The Political Independence Index: Ranking Actors' Power in Signed Social Network Graphs

Giuseppe (Joe) Labianca

University of Kentucky

(in collaboration with Jesse M. Fagan, Filip Agneessens, and Carlo J. Labianca)

1. Introduction: Power in Signed Graphs

A central issue in understanding any type of social network – whether comprised of individuals, groups, organizations, or nations – is recognizing which actor is powerful. Recent work has turned to improving our ability to identify powerful nodal positions in signed graphs, which have both positively and negatively-valenced ties (e.g., Everett & Borgatti, 2014; Smith, Halgin, Kidwell-Lopez, Labianca, Brass, & Borgatti, 2014). These networks are "politically charged" in that they include negative, de-energizing, adversarial, or threatening ties that might undermine the flows or interactions within the network, and might also contain coalitions and counter-coalitions of allies and friends. Smith, et al. (2014) introduced the Political Independence Index (PII) to assess the relative power of nodal positions specifically for social networks with signed ties because existing measures are either difficult to interpret when negative ties are present in a network (e.g., betweenness centrality) or have significant implementation issues in real-world signed graphs (cf., Rodan, 2011, for problems with Bonacich power centrality). PII has already been used to show that changes to a nation's size of military in the Post-World War II era can be predicted by the nation's power position in the network of international alliances and conflicts (Smith, et al., 2014). As theorized, when political independence increases, a nation does not need as large of a

military, suggesting that it sees itself in a stronger power position in the network.

PII is rooted in a "power-as-dependence" approach (Emerson, 1962, 1972). Smith et al (2014) argued that actors in politically charged networks seek autonomy, but might be impeded by adversaries who attempt to exert power over him. To counterbalance, the focal actor forms alliances in an attempt to outmaneuver the adversaries (Murnighan & Brass, 1991; Labianca & Brass, 2006). Smith, et al. (2014) theorized that the process of attracting allies is not without cost and might involve a loss of resources in a *quid pro quo* manner.

They provided the following example from an international conflict situation: A nation (A) at war with another nation (B) has a negative, adversarial tie. If a third nation (C) joins the war on nation B's side, it puts added pressure on the focal nation (A) to find allies (see Figure 1).

<<< Insert Figure 1 about here >>>

Even if a potential ally (D) doesn't get drawn in directly to the conflict, the ally can provide nation A with help (e.g., guns, political support in international bodies, training, trade). The focal nation (A) will, thus, have an incentive to offer resources to potential allies to join a formal alliance (e.g., by offering to eliminate all trade barriers to their goods). If, however, there is only one possible ally (D), that ally has a great deal of negotiating power to extract resources from the focal nation (A) in exchange for alliance. Thus, as the threats to the focal nation grow and the number of potential allies shrink, the focal nation's network positional power decreases.

This logic extends beyond the focal nation's direct ties. If the focal nation's (A) only potential ally (D) already has a great many allies (E, F, and G), the focal nation will likely need to offer more resources in return for nation D's assistance than a potential

ally who has no allies or who is itself under direct threat. This is irrespective of whether the other actor intentionally or overtly asks for more in return – the actor requesting the help will likely recognize the situation and will be more inclined to offer a more attractive package in return for an alliance. The extent to which the focal actor is dependent on potential allies that are themselves in powerful network positions – either because they have a lot of allies or are free of threats – decreases the focal actor's positional power and should result in poorer outcomes for the focal actor.

2. Political Independence Index

The Political Independence Index (PII) was introduced to attempt to capture this form of nodal power in a measure adapted for signed graphs. It employs the concept of the distance of a node to a line in a network, which is the distance from node *u* to an edge (*v*,*w*) as MIN(d(*u*,*v*),d(*u*,*w*)), where *d* is the ordinary geodesic distance (the shortest path) between pairs of nodes. Since the geodesic distance from a node to itself is zero, the distance of any edge (*u*,*w*) from *u* is the MIN(d(*u*,*u*),d(*u*,*w*)), which is the minimum of 0 and 1. Hence, a node's direct ties are distance 0 from itself and ties between a focal node's alters out to third parties are distance 1 from itself, and so on. It is on this distance that the beta attenuation rate will be applied.

For a node whose PII score is being calculated, P(*i*) is the number of positive edges at distance *i* from that node, and N(*i*) is the number of negative edges at distance *i* from that node. Then we have the PII as follows:

$$\sum_{i=0}^{K} \beta^i [P(i)^x - N(i)^x]$$

where β is an attenuation factor that discounts the importance of edges far away from the node (and is assumed to be negative), K is

the maximum distance from a node to a line that we are willing to consider, and *x* is defined as:

$$x \leq \frac{ln(2) - ln(|\beta|)}{ln(M)}$$

where M is the maximum number of ties incident on any node in the network. Similar to Bonacich power centrality (Bonacich & Lloyd, 2004), a negative value for beta implements the dependency logic that says that a focal actor's power is reduced if its allies have other allies they can rely on instead of the focal actor. Thus, a focal actor is powerful to the extent it has ties to weak others that depend politically on the actor for resources.

3. Future work requiring funding

Much of the work subsequent to Smith, et al. (2014) requires a great deal of computer programming, particularly for simulated networks, as we develop PII further in two main ways:

a. First, we are answering the question of how much ties at further distances from a node should matter when assessing a focal node's power. We are studying how PII acts in networks and how the beta attenuation rate affects PII scores for the nodal positions in many different politically charged networks (including simulated networks). We are creating a procedure and an R package for determining optimized, viable and reliable beta attenuation rates for researchers to use when employing PII.

b. PII itself needs to be advanced as well. The current version of PII is a geodesic-path based measure that does not consider any triadic effects. Returning to Figure 1, A's negative ties are to two alters (B and C) who are themselves allied; this situation is indistinguishable from one where B and C each have an additional ally, but where B and C are not directly allied. From a power-

as-dependence perspective, we might expect that having negative ties to alters that are allied might place ego in a weaker position because of the easier ability for the adversaries to coordinate their actions against ego. Therefore, we are introducing the Triadic Political Independence Index (PII) to better evaluated a node's power:

Let OUTN(*i*) be the number of pendant closed triads that involve a negative edge at distance *i* from the node, where pendant implies that two of the three edges are at distance i-1 (while the third is at distance i) and OUTP(*i*) be the number of pendant closed triads that involve a positive edge at distance *i* from the node (e.g., triad DFG). Note that by definition OUTN(0) and OUTP(0) will be 0.

Let INN (*i*) be the number of closed triads that involve a negative edge at distance *i* from the node where the other edges of the triad are also of distance *i* (e.g., triad BDE), and INP (*i*) be the number of closed triads that involve a positive edge at distance *i* from the node where the other edges making up the triad also are of distance i (e.g., triad CDG). Note that by definition INN(0) and INP(0) will be 0.

Then we have the TPII as follows:

$$\sum_{i=0}^{K} \beta^i \left[P(i)^x - N(i)^x + \delta[OUTN(i)^x - OUTP(i)^x + INN(i)^x - INP(i)^x]\right]$$

This new TPII will be evaluated to see how well it performs in terms of explaining outcomes such as changes in military size in the international system of alliances and conflicts compared to prior measures, as well as through network simulations.

4. Value of this work

The Political Independence Index is a research concept and method that can advance knowledge in the following areas:

• Monitoring changing international alliances and conflicts and predicting how nations will respond (e.g., changing international relations, growing or shrinking their military, engaging in military actions against specific targets)

• Analyzing and developing network position markers to anticipate changing international responses. For example, the recent coordinated action by Saudi Arabia, UAE, Bahrain, Egypt, and Yemen to place pressure on Qatar can be modelled in PII with a subsequent understanding of how much Qatar will likely change their own military in the future to deal with its weaker position, as well as who it is likely to form alliances with to counter the pressure.

• Improving our understanding of behaviors of relevance to national security. While this white paper highlights the international realm, the approach is flexible and can be used to, for example, understand who are powerful individuals in a legislature, with positive and negative ties being inferred by voting patterns. This can be used to identify powerful individuals even if they are not normally in the media spotlight.

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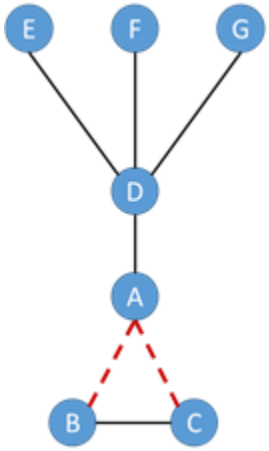
Figure 1. Measuring Political Independence.



(Based on: Smith et al., 2014)

Black, solid lines indicate positive ties. Red, dashed lines indicate negative ties. Actors' *political independence* is a function of: 1) having a large number of allies; 2) having a small number of adversaries; and, 3) having other actors dependent upon them. Political Independence Index Scores for the above actors, using a beta attenuation rate of -0.7, and ranked in terms of advantageous position in the network:

Actor	PII Score
Actor D	4.53
Actors B & C	1.13
Actors E, F, & G	-1.78
Actor A	-2.69