Terrorist Networks

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Abstract

Various relationships in connection with terrorism have been analyzed. However, studies regarding extremist groups and their inner workings are relatively sparse. For that usage, the network theory seems to be an adequate extension to gather knowledge with which to counter terrorist actions. Tools, such as the centrality measures can be adapted to game theory in order to identify crucial players within a network. A governmental removal of the so-called *key player* results in maximal loss of a network's overall outcome. Beside a general discussion of terrorism, terrorist networks and policy implications, I discuss the removal of the key player of two different terrorists groupings, namely the al-Qaeda's 9/11 network and the Jemaah Islamiyah network on Bali. For each, the centrality measures seem to work reliably for a rather intuitive and new analysis. Further, attention to the timing of governmental interventions of a terrorist threat could increase the damage to a terrorist group in the short and long-term.

Contents

1 Introduction

In recent history terrorism has progressively been placed on a par with religious violence. For example, Jihadist terrorism is currently quite visible in the media, but originally terrorism is not necessarily in touch with religion. Terrorism can be simply defined as a *political* motivated expression of violence addressed a large audience. An exact definition of this phenomenon, which is almost as old as human history, is almost impossible, since terrorism has evolved throughout time. More than 100 diplomatic and scholarly definitions exist (Krueger and Maleckova, 2003). Within these definitions several characteristics are often fulfilled: The political angle of terrorism is fundamental and it is not expressed directly in politics, but via threats targeted at innocent objectives. The non-state character of terrorism makes the difference to a war and the political intention differs to that of a normal crime. Attacks are difficult to anticipate, because they can choose their targets at random (e.g., via car bombings), or more precise targets (e.g., assassination). All this maximizes the psychological effect of an attack. (Enders and Sandler, 1993; Cronin, 2003; Sandler and Enders, 2004).

The application of economic methods on terrorism started with Landes (1987) and has been applied using various types of models (Sandler and Enders, 2004). The violent interaction between both opponents, terrorists and governments, gives the background for strategic decisions in conflicts and has shaped counter terrorism (Jaeger et al., 2012). The threat of terrorism hasn't been solved yet, but counter terrorism could be improved to minimize terrorism. Besides a general view of terrorism and its prevention, I will discuss elements of *network studies* to extent the currently constricted knowledge of terrorist networks, to learn about organizations and how to fight them effectively. Network theory provides a wide range of meaningful tools and an adaption to conventional economic methods is partially possible. That means, network theory offers interesting tools and and is further able to form an idea of similar patterns within different network types.

I proceed as follows: In section two a general overview on terrorism will be given, to understand the main features of terrorism and the prevention of terrorism. Section three illustrates a methodic explanation and analysis of some of the literature on terrorist networks, and again, its implications on counter terrorism. In section four, my ideas on the topic will be discussed as an extension of the findings so far, with dedication to improving counter terrorism policies and to provide incentives for future research. Itemizing counter terrorism in each section should underline the methodical progresses due to different applications.

2 Status quo: Terrorism in Economic Literature

2.1 Traces of Terrorism

The skyjacking attacks of September 11, 2001 (hereafter: 9/11) in New York and Washington have been the most dramatic terrorist attacks in recent history, causing nearly 3000 fatalities. Consequently a wide public debate was initiated, especially on constructing effective prevention policies. The attacks mark a turning point in different ways, for example, increased recognition of terrorist attacks in the media (Rohner and Frey, 2007), within public attention and academic research. Through the unique dimensions of these attacks, they are often excluded from decoding general patterns of terrorism (Krueger and Laitin, 2008). Asking for reasons why people carry out terrorist acts has employed plenty of scientists from various fields and various opinions and theories exist. As we will see later, economists could rectify some false stereotypes. With certainty, researching on terrorism-issues should always be done carefully, especially in respect to the underlying data sources and their boundaries of interpretation.

2.1.1 Data

Research on terrorism can divide terrorist incidents roughly into *domestic* and *transnational*. Each distinction provides interesting insights. Identify studies as domestic or international depends on the conflict investigated and the subject of the investigation. Based on the incident venue, terrorism can be classified as *domestic*, if 1) the origin of a terrorist organization, 2) the origin of the victim(s) (the so-called *target country*), and 3) the place of incident (where the terrorist attack takes place) are similar. Examples for within-country terrorism in literature are, at least partly, "The Troubles" in Northern Ireland and the ETA-conflict in the Basque Country. In other words, domestic terrorism is home-grown and focuses on local issues (Siqueira and Sandler, 2010).

Otherwise, terrorism can be labelled as *transnational* in cases that the settlement of terrorists, the targeted country, and the place of the incident are not similar (Li, 2005; Siqueira and Sandler, 2010). One prominent example is the al-Qaeda terrorist network.

Rating data on country-level is especially interesting to compare worldwide, general patterns. An international perspective allows an interesting approach for investigations, but also has to be treated carefully, because by exceeding national borders, many new influences and therefore additional variables could make models tremendously more complex. Further, international terrorism doesn't represent the major fraction of all terrorist activities. According to the "MIPT" Terrorism Knowledge Base (2004) for the year 2003, only about 15% of all recorded terrorist incidents are international, whereas 85% are classified as domestic terrorism (Abadie, 2006). Krueger and Laitin (2008) investigate 781 significant terrorist events at country level during the period from 1997 to 2003 and show that 44% of all attacks are classified as domestic attacks. In 87% the country of incident and the origin

of the perpetrators are the same. In other words, there may be a tendency for perpetrators to target international objectives at home, such as the murder of Wall Street Journal reporter Daniel Pearl in February 2002 by militants in Pakistan or the suicide attacks on foreign housing in Riyadh, Saudi Arabia on May 13, 2003. Still, international terrorism is surely worth considering, because it causes more attention and visibility than domestic attacks (Abadie, 2006). Also, cross-national studies are attractive because of their potential to identify and reflect supply and demand behaviors (Krueger and Laitin, 2008).

Generally, using transnational or domestic data can lead to different results for one and the same parameter. Nevertheless, studies on both types of terrorism are meaningful, but their usage depends on the intended aim of research and the investigated determinants. Subsequently, the causations and consequences of terrorism should be discussed.

2.1.2 Causations

Poverty

For a long time poverty had been assumed to act as a catalyst for terrorism. Poor economic conditions were supposed to increase the likelihood of political revolts, including terrorist actions. The former US President George W. Bush supported this view in a speech in 2002 (Krueger and Maleckova, 2003; Abadie, 2006). On the other side, a leader of the Hamas claimed that some of their suicide bombers came from rich families (Hassan, 2001). Recent empirical studies rather support the second idea.

To investigate the effects of poverty on terrorism, Krueger and Maleckova (2003) analyzed biographical information of 129 martyrs of Hezbollah's military wing (Al-Muqawama Al-Islamiya) from 1982 to 1994.[1] Eli Hurvitz of the Tel Aviv University extracted this information from Hezbollah's weekly newspaper, called "Al-Ahd". They compared biographical information about terrorists, such as age, poverty status and level of education with the "Lebanese Population and Housing Survey" (PHS) that collected information regarding 287,204 individuals. Their study shows a little, direct and positive connection between poverty and the participation in terrorism.[2] Further, in the Israeli–Palestinian conflict between the late 1980s and May 2002, Berrebi (2007) categorizes 31% of the civil Palestinian population as poor. Contrary, only 16% of terrorists from Hamas and the Palestinian Islamic Jihad (hereafter: PIJ) are poor.[3] That suggests that it is not poor, but financially

[1] The Lebanese Hezbollah supported radical groups, like the Palestinian Islamic Jihad, in their campaign against Israelites (Priest and Farah, 2002).

[2] The wealth status of terrorists is derived by information of the biographies revealing personal data (e.g., the family is rich) and seems more to be measured heuristically.

[3] There are three Palestinian main fractions struggling against Israel: 1) Fatah, which includes other groups, such as the Al-Aqsa Martyr Brigade, 2) Hamas and 3) Palestinian Islamic Jihad. Fatah was founded in 1959 and has been the controlling-group in the Palestinian national movement (first in the Palestinian Liberation Organization (PLO) and after the 1993 Oslo Accords, in the Palestinian National Authority). As major group, Fatah was the first negotiator with the Israeli government. Hamas and PIJ are rather fanatic and Hamas expanded their range of involvement since the 2006 Palestinian Legislative Council elections (Jaeger and Paserman, 2006).

privileged citizens who may be more susceptible to becoming terrorists.

Otherwise, Abadie (2006) examines the number of terrorist attacks and the per capita GDP (hereafter: GDP p.c.) on country level and comes to the conclusion, after adjusting geographic factors, that there is no significant association between the two variables. He is the first scientist who has attempted to measure terrorism by using data from an international risk agency, called the "World Market Research Center's Global Terrorism Index". The index rates the risk of terrorism in 186 countries. Further, the Human Development Index (hereafter: HDI) and inequality do not show a significant correlation with terrorism at conventional test levels. The HDI is a report size, that combines the logarithm of GPD p.c., years of schooling and life expectancy at birth (ul Haq, 1995, p. xii). Piazza (2006) and Krueger and Laitin (2008)[4] come to the same conclusion of no significant relationship between poverty and terrorism for countries with equal levels of civil liberties.

On the receiving end of terrorism, meaning the target countries, there is a positive association between GDP p.c. and being prone to attacks. The wealthier a country is, the more attractive it becomes as a target for terrorists (Abadie, 2006; Krueger and Laitin, 2008; Blomberg et al., 2004).

We can make note that the origin of terrorism is not clearly connected to the level of poverty. However, target countries become more attractive for terrorists the wealthier they become.

Education

Besides poverty, education is often analyzed for being connected to terrorism. Does a higher level of education cause more or less terrorist activity? For single cases it is well-known that terrorists enjoyed an above average education, also the al-Qaeda members of the 9/11 were all well-educated (Wilgoren, 2001). Berrebi (2007) finds a positive association between education and the membership in a terrorist organization (and further with becoming a suicide bomber). In general, 51% of Palestinian citizens completed at least high school education, with 15% doing some kind of higher education. Whereas almost all (96%) of the terrorists passed high school and 65% of them enjoyed higher education.

For this phenomenon of disproportionate levels of well-educated terrorists, Krueger and Maleckova (2003) give the following possible presumptions: Well-educated individuals have more desire for personal identification and they may be more likely to reflect about deficiencies in society. Further, potential terrorists could hope for a leadership position, after their deeds within the interests of the organization, and the relative pay advantage in a terrorist organization would be greater than in the legal labour sector. This explanation could be true, but seems to be counterintuitive. Education is supposed to be enlightening and high levels of education should confront people with the cruelty of terrorism rather than

[4] Additionally to the 781 international terrorist attacks, Krueger and Laitin (2008) now include 236 suicide attacks. Suicide attacks are meaningful, because of their clear character, whereas terrorism is often "mired in ambiguities".

encourage it. Crucial is the content of education. If schools are used as training camps or as base to provide fanatic content, the education provided could be biased (Krueger and Maleckova, 2003).

Another interesting point of view suggests that terrorist organizations choose their squad with respect to their qualifications. A highly-qualified individual is more reliable to carry out missions for the organization than a less skilled one (Krueger and Laitin, 2008). One qualitative evidence that terrorist groups select their members carefully by their skills is an al-Qaeda manual, found during a raid in Manchester by the Metropolitan Police (The United States Department of Justice).

We can make note that terrorism is rather positively related to education, but within an organization a diversity of qualifications still can exist. Since every single individual holds a specific function in a terrorist group, qualifications will be heterogenous and include foot soldiers as well as well-trained individuals (Krueger and Maleckova, 2003).

Democratic Level, Political Freedom and Civil Liberty

Summarizing democracy, political and civil aspects under one topic seems adequate, due to the interplay and redundancy of these parameters. Li (2005) presents two frequently discussed lines of argumentation within the literature, explaining how democracy could affect transnational terrorism activities. First, democratic rules allow and ensure a non-violent resolution of problems. Citizens instead choose a peaceful way of solution-making, rather than escaping in costly terrorist activities. Second, democracy encourages terrorism, because typical features of democracies, such as freedom of speech, movement and press stimulate terrorist activities by exploiting their liberalness. Treating democracy just as one unique variable could be misleading, since democracy embed further variables. Bueno de Mesquita and Dickson (2007) suggest there is no singular relation between the democratic level and terrorism, because several influences point in different directions and others interact with each other (possibly such as political freedom).

Abadie (2006) claims that the effects of political variables (also political freedom) on terrorism are generally non-linear, but for many countries the level of political rights is positively associated with a decline in terrorism (Krueger and Laitin, 2008). However, extremely low levels of political freedom cause negative effects on terrorism. For instance highly authoritarian countries[5] experience lower risks of terrorist assaults than some intermediate ranged countries (Collier et al., 2009). Authoritarian countries obviously control not only political decisions, but also suppress actions of dissidents. A great amplifier of terrorism is the media attention, but not necessarily in countries with limited freedom of speech and press. Whereas countries with intermediate levels are often in a phase of tran-

[5]Political Rights Index (PRI) is a measurement for political freedom in countries by the organization "Freedom House". Political freedom is scaled from 1-7 (low values represents high level of political rights). Highly authoritarian nations are measured with PRI =7, intermediate range of political rights are measured with PRI=4-6), http://www.freedomhouse.org/report/freedom-world/freedom-world-2012.

sition. These countries on their way to development may enjoy an economic upswing, but governmental structures are still weak and the political conditions fragile. Another factor contributing to the sensitivity of countries with intermediate levels of political rights could be that economic improvements may polarize people and produce domestic inequality. If a certain industry improves the aggregated welfare of a region, not all people will experience an upswing and could be more inclined to radicalize.

The influence of civil liberties on terrorism is a controversial topic within the literature. Krueger and Maleckova (2003) suggest civil liberties are more important than political freedom and greater levels of civil liberties are less prone to feeding international terrorism on average and vice versa. Whereas Enders and Sandler (2002) can't find a connection between civil liberties and terrorism.

Within countries on the receiving end of terrorism (the target countries) particular patterns are identifiable: Countries with lower levels of political rights seem less attractive to terrorist. Also nations with paucity of civil liberties are less fruitful as targets for terrorist groups (Krueger and Laitin, 2008).

More Parameters and Results

Further, not so popular parameters have been explored in connection with transnational terrorism and should be presented briefly.

For example linguistic fractionalization shows significant associations with terrorism. Also being married seems to spare citizens from risking their lives (Piazza, 2006). The country's size is positively related (Krueger and Laitin, 2008). Further, selected geographical specifications could attract terrorists more than others: So-called *failed states* are treated as hotbeds for terrorist activities. These regions or countries combine favorable features for terrorists. Failed states could bear risks, since they are considered by the international community as "sovereign". In these countries, governments are rather inconsequent, corrupt or may even actively support terrorist organizations. Furthermore, mountain locations (Afghanistan) or jungle locations (S.America) are good locations for terrorist facilities and allow space for training grounds and smuggling routes, which provides funding for terrorist organizations. Thus, terrorists could exploit the conditions of less-developed countries to prepare attacks in more developed locations (Abadie, 2006; Takeyh and Gvosdev, 2010; Zimmermann, 2011).

To summarize the causations of terrorism, the source of terrorism could be interpreted as a violent expression of political commitment, with participants from wealthy and well-educated backgrounds. Beside the existence of further parameters, these ones are at least key aspects in connection with terrorism (Piazza, 2006). Whereas disadvantageous economic factors do not seem to be a significant cause of terrorism.

2.1.3 Consequences

Several domestic occurrences are useful to gain insight into terrorists. Instead of scrutinizing *who* is prone to terrorism, now I would like to illustrate *how* terrorism affects societies by examining some of the economic and political consequences of prominent conflicts.

Terrorist attacks influence the quality of life and commerce in a conflict area. Abadie and Gardeazabal (2003) investigate the economic impact of the ETA terrorists in the Basque Country. ETA has been fighting to establish an independent Basque state since 1959. ETA's threat determines a negative effect of terrorism on GDP p.c. in the Basque Country, but not Spain in general. During a truce in the years 1998 and 1999, as the truce became credible, Basque stocks outperformed non-Basque stocks.

Conflicts' consequences do not necessarily stay local and can also impact adjacent regions. Besley and Mueller (2012) investigate "The Troubles", the struggle for Northern Ireland's constitutional status since the 1960s. The conflict has religious, political and military dimensions and has caused about 3500 deaths. Besley and Mueller (2012) suggest a negative relationship between house prices and violence (measured in number of fatalities). Real estate prices reflect the present and future appeal (and value) of living in an area. Furthermore, a high number of fatalities in a certain area, such as Belfast, cause a negative spillover effect on house prices in adjacent areas which have relatively less violence. This negative effect of neighboring violence on house prices could be explained by a decreasing attractiveness of housings close to a conflict. People fear that perhaps the neighboring conflict will shift or extend towards the other areas in future.

Beside economic consequences, terrorism is also able to affect political issues. I present two examples of Palestinian extremists' violence on the Israeli–Palestinian conflict concerning about the impact of terrorism on peace-making processes and on political goals: The first example of Kydd and Walter (2002) examines peace processes of combatants in civil wars from 1988 to 1998 and they discovered a higher fail-rate of the peace settlement after terrorist attacks.[6] This underlines possible non-military intentions of terrorists by applying strategies to exacerbate doubts on the targeted side. Further, the Palestinian-Israeli peace process is displayed from 1993 to 2001. During this period, six notable events (four signings of peace contracts and two elections) took place. Each event was escorted by exceptionally high numbers of terrorist attacks . In two cases the Israeli government suspended the negotiations. Unfortunately, the authors could not identify a general reason for why peace processes fail.[7] Nevertheless, they give possible intuitions as to why extremists succeed and moderate citizens return into a conflict situation, despite their preferences for a peaceful existence. Provocations of small fractions in society (such as terrorists) are seemly supported, if the level of mistrust among the targeted moderates is high. Or, if publics

[6] In 14 peace agreements only 25% were translated after terrorist attacks, whereas 60% without terrorist attacks.

[7] The authors idea is that a trust threshold exists, above which peace processes fail.

and the government are rather hard-liners and if the moderate opposition (from where an attack is originated) seems capable, but still not able to prevent attacks among own ranks. Weaker oppositions are rather excused for being incompetent in preventing terror, because of a lack of capability. Surely, the Palestinian-Israeli peace process is a specific example, further there could be other reasons why negotiations fail between two negotiators. The second example of Gould and Klor (2010) asks, if terrorism is an efficient tool for asserting political goals. During the period from 1988 to 2006,[8] the Israeli electorate experienced a move toward the political objectives of Palestinians, whereas Israelites tended to vote in favor of parties which supported Palestinian interests. The authors assume a response from changes in Israeli politics due to Palestinian terrorism. That could indicate that terrorists' actions are able to shift political behaviors of their opponents, at least to a certain degree. Generalizing these facts could imply that terrorists not only fosters pressure on an international level via the international community, but also on a domestic level (Hoffman, 2006; Gould and Klor, 2010).

After getting a basic understanding of what motivates terrorists in fighting such bloody struggles, I will now go on and discuss selected factors of terrorists' strategies and terrorism's prevention.

2.2 The Prevention of Terrorism

The prevention of terrorism should be mentioned briefly at this point. It is not the ambition of this thesis to summarize the complete existing literature. Highlighting approved literature should explain the general implications for the topic and should pave the way towards relevant issues later in this thesis

2.2.1 Purpose and Strategy of Terrorist Groups

Attacks of extremist groups are more than just acts of revenge or mindless expressions of violence. Despite the cruelty, terrorists' methods may be products of strategic plans.

A major purpose of terrorism is to radicalize the public by addressing wide audiences and in the best case, gaining support from them (Li, 2005). How far civilians tend to radicalize, depends (at least partly) on demographical circumstances. For instance, the Palestinians that experienced the outburst of the First Intifada in 1987 during their teenagers-years (here: 14-17 aged) are more likely to radicalize and support extremists than Palestinian contemporary witnesses of the Oslo Accordings in 1993 at the same age. An individual's radical preference a priori anticipates the individual's tendency towards extremists, if fatalities (killed by Israelites) among Palestinians occur (Jaeger et al., 2012). However, to achieve a radicalization of the public, terrorists carry out symbolic attacks on foreign property, such as embassies or international organizations (Krueger and Laitin, 2008). Also the magnitude tends to target on mass causalities. In the past, leftist-groups have especially

[8] During this period six parliamentary elections took place.

chosen to attack to extort a certain purpose, whereas nowadays fundamental groups tend to provoke rash countermeasures of governments to earn the sympathy of the public (Sandler and Enders, 2004). Today, terrorists prefer to carry out attacks in areas with higher densities of population and of press agencies, before or during events that attract media attention. Attacks serve as a specific form of communication in exchange with the rest of society. It is remarkable that initiating media attention in the Western World requires less fatalities than in developing Countries (Rohner and Frey, 2007). Terrorists are aware of the importance of media. In a letter in 2005 from al-Zawahiri (the current leader of al-Qaeda) to al-Zarqawi in Iraq, al-Zawahiri underlines the great importance of media, especially for gaining public support (Office of the Director of National Intelligence, 2005). Further, terrorism is issued against armies or army installations, that are considered by terrorist groups as "occupying" forces, like in Afghanistan, Bosnia, Jammu Kashmir, Kosovo, West Bank and Gaza Stripe (Krueger and Laitin, 2008).

Terrorists, possible sponsors and the opposing governments all have resources available and will allocate them in a way to maximize their utilities (Enders and Sandler, 1993). That would induce strategic decisions on both sides. Beginning with the recovery of potentially new members for extremist groupings, DeNardo (1985) spotted the "spur to mobilization" as one of the three purposes of terrorism. Bueno de Mesquita and Dickson (2007) consider how likely a terrorist provocation attract the support of moderate citizens. Governments and terrorists both struggle to gain support from society (Siqueira and Sandler, 2006). In the game-theoretic model of Bueno de Mesquita and Dickson (2007) terrorists provoke the government with attacks, intended to cause rash governmental counter measures. As mentioned, provoking the government is part of terrorists' methods with the goal to radicalize and convince publics. Thus, the chosen mode of counter-terrorism (hereafter: CT) is crucial, whether to discriminate the moderate population or not. Discriminated CT means that counterattacks are aimed at terrorists and the moderate population does not get harmed. This CT is more costly than indiscriminating CT and shrinks the rest resources for public welfare issues in a state (Siqueira and Sandler, 2006; Bueno de Mesquita and Dickson, 2007). Further, two types of governments exist, hard-liners and soft-liners. Active CT has ambiguous effects: On the one side, terrorists' capabilities become weaker. On the other side, less focus on public welfare worsens the economic situation, and hence, publics rather mobilize (rising levels of ideology of sympathizer) than participate in the normal economy. Both agents have different assets and make different decisions, meaning that balancing CT policies of governments is complex and both parties, government and terrorists, have to interact strategically.

Finally, terrorists have tools to articulate their interests and they are aware of their influence. But how can governments reply effectively to terrorism?

2.2.2 Counter-terrorism

Counter-terrorism is the governmental response to terrorists and can be roughly distinguished into *active* and *passive* (Enders and Sandler, 1993). CT is *active*, when a government intervenes directly against a certain terrorist group, such as the US-led "war on terrorism". Otherwise, CT is *passive*, when a government aims not directly on terrorists, but rather attempts to prevent future attacks, for instance, through installing bomb-detecting devices or metal detectors at airports.

Terrorists respond to these policies in different ways: Active CT could grieve terrorists even more, that they react strongly until their resources are depleted. Whereas through passive CT, terrorists rather change their attack mode, since prevention makes the original attack mode more costly. On May 16, 2012 in Berlin, the German Federal Criminal Agency "Bundeskriminalamt" arrested Maksud L., who is suspected to be an al-Qaeda member. The Federal Criminal Agency could secure 141 decrypted data files. A few of them were showcased.[9] The data was written by members of al-Qaeda's "Maktab al-Dawa" (office for propaganda). The al-Qaeda's authors propose the "Jihad at sea" for future operations. That means, terrorists should hijack a passenger ship (Musharbash, 2012). Since skyjackings are more complicated due to introduced secure arrangements after 9/11, and hence imply higher costs for terrorists, the al-Qaeda could now search for cheaper alternatives.[10] Both, skyjackings and ship-hijackings probably fulfill the same purpose for terrorists. In economic terms, we can title the change from one *attack mode* into a cheaper-, same purpose fulfilling one as *substitution*. Contrary, *complementary* attacks enhance themselves in their purpose. In other words, the combination of two complementary attack modes aggregates more basic commodities per attack mode than each attack mode for its own (Sandler and Enders, 2004). CT could induce a substitution into other types of attacks, if CT raises the price for a given attack mode. Thus, terrorists face increasing marginal costs for executing the original attack modes and will substitute towards less expensive attack modes.

Further, the time horizon of governmental interventions can be distinguished in short and long. A *short time horizon* considers the direct effect on terrorists' behavior due to governmental thwarts. Contrariwise, a *long time horizon* includes the consideration of the interplays of different attack modes.

However, antiterrorism can also push the number of future's actions (e.g., the US raid on Libya in April, 1986). The challenge for policy makers is to identify interrelations among the attack modes and then push terrorists to substitute into more harmless attacks modes. But, as long as operations appear randomly, an anticipation is difficult and a cost advantage is on the terrorists' side (Sandler and Enders, 2004). Avoiding externalities through combinations of complementary attack modes will be discussed later in connection

[9] On my request, the Federal Criminal Agency would not showcase all data, because of their high exclusivity for continuing investigations.

[10] This is an exemplary assumption and has not to reflect the reality.

with altering networks structures due to CT.

So far, CT just shifts problems from A to B. What seems more ambitious is a reduction of terrorism through a reduction of the causes. Since propaganda is a basic tool for terrorists, governments should make their policies credible and consistent, to gain citizens' trust. A high reliability is also a precondition for a possible bargaining with terrorists (Lapan and Sandler, 1988; Jaeger and Paserman, 2006). Rather domestic conflicts, like with the Irish Republican Army in Northern Ireland or the ETA in the Basque Country, demonstrate that bargaining (or introducing a peace process) could largely appease conflicts.

3 Terrorist Networks

Hitherto, literature assumed terrorist organizations as a monolithic, static entity. No specific assumptions about an organization's structure has been made. Considering terrorism by its structure occurs to be a more recent and promising approach. It is important to understand network structures, because terrorists can actively use their networks, almost as ordinary as all the world does. Networks serve terrorists to plan attacks, recruit new candidates, acquire and exchange knowledge (e.g., techniques to build bombs) and to organize fundings and trainings (Mifflin et al., 2006).

Network studies introduce dynamics (Carpenter et al., 2002) for countering terrorism and an anticipation of terrorists reactions may be more adequate. The extent to which structures are exogenous or affected by particular circumstances depends on each individual covert organization, and is probably best examined from case to case (Enders and Sandler, 1993). Network studies provide new means of studying terrorist networks, which allows for a more general consideration.

After a basic introduction into network theory, I will continue to focus on the economic literature of terrorist networks and subsequently skim network theory for terrorist networks.

3.1 A basic Introduction to Network Theory

Nodes and Links

Networks are represented by a *set of nodes*, $N = \{1, ..., n\}$ (Jackson, 2008, p. 20).[11] In network literature the size of the set of nodes N is often fixed. Here, the size of the set of nodes should be flexible (e.g., if CT removes an terrorist).[12] A Relationship for direct

[11] Synonymous with nodes: vertices, individuals, agents and players. In the case of terrorist networks, a node normally is equal to a single terrorist or a terrorist cell. Networks studies supply several methods to group equivalent nodes into different *community structures*. A community structure Π is part of the network N (Jackson, 2008, p. 443-446). Here, I take communities (or cells) as exogenously given, because in case of terrorism, media normally differs between the terrorists' geographical residence (e.g., the Al Qaeda cell in London). A geographical division of terrorist organizations seems plausible to track terrorists traces (c.f., The Economist (2012)).

[12] Network theory on the removal of nodes seems to be briefly. Related to the removal of a node is the secede of the network (for cooperative games) concerning about the allocation and maximization of the

communication is represented by a line between two nodes and is commonly called *a link*.[13] Creating a link requires the consent of both parties involved, but severance can be done unilaterally (Jackson and Wolinsky, 1996). A link can be *directed* or *undirected*. A relation g_{ij} between node i and j is directed , if $g_{ij} \neq g_{ji}$ is possible and communication goes just in one direction. On the other side a relation is undirected, if $g_{ij} = g_{ji}$ is possible. In case of terrorists, there may be some foot-soldiers who just receive commands from higher-ranked members of the group. But since feedback about the local situation could be important to higher-ranked members, I assume undirected network relations. Deciding for one or two-sided relations has basic implications for the modeling of a network.

Describing Graphs

A network can be described with a graph (N, g) consisting the set of nodes N, and a real-value $n \times n$ matrix g. The latter is often and also here an *adjacency matrix* that shows which are neighboring nodes. In case where the intensity of links differ and can take more values than 1 and 0 (connected or not) the graph can be denoted as *weighted* graph. Otherwise, it is standard to mention the existence of a link, but not its strength. Then a graph is *unweighted* and $g_{ij} \in \{0, 1\}$ (Jackson, 2008, 21-22). These notions are illustrated by the following example, a graph (N, g) with $N = \{1, 2, 3, 4\}$ and

$$g = \begin{pmatrix} 0 & 1 & 1 & 1 \\ 1 & 0 & 1 & 0 \\ 1 & 1 & 0 & 0 \\ 1 & 0 & 0 & 0 \end{pmatrix}$$

The network is pictured in FIGURE 3.1.[14] Assuming $g_{ii} = 0$, thus the values on the main diagonal are always zero. All nodes are able to reach each other via path components (i.e., network is *connected*). To explain what a path is, we need first to know that a *walk* is a sequence of links. A *path* is walk, that contains every node maximally once (here: e.g., $4 - 1 - 2 - 3-$), whereas a *cycle* (or *circle*) has the same start and end node (here: e.g., $1 - 2 - 3 - 1$) (Jackson, 2008, p. 24-26, 28).

society's value among its members (Jackson, 2008, p. 415-416).

[13] Synonymous with links: edges or ties.

[14] All Figures in this thesis are drawn with the application NETDRAW, an embedded tool of the social network analysis application UCINET.

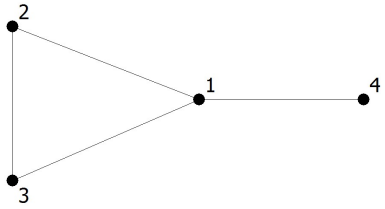

FIGURE 3.1 An undirected network with four nodes and four links

Number of Links and Network Density

Now we consider a network as a whole by its *density* that measures how-well the network is connected (i.e., number of links n), relative to the maximal number of links (Farley, 2003). The maximal number of links that connects all nodes with each other is $N(N-1)/2$. So, the density can be described as:

$$\rho = \frac{n}{N(N-1)/2}, \in [0,1]$$

(Enders and Su, 2007).[15] As long as the network is possibly connected, at least $N-1$ paths must exist, thus $\rho \in [2/N, 1]$. Otherwise the networks breaks in different subgroups for $\rho \in [0, 2/N]$ (Enders and Su, 2007; Jackson, 2008). In section 3.2 I will introduce a notion to describe the "relative density of a single node" in a network, called *degree centrality*. In the following chapters, additional notions and tools from network theory will be introduced.

3.2 Terrorist Networks and Economic Theory

3.2.1 Central Issues

Trade-off: Density versus Security in Networks

Criminal networks, and thereby also terrorist networks, differ explicitly from regular social networks due to the level of observability. Structures are widely covert, their members communicate secretly and are ambitious to maintain this secrecy. This distinction to normal social networks requires different approaches to terrorist networks which implies new challenges. Illegal organizations face a trade-off between internal coordination and external vulnerability (Calvo-Armengol and Moreno de Barreda, 2005). A high density enables high information flows, but on the other side the group's security shrinks and makes the clandestine network more visible and vulnerable towards authorities. The better a network is connected (by more links between the nodes), the higher the risk of getting detected and being shattered by the governmental opponents. Higher levels of density are desirable, because better linked networks function more effectively when the members trust each other.

[15] There is also an alternative way to derive the density via the average degree (degree: number of links per node) divided by $n-1$ (Jackson, 2008, p. 29).

Sharing information, like knowledge and ideologies, generates trust and cohesion among like-minded actors (Baccara and Bar-Isaac, 2008). Further, a better effectiveness allows groups to perform in more logistically complex attacks, such as simultaneous actions in different places or on different target objects. A higher density is probably supported by the development of new, hardly controllable technologies (like the internet) without restricting the levels of security (Enders and Su, 2007). But generally, a higher density causes a loss of security, and vice versa, less density implies more protection from getting detected. For instance, Intelligence services will be more attentive and informed, if a high communication traffic in a suspicious network exists.

You could extend this idea, by arguing that centrality (the relative importance of a certain node) has similar, or even stronger effects on security than density has. Because intelligence services will rather be able to concentrate on certain links between two players than on the complete network, since the boundaries of terrorist networks are not clearly drawn.

Topology and Strength of Ties

The level of density is likely to be influenced by the topology of a network (e.g., a connected tree structure has to have exactly $n-1$ links (Jackson, 2008, p. 27)). In other words, how the network is arranged could give indications of its density. Different types of network arrangements lead to varying effects, also for security patterns. Basic networks structures are the *tree*, *forest*, *star* or *circle*. A *tree* is a network without containing cycles and a *forest* can be described as a collection of trees. A *star* includes one node i that is involved in every link, i is called the *center* of the star (Jackson, 2008, p. 26). Further, a *chain* is a concatenation of n nodes, connected by $n-1$ links.

Now, according to Enders and Su (2007) I compare 1) a chain and 2) a star structure. The number of nodes should be fixed to five and the number of links to four, to permit equal conditions and equal levels of density.

1) Chain: one possible chain structure is (N, g) with $N = \{1, 2, 3, 4, 5\}$ and

$$g_c = \begin{pmatrix} 0 & 1 & 0 & 0 & 0 \\ 1 & 0 & 1 & 0 & 0 \\ 0 & 1 & 0 & 1 & 0 \\ 0 & 0 & 1 & 0 & 1 \\ 0 & 0 & 0 & 1 & 0 \end{pmatrix}$$

is rather arranged decentrally and seems to be rather secure, see FIGURE 3.2. The removal of one link (which could also be the leader of the network) splits the network into two separate networks, but remaining nodes are still able to communicate largely. Further, the number of links per node are relatively balanced (except the start and end nodes). In simplified style of a 'real-world' example, the Al-Aqsa Martyr Brigade (hereafter: AAMP)

could be considered. AAMP poses the military wing of Fatah in the Israeli-Palestinian conflict on Palestinian extremists' side. AAMP's structure is fairly decentralized (Jaeger and Paserman, 2006).

2) Star: one possible star structure is (N, g) with $N = \{1, 2, 3, 4, 5\}$ and

$$g_s = \begin{pmatrix} 0 & 1 & 1 & 1 & 1 \\ 1 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 \end{pmatrix}$$

a rather central arranged topology with the center node $i_{center} = 1$, c.f., FIGURE 3.3. A star structure is more likely to deal simultaneously with all players and logistical mistakes may be less likely than in a chain network. But a removal of the central player separates all other players from each other. In section 3.2 I will give exact implications for the disposition of a certain node. Here, it can be assumed that the center tends to be detected first, because of its strong connectivity (Enders and Su, 2007).[16] A 'real-world' example therefore would be the early Hamas, a well-organized Palestinian fraction with a centralized command-structure (Jaeger and Paserman, 2006).

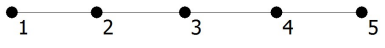

FIGURE 3.2 A chain network

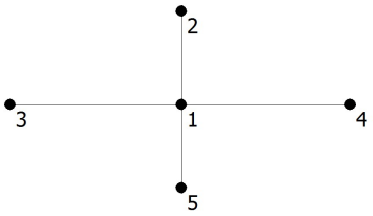

FIGURE 3.3 A star network

Now, the assumption of same levels of density for chain and star structures should be revoked and the following assumption imputed: If a terrorist organization prefers a centralized topology, the relative importance of coordination is greater than security issues (the opposite case for decentralized networks). Further, deciding on a certain topology generates preferences for the attack mode.[17]

A terrorist organization that prefers a centralized structure may focus on achieving network externalities. Terrorists will set their effort levels to maximize the expected net welfare. The optimal level of effort is well-coordinated by the central player (e.g., the center). High information flows allow individual effort-levels below the network's optimum,

[16] Unlike Enders and Su (2007) I have not introduced hierarchy jet, because there is no general need to do so.

[17] Simultaneous attacks, such as as the 9/11 attacks or embassy bombings in Kenya and Tanzania may prefer a centralized structure, whereas random suicide attacks need less coordination and prefer a decentralized, more resistant arrangement of the network's structure.

because each player receives utility from the rest of the players. But a centralized structure compromises a high density, and hence, high infiltration risks through the government.

On the other side, a decentralized or "loosely connected" network may have higher preferences for the group's security (Siqueira and Sandler, 2010). They are more resistant to external impacts, but at the same time network externalities are lower. Networks externalities are lower, because less coordination induces less interplays among players and individuals select their effort levels separately. Thus, an internalization of network effects is avoided. Thereby, individual decisions may lead to suboptimal outcomes for the complete network, and hence, the overall utility of the network is not maximized (Enders and Jindapon, 2009). According to terrorists, *decentralized* can be interpreted as different *cells* (local groups, e.g., Al Qaeda is shaped by internationally fragmented cells) acting mostly independent from each other (Baccara and Bar-Isaac, 2008) and responsibilities are delegated on a local level. A lack of coordination could entail free-riding behaviors of single members (or subgroups) among a network. I do not accurately point out issues on free riding, but rather assume that the effort level of each player is given by the local circumstances. Local coordination could result in distorting the radical-levels among a complete group. If players are more committed, radicalization will stabilize across the group. Otherwise, if the views of local campaigns are strong and do not necessarily support the agenda of the overall network, radicality-levels will diverge. An irresolute terrorist group could be less cogent in providing their goals and in bargaining with officials.[18] Conflicting interest among a group could also induce less sympathies and support from the public. This point should be clarified by an example: in Jordan, in 2005, three suicide attacks on hotels were executed by the al-Qaeda of Iraq. Among the victims were also Islamists, as provocation due to disagreements between Islamic fractions. Thus, the local support for al-Qaeda turned away towards the US-led coalition forces (Siqueira and Sandler, 2010).

Hierarchy

Hierarchy should just be discussed briefly, since its existence is not compelling for all networks types (e.g., hierarchy exists in tree-shaped network, but not in a cycle). The definitions of hierarchy vary, such as in general-daily-use it describes a ranked command structure. Whereas hierarchy according to the literature on terrorism insinuates no command structure. Hierarchy rather could be described inter alia as an ordered set (Farley, 2003) or simply as upside-down relation with different stages (Radner, 1993). The presence of different stages in a network could suggest a desired protection of the leader on top-level by minimizing his or her reachability (Enders and Su, 2007). Contrary, examples in the past exist, where leading members do not just act in the background, but also plan or even execute attacks themselves, for instance the Bader-Meinhof gang of the Red Army Fraction in the 1970s in Germany or Ahmad Sa'dat of the Popular Front of the Liberation

[18] For bargaining of governments with terrorists, see Lapan and Sandler (1988).

of Palestine. Here, members at the top of the organization hold functions throughout the complete hierarchical ladder (Enders and Jindapon, 2009). Arquilla et al. (1999) suggest a general flattening of terrorist groups' hierarchies, due to technological progress during the last decades (e.g., Middle East terrorism has visibly been moving towards a networking of organization).

Flat hierarchies necessitate decentralization that changes the distribution of authority (as discussed above).[19] Responsibilities and decision-making are highly decentralized and each sub-entity can act independently (Calvo-Armengol and Moreno de Barreda, 2005).

The factors discussed in this section should enlighten some of the implications for CT policies.

3.2.2 Implications for Counter-terrorism Policies

Terrorist groups signal via their network structures which preferences they set, regarding information flows and security patterns (if historical developments, etc. are not considered). Further, an interplay between CT and the structure of a terrorist organization may exist (Enders and Su, 2007). To assure a certain security level, the organization reacts by reducing the network's density, in response to increasing CT, and vice versa. A lower density allows for alterations in the network's structure.[20] The lower a network's density is, the looser the network's structure (i.e., decentralized). Attack modes which require high levels of density and coordination seem less attractive to terrorists, since infiltration increases the costs to maintain a constant density (Baccara and Bar-Isaac, 2008).[21] Loosening the network's structure results in a substitution towards less-complex attack modes, because of an increase of marginal costs of density-demanding attack modes. As described above, decentralization could lead to a loss of efficiency, due to less coordination among the network players. But less complex attacks modes do not necessarily have less impacts (e.g., fatalities). Further, terrorists grievances won't decline because of infiltration.

To summarize, infiltration policies are able reduce the network's density. This alters the network's topology and forces terrorists to substitute into less complex attack modes. More decentralization leads to diminishing network effects and thus increases the individual effort levels of terrorists (by assuming an achieved constant aggregate utility). CT is able to influence the price for an attack mode (Enders and Su, 2007) and terrorists have to decide, if they would rather accept the higher costs of density or losses of network effects. A centralized structure (e.g., star topology) chosen by an organization is related to high

[19] For future research there could be some relevant works for terrorist-issues in organization theory that also deals with hierarchies, e.g., Radner (1992, 1993), van Zandt (1999) or Maskin et al (2000): The latter investigates two models, which differ in the hierarchical order of functional and geographical division.

[20] E.g., Hamas responds to Israeli crackdown targeted to Hamas. Therethrough many leaders of the military wing of Hamas were arrested (i.e., removed) and as response, Hamas changed its hierarchical, centralized structure towards a rather compartmented one. That enables Hamas to operate more covert among its divisions.

[21] Costs, caused by a high density could be interpreted as opportunity costs for terrorists, by increasing the vulnerability of the network, e.g., loosing a collaborator, i.e. human capital.

levels of coordination but is also prone to CT. So, decentralized structures seem to be less vulnerable to CT efforts than centralized ones, but the lack of overall coordination may also lead to deficits in terms of promoting overall group goals (Siqueira and Sandler, 2010).

If one assumes that the aforementioned levels of equal levels of density in centralized and decentralized topologies are true; decentralized organizations are more resilient to CT measures, because they are more flexible and adaptive than classical structures. If a cell (sub-entity of the network) is destroyed, other cells within the network are still able to function (Baccara and Bar-Isaac, 2008; Calvo-Armengol and Moreno de Barreda, 2005). A rather balanced allocation of links among the nodes makes future investigations for authorities more difficult.

With regards to decentralized networks, the structure of certain cells is worth considering. Baccara and Bar-Isaac (2008) apply infinitely repeated multi-person prisoners' dilemma with focus on information, to test the trade-off between enhancing internal information and increasing external vulnerability through governmental detection. They found that binary cells, meaning cells containing two terrorists, seem to be fairly robust against different kinds of detection.[22] Hence, terrorists could fix the size of sub-entities to two members, to ensure optimal levels of security, and still keep intensive communication inside a cell (two terrorists could share a flat or take flight lessons together).

In the following sections and for the purpose of this thesis in general, further relevant literature regarding network theory will be consulted. An understanding of the implications of this theory on terrorist networks is desired and the knowledge gained so far should be further expanded by doing so.

3.3 Lessons to learn from Network Theory

Network theory is an interdisciplinary field and not just operated by economists, but also by fields like sociology, computer science, biology and physics, just to mention a few. This section will discuss relevant network literature regarding terrorist networks in order to contextualize it. This analysis makes no claim to be complete, rather the ambition is to provide a basic introduction to the relevant topics for terrorist networks. Network studies offer a vast range of tools to characterize networks from various perspectives, which can be distinguished as following. First, the *macro perspective* describe networks by generally looking at nodes and links to allow statements about how the network is shaped, such as I did above in section 3.1. Second, the *micro perspective* focuses on how nodes and links interplay with each other, such as stability patterns, allocation and centrality (Jackson, 2008).

[22] Baccara and Bar-Isaac (2008) differ between agent-based detection, where a detection of a terrorist is independent from his activity and cooperation-based detection, where detection depends on a terrorists activity.

3.3.1 Central Issues

Introducing aspects

"Normal" social networks differ from terrorist networks for different reasons, also based on their high level of secrecy. For instance, network theory normally sets costs of information-exchange (to access information). Communication is costly and implies a trade-off between obtained benefits and additional costs of a link (Jackson and Wolinsky, 1996). Participating in a network is not compelling, since a lack of knowledge can lead to exclude an individual (Cowan and Jonard, 2004). Whereas terrorist networks underly non-market aspects and price mechanisms for communication are not assumed as normal (Cabrales et al., 2011). As discussed above, secret networks have their own mechanisms and trade-offs to protect themselves. A lack of knowledge is not necessarily a reason to exclude an agent, but may be intended by leaders (e.g., a foot-soldier does not know the complete network's structure, hence, in case of detection he won't be able to tell any details).

A lower involvement of certain members could further foster recruitment opportunities. Patacchinia and Zenou (2008) suggest that the transition from non-crime to crime rises with increasing percentage of weak ties.[23] Their study focuses on petty crimes committed by teenagers in the US. Nevertheless the argumentation seems reasonable to make a connection to terrorism. Namely, weak ties among criminals do not facilitate a separation into criminals and non-criminals among a society, but supports the contact of individuals of a criminal network with individuals outside the network. If terrorists participate in daily-life (beside their criminal involvement), they are rather committed with non-terrorists and may gain new followers more easily for their terrorist goals.

Beside inter-relations across network boundaries, the relations inside the networks are relevant (Bala and Goyal, 1998). A typical way to quantify inner-relations and the importance of a network's single players are the centrality measures.

Centrality

Centrality ranks players of a network by their importance. Many different centrality variants have been developed and their application depends on the type of data and the investigated purpose. Four major types can be distinguished (Lindelauf et al., 2011; Jackson, 2008, p. 37-38):

1. Degree centrality
2. Closeness centrality
3. Betweenness centrality
4. Bonacich centrality (or broadly, inter-centrality)

[23] *The strength of ties*: The link between two nodes can be rather characterized as acquaintance (weak tie) or as friends (strong tie) (Patacchinia and Zenou, 2008).

1. Degree centrality is the simplest of the centrality measures and shows how well a node is connected (Jackson, 2008, p. 38-39). The degree of node i, $d_i(g)$ is the number of links which a nodes is involved in. In other words, the degree is the sum of all direct connections of a node with its neighbors. Degree centrality is defined by:

$$C_{degree}(i) = \frac{d_i(g)}{\mid n \mid -1},$$

with $n \neq 1$. Note that $0 \leq C_{degree}(i) \leq 1$.[24] Because this measure is so simple, imprecise interpretations can be made and interesting aspects are missing, e.g., where in the network is the node located.

2. Closeness centrality tracks how close a node is to any other node in the network. One measure of closeness centrality is the inverse of the average distance between a node i and any other node j, where $l_{(i,j)}$ denotes the shortest distance between two nodes (so-called *Valente-Foreman method*) (Borgatti et al., 2002). The Closeness centrality of i is:

$$C_i^{close}(g) = \frac{\mid n \mid -1}{\sum_{j \neq j} l(i,j)},$$

in the range $0 \leq C_i^{close}(g) \leq 1$. Just to mention, there are further ways to consider closeness (Lindelauf et al., 2011; Jackson, 2008, p. 39).

3. Betweenness centrality measures how well a node is situated, according to the paths that it lies on. The higher a node's importance, the more it enables information flow between other nodes (Lindelauf et al., 2011). Before denoting betweenness, it should be explained, what geodesic is. Geodesic is the shortest path between node i and j. $P_i(kj)$ describes the number of geodesics between k and j lying on i. $P(kj)$ is the total number of geodesic between nodes k and j. Thus, the ratio $P_i(kj)/P(kj)$ shows how important i is for connecting k and j on the shortest way. The betweenness centrality of node i is:

$$C_i^{between}(g) = \sum_{k \neq j : i \notin \{k,j\}} \frac{P_i(kj)/P(kj)}{(n-1)(n-2)/2},$$

in the range $0 \leq C_i^{between}(g) \leq 1$ (Lindelauf et al., 2011; Jackson, 2008, p. 33, 39).

Centralities 1 - 3 are purely geometric. A fourth category offers different tools and interactions with game theory. For example Lindelauf et al. (2011) apply game theory, based on the terrorist network structure and on additional, qualitative information about terrorists and their relationships, to track important terrorists. I will focus on the following rather prominent and general approach: Seeley (1949), Katz (1953) and Bonacich (1972) pave the way for Bonacich (1987) to develop a more intricate, but still elegant measure, commonly known as the *Bonacich centrality* Jackson (2008, p. 40).

[24] $C_{degree}(i) = 0$ is equivalent to an isolated node; $C_{degree}(i) = 1$ is equivalent to an fully connected node with $n-1$ links (assuming that $g_{ii} = 0$) .

4. Bonacich centrality, as a function $C^B(g, a, b)$[25] captures a node not just directly by its degree, but also by its *importance*[26] with respect to its neighbors. Using Bonacich is instructive for a node's proximity towards other important nodes. The idea is applied e.g., for citation rankings and the Google page ranking (Calvo-Armengol and Moreno de Barreda, 2005; Jackson, 2008, p. 40). The exogenous parameter b captures the importance of a node's indirect connections. A positive $b - value$ gives weight to a node that is connected to important nodes, analogously a negative $b - value$ gives weight to a node that is connected to unimportant nodes. Larger $\mid b \mid -values$ give greater weight to a node's distanced connections (e.g., two indirectly connected nodes via other nodes), and lower $\mid b \mid -values$ give greater weight to a node's closer (e.g., neighboring nodes) connections. (Analytictech, 2002; Jackson, 2008, p. 40 - 42).

Correspondingly, a node's inter-centrality can be taken as a player's activity level that depends on how active its neighbors are. Implementing this into a game theoretic environment, it is possible to say that a player's activity generates his or her payoff (by using a model for peer networks, e.g., like (Calvo-Armengol and Moreno de Barreda, 2005)) (Jackson, 2008, p. 291-292). Thus, centrality is linked to an optimization problem and equilibrium-levels can be identified.

Now, we are prepared to consider the implications of centrality for terrorism. Ballester et al. (2006) suggest the removal of the node with the highest Bonacich centrality in a network, is called the *key player*. The idea behind it is to harm the networks aggregated activity maximally. The key player has the highest optimal inter-centrality, but is not necessarily the player with the highest individual equilibrium outcome. However, there is a relation between the individual equilibrium outcome and the player's position in the network. The rising level of local interactions (in the means of density and size of a player's local interaction) is positively related to the aggregate equilibrium outcome. One could argue that a removal of the key player is not optimal, because there maybe players with higher single outcomes. This perspective is unilateral, while concerning the complete network and its aggregate outcome, removing the key player shrinks the overall outcome most. First, there is a direct effect on outcome, because less players contribute to the aggregate activity level. Second, an indirect effect which modifies the network's topology, and hence, players may tend to adopt other actions. In other words, a key player's direct effect on aggregate outcome might not be maximal, but the total influences can be taken as optimal.

Ballester et al. (2004) apply this approach to criminal networks. The equilibrium individual effect levels are proportional to the applied centrality measure of each criminal. Thus, strategic behavior (level of effort) of each player is related to the network's topology. Holding another position in the network entails to exert different crime effort of the single player. The proportionality between the contribution of each player to the aggregate

[25] g determines as normally the network's matrix, a captures a base value on each node.

[26] Importance means: with whom the neighbor is connected, i.e., the degree of the neighbor's neighbor and so on.

outcome and the centrality level describe a basic distinction to standard peer effects. Peer effects normally contribute intra-group externalities homogeneously.

Using centrality measures creates a preferable situation. The planner need not know every link, only the ranking of single players among the others. That is a great advantage for covert networks and their indistinct boundaries. Deficiencies of information about the network's structure (that is a great challenge of terrorist networks) getting partly relieved. Further, applying centrality allows a generalization of different network topologies. Statements can be made rather related to centrality, because different networks can lead to similar implications (for CT). The approach of the key player can be expanded to the key group, but won't find attention to any later point in thesis thesis.[27]

Removing the Key Player

To illustrate the actual effect of removing the key player, Calvo-Armengol and Zenou (2004) apply a general peers networks model to the al-Qaeda network of 9/11. Unlike most models, which take peer effects as homogenous for all players, the authors describe intra-group interactions exactly as a collection of all bilateral influences in the network. The so-called *Bonacich-Nash linkage* associates each player's equilibrium activity (by taking choices of the other's as given) to his position in the network. Subsequently, the intra-group structure is used to map the peer effects across all players. Thus, peer effects vary across the set of players, and hence, an identification of the optimal targets in the network is possible. As described above, the aim is to weaken the network maximally.

The al-Qaeda's 9/11 network pictured in FIGURE 3.4 consists of 19 terrorists, divided in four sub-entities, according to the airplanes they operated on. These 19 hijackers are connected by only 27 links. Thus the networks density is $\rho_0 = 0.1579$ with a *average path length* of 4.75 nodes. That implies the network protected its security by having a low density. A average path length of 4.75 for 19 nodes seems relatively much and indicates a distributed decentralized network.[28]

One week before 9/11, the network was strengthened with six additional links. These *shortcuts* were introduced for last-minute coordinations and increased the density by 18.49%, whereas the average path length declined by 40%. A removal of the key player with the highest inter-centrality, here Nawaf Alhazmi, achieves the highest decline of the group's output, compared to degree, closeness or betweenness centrality. It is remarkable, that degree centrality performs almost as good as inter-centrality (Calvo-Armengol and Zenou, 2004).

[27] The key group: a group among same-sized groups in the network, with the highest inter-centrality. Remark that group centrality is not a straightforward aggregation of its members centrality indexes.

[28] An average path length of 4.75 is high, compared to so-called *small worlds. They* illustrate short average path length, also in very large networks, c.f., Horvitz (2008)). For a more precise disposition of the network to reach small world regions, see e.g., Cowan and Jonard (2004).

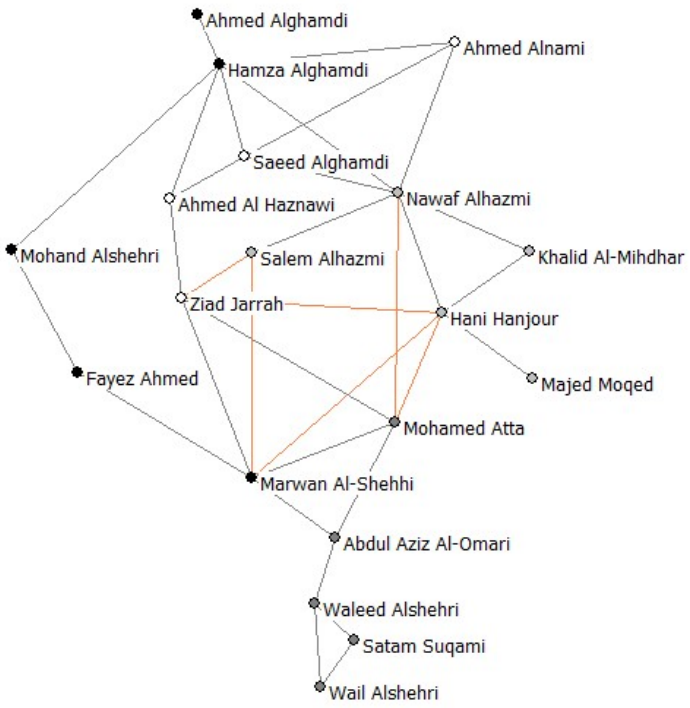

FIGURE 3.4 The al-Qaeda on-board network from Krebs (2002): UA-93 (white), AA-77 (light-gray), AA-11 (dark-grey), and UA-175 (black). Orange lines correspond to the short-cuts

3.3.2 Implications for Counter-terrorism Policies

Employing network theory seems to be an adequate extension of the topics in section 3.1. Not only general group characteristics, but also the role of single players is highlighted. Governments can benefit and address their goals against terrorism in a more targeted and strategic manner than standard CT policies do. A standard defensive policy reduces terrorists' activity for a certain attack mode (direct negative effect), but terrorists react strategically by evading relatively cost intensive attacks modes with a substitution towards marginally less expensive modes. Thus, terrorists will expand their knowledge and improve their technologies. Better equipment or tactics could lead to more commitment of each terrorist (indirect positive effect). Contrary, the removal of the key player has straightforward negative effects on terrorist activity. The inter-centralities of all remaining terrorists can be reduced (Ballester et al., 2004).

Surely it would be wrong to employ no more defensive CT measures. A certain level of defensive CT will always be necessary to protect vulnerable objects in society. But domestic policies should also be considered, whether defensive CT restricts public freedom and privacy or not. Since 9/11, the USA have turned from almost purely defensive to-

wards more proactive (c.f., Patriot Act and its contents) policies (Enders and Su, 2007). Proactive policies, such as the "war on terrorism" are able to shrink terrorist groups' sizes, but does not solve the problem "terror". As shown above, proactive interventions could lower a network's density. Consequently, the group's visibility is more complex, because decentralized structures emerge. Decentrality of a network may allow terror networks to "recover covered", by recruiting new members, moving to other countries and making new relationships with other extremist groupings, c.f. The Economist (2012) for the case of al-Qaeda. Proactive actions could also induce disadvantages for a government, because they could involve civilian mortality. As shown above, indiscriminate actions of a government could be positive for terrorists, by gaining public support. Whereas more targeted infiltration policies, such as removing the key player are preferred tools for two reasons. First, infiltration actions increase the likelihood of targeting real terrorists, not civilians. The terrorist group doesn't earn support of publics as easily as proactive CT might (Jaeger and Paserman, 2009). Second, removing the player of a network with the highest centrality and thereby the highest overall value of aggregate outcome among players with heterogenous effort-levels, can alter the whole distribution across a terrorist network, not just shifting problems from A to B (Ballester et al., 2004).

Finally, a suitable mixture of counter-terrorism policies seems to be effective. Especially foreign interventions should not just retain domestic interests, but also retain a country's reputation internationally.

3.4 Beyond Economic Theory

Terrorist networks are not just a subject of economists, but also of academics from other fields concerned with the tracking of terrorist networks. An overview of their development and achievements is given by Xu and Chen (2005) and Ressler (2006). Within this literature there are some trends and distinctions that I would like to present briefly. There are two major approaches, *collectors* and *modelers* which have increasingly been merged together.

Collectors simply collect data from terrorist events ex post and model the arising relations. For instance Krebs (2002) reconstruct the al-Qaeda bombers and the network around 9/11 from FIGURE 3.4. His work is recognized, also by economists, and is probably the most often used example or starting point for several studies.

On the other site, modelers deal with the simulation of covert network using little information by employing several applications. A pioneer in this field is K. M. Carley, who has written several papers on the topic (Ressler, 2006). Later, one of her works should be presented, within the context of my topics.

The development of this sub-literature can be divided historically into three classes: First, the *manual approach*, such as Krebs (2002), simply collects data after an attack and models a network. This qualitative approach is a nice way to illustrate, but does not allow for the construction of generalized trends or behaviors. Second, the *graphic-based*

approach uses applications that produce automatic graphical representations of criminal networks.[29] There is a growing literature on the third and last category, *Social Network Analysis* (hereafter: SNA) (Lindelauf et al., 2011). SNA should provide more advanced, analytical functionality and is instructive for terrorist's behaviors, supported by several applications, such as UCINET (Xu and Chen, 2005).[30]

Generally, there are interesting tools coming together from different fields, like sociology, psychology and computer science. Following, I will briefly present an often cited example of this literature:

Carley et al. (2002) distinguish between two kinds of protagonists, the *leader* (highest cognitive load) and *central* (most direct links) and examines two topologies, a hierarchical structure and a distributed decentralized structure, by removing crucial players. After removing the leader, the hierarchic structure destabilizes the network and the communication structure is more decentralized. Removing the central has a less destabilizing effect on the network and the performance seems hardly affected. In the distributed decentralized network, the leader and central are one and the same node. After removing this node, the leader and central are no longer one node. Now, the emerged leader is closer to the removed node than the emerged central. The two structures are randomly chosen, but the results roughly converge with my results so far.

4 Advanced Approaches

4.1 Extending the "Key Player Approach": Removing the Key Player

In literature regarding the "key player", the identification of the key player and the effect of a removal is discussed. I would like to illuminate, what actually happens to the network after the removal. The topic should be discussed in relation to the examples of the al-Qaeda's 9/11 network and the Jemaah Islamiyah network in Indonesia.[31] The latter was founded 1993 in Malaysia and became famous in 2002. On October 12, 2002, they killed 202 innocent civilians on Bali. The attack was part of the so-called "uhud" project. The project's aim was the ethnic cleansing of all non-Islamists in Indonesia (Lindelauf et al., 2011). The Jemaah Islamiyah network, pictured in FIGURE 4.1, consisted of 17 terrorists, with a network's density of $\rho_0 = 0,4559$, more than twice as dense as the al-Qaeda network. Moreover, its structure is different. The members are functionally divided and a disconnection of at least one cell deems the whole network futile, because the cell functions are reliant on each other.

[29] Examples are Analyst's Notebook, Netmap, XANALYS Link Explorer (former 'Watson'), and models by the company COPLINK.

[30] With UCINET also different centrality measures, such as eigenvector-centrality, can be calculated and serves as simple method to visualize networks. UCINET also contains different data bases. Further applications are MTML, COPLINK, etc.

[31] Surely comparing these two networks cannot made exactly (differences in attack modes, geographic coverage, etc.) but a consideration is still useful to learn from network structures of two almost same-sized networks. Remark, the application of these two examples is purely exemplary, but still enlightening for research on the topic.

The division of the al-Qaeda network on four independent teams makes the network less vulnerable.

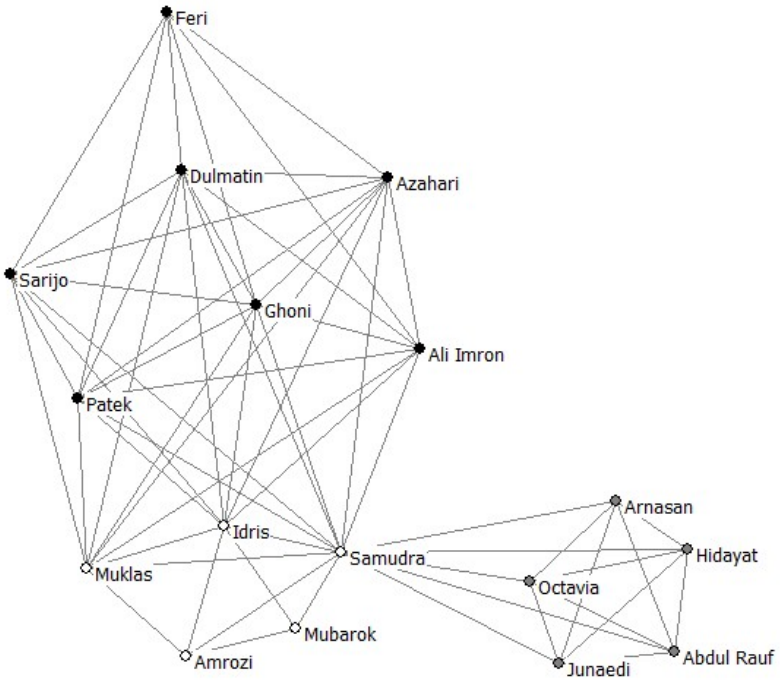

FIGURE 4.1 Operational network of Jemaah Islamiyah's Bali attack network from Lindelauf et al. (2011): Coordination team (white), support team (gray) and bomb-building team (black)

Following, the two networks are discussed:

The al-Qaeda network: The player with the highest Bonacich centrality (also ranked high for other centralities) of the al-Qaeda network is Nawaf Alhazmi (see: TABLE 4.1, p. 31). He seems to be of high importance, because he is one of only five players that are connected directly with all four teams. As you can see in TABLE 4.2, his removal changed the ranking throughout all centrality measures, some players made huge movements in their ranking. In other words, the removal of Nawaf Alhazmi disturbed the network's complete routine. After the removal, the terrorists in FIGURE 3.4 upper-left part are more distant from the rest of the network. This could be "good or bad" for CT: "Good", CT could break the network into two separate networks and makes the original terrorists's plan incapable of action. "Bad", also a progressing decentralization of the network makes a governmental detection more difficult. Whether such a situation is preferable for CT or not, depends on the government's level of knowledge about the network in the moment of the removal of the key player. I will give some advice regarding this dilemma in section 4.2.1.

The Jemaah Islamiyah network: Here the player with the highest Bonacich centrality (also highest ranked for the three other centrality measures, TABLE 4.3) is Samudra. He is connected with almost all of the players directly and he is the only one who connects the *coordination team* with the *bomb-building team*. In this sense, Samudra is a so-called *articulation point*. An articulation point is a node, whose removal disconnects the network at some point (Carpenter et al., 2002). As you can see in FIGURE 4.1, the removal of Samudra disconnects the support team from the two other teams and could cripple the network's actions. Samudra's high connectivity and his high level of influence (via his high connectivity) on the network is related to a high vulnerability (that's the well-known trade-off from section 3.1). Therefore, the removal of Samudra seems optimal to harm the network maximally.

The two different structured networks give insights of the key player's effects on the remaining rest of the network. How differently two similar sized networks can react, emphasizes that no "silver bullet" against terrorism exists. The Jemaah Islamiyah network seems conquered through the removal of the key player. Whereas the al-Qaeda's 9/11 network still poses a challenge and danger, if only one important terrorist is removed. This supports my results in section 3.2.1 regarding the features of the centralized star structure and the decentralized chain structure.

Beside concentrating on the removal, also other treatments of the key player are thinkable, e.g., to put him or her under special surveillance. Future analysis could optimize the treatment of important players in the network (Lindelauf et al., 2011). Following, I will give general intuitions and strategies to back up the outcome of CT. That could be also informative to combat effectively a 9/11-like network.

GENERAL The applied calculations are made according to the in section 3 explained centrality measures via UCINET from Borgatti et al. (2002). Other papers' rankings can deviate from mine, since they do not necessarily apply exactly equal methods or exogenous values. For Bonacich centrality: The b-value is set 0.5% lower than the maximum possible value for each calculation (Borgatti et al., 2002).

TABLE 4.1 & 4.3 Rankings for the original networks of al-Qaeda's 9/11 and Jemaah Islamiyah.

TABLE 4.2 & 4.4 Rankings for the al-Qaeda's 9/11 and Jemaah Islamiyah's network, after the removal of the node with highest Bonacich centrality, the *key player*.

no	Bonacich	Degree	Betweenness	Closeness
1	Nawaf Alhazmi	Nawaf Alhazmi	Nawaf Alhazmi	Mohamed Atta$^{\alpha}$
2	Hani Hanjour	Hamza Alghamdi$^{\alpha}$	Abdul Aziz Al-Omari	Nawaf Alhazmi$^{\alpha}$
3	Mohamed Atta	Hani Hanjour$^{\alpha}$	Mohamed Atta	Hani Hanjour$^{\beta}$
4	Marwan Al-Shehhi	Marwan Al-Shehhi$^{\alpha}$	Marwan Al-Shehhi	Marwan Al-Shehhi$^{\beta}$
5	Ziad Jarrah	Mohamed Atta$^{\beta}$	Waleed Alshehri	Ziad Jarrah
6	Hamza Alghamdi	Ziad Jarrah$^{\beta}$	Hamza Alghamdi	Hamza Alghamdi$^{\gamma}$
7	Salem Alhazmi	Saeed Alghamdi	Hani Hanjour	Salem Alhazmi$^{\gamma}$
8	Saeed Alghamdi	Abdul Aziz Al-Omari$^{\gamma}$	Ziad Jarrah	Abdul Aziz Al-Omari
9	Ahmed Alnami	Ahmed Al Haznawi$^{\gamma}$	Fayez Ahmed	Saeed Alghamdi
10	Ahmed Al Haznawi	Ahmed Alnami$^{\gamma}$	Mohand Alshehri	Ahmed Al Haznawi
11	Khalid Al-Mihdhar	Salem Alhazmi$^{\gamma}$	Ahmed Al Haznawi	Ahmed Alnami$^{\delta}$
12	Abdul Aziz Al-Omari	Waleed Alshehri$^{\gamma}$	Salem Alhazmi	Fayez Ahmed$^{\delta}$
13	Fayez Ahmed	Fayez Ahmed$^{\delta}$	Saeed Alghamdi	Khalid Al-Mihdhar
14	Majed Moqed	Khalid Al-Mihdhar$^{\delta}$	Ahmed Alghamdi$^{\alpha}$	Mohand Alshehri
15	Mohand Alshehri	Mohand Alshehri$^{\delta}$	Ahmed Alnami$^{\alpha}$	Majed Moqed
16	Ahmed Alghamdi	Satam Suqami$^{\delta}$	Khalid Al-Mihdhar$^{\alpha}$	Waleed Alshehri
17	Waleed Alshehri	Wail Alshehri$^{\delta}$	Majed Moqed$^{\alpha}$	Ahmed Alghamdi
18	Satam Suqami	Ahmed Alghamdi$^{\epsilon}$	Satam Suqami$^{\alpha}$	Satam Suqami$^{\epsilon}$
19	Wail Alshehri	Majed Moqed$^{\epsilon}$	Wail Alshehri$^{\alpha}$	Wail Alshehri$^{\epsilon}$

TABLE 4.1 Ranking for the al-Qaeda's 9/11 network by centralities.
$^{\alpha,\beta,\gamma,\delta,\epsilon}$ stand for equal ranks.

no	Bonacich	Degree	Betweenness	Closeness
1	Marwan Al-Shehhi	Marwan Al-Shehhi	Ziad Jarrah	Marwan Al-Shehhi
2	Ziad Jarrah	Hamza Alghamdi$^{\alpha}$	Marwan Al-Shehhi	Ziad Jarrah
3	Mohamed Atta	Hani Hanjour$^{\alpha}$	Abdul Aziz Al-Omari	Mohamed Atta
4	Hani Hanjour	Ziad Jarrah$^{\alpha}$	Ahmed Al Haznawi	Hani Hanjour
5	Abdul Aziz Al-Omari	Mohamed Atta	Hani Hanjour	Ahmed Al Haznawi$^{\alpha}$
6	Salem Alhazmi	Abdul Aziz Al-Omari$^{\beta}$	Waleed Alshehri	Fayez Ahmed$^{\alpha}$
7	Ahmed Al Haznawi	Ahmed Al Haznawi$^{\beta}$	Hamza Alghamdi	Abdul Aziz Al-Omari
8	Fayez Ahmed	Saeed Alghamdi$^{\beta}$	Mohamed Atta	Salem Alhazmi
9	Khalid Al-Mihdhar$^{\alpha}$	Waleed Alshehri$^{\beta}$	Fayez Ahmed	Mohand Alshehri
10	Majed Moqed$^{\alpha}$	Ahmed Alnami$^{\gamma}$	Mohand Alshehri	Hamza Alghamdi
11	Hamza Alghamdi	Fayez Ahmed$^{\gamma}$	Saeed Alghamdi	Saeed Alghamdi
12	Waleed Alshehri	Mohand Alshehri$^{\gamma}$	Ahmed Alghamdi$^{\alpha}$	Khalid Al-Mihdhar$^{\beta}$
13	Saeed Alghamdi	Salem Alhazmi$^{\gamma}$	Ahmed Alnami$^{\alpha}$	Majed Moqed$^{\beta}$
14	Mohand Alshehri	Satam Suqami$^{\gamma}$	Khalid Al-Mihdhar$^{\alpha}$	Waleed Alshehri$^{\beta}$
15	Ahmed Alnami	Wail Alshehri$^{\gamma}$	Majed Moqed$^{\alpha}$	Ahmed Alnami
16	Satam Suqami$^{\beta}$	Ahmed Alghamdi$^{\delta}$	Salem Alhazmi$^{\alpha}$	Ahmed Alghamdi
17	Wail Alshehri$^{\beta}$	Khalid Al-Mihdhar$^{\delta}$	Satam Suqami$^{\alpha}$	Satam Suqami$^{\gamma}$
18	Ahmed Alghamdi	Majed Moqed$^{\delta}$	Wail Alshehri$^{\alpha}$	Wail Alshehri$^{\gamma}$

TABLE 4.2 Ranking for the al-Qaeda's 9/11 network by centralities after the removal of the key player.

no	Bonacich	Degree	Betweenness	Closeness
1	Samudra	Samudra	Samudra	Samudra
2	Idris	Idris	Feri	Idris
3	Azahari$^{\alpha}$	Azahari$^{\alpha}$	Idris	Azahari$^{\alpha}$
4	Dulmatin$^{\alpha}$	Dulmatin$^{\alpha}$	Muklas	Dulmatin$^{\alpha}$
5	Ghoni$^{\alpha}$	Ghoni$^{\alpha}$	Azahari$^{\alpha}$	Ghoni$^{\alpha}$
6	Patek$^{\alpha}$	Muklas$^{\alpha}$	Dulmatin$^{\alpha}$	Muklas$^{\alpha}$
7	Muklas	Patek$^{\alpha}$	Ghoni$^{\alpha}$	Patek$^{\alpha}$
8	Ali Imron$^{\beta}$	Ali Imron$^{\beta}$	Patek$^{\alpha}$	Abdul Rauf$^{\beta}$
9	Sarijo$^{\beta}$	Sarijo$^{\beta}$	Ali Imron$^{\beta}$	Ali Imron$^{\beta}$
10	Feri	Feri	Sarijo$^{\beta}$	Arnasan$^{\beta}$
11	Amrozi	Abdul Rauf$^{\gamma}$	Amrozi	Hidayat$^{\beta}$
12	Mubarok	Arnasan$^{\gamma}$	Abdul Rauf$^{\gamma}$	Junaedi$^{\beta}$
13	Abdul Rauf$^{\gamma}$	Hidayat$^{\gamma}$	Arnasan$^{\gamma}$	Octavia$^{\beta}$
14	Arnasan	Junaedi$^{\gamma}$	Hidayat$^{\gamma}$	Sarijo$^{\beta}$
15	Hidayat	Octavia$^{\gamma}$	Junaedi$^{\gamma}$	Amrozi
16	Junaedi	Amrozi	Mubarok$^{\gamma}$	Mubarok
17	Octavia	Mubarok	Octavia$^{\gamma}$	Feri

TABLE 4.3 Ranking for Jemaah Islamiyah's network by centralities.

no	Bonacich	Degree	Betweenness	Closeness
1	Azahari$^{\alpha}$	Idris	Idris	Idris
2	Dulmatin$^{\alpha}$	Azahari$^{\alpha}$	Muklas	Azahari$^{\alpha}$
3	Ghoni$^{\alpha}$	Dulmatin$^{\alpha}$	Azahari$^{\alpha}$	Dulmatin$^{\alpha}$
4	Patek$^{\alpha}$	Ghoni$^{\alpha}$	Dulmatin$^{\alpha}$	Ghoni$^{\alpha}$
5	Idris	Muklas$^{\alpha}$	Ghoni$^{\alpha}$	Muklas$^{\alpha}$
6	Muklas	Patek$^{\alpha}$	Patek$^{\alpha}$	Patek$^{\alpha}$
7	Ali Imron$^{\beta}$	Ali Imron$^{\beta}$	Ali Imron$^{\beta}$	Ali Imron$^{\beta}$
8	Sarijo$^{\beta}$	Sarijo$^{\beta}$	Sarijo$^{\beta}$	Sarijo$^{\beta}$
9	Feri	Feri	Amrozi	Feri
10	Amrozi	Abdul Rauf$^{\gamma}$	Feri	Amrozi
11	Mubarok	Arnasan$^{\gamma}$	Abdul Rauf$^{\gamma}$	Mubarok
12	Abdul Rauf$^{\gamma}$	Hidayat$^{\gamma}$	Arnasan$^{\gamma}$	Abdul Rauf$^{\gamma}$
13	Arnasan$^{\gamma}$	Junaedi$^{\gamma}$	Hidayat$^{\gamma}$	Arnasan$^{\gamma}$
14	Hidayat$^{\gamma}$	Octavia$^{\gamma}$	Junaedi$^{\gamma}$	Hidayat$^{\gamma}$
15	Junaedi$^{\gamma}$	Amrozi	Mubarok	Junaedi$^{\gamma}$
16	Octavia$^{\gamma}$	Mubarok	Octavia$^{\gamma}$	Octavia$^{\gamma}$

TABLE 4.4 Ranking for Jemaah Islamiyah's network by centralities after the removal of the key player.

4.2 The Timing of Counter-terrorism

In literature, the relationship between different CT policies and terrorist attacks is well-researched, but the elaboration of strategic CT measures seems to be discussed only briefly. Therefore, I introduce the new perspective of *timing*. Despite its importance, to the best of my knowledge there have been no studies providing the approaches beneath.

The governmental decision *when* to intervene against terrorism is crucial for the effects of CT on a terrorist group. Too early interventions could make the terrorist network more decentralized but not totally disabled, whereas a too late intervention could have fatal consequences for innocent civilians.[32]

I assume two types of CT:

1) *infiltration* purely monitors in secrecy a network and the government doesn't interact with terrorists or influence them directly. During infiltration, the government gains knowledge about the network, but at the same time terrorists will progress in planning attacks and the risk of an attack increases, and hence, the public security declines.

2) *proactive* is directly addressed to a terrorist group and will improve public security proportional to the infiltration success in the short-term by baffling terrorist attacking plans. In the long-term, the remaining terrorists alter their network structure towards a more decentralized one and the government largely has to infiltrate again, to uncover the network's new structure. Right now, exactly this behavior can be identified in the fight against the al-Qaeda: The terrorist network is massively fought down, but a relocation of the network has avoided a total break down so far (The Economist, 2012).

To sum this up, we could say that the government faces a *hold-act dilemma*: Not to intervene actively for a long period means that a government can gain more knowledge about the network and important terrorists can be identified. I assume that the infiltration success is proportional to the infiltration duration. A subsequent active CT instead targets important terrorists (that combines discriminate and key player advantages) and the extremist network can be harmed maximally. Contrary, terrorists plan their attacks in a steady progress, new links can be made and the coordination of a future attack moves forward. Thus, the potential risk for an attack increases[33] and the public security shrinks. Analog to the terrorist's trade-off between network density and security from section 3.1, the government faces a related trade-off between the terrorist network's *density growth rate* and public security.[34]

To solve the dilemma, the government should find the best momentum to change from infiltration to proactive CT. As shown in FIGURE 3.4, the 9/11 al-Qaeda group expanded

[32] I will later explain, what "too early" means.

[33] The potential risk of an attack also increases without making new links over time. That terrorists make new links seems plausible for two reasons: 1) Since infiltration impacts terrorists not immediately, the could assume to be more secure from detection. Second, making new links supports the coordination across the network and was reality at 9/11, c.f., the short-cuts.

[34] It is important to consider the *density growth rate*, i.e., the change of density $\triangle^{p}_{0,1}$ from period t_0 to t_1, and not the absolute density.

their network by introducing six short-cuts right before the attacks and a positive density growth rate results. But not only the density also the players' centrality is instructive for governments to attack at an optimal moment. The 9/11 short-cuts are made among six of the seven highest ranked terrorists (ranked by Bonacich centrality). This could indicate, that the leading nodes deliberately avoided connection among them for security reasons for the most time. The creation of connections *among leading nodes* (i.e., with a high centrality) could especially be correlated with upcoming attacks and should alarm a government to intervene immediately. In this case, waiting with proactive intervention until leading terrorists get in intensified, direct contact with each other, maximizes the findings of infiltration efforts and the network can be harmed maximally.

In summary, not just the type of CT, but also the right timing is responsible for how successful the overall counter policy is. Network theory could be able to support ideal decisions. Since governments have to accept, that the problem "terrorism" cannot easily be solved by fighting with strong military power. Terrorism is smarter: before getting in existential danger, it moves back, decentralizes and forms new branches. As a government, acting with optimal timing does not necessarily destroy a network, but harms it when the network's output-loss is maximal. This view introduces dynamics to CT, based on the actual condition of terrorist threat.

5 Conclusions

Introducing network theory for terrorist issues seems to be adequate, particularly in terms of tracking and successfully fighting terrorism. In theory, CT provides a new type, i.e., infiltration, and terror prevention becomes more flexible and multifaceted (Cronin, 2003). It is essential to apply a suitable set of CT, since terrorist groups differ in their motives, historical development and objectives. Returning to network theory allows a generalization of the same patterns in varying networks. As we have seen, the dimensions of terrorism vary, which can sometimes result in academic ambiguity. Network measures take a firm stand and make a connection to usual game-theoretic methods. For a macro perspective the network's density and for a micro perspective the centrality measures look inside the networks' organizations. The centrality measures in particular can be applied to harm the network maximally and save public resources at the same time. Therefore, many researched trade-offs between governments and terrorists can be improved in favor of the governments. The centrality measures (each for its use) work adequately for the identification of important terrorists within a network, which I illustrate using the examples of the al-Qaeda's 9/11 and the Jemaah Islamiyah.

Furthermore, I suggest that the relationship between terrorists and governments should be understood as one of dynamic interplay. It has also been suggested that if government intervention is done at the optimal time the damage to the terrorist groups will be max-

imized. Since terrorists abide their security (in the trade-off with the network's density), the right timing could "trick" a proceeding decentralization in the short-term and harm the network, when it is most vulnerable (i.e., on the eve of an attack). Moreover, governments can learn to measure the level of threat. Not only politicians, but also media tend to rate terrorism rather as invisible or as absolutely dangerous. The timing-perspective allows for the diminishing of the acuteness of terrorist groups which is correlated to the network's connectivity. The idea seems to fit in the researched environment and a future research on the topic could support to fight terrorism more effectively.

However, the extent to which these approaches are able to prevent attacks, also depends on the work of Intelligence services. Improvements of the "communication and coordination within the Intelligence community" are surely supportive to transfer CT successfully (Feldstein, 2008). Beside the illustrated methods of tracking terrorist networks that are based on the quantity of terrorists' interactions, asking *in which way* terrorists communicate could partly answer recent disagreements regarding information privacy policies. Phrasing an adequate and nationwide framework of data preservation-issues is necessary to balance the trade-off between public privacy and the infiltration, and subsequently the prevention of terrorism. This framework might be basic for the creation of a nationwide cooperation of Intelligence in the digitized 21st century.

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