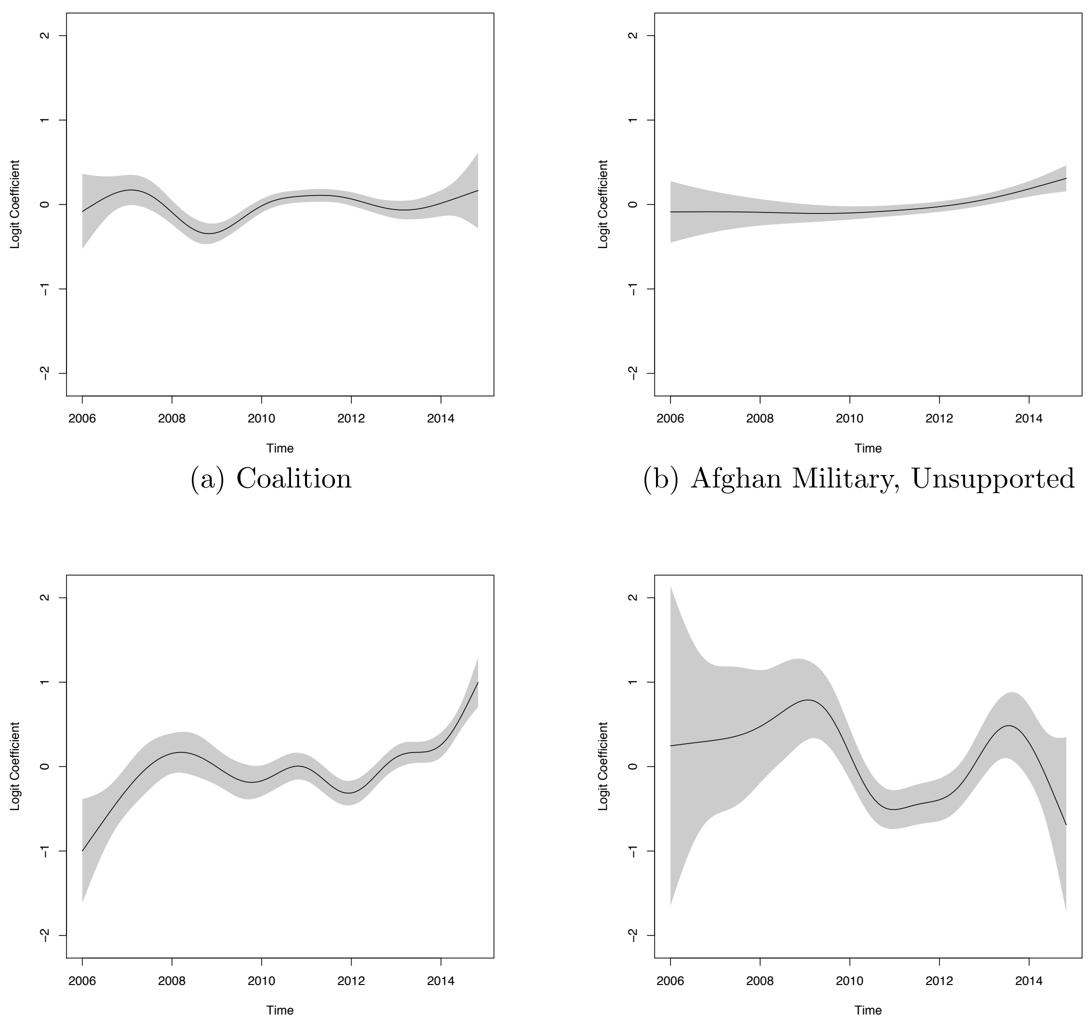
APPENDIX for

Insurgent Learning

— For Online Publication Only —

A Supplemental Econometric Results

Figure SI-1: Casualty Rate by Security Actor, Nonparametric Model



(a) Coalition

(b) Afghan Military, Unsupported

(c) Afghan Police

(d) Afghan Military, Supported

Generalized Additive Model with logit link function. Specification follows Column 8 in Table 3, except that the time interaction terms are allowed to be smooth rather than restricted to be linear.

Table SI-1: IED Outcomes as District-Week Rates (OLS)

	Detonation Rate		Casualty Rate Afghan Units		Casualty Rate Coalition Units	
	(1)	(2)	(3)	(4)	(5)	(6)
TIME	0.0000219	0.000306***	0.000566***	0.000539***	0.0000171	-0.000154
	(0.0000417)	(0.0000484)	(0.0000740)	(0.0000853)	(0.0000802)	(0.000105)
N	28162	28162	10899	10899	8857	8857
Clusters	376	376	339	339	266	266
R^2	0.0111	0.0184	0.0221	0.0517	0.00620	0.00865

Standard errors in parentheses

$^{\gamma}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

All models include district and week-of-year fixed effects (FE). Standard errors are clustered by district. Even numbered columns include a year fixed effect. Time is a linear trend. The model is estimated using ordinary least squares.

Table SI-2: IED Outcomes as District-Week Rates (GLM)

	Detonation Rate		Casualty Rate Afghan Units		Casualty Rate Coalition Units	
	(1)	(2)	(3)	(4)	(5)	(6)
TIME	0.000130	0.00127***	0.00237***	0.00236***	0.0000721	-0.000719
	(0.000163)	(0.000193)	(0.000294)	(0.000346)	(0.000373)	(0.000499)
N	28162	28162	10899	10899	8857	8857
Clusters	376	376	339	339	266	266

Standard errors in parentheses

$^{\gamma}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

All models include district and week-of-year fixed effects (FE). Standard errors are clustered by district. Even numbered columns include a year fixed effect. Time is a linear trend. The model is estimated using generalized least squares, with a binomial family and logit link functions.

Table SI-3: Outcome conditional on IED Explosion, accounting for aggregate trends in military spending

	(1)	(2)	(3)	(4)
Time	0.157***	0.154***	0.114***	
	(0.005)	(0.005)	(0.005)	
Time × Afg Military, Supported				−0.268**
				(0.110)
Time × Afg Military, Unsupp.				0.166***
				(0.040)
Time × Afg Police				0.192***
				(0.037)
Time × Civilian				0.152***
				(0.037)
Time × Coalition				0.045
				(0.035)
Time × NA				0.756***
				(0.041)
Ineffective|Dam/Dis/Destroyed	0.203***	−0.543	−1.591***	−4.571**
	(0.029)	(0.877)	(0.098)	(1.703)
Dam/Dis/Destroyed|Wounded	0.951***	0.212	−0.782***	−3.739**
	(0.030)	(0.877)	(0.098)	(1.703)
Wounded|Killed	2.370***	1.654*	0.776***	−2.152
	(0.032)	(0.877)	(0.099)	(1.703)
Grid square FE	No	Yes	Yes	Yes
Month of year FE	No	Yes	Yes	Yes
Target type FE	No	No	Yes	Yes
US Gov't annual support	No	No	No	Yes
N	36,690	36,690	36,690	36,690

*p < .1; **p < .05; ***p < .01

Proportional-odds ordered logit regression with levels "Ineffective", "Dam/Dis/Destroyed", "Wounded", "Killed".

Table SI-4: IED Outcomes as Rates, accounting for aggregate trends in military spending

	Detonation Rate		Casualty Rate Afghan Units		Casualty Rate Coalition Units	
	(1)	(2)	(3)	(4)	(5)	(6)
TIME	0.0000686	0.000549	0.000782***	0.00187$^{\gamma}$	0.000117	-0.000517
	(0.0000720)	(0.000580)	(0.000116)	(0.00109)	(0.000189)	(0.00130)
N	27223	27223	10725	10725	8670	8670
Clusters	375	375	338	338	263	263
R^2	0.0312	0.0316	0.0905	0.0917	0.0536	0.0539

Standard errors in parentheses

$^{\gamma}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

All models include district and week-of-year fixed effects (FE). Standard errors are clustered by district. Even numbered columns include a year fixed effect. Time is a linear trend. The model is estimated using ordinary least squares.

Table SI-5: Summary Statistics for Tables SI-1 and SI-2

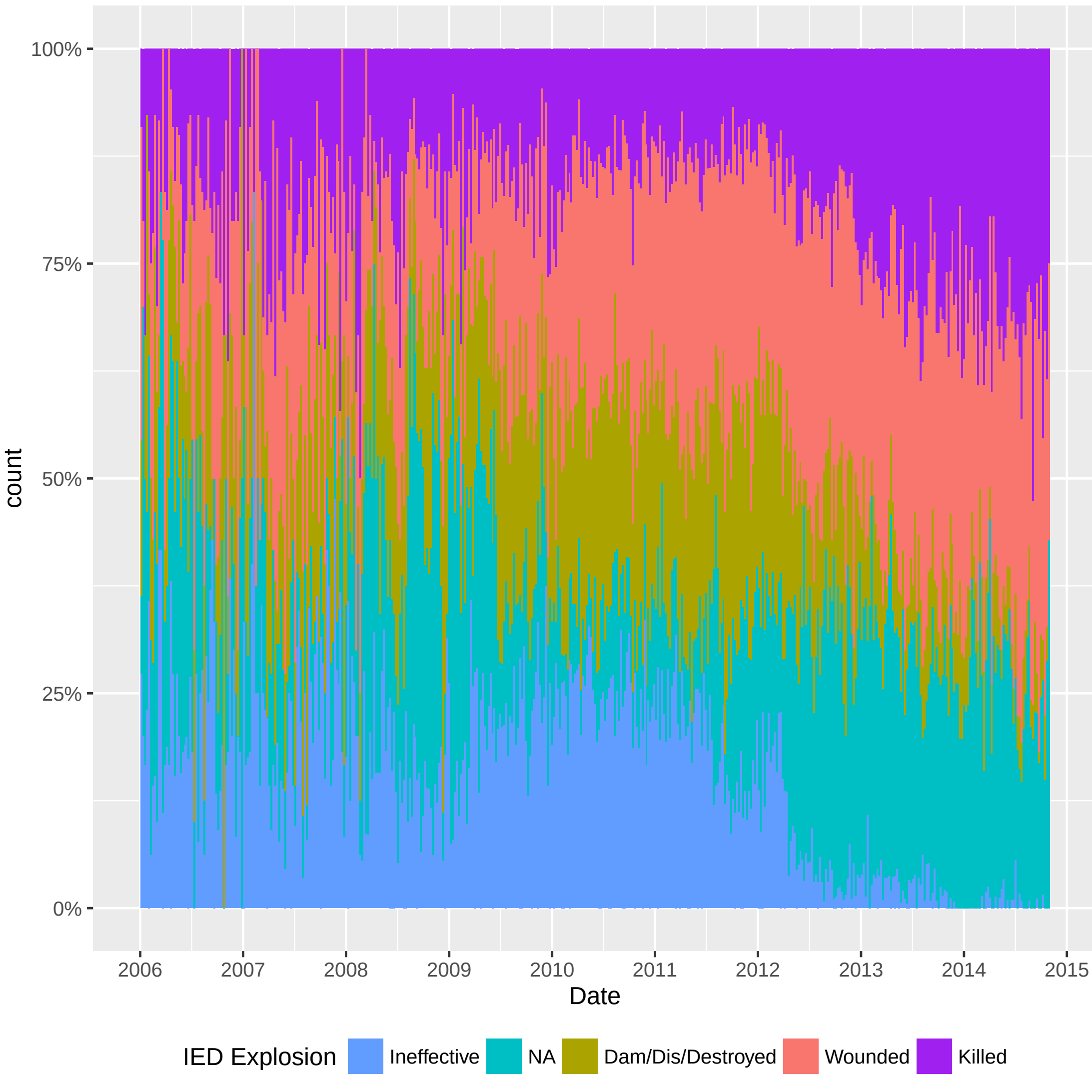
Variable	Mean	St. Dev.	Min.	Max.	N
IED detonation rate	0.493	0.426	0	1	28162
Casualty rate, Afghan forces	0.548	0.463	0	1	10899
Casualty rate, Coalition forces	0.297	0.405	0	1	8857
TIME (weekly)	2669.758	116.069	2392	2851	28162

B Additional Visualization of IED Operations/Outcomes

Here we consider the geography of bomb deployment in Afghanistan. Figure SI-5 shows the geographic distribution of IEDs across Afghanistan following a technique suggested by Grolemund and Wickham [2015]. Degrees of longitude are shown at the top of each chart, and degrees of latitude at the right.[21] The count of all IED events is on the left edge and the time range is on the bottom edge. Similar to the previous plots, we examine the period from 2006 to 2014. The maximum observed number of IED events in a given cell-year is just over 1600. For each longitude-latitude combination, a histogram following Figure 4 is shown (for the righthand chart, this is scaled to add up to 100%). Several patterns are

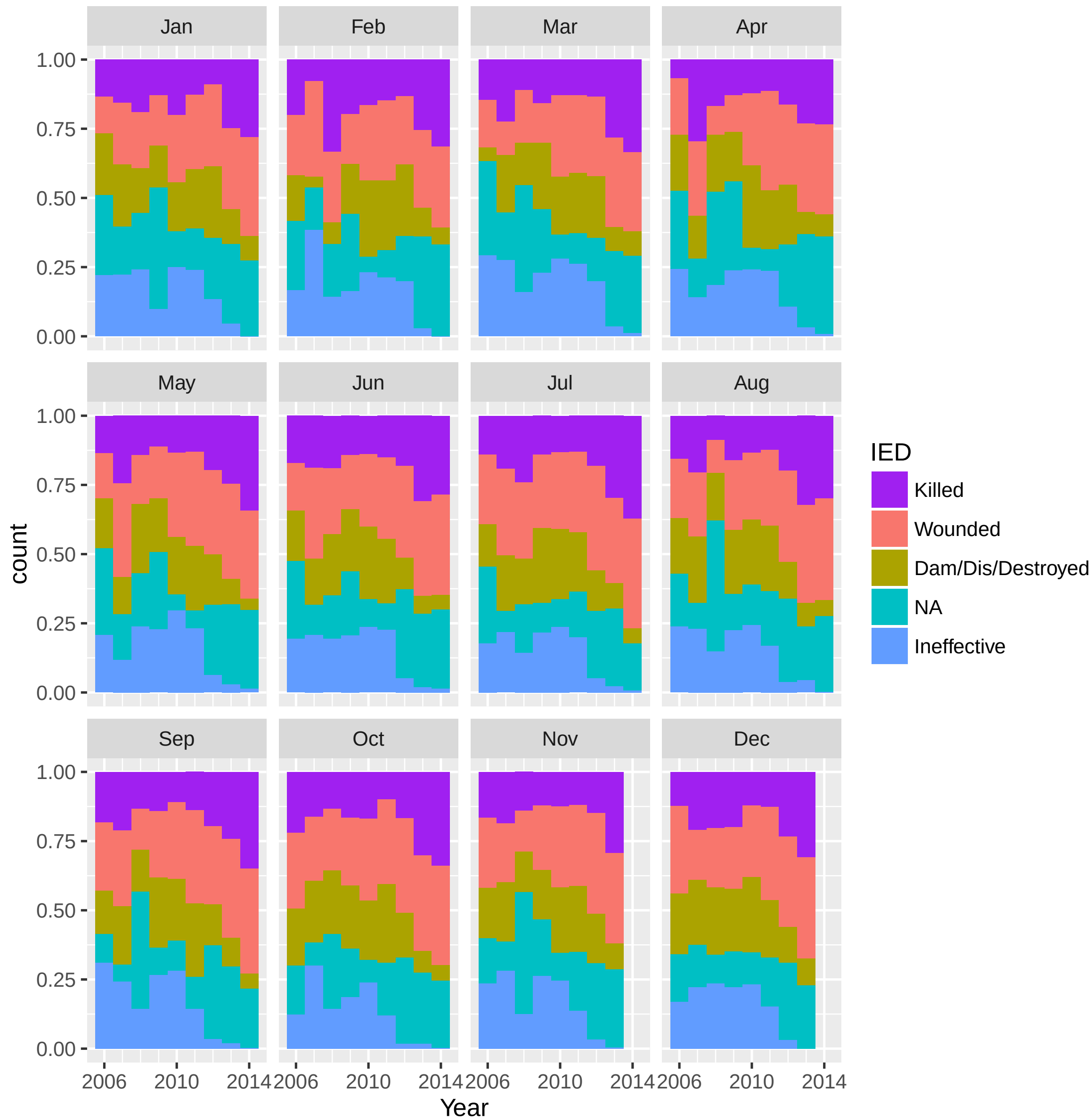
[21]Due to the varying geographic scale of provinces, however, producing a comparable map based on a breakdown by province would largely illegible. Alternatively, one could generate 34 separate plots, one for each province. We prefer for a simpler visualization.

Figure SI-2: Outcome of IED Explosions (sums to 100%)



apparent from these plots. First, almost all recorded attacks happen in the eastern and southern portions of Afghanistan, with very little activity in the north and west. IEDs are particularly concentrated in Hilmand and Kandahar provinces. A major reason for this is the ethnic composition of the country. The southern and eastern portions of the country are densely populated by Pashtuns (i.e., Taliban co-ethnics). Second, given the spatial concentration of IED activity, one might expect that the rate of insurgent effectiveness would diverge significantly across space. Yet Figure SI-5b shows that the effectiveness of IEDs in causing damage is nearly uniform across Afghanistan. No systematic downward

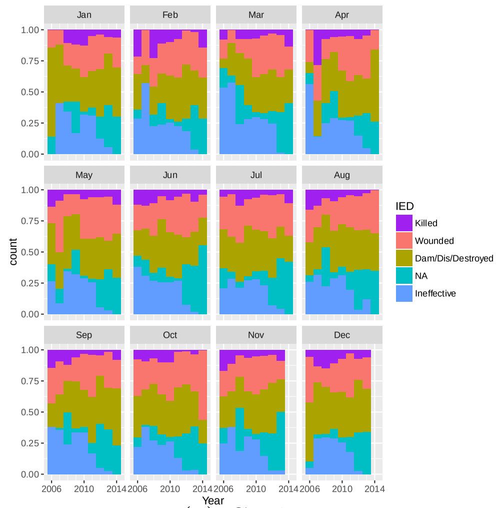
Figure SI-3: Outcome of IED Explosions by Month (sums to 100%)



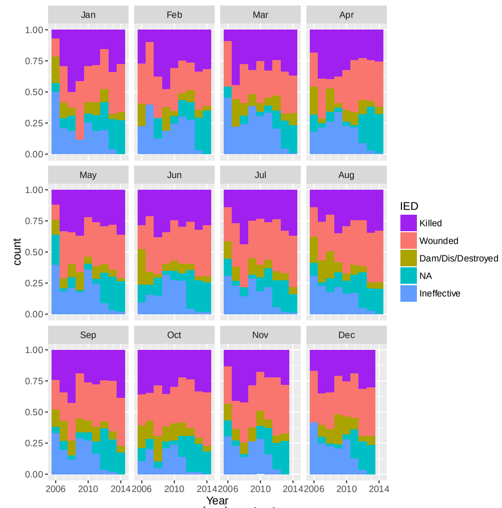
trend in IED effectiveness is visible in any part of Afghanistan. Instead, many plots trend upwards, indicating an increase in insurgent success as the campaign progressed.

C Additional Outcomes in Military Records

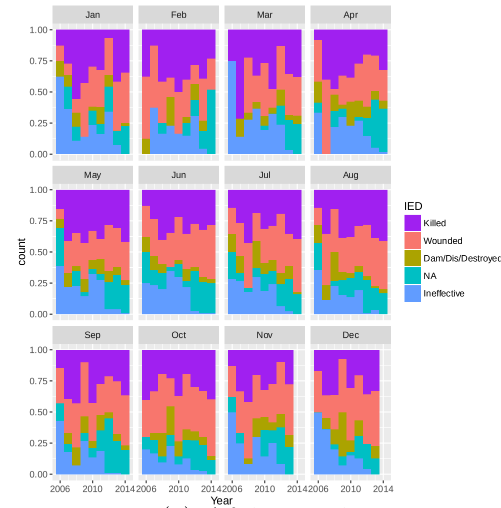
Figure SI-4: Outcome of IED Explosions by Month and Security Actor



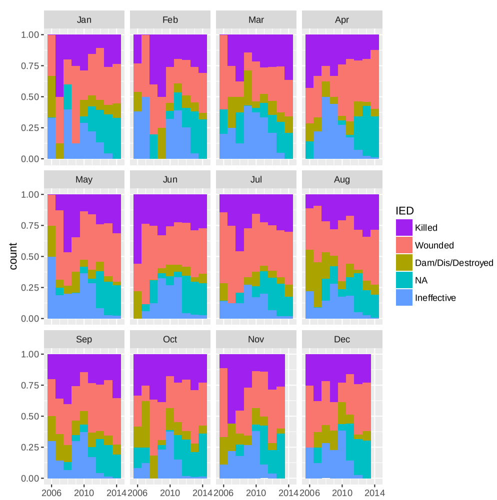
(a) Coalition



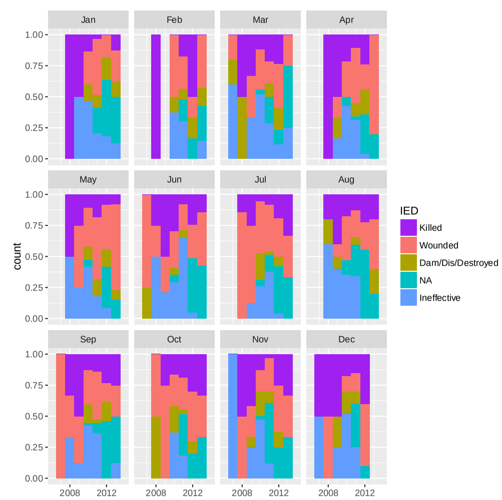
(b) Afghan



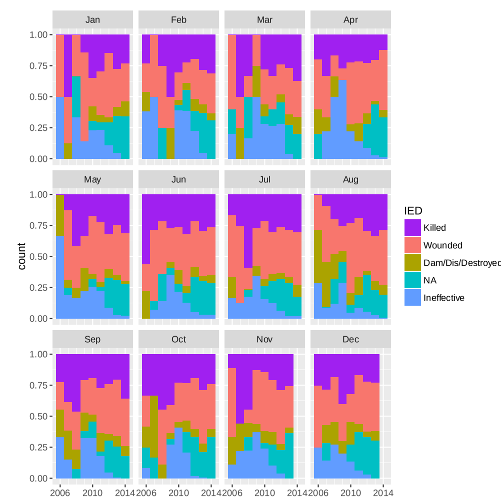
(c) Afghan Police



(d) Afghan Military

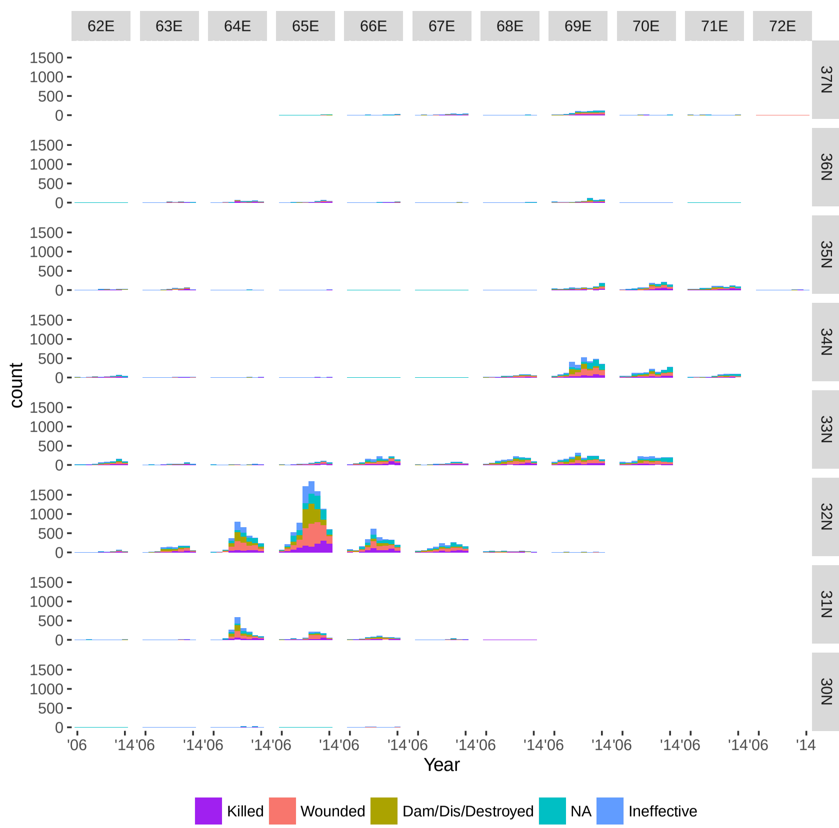


(e) Afghan Military, Supported

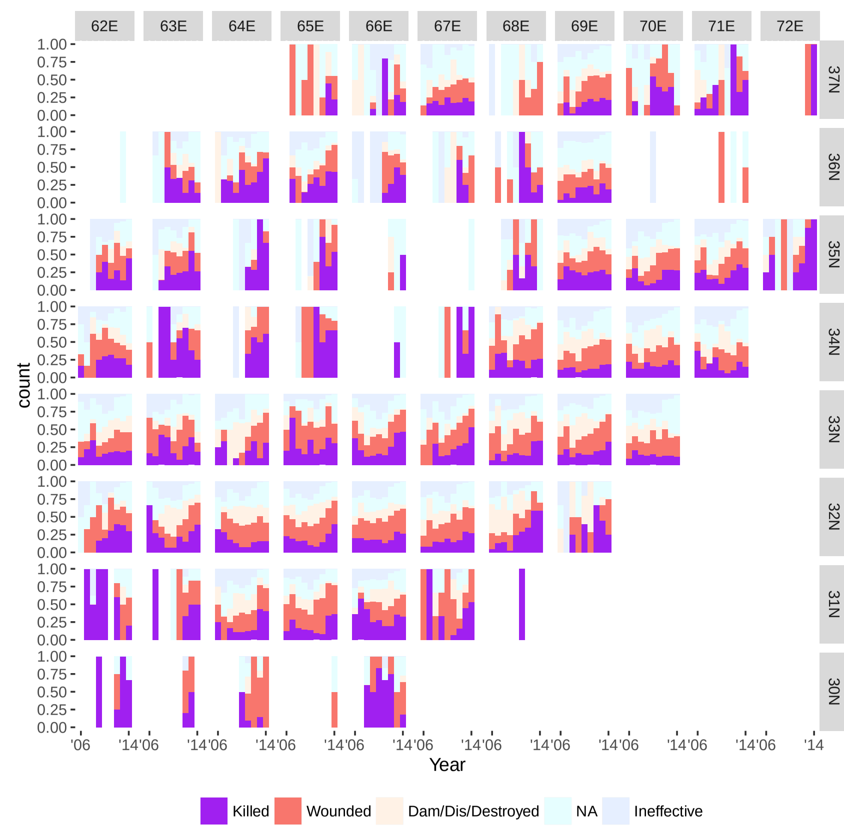


(f) Afghan Military, Unsupported

Figure SI-5: Outcomes of IED explosions in Afghanistan by Lat-Lon grid square



(a) Number of explosions with each outcome



(b) Outcome shares (sums to 100%)

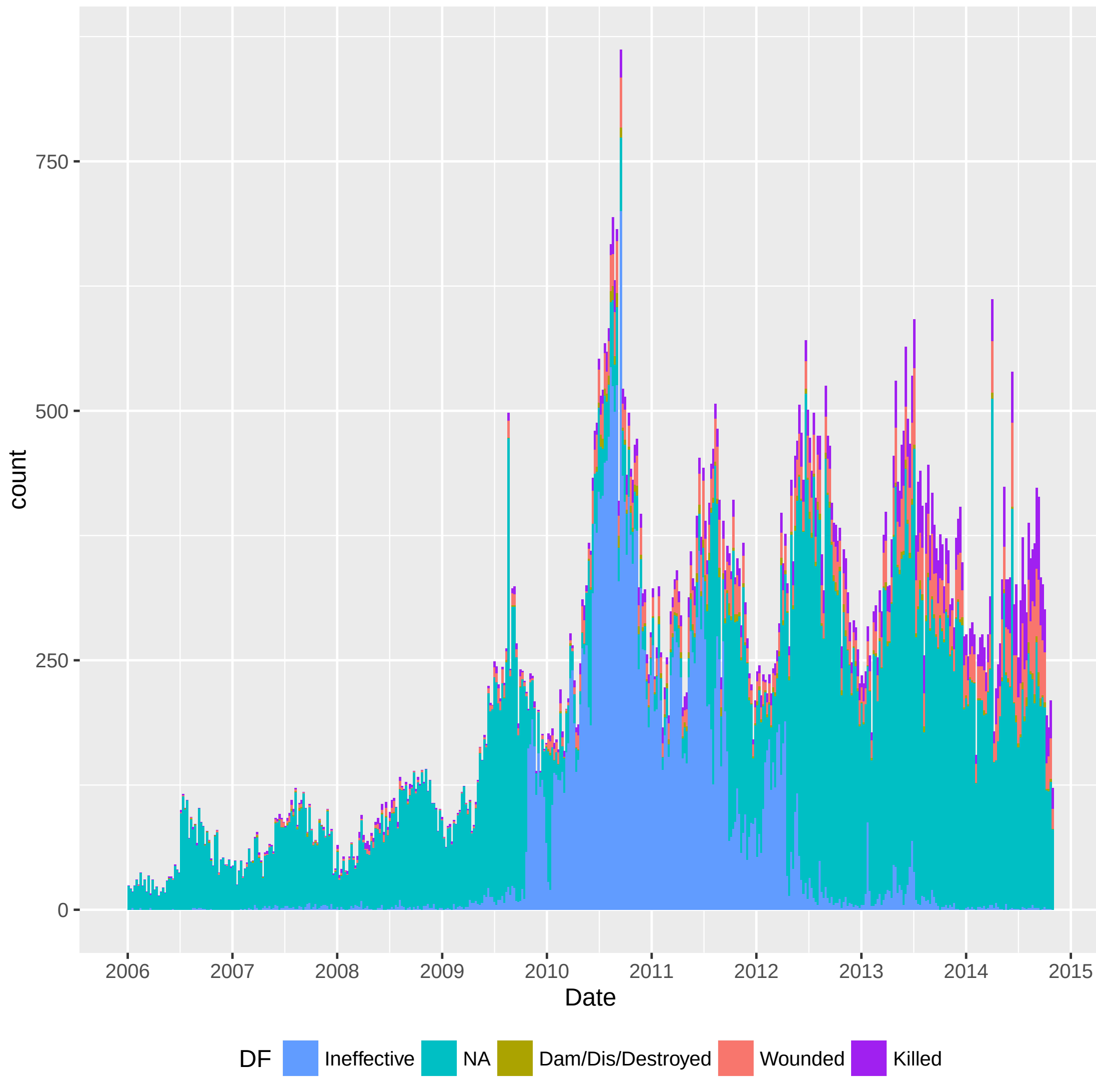


Figure SI-6: Direct Fire attacks (all of Afghanistan)

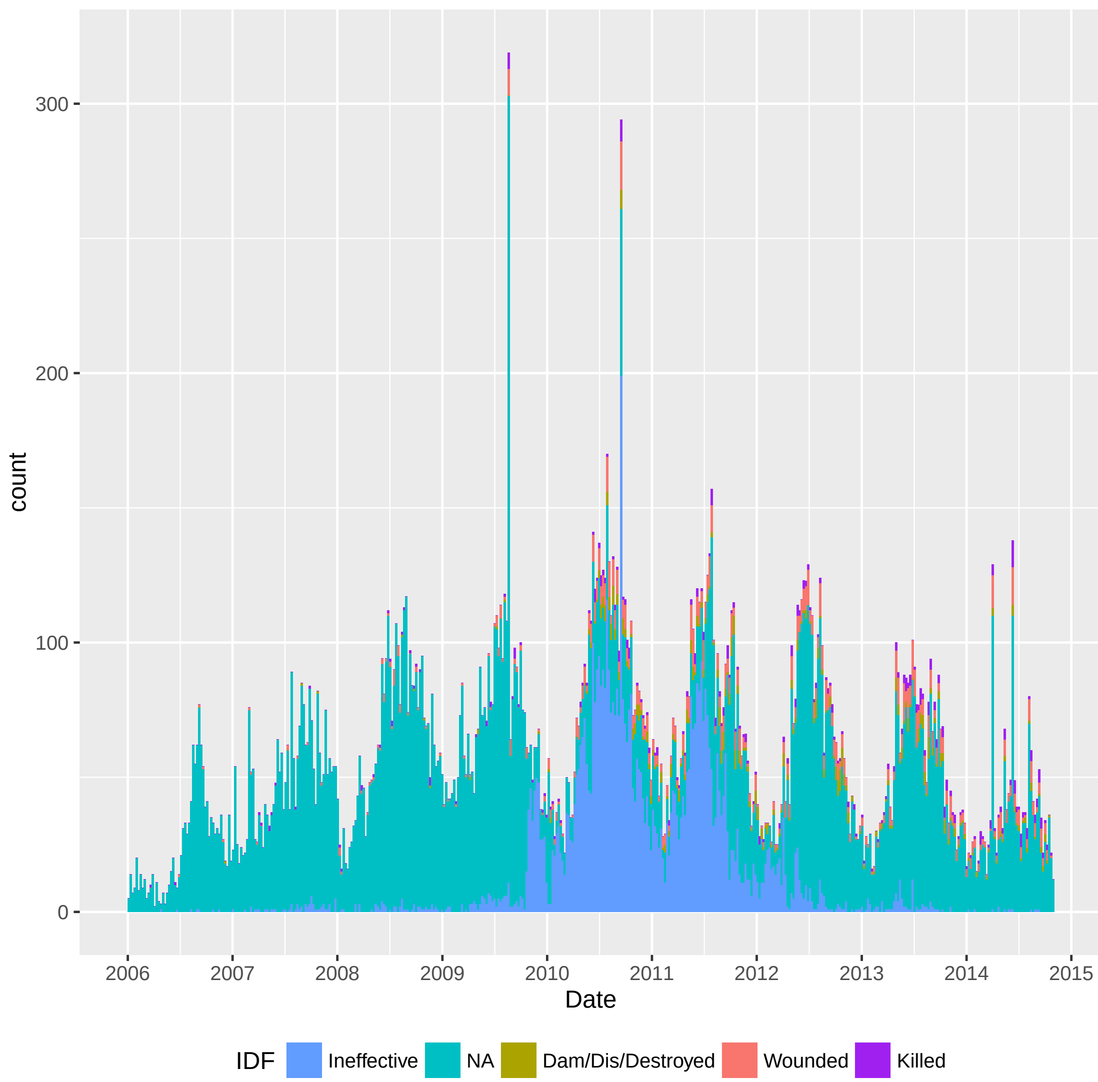


Figure SI-7: Indirect Fire attacks (all of Afghanistan)

D Potential Sources of Bias

The records were compiled by Coalition (primarily US) and host nation (Afghan) security forces. These events were collected as part of an 'operational' dataset that was intended for frequent evaluation (at an aggregate level) by commanders in the field and partner nations. The data passed through multiple points of evaluation (validation) before it entered the final version of the records which we utilize in this study. We thank Kyle Pizzey, who worked closely with the Afghanistan SIGACTS collection team, for confirming these institutional details.

We decompose four potential sources of bias: (1) underreporting of insurgent activity (in levels); (2) underreporting of casualty events by host nation (Afghan) forces; (3) underreporting of insurgent activity by Coalition forces; (4) declining quality of information during the security transition (2012-2014).

First, it is possible that the total number of attacks reported by Afghan forces in our data understates the true number of attacks, and does so to a greater extent in later years. This bias would not affect our results because we never use information on the total number of attacks in our analysis. Instead, we always analyze the outcome of an IED explosion conditional on the explosion happening, or the disposition (cleared or exploded) of an IED conditional on that IED appearing.

Second, it may be the case that Afghan forces deliberately underreported IED events that lead to casualties. This type of reporting error may have been driven by reputational concerns, particularly as districts were being evaluated for the security transition (districts were 'returned' to Afghan forces in tranches based on security assessments). If this bias were present, it would suggest that our estimates for Afghan forces are *downward* biased (i.e., casualty rates might have increased as a sharper rate than we report).

Third, Coalition forces may have similarly underreported casualty events. We find this highly unlikely as these events were rigorously vetted and reporting standards were clearly messaged to combatants. We anticipate that nearly the universe of combat activity involving

Coalition forces is present in our data (exceptions include operations that remain classified). We do not anticipate this bias would be large (if present). If present, however, our estimates would be *downward* biased here as well.

Fourth, related to our first concern, it is possible that the quality of information during the security transition declined sharply. However, as our nonparametric results suggest, our results are stable even if we exclude the transition period. To some extent, this is an empirical question that we can assess in the data. We observe a marginal decline in the completeness of our records at the tail end of 2014 (weeks 45 and above). For this reason, all our econometric results exclude this period.

E Proofs

Proof of Proposition 1. Consider

$$V^A = \sum_{t=1}^{T} \left[\frac{AC_t}{AC_t + DF_t} - cI_t^A \right] (1+r)^{-(t-1)} .$$

for $T = 2$, maximized with respect to I_1^A, I_2^A subject to

$$\begin{aligned} I_2^A (1+r)^{-1} &= Y^A - I_1^A \\ I_2^G (1+r)^{-1} &= Y^G - I_1^G \end{aligned} \tag{7}$$

and taking G's best response profile $\left\{I_1^G, I_2^G\right\}$ as given. Once we set $AC_0 = DF_0 = 0$ and we replace the budget constraints into V^A, we obtain the unconstrained maximand:

$$\begin{aligned} V^A = & \left[\frac{I_1^A}{I_1^A + I_1^G} \right] + \\ & \left[\frac{\alpha I_1^A + \gamma I_1^G + \left(Y^A - I_1^A\right)(1+r)}{\alpha I_1^A + \gamma I_1^G + \left(Y^A - I_1^A\right)(1+r) + \alpha I_1^G + \rho I_1^A + \left(Y^G - I_1^G\right)(1+r)} \right] (1+r)^{-1} - cY^A \end{aligned} \tag{8}$$

The first order condition with respect to I_1^A is:

$$\begin{aligned}\frac{\partial V^A}{\partial I_1^A} &= \frac{I_1^G}{\left(I_1^A+I_1^G\right)^2} - \left[\frac{(1+r)^{-1}}{\left(AC_2+DF_2\right)^2}\right]\times \\ &\quad [(1+r-\alpha)\left(AC_2+DF_2\right) - AC_2\left(1+r-\alpha-\rho\right)] \\ &= 0\end{aligned}$$

Repeating the exercise for G, we obtain the FOC:

$$\begin{aligned}\frac{\partial V^G}{\partial I_1^G} &= \frac{I_1^A}{\left(I_1^A+I_1^G\right)^2} - \left[\frac{(1+r)^{-1}}{\left(AC_2+DF_2\right)^2}\right]\times \\ &\quad [(1+r-\alpha)\left(AC_2+DF_2\right) - DF_2\left(1+r-\alpha-\gamma\right)] \\ &= 0\end{aligned}$$

Define $\chi = 1+r-\alpha$. Solving the system constituted of these two FOCs implies the unique equilibrium investment levels for A and G:

$$\begin{aligned}I_1^A &= \Delta \times \left[\chi Y^A + \gamma Y^G\right] \\ I_1^G &= \Delta \times \left[\chi Y^G + \rho Y^A\right]\end{aligned}$$

where

$$\Delta = \frac{(1+r)^2(Y^A+Y^G)^2}{\begin{array}{c} Y^{A2}\left((2+r^3-2r^2(\alpha-2)+2\alpha^2+2\gamma+\gamma^2-2\alpha\left(2+\gamma\right)-\gamma\rho+r(5-6\alpha+\alpha^2+2\gamma-\gamma\rho)\right) \\ +2Y^AY^G\left((r^3-2r^2(\alpha-2)+(\alpha-1)\left(2\left(\alpha-1\right)-\gamma-\rho\right)+r(5-6\alpha+\alpha^2+\gamma+\rho-\gamma\rho)\right) \\ +Y^{G2}\left((2+r^3-2r^2(\alpha-2)+2\alpha^2+2\rho+\rho^2-2\alpha\left(2+\rho\right)-\gamma\rho+r(5-6\alpha+\alpha^2+2\rho-\gamma\rho)\right)\end{array}}$$

and, through the budget constraints (7), we also have the unique equilibrium I_2^A and I_2^G. This construction proves existence and uniqueness of the Nash equilibrium.

Consider now the equilibrium insurgent effectiveness at periods 1 and 2 obtained by using the players' equilibrium investment strategies:

$$\begin{aligned} \frac{AC_1}{AC_1 + DF_1} &= \frac{\chi Y^A + \gamma Y^G}{(\chi+\rho) Y^A + (\chi+\gamma) Y^G} \\ \frac{AC_2}{AC_2 + DF_2} &= \frac{Y^A}{Y^A + Y^G}. \end{aligned}$$

Notice then that

$$\frac{\chi Y^A + \gamma Y^G}{(\chi+\rho) Y^A + (\chi+\gamma) Y^G} = \frac{Y^A}{Y^A + Y^G}$$

if it holds that

$$\frac{\gamma \left(Y^G\right)^2 - \rho \left(Y^A\right)^2}{\left(Y^A + Y^G\right)\left((\chi+\rho) Y^A + (\chi+\gamma) Y^G\right)} = 0$$

or

$$\frac{\rho}{\gamma} = \left(\frac{Y^G}{Y^A}\right)^2.$$

Notice further that

$$\begin{aligned} \frac{AC_1}{AC_1 + DF_1} &< \frac{AC_2}{AC_2 + DF_2} \\ &\Rightarrow \\ \left(\frac{Y^G}{Y^A}\right)^2 &< \frac{\rho}{\gamma}. \end{aligned}$$

This proves the proposition. ■

Proof of Proposition 2. Consider that

$$\rho/\gamma > \left(Y^G/Y^A\right)^2$$

implies

$$\frac{\rho\left(Y^A\right)^2-\gamma\left(Y^G\right)^2}{\chi Y^A+\gamma Y^G}>0$$

and notice that

$$\frac{\rho\left(Y^A\right)^2-\gamma\left(Y^G\right)^2}{\chi Y^A+\gamma Y^G}=\frac{I_1^G}{I_1^A}-\frac{Y^G}{Y^A}.$$

So from the argument above it holds that

$$\frac{I_1^G}{I_1^A}-\frac{Y^G}{Y^A}>0,$$

then this implies that the difference

$$\begin{aligned}\frac{I_2^G}{I_1^G}-\frac{I_2^A}{I_1^A} &= \\ \left(Y^G I_1^A-Y^A I_1^G\right)\frac{(1+r)}{Y^A Y^G} &< 0.\end{aligned}$$

This proves the proposition. ■