

What Happened to Suicide Bombings in Israel? Insights from a Terror Stock Model

EDWARD H. KAPLAN

Yale School of Management

and

Yale School of Medicine

New Haven, Connecticut, USA

ALEX MINTZ

Department of Political Science

Texas A&M University

College Station, Texas, USA

and

United Nations Studies

Yale University

New Haven, Connecticut, USA

SHAUL MISHAL

CLAUDIO SAMBAN

Department of Political Science

Tel Aviv University

Tel Aviv, Israel

An analysis of three years of suicide bombing data in Israel reveals an increase in such attacks through March 2002 followed by a steep decline through the end of 2003. The authors propose a terror-stock model that treats the suicide bombing attack rate as a function of the number of terrorists available to plan and execute suicide bombings. The intent of Israeli tactics such as targeted killings and preemptive arrests is to reduce the capacity of terror organizations to commit attacks. When fit to the data, this model suggests that the targeted killing of terror suspects sparks estimated recruitment to the terror stock that increases rather than decreases the rate of suicide bombings. Surprisingly, only the deaths of suspected terrorists, and not Palestinian civilians, are associated with such estimated recruitment. Although Israeli actions have reduced the rate of suicide bombings over time, it is preventive arrests rather than targeted killings that seem more responsible for this outcome.

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Address correspondence to Edward H. Kaplan, Yale School of Management and Yale School of Medicine, Box 208200, New Haven, CT 06520-8200, USA. E-mail: edward.kaplan@yale.edu

Suicide bombings have emerged as a major method favored by terrorist organizations in recent years (Atran, 2003; Pape, 2003). In Israel, there have been 85 suicide bombings within the 1967 border (the Green Line) during 2001–2003. The suicide bombing rate was not constant over these 3 years: there were 8 suicide bombings during the first half of 2001, 13 suicide bombings in March 2002 alone, yet only 17 such bombings in all of 2003, and 3 bombings in the first half of 2004 (Figure 1).¹ To prevent suicide bombings, Israel has employed tactical measures such as the targeted killings of terrorist operatives and leaders, intelligence-driven arrests of suspected terrorists, and en route interceptions of suicide bombers at checkpoints or roadblocks. This article develops statistical models that relate Israeli actions to suicide bombing attempts to see if (and how) such tactics plausibly account for the rise and fall of suicide bombings observed in the data.

The modeling approach adopted here is motivated by an earlier article by Keohane and Zeckhauser (2003), who proposed that terrorist activity could be viewed as the “product” of a “stock” of terror. These authors thought broadly of the terror stock as that combination of human, physical, and monetary resources needed to launch terror attacks. Countering terrorism in this framework amounts to reducing the capacity of terrorist organizations to operate via direct assaults on terrorists themselves (a direct “stock-reducing” activity), or by reducing the flow of resources (money, manpower, weapons and so on) to terror groups.

Given the principally human capital expended in suicide bombing operations, this article models suicide bombing attempts as a function of the number of terrorists available for the planning and execution of such attacks, and refers us to this number as the terror stock. The intent of Israeli tactics is to reduce the size of the terror stock, and thus reduce the rate of terror attacks. Although the true number of terrorists cannot be directly observed and must therefore be treated as a latent variable, removals from the terror stock via Israeli tactics such as targeted killings, arrests, en route interception of suicide bombers (to be explained further later), in addition to removals due to suicide

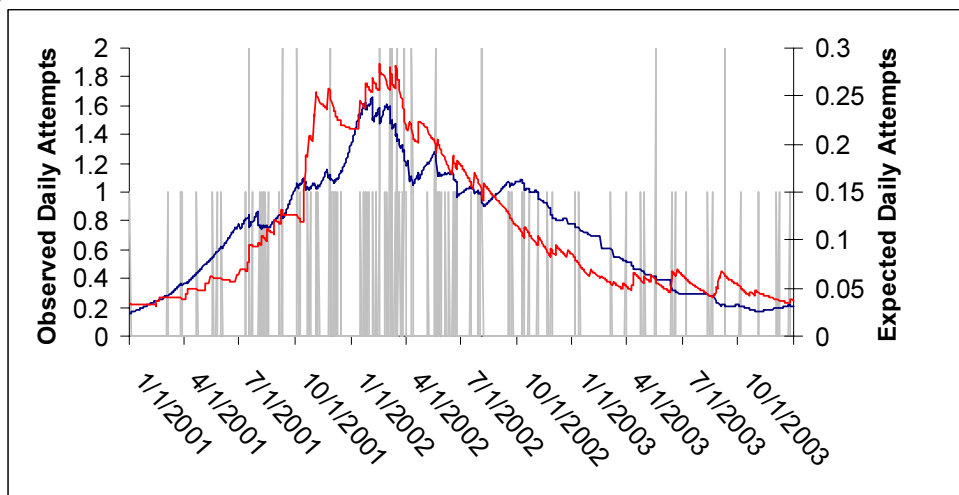


Figure 1. Observed (gray bars scaled to left axis) and expected daily suicide bombing attempts (constant recruitment model [blue line], on-target hit-dependent recruitment model [red line], both scaled to right axis) in Israel, 2001–2003. (See Color Plate I at end of issue.)

bombings themselves can be observed. This leaves the recruitment of terrorists as the key unobservable quantity that must be estimated statistically. A key question is whether Israeli tactics, in addition to directly removing terror operatives, also influence estimated terror recruitment. For example, both Atran (2003) and Pape (2003) have suggested that offensive military action or retaliation against terror organizations conducting suicide bombings are unlikely to succeed. The authors' model affords an opportunity to explore this hypothesis empirically. Finally, even though the size of the terror stock cannot be observed, the authors' models do produce very good estimates of the suicide bombing rate in Israel over time, both within the three years of their study, and also "out-of-sample" during the first four months of 2004, which suggests that the statistical relations uncovered, although not definitive, should be taken seriously.

Israeli Tactics and Data Sources

Perhaps Israel's most controversial prevention policy is the targeted killings (or hits) of suspected terrorists within guidelines demanding specific intelligence linking those targeted to impending terror attacks (Harel and Alon, 2002; David, 2003). B'tselem, the Israeli Information Center for Human Rights in the Occupied Territories, has maintained a database reporting the date, location, and names of those killed in such operations since September 2000, distinguishing between the deaths of those targeted and non-combatant civilians.² Table 1 summarizes the B'tselem data for the years 2001–2003. Although 44 of the reported 75 Israeli hits were "on-target" in that no civilians were killed, 10 hits were "botched" in that only civilians were killed. In the remaining 21 hits, both civilians and those targeted were killed. In total, Israeli hits killed 119 suspected terrorists and 80 civilians over 3 years. The cumulative number of target and civilian deaths over time appears in Figure 2.

Israel has also pursued the intelligence-driven capture and arrest of terror suspects by ground forces to prevent suicide bombings. These operations became much more frequent with the launch of Operation Defensive Shield following the suicide bombing that killed 30 and wounded another 140 Israelis at a Passover seder in Netanya on 27 March 2002. The Israel Defense Forces (IDF) does not report individual statistics regarding the number of terror suspects arrested for links to suicide bombings, but does provide monthly counts of "prevented suicide bombings" due to actions of the IDF, the General Security Services, or on occasion due to terrorist errors such as the premature detonation of explosives during bomb preparation.³ However, in an unusually detailed announcement, the IDF reported the specifics of nine "prevented suicide bombings"

Table 1
Summary of B'tselem data describing Israeli targeted hits on suspected terrorists

Hits killing	Number of hits	Number of civilian deaths	Number of target deaths
Only civilians	10	31	—
Civilians and targeted individuals	21	49	40
Only targeted individuals	44	—	79
Total	75	80	119

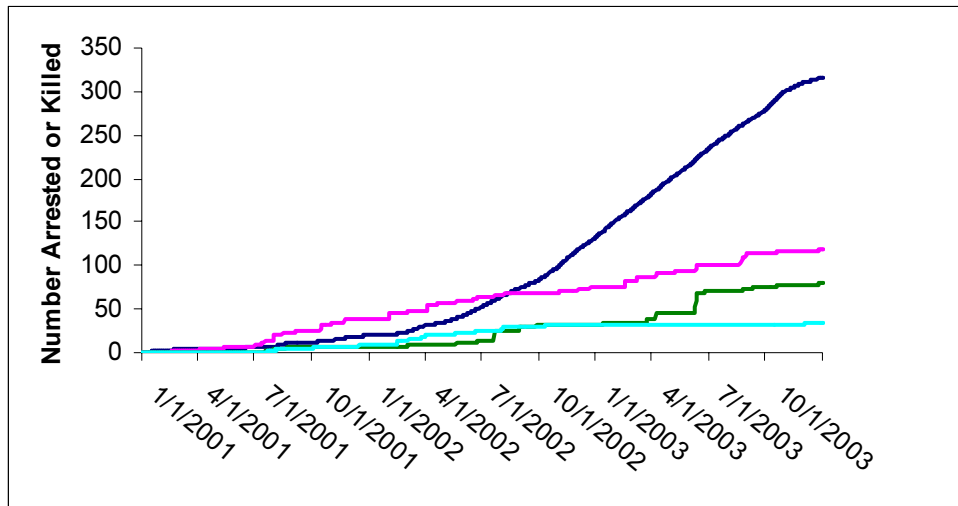


Figure 2. From 2001–2003, cumulative numbers of: terror suspects arrested in connection with suicide bombings (dark blue); terror suspects killed in targeted hits (pink); Palestinian civilians killed in targeted hits (green); and terrorists intercepted en route to executing suicide bombings (turquoise blue). (See Color Plate II at end of issue.)

during October through December 2003; all cases involved the arrests of terror suspects.⁴ The IDF data are therefore interpreted as preventive arrests; the cumulative number of these events over time also appears in Figure 2.

In addition to the 85 suicide bombings that occurred during the study period, a review of Israeli and Palestinian media sources by the authors revealed that Israeli security personnel intercepted an additional 35 terrorists en route to carrying out suicide bombing attacks. Unlike preventive arrests, these publicized interceptions occurred at checkpoints or roadblocks along the route the suicide bomber was traveling (Figure 2).⁵

A Terror-Stock Model of Suicide Bombings

As previously discussed, this article views suicide bombings as the product of an underlying stock of terror capacity. This unobserved terror stock is denominated in units of terrorists. Increases in the terror stock thus reflect the recruitment of new terrorists, whereas decreases occur due to Israeli tactical actions or because of suicide bombings themselves. The terror stock in the model is updated daily as

$$s_t = s_{t-1} + r_{t-1} - b_{t-1} - a_{t-1} - h_{t-1} - i_{t-1} \quad (1)$$

where s_t denotes the terror stock at the beginning of day t , r_{t-1} is the number of terrorists recruited on day $t - 1$, and b_{t-1} , a_{t-1} , h_{t-1} , and i_{t-1} refer to the number of terrorists removed from the stock on day $t - 1$ due to suicide bombings, arrests (taken as the daily average of observed monthly totals), targeted hits, and interceptions, respectively. Given the relatively short time frame of the study, other sources of attrition from terror activity were ignored.

The authors define a suicide bombing attempt as an actual or intercepted suicide bombing (so there are 120 suicide bombing attempts in the data). The occurrence of suicide bombing attempts over time is modeled as a Poisson process with an expected λ_t attempts on day t . This mean level of attempts is linked to the terror stock via the equation

$$\log \lambda_t = \beta_0 + \beta_1 s_t \quad (2)$$

thus a unit decline in the terror stock (whether due to a tactical action or a suicide bombing) implies a $100 \times \beta_1\%$ reduction in the expected number of suicide bombing attempts providing $\beta_1 > 0$.

Table 2 reports maximum likelihood parameter estimates and associated standard errors for different versions of the terror-stock model estimated from the observed suicide

Table 2
Maximum likelihood estimation of alternative terror-stock models

Variable	Constant recruitment per day (I)	Hit-dependent recruitment (II)	Differential hit-dependent recruitment (III)	On-target hit-dependent recruitment (IV)	Differential death-dependent recruitment (V)
Constant	-3.714 (0.433)	-3.263 (0.456)	-3.260 (0.462)	-3.379 (0.342)	-3.206 (0.488)
Terror stock	0.022 (0.004)	0.018 (0.004)	0.012 (0.006)	0.016 (0.002)	0.024 (0.007)
Constant recruiting rate	0.518 (0.019)	-0.014 (0.235)	-0.187 (0.431)	—	0.095 (0.165)
Hit-dependent recruiting rate	—	7.591 (3.264)	—	—	—
Botched hit-dependent recruiting rate	—	—	-9.004 (18.139)	—	—
On-target hit-dependent recruiting rate	—	—	13.089 (8.559)	8.626 (0.419)	—
Civilian death-dependent recruiting rate	—	—	—	—	0.979 (0.682)
Terror suspect death-dependent recruiting rate	—	—	—	—	3.059 (1.394)
Log likelihood	-366.1	-361.0	-360.1	-360.4	-361.9
Estimated total recruitment	567	554	556	561	547

Cell entries report parameter estimates (standard errors) for the different recruitment models. Also reported is the log-likelihood and estimated total recruitment associated with each model. The log-likelihood function maximized is $\sum_{t=1}^{1095} ((b_t + i_t) \log \lambda_t - \lambda_t)$ where b_t , i_t and λ_t are the observed and expected (via the terror-stock model) number of suicide bombing attempts on day t .

bombing and prevention tactics data described earlier. The simplest model (column I in Table 2) presumes a constant daily recruitment rate (\pm standard error) estimated to equal 0.52 (± 0.02) terrorists per day, or roughly 190 per year. The estimated β_1 value implies that each unit reduction in the terror stock corresponds to a 2.2% ($\pm 0.4\%$) reduction in the expected number of suicide bombing attempts. This model suggests that although reducing the terror stock has the desired effect of lessening the attempted suicide bombing rate (since $\beta_1 > 0$), recruitment replenishes the stock at a rapid rate. For example, the 75 targeted hits recorded in the B'tselem data killed 119 suspected terrorists for an average decrement in the terror stock of 1.6 terrorists per hit, yet at the estimated mean recruitment rate, this stock is restored after only three days.

Figure 1 shows observed (gray bars) and estimated daily suicide bombing attempts for the constant recruitment model (blue line). The model is broadly consistent with the observed data: when the estimated mean daily attack rate is high, observed bombing attempts occur with greater frequency (as seen by the clustering of the gray bars in the figure), although when the estimated attack rate is low, observed attempts are fewer and more widely spaced. The model suggests that the terror stock increased rapidly from the start of 2001 through March of 2002. During this time period, Israel pursued targeted killings of terrorist operatives in the West Bank, but as suggested previously, recruitment easily compensated for the resulting losses to the terror stock. With the launch of Operation Defensive Shield, Israel changed its tactics to focus more on arresting those believed to be involved with the planning and execution of suicide bombing missions (Figure 2). As is clear from Figure 1, this change in tactics appears to have led to a reduction in suicide bombing attempts over the rest of 2002 and 2003.

The results of the constant recruitment model suggest that although Israel's policy of targeted hits failed to control suicide bombings, arresting terror suspects has met with greater success. Why might this be the case? Is it possible that the apparent failure of targeted hits to control suicide bombings is because such hits were too infrequent to have a meaningful impact on the terror stock relative to ongoing recruitment? Alternatively, as has been argued (Atran, 2003; Pape, 2003), are targeted killings counterproductive in that such hits motivate the recruitment of terrorists, in which case hits would serve to increase rather than decrease the terror stock? To explore these questions, the authors allowed the terror stock recruitment rate on day t to depend on hits at time t in accord with the formula

$$r_t = \alpha_0 + \alpha_1 x_t \quad (3)$$

where x_t is the number of targeted hits executed by the IDF on day t , while α_0 and α_1 are parameters to be estimated. These parameters have natural interpretations: α_0 is the base daily recruitment rate irrespective of hits, whereas α_1 is the incremental number of new terror recruits in response to a hit. If hits serve to motivate recruitment, then α_1 will be positive; alternatively if hits deter recruitment, then α_1 would be negative. If α_1 equals zero, the constant recruitment discussed previously is obtained.⁶

The results from this analysis are shown in column II of Table 2. This hit-dependent recruitment model provides a significantly better statistical fit to the data than the constant recruitment model (likelihood-ratio $\chi^2 = 10.2$, $p = 0.0014$). The impact of a unit decrement in the terror stock is an estimated 1.8% ($\pm 0.4\%$) reduction in the expected suicide bombing attack rate, an effect similar to that estimated in the constant recruitment model. However, the estimated dependence of recruiting on hits is strong: each hit increases the terror stock by an estimated 7.6 (± 3.3) recruits. Furthermore, the

estimated base recruitment rate is not statistically different from zero, suggesting that hits account for all increases to the terror stock. Indeed, both the constant and hit-dependent recruitment models estimate similar total increases to the terror stock over the three years of the study (565 and 555, respectively), but the specific timing of recruitment differs—1 recruit every 2 days in the constant model versus 7.6 recruits following each targeted hit in the second model.

Although the analysis thus far has established a strong, positive statistical association between targeted hits and suicide bombing attempts via terror stock recruitment, is it plausible to treat this association as causal? Suppose that in a given month, terrorists select four different days on which to attempt suicide bombings in Israeli cities, but that Israeli intelligence agents obtain precise information regarding these plans. Suppose further that upon learning of these plans, Israeli authorities order targeted hits to prevent the bombings, but that only two hits are successful in doing so. At the end of the month, data would report that there were hits on four days, that there were suicide bombings following two of these hits, and that there were no suicide bombings on any other days. A statistical analysis of these data would suggest that hits were positively associated with suicide bombings, even though hits actually cut the number of suicide bombings in half. Might the present analysis suffer from a similar bias?

The B'tselem data provide an opportunity to address this concern. Although there were 75 hits carried out by the IDF, not all of these hits were successful in striking the intended targets. As shown in Table 1, 10 of these hits were botched in that only civilians were killed, whereas in the other 65 hits at least 1 of those targeted was killed. If the positive association between suicide bombing attempts and (via recruiting) targeted hits estimated in this analysis is an artifact of the timing of hits intended to disrupt bombings, this effect should be much stronger for botched hits that failed to kill those targeted than for on-target hits, and thus detectable in the data.

To test this proposition, the authors allowed the recruitment rate to depend differentially on botched versus on-target hits as

$$r_t = \alpha_0 + \alpha_1 x_t^B + \alpha_2 x_t^T \quad (4)$$

where x_t^B and x_t^T are the number of botched and on-target hits recorded in the B'tselem data on day t . The results are shown in column III of Table 2. First, distinguishing between botched and targeted hits does not improve the statistical fit of the model beyond our earlier hit-based recruitment model, which provides evidence against a differential effect of botched versus on-target hits on recruitment. Second, the estimated parameter values distinguishing the effects of botched versus on-target hits are inconsistent with the timing-artifact theory. Although the estimated effect of on-target hits is to increase the terror stock by 13.1 (± 8.6) recruits per hit, botched hits are estimated to reduce the terror stock by 9 (± 18) recruits per hit.

Not only do these results argue against the timing-artifact theory; they also suggest that although on-target hits motivate recruitment to the terror stock, botched hits fail to do so. Might it be that on-target hits alone account statistically for all of the increases to the terror stock? To investigate, the authors forced $\alpha_0 = \alpha_1 = 0$ in Equation (4) and re-estimated the remaining three parameters. The results are shown in column IV of Table 2. The estimated effect of a unit reduction in the terror stock is a 1.6% ($\pm 0.2\%$) reduction in the daily attempted bombing rate, whereas each on-target hit is associated with 8.6 (± 0.4) additions to the terror stock. Because 1.8 terror suspects are killed per on-target hit, this model suggests that on average, the terror stock increases by 6.8 for each

on-target hit. These results are conditional on having forced $\alpha_0 = \alpha_1 = 0$, but Table 2 shows that the hypothesis cannot be rejected that only on-target hits spark recruitment.⁷ Recruitment was also modeled as a function of the number of suspected terrorists and civilians killed (as opposed to the number of on-target and botched hits in Equation (4)), and found that although the terror stock responds to the deaths of terror suspects, there is no statistically significant effect of civilian deaths on recruitment (column V of Table 2), again refuting the timing-artifact theory.

The authors explored additional terror-stock model formulations allowing recruitment to depend on preventive arrests and successful suicide bombings in addition to targeted hits and preventive arrests (results not shown). They also investigated the effect of border closings and Israel's security fence: although there is evidence that border closings serve to facilitate preventive arrests, and that the security fence is protective in those locations where it exists (Figure 3),⁸ none of these formulations change the results of the parsimonious on-target hit recruitment model (column IV of Table 2).

The daily expected number of suicide bombing attempts under the on-target hit recruitment model is shown in Figure 1 (red line).⁹ Recalling that 35 out of 120 suicide bombing attempts were intercepted en route, successful suicide bombings can be predicted from this model by multiplying the estimated daily number of attempts by 85/120. The cumulative numbers of observed and modeled suicide bombings in Israel from 2001 through 2003 are shown in Figure 4. Data available on hits and preventive arrests through the end of April 2004 enable a further check on the reasonability of this model. There were an additional three suicide bombings in Israel during these four months. Using the parameters estimated from the 2001–2003 data, the model also predicts an additional three successful suicide bombings through the end of April 2004.

Discussion

This analysis suggests that preventive arrests, as opposed to the targeted killings of suspected terrorists, are responsible for the dramatic reduction in suicide bombings inside Israel since March 2002. Although on-target hits might remove an immediate terrorist threat, the present analysis suggests that such actions actually increase the terror stock via hit-dependent recruitment. It might be argued that because ground operations leading to preventive arrests place Israeli soldiers at great risk, missile strikes against terrorists are a safer tactic, but again the analysis suggests a flaw in this reasoning: even if hits reduce risks to Israeli soldiers, hits increase the expected suicide bombing rate due to the impact of hit-dependent recruiting on the terror stock, in turn increasing suicide bombing risks to the Israeli public at large.

Preventive arrests hold a further advantage over targeted hits. Thinking of terror organizations as networks (Krebs, 2001; Farley, 2003), targeted killings serve only to knock out individual nodes (terrorists). Arrests enable the interrogation of terror suspects, which could lead to the discovery of links to more nodes in the terror network. It is difficult to interrogate the target of a successful missile strike. That the B'tselem data suggest that hits targeting terrorists have killed two civilians for every three suspected terrorist deaths (Table 1) further adds to the arguments against the use of targeted hits. The authors also discovered that, surprisingly, it is the killing of terror suspects, and not Palestinian civilians, that appears to spark estimated recruitment to the terror stock. One interpretation of this result is that the terror organizations do not care about civilian lives, and are only motivated to recruit and retaliate when their organizations are threatened. An alternative interpretation is that when Israeli-targeted hits go awry and many

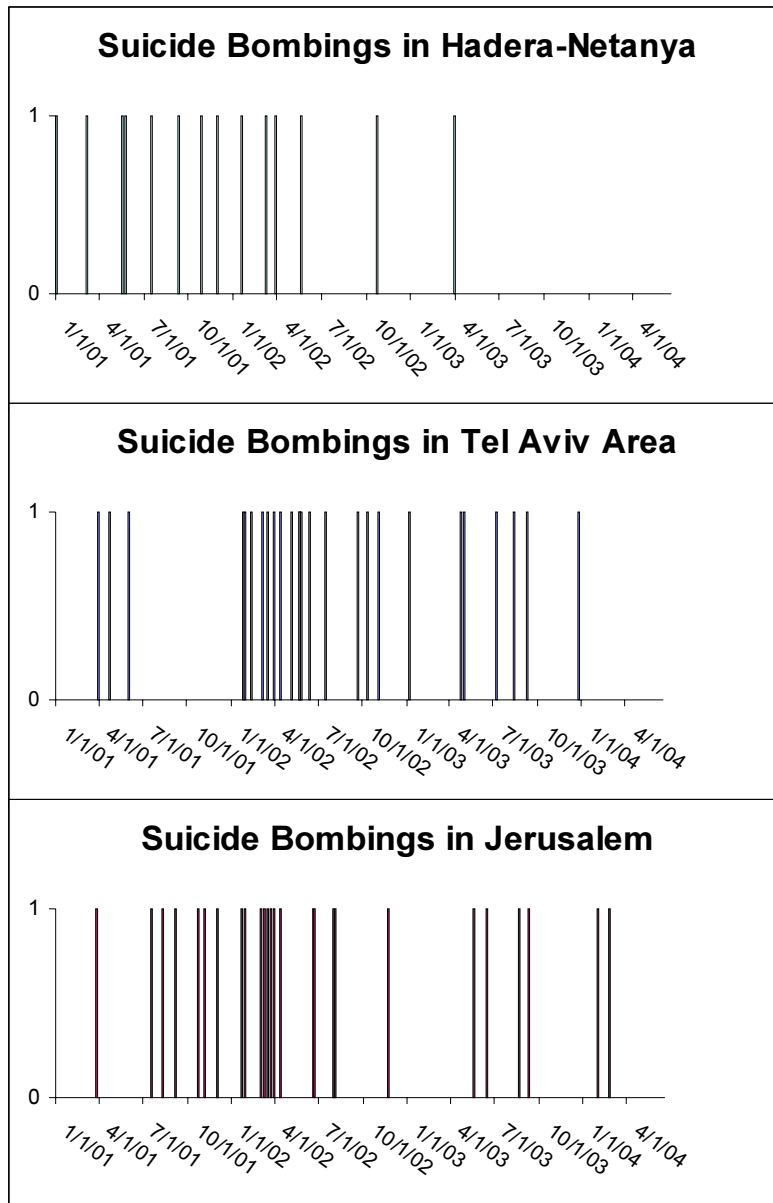


Figure 3. Observed suicide bombings in areas now protected (Hadera-Netanya) and unprotected (Tel Aviv, Jerusalem) by Israel’s security fence.

civilians are killed, terror organizations strategically choose to cease operations for a short time period, granting Palestinian leaders sympathetic attention from the media, world governments, and international bodies such as the United Nations.

To the authors’ knowledge, this study provides the first empirical support for previous suggestions that offensive military measures are unlikely to prove effective against suicide bombings (Atran, 2003; Pape, 2003). To the extent that the Israeli experience

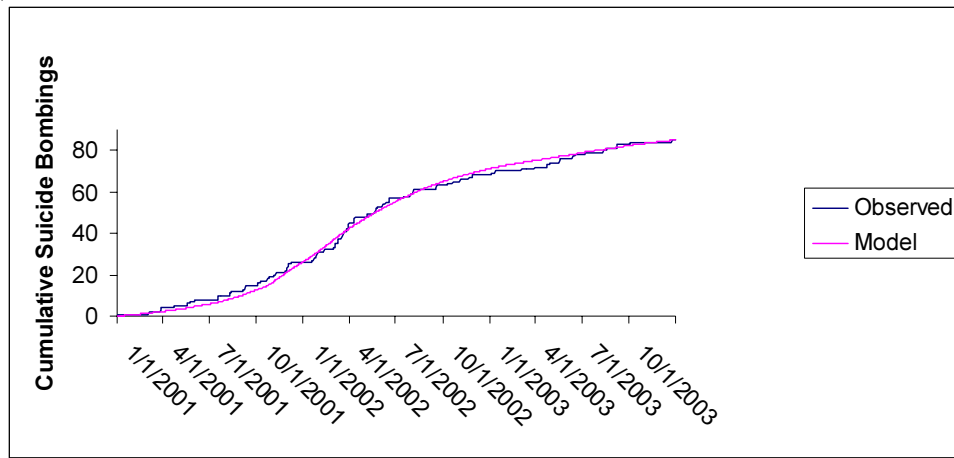


Figure 4. Observed (blue) and expected (pink) cumulative suicide bombings in Israel, 2001–2003. Expected values derive from the on-target hit-dependent recruitment model (Table 2, column IV) adjusted for interceptions as explained in the text. (See Color Plate III at end of issue.)

generalizes to other countries facing suicide bombing threats such as Afghanistan, Iraq, Russia, or Sri Lanka, investing in intelligence that leads to preventive arrests stands a better chance of success. The key tactical question in preventing suicide bombings is how to reduce the terror stock without inadvertently replenishing it and unduly harming civilians. Israel continues to rely on targeted killings, but this analysis suggests such hits are counterproductive. Arresting suspected terrorists appears to reduce suicide bombings without inducing the recruitment of additional terrorists, and likely delivers intelligence information leading to further life-saving reductions in the terror stock.

Notes

1. Data describing suicide bombings in Israel are available online from Israel's Ministry of Foreign Affairs (<http://www.mfa.gov.il/mfa/terrorism-%20obstacle20to%20peace/palestinian%20terror%20since%202000/>) and the International Policy Institute for Counter Terrorism's terror attack database (http://www.ict.org.il/arab_isr/arab-isr_frame.htm).

2. These data are available on-line from B'tselem (http://www.betselem.org/Hebrew/Statistics/Fatalities_Lists/Extrajudicial_Executions.asp; in Hebrew).

3. These data are available online from the Israel Defense Forces (<http://www1.idf.il/dover/site/mainpage.asp?sl=EN&id=22&docid=16703>).

4. This announcement is available online from the Israel Defense Forces (<http://www1.idf.il/dover/site/mainpage.asp?clr=1&sl=HE&id=7&docid=26412>; in Hebrew).

5. Numerous additional variables, including the terror organization sponsoring the attack, the origin and destination of each bomber, and whether there was a terror alert at the time of the attack have been assembled into a database for all suicide bombings and publicized interceptions in Israel during 2001–2003 (Mintz, A., Mishal, S., and Samban, C. 2004. "Suicide bombings in Israel." Available from the authors).

6. The authors also explored models where recruitment was allowed to depend on past hits via the formula $r_t = \alpha_0 + \alpha_1 \sum_{j=0}^t \theta^j x_j$ with θ restricted to fall between 0 and 1. Setting $\theta = 1$ makes recruitment depend on cumulative hits to date, whereas setting $\theta = 0$ forces recruitment to depend only on current hits as in Equation (3); intermediate values of θ allow past hits to influence

current recruitment but with geometrically decreasing weight. It was found that setting $\theta = 0$ produced the best statistical fit to the data, thus the authors' comments are restricted to such formulations.

7. Because the on-target hit-dependent model is a special case of Equation (4) with $\alpha_0 = \alpha_1 = 0$, it can be tested whether restricting recruiting to depend only on on-target hits significantly worsens the fit of the model. Comparing the log-likelihoods in columns III and IV of Table 2, the 0.3 point change in the log-likelihood is not sufficient to reject the hypothesis that only on-target hits matter ($\chi^2 = 0.6$, $p = 0.74$).

8. The authors obtained the dates on which Israel's borders with the West Bank were sealed from the Spokesman's Office of Israel's Ministry of Defense, and investigated whether suicide bombing attempts differed by closure versus non-closure days controlling for targeted hits and preventive arrests via the terror-stock model. Although there was no significant effect of border closures within this analysis (results not shown), the authors note that the number of preventive arrests is significantly higher during closure periods. Specifically, during 196 border closure days there were 81 preventive arrests, a rate of 150.8 per year. During the remaining 899 non-closure days there were 232 preventive arrests, a rate of 94.2 per year. This difference is highly significant, and suggests that border closures serve to facilitate operations intended to apprehend terrorists.

In July 2002, Israel began constructing a security fence with the intent of preventing terrorist infiltrations into Israel from the West Bank. By the end of 2003, however, only about one-fourth of this fence was completely operational. Having obtained the completion dates of individual fence segments from the Head of Israel's Seam Line Project, the authors investigated whether the cumulative number of kilometers completed was predictive of attempted suicide bombings, again controlling for hits and preventive arrests via the terror-stock model. Although there was no significant effect within this framework (results not shown), simply examining the locations of successful suicide bombings over time suggests that there has been a shift in the locations of successful bombings away from those areas now protected by the fence, as shown in Figure 3. Hadera and Netanya are located along the Mediterranean coast, and were the first major cities to be fully protected by completed sections of the security fence. By contrast, neither Tel Aviv nor Jerusalem are fully protected as the fence has yet to be completed across access routes from the West Bank to those cities.

9. Goodness-of-fit tests show that the on-target hit-dependent model provides a satisfactory match to the data (Pearson $\chi^2 = 20.8$ ($p = 0.1433$); likelihood-ratio $\chi^2 = 18.6$ ($p = 0.2324$); 15 degrees of freedom after grouping to achieve expected cell counts of at least 5).

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