The Cost-Effectiveness of Armored Tactical Wheeled Vehicles for Overseas U.S. Army Operations

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Abstract

This study uses For Official Use Only data on U.S. military operations to evaluate the large-scale Army policies to replace relatively light Type 1 Tactical Wheeled Vehicles (TWVs) with more heavily protected Type 2 variants and later to replace Type 2s with more heavily protected Type 3s. We find that Type 2 TWVs reduced fatalities at $1.1 million to $24.6 million per life saved, with our preferred cost estimates falling below the $7.5 million cost-effectiveness threshold, and did not reduce fatalities for administrative and support units. We find that replacing Type 2 with Type 3 TWVs did not appreciably reduce fatalities and was not cost-effective.

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Over the course of the Global War on Terror, the U.S. Army engaged in two large scale vehicle replacement programs that aimed to reduce the fatality and injury risk for U.S. troops. Both programs affected wheeled ground vehicles that were used for day-to-day operations by U.S. forces. The first replacement program involved replacing a large number of light Type 1 tactical wheeled vehicles (TWVs), which cost roughly $50,000 a piece in 2010 dollars, with $170,000 more heavily protected Type 2 TWVs. The second replacement program began at the same time that the first program was ending, and it involved replacing about 9,000 Type 2 TWVs with $600,000 Type 3 TWVs. The switch from Type 2 to Type 3 TWVs continues in current operations, and procurement expenditures on Type 3 TWVs totaled $35 billion in the first three years of that program. This study aims to determine the cost-effectiveness of these vehicle options in terms of expenditures per life saved.

By using data compiled from multiple Army and DoD sources to evaluate two recent, large-scale Army procurement initiatives, the current study aims to contribute to a quickly growing empirical literature in Economics that analyzes the effects of U.S. military policies (*e.g.*, Berman, Shapiro, and Felter, 2009; Davis, Murphy, and Topel, 2006; Greenstone, 2007; Hanson, Iyengar, and Monten, 2009; Rohlfs, 2010; Stiglitz and Bilmes, 2008; Walsten and Kosec, 2005).

This project is uses For Official Use Only (FOUO, *i.e.*, sensitive but unclassified) data on casualties, vehicle holdings and usage, and troop characteristics for an unbalanced monthly panel of U.S. Army battalions over 71 months. The current paper presents descriptive statistics and regression results that have been cleared for public released by the U.S. Department of Defense (DoD). Due to the sensitive nature of the data and the results in this paper and as conditions for DoD release, all vehicle systems are referred to with the generic titles of Type 1, 2, and 3 TWV, and the months of data are referred to numerically as one through 71. U.S. operations in the

Global War on Terror took place in two overseas theaters, which we refer to using the generic titles of Theaters A and B. The battalions used in this study all serve in Theater A and constitute a roughly 20% sample of U.S. Army battalions in that theater over those 71 months. To meet these conditions for public release, many of the sources used for the data and institutional details in this paper are excluded from the references list. A full version of the paper with names and descriptions of the vehicles, dates, and a complete set of references has been released internally by the U.S. Naval Postgraduate School as a Technical Report. That file is FOUO and has been approved for circulation to DoD employees (Rohlfs and Sullivan, 2011). As the source data are FOUO, they can only be requested from the originating agencies by DoD employees or contractors for government purposes.

The main estimation equations in this paper are ordinary least squares (OLS) and fixed effects regressions that express a unit's deaths in a given month as a function of its stocks of different vehicle types. We examine different sets of control variables, among them troop characteristics, fixed effects for month, province, and unit, province by month interaction effects, and unit-specific trends. The unit-level controls allow us to adjust for intrinsic differences between early and late receivers of the more protected vehicles. The province-by-month effects allow us to adjust for changes in the combat environment that may have influenced the allocation of the new vehicles across geographical areas. We also measure the effects of the phase-in policies on unit-level injuries and on the usage of different types of vehicles.

Our estimates are presented separately for four types of units: infantry, armored and cavalry, administrative and support, and other. For infantry units, we find that replacing a Type 1 with a Type 2 TWV reduced fatalities by 0.04 to 0.43 per month at $1.1 million to $24.6 million per life saved. Our preferred cost per life saved estimates are on the low end of this range and fall below commonly cited estimates of the Value of a Statistical Life (VSL) of $7.5 million (Holt, 2004; Stiglitz and Bilmes, 2008; Viscusi, 1993), indicating that replacing Type 1 with Type 2 TWVs was cost-effective for these units. Despite the Type 3 TWV's higher cost and the heavier armor, we find little difference in the effects on fatalities between the Type 3 and Type 2 TWVs, and replacing Type 2 with Type 3 TWVs does not appear to have been cost-effective. Relative to the effects for infantry units, we find slightly smaller effects of the policies on fatalities for units in the "other" category and little or no effects for administrative and support units. We find that replacing Type 1 TWVs with Type 2 or Type 3 TWVs caused armored and cavalry units to substitute away from heavier vehicles such as tracked vehicles, thus increasing fatalities for those units.

The estimates presented here measure the full reduced-form effects of changing vehicle type, taking into account the intrinsic properties of the vehicles and any behavioral responses by the units. While reducing fatalities was the primary aim of the policies, our estimates should be interpreted with the caveat that they do not capture other potential benefits, such as increasing mission success or reducing the number of improvised explosive device (IED) attacks. If we suppose that Type 2 TWVs were more effective or deterred more IED attacks than Type 1 TWVs and Type 3 TWVs more than Type 2 TWVs, then both policies were probably more cost-effective than our estimates suggest. Additionally, Type 3 TWVs were introduced into Theater A during a relatively safe period. We find very suggestive evidence that Type 3 TWVs would have been cost-effective had they been introduced during a more combat-intensive period of operations.

II. Data and Descriptive Results

A. Data Sources

The unit-level unbalanced monthly panel data used in this study measure a sample of U.S. Army battalions in Theater A over the course of a 71-month time frame. The original data are measured at the company level (six-digit Unit Identification Code, UIC) and are aggregated to the battalion level (four-digit UIC) so that the level of observation matches up most closely with the ways in which vehicles and tasks were assigned. All sources used here are FOUO unless noted otherwise; additional details are in the appendix.

Vehicle Quantities

Data on different units' vehicle holdings and usage come from the Theater A portion of AMSAA's Sample Data Collection (SDC, U.S. AMSAA, 2010). The SDC tracks a range of tactical and non-tactical ground vehicle systems and includes each vehicle's serial number, mileage, and unit affiliation. The data measure a representative sample of roughly one fifth of U.S. Army units in Theater A, and roughly one third of a typical sampled unit's TWVs appear in the data. The fraction of a unit's vehicles that were sampled is not observed and varies across units due to cooperativeness with the study, activity level, and distance from the data collectors' base of operations in Theater A's capital city (Horsley, 2010). The within-unit fraction of vehicles sampled appears to have been constant over time.[4]

To estimate the numbers of vehicles of each type in each unit, we assume that the sampling fraction for each vehicle type is constant across units and over time. We estimate these

[4] Active units were less able to accommodate the data collectors; however, the researchers' worked to ensure that usage and maintenance rates were similar between the SDC and the entire Army in Theater A. With the exception of the vehicle phase-in policies, the exact set of vehicles in the data (as identified by their serial numbers) within a unit is fairly stable, and it is rare for a specific vehicle to drop out of the sample and reappear in a later month. Such cases account for 2.5% of vehicle months, and adding them to the totals has little effect on our estimates. Some vehicle types were dropped from the set of tracked systems when miles driven for those systems were zero for the entire dataset for a few months; hence, unused vehicles tend to be excluded from the unit-level totals. Beginning midway through the sample period, all Type 1 TWVs were dropped for this reason (Simberg, 2007, 2010b).

sampling fractions so that, for each vehicle type, the ratio of vehicles per troop is the same for the SDC as for the entire Army in Theater A.[5] Theater-wide counts of Army vehicles, provided by AMSAA, measure tracked vehicle systems at 21 irregularly-spaced dates over the 71 months of the sample (Simberg, 2010a). Theater-wide vehicle and troop totals are linearly interpolated for in between dates.

Cost Estimates

Estimates of the costs for different TWV models were obtained through email requests to various cost experts in the Army and DoD. These costs include purchase prices as well as transport, gasoline, and maintenance costs. Transport costs are measured as the average amount reimbursed to the transportation commands per vehicle of that type and cover the entire cost of transport from base in the U.S. to its combat post in Theater A. In-theater fuel and maintenance costs are estimated to be \$5.50 and \$8.00 per mile for Type 1 TWVs and \$10.50 per mile for Type 2 and Type 3 TWVs. Dollar costs do not adjust for inflation and are current as of early 2010. Estimates of the in-theater lifespan of a Type 1 or Type 2 TWV range from two to five years. Given the short span of data available on Type 3 TWVs estimates do not yet exist of their in-theater lifespans. For the purposes of this study, we assume a one-way trip and three-year lifespan for all vehicle types, and we assume that each vehicle is used in combat for all three years.

[5] We estimate vehicle counts and mileages using a separate, constant adjustment factor for each vehicle type. These adjustment factors are calculated as (total Army vehicle months of that type in Theater A)/(total Army troop months in Theater A) divided by (Army vehicle months of that type in the Theater A SDC)/(Army troop months in the Theater A SDC). For Type 2 TWVs and for vehicle types other than TWVs, vehicle and troop months are totals over the sample period. The per troop figures for Type 1 TWVs are calculated though month 30, and the per troop figures for Type 3 TWVs are calculated beginning in month 43, so that only months in which the vehicle was in theater are used. The adjustment factors we use come out to 3.62 for Type 1 TWVs, 2.75 for Type 2 TWVs, 4.74 for Type 3 TWVs, and factors ranging from 0.80 to 1.11 for other vehicle types. Each unit-level vehicle mileage and count from the SDC is multiplied by the adjustment factor for its type to obtain our estimate of the total mileage and vehicle count for that unit.

Fatalities and Injuries

Unit casualties are measured using data requested from the U.S. Defense Manpower Data Center (DMDC, 2010a) that include date, city and country, type of casualty (*e.g.*, KIA), unit, and pay grade for all combat and non-combat deaths and combat injuries to U.S. military personnel over the sample period. Of the roughly 24,000 casualties incurred by U.S. Army units in Theater A over this period, 7.8% were Killed in Action (KIA), 2.5% were non-combat deaths, and the remainder were non-fatal injuries.[6]

One key descriptive variable that we obtain from the casualty data is unit location. Using Google Earth and ArcGIS, we determine the geographic coordinates of the casualty city for 81.9% of the U.S. Army casualties in Theater A and identify which of the 18 provinces in Theater A contains each coordinate pair. We assume that a unit's location is the province in which it incurred the most casualties that month. If a unit incurred no casualties with identifiable locations in that month, we use the closest month (before or afterwards) with available data. In 22% of cases, we were not able to identify the unit's location through this procedure. These observations are kept in the data with province equal to a nineteenth "unknown" category.[7]

Unit Characteristics

Additional data requested from DMDC (2008, 2010b) include the number of troops, the fraction that are officers, Private or Private First Class (PFC), high school graduates, male, black, and Hispanic, average days of deployment experience and age by unit and month, the unit's name, and its home state within the U.S. Using the name, we divide units into infantry, armored

[6] One death and seven non-fatal injuries are omitted from the last month of data.
[7] Dropping the 823 unit months with unknown locations has little effect on our estimates.

and cavalry, administrative and support, and other (including artillery, engineers, military police, and ordnance) based on the main set of tasks that each unit performs. The unit types that were used the most in combat were infantry, armored and cavalry units, with infantry patrolling more by foot and in TWVs and armored and cavalry making greater use of heavier vehicles such as tracked vehicles (About.com, 2010, U.S. Army, 2010; The U.S. Army Info Site, 2010).

For cases in which unit characteristics were missing for a given unit month but available for that unit for another month, we use the unit's characteristics for the nearest month (looking up to twenty months backward and forward). Of the 4,403 unit months describing 522 units in the SDC, data are imputed in this way for 141 cases describing 56 units, with nearly all of the imputed cases taken from the previous month. Another 730 cases describing 102 units are dropped from the sample due to missing unit characteristics data. These dropped units were not active in combat and the entire set experienced only two combat injuries and zero deaths over the sample period. The remaining sample includes 3,673 observations from 424 different units.[8]

B. Descriptive Results

Theater-wide Patterns

The theater-wide counts of Army TWVs from months one to 71 are plotted in panel A of Figure 1. The white area shows the total number of the Army's Type 1 TWVs in Theater A, the solid gray area shows Type 2 TWVs, and the black area shows Type 3 TWVs. Panel B of Figure 2 shows the numbers of U.S. troops in Theater A by quarter for the Army and other military branches. As panel A shows, in the first month of the theater-wide data, the total number of

[8] Troop characteristics are missing for these observations because no troops from those units were found in the DMDC's personnel file. For specifications that exclude the unit characteristics as controls, keeping these 730 observations in the data leads to substantially smaller fatality-reducing effects of both policies for infantry and "other" units, presumably because the omitted units are small and rarely engaged in combat. Dropping the 28 cases in which troops are less than 10 does not affect the results from this study.

Army TWVs in Theater A was 18,600, of which 5,700 were Type 2. The total number of U.S. Army troops at this time was 114,000, or 6.1 per TWV. The shift to Type 2 TWVs primarily occurred over months 20 to 40. The number of Type 1 TWVs peaked in the data in months 19 and 21 and then sharply declined, reaching zero by month 49.[9] The number of Type 2 TWVs increased steadily over the first year and a half of the sample, reaching a peak of 16,000 in month 42.

Panel A of Figure 1 also shows the shift from Type 2 to Type 3 TWVs from months 42 to 61. The number of Type 2 TWVs declined steadily from 16,000 in month 42 down to 7,800 in month 61. From months 42 to 45, the number of Army Type 3 TWVs in Theater A rose from zero to 423 and continued to rise over the next year and a half, peaking at 8,500 in 61. Over the last years of the sample, the numbers of Army Type 2 and Type 3 TWVs both declined, and by month 71, the Army's numbers of Type 3 and Type 2 TWVs had fallen to 6,700 and 5,900.[10]

Panel B shows the number of U.S. troops in Theater A, separately for the Army and other service branches. The average total number of U.S. troops in months one through 71 was 181,000 with a standard deviation of 19,000. The U.S. Army comprised about two-thirds of the total number of U.S. troops throughout the course of operations. The largest garrison of U.S. troops in Theater A was 218,000 in month 41. This total was achieved after a 54,000 increase in the number of troops over the previous nine months. Troop totals steadily declined thereafter, reaching their low point of 140,000 in the last month of data. Panels C and D of Figure 1 present the cost estimates from this study. Panel C shows the average cost per vehicle for each of the

[9] Beginning in months 39 to 49, a few different models of Type 1 TWVs were dropped from the data collection. While the numbers of these vehicles did not drop to exactly zero, by this time, use of the remaining vehicles of these types only occurred on bases (Simberg, 2010b).

[10] In addition to replacing vehicles, the Army enacted a large-scale policy to increase the availability of Interceptor Body Armor that was available to troops in Theater A. This policy took place in the first months of operations, and all Army personnel in Theater A had received the new armor before the start of the vehicle replacement programs studied here.

four vehicle systems studied, and panel D shows the Army's annualized expenditure on vehicles in Theater A by vehicle type. The white, gray striped, solid gray, and black areas correspond to Type 1, Type 1 variant, Type 2, and Type 3 TWVs, respectively. The per unit cost estimates in panel C assume a constant rate of usage of 484 miles per month, the rate observed for the average vehicle in the SDC data. Our estimated costs of a three-year deployment are $143,000 for a Type 1 TWV, $228,000 for the slightly more protected Type 1 variant TWV, $345,000 for a Type 2 TWV, and $780,000 for a Type 3 TWV. The annualized expenditures in panel D are calculated using the actual miles driven that month by the average vehicle of that type in the SDC. The fraction of Type 1 TWVs that are the more protected variant is assumed to be the same as in the SDC. The large area for Type 3 TWVs in panel D highlights the substantial cost of that vehicle system to the Army, despite the relatively low numbers of those vehicles.

Panel E of Figure 1 shows total U.S. Army casualties in Theater A by month over the entire war. The black area shows KIA, the gray area shows deaths other than KIA (deaths of wounds, deaths while captured or missing, and non-combat deaths), and the white area shows combat-related injuries. The Army incurred 34 deaths and 266 combat-related injuries in Theater A in the average month. The standard deviation in deaths across months is 23, the standard deviation in combat-related injuries is 166, and total Army casualties in Theater A often changed by more than 100 from one month to the next. Some of these changes are attributable to U.S.-led actions, such as the tactical decision to increase U.S. troop levels around month 32.; however, many are attributable to changes in insurgent activity and the numbers of IED attacks.

The totals in panel E help to illustrate how changes over time in the combat environment might bias our estimates. Injuries and fatalities increased to a local peak in month seven and declined thereafter until reaching a local trough in month 21. After month 21, casualties climbed steadily until reaching a global peak in month 38 and rapidly declined for the remaining months in the data. Supposing that the large ups and downs in casualty levels and the steep decline over the last few years are due to factors unrelated to the Army's vehicle fleet, it is necessary to control for these monthly changes in the combat environment to avoid bias in our estimates of the risk-reducing effects of Type 2 and Type 3 TWVs.

Descriptive Results for the SDC Units

Next, in Figures 2 and 3, we examine the time-series changes in vehicle stocks and casualties for each of the four unit types in the SDC. Descriptive statistics for all of the SDC variables are presented in the appendix. The four panels of Figure 2 show the numbers of TWVs monthly for the four different unit types in the data. The solid white areas correspond to Type 1 TWVs, the striped gray areas to the slightly more protected Type 1 variant TWVs, the solid gray areas to Type 2 TWVs, and the black areas to Type 3 TWVs.

The high variability in the vehicle numbers in Figure 2 is largely attributable to changes in the sample composition. The spike and later drop in infantry TWV quantities around month 29 is due to a drop from six to four in the number of units in the sample in month 28, a further drop to three units in month 29, and the addition of a different fourth unit in month 30. The spike in TWV quantities for the "other" category in the first few months of the sample is due to the number of units increasing from one to two from months 14 to 15 and again from three to four from months 17 to 18

The phase-in policies are both apparent in Figure 2 for all four unit types. The shift from Type 1 to Type 2 TWVs is soonest for infantry, with a sharp drop from an average of 123 Type 1 TWVs in month 17 to 19 Type 1 TWVs in the following month, and latest for administrative and support, who still had relatively large numbers of Type 1 TWVs around month 27. The Type 3 TWV phase-in is soonest and most pronounced for armored and cavalry, followed by infantry units. In their peak months, the average numbers of Type 3 TWVs were 62 for infantry, 59 for armored and cavalry, 18 for administrative and support, and 31 for other units.

Panels A through D of Figure 3 plot average casualties by unit type for the SDC data. As with panel E, casualties are highly variable across months, a phenomenon that is exacerbated by the changing sample composition in the SDC. Nevertheless, the general patterns from the theater-wide data also appear in Figure 3; we see lulls in casualties around month 22 followed by higher numbers in months 32 to 42 and few casualties in month 42 or later.

For infantry units in panel A, we see drops in casualties in month 18 (the month of the sharp phase-in of Type 2 TWVs) and in the month immediately afterward. This drop provides some very suggestive evidence of a negative effect of the Type 2 TWV phase-in for infantry units. For the remaining unit types, the Type 2 TWV phase-in occurred too slowly to disentangle its effects from gradual changes in the combat environment. The very low casualty rates observed in the months before the Type 3 TWV phase-in for infantry, administrative and support, and other units suggest that there is little that Type 3 TWVs could have done to further reduce casualties. For armored and cavalry units, the main increase in Type 3 TWVs occurred in month 46. While we see a drop to zero casualties in that month, casualties in the next three months were similar to the levels before the phase-in, and we do not see a long-term drop in casualties until month 50. The lack of a sharp and sustained decrease in casualties immediately after the Type 3 TWV phase-in provides some very suggestive evidence that there was not a large negative effect of the Type 3 TWV phase-in for armored and cavalry units.

IV. Model

Next, we develop an econometric framework for formally evaluating the cost-effectiveness of the phase-in policies. For a given unit i in month t, suppose that fatalities are determined according to the following linear equation:[11]

$$(1)\ fatalities_{it} = \sum_{j=1}^{3} \alpha_{cj}^{f} * q_{jit} + \boldsymbol{\beta}_{\mathbf{c}}^{\mathbf{f}\prime}\mathbf{x}_{\mathbf{it}} + \varepsilon_{it}^{f},$$

where q_{1it}, q_{2it}, and q_{3it} represent the quantities of each of three types of vehicles possessed by unit i in month t, $\mathbf{x}_{\mathbf{it}}$ is a vector of control variables that might include other vehicle quantities, troop characteristics, or fixed effects for month, province, month by province, or unit, ε_{it}^{f} is random error, and the coefficients are allowed to vary by the unit's classification c as infantry, armored or cavalry, administrative and support, or other. Let vehicle types one, two, and three be defined as Type 1, Type 2, and Type 3 TWVs, where the Type 1 variant TWVs are grouped together with other Type 1 TWVs due to small sample sizes.

Because the focus of this study is the effects of replacing one vehicle type with another, it is convenient to rearrange the terms in Equation (1) to obtain the following specification:

$$(2)\ fatalities_{it} = \left(\alpha_{c2}^{f} - \alpha_{c1}^{f}\right) * q_{2it} + \left(\alpha_{c3}^{f} - \alpha_{c1}^{f}\right) * q_{3it} + \alpha_{c1}^{f} * \sum_{j=1}^{3} q_{jit} + \boldsymbol{\beta}_{\mathbf{c}}^{\mathbf{f}\prime}\mathbf{x}_{\mathbf{it}} + \varepsilon_{it}^{f}.$$

Equation (2) serves as our main regression specification, with $\sum_{j=1}^{3} q_{jit}$, q_{2it}, q_{3it}, and varying formulations of $\mathbf{x}_{\mathbf{it}}$ as the regressors. The differences $\left(\alpha_{c2}^{f} - \alpha_{c1}^{f}\right)$ and $\left(\alpha_{c3}^{f} - \alpha_{c1}^{f}\right)$ measure the effects of replacing Type 1 TWV with a Type 2 or Type 3 TWV.

In order for OLS and fixed effects to consistently estimate these differences, we require that after controlling for unit-, location-, and time-specific determinants of fatalities as well as

[11] A linear functional form is used so that the fatalities and expenditures are treated symmetrically in the estimation procedures. For the specifications with relatively few control variables, when a Poisson regression is used, our estimated average marginal effects are highly imprecise and vary considerably across specifications. For the specifications with the larger sets of controls and fixed effects, the Poisson estimates generally fail to converge.

the total number $\sum_{j=1}^{3} q_{jit}$ of type one, two, and three vehicles, the unobserved determinants ε_{it}^{f} of fatalities are uncorrelated with unit i's time t numbers q_{2it} and q_{3it} of Type 2 and Type 3 TWVs. The fraction of a unit's vehicles that appear in the sample varies across units in ways that are not observable to the researcher, and $\sum_{j=1}^{3} q_{jit}$, q_{2it}, and q_{3it} are measured with error that is correlated with the factors determining this sampling fraction, among them units' activity levels and distance from the capital city. Because these fractions were roughly constant within units over time, we do not expect this bias to appear in our preferred specifications that include unit fixed effects in $\mathbf{x_{it}}$,. The large changes in vehicle quantities generated by the phase-in policies help to ensure that, even after including many controls and fixed effects in the regressions, sufficient within-unit and within-province-by-month exogenous variation remains in q_{2it} and q_{3it} to identify $\left(\alpha_{c2}^{f} - \alpha_{c1}^{f}\right)$ and $\left(\alpha_{c3}^{f} - \alpha_{c1}^{f}\right)$.

To relate these effects on fatalities to dollar costs, let p_{0j} denote the purchase price (including shipping cost), and let p_{1j} denote the additional cost per mile driven for a type j vehicle. Let $mileage_{jit}$ denote the miles driven of type j vehicles by unit i in month t, and define $expenditure_{it}$ as unit i's month t expense for all three vehicle types::[12]

(3) $expenditure_{it} = \sum_{j=1}^{3} \left(\frac{1}{36} p_{0j} * q_{jit} + p_{1j} * mileage_{jit}\right).$

Expenditures can be written as a linear function symmetrically to the fatalities equations:

(4) $expenditure_{it} = (\alpha_{c2}^{e} - \alpha_{c1}^{e}) * q_{2it} + (\alpha_{c3}^{e} - \alpha_{c1}^{e}) * q_{3it} + \alpha_{c1}^{e} * \sum_{j=1}^{3} q_{jit} + \boldsymbol{\beta}_{\mathbf{c}}^{\mathbf{e}\prime} \mathbf{x_{it}} + \varepsilon_{it}^{e},$

where $(\alpha_{c2}^{e} - \alpha_{c1}^{e})$ and $(\alpha_{c3}^{e} - \alpha_{c1}^{e})$ represent the monthly costs of replacing a Type 1 TWV with a Type 2 or Type 3 TWV. Expressing the costs of changing vehicle type through Equation (4) helps to ensure that the same factors are held constant and the same sets of observations are

[12] In practice, the purchase prices we use vary by unit and month based on the exact TWV models owned.

compared to one another for the cost as for the fatalities estimation. The mileage and expenditure data are constructed from the SDC sample and use the same sampling weights as the vehicle counts; consequently, the measurement error in vehicle quantities that affects the fatalities regressions does not affect the coefficients in Equation (4).

The cost per life saved from replacing a Type 1 with a Type 2 TWV is $-(\alpha_{c2}^{e} - \alpha_{c1}^{e})/(\alpha_{c2}^{f} - \alpha_{c1}^{f})$, negative one times the ratio of the coefficient on Type 2 TWVs in the expenditures equation divided by the coefficient on Type 2 TWVs in the fatalities equation. The cost per life saved from replacing a Type 2 TWV with a Type 3 TWV is $-(\alpha_{c3}^{e} - \alpha_{c2}^{e})/(\alpha_{c3}^{f} - \alpha_{c2}^{f})$, which is computed as negative one times the difference between the coefficient for Type 3 TWVs and the coefficient for Type 2 TWVs from Equation (4), all divided by the corresponding difference in coefficients from Equation (2). We calculate standard errors for these ratios by estimating Equations (2) and (4) together using seemingly unrelated regression and applying the delta method.

Other dependent variables considered in our analysis are combat-related injuries and miles driven of different vehicles. Measuring effects on injuries helps to identify a benefit of changing vehicle type not included in the cost per life saved calculations. In order to better interpret the effects on injuries, we compute ratios $(\alpha_{c2}^{i} - \alpha_{c1}^{i})/(\alpha_{c2}^{f} - \alpha_{c1}^{f})$ and $(\alpha_{c3}^{i} - \alpha_{c2}^{i})/(\alpha_{c3}^{f} - \alpha_{c2}^{f})$ of injuries reduced per life saved, where the i superscript denotes coefficients from the injury equation. Measuring effects on the mileage variables help to determine the extent to which the replacement policies led units to alter their behavior.

V. Results

A. Effects of Vehicle Replacements on Fatalities

The four panels of Table 1 present OLS and fixed effects estimates of Equation (2) separately for each of the four unit types. All three vehicle quantities are divided by 100 so that the coefficients can be interpreted as the monthly reductions in fatalities generated by 100-unit changes in vehicles. Within each panel, each column corresponds to a different set of control variables included in the vector $\mathbf{x_{it}}$. In column (1), the controls include only a constant term. Column (2) adds controls for other vehicle quantities and troop characteristics as well as a quadratic time effect.[13] Column (3) replaces the quadratic time effect with year by month fixed effects and adds province fixed effects. Column (4) replaces the year by month and province fixed effects with fixed effects for each province by year by month interaction. Column (5) replaces the province by year by month interactions with the quadratic time effect and adds unit fixed effects. Column (6) includes the year by month by province interactions and the unit fixed effects, and column (7) adds unit-specific monthly time trends. The standard errors adjust for clustering at the unit by year by quarter level.

In interpreting the results from Table 1, it is useful to have rough benchmark estimates of the thresholds for cost-effectiveness. Using the costs from panel C of Figure 2 of \$143,000 per Type 1 TWV, \$345,000 per Type 2 TWV, and \$780,000 per Type 3 TWV, the monthly cost of replacing 100 Type 1 with Type 2 TWVs is $\frac{100}{36} * (345{,}000 - 143{,}000) \approx 561{,}000$, and the monthly cost of replacing 100 Type 2 with Type 3 TWVs is $\frac{100}{36} * (780{,}000 - 345{,}000) \approx 1.21$ million. Assuming a VSL of \$7.5 million, replacing 100 Type 1 with Type 2 TWVs would have to reduce fatalities by at least $\frac{\$561{,}000}{\$7.5\text{ million}} \approx 0.075$ per month in order to be cost-effective. In order

[13] The month and year combinations in the sample are numbered chronologically from one to 71, and both the number of the month-year combination and its square are included as regressors.

for replacing 100 Type 2 with Type 3 TWVs to be cost-effective, the coefficient on Type 3 TWVs would have to exceed that on Type 2 TWVs by $\frac{\$1.2 \text{ million}}{\$7.5 \text{ million}} \approx 0.161$.

In the specifications with no controls in column (1), we observe negative effects of Type 2 TWVs for all of the unit types except administrative and support. This coefficient is significantly different from zero in one of the four cases; the magnitude is at the cost-effectiveness threshold for infantry units and does not meet this threshold for the other unit types. We also observe negative effects of Type 3 TWVs for all four unit types that are significantly different from zero in two and marginally significant in one of the four cases. The fatality-reducing effects of Type 3 TWVs in column (1) exceed those of Type 2 TWVs by 0.048 for infantry units, 0.035 for armored and cavalry and for administrative and support, and 0.023 for other units, and the difference in no case approaches the 0.161 cost-effectiveness threshold.

For infantry units in panel A, as additional controls are added to the regressions in columns (2) to (7), our estimated effects of Type 3 TWVs and Type 2 TWVs remain negative, and the coefficients for the two vehicle types have similar magnitudes. Across the seven specifications, our estimated effect of replacing 100 Type 1 with Type 2 TWVs ranges from -0.044 to -0.427 with average and median values of -0.157 and -0.281. While generally insignificant, this fatality-reducing effect exceeds the cost-effectiveness threshold in four of seven cases and in all three of the specifications that include unit fixed effects to adjust for cross-sectional variation in the fraction of vehicles included in the sample. Also for infantry units, our estimated effect of replacing 100 Type 1 with Type 3 TWVs ranges from -0.046 to -0.306, and the average and median differences between the coefficient on Type 3 TWVs and that on Type 2 TWVs are +0.017 and -0.002. Hence, we find that Type 3 TWVs offer little benefit beyond that of Type 2 TWVs, and their fatality-reducing effects do not appear to justify their costs. Our estimated effects for both vehicle types are stable across columns (1) to (5) and become considerably larger when unit fixed effects and province by month by year interactions are included in the same regressions in columns (6) and (7).

For the "other" unit category, we find that replacing 100 Type 1 with Type 2 TWVs would have reduced fatalities by 0.019 to 0.278 per month, an effect that is imprecisely estimated but exceeds the cost-effectiveness threshold in four of the seven specifications. We obtain similar estimates for Type 3 TWVs as for Type 2 TWVs, with effects ranging from 0.012 to 0.313 reduced fatalities per month and in no case exceeding the cost-effectiveness threshold. As with infantry units, the magnitudes of the coefficients are especially high in the specifications that include the most control variables.

Strangely, we find generally positive effects of Type 3 TWVs on fatalities for armored and cavalry units. For Type 2 TWVs, we find effects that are close to zero for most specifications but become large and positive in the specifications with the most controls. We observe a similar pattern of effects that are close to zero but become positive in the last columns for administrative and support units. While imprecise, these results suggest that Type 2 and Type 3 TWVs did not reduce fatalities in a cost-effective way for these unit types. We explore potential explanations for these positive effects in the appendix.

B. The Cost per Life Saved

Table 2 presents our cost per life saved estimates with corresponding standard errors. Within each panel and column, the top and bottom numbers are the estimated costs per life saved through replacing a Type 2 with a Type 3 TWV and through replacing a Type 1 with a Type 2

TWV. The unit types and controls are the same as in Table 1. The standard errors are computed using the delta method with clustering by unit x year x quarter.[14]

While imprecise, the patterns of estimates shown in Table 2 are generally consistent with our rough cost-effectiveness calculations above. For infantry units, in columns (1) to (4) with relatively few control variables, we find that replacing Type 1 with Type 2 TWVs, with costs per life saved ranging from $13.4 million to $24.6 million. When unit fixed effects are added to the regressions in columns (5) to (7), our estimated cost per life saved is close to the cost-effectiveness threshold at $9.1 million in one and well below the threshold at $1.1 million and $1.8 million in two of the three specifications. Because the Type 3 TWV policy's effects on fatalities, which are relatively small, appear in the denominator, we obtain a wide range of cost per life saved estimates for the substitution of Type 3 for Type 2 TWVs. Also for infantry units, we find that this policy was not cost-effective; we obtain four large cost per life saved estimates of $15.8 million, $49.7 million, $97.8 million, and $424 million, and three specifications in which the policy increased fatalities.

For the "other" category of units in panel D, in the first four specifications, we find high costs per life saved from replacing Type 1 with Type 2 TWVs, with estimates of $41.2 million, $72.0 million, $72.6 million, and $19.1 million. When unit fixed effects are included in the remaining three specifications, however, we find that the policy barely fails the cost-benefit test in one specification, with a cost per life saved of $10.1 million, and in the remaining two specifications, we find that the policy was cost-effective, with estimates of $4.12 million and

[14] Because the difference in fatalities appears in the denominator, the cost per life saved vacillates between infinity and negative infinity when this difference is close to zero. The linear approximation of the delta method does not capture this nonlinear, nonomonotonic relationship between the costs per life saved and the effects on fatalities. For the specifications with relatively large numbers of fixed effects, a 1,000-replication bootstrap fails to produce estimates. For the specifications with fewer controls, the bootstrapped standard errors are similar in magnitude to the asymptotic standard errors but with more of the very large standard errors in the billions of dollars per life saved.

$2.40 million per life saved. For replacing Type 2 with Type 3 TWVs, we find five high cost per life saved estimates of $20.0 million, $1.51 billion, $115 million, $18.5 million, and $48.0 million and two specifications in which the policy increased fatalities.

Of the remaining 14 estimates for armored and cavalry units, none pass the cost-benefit, with large cost per life saved estimates in four cases of $15.6 million, $35.4 million $40.4 million, and $55.4 million, and positive effects of the policies on fatalities in the other 10 cases. For administrative and support units, 10 of our 14 cost per life saved estimates are negative. The cases in panel C in which we find positive costs per life saved for substituting Type 3 for Type 2 TWVs are artifacts of the estimation procedure; in all of these cases, we find that Type 1 TWVs are the most cost-effective of the three vehicle types.[15]

Variation in the Cost per Life Saved

One of the main reasons for the small effects of Type 3 TWVs on fatalities is that they were introduced during a relatively calm period. The average TWV in the data was in a unit month with 0.419 days with deaths or combat-related injuries. For Type 2 and Type 3 TWVs, these averages are 0.443 and 0.101, respectively. If we assume that the vehicle replacement programs only affected deaths per casualty day (and not days of casualties), then multiplying the coefficient on Type 3 TWVs in Table 1 by four produces a rough estimate of the effect of replacing a Type 2 with a Type 3 TWV for a typical vehicle month. Applying this adjustment to our preferred specifications in columns 5 to 7 for infantry units, our estimated costs per life saved range from $\frac{\$1.2 \text{ million}}{4*0.306-0.357} \approx \$1.4$ million to $\frac{\$1.2 \text{ million}}{4*0.094-0.084} \approx \$4.1$ million. These back-of-

[15] For administrative and support units, our estimated cost per life saved from replacing Type 2 with Type 3 TWVs does not always have the opposite sign as our estimated effect on fatalities. This strange finding arises because replacing Type 2 with Type 3 TWVs is associated with large reductions in miles driven (and consequently usage costs) for this unit type, so that the policy reduced total TWV-related expenditures. Estimates of the effects on miles driven are presented in the appendix.

the-envelope estimates provide very suggestive evidence that the Type 3 TWV would have been highly cost-effective had it been introduced during a more intense period of the war.

Next, Table 3 presents cost per life saved estimates in which the sample is restricted to specific geographic areas and units. In columns (1) and (2), the sample is restricted to units located in the province of the capital city. In columns (3) and (4), the sample is restricted to units located in other provinces (including province unknown). In columns (5) and (6), the sample in each panel is restricted to units whose average miles driven per vehicle per month exceed the median for that unit type; the samples in columns (7) and (8) include units whose average miles driven per vehicle per month fall below these medians. The specifications in columns (1), (3), (5), and (7) control for other vehicle quantities, troop characteristics, and province by year by month fixed effects, as in column (4) of Tables 1 and 2. The specifications in columns (2), (4), (6), and (8) add unit fixed effects, as in column (6) of Tables 1 and 2.

Because units from the capital city and particularly active units were oversampled, the costs per life saved are likely to be overstated in columns (1), (2), (7), and (8) and understated in columns (3), (4), (5), and (6). Few of the cost per life saved estimates in Table 3 are on the borderline of cost-effectiveness, and adjusting for moderately-sized differences in the fraction of vehicles sampled per unit would not affect any of our cost-effectiveness determinations.[16]

The estimates from Table 3 indicate that replacing Type 2 with Type 3 TWVs was not cost-effective in any of the cases considered, with nine cases of costs per life saved that exceed the cost-effectiveness threshold, two cases in which the cost per life saved falls below the threshold but Type 1 TWVs are the most cost-effective option, 19 cases in which the policy is

[16] For an undersampled unit, a single TWV in the sample might represent four vehicles, while a single TWV in an oversampled unit's sample might represent only two vehicles. Using a weight of three for both unit types will bias our fatality coefficients and lead us in this example to overstate the undersampled unit's costs per life saved and understate the oversampled unit's costs per life saved by factors of $3/2$ and $3/4$, respectively.

found to have increased fatalities, and two cases in which no fatalities were observed (and the policy consequently had no effect on fatalities).

We find that the policy of replacing Type 1 with Type 2 TWVs was cost-effective for infantry and "other" units in the relatively dangerous area of the capital city province, with estimates ranging from \$0.65 million to \$11.2 million, below the cost-effectiveness threshold in three and just above the threshold in one of four cases. As in Table 2, the cost per life saved is lower in the specifications that include unit fixed effects. For infantry units, we find evidence that the policy may have been cost effective in other provinces as well, with a large cost per life saved of \$27.8 million in the specification without unit fixed effects but a low cost per life saved of \$0.51 million in the preferred specification that includes unit fixed effects. We find that the policy was not cost-effective for "other" unit types outside of the capital city province. For particularly active infantry and "other" unit types in columns (5) and (6), the specifications without unit fixed effects indicate that the policy was not cost-effective, but the preferred specifications with unit fixed effects show costs per life saved well below the cost-effectiveness threshold, at \$1.3 million and \$1.9 million. For less active infantry and "other" units, we find that the policy was not cost-effective. For armored and cavalry units, we find that the policy of replacing Type 1 with Type 2 TWVs fails the cost-benefit test in seven of eight cases considered here but may have been cost-effective in provinces other than the capital city province. For administrative and support units, we find that the policy fails the cost-benefit test in six of eight cases and in all four of the preferred specifications that include unit fixed effects.

C. Injury Reductions per Life Saved

Next, in Table 4, we measure reductions in combat injuries per life saved. Federal guidelines value minor, moderate, serious, severe, and critical injuries at 0.2%, 1.6%, 5.8%, 18.9%, and 76.3% of the VSL (Stiglitz and Bilmes, 2008; Venuto, 2002). Pollack and Rogers (2007) note that 70% of combat injuries are musculoskeletal, 55% are extremity wounds, and 26% are fractures. Supposing that the combat injuries are on average "serious" (the level of a fractured femur, Baker, *et al.*, 1974; Brohi, 2007), these guidelines indicate reducing combat injuries by one unit would generate a benefit of 0.189*$7.5 million ≈ $1.4 million.

Of the 56 estimates shown in the table, 42 are positive, indicating that the policies' effects on injuries generally have the same sign as their effects on fatalities. For infantry units, we find that the injury reductions per life saved through replacing Type 1 with Type 2 TWVs range from 0.89 to 6.14, with average and median values of 2.50 and 1.77. As in Table 2, our estimates for replacing Type 2 with Type 3 TWVs are highly variable due to the policy's small and imprecisely estimated effects appearing the in denominator. Also for infantry units, for replacing Type 2 with Type 3 TWVs, we find a wide range of estimates, from -100.1 to 12,000, with average and median values of 1,650 and 1.39. For units in the "other" category, our estimates for replacing Type 1 with Type 2 TWVs range from -2.13 to 7.66, with average and median values of 2.28 and 2.41, and our estimates for the Type 3 TWV policy range from -15.9 to 53.0, with average and median values of 3.98 and -1.79. For armored and cavalry and administrative and support units, for which the vehicle replacement policies generally increased fatalities, we tend to find positive effects on injuries as well.

For cases in which we find that the vehicle replacement policies reduced fatalities, taking injuries into account leads to somewhat lower cost per life saved estimates. If we suppose that the economic cost of a typical combat injury is 0.189 times that of a fatality, we can adjust each of our cost per life saved estimates for injuries by dividing by one plus 0.189 times the corresponding injury per life saved estimate from Table 4. For example, given the reduction of roughly injuries per life saved for infantry and other units for the policy of replacing Type 1 with Type 2 TWVs, this adjustment implies dividing our cost per life saved estimates by 1+0.189*2, or equivalently multiplying them by 0.73.

VI. Conclusion

This study uses FOUO data from various sources to determine the cost per life saved through the U.S. Army's large-scale policies to replace Type 1 with Type 2 TWVs and later to replace Type 2 with Type 3 TWVs. After controlling for unit-specific factors and province by year by month effects, we find that the shift from Type 1 to Type 2 TWVs was cost-effective for infantry units and for "other" unit types including artillery, engineers, military police, and ordnance. The majority of the reductions in fatalities were concentrated among vehicles with high levels of activity (as measured by miles driven per vehicle month) and in the capital city province, the most combat-intensive area. For the less active infantry and "other" units and for "other" unit types in other provinces, the switch to Type 2 TWVs does not appear to have been cost-effective. For armored and cavalry units and administrative and support units, we find that the switch from Type 1 to Type 2 TWVs did not reduce fatalities and in general was also not cost-effective. We find that Type 3 TWVs did not generate large reductions in fatalities beyond those achieved by the Type 2 TWVs and were not cost-effective for any unit type.

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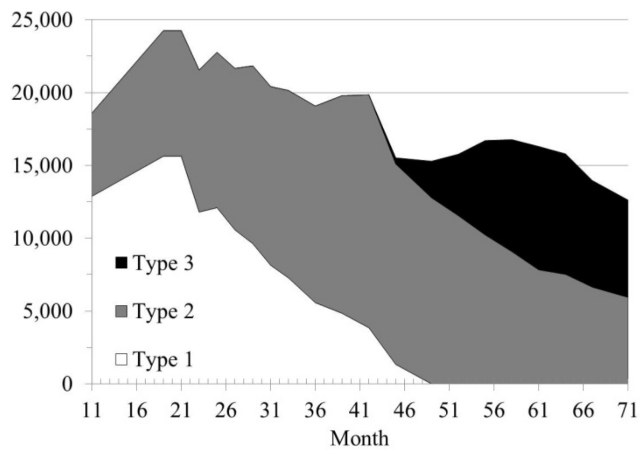
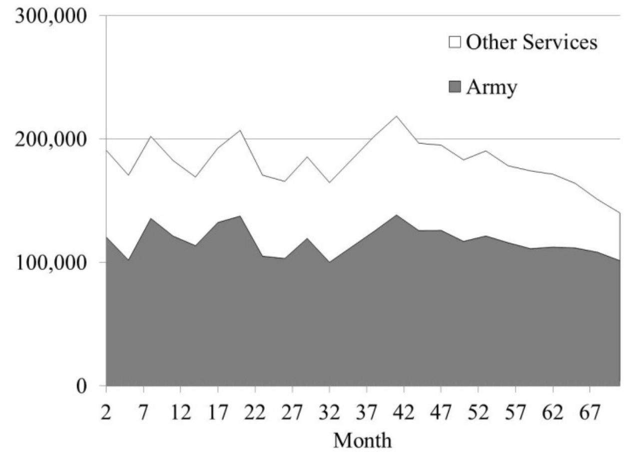
Figure 1: Army-wide Numbers of Vehicles and Troops,
Cost per Vehicle, Vehicle Expenditure, and Casualties in Theater A

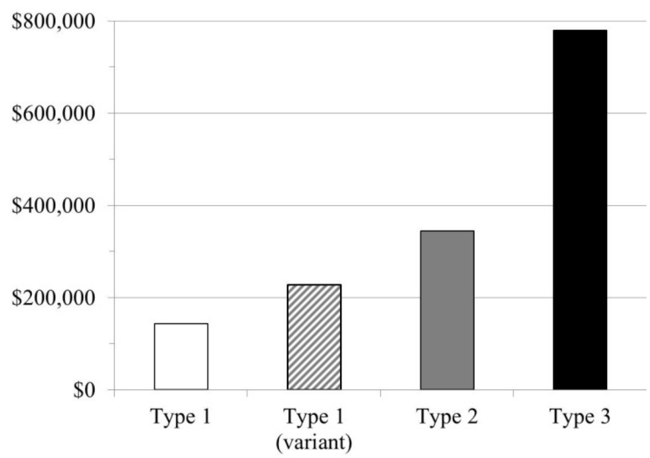
Panel A: Army TWVs in Theater A



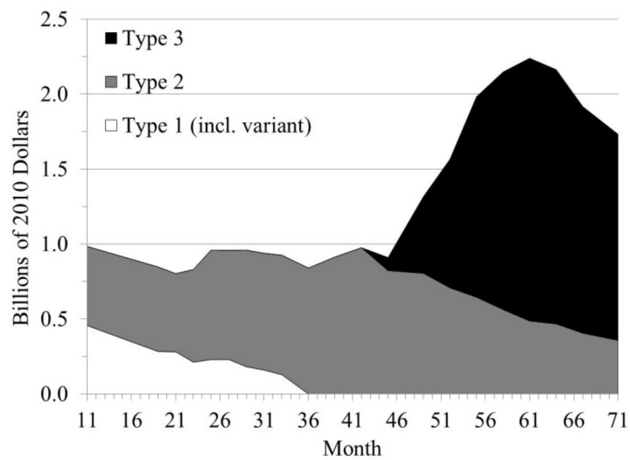
Panel B: U.S. Troops in Theater A



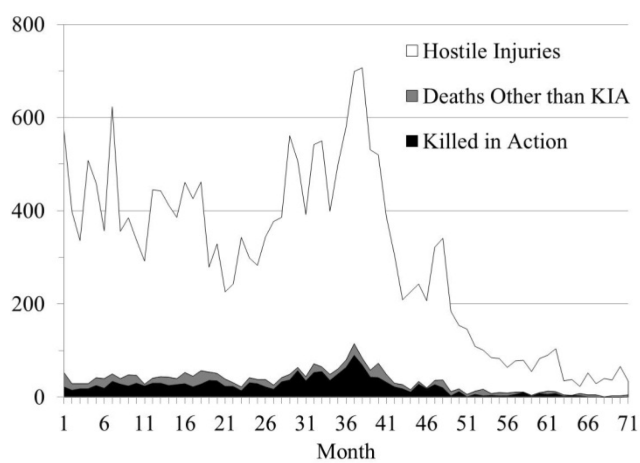
Panel C: Estimated Average Cost by Vehicle Type



Panel D: Annualized Army Expenditure on TWVs in Theater A

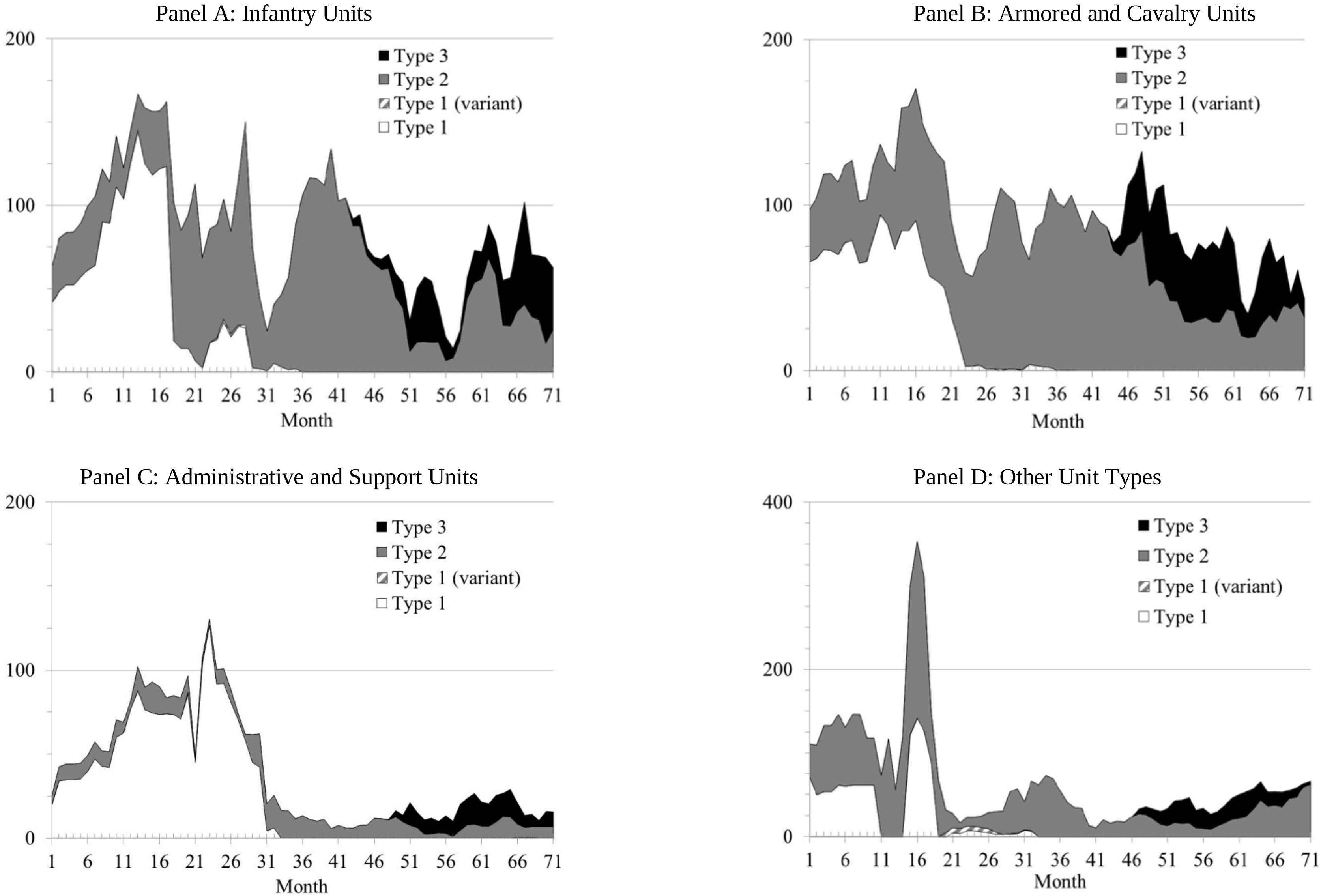


Panel E: Army-wide Casualties in Theater A



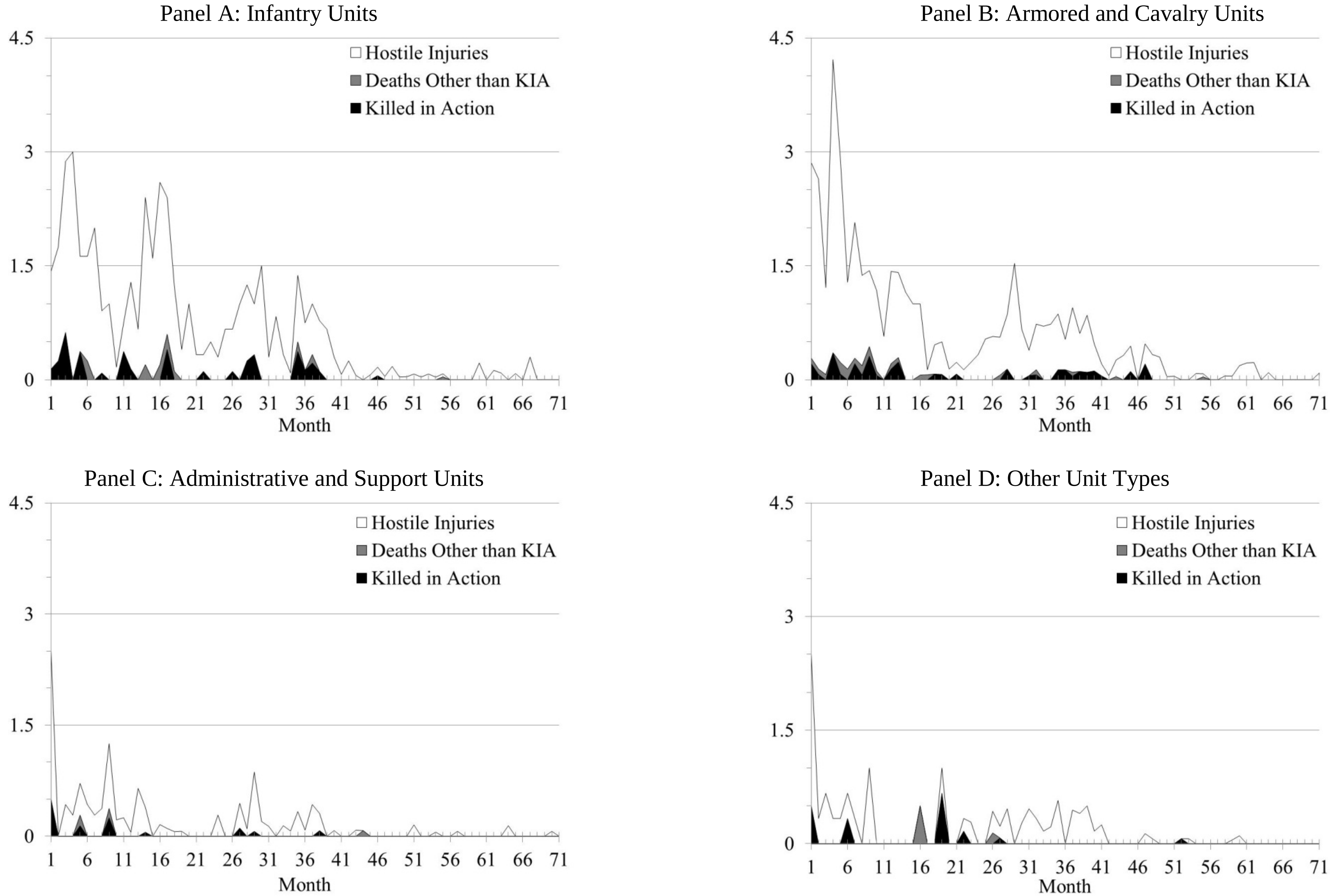
Notes to Figure 2: Data in panel A are taken from 21 measurements over the period from month 11 to month 71 (Simberg, 2010a). Quarterly troop numbers in panel B are taken from U.S. DoD (2010); data are missing for month 35. Cost per vehicle in panel C assumes a three-year life with average driving rates of 467 miles per month for each vehicle and a one-way shipment abroad. This cost estimate uses 2010 prices and takes into account gasoline, maintenance, and transportation expenditures. Annualized estimated expenditures in panel D use the same prices as the cost data, with an assumed three-year life per vehicle, with vehicle counts corresponding to those shown in panel A and miles driven taken from SDC data. Deaths other than KIA in panel E include deaths from injuries, deaths while captured or missing, and non-combat deaths. Additional details in the text.

Figure 2: TWV Quantities in the Average Unit in the SDC Dataset by Unit Type, Theater A, Months 1 to 71



Notes to Figure 3: Data and unit types defined in the notes to Table 1. Note the difference in scale between panels A to C and panel D.

Figure 3: Monthly Casualties in the Average Unit in the SDC Dataset by Unit Type, Theater A, Months 1 to 71



Notes to Figure 4: Casualty types defined in the same way as in panel D of Figure 2. Unit types and sample are the same as in Figure 3.

Table 1: Pooled OLS and Fixed Effects Estimates of Effects of TWVs on Deaths

Unit-by-Month Data, Dependent Variable is Unit-Level Deaths that Month	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A: Infantry Units, N = 815, Clusters = 355							
Type 3 TWVs/100	-0.123	-0.046	-0.067	-0.067	-0.094	-0.306	-0.275
	(0.035)**	(0.032)	(0.040)*	(0.054)	(0.070)	(0.216)	(0.233)
Type 2 TWVs/100	-0.075	-0.044	-0.045	-0.067	-0.084	-0.357	-0.427
	(0.035)**	(0.039)	(0.042)	(0.064)	(0.064)	(0.223)	(0.227)*
Type 1 TWVs/100	0.093	0.050	0.054	0.063	0.057	0.240	0.308
	(0.033)**	(0.034)	(0.038)	(0.053)	(0.067)	(0.205)	(0.219)
R^2	0.026	0.084	0.217	0.367	0.173	0.462	0.549
Panel B: Armored and Cavalry Units, N = 1213, Clusters = 518							
Type 3 TWVs/100	-0.061	0.050	0.047	0.034	0.032	0.107	0.308
	(0.033)*	(0.039)	(0.043)	(0.054)	(0.072)	(0.100)	(0.153)**
Type 2 TWVs/100	-0.026	0.012	0.011	-0.008	-0.016	0.059	0.214
	(0.028)	(0.028)	(0.032)	(0.044)	(0.050)	(0.065)	(0.111)*
Total TWVs/100	0.051	-0.011	-0.007	0.012	0.023	-0.034	-0.185
	(0.022)**	(0.024)	(0.028)	(0.040)	(0.050)	(0.066)	(0.110)*
R^2	0.015	0.072	0.140	0.293	0.137	0.355	0.412
Panel C: Administrative and Support Units, N = 961, Clusters = 404							
Type 3 TWVs/100	-0.023	-0.011	-0.014	0.000	0.026	0.050	0.084
	(0.009)**	(0.010)	(0.009)*	(0.011)	(0.089)	(0.074)	(0.097)
Type 2 TWVs/100	0.012	0.002	-0.001	0.004	0.115	0.058	0.085
	(0.011)	(0.013)	(0.014)	(0.019)	(0.090)	(0.063)	(0.097)
Total TWVs/100	0.000	-0.011	-0.008	-0.002	-0.084	-0.068	-0.086
	(0.002)	(0.005)*	(0.005)*	(0.005)	(0.093)	(0.073)	(0.097)*
R^2	0.001	0.038	0.169	0.499	0.149	0.648	0.689
Panel D: Other Units, N = 684, Clusters = 301							
Type 3 TWVs/100	-0.056	-0.012	-0.020	-0.073	-0.155	-0.272	-0.313
	(0.034)	(0.033)	(0.035)	(0.071)	(0.117)	(0.219)	(0.449)
Type 2 TWVs/100	-0.033	-0.019	-0.019	-0.075	-0.148	-0.194	-0.278
	(0.036)	(0.031)	(0.031)	(0.070)	(0.114)	(0.234)	(0.561)
Total TWVs/100	0.034	0.015	0.016	0.076	0.160	0.308	0.364
	(0.033)	(0.028)	(0.031)	(0.069)	(0.118)	(0.212)	(0.423)
R^2	0.011	0.065	0.366	0.605	0.216	0.690	0.761
Controls Include . . .							
Other Vehicles		Yes	Yes	Yes	Yes	Yes	Yes
Unit Characteristics		Yes	Yes	Yes	Yes	Yes	Yes
Quadratic in Month		Yes			Yes		
Year x Month FEs			Yes				
Province FEs			Yes				
Province x Year x Month FEs				Yes		Yes	Yes
Unit FEs					Yes	Yes	Yes
Unit-Specific Trends							Yes

Notes to Table 1: Within each panel, each column shows results from a separate OLS or fixed effects regression. The samples in panels A to D correspond to the unit types shown in columns (1) to (4) of Table A1. Standard errors adjust for clustering by unit x year x quarter interactions. The control variables included in the regressions vary across columns and are listed at the bottom of the table. "Other vehicles" controls include five variables for the numbers of different types of tactical and non-tactical vehicles other than TWVs, including tracked vehicles and trucks. Unit characteristics include the variables listed in rows 22 to 32 of Table A1. Province fixed effects include 19 categories, one of which is "unknown." Additional details in the text.

Table 2: Estimated Cost per Life Saved through Vehicle Substitutions

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Costs Presented in Millions of 2010 Dollars							
Panel A: Infantry Units, N = 815, Clusters = 355							
Type 3 in place of Type 2	$15.80	$423.7	$49.70	-$53,067	$97.80	-$21.83	-$7.827
	(5.374)**	(3,793)	(38.65)	(6.3.E+07)	(326.1)	(32.05)	(4.103)*
Type 2 in place of Type 1	$16.18	$24.58	$21.85	$13.35	$9.119	$1.131	$1.755
	(7.507)**	(21.14)	(19.20)	(9.321)	(6.496)	(0.549)**	(0.603)**
Panel B: Armored and Cavalry Units, N = 1213, Clusters = 518							
Type 3 in place of Type 2	$40.35	-$31.92	-$33.48	-$28.25	-$24.43	-$23.44	-$12.51
	(31.15)	(28.56)	(32.72)	(23.74)	(29.74)	(33.28)	(11.14)
Type 2 in place of Type 1	$15.61	-$35.88	-$40.69	$55.37	$35.36	-$8.905	-$2.515
	(16.46)	(80.37)	(111.3)	(243.2)	(106.0)	(7.836)	(1.108)**
Panel C: Administrative and Support Units, N = 961, Clusters = 404							
Type 3 in place of Type 2	$0.343	$10.78	$18.22	$69.18	$10.68	$125.4	$1,595
	(10.87)	(30.13)	(36.74)	(381.2)	(10.31)	(371.0)	(69,441)
Type 2 in place of Type 1	-$103.1	$465.6	$842.7	-$256.2	-$4.779	-$9.662	$4.838
	(98.17)	(2,423)	(8,959)	(961.3)	(3.430)	(7.236)	(3.462)
Panel D: Other Units, N = 684, Clusters = 301							
Type 3 in place of Type 2	$19.96	-$57.58	$1,506	-$398.0	$115.3	$18.46	$48.01
	(11.82)*	(75.65)	(72,628)	(2,036)	(256.7)	(8.472)**	(109.9)
Type 2 in place of Type 1	$41.23	$71.98	$72.55	$19.09	$10.13	$4.117	$2.396
	(44.10)	(116.1)	(103.1)	(11.73)	(8.669)	(3.193)	(2.259)
Controls Include . . .							
Other Vehicles		Yes	Yes	Yes	Yes	Yes	Yes
Unit Characteristics		Yes	Yes	Yes	Yes	Yes	Yes
Quadratic in Month		Yes			Yes		
Year x Month FEs			Yes				
Province FEs			Yes				
Province x Year x Month FEs				Yes		Yes	Yes
Unit FEs					Yes	Yes	Yes
Unit-Specific Trends							Yes

Notes to Table 2: Within each panel, each column shows estimates of the cost per life saved from replacing a Type 2 with a Type 3 TWV and the cost per life saved from replacing a Type 1 with a Type 2 TWV. These costs per life saved are estimated using the results from two sets of regressions. The first set of regressions estimates the effects of Type 3 and Type 2 TWVs on total TWV -related expenditure; the specifications for these regressions are the same as in Table 1 but with expenditure rather than deaths used as the dependent variable. The second set of regressions estimates the effects of Type 3 and Type 2 TWVs on deaths; these estimates are shown in Table 1. The cost per life saved for Type 2 in place of Type 1 TWVs is calculated as the coefficient on Type 2 TWVs in the expenditure equation divided by the corresponding coefficient in the fatalities equation, all multiplied by negative one. The cost per life saved for Type 3 in place of Type 2 TWVs is calculated as the coefficient on Type 3 minus the coefficient on Type 2 TWVs in the expenditure equation, all divided by the corresponding difference in the fatalities equation and multiplied by negative one. The control variables used in these equations are the same as shown in Table 1 and are also summarized at the bottom of this table. The standard errors are computed using the delta method (nlcom in Stata) with the cross-equation covariances in the coefficients estimated through seemingly-unrelated regression (suest in Stata). These standard errors are adjusted for clustering at the unit x year x quarter level. Additional details in the text.

Table 3: Estimated Costs per Life Saved for Specific Provinces and Time Periods

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Costs Presented in Millions of 2010 Dollars							
	Panel A: Infantry Units							
	Capital City Province		Other Provinces		High Intensity		Low Intensity	
Type 3 in place of Type 2	-$32.62 (49.44)	-$108.8 (1,418)	-$350.0 (3,907)	$1,976 (125,711)	-$21.23 (12.90)	-$6.996 (5.483)	$11.29 (6.954)	-$45.25 (288.0)
Type 2 in place of Type 1	$6.179 (3.083)**	$0.653 (0.537)	$27.79 (80.52)	$0.511 (0.562)	$27.83 (96.06)	$1.259 (0.740)*	-$5.850 (7.136)	$20.62 (272.5)
Obs (Unit x Month)	348		467		414		401	
Clusters (Unit x Qtr)	156		211		178		177	
	Panel B: Armored and Cavalry Units							
Type 3 in place of Type 2	-$19.64 (16.00)	-$10.45 (7.006)	-$73.07 (62.66)	$25.33 (23.76)	$486.6 (4,402)	$23.80 (22.81)	-$12.13 (8.024)	-$4.771 (2.175)**
Type 2 in place of Type 1	$59.73 (311.5)	-$13.20 (16.99)	-$59.38 (505.7)	$0.860 (0.486)*	-$52.56 (441.1)	-$3.728 (3.173)	$22.46 (73.70)	-$6.331 (6.340)
Obs (Unit x Month)	723		490		616		597	
Clusters (Unit x Qtr)	316		233		264		254	
	Panel C: Administrative and Support Units							
Type 3 in place of Type 2	-$27.74 (24.75)	-$31.97 (25.23)	-$13.05 (8.483)	$2.255 (3.304)	-$10.54 (7.948)	-$33.78 (29.23)	$18.40 (23.03)	$3.202 (21.98)
Type 2 in place of Type 1	$6.681 (7.344)	-$0.671 (0.474)	-$72.95 (38.45)*	-$42.32 (26.13)	$6.287 (5.235)	-$1.780 (2.328)	$91.83 (155.3)	$284.6 (1,190)
Obs (Unit x Month)	263		698		493		468	
Clusters (Unit x Qtr)	111		298		201		203	
	Panel D: Other Units							
Type 3 in place of Type 2	$188.2 (1,451)	$16.56 (12.86)	-$330.5 (512.4)	-$112.8 (148.4)	-$813.8 (9,666)	$50.60 (86.22)	No fatalities	
Type 2 in place of Type 1	$11.18 (4.493)**	$1.020 (0.359)**	-$13.64 (7.597)*	$79.66 (206.0)	-$2.289 (14.33)	$1.901 (1.390)		
Obs (Unit x Month)	237		447		349		335	
Clusters (Unit x Qtr)	108		199		155		146	
Controls Include . . .								
Other Vehicles	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Unit Characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province x Year x Month FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Unit FEs		Yes		Yes		Yes		Yes

Notes to Table 3: This table presents estimates of the cost per life saved through replacing Type 2 with Type 3 TWVs or Type 1 with Type 2 TWVs. The calculations and the structure of the table are the same as in Table 2; however, four different subsamples of the data are considered here to measure how the effects vary across provinces and over time. The control variables in columns (1), (3), (5), and (7) are the same as in column (4) of Tables 1 and 2, and the control variables in columns (2), (4), (6), and (8) are the same as in column (6) of Tables 1 and 2. The sample in columns (5) and (6) is restricted to the period from months one to forty-two, before, during, and after Type 2 TWVs were phased in but before Type 3 TWVs were introduced to U.S. Army units. The sample in columns (7) and (8) is restricted to the period from months 37 to 71, after Type 1 TWVs had been phased out and before, during, and after Type 3 TWVs were phased in. Additional details in the text.

Table 4: Estimated Injury Reduction per Life Saved

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A: Infantry Units, N = 815, Clusters = 355							
Type 3 in place of	6.142	-100.1	-3.235	11,675	1.394	1.187	2.089
Type 2	(2.086)**	(936.2)	(5.610)	(1.4.E+07)	(17.16)	(4.384)	(1.806)
Type 2 in place	6.140	1.525	2.379	3.699	1.065	1.771	0.890
of Type 1	(2.347)**	(4.548)	(4.909)	(4.019)	(3.321)	(1.675)	(0.720)
Panel B: Armored and Cavalry Units, N = 1213, Clusters = 518							
Type 3 in place of	7.580	8.392	9.307	9.087	7.426	9.885	3.287
Type 2	(5.198)	(6.614)	(7.883)	(6.634)	(8.382)	(12.59)	(2.273)
Type 2 in place	8.923	17.20	8.910	4.601	1.912	4.904	-0.957
of Type 1	(8.765)	(37.25)	(24.30)	(23.89)	(13.83)	(5.068)	(1.457)
Panel C: Administrative and Support Units, N = 961, Clusters = 404							
Type 3 in place of	9.104	13.89	9.580	-29.27	4.823	-21.00	145.6
Type 2	(4.765)*	(18.06)	(12.18)	(201.1)	(3.230)	(85.36)	(6,111)
Type 2 in place	11.37	30.81	-12.31	-19.93	3.109	-2.605	5.549
of Type 1	(10.09)	(145.6)	(191.5)	(113.1)	(1.606)*	(5.329)	(4.316)
Panel D: Other Units, N = 684, Clusters = 301							
Type 3 in place of	9.796	-15.08	52.99	-6.939	-15.94	-1.790	4.843
Type 2	(5.107)*	(21.59)	(2,564)	(46.71)	(43.39)	(1.517)	(10.90)
Type 2 in place	2.408	3.541	5.091	-2.134	7.662	0.861	-1.468
of Type 1	(3.952)	(8.780)	(9.869)	(3.066)	(6.674)	(1.981)	(2.803)
Controls Include . . .							
Other Vehicles		Yes	Yes	Yes	Yes	Yes	Yes
Unit Characteristics		Yes	Yes	Yes	Yes	Yes	Yes
Quadratic in Month		Yes			Yes		
Year x Month FEs			Yes				
Province FEs			Yes				
Province x Year x Month FEs				Yes		Yes	Yes
Unit FEs					Yes	Yes	Yes
Unit-Specific Trends							Yes

Notes to Table 4: Within each panel, each column shows estimates of the reduction in injuries that occurs per life saved from replacing a Type 2 with a Type 3 TWV and the cost per life saved from replacing a Type 1 with a Type 2 TWV. This ratio provides a measure of one benefit of Type 3 and Type 2 TWVs that units experienced in addition to the reductions in fatalities. The reduction in injuries per life saved is computed in the same way as the cost per life saved, except that total TWV-related expenditure is replaced with unit-level injuries as the dependent variable for the first equation, and the ratios of effects are not multiplied by negative one. Additional details in the text.

Appendix

A. Descriptive Statistics

Descriptive characteristics for our main sample are shown separately for each of the four types of units in the four columns of Table A1. Rows one to three present means and standard errors for the casualty variables, rows four through 11 show the miles driven variables and rows 12 through 19 show the vehicle quantity variables from the SDC data. Row twenty shows a dummy variable for whether the unit was in the capital city province, the province in which 69% of the sample's casualties occurred, and row 21shows a dummy variable for whether the unit's province is classified as unknown. Rows 22 to 32 show sample means for the other unit characteristics.

As the first three rows of Table A1 show, infantry and armored and cavalry units experienced four to six times more casualties in a given month than did administrative and support or "other" units. Adding across rows four to 11, vehicle usage was similar across the four unit types, ranging from 40,300 miles driven per month for administrative and support units to 59,900 miles per month for infantry and armored and cavalry units. Armored and cavalry units tended to have more vehicles than other units; adding across rows 12 to 19, infantry, administrative and support, and other units had 103.2, 72.5, and 89.2 vehicles in a typical month, while armored and cavalry units had 279.2. Armored and cavalry units had the most TWVs and tracked vehicles than other unit types, "other" units and infantry units had the most other armored vehicles (a category that includes personnel carriers and route clearance vehicles), and administrative and support units had the most other unarmored vehicles.

As the next two rows show, the more heavily equipped and combat active unit types were most likely to be located in the capital city province, with 59.6% of armored and cavalry observations and 42.7% of infantry observations being located there, as compared to 27.4% and 34.6% for administrative and support and other unit types. As might be expected, the units that were engaged in combat less are most likely to have province values of "Unknown." Administrative and support and other unit types have unknown locations in 30% of the cases, while infantry and armored and cavalry units both have unknown locations in 16% of cases.

From the unit characteristics variables in rows 22 to 32, we see that armored and cavalry units and infantry units had more personnel, at 635 and 595, as compared to 308 and 260 for administrative and support and other unit types. Troops in administrative and support units tended to be slightly older than personnel in other unit types, and they were more likely to be female and black. Troops in armored and cavalry divisions were less likely than troops in other division types to be privates or PFCs, and the units' home bases in the U.S. were more concentrated in the South and less in the West as compared to other unit types. Troops in other unit types were least likely to be officers, high school graduates, or minorities.

B. Effects of Vehicle Replacements on Miles Driven

From the perspective of a military planner making large-scale decisions, the ideal measures of cost-effectiveness take into account that vehicle replacement policies will change vehicle usage and estimate the observed changes in deaths given that such changes in usage occurred. It is not desirable in estimating the cost-effectiveness of the Type 2 and Type 3 TWVs to attempt to hold usage constant, and the true cost-effectiveness of the policies depends upon both the intrinsic properties of the vehicles and behavioral responses throughout the chain of command. Nevertheless, examining the vehicle replacement policies' effects on vehicle usage can help to explain some of the unusual findings from Table 1.

The regressions in Table A2 have similar specifications as in Table 1, except that the dependent variables are changed from fatalities to miles driven. Due to the larger magnitudes, the regressors are not divided by 100 for this table. As in the previous table, the four panels correspond to the four unit types. In columns (1) and (2), the dependent variable is miles driven that month in TWVs. In columns (3) and (4), the dependent variable is miles driven in tracked vehicles. In columns (5) and (6), the dependent variable is miles driven in other armored vehicles. In columns (7) and (8), the dependent variable is miles driven in unarmored vehicles other than TWVs. The sets of controls are the same as in Table 3.

Across the entire sample, the average TWV is driven 467.4 miles in a month, the average Abrams or Bradley is driven 151.7 miles, the average other armored vehicle is driven 185.7 miles , and the average other unarmored vehicle is driven 521.5 miles. Relative to these magnitudes, many of the results from Table A2 are imprecise and variable across specifications. For infantry units, many of our estimated coefficients change signs when fixed effects are added, and we do not observe strong and consistent effects of the vehicle replacements on usage of any of the vehicle types. For armored and cavalry units, in three out of four cases, we find fairly large negative effects of the vehicle replacement policies on the miles driven of tracked vehicles. For the Type 3 TWV policy, we also find moderately-sized negative effects on TWV miles and moderately-sized positive effects on miles driven of other unarmored vehicles. This shift away from tracked vehicles and toward unarmored vehicles may help to explain why we observe positive effects of the replacement policies on fatalities for this unit type. For administrative and support units, we also observe fairly large negative effects of the Type 3 TWV policy on TWV miles driven; however, the effects on vehicle usage in the specifications with fixed effects are not large and do not offer a ready explanation for the positive effects that we find of both replacement policies on fatalities for that unit type. For the other unit category, we observe large positive effects of both replacement policies on TWV miles; hence, providing these units with more heavily protected vehicles led them to shift toward more intensive usage of those vehicles.

Table A1: Descriptive Characteristics for Theater A, Unit by Month, Months 1 to 71

Variable		(1) Infantry	(2) Armored/Cavalry	(3) Admin & Support	(4) Other
Casualties					
1.	Killed in Action	0.037	0.042	0.007	0.010
		(0.009)	(0.007)	(0.003)	(0.004)
2.	Deaths	0.048	0.060	0.011	0.013
		(0.010)	(0.008)	(0.004)	(0.004)
3.	Hostile Injuries	0.395	0.505	0.113	0.105
		(0.040)	(0.037)	(0.020)	(0.016)
Miles Driven					
4.	Type 3 TWVs	6,561	4,478	1,978	6,032
		(1,124)	(559.8)	(277.4)	(697.3)
5.	Type 2 TWVs	37,927	22,596	6,975	25,547
		(3,923)	(1,264)	(949.7)	(3,143)
6.	Type 1 (variant)	77.31	6.551	0.000	763.4
	TWVs	(36.61)	(3.037)	(0.000)	(557.6)
7.	Type 1 TWVs	4,932	21,061	9,311	3,586
		(892.8)	(3,151)	(2,075)	(2,892)
8.	Heavy Tracked	15.50	742.6	0.000	0.000
	Vehicles	(12.11)	(75.09)	(0.000)	(0.000)
9.	Light Tracked	65.59	1,523	1.017	27.35
	Vehicles	(28.88)	(141.9)	(0.497)	(12.73)
10.	Other Armored	7,994	4,053	2,813	12,664
	Vehicles	(746.5)	(351.3)	(245.2)	(836.1)
11.	Other Vehicles	2,314	5,487	19,233	5,156
		(240.9)	(609.2)	(1,144)	(842.5)
Number of Vehicles					
12.	Type 3 TWVs	11.65	11.32	4.776	11.86
		(1.324)	(0.912)	(0.532)	(1.077)
13.	Type 2 TWVs	52.39	63.41	9.430	34.87
		(2.930)	(2.462)	(0.725)	(2.222)
14.	Type 1 (variant)	0.151	0.136	0.009	3.510
	TWVs	(0.072)	(0.085)	(0.009)	(1.358)
15.	Type 1 TWVs	21.61	157.9	26.35	16.65
		(4.351)	(21.83)	(3.863)	(6.955)
16.	Heavy Tracked	0.095	5.756	0.000	0.000
	Vehicles	(0.033)	(0.383)	(0.000)	(0.000)
17.	Light Tracked	0.277	11.65	0.010	0.062

Vehicles	(0.060)	(0.726)	(0.003)	(0.013)
18. Other Armored Vehicles	8.744	16.74	3.902	15.11
	(0.575)	(1.302)	(0.311)	(0.627)
19. Other Vehicles	8.282	12.28	28.01	7.130
	(0.652)	(0.694)	(1.124)	(0.682)
Location				
20. Capital City Province	0.427	0.596	0.274	0.346
	(0.017)	(0.014)	(0.014)	(0.018)
21. Province Unknown	0.164	0.157	0.304	0.303
	(0.013)	(0.010)	(0.015)	(0.018)
Unit Characteristics				
22. Troops	595.1	635.3	307.5	260.4
	(10.789)	(8.035)	(8.111)	(6.927)
23. Fraction Officer	0.010	0.008	0.009	0.003
	(0.001)	(0.000)	(0.001)	(0.000)
24. Fraction Private or PFC	0.067	0.049	0.061	0.064
	(0.002)	(0.001)	(0.002)	(0.002)
25. Average Days of Deployment	300.2	310.0	288.8	289.3
	(3.704)	(3.025)	(3.570)	(3.985)
26. Average Age	27.51	27.50	28.86	27.40
	(0.069)	(0.073)	(0.082)	(0.073)
27. Fraction High School Graduate	0.861	0.870	0.867	0.849
	(0.002)	(0.002)	(0.002)	(0.002)
28. Fraction Male	0.917	0.932	0.853	0.931
	(0.003)	(0.003)	(0.002)	(0.003)
29. Fraction Black	0.152	0.183	0.213	0.127
	(0.003)	(0.003)	(0.005)	(0.003)
30. Fraction Hispanic	0.102	0.113	0.107	0.086
	(0.003)	(0.001)	(0.003)	(0.003)
31. Home Station is Southern U.S.	0.429	0.692	0.448	0.432
	(0.017)	(0.013)	(0.016)	(0.019)
32. Home Station is Western U.S.	0.279	0.160	0.204	0.251
	(0.015)	(0.010)	(0.013)	(0.017)
Obs. (Unit Months)	815	1,213	961	684
Units	106	106	111	101

Notes to Table A1: Sample means presented with their standard errors in parentheses. Unit casualty and characteristics data were obtained from requests to the Defense Manpower Data Center (DMDC). Only a sample of vehicles is observed for every unit. Vehicle mileages and counts are estimates based on the mileages and numbers of vehicles that appear in the sample. The fraction of a unit's vehicles that appear in the dataset varied across units based on the difficulty of obtaining data from that unit (Horsley, 2010);

however, this fraction does not appear to have varied within units over time. We estimate vehicle counts and mileages using a separate, constant adjustment factor for each vehicle type, as described in the text. Each unit's province is computed as the province in which the most casualties occurred that month. For units with no casualties with known locations, the province is taken from the nearest month in which province is known. If the province is not known for any month, then the province is categorized as unknown. "Average days of deployment" measures the average of deployment experience in the Global War on Terror (including Theaters A and B) among troops in that unit. Vehicle quantities and usage data come from the Theater A SDC dataset from AMSAA. Infantry includes all units whose names include the words or phrases "airborne" (*i.e.*, paratrooper), "anti-armor," "combat," "infantry," "rifle," or "special forces," or abbreviations thereof, but excluding "combat support." Armored and cavalry include all units whose names include the words or phrases "armored" or "cavalry" or abbreviations thereof and are not infantry units. Administrative and support include all units whose names include "Army Materiel Command," "aviation," "chemical," "finance," "headquarters," "intelligence," "maintenance," "medical," "personnel," "post office," "recce" (*i.e.*, reconnaissance), "signal" (*i.e.*, communications), "support," "surveillance," "transportation," or abbreviations thereof and are not infantry, armored, or cavalry units. Units whose names could not be identified were placed in this category. Other units include those not falling into the previous three categories and include artillery, engineers, military police, and ordnance. Additional details in the text.

Table A2: Pooled OLS and Fixed Effects Estimates of Effects of TWVs on Vehicle Usage

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Infantry Units, N = 815, Clusters = 355								
Dependent Variable is Miles Driven by . . .								
	TWVs		Tracked Vehicles		Other Armored		Other Unarmored	
Type 3 TWVs	365.0	-116.2	-0.666	-0.034	29.69	-16.89	4.387	-9.984
	(136.2)**	(211.6)	(1.130)	(0.626)	(12.08)**	(16.15)	(8.362)	(19.56)
Type 2 TWVs	421.4	-41.27	-1.242	0.349	14.95	26.34	-8.900	0.860
	(155.3)**	(219.0)	(1.566)	(0.936)	(8.963)*	(23.27)	(5.453)	(9.943)
Total TWVs,	256.2	431.0	0.772	0.028	0.186	-7.635	2.604	-1.438
Types 1 to 3	(60.12)**	(181.6)**	(1.194)	(0.705)	(4.167)	(6.787)	(3.473)	(4.895)
R^2	0.891	0.981	0.691	0.848	0.918	0.960	0.857	0.937
Panel B: Armored and Cavalry Units, N = 1213, Clusters = 518								
Type 3 TWVs	-33.44	-21.76	-42.77	-9.230	2.369	-10.36	48.00	26.60
	(68.31)	(87.07)	(15.83)**	(20.80)	(9.288)	(7.940)	(18.93)**	(25.12)
Type 2 TWVs	35.12	109.4	-62.63	-61.85	7.171	7.776	2.345	17.14
	(59.04)	(67.69)	(20.27)**	(23.27)**	(3.269)**	(3.703)**	(18.21)	(23.15)
Total TWVs,	280.9	189.5	47.18	37.58	-2.764	-2.419	-30.44	-21.15
Types 1 to 3	(52.95)**	(69.95)**	(15.18)**	(18.18)**	(2.299)	(3.667)	(14.50)**	(21.83)
R^2	0.807	0.872	0.619	0.756	0.752	0.854	0.829	0.912
Panel C: Administrative and Support Units, N = 961, Clusters = 404								
Type 3 TWVs	-335.8	-189.9			-27.96	1.748	-40.12	-18.25
	(193.0)*	(231.7)			(11.24)**	(23.16)	(52.87)	(65.11)
Type 2 TWVs	492.9	-10.23			1.422	16.43	-68.34	19.38
	(214.5)**	(299.1)			(5.548)	(12.85)	(66.77)	(60.35)
Total TWVs,	362.0	519.3			0.896	-0.399	-14.84	24.84
Types 1 to 3	(87.36)**	(192.7)**			(0.900)	(1.258)	(19.64)	(25.27)
R^2	0.697	0.823			0.761	0.905	0.701	0.882
Panel D: Other Units, N = 684, Clusters = 301								
Type 3 TWVs	689.8	602.0	-7.402	4.387	14.40	114.9	-9.449	19.11
	(232.7)**	(170.0)**	(8.315)	(6.642)	(19.79)	(55.08)**	(155.8)	(363.1)
Type 2 TWVs	988.6	343.8	-7.769	2.594	20.82	56.84	-57.55	-93.19
	(226.1)**	(174.9)**	(8.688)	(5.501)	(16.25)	(54.42)	(142.1)	(360.4)
Total TWVs,	-233.7	92.98	7.335	-4.560	-6.079	-39.25	32.41	-21.07
Types 1 to 3	(219.8)	(141.1)	(8.247)	(6.756)	(15.26)	(38.14)	(156.4)	(366.9)
R^2	0.955	0.981	0.577	0.616	0.814	0.908	0.671	0.848
Controls Include . . .								
Other Vehicles	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Unit Characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province x Year x Month FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Unit FEs		Yes		Yes		Yes		Yes

Notes to Table A2: The organization of this table is the same as in Table 1, except that the dependent variables have changed to total miles driven that month of different vehicle types, added up across all vehicles of that type in the unit. The control variables are the same as in Table 3. No regressions are shown for tracked vehicle mileage for administrative and support units because none of those units had any tracked vehicles over the sample period. Additional details in the text.