Physics peeks into the ballot box

Santo Fortunato and Claudio Castellano

In different countries and over time, electoral features such as statistics of candidates' performance and turnout rates show universal behaviors. Are voters as predictable as atoms?

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The idea that humans might, on occasion, obey rules that yield predictable collective patterns dates back many years and has several illustrious fathers, including political philosopher John Stuart Mill and social scientists Auguste Comte and Adolphe Quetelet. Individuals may choose freely, but, the theory goes, when a great many individuals interact, their choices are influenced by the presence of the others, and regular collective behaviors may emerge. In the past two decades, this idea of humans as "social atoms" has inspired a flourishing field of investigation, made possible by the availability of large data sets on social phenomena and powerful computers to process them.

Statistical physics, developed to deal with collections of many particles, has provided a conceptual framework for understanding such systems, even though their elementary constituents are human beings. Clearly, the investigation of social atoms does not come without obstacles. The complexity of individuals and the intricacy of our interactions rule out the possibility of formulating principles and laws as rigorous as those applying to inanimate matter. Nevertheless, regular patterns in collective social phenomena abound, and they call for explanations, ideally expressible via simple models.

Papers by physicists studying elections started to appear in the late 1990s. By now, many different types of elections in several countries have been studied and modeled, and various issues have been addressed. In this Quick Study we discuss recent results concerning the competition between candidates in proportional elections and the statistics of turnout rates.

A universal performance pattern

Many candidates compete in elections for one or a few positions. Their success can range from landslide victory to complete failure. How does that huge variability come about?

In 1999 Raimundo Costa Filho and colleagues studied voter statistics for the general elections held in Brazil in October 1998. In the Brazilian proportional elections, in contrast to what occurs in the US, each electoral district has from a few to a few dozen representatives, and the number of seats won by a party is proportional to the number of votes received by all its candidates. Costa Filho and colleagues considered the votes received by all candidates, winners and losers, regardless of their electoral district or political affiliation. Away from the high and low extremes of candidate success, the number of candidates receiving v votes was inversely proportional to v. The analysis of the Brazilian election, though, neglected a factor that is fundamental in the political life of most countries: the influence of parties. A candidate's electoral success largely depends on the popularity of the political agenda of the candidate's party. The results of Brazil's election—and of those in other countries with similar voting schemes—reflect the complex, intertwined effects of competition among parties and competition among different candidates in the same party. Given the peculiarities of each country's specific political landscape, one can hardly expect to see similar results persist across national boundaries.

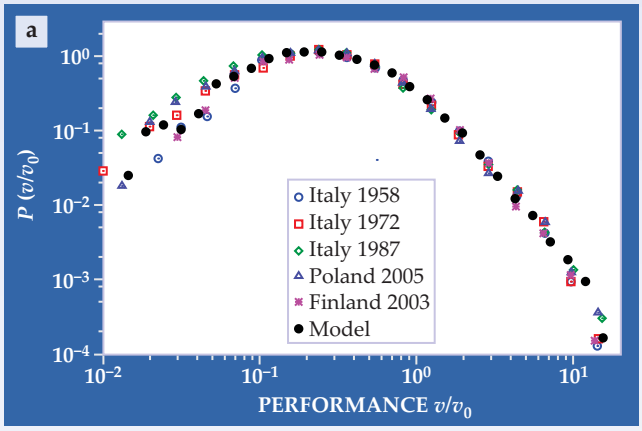
For that reason, we have proposed a different analysis for proportional elections. To disentangle the roles of party and candidate, we use as our key variable not the absolute candidate performance, expressed by the number of votes obtained, but rather the performance relative to the average for the candidates in the same party. That is, for each party list, we divide the number v of votes collected by each candidate by the average v_0 for all candidates on the list. As panel a of the figure shows, the fraction of candidates with a given relative performance is remarkably consistent both across countries and for elections conducted in the same country at different times. That universality, evident in elections spanning almost half a century, suggests an underlying basic feature of social dynamics, independent of the cultural, historical, economic, and technological context in which the elections took place.

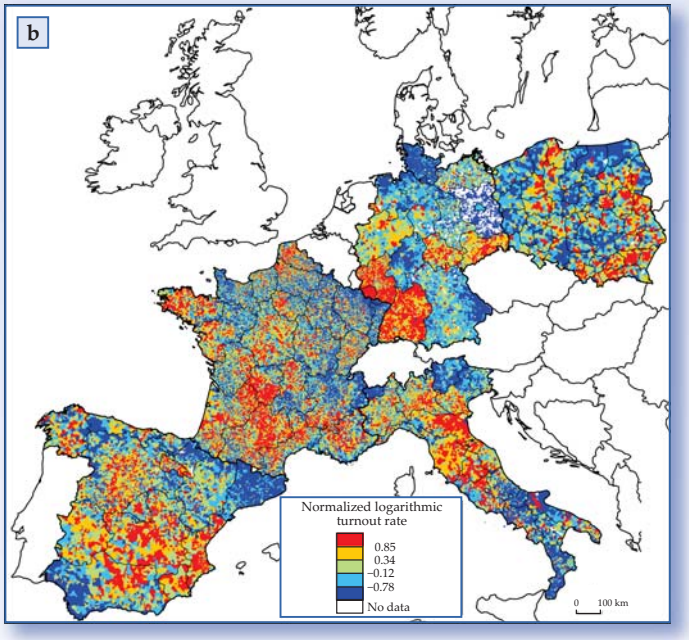
We model the election campaign as a word-of-mouth process, starting from the candidates and branching out to the community of voters through their social relationships. Each candidate convinces his or her immediate contacts with a certain probability r. Convinced voters, in turn, become activists and campaign in favor of the candidate they have chosen. In our model, voters, once convinced, do not change their minds. The campaigning stops once every voter has picked a candidate.

We take the number of contacts k of each individual to be a random variable distributed as $P(k) \propto k^{-\alpha}$; that broad distribution accounts for the large variability in personal inclinations and social stance. The model yields a distribution of candidates' performance, shown in panel a of the figure, that matches well the empirical profiles displayed there. Moreover, the result is robust with respect to variations in the parameters r and α. Perhaps not surprisingly, the most successful candidates are those who manage to acquire the largest number of voters in the initial stages of the word-of-mouth process.

Turnout rates

Imitation and adaptation are the main features of the social atom, and they frequently seem to overrule the individual freedom to make decisions. Knowing how people's deci-





Voters as social atoms. (a) The probability density P that a candidate will achieve a given degree of electoral success. The measure of performance is the number v of votes received by a candidate relative to the average v_0 received by the candidates on the party list. The resulting pattern is the same in different countries and years, which suggests the existence of a simple underlying mechanism behind the candidates' competition. A model based on preferences spreading by word of mouth does a good job at reproducing the universal curves. (Adapted from S. Fortunato, C. Castellano, *Phys. Rev. Lett.* **99**, 138701, 2007.) **(b)** Turnout for the 2004 European Parliament elections in France, Germany, Italy, Poland, and Spain. Red indicates municipalities with high turnout rates; blue indicates low turnout. The heterogeneous pattern displays long-range correlations between different geographical areas. That is, locations with high turnout are likely to be in the vicinity of other locations with high turnout (and likewise for low-turnout regions). The logarithmic turnout rate is defined in the text. (Adapted from C. Borghesi, J.-C. Raynal, J.-P. Bouchaud, *Plos ONE* **7**, e36289, 2012.)

sions are affected by those of their contacts is fundamental in marketing, policymaking, understanding large-scale panics, and more. Christian Borghesi and colleagues used space-resolved election data to address the role of contacts in the most important decision faced by a voter: Should I vote or not? Turnout statistics are available at the municipal level for many countries and years, so it's possible to check whether spatial correlations exist between turnout rates in different towns.

Borghesi and company considered a variable called the logarithmic turnout rate (LTR): the logarithm of the ratio of the number of registered voters who participated in an election to the number of those who did not. (In their analyses, the researchers had to suitably normalize the LTR; we won't worry about those details here.) They found that for municipalities having approximately the same population, the function specifying the likelihood for a given LTR is a skewed bell-shaped curve that is essentially the same in different countries and elections. The main result of their analysis, however, is that participation in elections is not independent in different places. As shown in panel b of the figure, turnout rates are correlated over long distances. The researchers considered elections held in several European countries and found that the usual mathematical function that quantifies those correlations is roughly proportional to $\ln(r/L)$, where r is the separation distance and L, a characteristic length scale, is on the order of the size of the country.

Furthermore, the researchers reproduced the phenomenology they uncovered with a decision model in which voters participate in an election only if their propensity to vote overcomes a threshold. That propensity results from three contributions: an idiosyncratic disposition specific to each individual and varying in time, a city-dependent term with spatial correlations at small scales, and a "cultural field" that varies slowly in space and time and that is responsible for the long-range spatial correlations of turnout rates.

Two mechanisms affect the evolution of the cultural field. First, people travel to neighboring cities and interact with acquaintances, carrying their own local cultural specificity and exchanging ideas and beliefs. In so doing, they narrow cultural differences between nearby areas. As a result, the cultural field undergoes a diffusion process over geographically separated locations. Second, the mood of the community in a given area may be influenced by events such as the closing down of a factory or the construction of new infrastructure. Such events can be modeled by including a random-noise term in the equation that governs the diffusion of the cultural field. The solution to that equation, once a transient dies off, displays the same spatial correlation profile discovered in the election data. The fit of the model curve with the empirical distributions reveals that the equilibration time for the dynamics of the cultural field is on the order of a century, a span consistent with the observed historical persistence of voting habits in different areas of a country.

The findings we have discussed here confirm that elections are phenomena that can be understood quantitatively with the concepts and tools of physics. This new line of research has just begun to dig into the wealth of information contained in electoral data. It promises to shed light on the decision processes of voters and can have a significant impact on the policies of governments and parties, the design of electoral systems, and the organization of political campaigns.

Additional resources

▶ M. Buchanan, *The Social Atom: Why the Rich Get Richer, Cheaters Get Caught, and Your Neighbor Usually Looks Like You*, Bloomsbury, New York (2007).

▶ C. Castellano, S. Fortunato, V. Loreto, "Statistical physics of social dynamics," *Rev. Mod. Phys.* **81**, 591 (2009).

▶ R. N. Costa Filho et al., "Scaling behavior in a proportional voting process," *Phys. Rev. E* **60**, 1067 (1999).