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TECHNO-SCIENTIFIC ACTIVITY AND WAR: A YEARLY TIME-SERIES ANALYSIS, 1500–1903 A. D.

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Previous research may have failed to find a general relationship between war and techno-scientific activity due to the failure (a) to treat the various types of war separately and (b) to use yearly rather than generational time series. Hence, the present study examined 404 consecutive years in European civilization from 1500 to 1903. Measures of four distinct kinds of war were defined and a log-transformed measure of techno-scientific activity was derived from a factor analysis of six histories and chronologies. The techno-science measure was regressed on the war measures plus a set of control variables. Techno-scientific activity was found to be a negative function of balance-of-power and defensive wars fought within Europe. In contrast, imperial and civil wars exerted no influence.

Introduction

It has often been asked whether warfare has any impact on creativity, including innovation in science and technology.[1] Although war has been shown to influence the appearance of certain ideologies[2] and the direction of women's fashions,[3] all quantitative inquires have failed to detect any consistent relationship between war and creativity.[4] The only exception is the demonstrated tendency for the number of war casualties to have a negative impact on contemporaneous medical discoveries and inventions.[5] Still, earlier research demonstrating this general null result has had two major methodological defficiencies. In the first place, all previous research treated war as a single unified phenomenon even though it can be quite reasonably argued that there are several distinct types of war, each exhibiting its own unique influence on scientific and technological activity. For example, internecine wars fought at the core of civilization may have a negative effect whereas imperialistic wars fought at the periphery could have a positive effect. Secondly, earlier studies employed rather large timewise units of analysis, usually around 20 or 25 years long. Such large aggregates may inadvertently bury more subtle effects which may operate on a year by year basis. For instance, *Price* has used yearly data to observe clear dips in the general exponential growth curve due to such large conflicts as the last two World Wars.[6] But these same conspicuous troughs in 1914–1919 and 1939–1945 become greatly obscured if we aggregate the years into the two 25-year periods of 1900–24 and 1925–49. Hence, the current research note seeks to measure the impact of different types of warfare on yearly fluctuations in science and technology.

Methodology

Six histories of science and technology were used to operationalize six distinct measures of scientific and technological activity from 1500 to 1903 A.D.[7] The tabulations of scientific and technological activity were then defined for each measure as the number of events cited for each year. Since such activity has exhibited an exponential growth,[8] each of the six raw tabulations was subjected to a logarithmic transformation. This transformation has the two-fold effect of (a) giving the measures a normal rather than a skewed distribution and (b) making the secular trend for the measures linear rather than exponential. A principal components factor analysis was then performed on the log-transformed data to check data reliability. Only one factor had an eigenvalue greater than unity, and this single factor accounted for 76% of the total variance in the six measures. Since the factor loadings were uniformly high (0.74 to 0.96), a linear composite was generated by simply summing all seven log-transformed measures. Let this linear composite be called *techno-scientific activity.*[9]

Wright presents in Tables 31 to 41 of his classic *A Study of War* a chronological listing of all the wars of modern Western civilization.[10] These tables provide the duration of each war along with the number of states participating. Moreover, four major types of war are distinguished: (a) balance-of-power wars "among state members of the modern family of nations", (b) civil wars "within a state member of the modern family of nations", (c) defensive wars "to defend modern civilization against an alien culture" (e.g., the Ottoman wars), and (d) imperial wars "to expand modern civilization at the expense of an alien culture" (e.g., Chinese, Islamic, etc.).[11] Except for imperial wars, each of these war types are further distinguished into those fought mainly inside Europe and those fought mainly outside Europe. Since Western techno-scientific activity prior to the twentieth century was entirely dominated by European scientists, only those balance-of-power, civil, and defensive wars fought within Europe were analyzed along with imperialistic wars involving European powers. Indicators of each of these four types of war were operationalized as the number of states participating in each war for each year of the time series.

Two sets of control variables were defined to refine the methodological procedure. First, *date* had to be introduced in order to further control for the exponential growth curve mentioned earlier. This variable is simply defined as the date of each yearly time unit. The introduction of this control variable means that we are concentrating on whether the occurrence of war affects deviations from the secular trend of exponential growth. This control has the added virtue of removing some potential artifacts due to any transhistorical biases. Second, it was quite apparent upon inspecting the sources that historians of science displayed a marked "response set." That is, in providing dates for many scientific and technological events, certain kinds of dates tended to be favored over others. In particular, years ending 5, 0, 50, and 00 seem to receive a disproportionate number of citations. Consequently, four dummy variables were defined to control for these dating proclivities.[12] Let us call these dummy variables the five year, ten-year, half-century, and century *dating bias intercepts.*

Results and discussion

Table 1 shows the results of regressing techno-scientific activity on the four war indicators and the five control variables.[13] Both standardized (β) and unstandardized (b) regression coefficients are presented along with the standard error of b and the corresponding F-rations for significance tests. In broad terms, the regression equation accounts for 61% of the yearly fluctuations in inventions and discoveries over the 404-year period. But also note the following three specific points:

Table 1
Time-series regression analysis:
Determinants of techno-scientific activity at yearly intervals

Variable	β	b	SE	F
Wars				
Balance of Power	-0.12	-0.078	0.020	15.31**
Civil	0.06	0.140	0.078	3.23
Defensive	-0.15	-0.388	0.088	19.55**
Imperial	0.03	0.067	0.069	0.95
Date	0.61	0.024	0.001	295.29**
Dating bias intercepts				
Century	0.00	-0.089	0.749	0.01
Half-century	0.14	3.768	0.818	21.19**
Ten-year	0.28	2.64	0.291	82.22**
Five-year	0.08	0.627	0.260	5.78*
Intercept (other)		-16.000		

Note: For the equation, $R^2 = 0.61$, $F(9,394) = 68.12$, $p<0.01$.
*$p<0.05$.
**$p<0.01$.

(1) Date has a conspicuously large positive relationship with scientific activity, thus supporting the earlier remark that science and technology have grown exponentially. Indeed, about 67% of the explained variance (or about 41% of the total variance) can be attributed to this general secular trend.

(2) Three dating bias intercepts are also highly significant and positive: The years ending in 5, 0, and 50 are credited with more techno-scientific events than years ending in 1, 2, 3, 4, 6, 7, 8 and 9. One the other hand, since the century bias is nonsignificant, bias towards the beginning of each century seems to be adequately explained by the ten-year dummy. Altogether, about 25% of the explained variance (or 15% of the total variance) in yearly techno-scientific fluctuations can be ascribed to pure dating proclivities on the part of historians. This finding suggests that extreme care must be exercised when interpreting the graphs of timewise fluctuations, for these dating biases can easily be mistaken for cyclical regularities.

(3) Only about 8% of the explained variance (or about 5% of the total variance) can be relegated to the war measures. And only two of the four types of warfare affect yearly fluctuations in the number of inventions and discoveries. On the one hand, balance-of-power and defensive wars have distinct negative effects. Thus, whenever Europe was engaged in internecine struggles or had to resist the onslaught of some alien culture, techno-scientific activity tended to decline. On the other hand, neither European civil wars nor imperialistic enterprises against alien civilizations prove relevant to predicting techno-scientific advance. The conclusion follows that only certain types of war affect the timewise course of science and technology.

Since we were forced by the nature of the data to end the time-series at 1903, the next question obviously becomes whether the same findings hold for twentieth century science. Judging from some of the tables published by *Price*,[14] my guess is that the results would hold for recent times as well. Although there have been no defensive wars fought this century, there have been two major balance-of-power wars fought within Europe. And as mentioned earlier, these two wars, World Wars I and II, did seem to have greatly depressed techno-scientific output.

Notes and references

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2. D. K. SIMONTON, The Socio-political Context of Philosophical Beliefs: A Transhistorical Causal Analysis, *Social Forces,* 54 (1976) 513–23.
3. D. K. SIMONTON, Women's Fashions and War: A Quantitative Comment, *Social Behavior and Personality,* 5 (1977) 285–88.

4. R. NAROLL, E. C. BENJAMIN, F. K. FOHL, M. J. FRIED, R. E. HILDRETH, J. M. SCHAEFER, Creativity: A Cross-Historical Pilot Survey, *Journal of Cross-Cultural Psychology*, 2 (1971) 181–88; D. K. SIMONTON, The Causal Relation between War and Scientific Discovery: An Exploratory Cross-National Analysis, *Journal of Cross-Cultural Psychology*, 7 (1976) 133–44.
5. D. K. SIMONTON, Interdisciplinary and Military Determinants of Scientific Productivity: A Cross-lagged Correlation Analysis, *Journal of Vocational Behavior*, 9 (1976) 53–62.
6. D. DE SOLLA PRICE, Ups and Downs in The Pulse of Science Technology, In J. GASTON *The Sociology of Science*, (Ed.), (San Francisco; Jossey-Bass, 1978), 162–71.
7. The six measures were: Ludwig DARMSTAEDTER, *Handbuch der Naturwissenschaften und der Technik* (Berlin; Springer, 1908); Ludwig DARMSTAEDTER and Rene Du BOIS-REYMOND, *4000 Jahre Pioner-Arbeit in den Exacten Wissenschaften* (Berlin; Stargardt, 1904); Franz FELDHAUS, *Lexicon der Erfindungen und Ertdeckungen auf den Gelieten der Neturwissenschaften und Technik* (Heidelberg; Winter, 1904); Felding GARRISON, *An Introduction to the History of Medicine* (Philadelphia; Saunders, 1929, 4th ed.); Humphrey T. PLEDGE, *Science Since 1500: A Short History of Mathematics, Physics, Chemistry, Biology*, (London; H. M. Stationary Office, 1939); Neville WILLIAMS, *Chronology of the Modern World: 1763 to the Present Time* (New York; McKay, 1968, rev. ed.) and Neville WILLIAMS, *Chronology of the Expanding World: 1492 to 1762* (New York; McKay, 1969). Except for the fact that the WILLIAMS measure was tabulated only back to 1763 using only the 1968 WILLIAMS work, these science measures were generated under the direction of PRICE, Professor of the History of Science and Medicine at Yale University. I continued the WILLIAMS measure back to 1500 using the 1969 WILLIAMS work and also double-checked all measures against the original sources. I am deeply grateful to PRICE for providing me this data. For his use of these same measures see PRICE, op. cit. note 6.
8. D. de SOLLA PRICE, *Little Science, Big Science*, (New York; Columbia University Press, 1963), 1–32.
9. Even though I chose the data transformations having the greatest justification, the principal findings are so robust as to survive all reasonable alternative transformations, including the study of each measure separatelly.
10. Q. WRIGHT, *A Study of War*, (Chicago; University of Chicago Press, 1965, 2nd ed.).
11. WRIGHT, op. cit. note 10, p. 641.
12. See J. JOHNSTON, *Econometric Methods*, (New York; McGraw-Hill, 1972, 2nd. ed.), 186–92.
13. Since the residuals were highly autocorrelated, a generalized least squares transformation was employed. The autoregression parameter was estimated at 0.48 using the Durbin–Watson Statistic. See J. JOHNSTON, op. cit. note 12.
14. D. de SOLLA PRICE, op. cit. note 6.