# To coerce or to cajole?
# Power hierarchies of social networks in institutional adaptation to endogenous crises

A Master's Thesis Submission for the Master's in Quantitative Methods in the Social Sciences

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**Abstract**

This paper examines a model of institutional adaptation proposed by political scientists Greif and Laitin in their 2004 paper "A Theory of Endogenous Institutional Change," specifically by focusing on the relational power differences of institutional actors in a social networks context, using the Catholic Church's Council of Constance as a case study. This paper shows that there are only peripheral differences in the network when one considers grammatical syntax for network construction; that one actor, King Sigismund, has a high value of absolute power relative to everyone else but is only one of the most powerful actors in terms of network centrality, while generally absolute power and network centrality are unequally distributed; and that King Sigismund had an extraordinarily high amount of absolute power, relative to his network centrality. Reflecting back to Greif and Laitin's theory, this suggests that, in moments of endogenous crisis, if an institution can construct ad hoc a scenario conducive to institutional adaptation, it can successfully adapt, even if a priori it did not have that structure.

## Introduction

In the ancient Roman myth of Cincinnatus, a lowly farmer was called upon to serve as a temporary dictator of Rome when rival tribes invaded the city. Instead of continuing his reign for the full six months that Roman law allowed, Cincinnatus resigned from his dictatorship after the two weeks of war and returned to his farm, refusing to let the ultimate power of dictatorship corrupt him. In many ways, the ideal of the "selfless dictator" was Rome's mechanism for institutional adaptation in the face of a crisis.

For the modern day political scientist, the study of institutions and crises remains a point of fascination, albeit a problematic one. Institutions – a collection of rules, customs, and behaviors that agents have agreed to follow – form the bedrock of interpersonal, national, and international systems, and the virtues for their persistence render it difficult to explain their changes. The fundamental problem at hand is how much can an institution change and still be the same institution. Political science as an academic field generally eschews explanations dependent on the individual, preferring to see institutions and organizations as a constant black box. But perhaps this disciplinary preference has hindered progress in better understanding institutional crises. Specifically, perhaps the social network within the institution can yield insight into the general pattern of micro-processes that allow an institution to adapt to a crisis while retaining its institutional identity.

To examine this point, this paper analyzes the social network of the 15$^{th}$ century Catholic Church, specifically during the Council of Constance, where the Church resolved a decades long endogenous crisis referred to as the Papal Schism. At the time, the Catholic Church was the most powerful political entity in the world, and functioned much like today's international institutions. By studying this historical event, there is no debate about the existence and

resolution of the crisis, and rich data about the actors, their statuses, and their alliances is readily available. Two research questions drive this exploration of a social network enduring institutional adaptation, making substantive and methodological contributions to the institutional adaptation and social networks literature. First, what was the social network's power hierarchy structure, both in terms of absolute power as well as power derived from an actor's position in the network, that allowed the institution to adapt to the endogenous crisis. Second, taking advantage that the Acts and Decrees of the Council are in Latin (a declining language), this paper asks whether considering the syntax surrounding actors' names yields a more nuanced and accurate social network than simple name counting, the current predominant method of social network construction from text mining.

This paper finds that, much like the efficacy of Cincinnatus's leadership in Rome, the social network at the Council of Constance featured a centralized and extraordinarily powerful actor in the network, who was in a position to coerce and cajole the other actors in the network into cooperation for a successful adaptation. This conclusion was drawn from a network that considered the syntax surrounding actors' names, since my analysis found that this method produced a network with wider variance in power differentials and a more nuanced network for peripheral actors.

After introducing the problem of institutional adaptation and the potential insights from social networks, I introduce the basic historical background information for the Council of Constance. I then describe the theory for the characteristics of the social network, based on Greif and Laitin's 2004 paper "A Theory of Endogenous Institutional Change," as well as why considering the nominal syntax could improve the accuracy of the analysis. Following a brief description of the data and my methods, I present the results of my analysis for determining the

differences between a network that considers syntax and one that does not, as well as a qualitative examination of network characteristics and a Bayesian model for analyzing power. I end with some concluding remarks about my findings and possible future research.

## Literature Review

In an effort to provide context for both this paper's theoretical and methodological contributions, this section presents the international relations' perspective on institutions and institutional adaptation, demonstrates how social network analysis can further the existing theories on institutional adaptation, discusses the relevance and importance of the case study choice within the international relations literature, and ends with a brief overview of methodological debate in mapping texts to social networks.

The field of international relations has developed a rich literature on international institutions. For the purposes of this paper, institutions are defined as a consciously compiled collection of principles, norms, rules, and decision-making procedures, a functional and rational choice approach in line with revered institutionalists Robert Keohane and Douglas North (Keohane, 1984; and North, 1990). As such, institutions provide the foundation of international negotiation, credibility, and cooperation by standardizing the rules of engagement and lengthening time horizons through theoretically infinite repeated interactions. By extension, institutions ultimately rely on "path dependence," meaning that the longer they persist, the more difficult they are to change but the greater their returns (North, 1990, page 34).

Traditional institutional literature encounters challenges when discussing adaptation – if institutions are to change, then the formalized rules that extend infinitely into the future begin to unravel. Two distinct approaches have emerged. The first, called "historical institutionalism"

and first developed in the 1960s (as exemplified by Thelen, 1999; Pierson, 2000; and Pierson and Skocpol, 2002), deeply explores an individual case – identifying key players, mechanisms, and political environments that allowed institutions to adapt – using anthropological approaches as opposed to rational choice models, and is often applied to historical cases. Pierson and Skocpol discuss "path dependence" as a "self-reinforcing or positive feedback process," where institutions have higher returns the longer that they persist (Pierson and Skocpol, 2002, page 6). Because of its largely qualitative nature, historical institutionalim is able to entertain multiple and complicated causal chains at a finer detail than a rational choice model. The self-reinforcing process can work as a theoretical mechanism for resolving sequencing questions when inferring causality for institutionalism adaptation (8). Thelen explains further the historical institutionalism perspective by differentiating between a rational choice model's emphasis on function for institutions versus historical institutionalism's emphasis on how institutions modify behavior and process tracing (Thelen, 1999, page 379). This methodology can be insightful for individual or small-n comparative cases, but the findings are difficult to generalize and offer too much accommodation to institutional change (Greif and Laitin, 2004).

The second approach, often referred to as "punctuated equilibrium" from a 1984 article by Stephen Krasner, uses game theory principles to describe institutional adaptation as a pseudo-biological evolutionary process, with long periods of stasis followed by rapid bursts of change (Krasner, 1984, page 242). This approach, a more recent development, sharply contrasts with historical instiutitonalism, and is often at odds with its fundamental approaches and assumptions (Thelen, 378-379). Krasner very distinctly differentiates between "institutional creation," "institutional stasis," and "institutional crisis," and, in combination with North's emphasis on path dependence, he has largely been interpreted as meaning that when an institution faces a

crisis, the "game" is over and the post-crisis institution is in fact a new institution (e.g. March and Olsen, 1998; Baumgartner et al, 2009). This second approach has largely dominated the institutional change literature, addressing similar subjects that fell under historical institutionalism. For example, Koremenos et al (2001) examine, from a rational choice perspective, the process tracing of how institutions are designed and established, a traditionally historical institutionalist topic, as a way for institutional participants to maximize their personal utility. Although widely used in a variety of contexts, punctuated equilibrium has some severe limitations. It requires all institutional participants to have complete knowledge of the game and payoffs at hand and the rationalizability to therefore always play their best response, which is not necessarily a reasonable expectation of individuals in a complex system. Should these assumptions fail, under strict punctuated equilibrium, the institution would be in crisis and therefore have to cease (Greif and Laitin, 2004, page 639). This approach also conveniently ignores that this lack of flexibility for institutional change itself undermines the reason that institutions are created and are perpetuated. In other words, if institutions have an expiration date in the foreseeable future, then actors would not want to invest the time and finances for creating and maintaining those institutions, and would therefore have reason to maximize short-term interests at the expense of long-term ones, nullifying the ability to have institutions.

Other scholars have proposed a third way that combines both approaches, in which institutions adapt according to punctuated equilibria while remaining the same institution. One such proposal, from Greif and Laitin, argues that only a crisis can force large institutional change, an acknowledgement to punctuated equilibrium, while introducing marginal behavior changes one might derive from process tracing ("quasi-parameters") that affect the "self-enforcement" of an institution, concepts that are rooted in historical institutionalism (Greif and

Laitin, 2004, page 639). If the new behaviors apply to a wider set of situations, then the institution is self-reinforcing; if these new behaviors apply to a smaller set, then it is self-undermining. After sufficient undermining, the institution is in crisis. If one were to incorporate marginal behavioral changes as part of the rules of the game, the necessary changes to adapt the institution should not be considered a new institution. This framework allows institutions to evolve and mature to changes in both exogenous and endogenous environments, but within a more regularized framework than established by historical institutionalism.

To illustrate their theory, Greif and Laitin compare two political systems as institutions in Medieval Genoa and Venice (Greif and Laitin, 2004, pages 640-644). While the application of their model is game theoretic, the relative power of elites and the mechanisms for the diffusion of information would lend themselves particularly well to social network analysis. The primary unit of analysis within the institution is the political family, and an established agreement between the political families allowed them to coordinate and cooperate within the institution. This oligarchy elected a centralized power to resolve any disputes. In Venice, this centralized power was the Doge, and in Genoa it was (depending on the time period) either consuls or a council of rectors. As the external and internal political dynamics changed, these political systems had to adapt, and it was the structure of the centralized power that determined whether the quasi-parameters promoted self-reinforcement or self-undermining. Specifically, Greif and Laitin argue, Venice was an example of self-reinforcement and Genoa was an example of self-undermining. Venice's institution was able to self-reinforce due to several institutional characteristics, including that the Doge was an elected monarch, Venetian families signed a pact to band together against any "renegade" family, and the Doge's power was somewhat limited to the distribution of rents and dispute resolution. This distribution of rents guaranteed that families

could prosper in Venice without being allied with powerful families, which in turn discouraged extensive militarization to gain power, keeping the family hierarchies relatively stable and equal through time. Although Greif and Laitin do not mention this, a logical extension of such a structure would also imply that the Doge was the primary disperser of information between the families, through his position as a distributor of rents and a significant authority in the center of the institution. In contrast, the multiple-actor design for the centralized power in Genoa both encapsulated and encouraged Genovese family rivalries, leading to essentially an arms race for power in the institution.

While Greif and Laitin's theory is clearly in game theoretic terms, their example with multiple actors of varying power, identities, and relationships could be easily visualized and analyzed in a social networks analysis. The actors are portrayed as nodes, the existence of ties portrays the relationships, and the value of the ties portrays the functional hierarchical differences within the institution. Translating Greif and Laitin's theory into social network terminology, a self-reinforcing institution should have only one node (the equivalent of the Doge) with a high measure of centrality within the network, in terms of being connected to the most number of people, being on the most number of shortest paths between any two actors, being the most capable of quickly sending communication to the rest of the network, or being the most connected to other well connected actors. In such an institution, the other nodes (the equivalent of the political families) should be of relatively equal power. In other words, re-creating the Venetian institution would generate something of a star diagram, with one central node and the other nodes fanning away and not connected to other nodes, whereas the Genovese institution would feature dense clusters of nodes with a few nodes (i.e. the consuls or rectors) bridging the clusters. When examining the attributes of each actor outside of their relative

relationships to each other, there should be one actor, most likely someone at the top of a nominal organizational hierarchy, who is more powerful than the other actors. An actor who is powerful within the network should be in a position to quickly disperse information throughout the network, since other members in the institution would know to pay attention to information coming from a powerful actor, but could also contain damaging information to a selected portion of the network if it served their end goal. In addition, an actor who has powerful attributes exogenous from the network should be in a position to coerce or cajole other members of the institution into cooperation for a plan to adapt the institution. The distinction between power derived from the network versus power derived from the institutional hierarchy are analogous to what some scholars have termed prominence from centrality as opposed to prominence from prestige (Freeman, 1978-79; Knoke and Burt, 1983). Constructing a network from an institution that one knows, a priori, successfully adapted to an endogenous crisis, and then analyzing that network for these network attributes would strengthen the operationalization of Greif and Laitin's theory.

To my knowledge, there has been no attempt to model international institutional adaptation through social networks, but there is an abundant and evolving empirical and theoretical literature on the value of being in the center of a network and the dispersal of information (see Huckfeldt and Sprague, 1987; Borgatti and Cross, 2003; Hafner-Burton and Montgomery, 2006; and Maggioni and Uberti, 2011). For example, the literature surrounding structural holes suggests that someone who connects disparate networks has unique perspectives, and is empowered to spread information (see Burt, 2004). Logically, the reverse is also true – if the actor who connects disparate networks finds it within their interests to not spread the information, they are empowered to do so with potentially no consequences. Theoretically,

influence and information could flow in similar ways throughout the network, and therefore someone who is highly centralized, or at least strategically placed, and is powerful could spread their influence throughout the network as well (Knoke and Burt, 1983). Actors in a position of power are also more able to ignore dissonant information, instead cycling through information that is more favorable for their purposes, which again proposes a mechanism where powerful people are more likely to focus on and disperse specific information that reinforces their power (Freeman, 1978-79; Huckfeldt and Sprague, 1987). These functional characteristics of a social network can, with a power network, be exploited to test Greif and Laitin's theory.

Creation of such a network from text analysis is challenging, especially since such an examination would require a study of the actors themselves as opposed to the more common approach of studying what actors say (Huffaker, 2010). An approximate methodological template is available in Rowe et al.'s 2007 paper analyzing social hierarchy from the Enron email dataset. In their paper, they constructed a directed socio-matrix of the Enron social network depending on who was in the sender and receiver fields of an email. They then weighted the edges between the nodes by the volume of correspondence, theorizing that actors with more emails are more important in the social hierarchy. They also computed the average response time between each sender and receiver pair, theorizing that when a receiver responded more quickly, the sender was of greater importance to that receiver. Using these measures, they ranked the Enron nodes into a social score, which allowed them to analyze the network for nodes with similar characteristics (i.e. homophily) and cliques. Finally, they compare the accuracy of their social hierarchy algorithm by comparing their ranked list to the Enron employee list.

Similar concepts can be adapted to the Council of Constance. Documentation of the personnel information, including working relationships and relative power relationships, is

readily available, and the Council itself represents an institution that faced a crisis and adapted. Since it is firmly in the past, there is no dispute that the crisis ended, or other factual outcomes of the meeting. Significantly, complete rosters of everyone in attendance – from the Holy Roman Emperor to the servants – are available, and therefore a qualitative check similar to Rowe et al's paper is possible. Some further modifications are required: instead of utilizing sender and receiver fields in an email, the text mining collects information on who was mentioned in the same sentence as other actors; instead of determining who is most important by response time, the text mining determines actor importance by the number of times they are mentioned in the text, theorizing that more important people are mentioned more often; and instead of examining the volume of correspondence, which might be more apt at capturing the intensity of relations within a department or between relatively equal colleagues (neither of which is directly analogous to this context), the text analysis determines the power differential between two actors by calculating the difference between the number of times each actor is mentioned.

This approach, while artificially a rather dramatic departure from traditional international relations subject matter and methodologies, is really a logical step forward. For example, international relations only recently began recognizing the legitimacy of studying a religious organization as an international political institution (for more on the discussion, see Berger et al, 1999; Wald & Wilcox, 2006; Zech, 2007; Miller, 2007). Given past case studies in the Medieval-Renaissance era and the rich information available, studying the Catholic Church is a way to forward this important development in the field (for other examples of using pre-18th century history for case studies, see Greif and Laitin, 2004; and Weingast, 1997). Furthermore, given that the 15th Century Catholic Church was the most powerful political entity in Europe where every nation was represented, it is more analogous to a modern day European Union or United

Nations than it is to the modern day Vatican, and therefore also more relevant to the study of traditional international relations issues (Vallier, 1971). Finally, by using individual actors as the nodes in the social network as the unit of analysis, as opposed to countries or organizations, this approach moves beyond the usual black-box perspective that dominates network analysis in international relations literature (Maoz et al, 2003; Hafner-Burton and Montgomery, 2006).

Since a full mapping of the working relationships and relative power in the social network requires text mining, a relatively new methodology for the social sciences, this case study also offers the opportunity to empirically test two approaches to text analysis (Huffaker, 2010; Roberts, 2000; Rowe et al, 2007; Seale et al, 2006). The first relies on simple word counting for data, while the second attempts to extract more sophisticated information from the texts by considering the full syntax of that word. Given that the Acts and Decrees of the Council of Constance are written in Latin, the grammatical importance of a word within a sentence is included within the word itself. As mentioned previously, the lists of persons from the Acts and Decrees provide a qualitative idea of where each person should place in the social network. In the spirit of the Rowe et al. paper's methodology, comparing this list to the social network based on textual analysis of simple word counting versus the social network based on grammatical parsing offers a unique opportunity to see if the more sophisticated methods yield a more accurate social network. It is worth noting that considering the grammatical syntax surrounding someone's name more closely approximates the operationalized relationship of sender and receiver fields from Rowe et al's study – for example, a sender is analogous to a subject in the sentence, while a receiver is analogous to an indirect or direct object. While the advantages or disadvantages of either approach are not well developed for the social sciences, this paper hopes to contribute to this nascent conversation.

The next section offers some background history for the Council of Constance, before moving on to descriptions of data, methods, and findings.

## Background: The Council of Constance[1]

The Council of Constance ended what is known as the Papal Schism or the Western Schism. In 1377, Pope Gregory XI returned to Rome, leaving behind the renowned corruption of the Avignon Papacy. When Gregory died a year later, the Cardinals, per Catholic Church custom, chose Pope Urban VI to be the new pope. Many Cardinals regretted choosing Urban, and a few months later retreated to the outskirts of Rome where they chose Pope Clement VII to be a second pope. Upon his election, Clement re-established the Papacy in Avignon, and thus began a period where there were two rival and apparently equally legitimate papacies.

Having two papacies was a disaster for the Catholic Church. By undermining Church doctrine for one true pope, it opened the possibility that other Church doctrines could be questioned – in fact, this crisis sowed the seeds for the Protestant Reformation a century later. It also required all political entities across Europe to choose which pope to consider the true pope, splitting what was a once a vast region unified under one institution. As popes from each side proceeded in parallel with Church business, the need to reconcile became more urgent. Throughout the 1390s and early 1400s there were several attempts to unify the Church. The most promising attempt was at the Council of Pisa in 1409, which drew reputable representatives

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1. The information presented in this section is compiled from several historical accounts on the Council of Constance. The two texts most widely used by historians are Hefele and Leclercq (1907) and Jedin and Dolan (1981). I highly recommend these resources for further information. Both texts have English translations available.

from both sides. The Council of Pisa deposed both the Rome and Avignon popes and elected a third pope, Pope Alexander V. Alexander died in 1410, and Pope John XXIII, rumored to be a former pirate wanted for arrest in Naples after having broken out of prison, succeeded him. Ultimately, neither Pope Gregory XII, the Roman claimant, nor Pope Benedict XIII, the Avignon claimant, recognized the Council of Pisa or the new pope, so the problem only intensified and the Church proceeded with three popes.

In parallel, wars in Germany and Eastern Europe that had been ongoing since the early 1380s began to wind down, and Sigismund, the particularly ambitious King of Hungary and Croatia, became King of Germany and a contested King of the Romans in the early 1410s. To cement his standing, Sigismund independently negotiated with each Pope to call a council in Constance. Unbeknownst to the others, Sigismund promised each pope to guarantee their position, and in return they would support his position as King of the Romans and become the Holy Roman Emperor. Having secured support from all three popes, Sigismund called for the Council of Constance, which first convened in November 1414. The Council was a lavish affair, with both religious actors and secular dignitaries attending in person and with representatives. An estimated 10-20,000 people encamped on the Lake of Constance for four years.

At the beginning of the Council, Gregory approached Sigismund with a new proposition – Gregory was terminally ill, and offered to volunteer to resign from the papacy in return for the Roman line of popes to be declared the true line, and an Italian replace him as pope. Sigismund agreed, and in the first year of the council Gregory resigned, John was deposed, and Benedict was deposed and then excommunicated. In 1417, the Council elected Martin V, an Italian, to be the new pope, finally ending the Papal Schism. The Council of Constance formally ended in 1418.

## Hypotheses

*Hypothesis One:* Regarding testing the importance of syntax, I hypothesize that considering the syntax will generate mechanically similar networks, but the power differential between Sigismund and the other actors in the network will be more clearly defined.

*Hypothesis Two:* Regarding institutional adaptation, based on Greif and Laitin's theory, I hypothesize that within the Council of Constance network King Sigismund will be the most powerful person, in terms of network centrality and weighted power.

## Description of Data and Data Collection

My primary data source will be the Acts and Decrees from the Council of Constance, using Tome IV of *Magnum oecumenicum Constantiense concilium* compiled by Church historian H. von der Hardt between 1696 and 1700. Von der Hardt's edition is the most widely used by Church scholars, and is equivalent to modern day meeting notes and press releases, since it contains detailed summaries of all the meetings during the Council as well as the publicly released final decisions from those meetings. As such, it provides rich details on the political relationships and statuses of the participants in the Council. Tome IV has 984 pages, excluding historical analyses by von der Hardt and other historical scholars as well as prints of key participants, maps, or other illustrations. Given that the current format is a copy from a 17$^{th}$ century printing press (and therefore not easily usable for text analysis), I took a random sample of 50 pages across the four years to mine for the social network. To construct a library of names for the social network, I collected every name mentioned in the Decrees (i.e. the "press releases"), creating a list of twenty-three actors after excluding biblical figures, deceased Church leaders, and dissidents. I chose this method for bounding the social network because I had a

modern printing of the decrees that was easier to read, and I thought it would be more specific to the most important actors as opposed to the blanket coverage of a complete list by von der Hardt in Tome II of *Magnum oecumenicum Constantiense concilium,* which has thousands of actors ranging from the Holy Roman Emperor to the servants. However, since von der Hardt's list includes political and religious rankings of each person, it is a useful cross-reference for the final network results.

I then mined von der Hardt's text, producing two name counts: one based on the total number of times the name of each of the twenty-three people appeared, which became a variable called "simple power," and one weighted count based on the total number of times a name appeared in each part of speech, which became a variable called "weighted power." The underlying theory is that names that appear more often indicate more power than names that appear less often, and that names that appear more often as the subject of a sentence indicate more power than names that appear more often as direct objects. In this case, this information is relatively easy to collect with text mining since Latin is a declining language, meaning that the ending of nouns change depending on that noun's part of speech. For example, consider the sentence, "The girl's mother went to the store with the dog; she bought a book for the girl." The first case is the nominative, used for subjects in a sentence. In the example sentence, "mother" is in the nominative. The second case is the genitive, used for possessives. In the example sentence, "girl's" is in the genitive. The third case is the dative, used for indirect objects. In the example sentence, "for the girl" is in the dative. The fourth case is the ablative, a case that takes on a variety of uses but can be identified by nouns paired with prepositions. In the example sentence, "with the dog" is in the ablative. Finally, the fifth case is the accusative, used for direct objects. In the example sentence, "book" is in the accusative.

To avoid double counting names whose declensions have overlapping written endings, the program weighted on a scale of 3: any time a person's name appeared in the nominative or the genitive, they received a score of 3, the dative or the ablative received a score of 2, and the accusative received a score of 1. Anytime there was additional uncertainty, the program erred on the lower weight. This is summarized in Table 1.

**Table 1: Power weighting on name syntax**

| Declension | Part of speech | Weight |
|---|---|---|
| Nominative | Subject | 3 |
| Genitive | Possessive | 3 |
| Dative | Indirect Object | 2 |
| Ablative | Prepositional subject | 2 |
| Accusative | Direct Object | 1 |

In a non-declining language, sophisticated text analysis can require complex analysis of words in the parts of speech. This complexity has been perhaps a hindrance for more in-depth text analysis, perhaps explaining why so much modern text analysis in political science relies on counting words. Testing to see if there is a difference between simply counting names versus counting the names per declension could shed light on the payoff from the extra effort needed to consider grammar.

## Testing the Power of Grammar

In order to properly test Greif and Laitin's hypothesis, I first needed to determine which graph is most appropriate. In other words, I first needed to test whether there is a statistically significant difference between a network where ties are valued with simple power versus ties valued with weighted power. To do this, I used exponential random graph models (ERGMs). ERGMs take the original network and randomly permutate the relationships while keeping the

key network characteristics constant, and compare the simulated network to the original network. If they are similar enough, then one considers the relationships in the original network to exist as if by chance. For the particular networks I tested, the existence of a tie is based on whether there is a power differential, and the value of the tie is the difference between the two actors' power scores. It is worth noting that, of the 506 possible relationships in the network, the weighted power network had 240 relationships (47% density, meaning that 47% of all possible ties actually exist) and the simple power network had 218 (43% density). In addition, simple power scores had a minimum of 0, a maximum of 65, with a mean of 5.83, a median of 1, and a standard deviation of 14.05. Weighted power scores had more than double the range of the simple power: a minimum of 0, a maximum of 138, with a mean of 12.91, a median of 3, and a standard deviation of 29.87. Given the greater range, it is not surprising perhaps that then there are more power differences across the network.

The ERGM results are shown in Table 2, indicating that both simple and weighted power differentials are highly statistically significant (p-value $< 0.0001$), though more so in the weighted power network. The edges are insignificant when the edge values are included, implying that, while it is not random who is specifically powerful in the network, it is potentially random who is more or less powerful than a given actor. Across different specifications, the AIC for the simple power network is slightly lower, indicating possibly a better model fit, and, while other network attributes are not significant, the magnitude and significance of the edge values were robust.

**Table 2: ERGM Results (standard errors in parentheses)**

| | Simple Power Base Model | Simple Power Model 2 | Simple Power Model 3 | Weighted Power Base Model | Weighted Power Model 2 | Weighted Power Model 3 |
|---|---|---|---|---|---|---|
| Edges | -0.278** (0.090) | -0.11 (0.097) | 0.190 (0.152) | -0.103 (0.089) | 0.090 (0.098) | 0.189 (0.147) |
| Edge Values | | -0.036*** (0.010) | -0.036*** (0.010) | | -0.019*** (0.005) | -0.019*** (0.005) |
| Position | | | -0.024 (0.297) | | | -0.001 (0.276) |
| Alliance | | | -0.028 (0.224) | | | 0.001 (0.215) |
| Nationality | | | -0.005 (0.265) | | | -0.010 (0.253) |
| Mentions/ Weighted Mentions | | | -2.921*** (0.525) | | | -1.966*** (0.546) |
| AIC | 693.8 | 675.2 | 617.6 | 702.1 | 679.1 | 668 |

In summary, based on the ERGMs, it is unclear which method is better. As a further investigation, I compared the edge lists between the simple and weighted powers to determine which twenty-two relationships were missing from the simple power network. There were no differences in the center of the network, but there was greater density in the periphery. For example, the weighted power network shows the King of Aragon being more powerful than the King of Castille, whereas the simple power network shows them as equals. The power differential is potentially accurate – according to von der Hardt's list, Pope Benedict XIII was of Aragon nobility and related to the King of Aragon and therefore was slightly higher ranked than the King of Castille – but, given that neither the King of Aragon nor the King of Castille were mentioned often in my text sample, it is unclear how much these relationship changes matter, especially when considering power in the center of the network.

For further analysis of the network to test Greif and Laitin's hypothesis, I decided to proceed with the weighted network, since there was more variation to exploit and a larger

number of ties. It should be noted that, as a robustness check, I did the same analysis with the simple power network, with similar results.

## Variables and Methods

After I determined to use the weighted power network, I proceeded with examining Greif and Laitin's theory. In order to make the connections more meaningful, I collected from the text information on whether two people were mentioned in the same sentence and created a binary adjacency matrix showing these connections. I then multiplied this binary matrix by the weighted power matrix, so that the basis for the ties was whether there was a power differential and whether they were mentioned in the same sentence. While this ensured that only actors who worked in similar contexts were compared, it did isolate eight of the twenty-three nodes.[2] In addition, I compiled an attribute table for the twenty-three actors, including the weighted mentions (described previously) as my key dependent variable. Note that King Sigismund has the highest weighted power score at 138, followed by Pope John XXIII at 58 and Pope Benedict XIII at 57, but thirteen of the twenty-three nodes have a weighted power score of 5 or less. The rank ordering of the weighted power scores roughly matches von der Hardt's list. This first result suggests that one actor has higher prominence from prestige than all other actors, but the equality of the rest of the network does not follow expectations from Greif and Laitin's theory. The independent variables were religious or secular position, an eight level factor, with levels 1 through 3 corresponding to secular positions (King, Duke, and Count), and levels 4 through 8 corresponding to religious positions (Pope, Cardinal, Archbishop, Bishop, and Proctor);

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2. I also ran the analysis on the weighted power matrix without the reduction multiplication, but the network was too dense for sensible results.

Alliance, a two level factor, where 1 corresponds to an alliance with the Italians (either the Pisan or Roman Pope) and 2 corresponds to an alliance with the French (note that 16 were allied with the Italians and 7 were allied with the French); and measures of centrality calculated from the network.

The measures of centrality are as follows: degree, which is the number of ties a given actor has to other actors; in-degree, which is the number of ties toward a given actor (in this case, a measure of how many actors are more powerful); out-degree, which is the number of ties away from a given actor (in this case, a measure of how many actors are less powerful); betweenness, which is the number of times an actor lies on the shortest path between two other actors; closeness, which is a measure of how quickly an actor can disperse information through the network (in this case, how well an actor can influence a network using their power); eigenvector, which is a measure of how well connected an actor is to other well connected actors; and, finally, Bonacich, a measure of how much an actor's importance is linked to the centrality of other actors in the network. Given that these measures are highly correlated and the sample size of the network is small, I standardized and combined the measures into a centrality index, which has a satisfactorily large standardized Cronbach's alpha of 0.86. The summary statistics of these measures, as well as the graph used to calculate the measure, are shown in Table 3. As is clear, most of these measures are not calculated on the valued, asymmetric matrix, which limits the influence and nuance the grammar-weighted ties can offer to any model, but also limits the nuance lost in the creation of the index. This also renders the distinction between absolute power and network centrality power more critical, since the network centrality power could underestimate an actor's true influence in the institution.

**Table 3: Summary Statistics for Network Centrality Measures**

| Centrality Measure | Type of Network for Calculation | Minimum | Maximum | Mean | Median | Standard Deviation |
|---|---|---|---|---|---|---|
| Degree | Connection graph | 0 | 9 | 1.91 | 2 | 2.19 |
| In-Degree | Binary and asymmetric power graph | 0 | 9 | 0.83 | 0 | 2.08 |
| Out-Degree | Binary and asymmetric power graph | 0 | 3 | 0.83 | 1 | 0.89 |
| Betweenness | Original power graph | 0 | 4.5 | 0.37 | 0 | 1.01 |
| Closeness | Original power graph, with isolates removed | 0 | 0.0005 | 0.0002 | 0. | 0.0002 |
| Eigenvector | Connection graph | 0 | 1 | 0.27 | 0.35 | 0.27 |
| Bonacich | Original power graph | 0 | 3.25 | 0.62 | 0.46 | 0.8 |
| Index | All of the above | -0.81 | 1.52 | 0 | 0.16 | 0.74 |

The first step for evaluating Greif and Laitin's theory is to see if, based on these measures of centrality and the weighted power mentions, one actor is more highly central across the appropriate measures than anyone else, while all other actors are approximately equally ranked. I explored these baseline checks qualitatively, both by examining the attribute tables as well as visually.

The second step is to model examine the relationship between centrality and power more rigorously. Given that there are only twenty-three actors in the social network, eight of those actors are peripheral because they are never mentioned in the same sentence as another actor, and there is high dependency between these observations, this is a difficult step. In addition, as can be seen in Figure 1, the data for the dependent variable is highly dispersed and clustered at lower

values, while King Sigismund is an outlier with both a high centrality index and a high number of mentions. Given the size and challenges of the data, I wanted to utilize as much information as possible for the model, and therefore decided to model the weighted power in a negative binomial Bayesian model as follows:

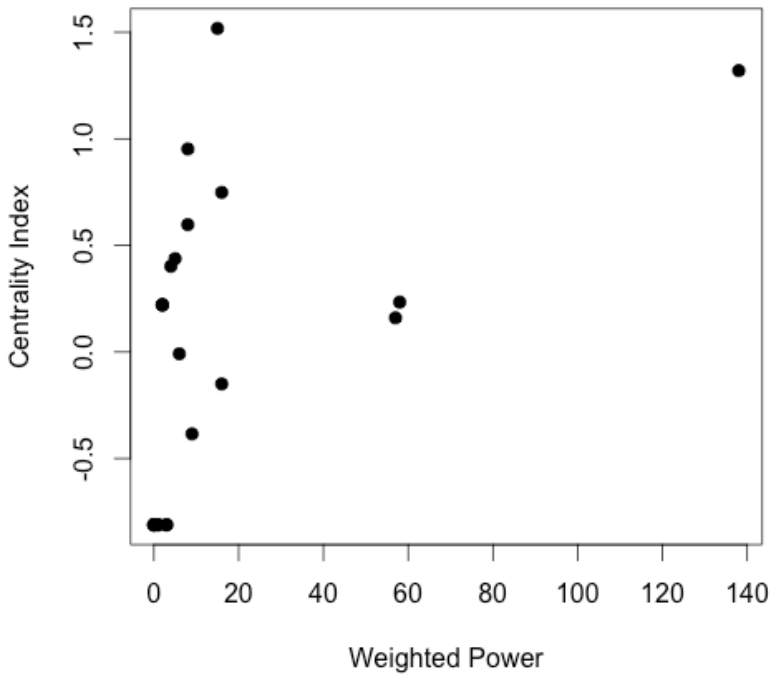
$$y_i \sim Negative\ Binomial\ (\mu_i)\ \forall\ i$$
$$\mu_i \sim e^{x_i^T \beta}$$
$$\beta_1 \sim Uniform(-\infty, \infty)$$
$$\beta_k \sim Normal(0, 1)\ \forall\ k > 0$$

In the model with the best fit, as determined with leave one out cross validation, the predictors $\beta_k$ included *index*, *alliance*, and factors indicating if the person being modeled was a *king* or a *pope*, to form the following model:

$$weighted\ power = \beta_1 + \beta_{k1} index + \beta_{k2} alliance + \beta_{k3} pope + \beta_{k4} king$$

To run this model, I used the R interface for the Bayesian statistical software Stan, giving the Markov Chain Monte Carlo 8 chains with 1000 iterations per chain to overcome the sample size deficiency. I chose a standard normal prior for its flexibility in uncertainty but additional conservativeness, given the small original sample size. As would be expected, the normal prior predicted well in the center of the distribution, but over predicted for actors with lower weighted power scores and under predicted for actors with higher weighted power scores. While the diagnostics for model fit and specification seem accurate, the output should still be interpreted more generally given the small sample size.

**Figure 1: Plot of Weighted Power versus Centrality Index**



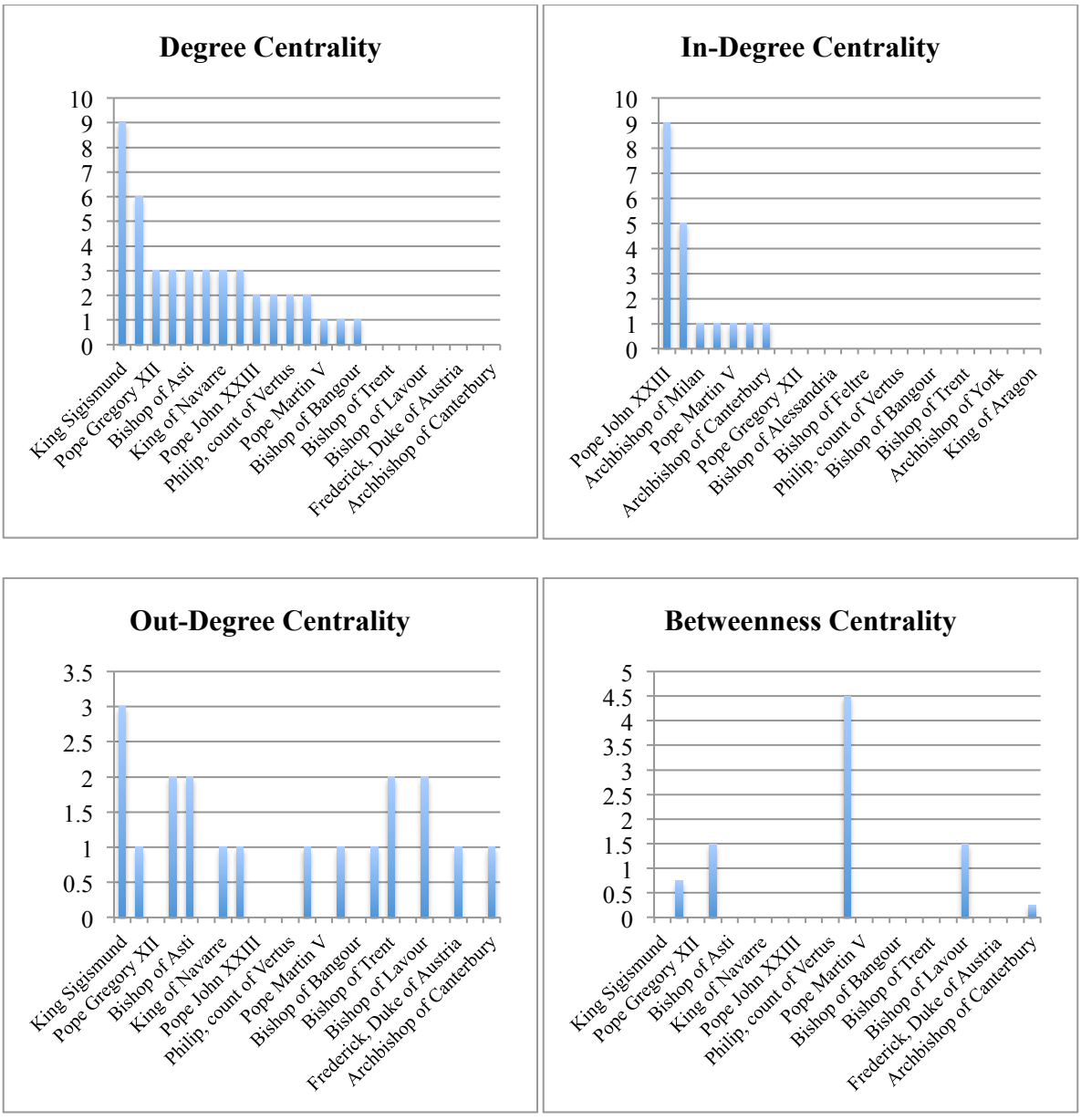

In the next section, I will discuss the results of both the qualitative and quantitative analysis.

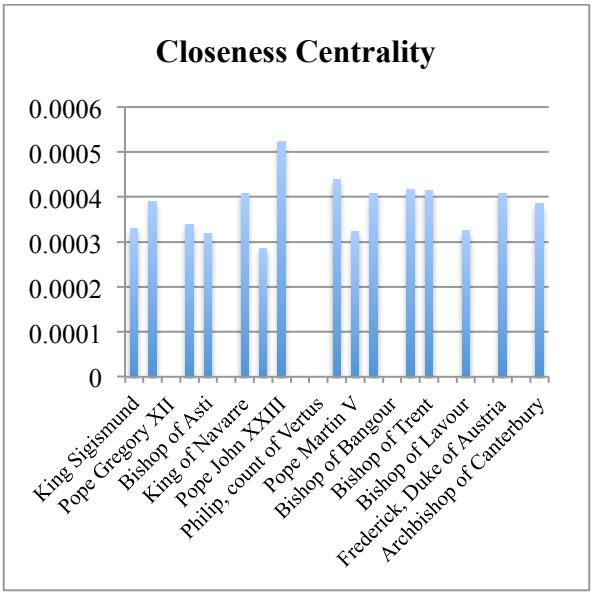
## Results

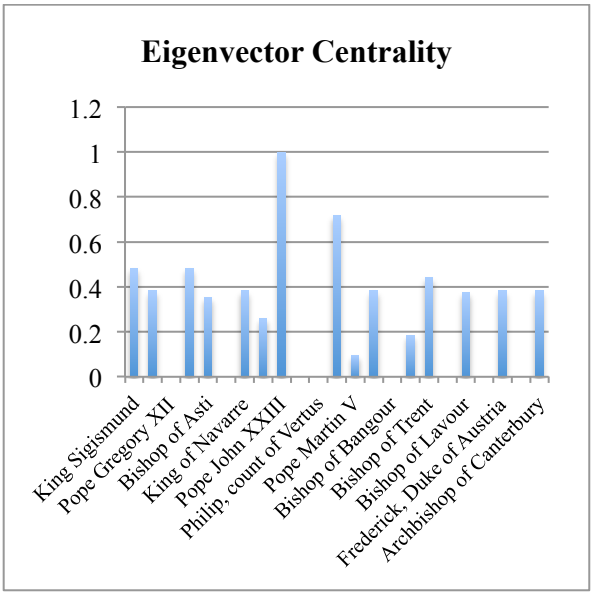
First, I explored the ranks within the measures of centrality to see if, qualitatively, there was support for Greif and Laitin's hypothesis. As can be seen in Figure 2, King Sigismund is the most central in three of the seven measures of centrality: degree, out-degree, and Bonacich. His lack of centrality for in-degree is not surprising, since it is a measure of how many people are above you in the hierarchy. His lack of closeness, betweenness, and eigenvector centrality possibly indicate a limit to King Sigismund's power in the network, specifically in terms of quick information dispersal (closeness), easily facilitating or disrupting communications between two actors (betweenness), or being connected to other well-connected actors (eigenvector).

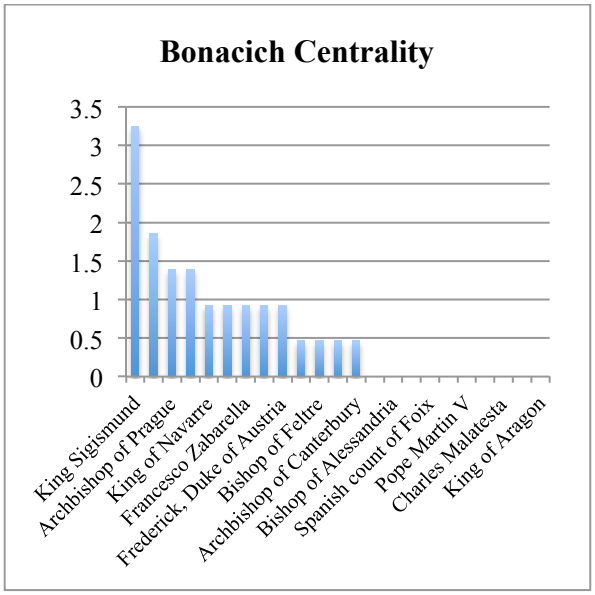
More generally, this suggests that, in practice, actors cannot have the complete domination suggested in the Greif and Laitin model, though there can still be a more dominant figure in the network.

**Figure 2: Distribution of actors across measures of centrality**





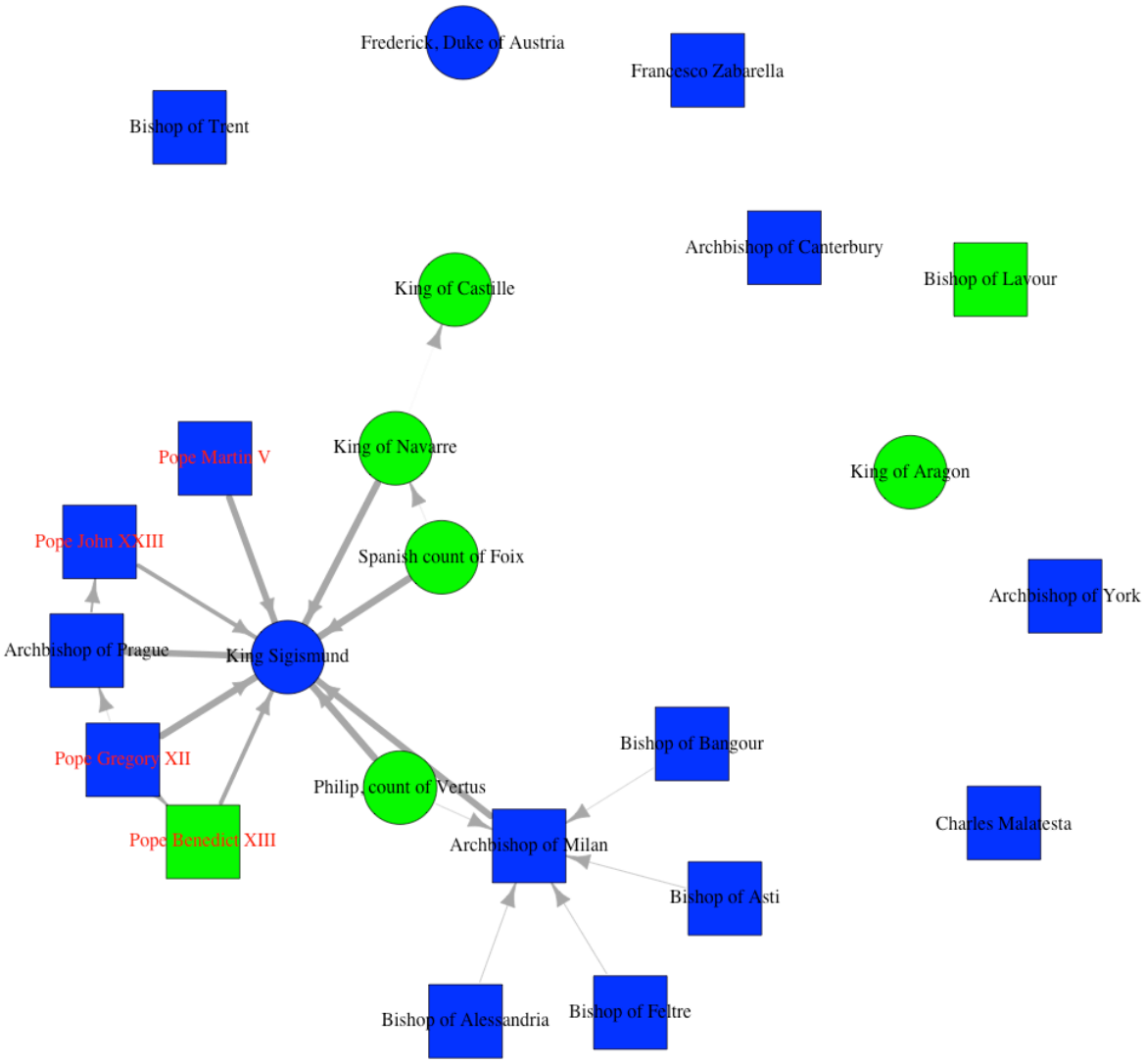




In addition, it is difficult to argue that for any given centrality measure there is one powerful person and the rest of the network is relatively equal. Oftentimes there appears to be a particularly central person for the given measure, and then two to three groups of relatively equal people below that. This does not undermine the Greif and Laitin model per se – in fact, it may just be a finer grained portrait of the network than illustrated in their model, which focused on families as units but not within the families. It could also be a function that King Sigismund was

powerful in ways that were exogenous to the network, but, in terms of network dynamics, he did not hold the sole power to disperse and withhold information and coerce actors into submission. While this is not directly in line with Greif and Laitin's theory, it is perhaps a more accurate depiction of a real institution, which is all the more plausible considering that Greif and Laitin's example might be simplified for game theory purposes. For example, if a smaller component within the network has one actor who is more powerful than the rest of that component, and that one more powerful actor is the sole tie to King Sigismund, that actor could influence the information flow between that smaller group and King Sigismund. If that one actor decided to not cooperate with King Sigismund, his power in the network would be diminished.

Consider Figure 3. Actors allied with the Italians are shown in blue, and actors allied with the French are shown in green; circle nodes are for political actors and square nodes are for religious actors; the four popes' names are highlighted in red; arrows are pointing toward the more powerful person in the power differential; and edges that have a larger power differential are thicker. If, for example, The Bishop of Alessandria and the Bishop of Asti had information for King Sigismund that would have undermined the Archbishop of Milan's authority, The Archbishop of Milan could unilaterally withhold that information from King Sigismund, depriving King Sigismund of the network power to decide how to handle that information.

**Figure 3: The Social Network of the Council of Constance**




The Archbishop of Milan actually offers an interesting contrast to King Sigismund. He has a fairly low weighted power score of only 15 (recall that King Sigismund's weighted power score is 138). He is also not connected directly to any popes, and, with the exception of Philip, the Count of Vertus, he has no secular connections. However, in terms of the centrality index, he is the most powerful actor, with a score of 1.51, and is the only actor more powerful than King Sigismund from a network centrality perspective. Historically, Northern Italy was a stronghold

for Pope Gregory support, and, given Gregory's upper hand in the institutional adaptation negotiation process, it is not surprising that he would be an important actor in the network. The bishops of Asti and Alessandria are also from Northern Italy, and would have reported to the Archbishop of Milan. Qualitatively, throughout von der Hardt's text, those three men are often mentioned as volunteering to undertake an important negotiation. Therefore, the Archbishop of Milan's high centrality might be a function of King Sigismund's and Pope Gregory's delegating tasks to a trusted supporter.

This example aside, given that this visualization emphasizes the differences in power as conceptualized through weighted mentions, King Sigismund seems to be the most powerful actor in the network, with the largest and most numerous power differentials. This again suggests that the measures of power as operationalized through network centrality versus through the weighted power score are not completely congruent. For example, most of the time that King Sigismund is mentioned in the text, he is not mentioned with another actor. Conversely, if an actor is mentioned few times in the text but consistently mentioned with other people, their power as conceptualized through the network is amplified even if their weighted power is relatively low. In such a case, one might have the network position to be influential, but not the weighted power to utilize that position for influence. From a Greif and Laitin perspective, one would want to have both the position and the weighted power to influence.

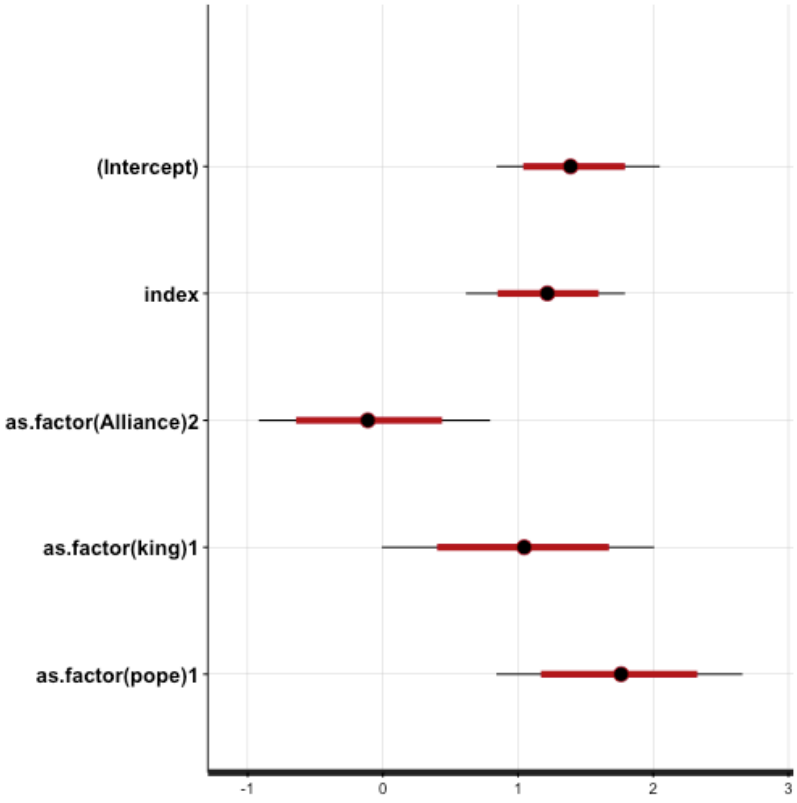
In an attempt to understand the relationships between the two power concepts more fully, I modeled weighted power as a function of the centrality index, alliance, and being a king or pope relative to another position. The posterior estimates and the 95% credible intervals, with an effective sample size minimum of 2,014, are shown in Table 3 and visually in Figure 4, where the black dots indicate the means, the red lines indicate the 80% credible interval, and the black

lines indicate the 95% credible confidence interval. Note that the model diagnostic plots (see Appendix 1) indicated the model converged and matched general assumptions. The posterior estimates suggest that, generally speaking, having a higher centrality index is associated with higher weighted power; the effect of being allied with the French on weighted power, relative to the effect of being allied with the Italians, is unclear, since the mean is negative but the credible interval crosses zero and there were only seven French allies in the network (three of which were isolates); the effect of being a king is associated with higher weighted power; and the effect of being a pope is associated with a higher weighted power. Given the small original sample size, it is unclear whether these credible intervals capture the true mean, so more rigorous analysis of this table is discouraged.

**Table 3: Posterior Estimates**

| Variable | Mean | Standard Deviation | 2.5% | 97.5% |
|---|---|---|---|---|
| *index* | 1.4 | 0.3 | 0.8 | 2.1 |
| *alliance* (French) | -0.2 | 0.5 | -1.1 | 0.8 |
| *king* | 1.4 | 0.6 | 0.3 | 2.6 |
| *pope* | 2.3 | 0.5 | 1.3 | 3.5 |

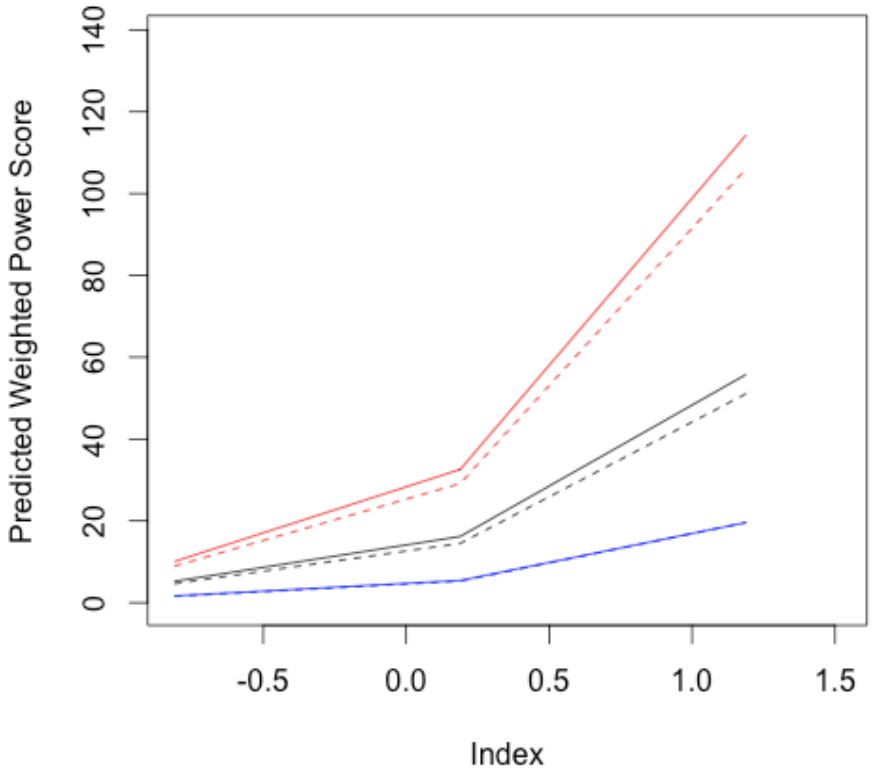
**Figure 4: Bayesian Model Findings and Credibility**




In an effort to examine the trends of these parameters further, I drew from the predictive posterior distribution to evaluate the predicted effect of being a king, a pope, and other, and allied with the French or Italians. A plot of these predictions is shown in Figure 4. The red lines are the predicted lines for popes, the black lines are the predicted lines for kings, and the blue lines are the predicted lines for the other positions. The solid lines are for actors allied with the Italians, and the dashed lines are for actors allied with the French. Again, note that this plot should be interpreted very carefully – for example, King Sigismund is the only actor with the king position and allied with the Italians, so the solid black line is extrapolated on King Sigismund alone, while Pope Benedict XIII is the only actor with the pope position allied with the French, so the dashed red line is extrapolated on Pope Benedict XIII alone. Although the

95% credible interval crossed 0, the plots indicate that the French allies are consistently predicted to have lower weighted power scores than Italian allies. The "other" position category has a lower predicted weighted power score than either popes or kings, despite the actor with the highest centrality index being an Archbishop, again emphasizing the distinction between in-network and out of network power derivations. The plot also indicates that the popes are expected to have a higher weighted power score than the kings, which is surprising in light of us knowing the true highest weighted power score is assigned to a King. In other words, according to this predictive distribution, an actor with King Sigismund's characteristics – a king, allied with the Italians, with his centrality index score – should only have a weighted power score of about 95, while actors with the popes' characteristics should be mentioned much more frequently than they actually are. King Sigismund's true weighted power value at 138, which historians attribute to saving the Catholic Church, was extraordinarily high.

**Figure 5: Posterior Predictive Distribution for positions and alliances**




Two major themes emerged from this analysis. First, the reconciliation of the differences between power as conceptualized from weighted mentions versus from network centrality is imprecise, especially for someone as powerful in one dimension as King Sigismund, is not straightforward. One proposal is that an actor has a certain amount of a prior power, and some of that power is derived from being part of the network (as measured by network centrality) and some of that power is derived from other sources, such as personal characteristics or land holdings or wealth. The weighted power score seems to have a positive relationship with network centrality, and as such could be seen as a measure for this a priori power, while the difference between the weighted power score and network centrality could be the power as derived from other sources.

Second, this plot also suggests that the Catholic Church survived the endogenous crisis due to lucky circumstances: a man, with unexpectedly large power, as evidenced by the posterior predictive distribution but also by King Sigismund's clear outlier status from Figure 1, was able to embed himself in the network for the Council of Constance and coerce and cajole the factions to a settlement. In more normal circumstances, perhaps, a pope would have been considered a more powerful actor, but, since the papacy was the very thing under contention, an outsider power had to step in. In many ways this is not a satisfactory result, not least because it lacks generalizability to other cases. Moreover, the Catholic Church does not seem to have had the general characteristic described by Greif and Laitin: while one actor dominated overall power, he did not dominate within network power, and power both within the network and overall power seems to be relatively unequally distributed. This findings, lends some final credence to Greif and Laitin's hypothesis about the role of a strong man in institutional adaptation, though perhaps the restrictions on the general network layout within the institution can be loosened. Further studies using other networks of institutions adapting to endogenous crises, ideally with larger sample sizes, could expand upon this conclusion.

## Conclusion

This thesis set out to examine two research questions, using the Council of Constance as a case study. First, it examined what was the social network's power hierarchy structure that allowed the institutional adaptation to the endogenous crisis, using Greif and Laitin's theoretical framework. Second, taking advantage that the Acts and Decrees of the Council are in Latin, this paper asked whether considering the syntax surrounding actors' names yields a more nuanced and accurate social network than simple name counting, the current predominant method of

social network construction.

The evidence for whether it is worthwhile to consider the syntax of names for the social network is mixed. The exponential random graph models suggest that the ties valued with the syntax weights have more explanatory power than the un-weighted ties, but the relationships in both networks are highly statistically significant. Weighting the mentions with syntax yields 44 more power differentials than the un-weighted mentions, though the changes seem to be in the periphery of the network and do not affect the measures of centrality. Overall, my analysis does not provide sufficient evidence to determine whether syntax matters, and most likely the answer to that question would depend on context. Part of this lack of influence from syntax could stem from the fact that the ability to exploit valued and directed ties when calculating network centrality is limited. As the field develops to better incorporate this more sophisticated data, this point should be revisited.

The evidence for supporting Greif and Laitin's theory is also mixed. In terms of overall power, as measured using the weighted mentions from the text, King Sigismund was much more powerful than any other actor. In terms of network power, King Sigismund had the highest value for only three of the six centrality measures that would indicate high power in the network. When modeling overall power as a function of network power and actor attributes, it is clear that King Sigismund had an extraordinarily large amount of power, suggesting that the emergence of King Sigismund given the Catholic Church's institutional structure was highly unusual. Based on these findings, one can assume that King Sigismund had enough network power to utilize his overall power, but he was not the sole powerful person from a network perspective. When considering the rest of the network, there seems to be little evidence of the largely equally powerful actors as suggested by the Venetian family structure. This is perhaps a finer grained

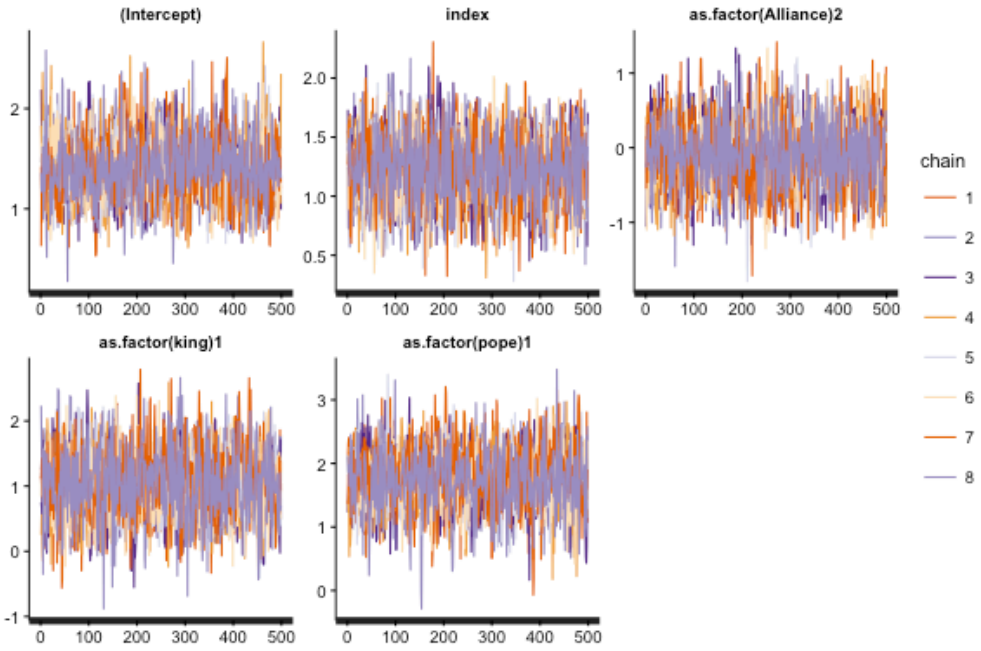
illustration of the network than provided by Greif and Laitin, but further analysis on other institutional networks is needed to confirm if this is the case.

These results could be strengthened in several ways. Substantively, the Council of Constance network could be compared to networks of other institutions undergoing an endogenous crisis and either successfully adapted, ideally from another era if documentation is available, or failed to adapt. As an example of failed adaptation, most of the same actors met in 1409 at the Council of Pisa to address the Papal Schism crisis. Historians argue that, since King Sigismund was still embroiled in his political battles in 1409, there was no single dominant figure in that Council, a possible reason for the failure; if the documentation was retrieved from the Vatican archives, it would be interesting to see if this qualitative account was supported quantitatively using my text mining and social networks approach. Methodologically, a larger sample size from the Council of Constance documents could yield a denser network of relationships or expand the variation in relative power, which should lend further support to the weighted network. As of now, powerful actors in the network are powerful simply because they are powerful. This tautology is unsatisfying, and could be another avenue for future research.

As a final note, this paper implies that an institution's structure does not necessarily dictate successful adaptation. Excluding King Sigismund, the Catholic Church clearly had an institutional structure more similar to Genoa than Venice. But, perhaps with a little bit of luck and most likely unintentionally, the Catholic Church was able to make an ad hoc structure to more closely resemble Venice with the addition of King Sigismund. This suggests that, with the right people and proper maneuvering, institutions can reposition themselves for successful adaptation to endogenous crises.

# Appendix 1: Bayesian Model Diagnostic Plots

## Figure 1: Markov Chain Convergence




## Figure 2: Interquartile Range Test

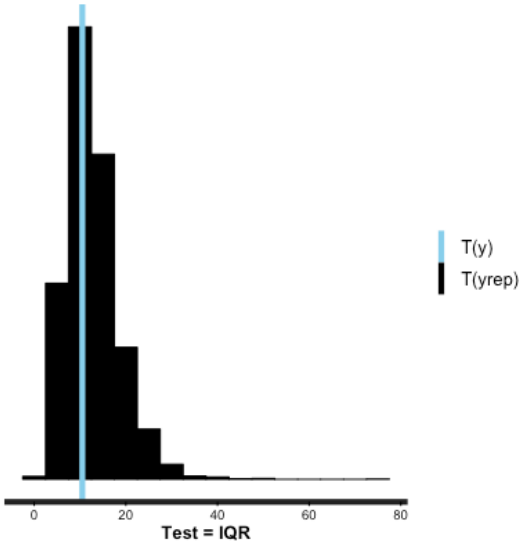


**Figure 3: Residuals from *yrep***

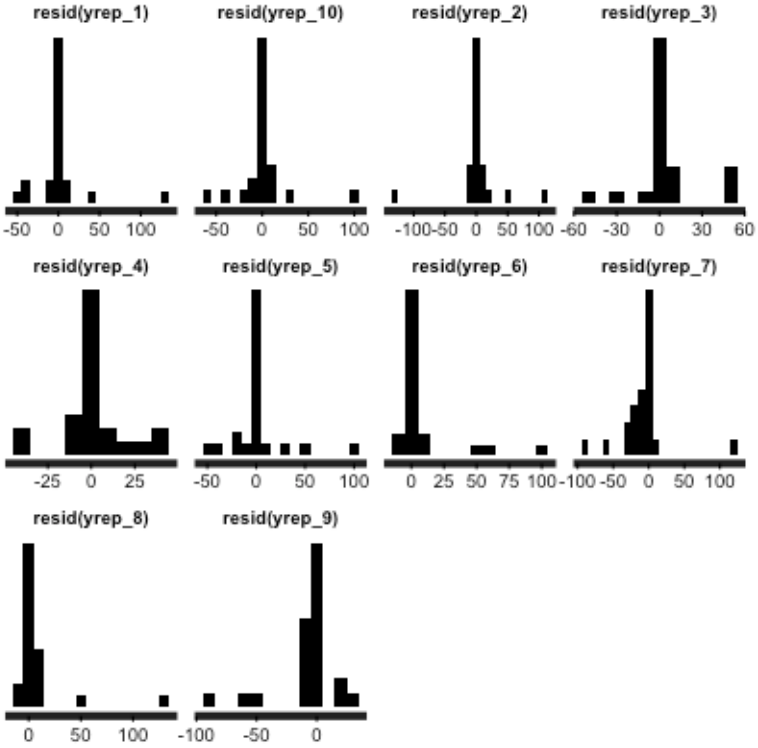
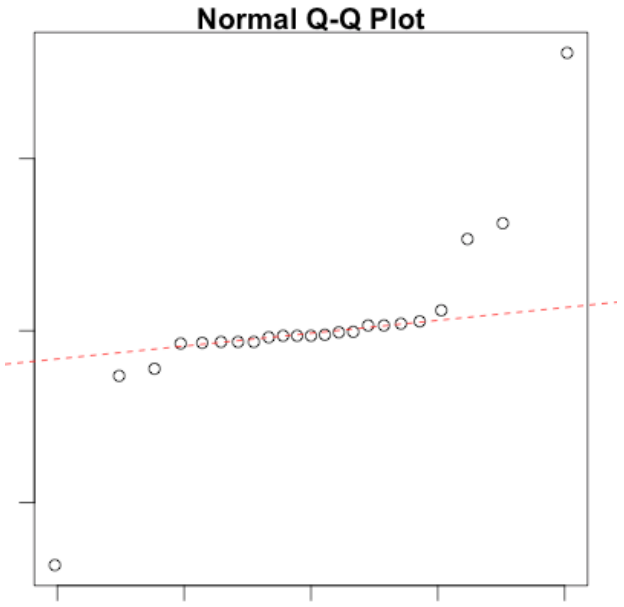



**Figure 4: QQ Plot for a Normal Prior**



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