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This Briefing Paper addresses the potential of mathematical models to identify risk, resilience and volatility factors in terrorist activities. Analysis of terrorist events in three South East Asian states – Indonesia, Thailand and the Philippines – were undertaken using self-exciting models. The authors propose that the mathematical model findings for each state can be useful in determining counter-terrorism policy and practice, and advocate further research into this methodology.

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Modelling the Dimensions of Terrorist Activity: Risk, Resilience and Volatility

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Introduction

Patterns of terrorist activity show great variation over short periods of time. Closely examining this variation from multiple perspectives can help understand the risks associated with terrorist activity. The framework proposed in White, Porter & Mazerolle (2012) notes that the temporal patterns of terrorist activity can consist of three components: risk, resilience and volatility. Drawing on the current understanding of terrorist activity and sophisticated mathematical models, this paper offers a quantitative description of these three properties, illustrated by the different and diverse histories of terrorism in Indonesia, the Philippines, and Thailand between 2000 and 2010. These histories are outlined below.

Indonesia

The early 21st century has seen some of the deadliest terrorist attacks in Indonesian history. Spurred by the desire for self-determination, religious and ideological motivations, terrorist organisations in Indonesia have waged a bloody war against the state. A resurgence of the separatist group, the Free Aceh Movement (GAM) occurred in the early 21st century (Ross, 2005), after a prolonged period of ceasefire was interrupted by a failed peace agreement with the government. GAM's activities tapered off in 2004 and 2005 as they reached an accord with the government, and joined the mainstream political process. This period also saw the rise of Jemaah Islamiyah (JI), a radical Islamist group responsible for the Bali bombings on October 12th, 2002, killing over 200 people. The Bali bombings have been labelled the deadliest terrorist attack since the events of September 11th, 2001. The rise of JI over the last decade has seen almost an annual frequency of attacks (Abuza, 2010). Despite this, 2001 marks the start of a steady decline in the frequency of terrorist activity in Indonesia (Porter, White & Mazerolle, 2012).

The Philippines

Territorial conflicts over independence have occurred throughout the Philippines' history for over 400 years. These conflicts are centered in the Mindanao region, and encompass both ethnic and religious differences. Violence in the 21st century is the product of a new wave of increased religious extremism, though still related to the larger scale conflicts involving self-determination and other political rights (Banlaoi, 2007). In 2000 the Philippine government abolished a peace agreement with the Moro Islamic Liberation Front (MILF), who retaliated by declaring a jihad, marking a resurgence of terrorist activity in the Philippines. The Abu Sayyaf Group (ASG) has also gained prominence over the last decade, with some arguing it is the

most active and most violent of Islamic separatist movements in the Philippines (ADL, 2004). The conflict between these terrorist groups and the Filipino government has seen peaks of activity in 2000 and 2003, with a substantial increase from 2008 to 2010. As forecast by Labrador (2002), the period from 2000 through to 2010 saw increased violence across the Philippines.

Thailand

Thailand has a history of conflict with Malay Muslims in the southern provinces of Yala, Pantani and Narthwat. This conflict lacks central organization and is a result of independent actors from a variety of established groups (Chalk, 2008). These long-standing tensions escalated after the 2001 elections and installation of the Thai Rak Thai party, which overturned many of the existing government policies concerning the treatment and representation of Malay-Muslims. In 2003 the Thai government supported the US led invasion of Iraq. This, coupled with the corruption of the national police force and increased presence of JI (Chongkittavorn, 2004) led to a significant escalation in the tempo and severity of attacks, with several attacks on military and police targets, culminating in the siege of the Krue Se mosque (Chalk, 2008).

All the above conflicts pose a major transnational threat in the South East Asian region and an extraordinary amount of funding, resources and aid is dedicated to counter-terrorism interventions. The events of September 11th, 2001 stimulated a massive increase in government spending all over the world to fund research into empirical methods for assessing patterns of terrorist acts, which would allow a more objective evaluation and comparison of activity patterns for both tactical and strategic analysis, and in assessing the effectiveness of counter-terrorism interventions.

Current Framework

A sizeable body of theoretical and empirical research suggests that terrorist events do cluster over time, and self-exciting models are a good model to illustrate this. For example,

Figure 1

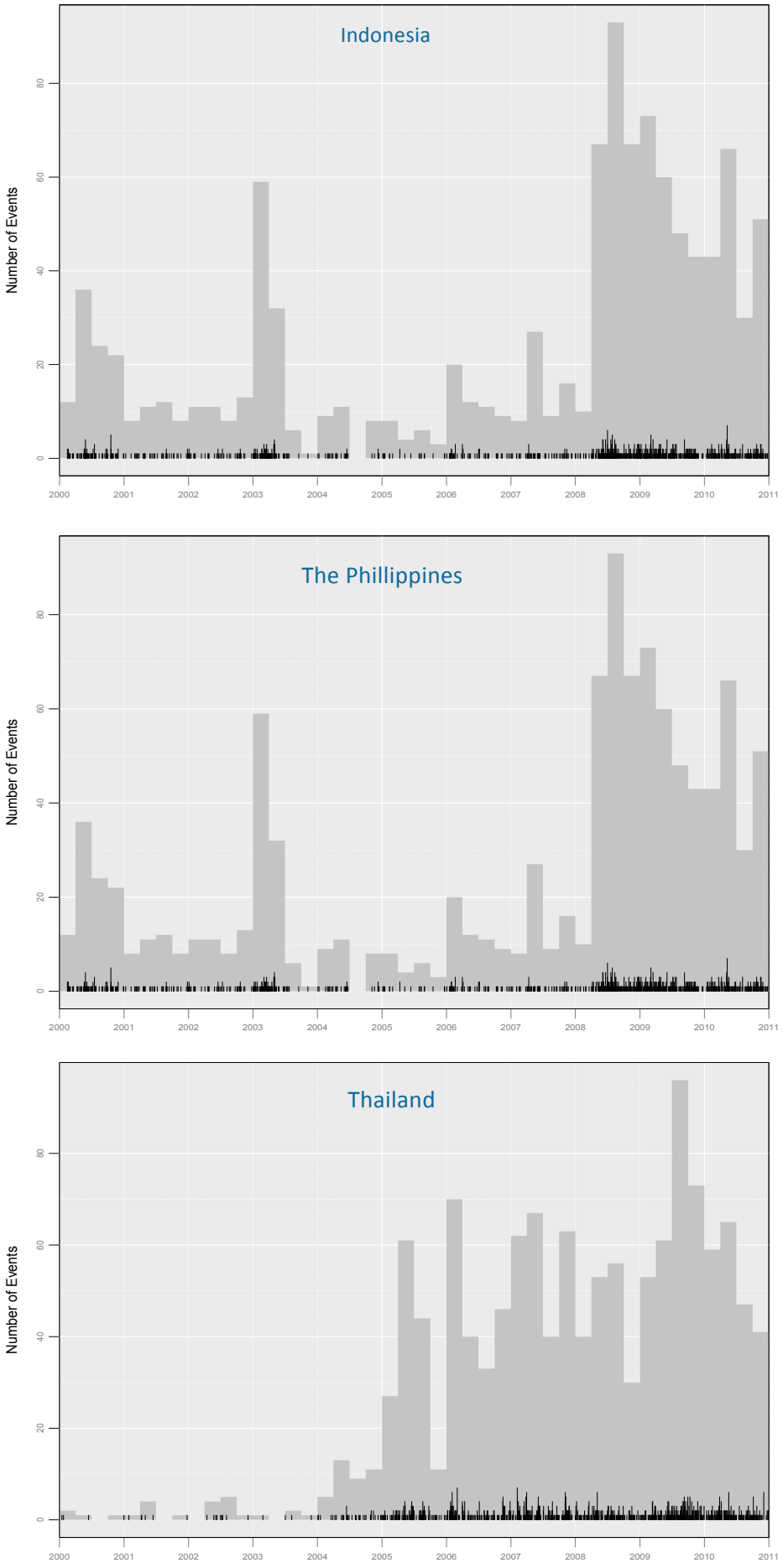
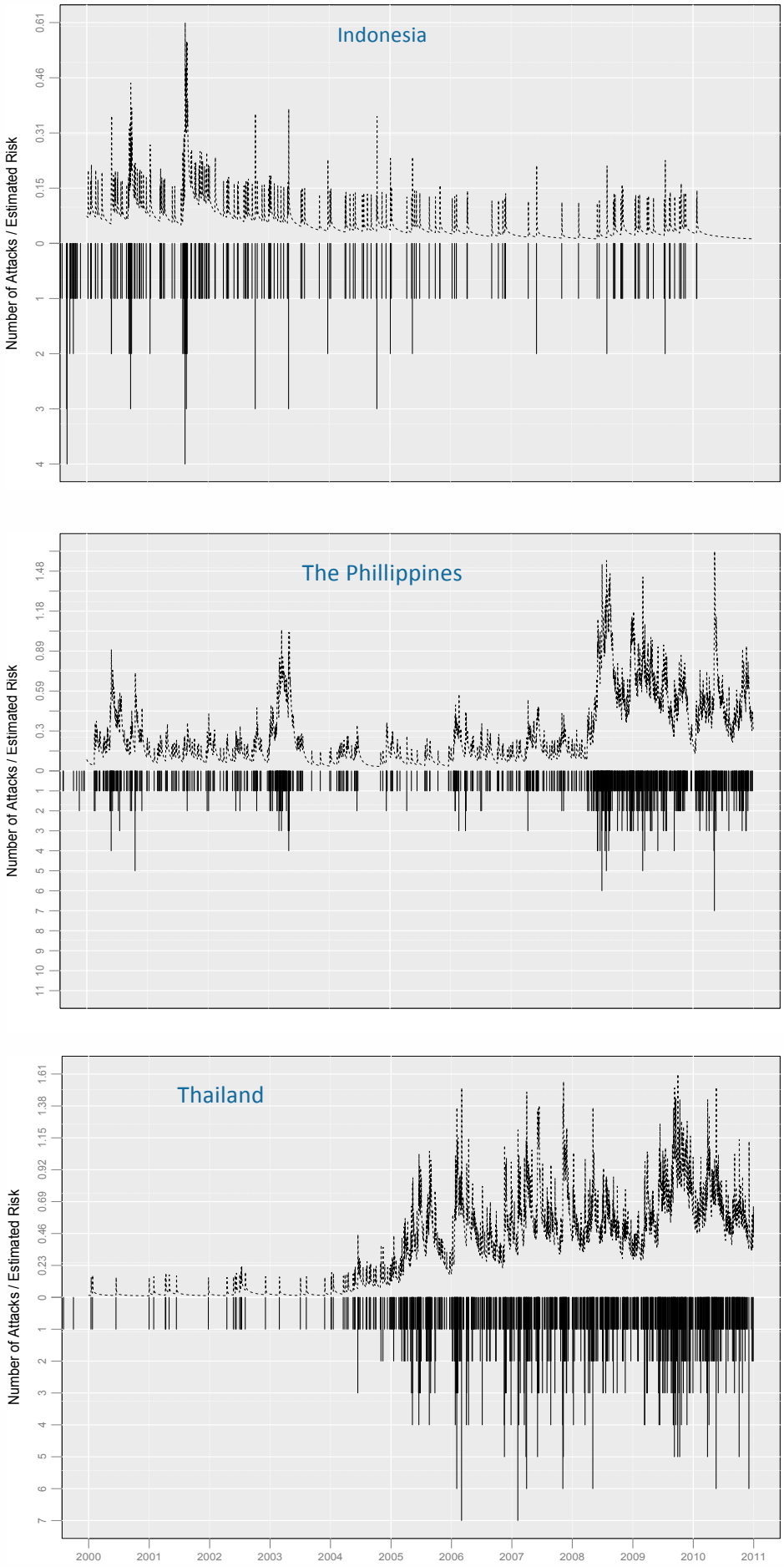


Figure 2



Midlarsky (1978) examines politically-motivated violence as a series of related events, where each event influences the probability of subsequent events. These patterns are further observed in military coups (Li & Thompson, 1975), international terrorism (Behlendorf, LaFree & Legault, 2012; Midlarsky, 1980), airline hijackings (Holden, 1986), and insurgent activity (Braithwaite & Johnson, 2012; LaFree Dugan & Korte, 2009; Telesca & Lovallo, 2006; Townsley, Johnson & Ratcliffe, 2008). Clustering patterns emerging from an analysis of terrorist activity can best be illustrated using self-exciting models.

Clustering behavior can be modeled using a generalisation of the Hawkes self-exciting point process model (see Hawkes, 1971). Self-exciting models assume that the occurrence of a terrorist event "excites" the overall terrorist process and elevates the probability of future events as a function of the time since past events. The resulting framework provides an empirical platform for measuring and comparing fluctuations in terrorist activity over time using three parameters; risk, resilience, and volatility. In this context, risk is defined as a function of the expected number of terrorist events: the higher the expected number of events, the greater the risk. Resilience is defined as the length of time after an initial event for the risk to return to a pre-event level, defined as a proportion of the increase in risk caused by the event. Volatility is defined as the expected number of events spawned by a previous terrorist event. This definition refers to the total increase in risk caused by the terrorist attack, in contrast to resilience, which is related to the temporary increase in risk attributable to the terrorist attack. Mathematical models, such as the self-exciting model, create metrics to interpret risk, resilience, and volatility, which allow for comparisons of terrorist activity to be made between nations and regions.

Method and Findings

The data used for this article were extracted from the Global Terrorism Database (GTD), an open-source database maintained by the Studies of Terrorism and Responses to Terrorism (START) consortium at the University of Maryland. (LaFree & Dugan, 2007). The database contains records of terrorist incidents by attributes including date of occurrence, weapons used, target characteristics, outcome of attack, location, and group responsible. The data are aggregated by their unique event indicator variable, which identified groups of incidents as part of a larger coordinated event. A summary for the three countries is shown in Table 1. These events are then modelled as following a negative-binomial distribution with a mean following a Hawkes self-exciting process, described in White, Porter & Mazerolle (2012). The resulting model parameters are easily interpreted as for a Poisson point process model, and are directly relatable to the conceptual models for risk, resilience and volatility.

Table 1: Summary of terrorist activity by country 2000-2010

Country	Unique Events	Attacks	Event Days	% Coordinated
Indonesia	231	309	196	25.2%
The Philippines	1086	1207	807	10.0%
Thailand	1304	1472	832	11.4%

Results shown in Table 2, and Figures 1 and 2 indicate that of the three countries, Indonesia has the lowest average risk and volatility, and the highest resilience. The lower risk and volatility are a reflection of the lower number of attacks in Indonesia and the short resilience period is indicative of the relatively sporadic nature of terrorist activity in Indonesia. The high risk and low resilience in the Philippines indicates a more intense, less clustered pattern of terrorism. The high average risk and volatility in Thailand is consistent with the recent dramatic increase in the level of terrorist activity. The individual contexts by which terrorism occurs in these three countries may have a substantial impact on any causal explanations resulting from the modeling framework presented here.

Table 2: Parameter Estimates of Risk, Resilience and Volatility for Indonesia, the Philippines and Thailand 2000-2010

	Average Risk	Baseline Risk	Volatility	Resilience	Cluster Size
	m	m	a	Eq. (7)	1/(1-a)
Indonesia	0.057	0.005(0.008)	0.820(0.130)	19 days	5.567 events
The Philippines	0.270	0.033(0.008)	0.881(0.044)	39 days	8.385 events
Thailand	0.324	0.010(0.004)	0.994(0.038)	31 days	168.028 events

Implications

Attributing a mathematical modeling approach to terrorist activity has substantial implications for understanding terrorist behaviour that both accounts for the clustering in the temporal attack pattern, and also provides a set of conceptual interpretations that are directly related to the properties of risk, resilience, and volatility. While there are limitations for the self- exciting model, it has the potential to inform policy and practice in a number of ways. The most important is the provision of benchmark indicators for terrorist activity in each country in terms of risk, resilience, and volatility. These can be used to evaluate the success of past and future counterterrorism intervention strategies in a far more accurate way than the commonly used simple absence of attacks (Perl, 2007). Furthermore, the risk, resilience and volatility results from self-exciting models can be related to current counter terrorism intervention and policy techniques employed by Indonesia, Thailand and the Philippines in determining their success or failure. For example, high risk and volatility and low resilience in the Philippines are indicative of a largely ineffective government program to combat the violence, and the nature and duration of the conflict. Similarly, the recent outbreak of more intense terrorist activity in Thailand, and the government's poor response, is reflected in its high risk and volatility.

The use of an appropriate modeling technique allows more certainty in understanding and predicting terrorist activity. Within this particular study, the exact cause of clustering behavior was excluded in order to focus on an equitable comparison between the three Southeast Asian countries. However, such contributory factors as attack type, casualties, group, or response may provide valuable information about the terrorism process and should not be discounted in future studies, allowing an in-depth exploration of the effects of including additional variables to the self-exciting models.

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