Online Appendix for: Air Superiority and Battlefield Victory

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Appendix A

- Appendix Table 1: Summary Statistics

Table 1: Summary Statistics

Statistic	N	Mean	St. Dev.	Min	Max
Outcome	99	0.48	0.50	0	1
Air Superiority	99	0.40	0.49	0	1
Air Parity	99	0.23	0.42	0	1
Modern System	99	1.52	1.22	0	3
Democracy	99	0.32	0.47	0	1
Anocracy	99	0.18	0.39	0	1
CINC	99	0.06	0.08	0.0001	0.28
Troops Engaged	99	161,003.90	337,222.50	100	2,300,000
Opponent Troops Engaged	99	164,353.50	326,813.10	100	2,300,000
Past Coups	99	0.28	0.70	0	4

- Appendix Table 2: Correlation Matrix

	win	airsup	airparity	msadopt	d6	anoc	cinc	troopsengaged	oppotroops	coups
win	1									
Air Superiority	0.77	1								
Air Parity	-0.15	-0.45	1							
Modern System	0.51	0.52	-0.33	1						
Democracy	0.41	0.36	-0.07	0.31	1					
Anocracy	-0.35	-0.33	0.36	-0.37	-0.33	1				
CINC Score	0.45	0.46	-0.19	0.46	0.14	-0.26	1			
Troops Engaged	0.05	0.1	-0.21	0.1	-0.05	-0.15	0.24	1		
Opptroops Engaged	0	0.07	-0.22	0.13	0.06	-0.12	0.21	0.82	1	
Past Coups	-0.19	-0.22	0.05	-0.11	-0.28	0.18	-0.24	-0.09	-0.14	1

Table 2: Correlation Matrix

- Appendix Table 3: Logistic Regression Estimates, Models 1-4,

Table 3: Models 1-4: Logistic Regression Estimates, 1932-2003

	DV: Decisive Battle Outcome			
	Model 1	Model 2	Model 3	Model 4
	(Base)	(Air Sup)	(Chng Dem Ref)	(1946-2003)
Air Superiority		5.58***	5.46***	5.83***
		(1.27)	(1.24)	(1.96)
Air Parity		3.09***	2.54**	2.43
		(1.18)	(1.05)	(1.58)
Modern System	0.65**	0.82**	0.82**	0.78
	(0.28)	(0.41)	(0.39)	(0.58)
Democracy	1.90***	1.15	1.57*	1.02
	(0.69)	(1.00)	(0.94)	(1.25)
Anocracy	−0.68	−1.62		−1.99
	(0.89)	(1.34)		(1.87)
CINC	14.09***	8.28	9.68	13.96
	(5.23)	(7.25)	(7.26)	(14.57)
Troops Engaged	0.000002	0.000003	0.000004	−0.000002
	(0.000002)	(0.000003)	(0.000003)	(0.00001)
Opponent Troops Engaged	−0.000003*	−0.00001	−0.00001	−0.000003
	(0.000002)	(0.000004)	(0.000004)	(0.00001)
Past Coups	0.04	0.45	0.25	−0.40
	(0.42)	(0.53)	(0.50)	(1.03)
CONSTANT	−2.01***	−4.63***	−4.68***	−3.93**
	(0.62)	(1.27)	(1.21)	(1.64)
Observations	99	99	99	63
Log likelihood	−42.86	−22.88	−23.71	−14.49
Akaike information criterion	101.73	65.76	65.42	48.98

Notes: ***p < .01; **p < .05; *p < .1
Two-tail significance levels
Cell entries are coefficients, with standard errors in parentheses.
Standard errors clustered on country.

- Appendix Table 4: Logistic Regression Estimates, Models 5-6

Table 4: Logistic Regression Estimates of Air Superiority on IWD War Outcome, 1932-2003

	DV: IWD War Outcome	
	IWD Wars and Subwars	IWD Wars
	Model 5	Model 6
Air Superiority	4.50^{***}	20.47
	(1.30)	(2,215.17)
Air Parity	3.20^{***}	19.04
	(1.20)	(2,215.17)
Modern System	0.02	−0.10
	(0.31)	(0.38)
Democracy	2.03^{***}	2.31^{***}
	(0.73)	(0.82)
CINC	-8.47^{*}	-9.19^{*}
	(4.48)	(4.73)
Troops Engaged	0.000000	0.000000
	(0.000002)	(0.000002)
Opponent Troops Engaged	−0.000001	0.000000
	(0.000002)	(0.000004)
Past Coups	0.29	0.87
	(0.86)	(1.11)
CONSTANT	-4.03^{***}	−19.79
	(1.19)	(2,215.17)
Observations	87	73
Log likelihood	−34.04	−27.01
Akaike information criterion	86.08	72.02

Notes: $^{***}p < .01$; $^{**}p < .05$; $^{*}p < .1$
Two-tail significance levels
Cell entries are coefficients, with standard errors in parentheses.
Standard errors clustered on country.

Table 5: Logistic Regression Estimates, 1932-2003

	DV: Decisive Battle Outcome Air Superiority Alternate Coding
Air Superiority Alternate Coding	4.51^{***}
	(1.05)
Air Parity Alternate Coding	2.33^{**}
	(0.96)
Modern System	0.78^{**}
	(0.36)
Democracy	1.55^{*}
	(0.92)
Anocracy	-1.29
	(1.24)
CINC	8.33
	(7.04)
Troops Engaged	0.000004
	(0.000002)
Opponent Troops Engaged	-0.000005^{*}
	(0.000003)
Past Coups	0.44
	(0.49)
CONSTANT	-4.18^{***}
	(1.06)
Observations	99
Log likelihood	-27.82
Akaike information criterion	75.64
Notes:	***p $<$ .01; **p $<$ .05; *p $<$ .1 Two-tail significance levels; Standard Errors Clustered on Country Cell entries are coefficients with standard errors in parentheses.

Table 6: Logistic Regression Estimates, 1932-2003

	DV: Decisive Battle Outcome Terrain Robustness
Air Superiority	6.18^{***}
	(1.66)
Air Parity	2.88^{**}
	(1.25)
Modern System	0.73^{*}
	(0.44)
Democracy	1.16
	(1.08)
Anocracy	-1.46
	(1.46)
CINC	7.92
	(8.04)
Troops Engaged	0.00001
	(0.00001)
Opponent Troops Engaged	-0.00001
	(0.00001)
Past Coups	0.44
	(0.54)
Terrain	0.79
	(2.00)
CONSTANT	-5.03^{**}
	(2.1)
Observations	92
Log likelihood	-19.22
Akaike information criterion	60.43
Notes:	$^{***}p < .01$; $^{**}p < .05$; $^{*}p < .1$ Two-tail significance levels; Standard Errors Clustered on Country Cell entries are coefficients with standard errors in parentheses.

Table 7: Air Superiority and Loss-Exchange Ratios

	Air Superiority b/se	Modern System b/se	Combined b/se
Air Superiority	-1.500*		-1.556+
	(0.540)		(0.772)
Modern System		-0.030	0.217
		(0.975)	(1.096)
Polity2	0.129	0.063	0.127
	(0.104)	(0.125)	(0.108)
National Capabilities	19.271+	13.289	18.366*
	(9.897)	(9.530)	(7.823)
Civil-Military Relations	1.358	1.408	1.423
	(1.325)	(1.464)	(1.386)
Constant	1.296	0.948	1.075
	(1.613)	(1.944)	(1.825)
Observations	31	31	31

Notes: *p $<$ .05; +p$<$.1
Two-tail significance levels; Standard errors clustered on country

All covariates in this analysis are measured as discussed for the main models. We draw information on loss exchange rates from two data sources. For every decisive battle that appears in the Biddle & Long (2004) replication data, we use their LER figures. For battles that don't appear in Biddle & Long, we fill in using the LERD dataset by McNabb Cochran & Long (2017).

Discussion of Covariates

Modern System: Modern system's adoption ranges from "0" (no modern system adoption) to "3" (full modern system adoption). Modern System is based on the extent to which each combatant's forces employ cover and concealment, dispersion of forces, small-unit independent maneuver, use of combined arms, force concentration at the point of attack, defensive depth, and the ratio of operational reserves to frontline forces(Grauer and Horowitz, 2012).

Democracy, Anocracy and Autocracy: The variable Democracy equals one if a country scores seventeen or higher on the Polity IV democracy-autocracy index, zero otherwise. Anocracy equals one if a country scores between six and sixteen inclusive on this index, zero otherwise. Autocracy is the reference category in our models. Data come from the Polity IV project (Marshall et al., 2010).

National Capability: National Capability is a country's score on the Correlates of War Composite Indicator of National Capabilities (CINC) (Singer et al., 1972).

Civil-Military Relations: We measure Civil-Military Relations in the same way that Grauer and Horowitz do. We use their measure of the number of military coups in a country in the last 5 year period (Grauer and Horowitz, 2012).

Troops Engaged: Troops Engaged and Opponent Troops Engaged measure (Grauer and Horowitz, 2012).the number of troops engaged in battle for each side of the conflict. Both measures of troop strength are devised by (Grauer and Horowitz, 2012).

Logged GDP Per Capita: Finally, we also include a control for logged GDP per capita that is drawn from the Grauer and Horowitz (2012) replication data (Grauer and Horowitz, 2012).

Comparison with Saunders and Souva Expected Air Power Measure

The measure presented in Saunders and Souva (2019) is not a direct measure of air superiority. Saunders and Souva create a measure that takes into account the number of fighters in a state's air force inventory as well as the technological quality of those fighters. This is a useful measure in that it can be used in comparisons between states regardless of whether they actually engage in conflict or not, making it useful for assessing questions about conflict onset and potential selection into conflict. However, this measure is limited because it is only an indirect measure of air superiority. Much more goes into achieving air superiority than simply fighter aircraft. A perfect predictive measure of air superiority must also account for the training and skill of the pilots, availability of spare parts and fuel, the effectiveness of ground based air-defenses, the effectiveness and availability of radar and electronic warfare equipment, distance of the combat zone from each side's airfields and a number of other factors that are important in determining victory in the air. A purely quantitative measure of air superiority has great difficulty in capturing how all of these factors interrelate to determine air superiority. Thus, the Saunders and Souva EAS measure is necessarily only an approximation of actual air combat outcomes. Qualitative expert-coding procedures can and do provide a much more precise measure of actual achieved air superiority. Thus, when exploring questions related to conflict outcomes we argue that our more precise measure of achieved air superiority is superior to the Saunders and Souva measure of expected air superiority. We provide summary statistic below to further explain why that is the case.

Table 8: Cross tabulation of Saunders and Souva Expected Air Superiority (EAS) with Expert Coded Air Superiority.

	Inferiority	Parity	Superiority	Total
EAS = 0	10 (5)	7 (6.8)	2 (7.2)	19
EAS =1	0 (1.3)	1 (1.8)	4 (1.9)	5
EAS =2	1 (4.7)	7 (6.4)	10 (6.9)	18
Total	11	15	16	42

Observed value over (Expected) value
Pearson chi2 = 17.2471 Pr = 0.002

A cross tabulation of EAS and air superiority provides interesting insight into the difference between the two measures. A Chi^2 value of 17.3 and p-value of 0.002 show that we may reject the null hypothesis that these two measures are independent of one another. EAS and achieved air superiority are clearly measuring aspects of the same concept. However, note that while EAS predicts well in terms of combatants that go on to achieve either air inferiority or air superiority, EAS has a much more difficult time predicting an actual outcome of air parity –about equal to what we would expect from random chance.

An interesting illustration of why EAS has difficulty predicting cases of parity occurs during the Nagorno-Karabakh War between Armenia and Azerbaijan (1992-1994). EAS predicts that Azerbaijan should have held air superiority during the war, however, our qualitative coding reveals that Azerbaijani forces were unable to benefit from their numerical superiority in the air. Armenia had virtually no air force at all during this war, owning only 2 poorly maintained Su-25 fighter bombers. In contrast, Azerbaijan owned four squadrons (46 aircraft) composed of MiG-21 and MiG-25 air superiority fighters along with a contingent of Su-24 close air support aircraft. Further, Azerbaijan had hired well trained Russian and Ukrainian mercenary pilots to fly these aircraft. As the EAS measure suggests, on paper Azerbaijan should have easily dominated

the skies with its fighters and should have been able to employ its ground attack aircraft to maximum effect. However, while lacking in aircraft, Armenia had invested heavily in a sophisticated surface to air missile network. This air defense system was ultimately responsible for shooting down over half of the Azerbaijani air force and prevented the remainder from playing any significant role in the fighting. This example is illustrative of the cases where air parity attains while EAS yet predicts clear air superiority or inferiority. Ground based air defenses, concealment, distance from airfields, and many other factors that are important in air combat can do little to *win* air superiority for the inferior side, but they can do a great deal to neutralize a more powerful country's advantages, leading to cases of air parity where a measure relying only on aircraft inventories would predict air superiority for the numerically and technologically superior side.

Table 9: Correlation of EAS With Air Superiority.

	EAS	Air Superiority
EAS	1.00	
Air Superiority	0.7424	1.00

Further, in predicting inferiority/superiority, EAS correlates with actual achieved inferiority/superiority at 0.74 in our data. This is a strong positive correlation, but demonstrates that EAS is far from the perfect measure of air-combat outcomes. Where the research design of a study allows a more accurate measure to be used, such as the measure we introduce in this article that is designed for studying combat outcomes, researchers should elect to use the more accurate measure over the approximation.

References

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