Econometrica Supplementary Material

SUPPLEMENT TO "REVOLT ON THE NILE: ECONOMIC SHOCKS, RELIGION, AND POLITICAL POWER"

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A.1. SENSITIVITY CHECKS AND ADDITIONAL RESULTS

A.1.1. *Relation to Duration Models*

EVEN WHEN AN UNDERLYING DURATION such as a head judge's time in office is continuous, measurements of such durations are often discrete. This is the case in many economic applications and is also true for the duration of the head judge in office. When a duration is only known to fall within a certain time interval (such as a Nile year), the exact duration is not observed and the data are often referred to as grouped duration data.

The analysis in the main text is closely related to the specification commonly used in such group duration settings (see, for example, Meyer (1990), Ryu (1994), Jenkins (1995), and Sueyoshi (1995)). In the context of this paper, the relevant "grouped-data" duration model can be estimated by splitting each head judge duration into the Nile years in which he was in office. Then, for each judge-year observation, the dependent variable is equal to 1 if the judge was replaced in that year and 0 otherwise. For example, if a head judge was replaced in the third Nile year following his appointment, three observations would be created. The dependent variable in the first two observations would be equal to 0 and that in the third would equal 1.

In Table A.I, I investigate the extent to which results are robust to estimation using such grouped-data specifications. In columns 1–4 of Table A.I, I present results using the linear probability model. In column 1, I present results using the baseline sample without additional controls, whereas in column 2, I add period dummies. In column 3, I repeat the analysis using the judge-month as the unit of observation (see below for a detailed description of these data). In column 4, I use all observations after 1169.

In columns 5–10, I present the results derived from nonlinear models. I can only do this in the full sample after 1169, because on the baseline sample, there are no judge replacements in Nile shock years. In columns 5–7, I omit period dummies and thus constrain the baseline hazard to be constant. In columns 8–10, I include period dummies and thus allow the baseline hazard to vary arbitrarily across periods (e.g., Sueyoshi (1995)).[1] In columns 5 and 8, I estimate the effect of Nile shocks on judge replacement using the proportional hazards

[1]I pool the period dummies after the fourth year in these nonlinear specifications to avoid dropping observations.

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TABLE A.I

ROBUSTNESS TO GROUPED DURATION ANALYSIS[a]

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Shock	−0.24***	−0.22***	−0.020***	−0.20***	−2.13**	−2.25**	−1.14**	−2.07**	−2.24**	−1.21**
	(0.03)	(0.05)	(0.004)	(0.05)	(1.01)	(1.02)	(0.45)	(1.01)	(1.04)	(0.49)
Hazard/odds ratio					0.12	0.11		0.13	0.11	
Marginal effect					−0.21	−0.21	−0.21	−0.19	−0.20	−0.20
Period dummies?	No	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes
Estimation	OLS	OLS	OLS	OLS	PHM	Logit	Probit	PHM	Logit	Probit
Sample	Baseline	Baseline	Baseline	≥1169	≥1169	≥1169	≥1169	≥1169	≥1169	≥1169
Time	Year	Year	Month	Year	Year	Year	Year	Year	Year	Year
N	361	361	3530	376	376	376	376	376	376	376

[a]The dependent variable is a dummy equal to 1 if judge i was replaced in time period t. Shock is an indicator variable equal to 1 if the flood residual is in the upper 5% or lower 5% of the flood distribution. The rows labeled Hazard/odds ratio and Marginal effect report the hazard ratio, odds ratio, and marginal effects evaluated at the mean of the covariates where relevant. PHM denotes estimation using a proportional hazards model as described in the text. Standard errors are given in parentheses (those in columns 1, 2, and 4 allow for arbitrary correlation within decade, whereas in column 3 the standard error is robust to arbitrary correlation within Nile years). ***, **, and * indicate significance at the 1%, 5%, and 10% levels.

model following the approach in Meyer (1990).[2] In columns 6 and 9, I estimate the effects of Nile shocks on judge replacement using a logit specification. In columns 7 and 10, I estimate the shock effects using a probit specification. For these specifications, I present marginal effects (evaluated at the mean of the period dummies where relevant) and the relevant hazard/odds ratio. As these results show, the marginal effects obtained in the nonlinear models are almost identical to those obtained using the linear probability model.

Since the head judges in the main series are "stacked" by calendar time, the analysis in the main text is closely linked to such grouped duration specifications when time is measured in Nile years. The main differences are that the analysis in the main text omits some short-lived judges by making the Nile year the unit of observation and estimates the replacement probability using a linear probability model instead of a nonlinear specification. Thus, it is not surprising that the results using grouped duration specifications are similar to those presented in the main text.

A.1.2. *Judge Changes and Flood Residuals*

How sensitive are the results to the choice of trend and cutoffs? I investigate this question in Table A.II. Columns 1–7 use the baseline sample, whereas results reported in columns 8–14 were estimated on the sample including all years after 1169. The row labeled Shock provides the estimates of β_1 from equation (1) of the main text. The row labeled ShockHP provides the estimates of β_1 from equation (1) when calculating the Nile shock variable using deviations from an HP filter with the HP parameter value set to 6.25 as suggested by Ravn and Uhlig (2002). The rows labeled ShockMA and ShockAR perform the same exercise using deviations from a 25 year moving average and an AR(15).[3] Although the point estimates decrease in absolute value when compared to the results obtained using $shock_t$, they remain negative.[4]

In the rows labeled Shock5, Shock15, and Shock25, I present results using the top and bottom 2.5%, 7.5%, and 12.5% of flood deviations from a linear trend, respectively. The results show that while the point estimates are generally similar to those obtained using the variable $shock_t$ when the 5% cutoff is used, the point estimates decrease sharply and lose statistical significance when the 15% and 25% cutoffs are used in the baseline sample. These results are consistent with historical evidence that only extreme shocks led to significant increases in social unrest, and suggest that variables constructed using

[2]The results presented here abstract from unobserved heterogeneity. Results that allow for unobserved heterogeneity as in Meyer (1990) yield similar results to those presented.

[3]The AR lag length was chosen using the Akaike information criterion (AIC) and setting the maximum lag length equal to 30.

[4]Consequently, these results are consistent with the hypothesis that the use of nonlinear trends to construct the shock variable decreases the precision with which this variable measures actual Nile shocks.

TABLE A.II

TRENDS AND JUDGE REPLACEMENT[a]

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Shock	−33.50***							−37.73***						
	(6.78)							(7.19)						
ShockHP		−15.38							−16.20*					
		(10.20)							(9.56)					
ShockMA			−22.94***							−23.53***				
			(8.73)							(8.34)				
ShockAR				−12.04							−13.33			
				(13.64)							(13.07)			
Shock5					−30.08***							−30.00***		
					(8.72)							(10.00)		
Shock15						−9.92							−11.66	
						(9.23)							(8.75)	
Shock25							−7.85							−7.16
							(7.50)							(7.26)
Sample	BL	BL	BL	BL	BL	BL	BL	BL^+	BL^+	BL^+	BL^+	BL^+	BL^+	BL^+
N	257	257	257	257	257	257	257	269	269	269	269	269	269	269

[a]The dependent variable is a dummy equal to 1 if the incumbent judge at start of Nile year *t* was replaced in the following year. Throughout, I report 100 times the estimated coefficients. ShockHP is an indicator variable equal to 1 if the flood residual calculated using the HP trend is in the upper 5% or lower 5% of the flood distribution. ShockMA is an indicator variable equal to 1 if the flood residual calculated using a 25 year moving average is in the upper 5% or lower 5% of the flood distribution. ShockAR is an indicator variable equal to 1 if the flood residual calculated using an AR(15) is in the upper 5% or lower 5% of the flood distribution. Shock5 is an indicator variable equal to 1 if the flood residual calculated using a linear trend is in the upper 2.5% or lower 2.5% of the flood distribution. Shock15 is an indicator variable equal to 1 if the flood residual calculated using a linear trend is in the upper 7.5% or lower 7.5% of the flood distribution. Shock25 is an indicator variable equal to 1 if the flood residual calculated using a linear trend is in the upper 12.5% or lower 12.5% of the flood distribution. BL^+ denotes the entire sample after 1169 and BL denotes the baseline sample. Standard errors, assuming the error structure is autocorrelated up to 10 lags and heteroscedastic, are presented in parentheses. All regressions include decade dummies. ***, **, and * indicate significance at the 1%, 5%, and 10% levels.

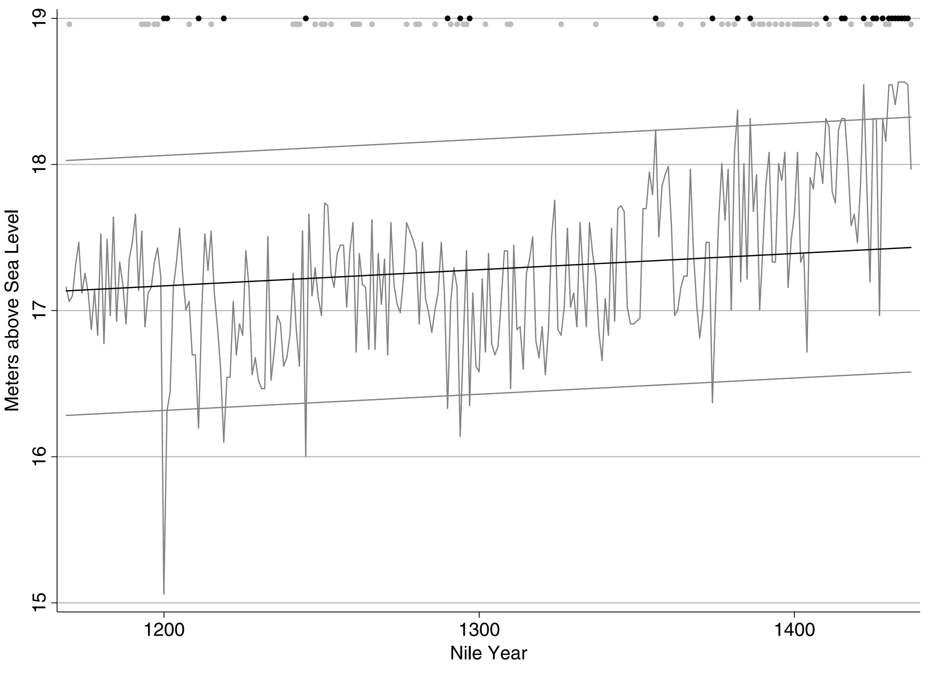

FIGURE A.1.—Nile shocks and judge replacement on the entire post-1169 sample. Gray dots at the top of the graph denote years with judge replacement; black dots denote Nile shocks.

the 15% and 25% cutoffs measure these shocks less precisely than the variable $shock_t$ used throughout the analysis in the main text.

A.1.3. *Results Including Years After 1425*

Figure A.1 reproduces Figure 1 of the main text when the years after 1425 are included. In Tables A.III and A.IV, I replicate the analysis from Tables II and III of the main text when I add the Nile years after 1425 to the baseline sample. Here I simply note that the results in Tables A.III and A.IV are qualitatively similar to those presented in the main text.

A.1.4. *Religious and Secular Structures*

In this section, I investigate the results on relative allocations to religious structures in greater detail. The results presented in the main text provide the differences-in-differences coefficient for religious structures with respect to secular structures. The standardized number of religious and secular struc-

TABLE A.III

NILE SHOCKS, JUDGE REPLACEMENT, AND MONUMENT CONSTRUCTION: ALL OBSERVATIONS AFTER 1169[a]

	Dependent Variable: Judge Replaced on $[t, t+1)$					Standardized Monuments				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Shock	−20.43***	−21.86***	−37.73***	−32.39***	−33.20***	79.78**	70.70**	79.79	74.90**	93.40**
	(4.76)	(4.67)	(7.19)	(6.75)	(7.03)	(35.74)	(35.37)	(54.05)	(37.68)	(42.66)
AR(10)	[0.03]	[0.05]	[0.00]	[0.78]	[0.66]	[0.01]	[0.03]	[0.00]	[0.76]	[0.65]
p-Value (5 leads)				[0.24]					[0.84]	
p-Value (5 lags)				[0.93]					[0.22]	
p-Value (10 leads)					[0.78]					[0.91]
p-Value (10 lags)					[0.00]					[0.93]
Dynasty dummies?	No	Yes	No	Yes	Yes	No	Yes	No	Yes	Yes
Decade dummies?	No	No	Yes	No	No	No	No	Yes	No	No
N	269	269	269	264	259	269	269	269	264	259

[a]The dependent variable in columns 1–5 is a dummy equal to 1 if the incumbent judge at start of Nile year t is replaced in the following year, whereas the dependent variable in columns 6–10 is a standardized measure of the relative allocation of new constructions to religious structures as explained in the text. In columns 1–5, I report 100 times the estimated coefficient. Shock is an indicator variable equal to 1 if the flood residual is in the upper 5% or lower 5% of the flood distribution. The row labeled AR(10) provides the p-value for the Breusch–Godfrey test with the null hypothesis of no autocorrelation up to 10 lags. The rows p-Value provide the p-value for the test of the null hypothesis that the coefficients on the stated number of leads and lags of Nile shocks are jointly equal to 0. Standard errors, assuming the error structure is autocorrelated up to 10 lags and heteroscedastic, are presented in parentheses, aside from those in columns 4, 5, 9, and 10, which are robust to heteroscedasticity. ***, **, and * indicate significance at the 1%, 5%, and 10% levels.

TABLE A.IV

POSSIBLE CAUSAL CHANNELS: ALL OBSERVATIONS AFTER 1169[a]

	Prayer	Judge	Judge	Crusade	Judge	High Prices	Unrest	Sultan	Sultan	Judge
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Shock	−44.43***		−44.60***	−10.32		102.75***	83.46*	−1.96		
	(14.18)		(8.38)	(24.44)		(32.61)	(43.65)	(7.76)		
Shock ∗ Baseline		−37.73***								
		(7.17)								
Shock ∗ Early		−7.61								
		(7.28)								
MalikiShock			−11.03**							
			(4.80)							
HanafiShock			7.59							
			(12.45)							
HanbaliShock			−4.60							
			(7.00)							

(*Continues*)

TABLE A.IV—*Continued*

	Prayer	Judge	Judge	Crusade	Judge	High Prices	Unrest	Sultan	Sultan	Judge
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(Crusade)/100					−3.69*					
					(2.06)					
Shock5									19.03	
									(16.27)	
(High Prices)/100										−36.72**
										(15.05)
										[−50.49, −10.98]
p-Value		[0.00]	[0.00]							
Estimation	OLS	OLS	SUR	OLS	OLS	OLS	OLS	OLS	OLS	IV
N	266	797	172	266	266	266	266	540	540	266
Sample	Maq.	All	>1265	Maq.	Maq.	Maq.	Maq.	Ind.	Ind.	Maq.

[a]The dependent variable in the columns marked Judge (Sultan) is a dummy equal to 1 if the incumbent judge (sovereign) at the start of Nile year *t* is replaced in the following year. In these columns, I report 100 times the estimated coefficient. The columns Prayer, Crusade, High Prices, and Unrest denote the use of standardized measures of the extent to which prayer, Crusaders, high prices, and unrest are mentioned in Maqrizi's chronicle. Shock is an indicator variable equal to 1 if the flood residual is in the upper 5% or lower 5% of the flood distribution. Shock5 is an indicator variable equal to 1 if the flood residual is in the upper 2.5% or lower 2.5% of the flood distribution. The entries MalikiShock, HanafiShock and HanbaliShock provide the coefficient on the variable Shock in regression (1) of the main text estimated using SUR when head judge replacements from the Maliki, Hanafi, and Hanbali schools are used as the dependent variable (the coefficient on the Shafii head judge is provided in the first row of column 3). The row *p*-Value provides the *p*-value corresponding to the test that all the provided coefficients in the column are equal. In the row sample, Maq. denotes the years in the baseline sample in which the variables constructed using Maqrizi's chronicle are available and Ind. denotes years in both the early and baseline samples in which Egypt was not part of a larger empire. Standard errors, assuming the error structure is autocorrelated up to 10 lags and heteroscedastic, are presented in parentheses aside from those in column 3, where they are robust to heteroscedasticity. All regressions include decade dummies. ***, **, and * indicate significance at the 1%, 5%, and 10% levels.

tures begun in Nile year t are denoted by Rel_t and Sec_t, respectively. In the main text, I estimate the specification

$$(1) \qquad [Rel_t - Sec_t] = \beta_0 + \beta_1 shock_t + \boldsymbol{\gamma}'\mathbf{x} + \varepsilon_t.$$

The point estimate on the shock variable is positive, showing that the difference $[Rel_t - Sec_t]$ was higher in Nile shock years than in other periods. Here I examine the robustness of this result to the definition of religious and secular buildings. Throughout the analysis in this section, I include all years after 1169 because when I do this, the point estimates are estimated a bit more precisely.

In the main text, religious structures include convents, *khanqas*, madrasas, *mashhads*, mausoleums, mosques, and *zawiyas*, while secular structures include aqueducts, baths, bridges, caravansaries, cisterns, citadels, fountains, gates, halls, hospitals, nilometers, palaces, and walls. In columns 1–3 of Table A.V, I provide results using this baseline definition and split the differences-in-differences coefficient into its two constituent parts. The point estimate in column 1 shows that during Nile shocks, more religious constructions were begun than during other periods, although this coefficient is not statistically significant. The estimate in column 2 shows that fewer secular structures were begun during Nile shocks and that this coefficient is statistically significant. The difference between the point estimates in columns 1 and 2 is given in column 3, and is the differences-in-differences coefficient. In the text, I suggest that this relative increase in allocation to religious structures is indicative of a Nile-induced increase in the head judge's political power.

One potential worry is that the relative increase in religious structures is being driven by increased allocations to mausoleums or to other buildings used to bury prominent individuals who were killed by Nile-induced hunger and/or disease. In columns 4–6 of Table A.V, I omit religious buildings associated with death (mausoleums, *mashhads*, and *zawiyas*). The qualitative implication of the results remain robust to this exercise.

Another alternative interpretation of this result is that secular constructions are more procyclical than religious ones for purely economic reasons (e.g., demand for secular structures that served commercial purposes). If this were true, one would expect such procyclical behavior to be limited to secular structures that served commercial purposes such as caravansaries or bridges. In columns 7–9 of Table A.V, I limit secular constructions to include gates, citadels, halls, palaces, and city walls, and thus exclude those that presumably served commercial purposes. The results remain robust to this exercise and provide some evidence against the importance of variation in the demand for commercial structures in driving the results.

A.1.5. *Sovereign Changes*

How robust are the sovereign change results? In Table A.VI, I explore this question. In the odd-numbered columns, I report the results using the $shock_t$

TABLE A.V

RELIGIOUS AND SECULAR STRUCTURES[a]

	Religious	Secular	Dif	Religious	Secular	Dif	Religious	Secular	Dif
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Shock	41.48	−38.30***	79.78**	36.96	−38.30***	75.26*	41.48	−22.67**	64.15*
	(32.11)	(10.09)	(35.74)	(38.54)	(10.09)	(42.52)	(32.11)	(10.17)	(34.34)
Structures	All	All	All	ND	ND	ND	NC	NC	NC

[a]The dependent variable in columns 1, 4, and 7 is 100 times the number of religious constructions begun in each year normalized to have mean zero and unit variance. The dependent variable in columns 2, 5, and 8 provides the same metric using secular buildings, whereas the dependent variable in columns 3, 6, and 9 provides the difference between the two. The regressions in columns 4–6 omit all structures associated with death, whereas regressions in columns 7–9 omit those associated with commerce. Regressions use all observations after 1169 CE and do not include decade or dynasty dummies. Standard errors, assuming the error structure is autocorrelated up to 10 lags and heteroscedastic, are presented in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels.

TABLE A.VI

SOVEREIGN CHANGES[a]

	Sultan									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Shock	4.50		7.57		9.25		1.59		−3.58	
	(5.96)		(5.98)		(7.09)		(7.53)		(11.79)	
Shock5		16.11*		22.27**		34.24**		28.42*		17.29
		(9.06)		(8.76)		(14.61)		(15.87)		(24.49)
Sample	All	All	≤1425	≤1425	Ind.	Ind.	Ind.	Ind.	Base	Base
Decade dummies	No	No	No	No	No	No	Yes	Yes	Yes	Yes
N	797	797	785	785	528	528	528	528	257	257

[a]The dependent variable is a dummy equal to 1 if the sultan at start of Nile year *t* is replaced in the following year. Throughout, I report 100 times the estimated coefficients. Shock is an indicator variable equal to 1 if the flood residual is in the upper 5% or lower 5% of the flood distribution. Shock5 is an indicator variable equal to 1 if the flood residual is in the upper 2.5% or lower 2.5% of the flood distribution. Ind. denotes years in which Egypt was not a province of a non-Egyptian based dynasty prior to 1425, whereas Base denotes the baseline sample. Standard errors, assuming the error structure is autocorrelated up to 10 lags and heteroscedastic, are presented in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels.

TABLE A.VII

FLOODS AND DROUGHTS: MAQRIZI[a]

	Prayer		High Prices		Unrest	
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Baseline						
Drought	−42.01***	−15.32*	198.00***	170.42***	126.46**	161.51**
	(15.02)	(7.86)	(61.07)	(55.26)	(61.14)	(73.37)
Flood	−32.84**	−50.51***	42.94*	40.33**	−4.41	−6.00
	(10.66)	(16.71)	(22.06)	(16.19)	(35.69)	(24.25)
p-Value	[0.55]	[0.06]	[0.02]	[0.03]	[0.05]	[0.03]
Decade dummies?	No	Yes	No	Yes	No	Yes
N	254	254	254	254	254	254
Panel B: After 1169						
Drought	−43.07***	−15.32*	197.62***	170.42***	126.05**	161.51**
	(14.99)	(7.85)	(61.08)	(55.22)	(61.08)	(73.32)
Flood	−25.27**	−70.68***	47.71***	41.73***	20.09	13.10
	(10.72)	(20.01)	(13.24)	(12.45)	(20.15)	(21.68)
p-Value	[0.24]	[0.01]	[0.02]	[0.02]	[0.08]	[0.05]
Decade dummies?	No	Yes	No	Yes	No	Yes
N	266	266	266	266	266	266

[a]The columns Prayer, High Prices, and Unrest denote the use of standardized measures of the extent to which prayer, high prices, and unrest are mentioned in Maqrizi's chronicle as the dependent variable. Drought is an indicator variable equal to 1 if the flood residual is in the lower 5% of the flood distribution, whereas flood is an indicator equal to 1 if the flood residual is in the upper 5% of the distribution. Standard errors, assuming the error structure is autocorrelated up to 10 lags and heteroscedastic, are presented in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels.

variable, whereas in the even-numbered columns, I report results obtained using the $shock5_t$ variable. These results show that although results calculated using the $shock5_t$ variable are generally large and statistically significant, those calculated using the $shock_t$ variable are not statistically significant. This is consistent with the possibility noted in the main text that only the severest Nile shocks led to changes in the sovereign in equilibrium.

A.1.6. *Droughts and Floods*

Did abnormally low Nile floods have a greater effect on the outcomes of interest than abnormally high ones? In Table A.VII, I investigate this question using the metrics derived from Maqrizi's chronicle. In panel A, analysis is limited to the baseline sample, whereas in panel B, I include all observations after 1169. In the row labeled p-value, I provide the p-value for the test that the coefficients on drought and floods are equal.

In general, while both the sign and statistical significance on the drought and flood variables are similar, the data often reject the null hypothesis that the coefficients on droughts and floods are equal. This suggests that Nile droughts may have caused more severe increases in food prices and unrest than Nile floods. However, the data do not reject the null hypothesis that the effects of Nile floods and droughts on judge dismissal and relative allocations to religious structures were equal.

Do these results stand in contradiction? Not necessarily, since it is possible that both Nile floods and Nile droughts led the potential for unrest to increase above the threshold beyond which the sovereign found it optimal to increase concessions to the head judge to a sufficient degree that his replacement probability fell. In other words, it is possible that even for medium amounts of potential unrest the sovereign found it optimal to meet the judge's demands and that further increases in unrest beyond this threshold had less of an effect on concessions to the judge. Unfortunately, data limitations render it impossible to investigate this or other hypotheses regarding the differential effects of Nile droughts and floods with any degree of certainty. For this reason, I have preferred to stress that both Nile droughts and floods seem to have increased the propensity for unrest and have concentrated on the pooled coefficients.

A.1.7. *Results by Lunar Months, Eclipses, and Ramadan*

In Table A.VIII, I investigate the effects of Nile shocks when the lunar month is used as the unit of observation on the entire post-1169 sample. In column 1, I regress the judge replacement dummy on the shock variable. In column 2, I add decade dummies, and in column 3, I add solar year and solar month dummies (recall that the Nile shock variable varies by Nile year). These results are qualitatively similar to the results obtained when the Nile year is used as the unit of observation.

In columns 4–6, I add an indicator equal to 1 if a solar eclipse occurred in a given month.[5] Eclipses are thought to have increased religiosity (Akasoy (2007, pp. 394–395)). Thus, if increases in religiosity are generating the results, I would expect to see a negative relationship between eclipses and head judge replacement. The results, however, are not consistent with this hypothesis.

Finally, in columns 7–9, I add an indicator variable equal to 1 if the month was Ramadan. Recent research has found evidence of increases in religiosity during Ramadan in modern Turkey (Akay, Karabulut, and Martinsson (2011)). Historically this also appears to have been the case. For example, prayers during Ramadan in the medieval period were believed to be "worth scores or even hundreds of prayers on normal occasions" (Berkey (2001, p. 47)). Consequently, if increases in religiosity or increases in the demand for religious services were driving the Nile results, one would expect to see significant decreases in the judge replacement probability during Ramadan. Results in columns 7–9, however, show that this prediction is not borne out by the data.

[5]Data on solar eclipses are drawn from Espenak and Meeus (2006) and include all solar eclipses (total, annular, partial, and hybrid) that could be seen from Cairo.

TABLE A.VIII

NILE SHOCKS, ECLIPSES, RAMADAN, AND JUDGE REPLACEMENT: RESULTS AT THE MONTHLY LEVEL[a]

	Dependent Variable: Incumbent Judge at t Replaced on $[t, t+1)$								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Shock	−2.18***	−3.86***	−4.22***	−2.18***	−3.86***	−4.23***	−2.18***	−3.86***	−4.22***
	(0.45)	(0.87)	(1.18)	(0.44)	(0.87)	(1.18)	(0.45)	(0.87)	(1.18)
Eclipse				1.23	1.19	1.34			
				(2.03)	(2.04)	(2.15)			
Ramadan							−0.13	−0.14	−0.26
							(0.94)	(0.94)	(0.93)
Decade dummies?	No	Yes	No	No	Yes	No	No	Yes	No
Solar year dummies?	No	No	Yes	No	No	Yes	No	No	Yes
Solar month dummies?	No	No	Yes	No	No	Yes	No	No	Yes
p-Value				[0.07]	[0.02]	[0.02]	[0.04]	[0.00]	[0.01]
N	3327	3327	3327	3327	3327	3327	3327	3327	3327

[a]The dependent variable is a dummy equal to 1 if the incumbent judge at start of lunar month t is replaced in the following month. Throughout, I report 100 times the estimated coefficients. Shock is an indicator variable equal to 1 if the flood residual is in the upper 5% or lower 5% of the flood distribution. Eclipse is an indicator equal to 1 if a solar eclipse occurred in month t, whereas Ramadan is equal to 1 if the month is Ramadan. The row p-Value provides the p-value for the test that the coefficients on Eclipse/Ramadan and Shock are equal. Standard errors are clustered by Nile year. ***, **, and * indicate significance at the 1% , 5%, and 10% levels.

The point estimates on the Ramadan dummy are small in absolute value and not statistically significant.

A.2. DATA

A.2.1. *Lunar and Solar Years*

The data sources often use the hijri calendar. Hijri years are lunar years that consist of 354 days (355 days in a lunar leap year) and have 12 months that alternate between 29 and 30 days. The first day of the first hijri year corresponds to the solar date July 16th 622 CE (solar years and CE years are used interchangeably), the day the Prophet Muhammad made his *Hijra* or migration from Mecca to Medina. Since the lunar year, hijri, or AH year is approximately 11 days shorter than the solar year, the first day of the lunar year slowly "cycles backward" through the solar year. Thus, the lunar months have no calendar regularity. This has important implications for the correct assignment of the Nile flood data as discussed below.

A.2.2. *Nile Flood Data*

The historians Ibn al-Hijazi and Taghri Birdi provide two separate sets of Nile flood data. Hijazi's statistics cover the interval [1, 873] AH, whereas Taghri Birdi's statistics span the years [20, 855] AH. Both data sets appear to be copies of the original records kept by the guardian of the nilometer on the island of Rauda. The authors give the yearly maximum and minimum level of the Nile flood by lunar year.

Scholars agree that these data provide credible estimates of the true Nile flood levels and Hijazi's data have been extensively used in the climatology literature. The data, however, contain two sources of measurement error. First, both data sets have transcription errors. It is straightforward to show that this source of error attenuates the coefficients of interest under plausible assumptions. Second, both authors assigned the yearly Nile flood maxima and minima to lunar years. The assignment of the flood levels to lunar years introduces an additional source of measurement error if left uncorrected.

To better understand this problem, consider the flood that occurred in the year 1008 CE. Hijazi recorded this flood level as having occurred in the year 398 AH, which spanned the solar interval [17 September 1007, 4 September 1008]. However, information regarding the maximum Nile flood level began to be revealed in July. Consequently, if I assigned the flood recorded by Hijazi in 398 AH to that lunar year, only the lunar dates corresponding to the solar interval [1 July 1008, 4 September 1008] would be correctly assigned. I would spuriously assign to the remainder of dates in the lunar year 398 the flood that occurred in 1008 CE, when in reality these dates were treated by the Nile flood that occurred in 1007 CE.

To further complicate matters, neither Hijazi nor Taghri Birdi appears to have necessarily recorded Nile floods in the lunar year in which the maximum flood level occurred. Hijazi seems to have assigned solar year floods to lunar years by convention. I use the Toussoun (1925) mapping to assign the flood levels to the CE year in which they occurred.

Although there is enough information to construct such a mapping for Hijazi's data, it is not possible to determine which solar year flood Taghri Birdi recorded in each lunar year.[6] For this reason, I use Hijazi's data throughout the paper.

A.2.3. *Head Judge Data*

Ibn Hajar (1449 [1998]) provided the month and year of head judge changes. Of the 245 judge changes reported by Ibn Hajar on the interval [20, 10th month of 842] AH, the year of replacement was available (or could be imputed) for 239 changes (98%), and the year and month of replacement were available for 209 changes (85%).

Missing replacement dates were imputed as follows. Ibn Hajar (1449 [1998], pp. 4–21) provided a poem that lists Egypt's judges in chronological order.[7] When a judge's replacement date was missing, I replaced this missing date with the appointment date of the judge who chronologically followed him in the poem. When the appointment month/year of the following judge was also missing, the replacement month/year was left blank. Judge changes missing the month but containing the year of change were assigned the month 6.

When there was more than one head judge after 1265 CE, I included the dismissal date of the Shafii judge in the main series (the Shafii school was the most influential in Egypt during the Mamluk era).[8] After 1265 CE, I created three additional series for the head judges of the three other law schools in an identical manner to those for the Shafii school.

Since the head judge data do not completely cover the hijri year 842, I discard it from the sample. The data set consequently contains 239 judge replacements on the interval [20, 841] AH.

Although the head judge change data are given by lunar months and years, Nile floods followed the solar calendar. To correctly assign each Nile flood to

[6]The mapping from lunar to solar years is made possible in Hijazi's data by the fact that he generally skips every 34th lunar year. Taghri Birdi's data do not follow such a pattern, making the exact mapping between lunar and solar years unclear. See Popper (1951, pp. 123–149) for a detailed discussion.

[7]A spread sheet that documents the construction of this data set is available on request.

[8]There was also more than one head judge briefly under the Fatimids. During the Fatimid period, I included the Ismaili (Shia) head judge, since the head judges were generally Ismaili under the Fatimids.

the lunar months it treated, I developed a mapping from lunar months/years to solar months/years using the tables provided in Freeman-Grenville (1995).[9]

To create the mapping between lunar and solar months, I first calculated the percentage of each lunar month occupied by a given solar month. I then assigned a lunar month to a solar month if the solar month occupied 50% or more (15 days or more) of the lunar month. When the lunar month was evenly divided between two solar months, I used the earlier of the two solar months. Sometimes two different lunar months are assigned to one solar month (that is, one solar month occupied 50% or more of two lunar months).

Equipped with this mapping, I defined a Nile year to run from July through June of the solar year (since these were approximately the dates treated by each Nile flood level). I then assigned the Nile flood from CE year t to the lunar months in the interval [July t, June $t+1$].

Throughout much of the analysis I use the Nile year as the unit of observation. Collapsing the monthly data down to the Nile year level was straightforward. The merged data sets span the interval [20, 841] AH. Since the year 841 AH ended on June 23, 1438 CE, the data set contains 797 Nile years [641, 1437]. In other words, the data cover the interval [July 641, June 1438] CE.

If regressions are run at the lunar level, there are 9857 observations in the entire sample. This number can be understood as follows. If I ran the regressions at the solar month level, I would have $797 * 12 = 9564$ observations. Since there are 293 solar years containing 13 lunar months, the total number of monthly observations is $9564 + 293 = 9857$.

A.2.4. *Other Data*

In this section, I explain in detail the construction of the variables that have not yet been fully explained.

A.2.4.1. *Maqrizi Chronicle Data*

I used a digitized version of the historian Maqrizi's chronicle (1364–1442 CE) *al-Sulūk li-Ma'arifat Duwal al-Mulūk* (available at http://www.al-eman.com) to construct the relevant variables. In this chronicle, Maqrizi—one of the most trusted sources for information on Egypt in the period covered by his writings—provides a yearly description of events in Egypt.[10]

The proxy for religiosity is constructed in the spirit of Baker, Bloom, and Davis (2011). I use Microsoft Word's search function to calculate the number of times Maqrizi used the Arabic word for prayer (*ṣalāh*) in his description of

[9]I use the Julian calendar as a proxy for the solar (tropical) calendar for simplicity, while recognizing that this calendar slowly diverged from the solar calendar. By 1582, this calendar had diverged from the tropical calendar by 10 days.

[10]The digitized version of Maqrizi's chronicle overlaps with the baseline data set on the Nile year interval [1172, 1437] and provides a narrative of events by lunar year.

the events of each year. I then normalize by the total number of words Maqrizi used in his chronicle entry for that year and take the weighted average of this quantity for the lunar years that overlapped with at least part of a given Nile year (where the weights are the percentage of the Nile year occupied by the respective lunar year). I then standardize this quantity by subtracting the mean, dividing by the standard deviation, and multiplying by 100.

The proxy for high prices measures the extent to which the word *ghalā'* appears in each year and is constructed as above. This term refers to a period of high food prices or a rise in such prices (Allouche (1994, pp. 7–12)).

The proxy for unrest is the sum of the number of times Maqrizi used the words *fitna* (riot, discord, dissension, or civil strife; Wehr (1980, p. 696)), *qitāl* (combat or battle; Wehr (1980, p. 743)), or the root n-h-b (to plunder, loot, or take by force; Wehr (1980, p. 1002)) interacted with an indicator equal to 1 if Maqrizi mentions the term *ghalā'* at least once in that year.[11] The first two words attempt to measure unrest broadly and the last word attempts to measure looting by the populace (a close reading of Maqrizi's chronicle suggests that his use of the root n-h-b was more likely to refer to looting by the populace (rather than by the military) during periods of high prices). It is important to note that since Maqrizi does not use any single term to refer to such events, and the nouns and verbs used to denote unrest often have alternative meanings (for example, *fitna* can also mean lust), this metric is likely a rougher proxy for the underlying quantities of interest than the other metrics derived from Maqrizi's chronicle.

A.2.4.2. *Sovereign Changes*

The months of sovereign changes are drawn from Sami (1916).

A.2.5. *Summary Statistics*

In Table A.IX, I present summary statistics by dynasty when the Nile year is used as the unit of observation. One interesting pattern that emerges from an inspection of Table A.IX is that the probability of a Nile shock was lower during the Fatimid and Ayyubid dynasties than during other periods. It is possible that this pattern is due to long-term variation in Ethiopian rainfall patterns. Also, although the probability of a judge replacement remained roughly constant over time, changes in the sovereign of Egypt were more likely during the "province dynasty" (when the sovereign was a governor appointed by the Caliph in Medina, Damascus, or Baghdad) and less likely during the Fatimid dynasty.

[11] Although Wehr (1980) is a dictionary of modern Arabic, these words had similar meanings in the medieval period. See, for example, Lane (1893 [1984]).

TABLE A.IX

SUMMARY STATISTICS[a]

	Shock	Judge	Sultan	Monuments	Prayer	High Prices	Unrest	Crusade	*N* [Maqrizi]
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Province (mean)	0.14	20.23	36.19	−21.98					257
Province (std)	0.35	40.25	48.15	37.16					
Tulinid/Ikhshidid (mean)	0.13	18.31	15.49	−32.47					71
Tulinid/Ikhshidid (std)	0.34	38.95	36.44	88.21					
Fatimid (mean)	0.04	20.00	5.50	−16.47					200
Fatimid (std)	0.20	40.10	22.86	119.13					
Ayyubid (mean)	0.06	14.81	9.88	−13.32	−19.16	−12.20	26.84	80.50	81 [78]
Ayyubid (std)	0.24	35.75	30.02	164.36	118.20	97.37	142.08	148.08	
Mamluk (mean)	0.11	25.53	18.09	65.56	7.95	5.06	−11.14	−33.40	188
Mamluk (std)	0.32	43.72	38.59	201.84	90.56	100.89	73.72	36.31	
After 1169 (mean)	0.10	22.30	15.61	41.81	0.00	0.00	0.00	0.00	269 [266]
After 1169 (std)	0.30	41.71	36.37	194.43	100.00	100.00	100.00	100.00	
Early (mean)	0.10	19.89	21.78	−21.30					528
Early (std)	0.30	39.95	41.31	84.20					
Baseline (mean)	0.07	22.18	15.95	37.80	−0.51	−1.75	−1.61	1.15	257 [254]
Baseline (std)	0.25	41.63	36.69	194.54	100.96	101.47	100.63	102.09	

[a]The mean and standard deviation of each variable is given by time period in the rows marked (mean) and (std), respectively. Shock is an indicator variable equal to 1 if the flood residual is in the upper 5% or lower 5% of the flood distribution. Judge is a dummy equal to 1 if the incumbent judge at start of Nile year t is replaced in the following year and 0 otherwise. Sultan is equal to 1 if the incumbent sovereign at start of Nile year t is replaced in the following year and 0 otherwise. For both of these dummies, I report 100 times the estimated means and standard deviations. Monuments denotes a standardized measure of the relative allocation of new constructions to religious structures as explained in the text. The columns Prayer, High Prices, Unrest, and Crusade provide summary statistics of measures of the extent to which prayer, high prices, unrest, and Crusaders are mentioned in Maqrizi's chronicle as explained in the text. N [Maqrizi] provides the number of observations; those for the variables constructed using Maqrizi's chronicle are provided in brackets.

A.3. DATA AFTER 1517: NILE SHOCKS AND REVOLTS

The Nile flood data used in the main text end in the 15th century. Although flood data from later periods are available, these are less complete than the data used in the main text. Figure A.2 demonstrates this by plotting the available Nile maxima in the years for which they are available after 1517 CE (the date of the start of the Ottoman conquest of Egypt) until the start of British occupation in 1882 (shortly after which the opening of the Assuan Dam markedly affected the Nile's annual flood level (Popper (1951, p. 226))). This figure shows that while the Nile flood maxima are largely missing prior to 1700 CE, after this date the time series is more complete.[12]

Although Egypt experienced institutional changes between the 15th and 19th centuries, the evidence suggests that Nile shocks continued to affect the probability of popular revolt through the 19th century (Baer (1969, 1977)). To empirically investigate the extent to which this was the case, I use Baer (1969, 1977) to compile a list of popular revolts starting in 1678 CE (the year of the

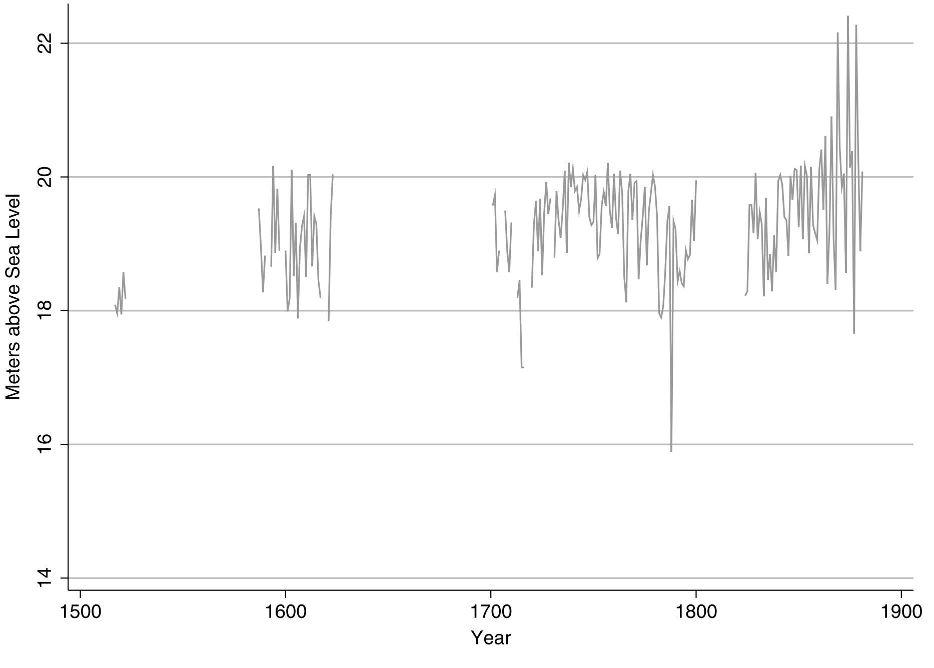

FIGURE A.2.—Annual Nile maxima from 1517 to 1882 CE.

[12]These data are drawn from Toussoun (1925).

TABLE A.X

NILE SHOCKS AND REVOLTS AFTER 1678[a]

	Dependent Variable: Revolt			
	(1)	(2)	(3)	(4)
Shock	21.67*		17.49*	
	(12.33)		(10.05)	
Drought		34.17*		19.39
		(19.26)		(16.12)
Flood		9.17		15.53
		(12.06)		(9.91)
Decade dummies?	No	No	Yes	Yes
p-Value		[0.24]		[0.83]
N	155	155	155	155

[a]The dependent variable is a dummy equal to 1 if there was a popular revolt in solar year t. Throughout, I report 100 times the estimated coefficients. Shock is an indicator variable equal to 1 if the flood residual is in the upper 5% or lower 5% of the flood distribution. Drought is an indicator variable equal to 1 if the flood residual is in the lower 5% of the flood distribution, whereas flood is an indicator equal to 1 if the flood residual is in upper 5% of the distribution. The row p-Value provides the p-value for the test that the coefficients on Drought and Flood are equal. Standard errors, assuming the error structure is autocorrelated up to 10 lags and heteroscedastic, are presented in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels.

first revolt provided in these sources).[13] These sources provide an opportunity to directly investigate the extent to which Nile shocks increased the probability of popular revolt on the interval [1678, 1882] CE. To do this, in columns 1–4 of Table A.X, I present results from the regression

$$(2) \qquad revolt_t = \beta_0 + \beta_1 shock_t + \boldsymbol{\gamma}'\mathbf{x} + \varepsilon_t,$$

where $revolt_t$ is equal to 1 if Baer (1969, 1977) reported a revolt in solar year t and 0 otherwise, and $shock_t$ is an indicator equal to 1 if the Nile deviation from the linear trend on the interval [1678, 1882] CE in solar year t is in the top 5% or lower 5% of the flood distribution.[14] Estimates of β_1 are presented in columns 1 and 3, and show that there is a positive correlation between Nile shocks and revolts that is statistically significant at the 10% level. The point estimates suggest that Nile shocks increased the probability of a popular revolt by roughly 20 percentage points. In columns 2 and 4, I present the results from breaking $shock_t$ into its two components. The data do not reject the null hypothesis that droughts and floods had similar effects on the propensity for revolt.

[13]I used Baer (1977) as my source for revolts before 1805 CE and Baer (1969) for revolts after this date.

[14]I use the solar year as the unit of observations for these regressions since the month the revolt began is not available for many revolts.

Unfortunately, after the Ottoman conquest of Egypt, the head judge was Turkish, and although it is believed that members of the local religious elites continued to play a similar role to that played by the head judge in earlier periods, there was no equivalent to the earlier position of head judge (Winter (1992, Chapter 4)). Consequently, it is impossible to replicate the head judge analysis in this later period.

ADDITIONAL REFERENCES

AKASOY, A. (2007): "Islamic Attitudes to Disasters in the Middle Ages: A Comparison of Earthquakes and Plagues," *The Medieval History Journal*, 10, 387–410. [13]

AKAY, A., G. KARABULUT, AND P. MARTINSSON (2011): "The Effect of Religiosity and Religious Festivals on Positional Concerns: An Experimental Investigation of Ramadan," Report. [13]

ALLOUCHE, A. (1994): *Mamluk Economics: A Study and Translation of al-Maqrizi's Ighatha*. Salt Lake City: University of Utah Press. [18]

BAER, G. (1969): "Submissiveness and Revolt of the Fellah," in *Studies in the Social History of Modern Egypt*. Chicago: University of Chicago Press, 93–108. [20,21]

——— (1977): "Popular Revolt in Ottoman Cairo," *Der Islam*, 54 (2), 213–242. [20,21]

BERKEY, J. (2001): *Popular Preaching and Religious Authority in the Medieval Islamic Near East*. Seattle: University of Washington Press. [13]

ESPENAK, F., AND J. MEEUS (2006): *Five Millennium Canon of Solar Eclipses: 2000 BCE to 3000 CE*. Washington, DC: National Aeronautics and Space Administration. [13]

FREEMAN-GRENVILLE, G. S. P. (1995): *The Islamic and Christian Calendars AD 622–2222 (AH 1–1650)*. Reading: Garnet Publishing. [17]

JENKINS, S. (1995): "Easy Estimation Methods for Discrete-Time Duration Models," *Oxford Bulletin of Economics and Statistics*, 57 (1), 129–138. [1]

LANE, E. W. (1893 [1984]): *Arabic–English Lexicon*. Cambridge: Islamic Texts Society. [18]

MEYER, B. (1990): "Unemployment Insurance and Unemployment Spells," *Econometrica*, 58 (4), 757–782. [1,3]

RAVN, M., AND H. UHLIG (2002): "On Adjusting the Hodrick–Prescott Filter for the Frequency of Observations," *Review of Economics and Statistics*, 84 (2), 371–380. [3]

RYU, K. (1994): "Group Duration Analysis of the Proportional Hazard Model: Minimum Chi-Sqaured Estimators and Specifiation Tests," *Journal of the American Statistical Association*, 89 (428), 1386–1397. [1]

SAMI, A. (1916): *Taqwīm al-Nīl*. Cairo: Maṭb'a al-'Amiriya. [18]

TOUSSOUN, O. (1925): *Memoire sur l'Histoire du Nil*. Cairo: Institut français d'archéologie orientale. [16,20]

WEHR, H. (1980): *A Dictionary of Modern Written Arabic*. Beirut: Librairie du Liban. [18]

WINTER, M. (1992): *Egyptian Society Under Ottoman Rule 1517–1798*. New York: Routledge. [22]

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