



Contents lists available at ScienceDirect

Physica A

journal homepage: www.elsevier.com/locate/physa

Gender difference in candidature processes for Brazilian elections

M. Cardoso ^{a,*}, R.S. Mendes ^{b,c}, J.T.G. Souza ^a, H.V. Ribeiro ^b

^a Universidade Tecnológica Federal do Paraná, Campus Campo Mourão, 87301-006, Campo Mourão, Paraná, Brazil

^b Departamento de Física, Universidade Estadual de Maringá, Av. Colombo 5790, 87020-900, Maringá, PR, Brazil

^c National Institute of Science and Technology for Complex Systems, CNPq, Rua Xavier Sigaud 150, 22290-180, Rio de Janeiro, RJ, Brazil



ARTICLE INFO

Article history:

Received 19 March 2019

Received in revised form 30 July 2019

Available online 3 September 2019

ABSTRACT

Researchers of several areas have reported that there are still significant gender differences in their performances within different social systems, as in science and on-line communities, for example. This paper focuses on the gender difference in politic candidature processes, investigating the effect of the electorate size upon the candidate numbers, by considering the electorate of each Brazilian city and the respective number of candidates for Mayor and City Council Member (for women and men separately). We detected a sharp gap between the number of male candidates and number of female candidates, with the disadvantage occurring to greater intent in Mayoral elections. We also found non-linear mean correspondences, allometries. The allometric exponents display values very close to the City Council Member candidatures for women and men. However, they have notable smaller values for women than for men in Mayoral candidature. This shows a political hierarchy: the most influential position is related to the greater female underrepresentation.

© 2019 Published by Elsevier B.V.

1. Introduction

Despite disparities in gender seem to be decreasing across a variety of societal fields, the underrepresentation of women still persists in several of activities kinds. For example, researchers' scientific production and especially in politics. In particular, the gender discrepancy is prominent in the Brazilian politics. The insertion of women in Brazilian politics [1] had the first woman in position as a Voter – 1928, as a Mayor – 1929, as a Federal Legislative – 1933, as a State Legislative – 1935, as a Minister State – 1982, as a Govern State – 1986 and as a President – 2010. The women have been getting permission to vote since 1932. It is possible to note a remarkable delay in the insertion of women in Brazilian politics. In 2009, in attempt to narrow this gap was amended the law that establishes norms for the Brazilian elections [2] set the requirement minimum percentage of 30% for women candidates per party. This delay in the female's participation in Brazilian politics directed our interest in conducting an investigation in this direction. In this paper we developed a study about politics candidature of women and men in City Council Member and Mayor Brazilian elections.

Numerous researches have been investigating gender differences and their motivations within many social systems. For instance, in the scientific research field, tools of complex systems have been used to comprehend the dynamics of genders in science. A clear contrast in publication rate between men and women is observed in [3,4] in the areas of

* Corresponding author.

E-mail address: magdadm@utfpr.edu.br (M. Cardoso).

Table 1

Table of the annual total percentages for female voters, male voters, female candidates for city council member, male candidates for city council member, female candidates for Mayor, male candidates for Mayor. Ones labeled by FV, MV, FC-CCM, MC-CCM, FC-M, MC-M, respectively.

Year	% FV	% MV	% FC-CCM	% MC-CCM	% FC-M	% MC-M
2000	50.9	49.4	19.2	80.8	7.6	92.4
2004	51.3	48.7	22.0	78.0	9.5	90.5
2008	51.8	48.2	22.0	78.0	11.1	88.9
2012	51.9	48.1	32.7	67.3	13.2	86.8
2016	52.3	47.7	33.1	66.9	13.0	87.0

the science, technology, engineering, and mathematics. In the same context, [5] reported that the smaller number of distinct co-authors on the female faculty careers can be explained by their shorter career lengths and lower number of publications. Looking still over on academic publications, specifically for publications in mathematics [6] informed female disadvantage significant when she pursues an academic career in mathematics. An explanation for this disadvantage can be seen in [7] which suggested that the sex difference in mathematics anxiety contributes to this disparity. The gender gap in publications has also been found across the natural sciences, social sciences, and humanities [8]. Also in the publication context, [9] presented evidence that women have fewer opportunities to take part in peer review. In addition to publications, gender difference in patenting in the academic life sciences was also analyzed in [10] which showed that there is a gender gap but has improved over time. In the scenery of the participation in on-line communities [11,12] revealed that women are likewise in disadvantage in relation to men.

The electoral processes are also of interest to many researchers and very significant for the general society. In this direction, by using empirical data, several works have been made. The papers [13,14] proposed power law distribution to model voting system for Brazilian election. However, in an attempt to enhance the fit for these data, [15] suggested a generalized Zipf's law. By using an opinion dynamics model, [16–18] reproduced the power law behavior found in the works cited above. Taking into account the size party, [19–21] analyzed the distribution of the number of votes received by candidates. A model to study the effect tactical voting on plurality elections introduced by [22] explained the polarization of votes between two candidates. The cost of electoral campaigns was analyzed in [23] showing that top candidates spend more money per vote than the less successful. The paper [24] investigated plurality voting system on Mayor Brazilian elections. In addition to the distribution of votes, [25,26] investigated the spatial correlation of the turnout rates with the distance between towns. In [27] an entropy approach was associated with proportions of abstentionists, blank votes and null votes. [28] investigated the relations between the numbers of members of political parties. Power law dependencies between correlation measures and party size were obtained in [29]. The papers [30,31] presented statistical approaches to identify fraud in elections. A study about parliamentary presence was developed in [32].

In [33,34] allometry concept was used to investigate candidature in City Council Member and Mayor elections and party affiliation, which allowed to verify a clear hierarchy for the exponents, where the most influential politics position corresponds to the smallest value. In a broad context, the use of allometries proved to be a powerful tool to identify hierarchies. Allometries have been employed in several other contexts such as in the study of urban indicators [35–37]. This work aims to investigate performance of genders in politics, for this we employed the allometry concept for data of candidatures in City Council Member and Mayor elections.

2. Data presentation and analysis

Our database consist of the numbers of male candidates and female candidates, numbers of male voters and female voters, per each Brazilian city for Mayoral and City Council Member elections in the years 2000, 2004, 2008, 2012 and 2016. We chose these years because general elections in Brazil are held every four years, when each city votes for their representatives in the executive (Mayor) and legislative (City Council Member). Besides, we focus on Mayoral and City Council Member elections because they are municipal elections and provide us a large database. These data are available by Brazilian Electoral Supreme Court [1]. For the executive only one Mayor wins and for the legislative the number of the winners is related to size of the local populations. From 2000 to 2016 in Brazil, the number of cities approximately remained constant (5561–5570), the total population varied of 169, 799, 170 to 206, 081, 432 and the electorate size from 109, 826, 263 to 146, 470, 911. The electorate size has increased from 65% to 71% of the total Brazilian population between 2000 and 2016. The annual total percentages of the voters, candidates for City Council Member, candidates for Mayor, for women and men as displayed in Table 1.

2.1. Elections for City Council Member and gender

In order to account for the effect of electorate size upon the candidature processes of women and men for City Council Member, we start examining whether a gender pattern appears when we analyze the number of candidates C versus number of voters V for each Brazilian city investigated. We showed the scatter plot of the logarithm these variables in Fig. 1. Observe that besides of notorious differences the gender data goes in the direction of overlapping over the years.

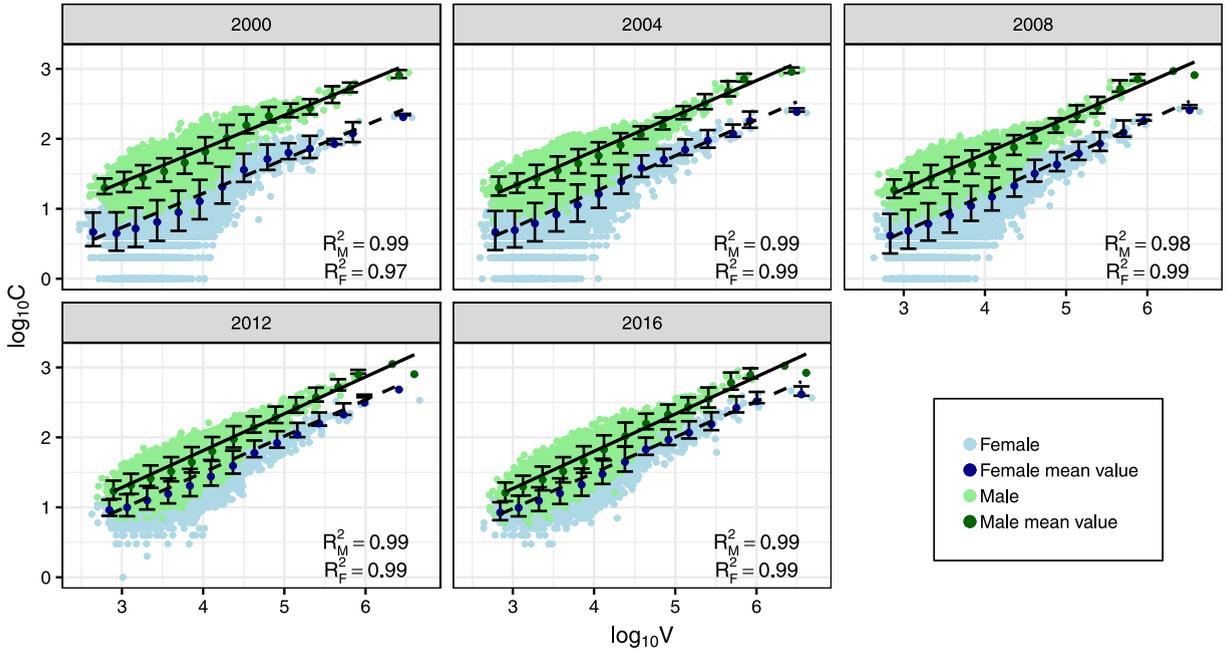


Fig. 1. Scatter plot of the $\log_{10} V$ versus $\log_{10} C$ for the 2000, 2004, 2008, 2012 and 2016 Brazilian City Council Member elections, where V and C represents the voters numbers and the candidate numbers in each city, respectively. The light green dots represent the men data and light blue dots the women data. Notably, the gender data present a tendency to collapse over the years. The dark green dots represent the mean values of the men scatter plot and dark blue dots represent the mean value of the woman scatter plots, which are the mean values of the variables $\log_{10} V$ and $\log_{10} C$ in windows ω equally spaced in $\log_{10} V$, presented with their respective linear fits, the black straight lines for men and the black dashed lines for women. The error bars are standard deviations from the mean value in each ω windows. R_M^2 and R_F^2 are the determination coefficients for the linear fits from the mean values for men and women candidates, respectively.

However, this partial overlap of data should be viewed with caution, since the scale of the graphs is logarithmic. Despite the fluctuations, it is also possible to perceive an allometric tendency, that is an increasing of C with V following a power law:

$$C \sim V^\alpha. \tag{1}$$

A way to rightly interpret these results, overcoming the fluctuations, is to construct logarithmically spaced equally windows in the variable V , ω , and to calculate the mean values of $\log_{10} V$ and $\log_{10} C$ for the inside points. By using this procedure, in contrast to directly employ all date, we showed the mean values and their linear fits in Fig. 1. The linear fit of the mean values confirms the power law tendencies suggested from the scatter plots. It allows us to write

$$\langle \log_{10} C \rangle = A + \alpha \langle \log_{10} V \rangle, \tag{2}$$

with the brackets representing the averages and A and α parameters to be adjusted. These parameters are shown in Fig. 2. The proximity of the intercepts, A , shown that the mean number of women candidates tend to closer of the mean number of men candidates. We also examined the fluctuations of the data relative to the mean values at each window ω . We found that the variances σ_w^2 remain approximately constant, mainly for male candidates as illustrated in Fig. 3. This fact suggests the model

$$C = a \zeta V^\alpha, \tag{3}$$

where ζ is a stochastic noise, a and α parameters according with (2). Indeed, the model (3) encompasses the mean power law and the fluctuations when the variance is constant.

Note that equal allometric exponents α imply the mean relations $C_M = a_M V^\alpha$ for men and $C_F = a_F V^\alpha$ for women, where V is the number of male and female voters added (in contrast to the previous analysis employing V as the number of voters of the gender considered). In this case, one has $C_F/C_M = a_F/a_M$, that is, C_F/C_M does not depend on V . Fig. 4 shows $\langle C_F/C_M \rangle$ versus $\langle \log_{10} V \rangle$, for all City Council Member elections in our database. Note that an approximate agreement with C_F/C_M not depending on V is verified. This agreement occurs because the male or female voter numbers are close to $V/2$ for each Brazilian city, there are fluctuations in the data (Fig. 1), and there are small differences between the allometric exponents for male and female cases (Fig. 2). It should also be noted that Fig. 4 shows a significant increase in the women candidate numbers after the enactment of a 2009 Brazilian law that sets a minimum of 30% of the numbers of women candidates [2].

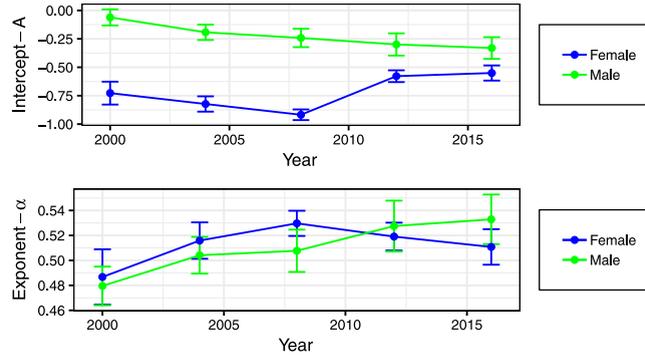


Fig. 2. The evolution of the intercepts A and the exponents α of the power laws presented in Fig. 1 (for all City Council Member election in database). The dark green dots represent the men data and the dark blue dots refer to the women data. The error bars are the standard errors for the linear fits.

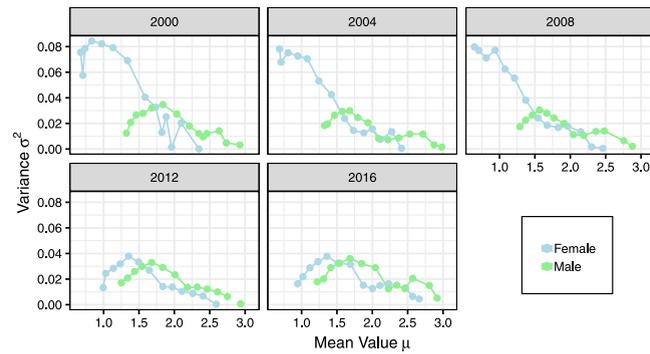


Fig. 3. The variances σ_w^2 versus the mean values $\mu = \langle \log_{10} C \rangle$ in each ω window equally spaced in $\log_{10} V$ and for all City Council Member election in database.

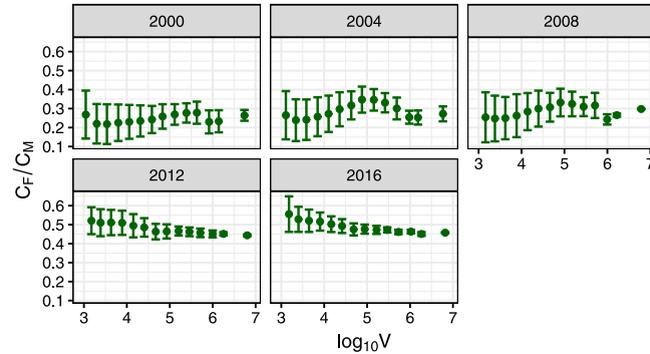


Fig. 4. The mean values of the ratio between the female candidate number C_F and male candidate number C_M versus $\langle \log_{10} V \rangle$, in ω windows equally spaced in $\log_{10} V$ for City Council Member elections, where V represents the total number of voters. The error bars are the standard deviations from the mean value of the ratios in the ω windows.

2.2. Elections for Mayor and gender

To investigate the candidature process for Mayor elections, we employed the same procedure used previously for the City Council Member elections. We also find mean power law behaviors as can be seen in Fig. 5. However, in contrast to City Council Member elections, the data present significant differences in the exponents along the years analyzed here. In addition, we verified that the mean number of women candidates for Mayor is much less than mean value for men candidates. As consequence the discrepancy is enhanced in big cities. Note that the above results are essentially tendencies, because they report mean behaviors of the data. Thus, for instance, if we select particular cities at random we can identify some deviations from the tendencies reported above. As a further concern, we mention that the mean behaviors present in Fig. 5 are less precise than one displayed in Fig. 1.

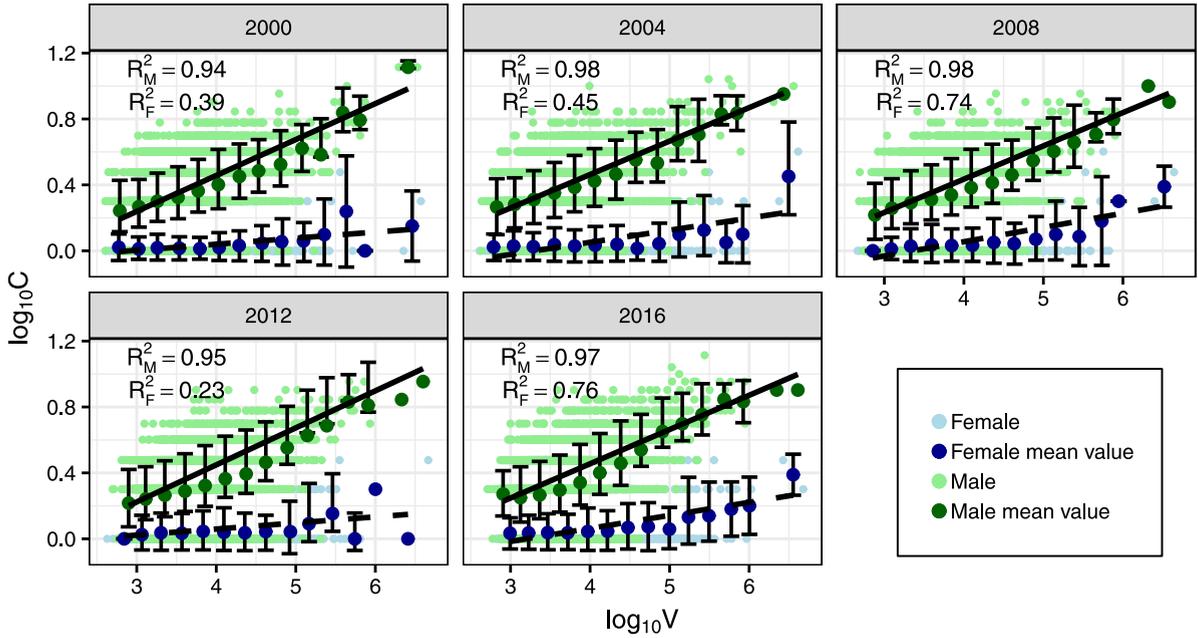


Fig. 5. Scatter plot of the variables $\log_{10} V$ versus $\log_{10} C$ for the 2000, 2004, 2008, 2012 and 2016 Brazilian Mayor elections, where V and C represents the voters numbers and the candidate numbers, respectively, in each city. The light green dots represent the men data and light blue dots the women data. The dark green (for men) and dark blue (for women) dots represent the mean values of the variables $\log_{10} V$ and $\log_{10} C$ in windows ω equally spaced in $\log_{10} V$, the black straight lines (with determination coefficients R_M^2) and the black dashed lines (with determination coefficients R_F^2) are their respective linear fits. The error bars are standard deviations from the mean value in each ω window.

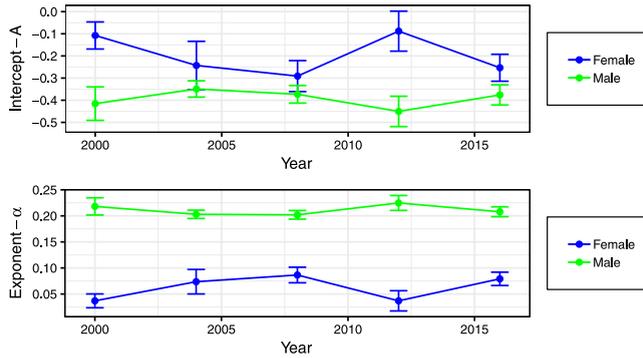


Fig. 6. The evolution of the intercepts A and the exponents α of the mean tendencies of the power laws for Brazilian city Mayor elections, displayed in Fig. 5. Dark green symbols refer to men and the dark blue symbols refer to women. The error bars are the standard errors for these linear fits.

Also about the mean behaviors, Fig. 6 resumes the dynamics of the men and women in Mayor elections. The exponents, in particular, are nearly constant from 2000 to 2016. In turn, the intercepts are also approximately constant for women. And, for men, the intercepts present oscillations. In addition, we investigate data fluctuations around the mean values in each ω window. In this direction, Fig. 7 displays the corresponding variances, showing that they are approximately constant. This result indicates that the model (3), for City Council Member elections, can be also employed for Mayor elections.

3. Discussions and conclusions

In our study the use of the allometry concept enabled us to detect a substantial gap between genders in candidature processes for City Council Member and Mayor Brazilian elections. We provided a robust result, a general rule based on the average behavior (allometries), which allows us to relate electorate size and candidate numbers by gender. The success of this allometric approach is in consonance with several other studies of social systems, for example, in the investigation of scaling in cities [38,39]. The procedures and results of our analysis are considerably summarized in Figs. 1 and 5.

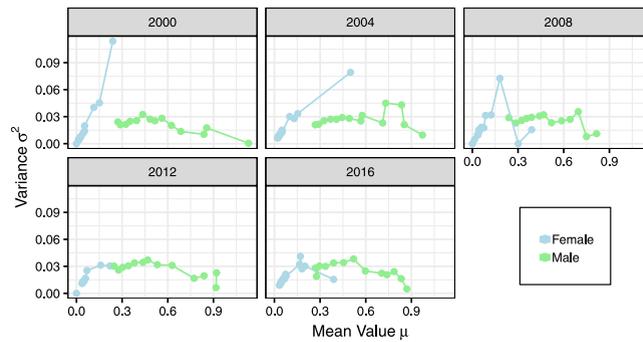


Fig. 7. For Mayor elections, variances σ_w^2 versus the mean values $\mu = (\log_{10} C)$ in each ω windows equally spaced in $\log_{10} V$.

For the City Council Member elections case, the exponents for male and female are very close along our database. This indicates that the mean relative difficulty to be a Council City Member Candidate, measured as the ratio between the number of male candidates and the number of female candidates, does not heavily depend of the number of electors of each city. Furthermore, there is a tendency of the gender data to be closer over the years as can be viewed in Fig. 1 and Table 1. This reveals that the female behavior is increasingly similar the male one. In particular, it is remarkable that since 2012 this approximation has been occurring more rapidly, due the amended of the law that establishes norms for the Brazilian elections [2] that in 2009 established the minimum requirement percentage of 30% of women candidates per party. This sharp approximation from 2012 is quantitatively manifested in the values of the allometric intercepts and exponents shown in Fig. 2. Consistently with this law, note that practically there are no more cities with few female candidates since 2012, Fig. 1. These aspects related to the 2009 law are also put in evidence by the analysis of the ratio between the number of women and men candidates, Fig. 4.

In turn, in the Mayor elections case, the allometric exponents became significantly higher for men than for women. This result shows, in contrast to the Council City Member case, the mean relative difficulty to be Mayoral candidate for women increases a lot, with the electorate size, in comparison with men. Despite this discrepancy, it is noteworthy that the number of female candidates, compared to male, has been increasing for both types of elections along the years, Table 1.

Concerning the fluctuations around of the average allometric behavior, it was verified, when the data are divided into windows equally spaced in logarithm, that the standard deviations are approximately constant along our database. Thus, if some data deviate a lot from the average behavior it may point to an exceptional aspect, such as an extraordinary disadvantage for women. In this situation, a more careful analysis could be carried in order to try to identify if there are specific reasons for this result. Before the 2009 law, there was a clear contrast between the variances for male and female candidates for City Council Member elections. This disparity essentially disappeared in subsequent elections. On the other hand, for 2000, 2004 and 2008 Mayor elections, the variance discrepancy between men and women is essentially removed disregarding the few outlier cases. For other actions in general (as laws), an analysis of variance as a function of mean values may also help to indicate causalities underlying social phenomena [40].

The above results seem to indicate the presence of allometry in female underrepresentation in elections in general, although the verification of this hypothesis for other countries requires more investigative efforts. In addition to this disadvantage for women, our results point out in the direction to another political hierarchy: the most influential position is related to greater female underrepresentation.

Acknowledgments

We thank CNPq and CAPES (Brazilian agencies) for financial support.

References

- [1] <http://www.tse.gov.br>.
- [2] Brazil Law No. 12, 034, September 29th, 2009.
- [3] M.R.E. Symonds, N.J. Gemmill, T.L. Braisher, K.L. Gorringer, M.A. Elgar, Gender differences in publication output: Towards an unbiased metric of research performance, *PLoS One* 1 (2006) e127.
- [4] J. Duch, X.H.T. Zeng, M. S.Pardo, F. Radicchi, S. Otis, T.K. Woodruff, L.A.N. Amaral, The possible role of resource requirements and academic career-choice risk on gender differences in publication rate and impact, *PLoS One* 7 (2012) e51332.
- [5] X.H.T. Zeng, J. Duch, M.S. Pardo, F. Radicchi, H.V. Ribeiro, T.K. Woodruff, L.A.N. Amaral, Differences in collaboration patterns across discipline, career stage, and gender, *PLoS One* 14 (2016) e1002573.
- [6] H.M. Brandt, L. Santamaría, M. Tullney, The effect of gender in the publication patterns in mathematics, *PLoS One* 11 (2016) e0165367.
- [7] G. Stoet, D.H. Bailey, A.M. Moore, D.C. Geary, Countries with higher levels of gender equality show larger national sex differences in mathematics anxiety and relatively lower parental mathematics valuation for girls, *PLoS One* 11 (2016) e0153857.

- [8] J.D. West, J. Jacquet, M.M. King, S.J. Correll, C.T. Bergstrom, The role of gender in scholarly authorship, *PLoS One* 8 (2013) e66212.
- [9] J. Lerbach, B. Hanson, Journals invite too few women to referee. A comment, *Nature* 541 (2016) 455–457.
- [10] W.W. Ding, F. Murray, T.E. Stuart, Gender differences in patenting in the academic life sciences, *Science* 313 (2006) 665–667.
- [11] B.M. Hill, A. Shaw, The wikipedia gender gap revisited: Characterizing survey response bias with propensity score estimation, *PLoS One* 8 (2013) e65782.
- [12] C. Wagner, E.G. Garrido, D. Garcia, F. Menczer, Women through the glass ceiling: gender asymmetries in Wikipedia, *EPJ Data Sci.* 5 (2016) 5.
- [13] R.N. Costa Filho, M.P. Almeida, J.S. Andrade, J.E. Moreira, Scaling behavior in a proportional voting process, *Phys. Rev. E* 60 (1999) 1067–1068.
- [14] R.N. Costa Filho, M.P. Almeida, Brazilian elections: voting for a scaling democracy, *Physica A* 322 (2003) 698–700.
- [15] M.L. Lyra, U.M.S. Costa, R.N. Costa Filho, J.S. Andrade, Generalized Zipf's law in proportional voting processes, *Europhys. Lett.* 62 (2003) 131–137.
- [16] A.T. Bernardes, D. Stauffer, J. Kertész, Election results and the Sznajd model on Barabási network, *Eur. Phys. J. B* 25 (2002) 123–127.
- [17] M.C. González, A.O. Sousa, H.J. Herrmann, Opinion formation on a deterministic pseudo-fractal network, *Internat. J. Modern Phys. C* 16 (2004) 45–57.
- [18] G. Travieso, L.F. Costa, Spread of opinions and proportional voting, *Phys. Rev. E* 74 (2006) 036112.
- [19] S. Fortunado, C. Castellano, Scaling and universality in proportional elections, *Phys. Rev. Lett.* 99 (2007) 138701.
- [20] L.E. Araripe, R.N. Costa Filho, Role of parties in the vote distribution of proportional elections, *Physica A* 388 (2009) 4167–4170.
- [21] A. Chatterjee, M. Mitrovic, S. Fortunato, Universality in voting behavior: an empirical analysis, *Sci. Rep.* 3 (2013) 1049.
- [22] N.A.M. Araújo, J.S. Andrade Jr, H.J. Herrmann, Tactical voting in plurality elections, *PLoS One* 13 (2018) e0201654.
- [23] H.P.M. Melo, S.D.S. Reis, A.A. Moreira, H.A. Makse, J.S. Andrade Jr, The price of a vote: Diseconomy in proportional elections, *PLoS One* 13 (2018) e0201654.
- [24] L.E. Araripe, R.N. Costa Filho, H.J. Herrmann, J.S. Andrade, Plurality voting: the statistical laws of democracy in Brazil, *Internat. J. Modern Phys. C* 17 (2006) 1809–1813.
- [25] C. Borgheci, J.P. Bouchaud, Spatial correlations in vote statistics: a diffusive field model for decision-making, *Eur. Phys. J. B* 75 (2010) 395–404.
- [26] C. Borgheci, J.-C. Raynal, J.-P. Bouchaud, Election turnout statistics in many countries: similarities, differences, and a diffusive field model for decision-making, *PLoS One* 7 (2012) e36289.
- [27] C. Borgheci, J. Chiche, J.-P. Nadal, Between order and disorder: a 'weak law' on recent electoral behavior among urban voters, *PLoS One* 7 (2012) e39916.
- [28] J.J. Schneider, C. Hirtreiter, The impact of election results on the member numbers of the large parties in Bavaria and Germany, *Internat. J. Modern Phys. C* 8 (2005) 1165–1215.
- [29] C.A. Andresen, H.F. Hansen, A. HANSEN, J.S. Vasconcelos, Correlations between politics party size and voter memory: a statistical analysis of opinion polls, *Internat. J. Modern Phys. C* 11 (2008) 1647–1657.
- [30] P. Klimek, Y. Yegorov, R. Hanel, S. Thurner, Statistical detection of systematic election irregularities, *Proc. Natl. Acad. Sci. USA* 109 (2012) 16469–16473.
- [31] D. Kobak, S. Shpilkin, M.S. Pshenichnikov, Statistical anomalies in 2011–2012 Russian elections revealed by 2D correlation analysis, *arXiv: 1205.0741v2 [physics.soc-ph]*.
- [32] D.S. Vieira, J.M.E. Riveros, M. Jauregui, R.S. Mendes, Anomalous diffusion behavior in parliamentary presence, *Phys. Rev. E* 99 (2019) 042141.
- [33] M.C. Mantovani, H.V. Ribeiro, M.V. Moro, S. Picole, R.S. Mendes, Scaling laws and universality in the choice of election candidates, *Europhys. Lett.* 96 (2011) 48001.
- [34] M.C. Mantovani, H.V. Ribeiro, E.K. Lenzi, R.S. Mendes, Engagement in the electoral processes: scaling laws and the role of the politics position, *Phys. Rev. E* 88 (2013) 024802.
- [35] L.G.A. Alves, R.S. Mendes, E.K. Lenzi, Haroldo V. Ribeiro, Scale-adjusted metrics for predicting the evolution of urban indicators and quantifying the performance of cities, *PLoS One* 10 (2005) e0134862.
- [36] L.G.A. Alves, H.V. Ribeiro, E.K. Lenzi, R.S. Mendes, Empirical analysis on the connection between power-law distributions and allometries for urban indicators, *Physica A* 409 (2014) 175–182.
- [37] L.M.A. Bettencourt, J. Lobo, D. Helbing, C. Kuhnert, G.B. West, Growth, innovation, scaling, and the pace of life in cities, *Proc. Natl. Acad. Sci. USA* 104 (2007) 7301–7306.
- [38] L.M.A. Bettencourt, The origins of scaling in cities, *Science* 340 (2013) 1438.
- [39] J. Lobo, L.M.A. Bettencourt, D. D. Strumsky, G.B. West, Urban scaling and the production function for cities, *PLoS One* 8 (2013) e58407.
- [40] L. Muchnik, S. Pei, L.C. Parra, S.D.S. Reis, J.S. Andrade Jr, S. Havlin, H.A. Makse, Origins of power-law degree distribution in the heterogeneity of human activity in social networks, *Sci. Rep.* 3 (2013) 1783.