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Optimizing the Community's Supports in Counter-Terrorism Operations: A Sticks – Carrots Game Theoretic Model

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Authors' contributions

The work, one of the pilot studies of a PhD research study in Mathematical Terrorism – "The Systemic Approach to Combating Terrorist Organization: A Mathematical Perspective", was carried out in collaboration among all authors. As expected Author MOO the study's principal supervisor proposed the study design, wrote the protocol and the first draft of the manuscript. While authors IJU and AOA jointly performed the mathematical modeling, analysis and simulation, managed the analyses of the study as well as the relevant literature searches. By these attributes, all the authors have read and approved the final manuscript.

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ABSTRACT

A terrorist group's (TG) ability to withstand attacks and recovered from sudden high strength depreciation after a major counterterrorism operation, as well as the Security Agencies' (SA) ability to execute successful credible counter-terrorism operation is a function of both their individual bureaucratic structures and the level of community's supports each organization is able to optimize within the period of operation. To study the security implications of undermining a given community's optimal supports, we present and analysed a two-person two-periods evolutionary

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game theoretic model for an interaction between the SA and the TG; each playing either the "Sticks" or the "Carrots" or mixed strategies to win the community's optimal supports. In the symmetric game variant, the result of the analysis shows that if the operational cost drops by 80%, then the SA playing the "Stick" may enjoy 50:50 chance of winning the community's optimal supports. But if the cost rises by at least 30%, then SA playing the "Sticks" would be at-most 33.3% advantageous, while the "Carrots" approach would yield at-least 66.7% advantage. In the asymmetric variant, if the operational cost drops by 80%, then SA playing the "Sticks" would enjoy 100% chance of winning the community's optimal supports, while the "Carrots" would yield at most 20% advantage. But if the cost rises by at least 30%, then SA playing the "Sticks" would enjoy 50:50 advantage. Comparatively, the TG would enjoy 50:50 chance of winning the community's optimal supports by playing the "Sticks" if the cost of operation drops by 90%. But if the cost rises by at least 20%, then TG playing the "Sticks" would enjoy at most 33.3% while the "Carrots" would yield at least 66.7% advantage. Thus, the cost of operation is the major determinant of either player's strategic approach. Under the mixed strategy, if the benefit of operation exceeds its cost, then SA playing the "Sticks" is an evolutionary stable strategy (ESS), otherwise, combining the "Sticks and Carrots" simultaneously would yield an ESS. Summarily, the SAs' stake in terrorism prevention and control using the "Sticks" approach is proportional to its operational cost and vice versa. Therefore, considering the capital intensive as well as the intelligence deficient characteristics of the "Sticks" approach, the SA cannot prevent/control terrorism using the "Stick" instruments only. Rather a viable "Carrots" approach or its combination with credible "Sticks" instruments would be necessary and sufficient to win the community's optimal supports for effective terrorism prevention and control.

Keywords: Evolutionary stable strategy; sticks and carrots approach; security agencies; terrorist group; community's optimal supports; terrorism.

1. BACKGROUND OF THE STUDY

In what appears to be a stroke of irony, perhaps, most world government had been on the rampage to launching a harsh crackdown on institutions and individuals that allegedly supports or glorify terrorism, since the bombing of the World Trade Centre in September 11th 2001 by the Al-Qaida terrorist group [1,2]. There is no doubt that these counter-terrorism (CT) measures were aimed at criminalizing terrorism and its propaganda as well as other forms of socio-moral supports to the organization. Thereby raising the costs of terrorism or being associated with a terrorist organization for individuals who would otherwise be willing to provide such supports like dissemination of propaganda, raise funds, recruit operatives, procure logistics and supplies, facilitate travels, and/or provide safe haven for terrorist activities, etc. However, the security implications of the deleterious boomerang effect of such collective punishment and indiscriminate violence approaches have only recently been analysed quantitatively but not fully understood [3,4,5,6].

Perhaps a brief recap of the major CT measures of some world leaders in the last decades would drive home the efficacy of this study. The Nigerian government, for example, arose from its aftermath high profile cases of vandalism and militant attacks on its major oil installations, oil bunkering and kidnapping for ransom by the Niger Delta militant groups; frequent holocaust of attack on public offices, worship centres, educational institutions, and kidnapping for ransom by Boko Haram terrorist groups and widespread incident of armed robbery, political assassination, armed banditry and other forms of organized crimes between 2009 and 2011 to enacted stringent measures tagged "*Terrorism Prevention Acts (TPA) 2011 and 2013"* respectively [7,8].

Barely six months into the enactment of these Acts, villages, communities and organizations suspected to harbour or abet terrorists were ransacked by fierce-looking security operatives. Innocent young men and women suspected to abetting or joined Boko Haram were picked up from their houses and on the streets and taken to military detentions and prisons. According to Amnesty International [9,10] in the first six months of 2013 alone, about 950 suspects were unlawfully detained by the Nigerian government. If and when these victims make their way out of detentions or prisons alive (of course many died of disease, starvation or torture), their animosity and disaffection, and perhaps those of their respective communities increased against the government. Thus, provoking "Herostratos syndrome" in the susceptible youth population,

who eventually became easy prey and targets for Boko Haram's recruitment agenda [7,8].

It is worth noted that other democratic nations are not exempted from these anti-humane policies, gross violation and abuse of fundamental human right of the citizenry in the guise of preventing or combating terrorism. For example too, the French government has also launched a harsh crackdown on speeches that allegedly supports or glorify terrorism in less than a week into the aftermath of the Charlie Hebdo terrorist attack. In a circular published on 12th January 2015, the French Minister of Justice - Christiane Taubira instructed prosecutors to take tough action against persons or institutions who purportedly defend or glorify terrorism. These restrictions later expanded from the existing prohibitions on incitement to a much broader and less defined areas such as the *"glorification of"* and *"apologie du terrorisme"* [11]. Thus, within three weeks into the policy, about 150 prosecutions were launched with 18 people convicted and imprisoned largely for the crime of *"apologie du terrorisme"* [12,13,14].

In a similar effort, the President Francois Hollande also signed on 9th February 2015 a decree legalizing the French government to ban without a court order websites suspected to advocating terrorism [15]. The 2004 Madrid train bombings and the 2005 London terrorist attacks also added urgency to the issue of devising preventive security measures in an era of rising extremist violence and suicide terrorism.

Consequently, the US governments and other liberal democracies also adopted various anti-humane measures aimed at curtailing the growth and operations of terrorist organizations inside liberal societies [1]. For instance, as one of its post 9/11 CT measures, the US President George Bush, on 26th October 2001, signed into law the *"Patriot Act";* which not only criminalized any forms of supports to groups designated as terrorist organizations but also formally domesticated the conventional military-offensive approach to drive its popular "terrorist leadership decapitation" strategy [16,17,18]. These lead to the assassination of key Al-Qaida and ISIS leaders, including Osama Bin Laden - the mastermind of 9/11 World Trade Centre bombing, through several drone attacks.

In 2002, Denmark government also enacted a law to criminalize instigation of acts of terrorism. This follows by Australia in 2005, who included various forms of seditions into its CT laws and gave public officials the power to ban groups suspected to advocate terrorism. In 2006, the United Kingdom also passed into law the *"Terrorist Act"* that also outlaws any act of glorification of terrorism, or encouragement and preparation of terrorist activities or agenda [19],[1]. The list of world leaders' anti-humane CT measures is inexhaustible.

Notwithstanding the prevalence of these anti-humane CT measures of world leaders as a strategy for states to fight the scourge of terrorism (and other institutions of organized crimes), there is little conclusive evidence that these strategies are successful in disrupting terrorist campaigns or even mitigating its destructive effects. There is also practically few quantitative works on identifying the conditions that may impact negatively or positively on the effectiveness of these measures, and whether its effectiveness can be generalized to all terrorist organizational structures. However, considering the high resilience structure and proliferation of domestic terrorist organizations and other institutions of organized crimes in the last decades, in the face of frequent and severe military-offensive CT measures, terrorism research scholars has debunk the potency of these anti-humane CT measures to mitigate the scourge of terrorism the world over [20,21,22,18],[5,6].

1.1 The Psychological Theory of Terrorism Prevention and Control

Considering the moral vulnerability of these anti-humane CT measures as evidenced in the alarming and insurmountable severity and frequency of terrorist attacks; the ever growing and more dynamically diffused terrorist organizations - with increasing number of groups, networks and individuals exploiting global trends, including the emergence of more secure modes of communications; the expansion of social and mass media, and persistent instability across several regions. To sufficiently mitigate the evolving threats that today's geographically more dispersed and tactically more diversified terrorists pose, the state's approach to combating terrorism must also change. This should involves adjusting the existing strategies to meet the evolving threats and new facts, and discarding those strategies that have not yield sustainable results and applying new approaches informed by experience and judgment. Hence terrorism research scholars have advocated the application of some psychological motivation

theory to CT measures. Under this theory, the use of combine positive incentives or reward (Carrots) and negative incentive or punishment (sticks) to elicit or coerce behaviour compliance from adaptable adversary is recommended as a complementary strategy to the sole and dominant conventional military-offensive approach [23,24,25].

1.1.1 The "Carrots" Approach to Terrorism Prevention and Control

The "Carrots" or positive incentives, for example is not limited to providing goods and services, or valuable alternative vocational opportunities to persons or groups of persons that are willing to refrain from terrorism. That is making non-terrorist ventures more lucrative and attractive than terrorism [26,23,24,25]. These examples of positive incentives may not be limited to direct monetary transfers; economic assistance to susceptible operatives, individual and terrorist host communities (e.g. provision of social amenities, lucrative job placement, educational scholarship schemes, etc.); provision of palliative measures to victims of terrorism, and building cordial friendly relationship with host communities; lifting of sanctions or stiff penalties; period of seize-fire, amnesty program, suspension of prison sentences, de-radicalization, rehabilitation and reintegration of repented terrorists, and removal of taxes or customs duties on non-terrorism related business [27],[28],[29].

1.1.2 The "Sticks" Approach to Terrorism Prevention and Control

On the other hand, negative incentives or coercive or "Sticks" approach may include the dominant military-offensive retaliatory approach and other measures intended to increase the cost of terrorism for potential terrorist groups or individuals or terrorist sponsored communities or states, by such means as imposing trade restrictions, freezing the financial assets, arrest and assassination of operatives, restricting how the terrorist operates, and liberty-reducing measures, [27],[28],[29]. Positive and negative incentives may also be interpreted in terms of income effects. Enders and Sandler [28] refer to *"freezing terrorist's financial assets"* which reduces their war chest and their overall ability to conduct a campaign of terror. Lakdawalla and Zanjani [30] observed that *"protection reduces the payoff to terrorism".* They argued that *"deterrence due to income reduction takes place insofar as private self-protection raises the level of non-violent activities and lowers the total amount of violent terror investments".* Finally, Hausken [31] also opined that defensive investment not only helps defend the government's asset but also reduces the terrorist's resources, so that the terrorist's attack effort becomes minimal.

1.1.3 "Carrots" as an Arbitration Processes

In this study, we may not explicitly concern about the issue of negotiating with terrorists, since conventional wisdom abhors negotiation with terrorists or other similar adversaries (such as rogue States); though, some States had sometimes negotiated with insurgents. In particular, Spector [32] captures negotiations between Israel and the Palestine Liberation Organization; the US and Haiti; the US and North Korea, and Great Britain and Sinn Fein. Thus, Spector [32], argues that *"despite the risks inherent in negotiating with terrorists, the risks of following a no-negotiation policy are likely to be more deadly. Therefore, States need to assess terrorist interests and intentions to find out if there are reasonable entry points for negotiation and take advantage of these to transform the conflict."* Similarly, Pruitt [33] considers both the peace process in Northern Ireland and negotiations with Islamic terrorist groups. He suggests that the success of negotiations depends on flexible attitudes on the part of both parties, and that though many argued against negotiating with terrorists but most of them do not take into cognizance the secret backchannel talks, which are usually the method of choice in first approaching these groups. He also observes that *"negotiation with non-ideological ethno-nationalist terrorists is more common and more successful than with other kinds of terrorists".*

However, in this paper, though we are not particularly concern about negotiation with the terrorist but with terrorist host communities; about the conditions under which the State would be willing to offer terrorist host communities positive incentives in order to gain their cooperation and optimal supports for a more strategic and tactical collaboration toward the enhancement of (i) credible intelligence gathering for smart targeting of terrorist locations and terrorist attrition accuracy, (ii) effort that would provoke and boost terrorist internal personnel drain through voluntary defection and (iii) effort that would synergize the efficient de-legitimization of terrorism and its propaganda within the host communities.

1.2 The Statement of the Problem

Considering the asymmetric nature of the global-war-on-terror and its heterogeneous battle field, the difficulty of effective prevention of terrorism is not only compounded by the dwindling quality and insufficiency of credible intelligence gathering but also by the deleterious boomerang effects associated with most contemporary CT measures, especially the conventional military-offensive approach. Research scholars observed that the effect of blowback action occasioned by the collateral damages and mass killing of innocent civilian population during military offensive against terrorists' cells within a community often incites the spirit of disaffection and animosity among the local population and hence provoking "Herostratos syndrome" in the disaffected youth population (the source of new insurgents). This in-turn help to harvest undue popular supports to terrorist organizations, pump up new recruits and even increasing the number of new insurgents groups in the region [27],[3],[34],[4].

Therefore, if the relevant security agencies must optimally prevent and control terrorism, such a deleterious boomerang effects must not only be avoided but a viable measure aimed at harnessing and optimizing some level of community's popular supports for the security agencies is a cine qua non. By intuition and existing scholarship, the cost of preventing terrorist activities is a function of the level of activities a given security agency chooses toward optimizing the supports of a given terrorist host community. Thus, to address the question of *"how does the policy of undermining the supports of a given terrorist's host community during CT operations affect the likelihood of terrorism prevention and control?"* we present and analyse a two-player two-periods game theoretic model of an interaction between the security agencies (SA) and terrorist groups (TG); in which the outcome of period-1 interaction determines the period-2 interaction. That is if there is zero (very minimal) civilian casualties in period-1, the SA will enjoy optimal support from the host community in expense of the TG in period-2, and contrary if otherwise.

1.3 The "Sticks-Carrots" Mathematical Game Theoretic Model

The "Sticks-Carrots" mathematical strategic stage game is synonymous to the traditional *"Hawk-Dove"* scenario; where two classes of intelligence animals in a population competes over a class of highly intelligence prey with value $x_i(t) \geq 1$ at any point in time. Strategically, each animal can behave like a "Dove" (cooperate) or like a "Hawk" (coercive) to optimize its number of prey. The best outcome for each animal is that in which one acts like a "Dove" while the other acts like a "Hawk" simultaneously. While the worst outcome is that in which both animals act like "Hawk" simultaneously. For optimal access to the prey, each animal may prefers to be "Dovish" if its opponent is "Hawkish" and "Hawkish" if its opponent is "Dovish".

The present study uncovers novel results regarding the dynamic consequences of the anti-human CT measures - a result that is missing from contemporary scholarly and policy debates about terrorism prevention. The strategic game theoretic analysis underscores the importance of assessing such strategy of preventing terrorism in the light of the incentives of security agencies responsible for terrorism prevention. Our target is to derive an analytical game model of CT operation that would not only help to boost the morale of the CT operatives so that the anticipated CT operations against a given terrorist group would be successful, but would also serve as a quantitative metrics for evaluating the probability of winning or losing a given CT operation.

Synonymous with mathematical game theory, the refinement of our ideas should enable security operatives to be able to state emphatically, for example, that they are 85% certain that there shall be no further acts of terrorism within a community or State; though there is still a 15% chance that terrorists might commit another deadly attack. The study has the potential to inform both scholars and CT policy makers on the optimal strategy for allocating the available resources towards effective terrorism prevention and control. The simplicity of our model should hopefully make it an attractive target for extensions by enterprising students of military operations research (MOR) and game theoretic analyst. The study also has the synergy to demonstrate that, terrorism though complex and divergent a socio-economic system is an area where mathematical methods can make an impact in a variety of targets and research problems.

2. RELEVANCE ACADEMIC LITERATURE

A terrorist group's ability to withstand attacks or recover suddenly after some period of declined in

its strength and capability is a function of both its bureaucratic structure as well as the level of optimal supports it's enjoying from its host community. Therefore, analysing the effects of certain CT measures on SA's propensity to prevent and control terrorism, the present article differs from existing works by providing a novel mathematical lens through which to evaluate the effectiveness of a given CT policy. A great deal of research have sought quantitatively to understand the implications of a given CT measure on terrorists' behaviour, and its organizational resilience characteristics [3],[34],[35],[36],[23-6]. However, much of these works looks at one specific tactical approach, such as leadership decapitation [3],[35], [21,22], [17], or multiple class targeting [34],[36],[23-25],[29] through the dominant military-offensive strategy psychologically tagged the "Sticks" approach. Similarly, some studies have suggested that the combination of conciliatory (Carrots) and coercive (Sticks) approaches may have distinct effects on terrorist strength and sustainability and thus, its violence rate but such research is only limited and of recent [34], [37],[23-25].

However, much of the optimism surrounding the effectiveness of some CT measures such as leadership decapitation as well as the "Sticks" and "Carrots" approaches are grounded on theories that analyses the dynamical evolution of the organizations rather than the psychological implication of the CT measures. For instance, in addressing the question of "*how do the 'carrots' and/or 'sticks' approaches impact on terrorists' strength and sustainability"* Udoh et al [23,24], posit that *"though the simultaneous use of the 'Sticks and Carrots' may be cost intensive and challenging, yet it has the propensity to drive the organization's dynamical evolution to a vulnerable value in some future time, while the 'carrots' approach though susceptible to misconstrue and abuse has propensity of interdicting more terrorist operatives' than otherwise".*

Others like Bandyopadhyay and Sandler [38] while considering how pre-emption and defence interaction with each other noted that high-cost defenders (force) are likely to rely more heavily on pre-emption, while too little pre-emption may exacerbate the problem of excessive defence by making for an even more insecure environment. Similarly, scholars like Sandler, et al [14], noted that *"offensive actions against terrorists and their supporters, while possibly effective at diminishing terrorist strength, do not seem to be cost effective given their high expenses relative to the current magnitude of the terrorism problem*". In Bier et al [39], the author considered the option of making attacks more costly for terrorists by employing the "Sticks" and "Carrots" approaches symmetrically - an assumption which is almost certain to be violated in practice. In another development, other researchers also pointed out some of the key differences between deterrence of terrorism through the threat of retaliation and other alternative strategies for protection, such as making oneself less vulnerable or providing incentives for cooperation [26],[37],[40],[41].

One argument against positive incentives (Carrots) is that such privilege may encourage terrorists to continue fighting, or even become a snare to attract the arrival of new terrorist groups. But in this paper, we assume that positive incentives are conditional and hence provided only if the terrorist are willing to cooperate to surrender, lay down arms, denounce terrorism, and stop launching any more attacks. And to the host community if they are willing to collaborate with security agencies to sponsor credible intelligence for smart targeting of recalcitrant terrorists as well as synergise the effective de-legitimization of terrorism and its propaganda within the community. Of course, there is a premise that the State may offer positive incentives and find that the terrorists or the host community still refuse to cooperate and hence further attacks still occurs. In this regard, Udoh, et al, [23-25] make an analogy with the idea of credible threats (combining the carrots and sticks simultaneously). For example, the state may threaten massive retaliation if terrorist or the host community refuses to cooperate or if further attacks are launched after the terrorist or the community has accepted positive incentives. Thus, the applicability of our model is limited to a situation that the State must have a credible threat of retaliation or other enforcement mechanism (e.g., situations in which retaliation is not too costly, or counterproductive to CT objectives etc.).

Considering that a community's optimal support is one of the necessary and sufficient conditions for a terrorist group to maintain stability in its strength and build up resilience capacity following a successful CT operation, research scholars observed that organizations with high levels of communal supports have easier time and access to acquire the resources necessary to carry out effective campaigns [26,37,40,41]. Other scholars including Kress and Szechtman

[36] and Scott [42] have observed that effective counterinsurgencies require vast amounts of community's supports. Militant organizations for example, also recognize the importance of its host community's supports to operate and function optimally in the face of stiff security oppositions [43],[44]. Eli et al [40] and Dugan, et al [37], both agreed that terrorist groups with optimal community supports are likely to be seen as legitimate by their communities. This further increases their strength, effectiveness and sustainability. As a result, counterinsurgency strategy that focused on winning the "hearts and minds" of the locals, reduces the desire for rebellion. Underlying this approach is the idea that by identifying and addressing the grievances (causes of insurgency), counterinsurgents will gain local supports that could otherwise help insurgents. Udoh et al [5,6] observed that this may not be unconnected with the erroneous belief that most ethno-religious ideology driven and separatist organizations are fighting the course of the community from which they emerge. Hence, they often have higher levels of communal support than ethno-political ideology driven organizations.

On the other hand, terrorist groups that provide social services to their local communities may experience increased public support, and thus a boost to their public image. Popular support contributes to terrorist groups' resolve and stability in many ways. It allows the group to recruit, raise money, provide critical resources, and ensure its ability to operate as a covert organization, encourage more violent behaviour, and maintain political and ideological relevance. Thus, supporters can provide useful information to boost prospective terrorist recruitment processes. Kress and Szechtman [36] and Pruitt [33] noted that provision of resources, information, and recruits by the local community is fundamental to understanding the success of rebellions.

Furthermore, in today's ethno-religious ideologies driven terrorist organizations, the use of anti-humane strategy in countering terrorism can be problematic, morally provocative and contemptuous; hence vulnerable to high degree of blowback action and incitement of "Herostratos" syndrome in the susceptible youth population. As such measure is seen as a serious threat to their religious beliefs, collective aspiration and survival of the community or religion. Thus, any attack on members of the organization especially their leaders, usually creates disaffection, rancour, disharmony and tension among the local population, who sees the course of such individual as representing the collective aspiration and interest of the community. This help to fuel and heighten animosity as well as fanning the amber of enmity between the government and the locals; and often times causing uproar and blowback actions often experienced after every major arrest or assassination of a terrorist leader. Blowback actions often provoke "Herostratos syndrome" among the youth population, which help to pump-up more support and recruitment to the terrorist organization [27],[34],[36].

A good example is the consequential post 9/11 "terror-war-of-attrition" strategies spearheaded by the US, and the criticisms expressed by foreign governments, members of Congress, human rights activists, journalists, and academics regarding the treatment of detainees at Guantanamo Bay in Cuba [45],[46],[16], the use of unmanned aerial vehicles (UAVs) in air-strikes in Pakistan, Iraq and Syria and the innocent civilian casualties caused by the US troops [47],[48],[49],[50] and North Atlantic Treaty Organization (NATO) military operations in Afghanistan [3],[51] as well as the multi-national joint military operations in North-Eastern Nigeria in the guise of fighting Boko Haram terrorist group [9,10],[44],[7],[8].Therefore, in an effort to marshal resources toward building coalition against international terrorism, countries and international bodies had heavily relied on strategies that are intended to change the incentives of both the terrorists and their supporters. Key among these strategies is the "sticks" and "carrots" approaches. Other nations has also capitalized on the "carrots" approach to incite or encourage a high internal personnel defection in local militia and domestic terrorist groups; with the hidden objectives of gathering sufficient credible intelligence for smart targeting of terrorist locations; taking the local populations supports away from the terrorists and as well as building a credible "in-policing" mechanism with the locals. Taking the local populations supports away from the terrorist's organization would create serious havoc for the terrorists and its cause receives less attention and therefore becomes delegitimized.

The "Carrots" instrument which is provided to elicit voluntary behaviour compliance in either the terrorist operatives or the local population with implied preferences or explicit direction, is rooted in the belief that reward would have a more

positive or long-lasting effects, and would be viewed either as a due compensation for desired performance or as unprejudiced payment for services rendered. Unfortunately, with the inherent psychological inclination of abused and misconstrued objectives, the perception from the recipients of "carrots" may be of a bribe tainting both the donor and recipient or equally distasteful payment from a master to a servant. If the "carrots" is offered arrogantly by a strong State without cognizance of the recipients who may see the "carrots" as bribes or arm-twisting, the results may be short termed and counter-productive in the longer term. Therefore, to harvest the desired utility of the "carrots" instruments, the State must be unprejudiced and proportional in its application of rewards and punishments, which in turn should be aligned with an unprejudiced motive. Such motive must be just in the eyes of the locals, the terrorists and other stakeholders, not simply in the eyes of the Donor State. In such a situation, the reward for compliance would not be seen as a bribe or a payment for ransom, but simply as an expected reward of working for a just course. To make the States unprejudiced motive more compelling and attractive to the terrorists and the locals, their different values and perceptions must be taken into consideration.

Furthermore, considering the high correlation between ideological strength and insurgent community size, and given insurgents employment of ideology as a currency to recruit supporters; the size of the insurgent community may serve as a proximal metric of its ideological strength. Therefore, as an extension of the idea of "smart-target" eradication of ideology, Weaver [52] observed that "reduction in killing" approach, could serve as a productive alternative to the various anti-humane CT strategies. Terrorism, mostly ideologically (ethno-religious or ethno-political) driven crime, and ideal CT measures mostly constrained by the heterogeneity of the terrain [53]; asymmetric nature of the battle field [54] insufficient and unreliable data/information and limited human resources, requires a compendium of counter-ideology driven methodologies, strategies, and proactive synergies from both inter/intra ideological collaborators. Such synergies are only possible in an atmosphere that is devoid of rancour, acrimony, coercion, tension, intimidation and fear but congenial to expression of both self and nationalist opinions – an atmosphere that engenders trust and confidence building between the governed and the government, as well as stimulate healthy civil-military relationship. A society that engenders and guarantees not only free flow of information, protect freedom of expression but respect and educate its citizens of their fundamental human right.

Most often, accurate knowledge of what is happening, why it happens and what will happen in advance in the society is obviously part of the solution. Therefore, proper identification and classification of the nature and causes of terrorism is one of the needed ingredients in CT measures [46]. According to Amnesty International [9,10] and Human Rights Watch [16] alienation of citizen from government due to unclear and improper orientation of the citizen on government's socio-economic policies and developmental agenda; gross ignorance and high rate of illiteracy and as well as other socio-economic problems such as high rate of youth unemployment and high poverty index are major drivers of terrorism ideologies [44],[7],[8]. Therefore, in this paper we develop an analytical framework that allows us to scrutinize the micro-foundations of CT measures aimed at increasing the cost of terrorism and also assessing the consequences of such policies. Our aim is to use a mathematical game theoretic analysis to study the possible security implications of adopting policies that withdrew the community's optimal supports from CT operatives. As observed earlier, the strategic game theoretic analysis underscores the importance of assessing such strategy of terrorism prevention and control in light of the incentives of security agencies responsible for terrorism prevention. It suggests that in a society in which State respond to major terrorist attacks by promulgating anti-humane policies, security agencies try less efficient to prevent terrorism because the pain of the attack is ameliorated somewhat by the future gains from having an ideal CT society; a finding that has several important institutional and policy implications. The game theoretic analysis can also help understanding the effectiveness of preventive measures in situations in which governments engage in pre-emptive actions to foil various social ills and, as such it contributes in no small measure to the growing political economy of prevention.

2.1 Mathematical Game Theoretic of Counter-Terrorism

By the implication of Gelernter's [55] law of loopholes in action: *"every loophole will eventually be exploited by terrorist, and every*

loophole can eventually be closed by the government". Terrorists exploit every security loopholes through continual exploration and once discovered, specific defensive measures have to be put in place to close such loophole. The net effect of this law is an ever-expanding set of security rules and requirements. Such rules and requirements are useful for helping prevent the reoccurrence of a particular type of incident. But when a determined adversary's focus is on causing general destruction and mayhem, then as one loophole is plugged, the adversary simply shifts its attention and energies to looking for and trying to exploit a different loophole. The problem of countering terrorism, of course, is that it is impossible to defend all potential targets and their associated loopholes against the threats of adversaries at all time. While it is important to review and implement certain new ideas and improved defensive tactics, it is equally as important (and arguably more important) to implement offensive strategies to deter and disrupt these adversaries. The question now is; *"how does the policy of undermining the optimal supports of a given host community during CT operations affect the likelihood of terrorism prevention and control?"* One such approach of addressing this question is through the use of game theory - the mathematical based study and analysis of adversarial conflicts [41],[5]. In the classical *"The Compleat Strategyst*" by Williams [56], the author characterizes strategic games of conflict into the following:

- ***A Conflict:*** the participants (e.g., individuals, organizations, countries; known as "players" in game theory parlance) are at cross-purposes or have opposing interests.
- ***Adversarial reaction and interaction:*** each player has some control over the course of the conflict or its outcome via one or more decisions.
- ***Outside forces:*** some aspects of the conflict are outside of the players' control and may be governed by chance or are unknown.

These characteristics clearly apply to CT operations, and game theoretic methods provide a structured way to examine how two adversaries will interact under various conflict scenarios. The results often provide insight into why real-world adversaries behave the way they do. Until recently Von Neumann [57], had enjoyed the monopoly of piloting the first extensive treatment of game theory in his book *"Theory of Games and Economic Behaviour"*. However, in the middle and late 20th century, a great deal of game theoretic research also focused on analysing the arms race, nuclear brinkmanship, and cold war strategies [58],[59]. While in the 21st century, game theory was also applied to terrorism, and 9/11 event help to expand these scope [60],[58],[5],[41]. Recent mathematical game theoretic approach to terrorism had assessed the strategic methodologies of nations' expenditures for terrorism prevention and the resulting implications of terrorist attacked. This measure evaluate how the various military-offensive strategies encourage or discourage States from sponsoring terrorism [59],[41]; assessment of insurance risks via models that explicitly account for malicious terrorist intent [46]; determination of whether or not a State policy of non-negotiation with terrorist hostage-takers would deters such behaviour and under what conditions [26]; evaluation of the effects of focusing national CT policy on deterrence or prevention and the deleterious boomerang effects of some CT measures [5].

2.2 Evolutionary Dynamic Game Theoretic of Counter-Terrorism

To address the problem statement, we present and analyse a two-player two-period evolutionary dynamic game (EDG) theoretic model of an interaction between security agencies (SA) and terrorist groups (TG) in which the outcome of period-1 interaction determines the period-2 interaction. In the present EDG theoretic model - *"Sticks-Carrots"* game, the two players - SA and TG are competing for a single resource – the community's optimal supports $x_i(t)$ so as to enable its overrun each other. Strategically, each player is at liberty to choose either the "Sticks" or the "Carrots" approach or a combination of both to win the community's optimal supports; depending on which strategy will yield the maximum payoff. The best outcome for each player is that in which one employs the *"Carrots"* approach while the other employs the *"Sticks"* approach simultaneously and vice versa. That is each player prefers to gives *"positive incentives"* to the community to support its activities, if its opponent employ *"coercive actions",* and vice versa.

As an asymmetric conflict, the loss of a community's optimal supports by one player, may not "strictly" translate to a complete gain to the other player and vice versa. But however, the payoff of the EDG is judge in-terms of the benefit

and cost of the contest. Thus, if both players play the *"Sticks"* simultaneously, the incentive is only reduced by the cost of the conflict and split equally among the player. Psychologically, the viewpoint in the game is that each player must act in such a manner that the least community supports its can win is as great as possible irrespective of what its opponent does. Considering the above argument, the strategic game theoretic reduces to a constant-sum game.

2.2.1 Rule of the Game

Consequent upon the deleterious boomerang effects of some CT measures, the rule of the stage game is that *"if there are low civilian casualty in period-1, the level of community optimal support to* SA *increase in expense of TG in period-2, and thus* SA *plays a game with higher community's optimal supports,* $(x_i(t) \geq 1,)$ *while* TG *play a game with lower community's supports* $(x_i(t) < 1)$ *in period-2. However, if there are high civilian casualty in period-1, then the level of community's optimal support to TG increases in expense of SA, and in this contingency, the SA play a game with lower community's optimal supports* $(x_i(t) < 1)$ *and TG play a game with higher community's optimal supports* $(x_i(t) \geq 1)$ *in the period-2".*

The fact that the value of $x_i(t)$ to SA is higher in period-2 if the outcome of the period-1 is low civilian casualties and vice-versa creates dynamic incentives. That is, the prospect of changing the *"level of CT activities"* should high civilian casualty occur in period-1, changes the period-2 stakes of terrorism prevention and control, which in turn alters the period-1 incentives of the players. For simplicity of exposition, we suppress time variables from the presentation of the players' actions in the stage game. By community's optimal supports, the model is hypothesizing not only the socio-moral strategic collaboration toward the enhancement of credible intelligence gathering for smart targeting of terrorist locations, terrorist attrition accuracy and internal personnel desertion rate but also for synergizing efficient de-legitimization of terrorism and its propaganda within the populace.

2.2.2 The Dynamics of the "Sticks-Carrots" Game

The basic idea of the "Sticks-Carrots" synonymous to the traditional Hawk-Dove game [23] is that the SA and TG are competing for a single resource, in this case the community's optimal supports. Winning the community's optimal support brings a benefit $(b > 0)$ to its winner, hence each player have the opportunity to play the "Sticks" while its opponent plays the "Carrots" simultaneously and vice versa. The payoffs are maximized when both players play the "Carrots". Unfortunately, most "Carrots" program in asymmetric conflict is often prone to abuse hence it pays to play the "Sticks" sometime. Couching the EDG in terms of the costs $(c > 0)$ and benefits $(b > 0)$ of winning the community's optimal supports, we see that if both players play the "Sticks" simultaneously there will be a fight and by the ethno-religious ideologies drivers of most contemporary terrorism, the TG may win some level of the community's supports. Thus, the average payoff of both players playing the "Sticks" simultaneously is $\frac{1}{2}(b-c)$. But if either of the players plays the "Sticks" when its opponent plays the "Carrots" simultaneously, the "Sticks" player receive the payoff of zero, while the payoff of the "Carrots" player receive the payoff of $(b > 0)$. If both players play the "Carrots" simultaneously, the benefit $(b > 0)$ of the community's optimal supports is split equally, such that each play gets an average payoff of $\left(\frac{b}{2}\right)$. The strategic form of the game is given by the payoff matrix of Fig. (1):

Terrorist Group

Security Agency	S	C
S	$\frac{1}{2}(b-c), \frac{1}{2}(b-c)$	$0, b$
C	$b, 0$	$\frac{b}{2}, \frac{b}{2}$

Fig. 1(a). Payoff matrix

Security Agency

	S	C
S	$\frac{1}{2}(b-c)$	0
C	b	$\frac{b}{2}$

Fig. 1(b). SA payoff matrix

Terrorist Group

	S	C
S	$\frac{1}{2}(b-c)$	b
C	0	$\frac{b}{2}$

Fig. 1(c). TG payoff matrix

3. ANALYSIS OF THE EVOLUTIONARY DYNAMIC GAME THEORETIC MODEL

The idea of evolutionary stable strategy (ESS) in a typical Hawk-Dove game, as observed by Essam [61] was introduced and defined by the British biologists Maynard and Price in [62]. The idea is that in a given contest, on average, one strategy will win over any other strategies. Thus, a player with ESS ought to additionally have the advantage of doing great when set against players utilizing the same strategy. This is important, because a successful strategy is likely to be common and the player will probably have to compete with others who are employing it. However, ESS does not have to be a single strategy, but can be a combination of strategies or a combination of players where each utilizes only one strategy. According to Essam [61] two conditions for a strategy X to be a ESS are:

Condition 3.0: Let $\pi(X,X)$ denotes a player-i payoff for playing X strategy against player-j playing X strategy simultaneously, and $\pi(Y,X)$ denotes a player-i payoff for playing X strategy against player-j playing Y strategy simultaneously. Then X is an ESS if either:

(i) $\pi(X,X) > \pi(Y,X)$: Payoff for playing X against X simultaneously is greater than that of playing Y against X simultaneously, for all $X \neq Y$. Or

(ii) $\pi(X,X) = \pi(Y,X)\ and\ \pi(X,Y) > \pi(Y,Y)$: Payoff for playing X against X simultaneously is equal to that of playing Y against X simultaneously, for all $X \neq Y$, or

Note that either condition (i) or (ii) will do and that the previous is a more grounded condition than the later. Clearly, if condition (i) holds, then Y player will commonly lose against X player, and along these lines Y payoff can't even increase with any achievement. If condition (ii) holds, then Y player does as well against X player; as X player will lose against itself but it loses to X player against other Y player, and therefore it cannot multiply. In short, Y players cannot successfully invade a population of X players. It is conceivable to present a strategy that is stronger than an ESS, namely, an unbeatable strategy.

Definition 3.1: Strategy X is unbeatable if, given whatever other strategy Y:

$$\pi(X,X) = \pi(Y,X) \text{ and } \pi(X,Y) > \pi(Y,Y) \quad (3.0)$$

3.1 Evolutionary Stable Strategy of the "Sticks-Carrots" Game

Consider the game in Fig. (1); by Condition 3.0 the (C,C) is an unstable strategy since

$$\frac{1}{2}b = \pi(C,C) < \pi(S,D) = b \quad (3.1)$$

This is intuitive and consistent with existing scholarship which depicts "Carrots" objective in CT operations as susceptible to psychological abused and misconstrued. Thus, a purely "Carroted" community can always be coerced to cooperate, since

$$\pi(S,S) = \frac{1}{2}(b-c)\ and\ \pi(C,S) = 0 \quad (3.2)$$

The "Sticks" therefore is an ESS if $b > c$, but if $b < c$, then neither the "Sticks" nor the "Carrots" is an ESS. *But what would happen if both players are able to play mixed strategies as the game in Fig. (1) shows; if there exist a mixed strategy that is evolutionary stable?*

Suppose both players are able to play a mixed strategy, i.e. sometimes "Sticks" and sometimes "Carrots" with probabilities p and $(1-p)$ respectively. For a mixed ESS say D to exist the following must hold:

$$\pi(C,D) = \pi(S,D) = \pi(D,D) \quad (3.3)$$

Suppose also that there exists an ESS in which "Sticks" and "Carrots", which are played with positive probability, have different payoffs. Then it is worthwhile for the player to increase the weight given to the strategy with the highest payoff since this will increase expected utility. But this means that the original mixed strategy was not a best response and hence not part of an ESS, which is a contradiction. Therefore, it must be that in an ESS all strategies with positive probability yield the same payoff. Thus:

$$\left.\begin{aligned} \pi(S,D) = \pi(C,D) &\Leftrightarrow p\pi(S,S) + (1-p)\pi(S,C) = p\pi(C,S) + (1-p)\pi(C,C) \\ &\Leftrightarrow \frac{p}{2}(b-c) + (1-p)b = (1-p)\frac{b}{2} \\ &\Leftrightarrow p = bc^{-1} \end{aligned}\right\} \quad (3.4)$$

Thus, a mixed strategy with a probability (bc^{-1}) of playing "Sticks" and a probability $\left(\frac{c-b}{c}\right)$ of playing "Carrots" is an ESS that cannot be overcome by players playing one of the pure strategies of "Sticks" or "Carrots".

3.2 Nash Equilibrium of the "Sticks –Carrots" Game

To find the Nash equilibrium point of this game that is intuitive and consistent with empirical evidence, let β be the probability of SA playing the "Sticks" and $(1-\beta)$ be the probability of SA playing the "Carrots" conditional on TG playing the "Sticks" (in the first column) and "Carrots" (in the second column) respectively. Similarly, let α be the probability of TG playing the "Sticks" and $(1-\alpha)$ be the probability of TG playing the "Carrots" conditional on SA playing the "Sticks" (in the first row) and "Carrots" (in the second row) respectively. Therefore, SA's payoff or best-response function can be given by:

$$\pi_1(\beta,\alpha) = \beta\alpha\pi_1(HH) + \beta(1-\alpha)\pi_1(HD) - \alpha(1-\beta)\pi_1(DH) + (1-\beta)(1-\alpha)\pi_1(DD) \qquad (3.5a)$$

Apply Fig. (1), the SA's payoff is given by:

$$\left.\begin{aligned}\pi_1(\beta,\alpha) &= \frac{\alpha\beta}{2}(b-c) + \alpha b(1-\beta) + (1-\alpha)(0) + (1-\alpha)(1-\beta)\frac{b}{2}\\ &= \frac{1}{2}(b(1+\alpha-\beta) - c\alpha\beta)\end{aligned}\right\} \qquad (3.5b)$$

By similar algebra the TG's payoff function can also be given by:

$$\pi_2(\beta,\alpha) = \beta\alpha\pi_2(HH) + \beta(1-\alpha)\pi_2(HD) - \alpha(1-\beta)\pi_2(DH) + (1-\beta)(1-\alpha)\pi_2(DD) \qquad (3.6a)$$

Also apply Fig. (1), the TG's payoff is given by:

$$\left.\begin{aligned}\pi_2(\beta,\alpha) &= \frac{\alpha\beta}{2}(b-c) + \alpha(1-\beta)(0) + (1-\alpha)\beta b + (1-\alpha)(1-\beta)\frac{b}{2}\\ &= \frac{1}{2}(b(1-\alpha+\beta) - c\alpha\beta)\end{aligned}\right\} \qquad (3.6b)$$

Since the objective of SA is terrorism prevention and control, then $\pi_1(\beta,\alpha) > \pi_2(\beta,\alpha); and\ \pi_1(\beta,\alpha) - \pi_2(\beta,\alpha) = \Delta_1$ - denotes SA stake in terrorism prevention and control:

$$\left.\begin{aligned}\Delta_1 &= \pi_1(\beta,\alpha) - \pi_2(\beta,\alpha)\\ &= \frac{1}{2}(b(1+\alpha-\beta) - c\alpha\beta) - \frac{1}{2}(b(1-\alpha+\beta) - c\alpha\beta)\\ \Delta_1 &= (\alpha-\beta)b\end{aligned}\right\} \qquad (3.7a)$$

Similarly, if TG must succeed in perpetrating acts of terrorism, then $\pi_2(\beta,\alpha) > \pi_1(\beta,\alpha); and\ \pi_2(\beta,\alpha) - \pi_1(\beta,\alpha) = \Delta_2$ – denotes TG's stake in perpetrating acts of terrorism:

$$\left.\begin{aligned}\Delta_2 &= \pi_2(\beta,\alpha) - \pi_1(\beta,\alpha)\\ &= \frac{1}{2}(b(1-\alpha+\beta) - c\alpha\beta) - \frac{1}{2}(b(1+\alpha-\beta) - c\alpha\beta)\\ \Delta_2 &= (\beta-\alpha)b\end{aligned}\right\} \qquad (3.7b)$$

Furthermore, taking the partial derivative of equation 3.5(b) wrt (α), we have:

$$\frac{\partial\pi_1}{\partial\alpha} = \frac{b-\beta c}{2}\begin{cases}>0; & if\ \beta < bc^{-1}\\ =0; & if\ \beta = bc^{-1}\\ <0; & if\ \beta > bc^{-1}\end{cases} \qquad (3.8a)$$

So that the optimal α is given by

$$\alpha = \begin{cases} 1; & if\ \beta < bc^{-1} \\ [0,1]; & if\ \beta = bc^{-1} \\ 0; & if\ \beta > bc^{-1} \end{cases} \quad (3.8b)$$

Similarly, taking the partial derivative of equation 3.6(b) wrt (β), we have:

$$\frac{\partial \pi_2}{\partial \beta} = \frac{b - \alpha c}{2} \begin{cases} > 0; & if\ \alpha < bc^{-1} \\ = 0; & if\ \alpha = bc^{-1} \\ < 0; & if\ \alpha > bc^{-1} \end{cases} \quad (3.9a)$$

So that the optimal β is given by

$$\beta = \begin{cases} 1; & if\ \alpha > bc^{-1} \\ [0,1]; & if\ \alpha = bc^{-1} \\ 0; & if\ \alpha < bc^{-1} \end{cases} \quad (3.9b)$$

This gives the diagram depicted in Fig. (2). The best response functions intersect in three places, each of which is a Nash equilibrium. However, the only symmetric Nash equilibrium, in which the players cannot condition their moves on whether they are SA or TG is the mixed-strategy Nash equilibrium (bc^{-1}, bc^{-1}).

4. RESULTS OF THE ANALYSIS AND DISCUSSION

Considering the inherent deleterious boomerang effect associated with the cost intensive "Sticks" approach (military offensive) to combating terrorism, the result of analysis can be interpreted practically under the two sub-game variants (i) Symmetric game, and (ii) Asymmetric game, (iii) The security rationale of playing the "Sticks", the "Carrots" and the combined "Carrots and Sticks" strategy.

4.1 The Symmetric Game: Practical Example-1

Suppose the benefit of winning the community's optimal support $(b = 1)$ and the cost is $(c \geq 1)$. Time is valuable; until the first concession each player loses one unit of payoff per unit of time. From Fig. 1(a), a game that captures this scenario; shown in Fig. 3, has two Nash equilibriums *SC* and *CS* corresponding to two different conventions about the player who yields.

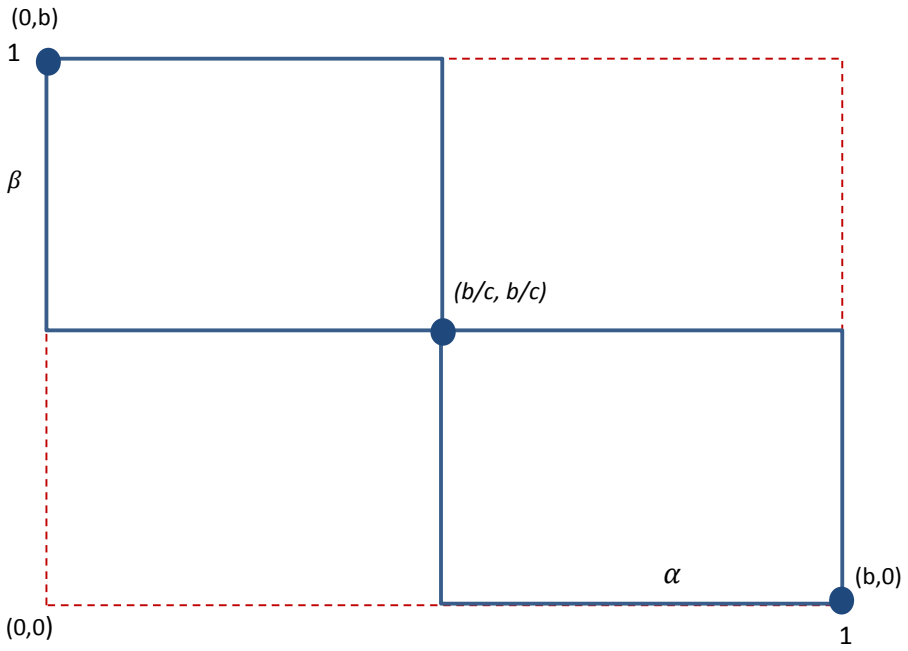

Fig. 2. Nash equilibriums in "Sticks-Carrots" CT game

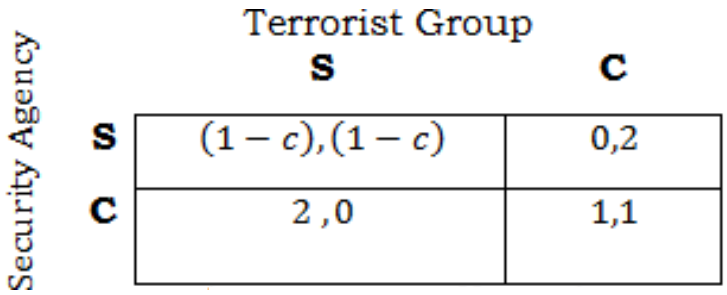

Fig. 3. Payoff matrix

In order to find the players' security (or max-min) strategies in the symmetric game, let:

(i) $EU_1(\beta|S)$ denotes SA's expected payoff conditional on TG playing the "Sticks" (in first column),
(ii) $EU_1(\beta|C)$ denotes SA's expected payoff conditional on TG playing the "Carrots" (in second column),
(iii) $EU_2(\alpha|S)$ denotes TG's expected payoff conditional on SA playing the "Sticks" (in the first row), and
(iv) $EU_2(\alpha|C)$ denotes TG's expected payoff conditional on SA playing the "Carrots" (in the second row).

Therefore from Fig. 3,

$$\left.\begin{matrix} EU_1(\beta|S) = -\beta - \beta c + 2 \\ EU_1(\beta|C) = 1 - \beta \end{matrix}\right\} \Rightarrow \beta = c^{-1} \quad (4.0a)$$

Note: that $EU_1(\beta|S)$ represents the expected utility that SA obtains from randomizing between the "Sticks" (with probability β) and the "Carrots" (with probability $1-\beta$) conditional on TG playing the "Sticks" (in the first column) and "Carrots" (in the second column) respectively. By equation (7a); $EU_1(p|C) = EU_1(p|S) = 1 - c^{-1}$. Also, TG's expected payoff $EU_2(\alpha|S)$ and $EU_2(\alpha|C)$ conditional on SA playing the "Sticks" (in the first row) and "Carrots" (in the second row) respectively are:

$$\left.\begin{matrix} EU_2(\alpha|S) = -\alpha - \alpha c + 2 \\ EU_2(\alpha|C) = 1 - \alpha \end{matrix}\right\} \Rightarrow \alpha = c^{-1} \quad (4.0b)$$

Note that $EU_2(\alpha|S)$ represents the expected utility that TG obtains from randomizing between the "Sticks" (with probability α) and the "Carrots" (with probability $1-\alpha$) conditional on SA playing the "Sticks" (in the first row) and "Carrots" (in the second row) respectively. By equation (4.0b), $EU_2(p|C) = EU_2(p|S) = 1 - c^{-1}$, and by equation (3.8a) the SA's stake in terrorism prevention by the "Sticks" approach $\Delta_1 = (\alpha - \beta)b = 0$. And by equation 38(b) $TG's$ stake in perpetrating acts of terrorism by "Sticks" approach $\Delta_2 = (\beta - \alpha)b = 0$. The SA's security strategy in the symmetric game is depicted diagrammatically in Fig. (4).

Thus, considering that the primary objective of SA is to win the given community's optimal support for effective terrorism prevention and control, the equation (4.0a) shows that under the symmetric game, the probability of achieving this proud objective by playing the "Sticks" is inversely proportional to the cost of executing a credible CT operations $(i.e. \beta = c^{-1})$ – free-collateral damage and free-civilian casualty CT operations. Thus, if the cost of executing credible CT operation is high, then SA playing the "Sticks" with a probability of (c^{-1}) is not an optimal strategy; as this would amount to *"burning the candle at both ends"*. Rather playing the "Carrots" with a probability of $(1 - c^{-1})$ would yield an optimal strategy. As the "Carrots" would not only help to mitigate the inherent blowback syndrome of the "Sticks" approach; won the community's optimal supports and cooperation for credible intelligence gathering but also help to wean back susceptible terrorist and individuals from terrorism and other insurgency activities. Furthermore, to mitigate the inherent psychological abuse and misconstrued of the "Carrots" objectives, a meticulous combination of "Carrots and Sticks" approaches with a probability of (bc^{-1}) is an evolutionary stable strategy (ESS). In such combination, while the "Carrots" instruments would serve as a motivator, the "Sticks" factors would help to check possible abuse of the "Carrots" as well as coerce compliance from recalcitrant "Carrots" recipients. This would help the SA to consolidate on the community's optimal supports, provided such "sticks" approach is not cost intensive or counterproductive to the CT objectives

Table 1. Data Statistics of the Symmetric Game

Cost of CT (c)	0.1	0.2	0.3	0.04	0.5	0.6	0.7	0.8	0.9	0.1
SA: Sticks (β)	1	0.5	0.333	0.25	0.2	0.167	0.143	0.125	0.111	0.1
SA: Carrots $(1-\beta)$	0	0.5	0.667	0.75	0.8	0.833	0.857	0.875	0.889	0.9

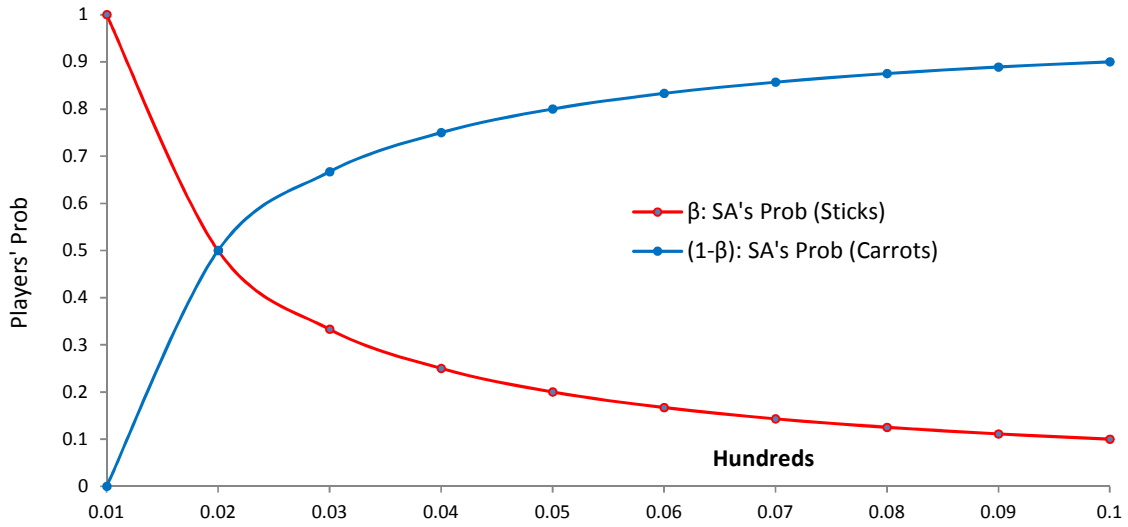

Fig. 4. Security Strategy of the Symmetric Game

The Fig. 4 also corroborates the hypothesis that, the SA's probability of playing either the "Sticks" or "Carrots" in the stage game, varies with the cost of executing a credible CT operation. Thus, the red curve shows that if the operational cost is high, then SA playing the "Carrots" would yield a higher probability of winning the community's optimal supports than playing the "Sticks" and vice versa.

However, if the operational cost drops by 80% (0.02), then SA playing the "Sticks" or the "Carrots" would yield a 50:50 (0.5) probability. Comparatively, at 30% rise in the operational cost, the SA playing the "Sticks" would have at-most 0.333 (33.3%%) probability of winning the given community's optimal supports for effective terrorism prevention and control, while the "Carrots" would yield at-least 0.667 (66.7%) probability. These parameters are intuitive and consistence with empirical evidence and are synonymous with the TG's security strategies; as both players would enjoy 50:50 chance of playing the "Carrots" at high operational cost or the "Stick" at low operational cost.

Therefore, considering the high cost of acquiring the necessary and sufficient military arsenals, logistics and intelligence for executing credible CT operation, the analysis shows that playing the "Carrots" with the probability of $(1-c^{-1})$ is an optimal strategy. As a viable "Carrots" would not only guaranteed zero collateral damages and civilian casualty-free operation; elicit the community's optimal supports and cooperation for credible intelligence gathering; wean susceptible terrorists operatives and individuals from terrorism and other insurgency activities but would also help to build the needed confidence, cooperation and trust necessary for efficient collaborative image laundry/anti-terrorism propaganda's campaign and also synergize the effective de-legitimization of terrorism and its propaganda within the populace. General both players stakes in stage game by "Sticks" approach is zero. Hence, both players cannot elicit a given community's optimal support for their successful operation by the "Sticks" approach.

4.2 The Asymmetric Game: Practical Example 2

Considering the ethno-religious ideology drivers of most contemporary terrorism, and the inherent strong communal bonds existing between a terrorist operative and its host community as well as the common erroneous believes that the

terrorists are fighting for the good of the community; the benefit of the stage game in an heterogeneous environment may split in the ratio of $b_0:(b-b_0)$; where $(b_0>0)$ denotes the fanatical population and $(b-b_0)$ denotes the non-fanatical populations. Thus, in such scenario, if the SA plays the "Carrots" while TG plays the "Sticks" simultaneously, the community's optimal supports will split such that SA receives the payoff $(b-b_0)$ (non-fanatical), while the TG receives the payoff of b_0 (the fanatical). But if the TG plays the "Carrots while the SA plays "Sticks" simultaneously; then TG would receive the payoff of $b>0$ while the SA crash out $(b=0)$. However, if both players play the "Sticks" simultaneously, the outcome would split such that the SA would receive an average payoff of $\frac{1}{2}(2b-b_0-c)$, while the TG would receive an average payoff of $\frac{1}{2}(b_0-c)$. Fig. 5 is a game that captures this conceptualization.

Terrorist Group

Security Agency	S	C
S	$\left(\frac{2b-b_0-c}{2}\right), \frac{b_0-c}{2}$	$0, b$
C	$(b-b_0), b_0$	$\frac{b}{2}, \frac{b}{2}$

Fig. 5. Asymmetric Payoff Matrix

Similarly, to determine the security (Max-min) strategies of the players in the asymmetric game, let

(i) $EU_1(\beta|S)$ denotes SA's expected payoff conditional on TG playing the "Sticks" (in first column),
(ii) $EU_1(\beta|C)$ denotes SA's expected payoff conditional on TG playing the "Carrots" (in second column),

Therefore from Fig. 5,

$$\left.\begin{aligned} EU_1(\beta|S) &= \frac{1}{2}\beta b_0 - \frac{1}{2}\beta c - b_0 + 1 \\ EU_1(\beta|C) &= \frac{1}{2}(1-\beta) \end{aligned}\right\} \Rightarrow \beta = \frac{2b_0-1}{b_0-c+1};\ \lim_{b_0\to 0}\beta = [c-1]^{-1} \qquad (4.1a)$$

Similarly, let

(i) $EU_2(\alpha|S)$ denotes TG's expected payoff conditional on SA playing the "Sticks" (in the first row), and
(ii) $EU_2(\alpha|C)$ denotes TG's expected payoff conditional on SA playing the "Carrots" (in the second row).

And from Fig. 5,

$$\left.\begin{aligned} EU_2(\alpha|S) &= \frac{1}{2}\alpha b_0 - \frac{1}{2}\alpha c - \alpha + 1 \\ EU_2(\alpha|C) &= \alpha b_0 - \frac{1}{2}\alpha + \frac{1}{2} \end{aligned}\right\} \Rightarrow \alpha = \frac{1}{b_0+c+1};\ \lim_{b_0\to 0}\alpha = [c+1]^{-1} \qquad (4.1b)$$

By equation (3.8a) the SA's stake in terrorism prevention and control by the "Sticks" approach is given by:

$$\Delta_1 = (\alpha-\beta)b = -2(c^2-1)^{-1} \qquad (4.1c)$$

Also by equation (3.8b) the TG's stakes in perpetrating terrorist acts by "Sticks" is given by

$$\Delta_2 = (\beta-\alpha)b = 2(c^2-1)^{-1} \qquad (4.1b)$$

This result is diagrammatically depicted in Fig. 6:

Table 2. Data Statistics of the Asymmetric Game

Cost of CT (c):	**0.1**	**0.2**	**0.3**	**0.04**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1**
TG – Sticks (α):	0.5	0.333	0.25	0.2	0.167	0.143	0.125	0.111	0.1	0.09
TG – Carrots $(1-\alpha)$:	0.5	0.667	0.75	0.8	0.833	0.857	0.875	0.889	0.9	0.909
SA – Sticks (β):		1.0	0.5	0.333	0.25	0.2	0.167	0.143	0.125	0.111
SA – Carrots $(1-\beta)$:		0	0.5	0.667	0.75	0.8	0.833	0.857	0.875	0.889
SA's Stake (Δ_1):		-0.667	-0.25	-0.133	-0.083	-0.057	-0.042	-0.032	-0.025	-0.02
TG's Stake (Δ_2):		0.667	0.25	0.133	0.083	0.057	0.042	0.032	0.025	0.02

The Fig. 6 shows that under the Asymmetric game; the players' probability of playing either of the "Sticks" or the "Carrots" strategies also varies with the cost of executing credible CT operations. Thus, at 80% (0.02) drops in the operational cost, the SA playing the "Sticks" would have 100% chance of winning the community's optimal supports, while the "Carrots" would yield 0% chance. Conversely, the TG playing the "Sticks" at 80% (0.02) drop in operational cost would enjoy at least 33.3% (0.333) of optimizing the community's support for disastrous terrorist activities, while the "Carrots" would yield at most 66.7% (0.667) chance.

However, if the cost of CT operation drops by 70% (0.03), then SA playing the "Sticks" or the "Carrots" would have 50:50 chance of winning the community's optimal supports, while the TG would only enjoy a 50:50 chance of winning the community's optimal supports for terrorism activities by either "Sticks" or "Carrots" approach if the operational cost drops by 90%. Thus, at high operational cost both players have high probability of winning the community's optimal supports for their respective objectives by playing "Carrots" than playing the "Sticks".

By comparatively analysis, the black doted curves of Fig. 6 shows emphatically that under the asymmetric game, the SA's stakes in terrorism prevention/control through the "Stick" approach is virtually unpredictable in view of the cost implication of plotting a credible CT operation, hence the negative probabilities. While the orange doted curve shows that TG's stake in terrorism perpetration decrease exponentially with increase operational cost, hence the positive probabilities. Generally, if the cost of operation is low, playing the "Sticks" favours both players, and playing the "Carrots" if otherwise.

4.3 Evolutionary Stable Strategy (ESS)

Under the available mixed strategies of "Sticks" and "Carrots", the analysis also shows that if the benefit of executing a credible CT operation exceed the operational cost $(b > c)$, then SA playing the "Sticks" or the "Carrots" is an ESS, otherwise neither the "Sticks" nor the "Carrots" is an ESS. However, if the operational cost exceeds the benefit $(b < c)$, then a combination of the "Sticks and Carrots" approaches would yield an ESS with a probability of bc^{-1}, and a mixed strategy Nash equilibrium of (bc^{-1}, bc^{-1}). Thus, considering the inherent propensity of abuse and misconstrued of "Carrots" objectives, in the event of failed "Carrots" approach a combination of "Sticks" (credible threat of retaliation or other enforcement mechanism) with viable "Carrots" is necessary and sufficient strategy to elicit the community's optimal support and cooperation for effective terrorism prevention/control; provided such retaliatory threat is not cost intensive or counterproductive to the CT objectives. The idea behind ESS is that in a given contest such as CT operation, on average, one strategy must win over any other strategies. Thus, a player with ESS ought to additionally have the advantage of doing great even when set against another player utilizing the same strategy.

4.4 The Security Rationale of Playing the "Sticks" Strategy

Considering the cost implication of executing a credible (civilian casualty-free) CT operation, the red curves of Figs. 4 and 6, above shows that the probability of both players winning the community's optimal support for their respective agenda through the "Sticks" strategy decreases exponentially with the cost of operations in both variants of the game. For the asymmetric game, the minimum operational cost of the "Sticks" approach that would harvest the maximum community's support (100%) for the SA is when the cost drops by 80%, while the symmetric game would yield the maximum community support at 90% drop in operational cost.

Thus, with the purely "Sticks" strategy, neither of the players can optimize the community's support for their respective agenda. As such strategy is susceptible to high-mindedness, human victimization, collateral damages and high civilian casualties that provoke "Herostratos syndrome", fuel and heighten animosity within the disaffected youth populations. These often harvest the community's optimal supports to the TG in expense of the SA. And since the success of CT operation depends to a greater extent on the host community's optimal supports, cooperation and collaboration for at least credible intelligence gathering for smart targeting of terrorist locations, therefore, the SA cannot optimally prevent terrorism with the "Sticks" approach only. Though the variability of operational cost with the SA probability of optimizing the community supports is a little preferential to SA, the purely "Sticks" approach is counter-productive to the government counterterrorism objectives.

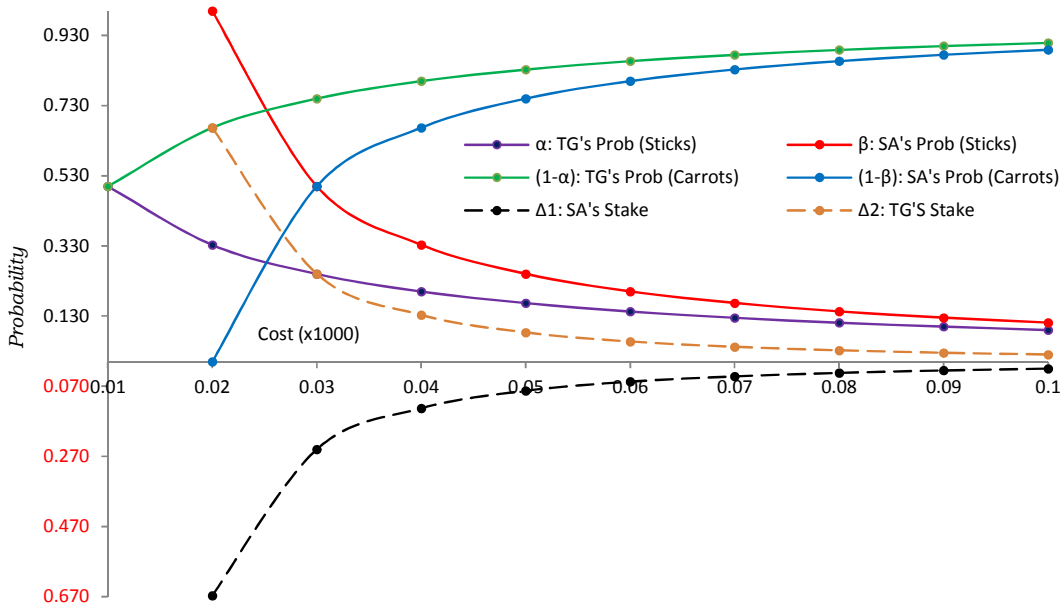

Fig. 6. Security Strategy of the Asymmetric Game

4.5 The Security Rationale of Playing the "Carrots" Strategy

Similarly, given the cost implication of a credible (civilian casualty-free) CT operation, the blue curves of Figs. 4 and 6, above shows that the probability of both players winning the community's optimal support for their respective objectives through the "Carrots" strategy in both variants of the game exhibit a parabolic increase with the cost of operations. Comparatively, in the asymmetric game the minimum operational cost that would harvest at least 50% of the community's optimal supports to SA is when the cost rise by 30%, while the SA would enjoy as much as 88.9% of the community's optimal support when the cost of operation rises by 70%. In the symmetric variant, the minimum operational cost that could harvest at least 50% of the community's support is when the cost rises by 20%, while the SA would enjoy as much as 90% of the community's optimal support when the cost of operation rises by 80%.

Thus, with viable "Carrots" instruments, the SA is certain of optimizing the community's support for credible terrorism prevention/control. As such strategy is capable of beguiling, motivating, and eliciting behaviour compliance and cooperation from both the adaptive adversary and the locals. A viable "Carrots" instrument would not only (i) yield zero collateral damage and civilian casualties; (ii) elicit the community's optimal supports and cooperation for credible intelligence gathering (since the locals have much better intelligence as to who are, and where the terrorists are located in their community); (iii) wean susceptible terrorists operatives/individuals from terrorism and other related vices, but also (iv) help to build credible trust, confidence, and cooperation necessary for efficient collaborative image laundry/anti-terrorism ideologies campaign operations as well as help to de-legitimize terrorism and its propaganda within the populace.

Since most terrorists do not wear identifying uniforms, nor confine themselves to a remarkable geographical hub (e.g. barracks), nor do they obey the conventional warfare rules and regulation; therefore ideal CT measures must include a commitment to psychologically de-legitimize terrorism and its propaganda among local populace. For effective and efficient de-legitimization process, government must give the local population more legitimacy and concession in order to gain their cooperation and optimal supports. The SA must promote, encourage and protect the privacy of local population who can serve as necessary informants. They must collaborate and work together with the local communities, motivate and respect their fundamental human right as these will engender

trust and confidence building between the governed and the government.

The use of "Carrots" approach would elicit the necessary moral supports for the initiation of an all-inclusive, proactive and efficient in-group-policing mechanism between the SA and the local population. In-group-policing and cooperation with the local population will yield much more result than military crackdowns on innocent civilian population; and the collective punishment approach as well as the indiscriminate violence strategies of the "Sticks" approach. Moreover, taking the local populations support away from the terrorist's organization will creates serious havoc for the terrorists and its cause receives less attention and thus becomes delegitimized. These efforts are not only the necessary and sufficient conditions but imperative because every ethno-ideological driven terrorism are derivatives of a specific part of the population and are perceived to fight for the course and rights of their group. Hence they oftentimes find great support within their host community and their course is seen as a legitimate.

4.6 The Security Rationale of Playing the Combined "Carrots and Sticks" Strategy

Unfortunately, considering the inherent psychological inclination of abused and misconstrued objectives, the perception from "Carrots" recipients may be of a bribe tainting both the donor and recipient or equally distasteful payment from a master to a servant. Thus, if "Carrots" is offered arrogantly by the State without cognizance of the recipients narrow-mindedness, who may see the "Carrots" as bribes or arm-twisting, the results may be short termed and counter-productive in the longer term. Therefore, to harvest the desired utility of the "Carrots", the analysis also shows that the simultaneous deployment of the "Sticks" with the "Carrots" (mixed strategy) would help to consolidate the gain from the viable "Carrots" instruments.

While the State must be unprejudiced and proportional in its application of "rewards" (Carrots) and "punishments" (Sticks), their unprejudiced motive must also be just in the eyes of the locals, the terrorists and other stakeholders, not simply in the eyes of the Donor State. In such a situation, the reward for compliance would not be seen as a bribe or a payment for ransom, but simply as an expected consequence of working for a just course. To make the States unprejudiced motive more compelling and attractive to the terrorists and the locals, their different values and perceptions must be taken into consideration. Thus, the simultaneous application of the "Sticks and Carrots" instruments in such asymmetric warfare as CT operation and in heterogeneous battlefield would yield an evolutionary stable strategy (ESS).

5. CONCLUSION

In the wake of incessant high profile terrorist attacks and other insurgency activities that characterized the 21st century, liberal society began witnessing what has become almost a rite of victimization, privacy-invasion and rise in aggressive inhumane policies, all in the guise to preventing terrorism and the propagation of its propaganda. It's not uncommon that when terrorists strike; there is an overwhelming political obligation to fix things so that the events will not be repeated. However, the *what if something awful happens again syndrome* has created a political scenario in which it is easier for any aggressive anti-humane CT policies to be formulated with immediate alacrity, since no politician wants to be blamed or termed lackadaisical in respect of national security protection. To aggravate the problem, the aftermath of any terrorist attacks has afforded security agencies the opportunities to push for CT measures that are not attainable in ideal democracy, regardless of their ineffectiveness and unethical implications.

While the symbolic and political rationales of such measures are clear, perhaps less understood are the implications of the high-mindedness and havoc it raise on large population of innocent civilians as well as it counter-productivity to the relevant government CT objectives. To study the possible security implications of such CT measures which undermine the optimal supports of the populace during CT operations, we've develop a two-person-two-period evolutionary game-theoretic model of an interaction between the security agencies and terrorist organizations competing for the optimal support of a given host community in order to actualize their respective mandates.

Considering the cost implications and the benefits of executing a credible (civilian casualty-free) CT operation, the results of the analyses shows that any measure (military-offensive or

Sticks) that is capable of undermining the optimal supports of a given host community, cannot engender or guarantee high probability of terrorism prevention and control. But rather, such effort may invoke a deleterious boomerang effect that in-turn harvest undue supports and recruits for the terrorist. Thus, making the terrorist organization more resilience with more terrorist activities than would ideally be expected [3],[34],[4],[5,6].

In the comparative variant, the analysis also shows that a measure (e.g. Carrots) that could garner or elicit the host community's optimal supports and cooperation would be economically more viable and susceptible to yielding a high probability of terrorism preventing/control than otherwise. However, since research has shown that a purely "Carroted" system is susceptible to psychological abused or misconstrued, the analysis further highlighted and appraised the essence of simultaneous deployment of viable "Carrots" with credible "Sticks" (credible threat of retaliation or other enforcement mechanism) approaches, to yield an evolutionary stable strategy (ESS). The complementation of the "Carrots" approach with credible threat is not only necessary to coerce behaviour compliance or cooperation from recalcitrant "Carrots" recipients, but also to synergize credible intelligence gathering environment as well as effective de-legitimization of terrorism and its propaganda from the community, hence optimizing the system performance.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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