

Civil War and Economic Growth

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This project evolves from a co-authored article, *Civil War and Economic Growth*, presented at the American Political Science Association Conference in September of 2005 and a Structures and Evolutions of Institutions Conference at Stanford in November of 2005. The objective of this article was to use data to understand how the relationships between war and economic growth differ across and within regions. However, this article did not employ computerized statistical pattern recognition techniques to find patterns in the civil war data and relied instead on analysis of summary statistics and graphs of individual country's growth patterns during their civil wars.

The significance of the topic in question justified the analysis. My advisor and co-author, James Fearon, who may be the nations' leading academic expert on civil wars, testified on September 15, 2006 to the U.S. House of Representatives, Committee on Government Reform, Subcommittee on National Security, Emergency Threats, and International Relations on "Iraq: Democracy or Civil War." He spoke on how Iraq fits into the general pattern of civil wars and what this implies for United States policy on Iraq looking forward. A deep understanding of patterns of civil war and economic growth informs government decision-making and policy concerning civil wars such as Iraq.

My project improves on the previous analysis by using a systematic unsupervised learning technique to find patterns in the civil war data and cluster civil wars in various countries into different groups. Thus, my project adds additional scientific rigor to the problem space of elucidating general civil war and economic growth patterns. My project also aids in selecting cases where civil wars were uncharacteristically less destructive than usual for potential case-study analysis on how international interventions may have played a role in placing civil wars into one grouping category versus another. Given that civil wars are generally horrendous events involving massive suffering, my analysis provides scientific knowledge on an extremely important topic.

Methodology Summary

This clustering analysis analyzes 118 individual civil wars with data points in R^3 specified as the: (average growth rate of the country in question in the five year period preceding the war, average growth rate of the country in question during the war, and average growth rate of the country in question in the five year period following the war). The economic growth data comes from Fearon's data estimates computed using Penn World Tables 5.6 income series data which has been extended forward and backward using World Bank estimated growth rates and imputed values using estimates of per capita energy consumption when possible.

The objective of this analysis is to determine whether unsupervised learning techniques will determine natural clusters grouping individual civil wars according to the divergent economic growth paths experienced by individual countries during these civil wars. K-

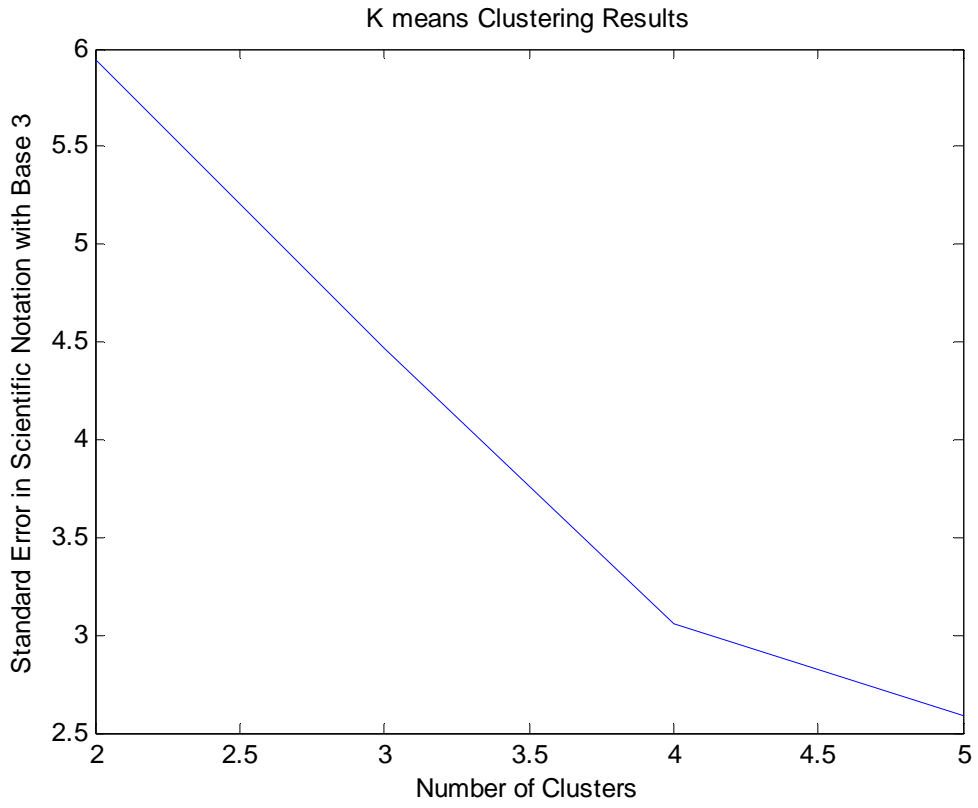
means clustering, a widely implemented unsupervised learning technique, assigns data values to a fixed (k) number of clusters with the goal of minimizing a measure of dispersion within the clusters and maximizing the difference between the means of the different clusters. This analysis utilizes k -means clustering to understand the data relationships between economic growth and civil war.

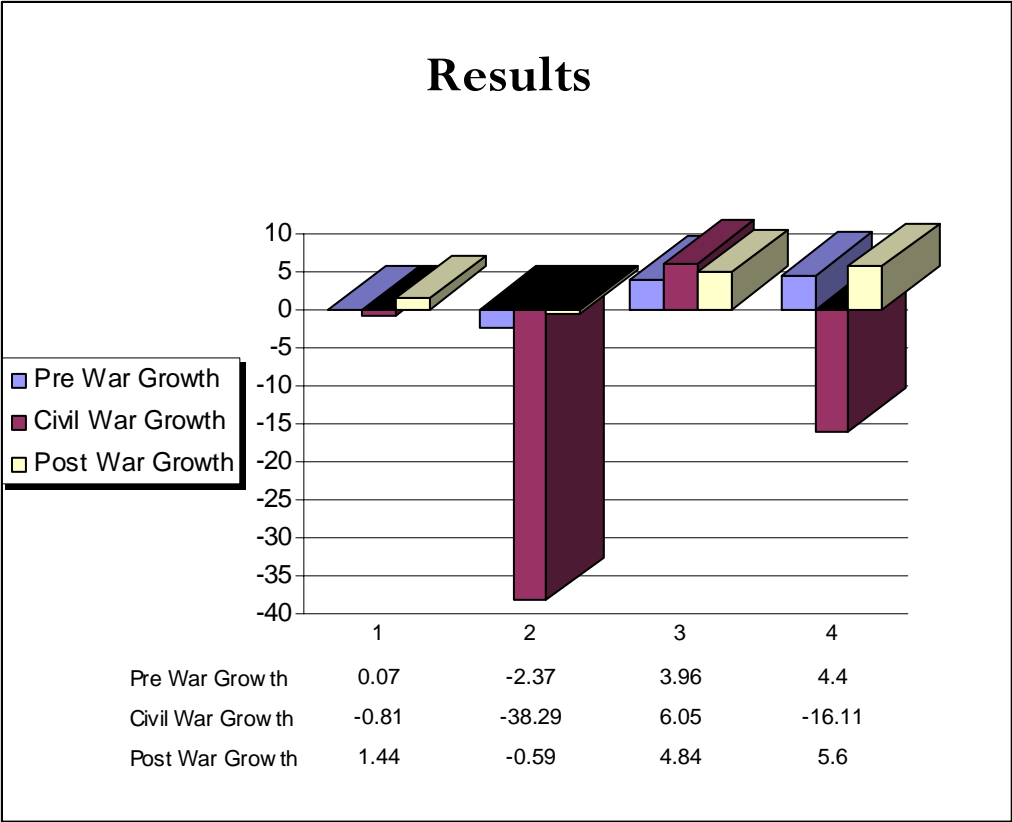
Since the appropriate number of data clusters is considered a variable to be learned during this analysis, I hypothesized that if natural clusters do exist for the data, the number of clusters is between two and five. I implemented k -means clustering for $k = 2, 3, 4, 5$, calculated the standard errors for each cluster size and looked for a distinct knee, peak, or dip in a plot of the standard error versus cluster size to determine the appropriate number of data clusters. I initialized the initial data values for the clustering analysis by selecting a random sample of 33% of the data, taking a fixed data point as the first initial centroid within this random sample, and then using a greedy algorithm to select $(k-1)$ other centroids in this random sample farthest from the other selected centroids. The k -means clustering algorithm repeated until the algorithm converged on a particular set of centroid points, using the Euclidean distance metric to calculate distances between points. The algorithm was run for each cluster size about five times and the centroids with the smallest standard error for each of the multiple runs of the algorithm were selected to represent the algorithm's predictions for the specified value of k . My additional implementation procedures reduce the sensitivity of k -means clustering to outlier points selected as initial centroids by sampling from a random sample where outliers are less likely to be found, to very similar points selected as initial centroids by using the greedy algorithm to select initial centroids with distances as far as possible from each other, and to selection of local instead of global minima by conducting multiple runs of k -means clustering for each value of k .

Possible extensions to this work include implementing an agglomerative hierarchical clustering procedure or application of expectation-maximization to data clustering. Data points could also be extended to include data values specifying region or type of civil war (ideological, struggle for the center, ethnic separatist, etc). The analysis could also be conducted with more hypothesized clusters in order to find natural sub-clusters of civil war growth patterns and outlier types of civil wars.

Results

The computerized clustering analysis classified the data in similar but not identical ways to the results found in the original paper. My k -means clustering algorithm selected four natural data clusters as the appropriate number of clusters and grouped two of the original paper's suggested clusters into one individual cluster while finding two unpredicted civil war clusters. However, when the algorithm was run with $k = 5$, the algorithm did separate the data into all three of the original paper's hypothesized clusters in addition to the two newly found data clusters. The results are presented below in chart, graph, and tabular form.





The data suggests that there are four patterns in the way that income involves in countries that are experiencing a civil war:

1. *Stalemate.* This cluster characterizes the majority of civil wars. The use of the mean value to describe this cluster conceals much of the within-cluster variation since individual civil wars in this cluster vary greatly in terms of during war and post-war economic growth. However, the average civil war for this cluster occurs in a country experiencing stagnant levels of pre-war economic growth, slightly negative growth during a civil war, and slightly positive levels of post-war economic growth.
2. *Catastrophe.* Some countries experience negative growth prior to the civil war, experience a calamitous civil war, and then experience slightly negative growth following the civil war.
3. *Boon.* Some countries enter into a civil war with positive growth levels, experience a small upward turn in growth for the duration of the civil war, and then exit war with positive growth levels.
4. *Interruption Catastrophe.* Some countries experienced rapid levels of growth prior to the war, experience a ruinous civil war, and then return to rapid levels of post-war growth.

	1	2	3	4
CUBA	SOMALIA	YUGOSLAVIA	COSTARICA	DOMINICANREP.
HAITI	SOMALIA	MOLDOVA	ARGENTINA	NICARAGUA
GUATEMALA	DJIBOUTI	GEORGIA	GREECE	CYPRUS
ELSALVADOR	ETHIOPIA	AZERBAIJAN	NIGERIA	GUINEABISSAU
NICARAGUA	ETHIOPIA	YEMEN	DEM.REP.CONGO	RWANDA
COLOMBIA	ANGOLA		UGANDA	IRAN
COLOMBIA	ANGOLA		ALGERIA	JORDAN
PERU	MOZAMBIQUE		IRAQ	AFGHANISTAN
BOLIVIA	ZIMBABWE		YEMENARABREP.	TAJKISTAN
PARAGUAY	ZIMBABWE		YEMENPEOP.REP.	CAMBODIA
ARGENTINA	SOUTHAFRICA		AFGHANISTAN	
UK	MOROCCO		CHINA	
CROATIA	ALGERIA		CHINA	
BOSNIA	SUDAN		CHINA	
RUSSIA	SUDAN		CHINA	
RUSSIA	IRAN		KOREA,S.	
RUSSIA	TURKEY		INDIA	
RUSSIA	TURKEY		INDIA	
RUSSIA	IRAQ		BANGLADESH	
RUSSIA	LEBANON		BURMA	
MALI	LEBANON		SRILANKA	
SENEGAL	ISRAEL		THAILAND	
IVORYCOAST	YEMENARABREP.		CAMBODIA	
LIBERIA	INDIA		LAOS	
LIBERIA	PAKISTAN		VIETNAM,S.	
SIERRALEONE	PAKISTAN		PHILIPPINES	
CENTRALAFREP	PAKISTAN		INDONESIA	
CHAD	SRILANKA		INDONESIA	
CHAD	SRILANKA		INDONESIA	
CONGO	NEPAL		INDONESIA	
DEM.REP.CONGO	PHILIPPINES		INDONESIA	
DEM.REP.CONGO	PHILIPPINES		INDONESIA	
DEM.REP.CONGO	INDONESIA		INDONESIA	
UGANDA	PAPUAN.G.			
BURUNDI				
BURUNDI				
BURUNDI				
RWANDA				