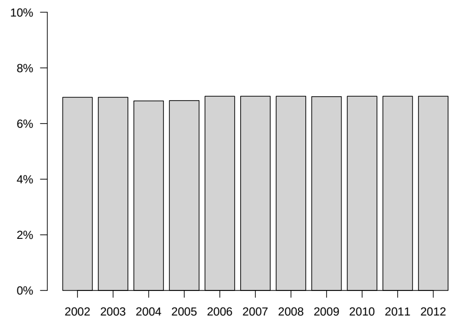
# **Appendix for:**
# Complex Dependence in Foreign Direct Investment: Network Theory and Empirical Analysis


**Abstract**

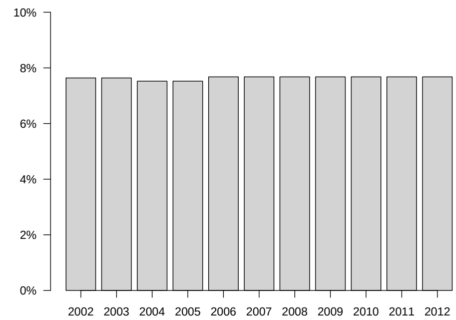
We develop theory that accounts for complex dependence in foreign direct investment (FDI) relationships. Conventional theories of FDI focus on firm-, country-, or dyad-level characteristics to account for cross-border capital movements. Yet, today's globalization is characterized by the increasing fragmentation and dispersion of production processes, which gives rise to complex dependence among production relationships. Consequently, FDI flows should be represented and theorized as a network. Specifically, we argue that FDI flows are reciprocal and transitive. We test these hypotheses along with conventional covariate determinants of FDI using an exponential random graph model (ERGM) for weighted networks. We find that FDI networks exhibit both reciprocity and transitivity. Our network approach to studying FDI provides new insights into global investment flows and their political and economic consequences. In addition to our substantive findings, we offer a broad methodological contribution by introducing the ERGM for count-weighted networks in political science.

# A Summary Statistics

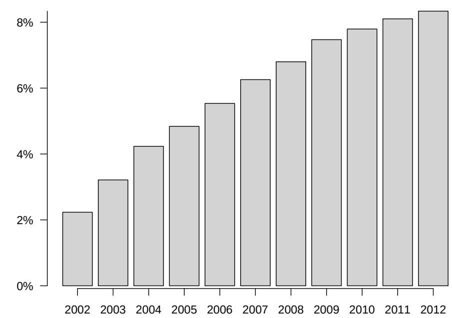
Alliance Treaty



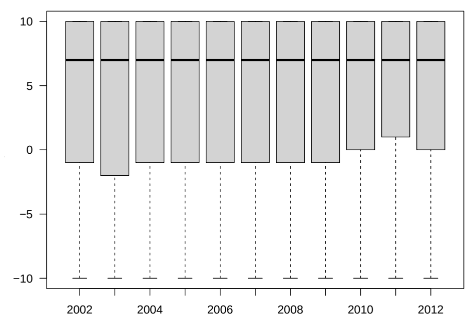

Defense Treaty



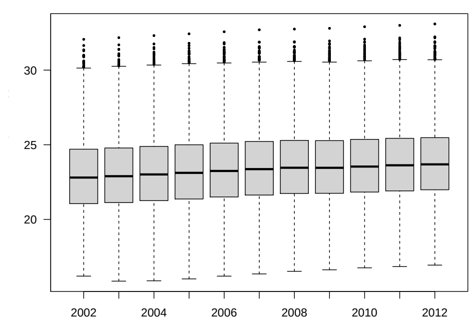

Bilateral Investment Treaty



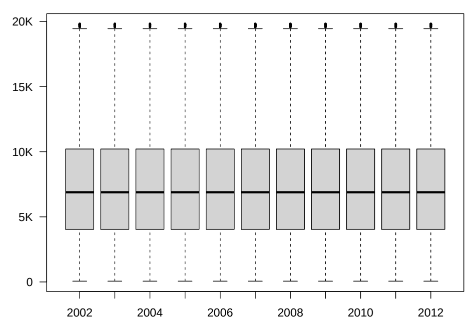

Polity




Dyad GDP Product




Distance



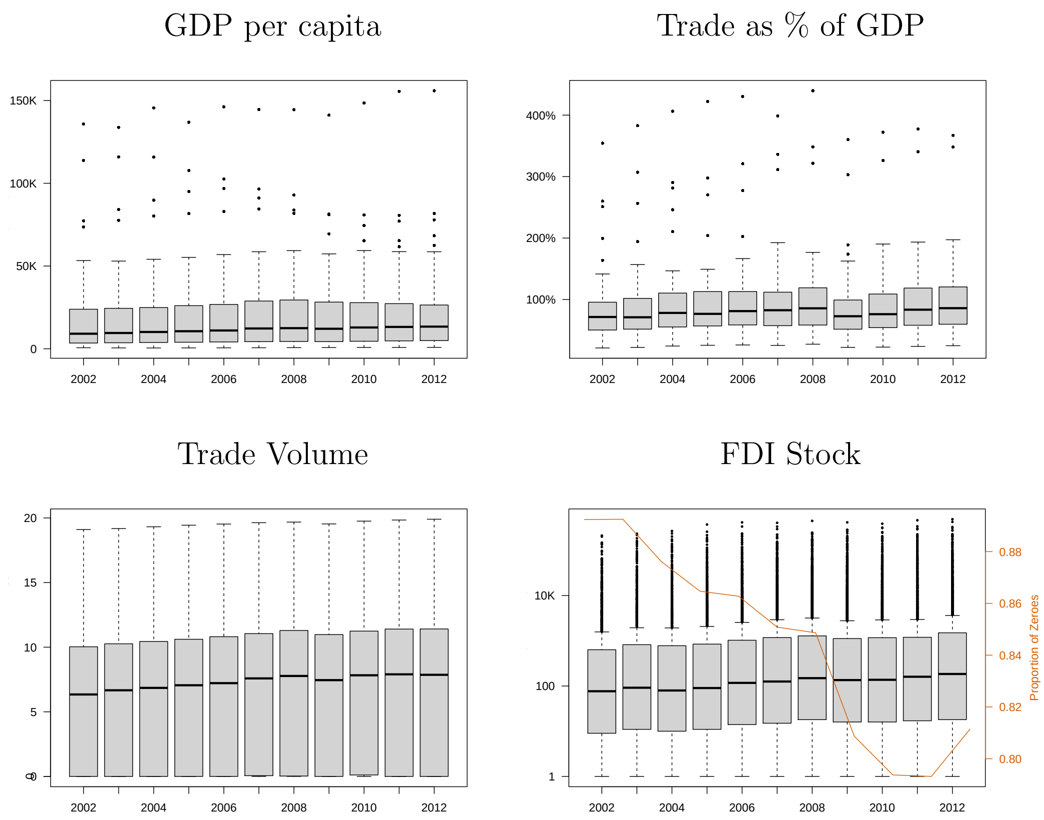



Table A: Summary Statistics.

Table B: Correlation Matrix

| | Mass | Distance | Polity |
|---|---|---|---|
| Mass | 1 | -0.003 | 0.091 |
| Distance (logged) | -0.003 | 1 | 0.008 |
| Polity | 0.091 | 0.008 | 1 |
| Trade Openness | -0.166 | -0.057 | -0.078 |
| BITs | 0.141 | -0.085 | 0.018 |
| Trade Volume | 0.714 | -0.215 | 0.215 |
| GDP per capita (logged) | 0.392 | -0.084 | 0.166 |
| Alliance Treaty | 0.133 | -0.348 | 0.073 |
| Defense Treaty | 0.065 | -0.391 | 0.065 |

| | Trade Openness | BITs | Trade Volume |
|---|---|---|---|
| Mass | -0.166 | 0.141 | 0.714 |
| Distance (logged) | -0.057 | -0.085 | -0.215 |
| Polity | -0.078 | 0.018 | 0.215 |
| Trade Openness | 1 | 0.032 | -0.055 |
| BITs | 0.032 | 1 | 0.143 |
| Trade Volume | -0.055 | 0.143 | 1 |
| GDP per capita (logged) | 0.225 | 0.093 | 0.330 |
| Alliance Treaty | -0.044 | 0.021 | 0.216 |
| Defense Treaty | -0.046 | 0.010 | 0.177 |

| | GDP per capita | Alliance Treaty | Defense Treaty |
|---|---|---|---|
| Mass | 0.392 | 0.133 | 0.065 |
| Distance | -0.084 | -0.348 | -0.391 |
| Polity | 0.166 | 0.073 | 0.065 |
| Trade Openness | 0.225 | -0.044 | -0.046 |
| BITs | 0.093 | 0.021 | 0.010 |
| Trade Volume | 0.330 | 0.216 | 0.177 |
| GDP per capita (logged) | 1 | 0.098 | 0.038 |
| Alliance Treaty | 0.098 | 1 | 0.850 |
| Defense Treaty | 0.038 | 0.850 | 1 |

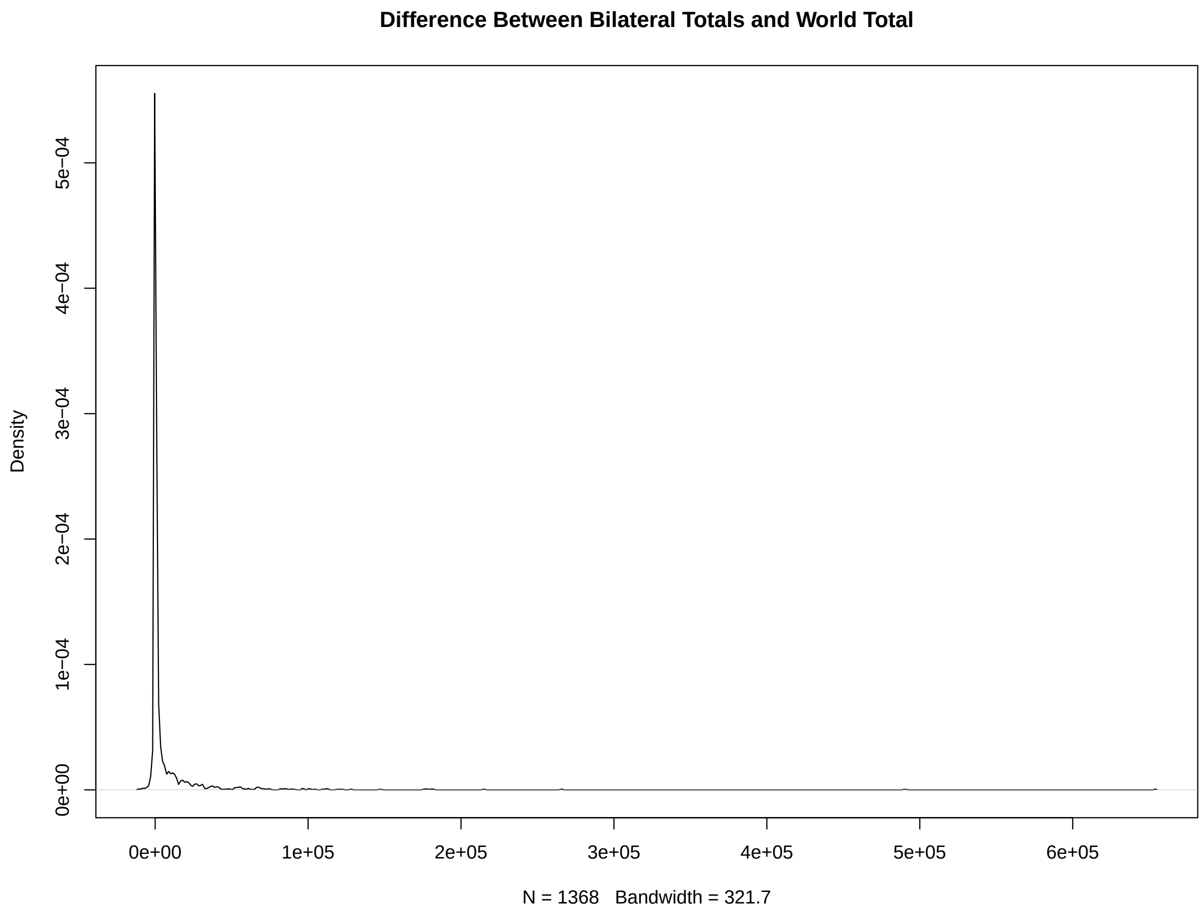



Figure A: Density Plot of the Difference between Total FDI stocks and Summing Bilateral FDI stocks.

## B Time-Pooled Model Results

For robustness checks, we re-estimate the count ERGM by pooling the data, which is common in the literature for regression based models. Figure B shows that after pooling, network terms remain positive and statistically significant, supporting our hypothesis that reciprocity and transitivity characterize FDI flows. The exogenous covariates from the pooled model are presented in Table C. The estimates are similar to yearly results in terms of direction and statistical significance.

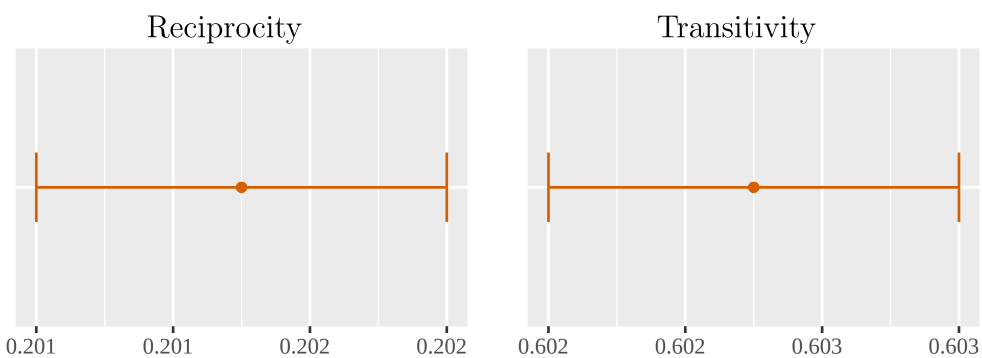
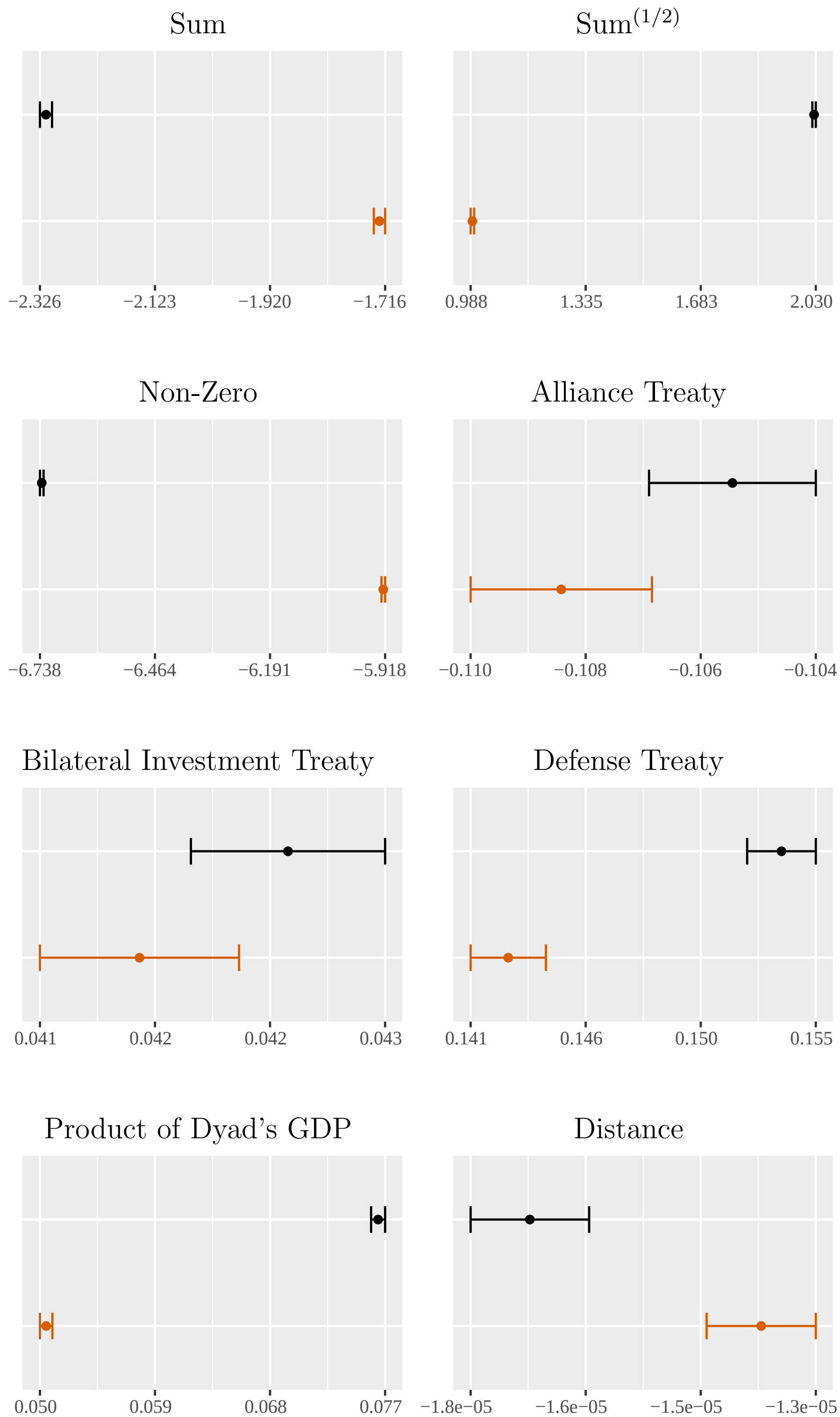



Figure B: Estimates of Dependence terms in time-pooled ERGMs. Bars span 95% confidence intervals.

The results also show that ignoring network structure lead to biased estimates in several covariates. We see significant differences in the coefficients for distance, the product of dyad's GDP, the three treaty variables, as well as origin and destination's GDP per capita, Polity, and trade openness. These findings are consistent with those from the yearly models. It illustrates that failure to include network structure results in biased estimates.



Sum
−2.326
−2.123
−1.920
−1.716
Sum(1/2)
0.988
1.335
1.683
2.030
Non-Zero
−6.738
−6.464
−6.191
−5.918
Alliance Treaty
−0.110
−0.108
−0.106
−0.104
Bilateral Investment Treaty
0.041
0.042
0.042
0.043
Defense Treaty
0.141
0.146
0.150
0.155
Product of Dyad's GDP
0.050
0.059
0.068
0.077
Distance
−1.8e−05
−1.6e−05
−1.5e−05
−1.3e−05

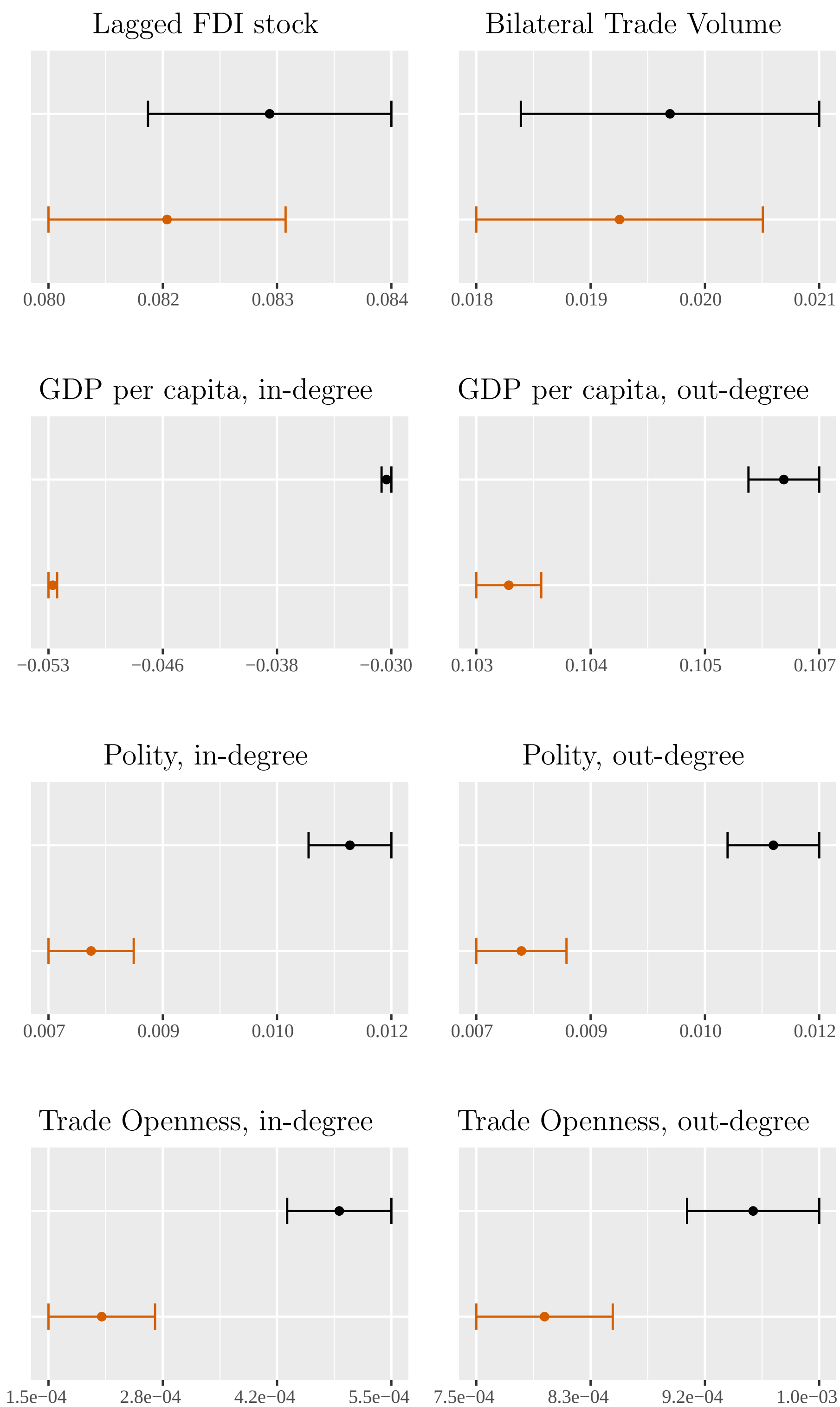



Table C: Estimates of terms in time-pooled ERGMs. Bars span 95% confidence intervals. Black coefficient representations are from models excluding dependence terms (i.e., transitivity and reciprocity).

# C Subset by Missingness Results

In the paper, we imputed missing values with zeros. In this section, we check whether our results are robust if we analyze a subset of the data set based on the level of missingness. To subset the data, we approximate total level of missingness in the adjacency matrices ($q$) by using the proportion of missing values for each node ($p$). We conduct two robustness checks: (1) when $p = 0.86$, $q \approx 0.50$ and $n = 70$; and (2) when $p = 0.72$, $q \approx 0.25$ and $n = 28$. In the first case, we only include nodes with missing values that are 86% or less of the possible edges for the entire data set, which leaves us with an adjacency matrix that is only missing 50% of the values (70 countries in total). Similarly, the second set only includes nodes with missing values that are 72% or less of the possible edges for the entire dataset, which leaves us with an adjacency matrix that is only missing 25% of the values (28 countries in total). Following our approach in the paper, we impute missing values in the two subsets of the data with zeros.

Figures C and D present the results for the two robustness checks, respectively. We see that FDI networks show strong transitivity for all years, but reciprocity effects become weak and insignificant in some years. This may be because most nodes (i.e. states) in the subsets are developed countries that have substantial two-way FDI flows between them and thus there is little variation in the level of reciprocity.

### C.1 q ≈ 0.50

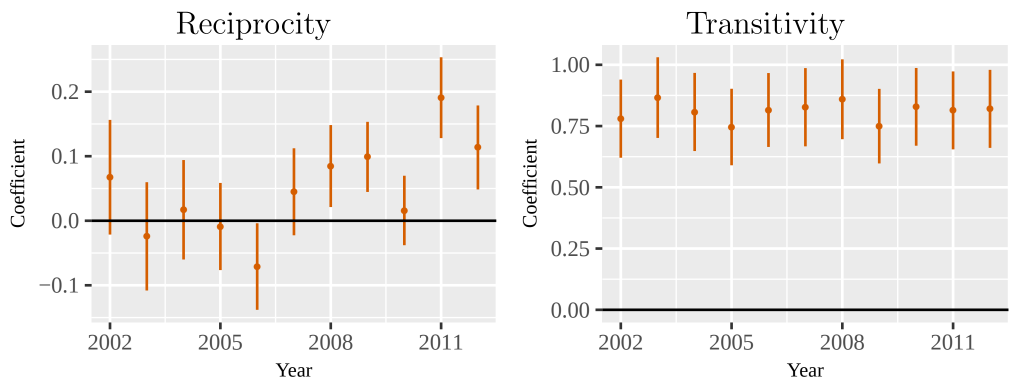



Figure C: Estimates of Dependence terms. Bars span 95% confidence intervals.

### C.2 q ≈ 0.25

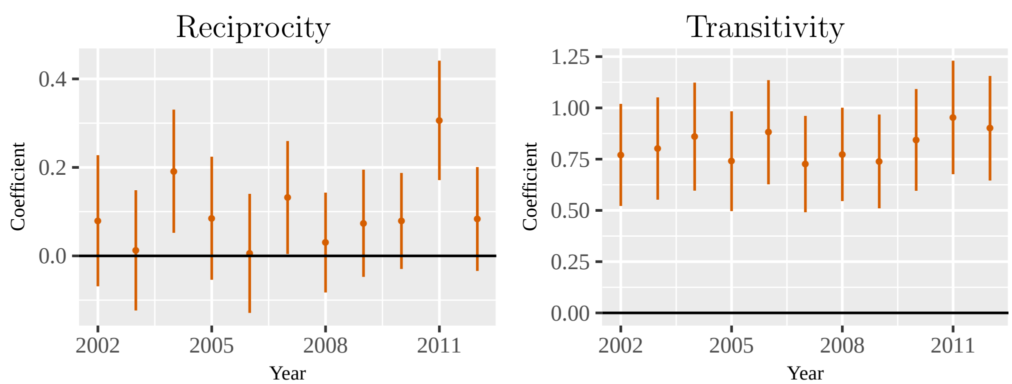



Figure D: Estimates of Dependence terms. Bars span 95% confidence intervals.

## D Multiple Imputations with Amelia Results

In this section, we utilize the `R` package Amelia to impute the missing values in the full data set, when $q \approx 0.50$, and when $q \approx 0.25$ (Honaker, King, Blackwell et al., 2011; King, Honaker, Joseph and Scheve, 2002). Figures E and F show the results. We see that transitivity effects are significant in all years and reciprocity effects are also significant in most years. The results in Sections C and D give us confidence that our findings regarding the reciprocity and transitivity of FDI are not driven by the pattern of missingness in the data set.

## D.1 Full


Figure E: Estimates of Dependence terms. Bars span 95% confidence intervals.

## D.2 q ≈ 0.50


Figure F: Estimates of Dependence terms. Bars span 95% confidence intervals.

## D.3 q ≈ 0.25

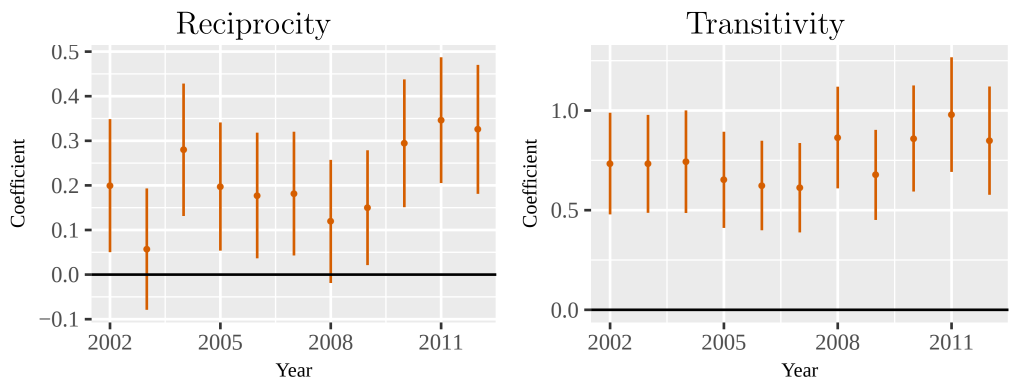



Figure G: Estimates of Dependence terms. Bars span 95% confidence intervals.

# E Results with Tax Havens Removed

One potential concern with bilateral FDI data is that they include round-tripping FDI, in which domestic firms channel funds to a foreign country (typically a tax haven) and invest back as "foreign capital" to take advantage of preferential policies that their home countries offer to foreign investors (Borga, 2016). Round-tripping FDI in itself could inflate reciprocity. To check whether our results are driven by round-tripping FDI, we re-estimated the model by excluding tax havens. We used the list of 17 tax havens published by the European Union on December 5, 2017. They are American Samoa, Bahrain, Barbados, Republic of Korea, United Arab Emirates, Grenada, Guam, Macao, Marshall Islands, Mongolia, Namibia, Palau, Panama, Saint Lucia, Samoa, Trinidad and Tobago, Tunisia.[1] Because the data had already been subset based on available covariates, there were only eight left to remove. This included South Korea, Mongolia, Namibia, Panama, Trinidad and Tobago, Tunisia, Bahrain, and the United Arab Emirates. Figure H plots the results on reciprocity and transitivity. We see that the results on reciprocity become a little weaker when tax havens are excluded,

[1]See Council of the European Union. 2017. "The EU List of Non-Cooperative Jurisdictions for Tax Purposes." Available at `http://www.consilium.europa.eu/media/31945/st15429en17.pdf`, accessed June 11, 2018.

but they remain significant in most years. Removing tax havens does not affect transitivity.

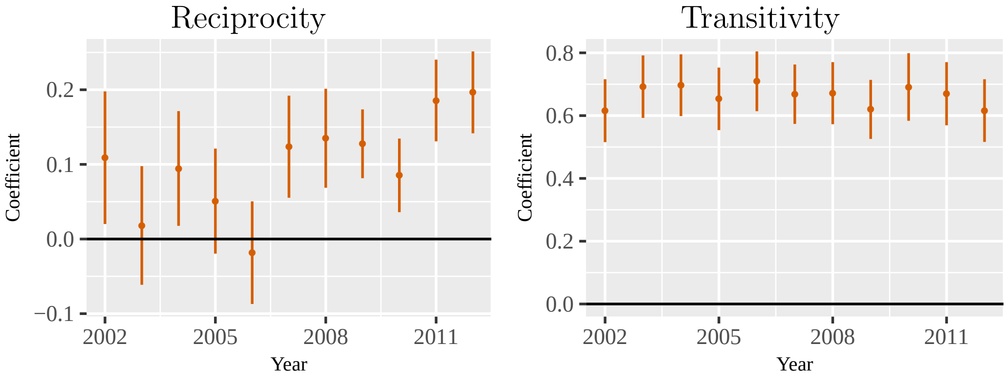



Figure H: Estimates of Dependence terms. Bars span 95% confidence intervals.

# References

Borga, Maria. 2016. "Not All Foreign Direct Investment Is Foreign: The Extent of Round-Tripping." *Columbia FDI Perspectives* No. 172:1–3.

Honaker, James, Gary King, Matthew Blackwell et al. 2011. "Amelia II: A program for missing data." *Journal of statistical software* 45(7):1–47.

King, Gary, James Honaker, Anne Joseph and Kenneth Scheve. 2002. "Analyzing Incomplete Political Science Data: An Alternative Algorithm for Multiple Imputation." *American Political Science Review* 95(1):49–69.