Government Information Quarterly 33 (2016) 453–459

Contents lists available at ScienceDirect

Government Information Quarterly

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

The diffusion of internet voting. Usage patterns of internet voting in Estonia between 2005 and 2015☆

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ARTICLE INFO

Article history:
Received 28 December 2015
Received in revised form 21 June 2016
Accepted 22 June 2016
Available online 12 July 2016

Keywords:
Internet voting
E-voting
Diffusion
Voting behavior

ABSTRACT

E-voting has the potential to lower participation thresholds and increase turnout, but its technical complexity may produce other barriers to participation. Using Rogers' theory of the diffusion of innovations, we examined how the use of e-voting has changed over time. Data from eight e-enabled elections between 2005 and 2015 in Estonia, were used to investigate changes to the profile of e-voters and contrast them to those voting by conventional means. Owing to the aggregate share of e-voters increasing with each election, with one third of voters now casting their vote remotely over the internet, there was a lack of conclusive evidence regarding whether the new voting technology had diffused homogenously among the voting population, or remained a channel for the resourceful and privileged. Our findings show that diffusion has taken place, but not until after the first three e-enabled elections. Thus, internet voting has the potential to be used by a wide range of voter types, bridge societal divisions, and emerge as an inclusive innovative voting technology.

1. Introduction

Remote internet voting[1] has long been discussed as a means of increasing voter turnout in developed democracies, especially among younger people (Alvarez & Hall, 2004; Alvarez, Hall, & Llewellyn, 2008; Norris, 2001, 2003). However, such technology can only have a significant impact on political participation when its usage becomes widely diffused. Voting technologies can empower people who have faced participation hurdles (Vassil & Weber, 2011). Socially excluded groups or people with reduced mobility should especially benefit from modes that make it easier to cast a vote (Alvarez & Hall, 2004; Gibson, 2001). Such increased empowerment might also increase voter confidence and their willingness to participate in elections (Alvarez & Hall, 2006; Alvarez et al., 2008). As participation is required for effective representation, easily usable voting modes should, in theory, ensure a better overlap between the elected representatives and society. However, technology can also present additional barriers to the already disadvantaged, in effect nullifying its theoretical promise (Berinsky, 2005; Norris, 2003). It also needs to be acknowledged that e-voting will not address underlining reasons for abstention, such as political disillusionment or a lack of political interest. This does not mean that internet voting is a "technological fix" to an issue that cannot be fixed using technology. E-voting can impact turnout among those who have accessibility problems, such as the disabled and elderly. Moreover, it can also mobilize those who do not have clear mobility problems, but who simply do not vote due to inconveniences related to conventional voting. Thus, e-voting is first and foremost a convenient voting method and therefore should appeal to those parts of the electorate who have abstained due to paper voting being too cumbersome.

The actual practice of remote e-voting has been implemented in a limited number of countries. Exactly how remote e-voting influences voting behavior and parties' strategies is unknown. Studies on technology usage show that the most likely users and beneficiaries are young, technology savvy, well-resourced, and connected people (Schlozman, Verba, & Brady, 2010; van Dijk, 2000, 2005). There is clear evidence that the same applies to the early adopters of e-voting (Alvarez, Hall, & Trechsel, 2009; Trechsel & Vassil, 2011). However, what we do not know is whether e-voting has the potential to diffuse beyond this subpopulation to a broader and less homogenous group of voters, or whether it remains a tool for those with skills and resources. As diffusion is the prerequisite of e-voting having a large impact upon turnout, discussions about how and why new modes of voting might improve participation or representation, require empirical evidence of the

☆ This research was supported by Estonian Research Council grant nr. PUT523.
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[1] We use the terms e-voting, remote internet voting, and internet voting interchangeably throughout this paper to describe online voting using a remote computer and digital identification, i.e. voting without visiting a polling station.

http://dx.doi.org/10.1016/j.giq.2016.06.007

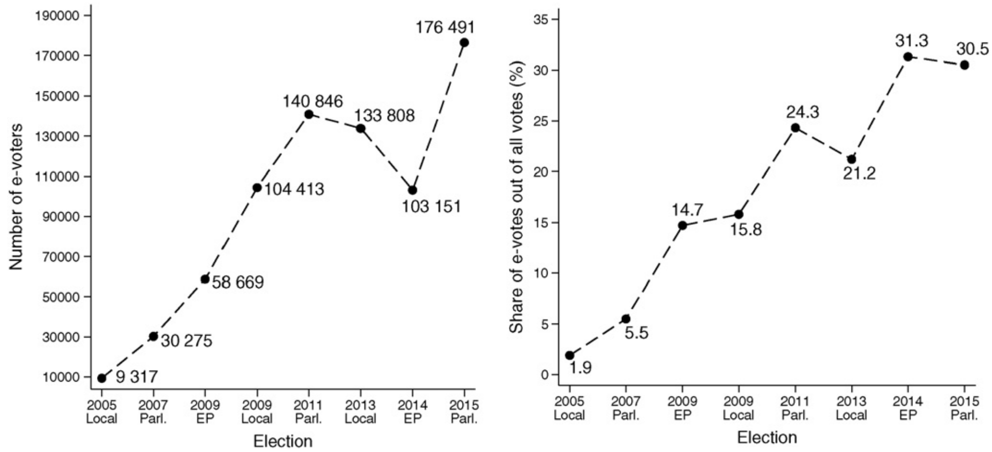

Fig. 1. Dynamics of e-voting in Estonia, 2005–2015.

conditions and patterns by which new technologies are adopted over time. If the rate of adoption of a new voting technology is slow and its diffusion limited to specific subpopulations of the electorate, it is unlikely that e-voting will have a positive impact upon voter turnout and quality of representation.

This paper addresses precisely the question: Who are the e-voters and has their profile changed over time? We used unique cross-sectional survey data from all eight of the legally binding e-enabled elections in Estonia between 2005 and 2015. Our goal was to determine whether the technology has diffused among the voter population, or whether it remains a convenient technical solution for a group of people already engaged in politics and who face limited barriers to participation in the first place.

1.1. E-voting in Estonia

Since 2005, Estonia has had a total of eight e-enabled elections where eligible voters could cast binding ballots over the internet. Internet voting has been used for local, national and European elections. The number of e-voters in the first e-enabled election was only 9317 (Fig. 1). However, the number increased in each succeeding election, reaching 176,491 in the 2015 national elections. In relative terms, the share of internet votes of total votes grew from a mere 2% in 2005 to >30% in 2014 and 2015.

A prerequisite for casting an electronic vote is a credit card sized electronic ID-card,[2] which are compulsory for all Estonian residents. Using digital identification, voters can use their personal computers when connected to the internet and equipped with a smart card reader, to cast an electronic vote (Alvarez et al., 2009). E-voting is available during the advanced voting period via a website hosted by the Estonian National Electoral Committee (2005–2011). E-voting itself involves three steps; first, the user opens the website and with their ID-card and first PIN-code to identify themselves, enters the system; second, after the system has verified the identity of the voter, it displays the list of candidates by party in the voter's respective district; third, by clicking on a candidate's name and then entering their second PIN-code, the voter casts their vote.[3]

The first five elections were reasonably similar for the user-end, with the only marked difference being the length of period during which e-voting was available: three days in 2005 and 2007; and 7 days in 2009, 2011 and 2013. From 2009, e-voters needed to download a voting program instead of voting via the web-embedded application. In 2013, a vote verification feature was introduced to the e-voting system that allowed voters to verify—using a smartphone or tablet—whether their electronic vote was received as cast. Other than these differences, the eight *e*-enabled elections were reasonably similar, providing a valid point of comparison of the related dynamics in user behavior.

On the technical side, e-voting requires internet access and a minimum level of computer literacy, both of which are not universal in Estonia. However, the act of e-voting is no more difficult than other online activities, such as banking or shopping.

2. Measuring diffusion

Theories on the diffusion of technological innovations provide a foundation for measuring and explaining the potential spread of e-voting in a society. The classical accounts of the diffusion of innovations provided by Ryan and Gross (1943) and Rogers (2003[1962]) have stood the test of time, being used over the years to explain a wide variety of phenomena, ranging from the spread of agricultural practices (e.g. Fliegel, 1993) to political reforms and policies (e.g. Starr, 1991; Jahn, 2006), medical practices (e.g. Greenhalgh, Robert, Macfarlane, Bate, & Kyriakidou, 2004), management (e.g. Abrahamson, 1991), and most crucially, technological applications in very different fields (e.g. MacVaugh & Schiavone, 2010). Rogers' (2003) account sees the diffusion of technology as a sequence of steps in an *innovation decision process*. This process includes gaining knowledge of the technology, being convinced of its usefulness, and ultimately, deciding to implement it. Adoption occurs if expectations are positively confirmed by experience. Once a distinct subgroup has reached the adoption stage and built up a critical mass of users, subsequent diffusion is reminiscent of a bank-run, where the number of people adopting it is partly a function of the number of prior adopters (Rogers, 2003: 206). This sequence has been demonstrated to apply to both collective and individual actors (see Wejnert, 2002).

The crucial aspect of using Rogers' account to explain e-voting regards the changing profile of adopters of technology at different stages of the process. The first adopters tend to be a small number of well-informed, innovative risk-takers (Rogers, 2003: 263). The secondary and tertiary adopters should more closely resemble the general population, and the unique characteristics associated with the first adopters should continually become less prominent. Eventually, even technological laggards might be motivated to adopt the technology, as the relative gains outweigh the costs of adopting (Rogers, 2003: 263–265).

As with every new internet technology, adoption requires a certain level of digital literacy, which is not always evenly distributed across social groups. This suggests that internet voting is most likely to appeal to

[2] Since 2011 voters can also use a smartphone-based mobile ID (using a special SIM card and PIN-codes) to authenticate themselves to the e-voting system. The ID card, however, is the more widely used identification method.

[3] For further details on the process of e-voting, see: http://vvk.ee/voting-methods-in-estonia/engindex/; Estonian National Electoral Committee (2005); OSCE/ODIHR (2007, 2011); Vassil and Weber (2011); Trechsel and Vassil (2011).

those with a good command of modern technologies. It is precisely this mechanism that has fueled accounts claiming that e-democracy in general reflects underlining societal divisions and even augments these by further marginalizing the marginalized and connecting the connected (Alvarez & Nagler, 2000; Van Dijk, 2000, 2005; Margolis and Resnick, 2000; Putnam, 2001; Wilhelm, 2000). New voting technologies might therefore also only diffuse among a distinct non-random subpopulation of voters distinguished by higher socio-economic status, but not beyond.

Eventually it remains an empirical question that can be tested using Roger's theoretical framework. The literature on diffusion suggested two different expectations for our subsequent analyses. First, we expected a gradual dispersion of e-voting usage, driven by early adopters, who would be distinguishable by their socio-demographic profile: younger, better-educated, and comparatively economically well-off individuals. Presumably, they should also be more technology savvy and trust the technology more. As the use of technology widens with each additional e-enabled election, a gradual increase in the number of e-voters should be observable. Over time, these new e-voters should result in the total group of e-voters becoming less distinct from paper ballot voters, both in terms of socio-demographics, as well as behavioral and attitudinal characteristics. If diffusion of a technology is actually taking place, the population of e-voters will become more heterogeneous over time. Thus, we expected that the characteristics associated with the likelihood of e-voting during the first e-enabled elections would subsequently become less pronounced and lose their explanatory power. Based on this, we formulated a first hypothesis to identify the presence of diffusion:

H1. Characteristics that explained e-voting during the first e-enabled elections will lose their predictive power over time, suggesting that usage of internet voting has diffused among the electorate.

A contrary expectation, however, follows from the fact that a new voting technology can present a barrier to potential users. Thus, although a technology might spread according to the initial sequence suggested by Rogers and user numbers initially rise, a barrier may prevent larger segments of potential users from adopting the new technology. We posited that the likely barriers would be an insufficient level of digital literacy, a lack of trust in the e-voting system, and age related factors. If such barriers do indeed exist e-voters will remain a distinct subgroup of total voters, because the growth of e-voters will plateau owing to the technology failing to bridge the gap between more and less technology-savvy voters. It would also mean that first-time e-voters should remain clearly distinguishable from paper ballot voters, irrespective of time or a growth in e-voters. Thus, our competing hypothesis was:

H2. Characteristics that explained e-voting during the first e-enabled elections would *retain* their predictive power over time, suggesting that usage of internet voting has not diffused among the electorate.

3. Data, variables and model specification

In order to investigate whether diffusion of e-voting occurred, we used a unique series of individual-level surveys, whereby data were collected after each of the eight e-enabled elections in Estonia. We chose to work with different types of elections in one temporal sequence. Thus, we deliberately ignored the possibility that different election types may mobilize different voter types, vary in saliency, and influence overall turnout. However, as we were interested in measuring diffusion as a function of recurring experiences with e-voting, we compared elections over time. We argue that diffusion should be observable irrespective of whether elections are treated as one temporal sequence or grouped according to type or cycle, as time is a proxy for cycle and vice versa. We return to the empirical implications of this analytical choice in the discussion section.

The first five surveys consisted of quota sampling (with the sample containing an almost equal share of internet voters, ballot-paper voters, and non-voters), to ensure a sufficient number of e-voters for analysis; all surveys had a sample size of 1000 respondents and used the CATI method. The three subsequent surveys consisted of stratified random sampling, because the number of e-voters in the overall voting population had become sufficiently large for analysis (Fig. 1). They also had a sample size of 1000 respondents and used the CAPI method. The surveys had response rates of 62.3%, 61.7% and 60.0% in 2013, 2014 and 2015 respectively.[4] All were post-election surveys conducted during the three week period post-election day and are representative of the voting eligible population. Table 1 shows the sample composition according to voting mode.

3.1. Variable selection

Our dependent variable consisted of a dichotomy of factors that distinguished e-voters from ballot-paper voters. However, we must be explicit about our choice of response category of interest, because comparing e-voters to regular voters over time across elections inevitably introduces noise. Such noise was owing to the fact that in later elections, the population of e-voters contained first-time e-voters (early adopters in the first elections) and those who had voted online in multiple elections. As the motivations and characteristics of these groups may differ considerably (Rogers, 2003), we preferred—in-line with our theoretical argument—to decompose the response category to distinguish between first time and recurring e-voters in each election. We chose to compare ballot-paper voters (coded as 0) only to first time e-voters (coded 1) in each e-enabled election. Effectively, our operationalization yielded a response category that captured first time e-voters that were: early adopters in the first elections; the early majority and majority voters in subsequent elections; and late majority and laggards in the most recent elections. Any change in the profile of first time e-voters would thus reveal whether diffusion of the new voting technology occurred.

Prior studies in diverse settings on diffusion patterns have demonstrated effects of socio-demographic and economic factors, including ethnicity, in predicting diffusion among actors (e.g. Berry & Berry, 1990; Hedström, 1994; Tolnay & Glynn, 1994). More importantly, prior studies on e-voting in Estonia have shown that age, education, trust in the e-voting system, and first-language, should be particularly strong predictors of whether someone e-votes (Trechsel & Vassil, 2011). The latter is true due to the fact that Estonia is a multilingual society with about one third of the population Russian-speaking. As the system of e-voting is only offered in the Estonian language, it could limit its use among the Russian-speaking minority (Trechsel & Vassil, 2010). In addition, economic well-being and literacy with new technologies, have been shown to be systematically correlated with the likelihood of internet voting (Alvarez et al., 2009; Trechsel & Vassil, 2011; Vassil & Weber, 2011). Finally, people's political self-positioning (e.g. left or right) may provide a useful control for our models, because aggregate election results consistently show that liberal parties gain more e-votes than those on the ideological left.[5]

Following these empirical accounts, we used the following independent variables for our analysis: both age in years and age squared (to allow for non-linear effects); education (using a dummy variable for higher education, with secondary and elementary education as the reference); gender (male = 1; female = 0); ethnicity (Estonian as home language = 1; Russian as home language = 0); income (measured by decile); computer literacy (using a dummy for good skills level, with average and basic levels as reference); trust toward the e-voting system

[4] Comparable response rates for earlier surveys cannot be computed because they used quota-sampling and CATI methods.

[5] Further information is available on the National Electoral Committee website: www.vvk.ee

Table 1
Voter types in the sample.

Voter type	2005 local	2007 national	2009 EP	2009 local	2011 national	2013 local	2014 EP	2015 national	Total
Normal voter	318	450	448	403	480	560	477	613	3749
(%)	(33.9)	(45.8)	(44.93)	(40.3)	(47.7)	(53.8)	(48.0)	(61.4)	(47.1)
1st time e-voter	315	309	264	108	139	65	48	62	1310
(%)	(33.6)	(31.5)	(26.5)	(10.8)	(13.8)	(6.2)	(4.8)	(6.2)	(16.5)
Recurring e-voter	0	60	85	142	72	106	90	134	689
(%)	(0.0)	(6.1)	(8.5)	(14.2)	(7.2)	(10.2)	(9.1)	(13.4)	(8.7)
Non-voter	306	163	200	347	316	311	379	190	2212
(%)	(32.6)	(16.6)	(20.1)	(34.7)	(31.4)	(29.9)	(38.1)	(19.0)	(27.8)
Total	939	982	993	1000	1007	1042	994	999	7956
(%)	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)

Column percentages might not sum to 100% due to rounding.

(trust = 1; no trust = 0)[6]; and political left-right self-positioning (using a 10 point scale).

3.2. Model specification

In order to evaluate whether a diffusion mechanism was at play, we estimated a separate logistic regression model for each of the eight elections, and compared the coefficients for each independent variable and model fit over time. If the diffusion process happened as stated in H1, we should observe a gradual reduction in model fit and disappearing covariate effects in terms of magnitude and statistical significance over time, which would confirm that the sample of first time e-voters had indeed become more heterogeneous. By contrast, if the effects retained their power and significance, it would suggest that the sample of first time e-voters in later elections were as distinct in terms of their characteristics as during the first few elections, thus confirming H2. The model took the following generic form (Eq. (1)):

$$\ln\left\{\frac{Pr(evote=1)}{1-Pr(evote=1)}\right\}=\beta_0+\beta_i X_i \quad (1)$$

where X_i is the vector of the listed independent variables for individual i; the model was estimated separately for each of the eight elections. Our particular interest was in how β_i changes over time. We were not interested in any particular covariate effects per se, but whether and how the effects of independent variables changed over time.

For improved interpretation, we converted the logistic regression coefficients into average marginal effects, which show the average of the variation induced in the probability of interest by a marginal change in an independent variable for each individual in the sample (Baum, 2006). An average marginal effect is interpreted as an effect of one-unit change of the independent variable on the change of probability of interest. The appeal of average marginal effects in our analytical setting, was that they are less affected by unobserved heterogeneity that is unrelated to the independent variables in the model, and can thus be compared across models, groups, samples, or years (Mood, 2010: 78). Missing values were multiply imputed for all datasets.[7]

4. Findings

The findings from all eight regression models, with relevant fit diagnostics, are presented in Table 2. First and foremost, we saw that associations between e-voting and age, ethnicity, computer literacy, and trust toward e-voting, weakened substantially with time. More specifically, Fig. 2 displays the non-linear impact of age-squared on the likelihood of internet voting. The findings clearly show that the effect of age flattens gradually over time. Only for the first three elections did age have the expected inverted U-shape effect on the probability of voting online. The likelihood of internet voting was initially highest among 40 to 50 year olds, and lowest for the younger and older. However, this once strong relationship started to gradually disappear after the third e-enabled election in 2009, flattening and losing its predictive power entirely by the fourth election. We assumed from this that over time, the likelihood of e-voting becomes almost equally probable for all age groups.

Similarly, and in accordance with previous studies, we found that the Estonian language was an important predictor of e-voting during the first e-enabled elections. Between the 2005 and 2009 elections, ethnic Estonians were approximately 26–38 percentage points more likely to vote online compared to non-Estonians. However, this difference was lower by more than half by 2011, and had completely vanished by the 2014 elections. We infer from this that ethnicity has lost its explanatory power over internet voting, and as with the effect of age, most of this explanatory power seemed to disappeared after the third election, rendering the once significant disparity between Estonian and Russian-speakers, with respect to internet voting, negligible (Fig. 3).

Computer literacy followed the same trail: it shows strong association with the likelihood of internet voting, with those with high PC-skills approximately 17 percentage points more likely to vote online than those with average and poor skills. This is not surprising, as the general setup of the e-voting system requires several interactions with a computer, relevant peripherals, and the ID-card. The effect was consistent over the first two elections, after which it became insignificant, providing evidence that voters may have become more familiar with the system and learned to use it (Fig. 3). However, we did find it surprisingly that the effect of PC-literacy reappeared during the last election of 2015, with a small effect at the 0.01 level. We believe this was partly due to differences in the electorates between different election types.

Trust toward the system of e-voting has been shown to be one of the strongest predictors of e-voting (Trechsel & Vassil, 2011). We observed the same, but only for the first e-enabled elections. In particular, we saw that those who trusted the system of e-voting were about 49 percentage points more likely to vote online than those who found it less trustworthy. The effect hovered between 35 and 70 percentage points in the first four e-enabled elections and then significantly lost its explanatory power. Unlike previous variables, trust decreased substantially in effect size, but retained its statistical significance (Fig. 3).

Regarding education, gender, income, and left-right self-position, we found no substantially strong relationships (Table 2). A higher education appeared to be weakly but positively associated with internet voting, though its effect was not consistent. The same was the case for gender and income. As for left-right self-positioning, we found it particularly reassuring that nowhere in the data did we find a statistically significant and sizable effect to provide evidence that internet voting is unequally likely for those on the left compared to the right of the political spectrum.

Taken together, we found that multiple socio-demographic and attitudinal variables were strongly associated with the likelihood of

[6] The dummy was created from a four item Likert scale (2005–2011) or a 10 category ordinal item scale (2013–2015). Both variables were split at the middle, with people who trusted or tended to trust coded as 1, and those with no trust or a tendency not to trust coded as 0.

[7] We used STATA's *margins* package to compute average marginal effects, and their *mi-impute* package to multiply impute missing values.

Table 2
Predicting first time e-voting (base: only paper ballot voters).

	2005 local	2007 national	2009 EP	2009 local	2011 national	2013 local	2014 EP	2015 national
Age	1.72**	1.77**	1.97***	1.28	0.54	0.24	0.23	0.57
	(0.58)	(0.57)	(0.58)	(0.69)	(0.52)	(0.42)	(0.37)	(0.39)
Age^2	−0.02**	−0.02**	−0.02***	−0.02*	−0.01	0.00	0.00	−0.01
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.00)	(0.00)	(0.00)
Estonian language	26.05***	38.40***	29.86***	11.86*	14.66**	2.31*	1.68	5.92
	(5.23)	(7.08)	(7.50)	(4.92)	(5.57)	(3.43)	(2.61)	(3.60)
PC literacy: good	17.35***	16.60***	3.75	0.86	5.40	5.10	3.57	9.88**
	(3.56)	(3.41)	(3.68)	(3.75)	(3.34)	(2.82)	(2.72)	(3.06)
Trust e-voting	49.25***	36.23***	69.56***	35.30***	25.25***	14.80***	9.25**	13.50***
	(4.00)	(5.35)	(11.51)	(7.67)	(3.73)	(3.63)	(3.28)	(3.38)
Left-right self-position	−0.17	0.13	−0.04	−0.26	0.54	0.42	0.32	0.19
	(0.72)	(0.78)	(0.66)	(0.90)	(0.70)	(0.53)	(0.48)	(0.63)
Education: higher	5.24	8.81**	9.01**	5.06	8.98**	5.50*	1.50	4.34
	(3.33)	(3.29)	(3.26)	(3.52)	(3.03)	(2.48)	(2.28)	(2.63)
Male	−1.04	2.05	0.47	0.09	6.38*	1.81	−1.56	5.11*
	(3.13)	(3.12)	(3.18)	(3.35)	(2.91)	(2.36)	(2.10)	(2.41)
Income decile	0.31	1.79**	0.85	0.97	0.97*	−0.10	0.23	−0.58
	(0.58)	(0.59)	(0.60)	(0.63)	(0.48)	(0.46)	(0.42)	(0.53)
Constant	−7.49***	−7.54***	−9.09***	−5.90***	−5.45***	−4.70***	−4.71***	−6.54***
	(1.12)	(0.96)	(1.25)	(1.32)	(1.11)	(1.38)	(1.50)	(1.39)
Observations	633	759	712	511	619	625	646	617
Nagelkerke Pseudo R^2	0.52	0.36	0.41	0.34	0.37	0.24	0.16	0.18
Correctly classified	0.78	0.74	0.72	0.81	0.81	0.90	0.93	0.90
Sensitivity	0.90	0.67	0.68	0.24	0.40	0	0	0
Specificity	0.66	0.79	0.75	0.96	0.76	1	1	1

Average marginal effects as percentages. Standard errors in parentheses.
*** $p < 0.001$.
** $p < 0.01$.
* $p < 0.05$.

internet voting in the first three e-enabled elections, but they started to gradually lose their explanatory power over time, becoming less and less relevant. Thus, we took this as the first evidence of diffusion having taken place and that the data supports H1.

However, as the diffusion process should render the first-time e-voter population more heterogeneous over time, not only the individual effects of covariates should weaken, but also the fit of the model. Conversely, if no diffusion has taken place, model fit should remain relatively immune to change over time. Fig. 4 presents various model fit parameters over time. First, there was a significant drop in model performance, as measured by the drop in pseudo-R^2, reducing from a healthy 0.52 in 2005 to 0.18 in 2015. This clearly points to increasing heterogeneity among first time e-voters, providing evidence that diffusion was indeed taking place. More importantly, there was a radical drop in the model's sensitivity, i.e. its ability to correctly classify first time e-voters (the true positives). Fig. 4 shows that it substantially dropped after the third election. Moreover, from the 2013 election onward the model failed to classify e-voters. In sum, the diminishing effect of covariates in explaining first time e-voters, as well as a lower overall model performance, with time, allowed us to refute H2 and support the thesis of ongoing diffusion based upon the increasing heterogeneity of e-voters. Notice that the general classification accuracy of the model remained high throughout the years; this was because it initially correctly predicted e-voters *and* ballot-paper voters, and continued to

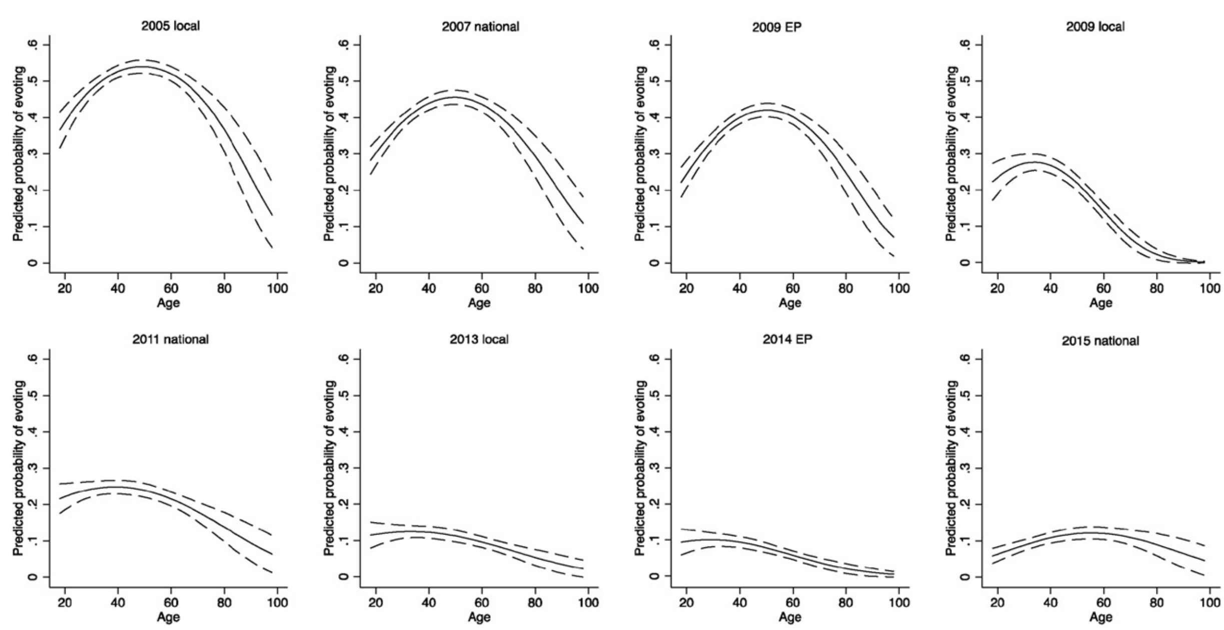

Fig. 2. Effect of age on the likelihood of e-voting.

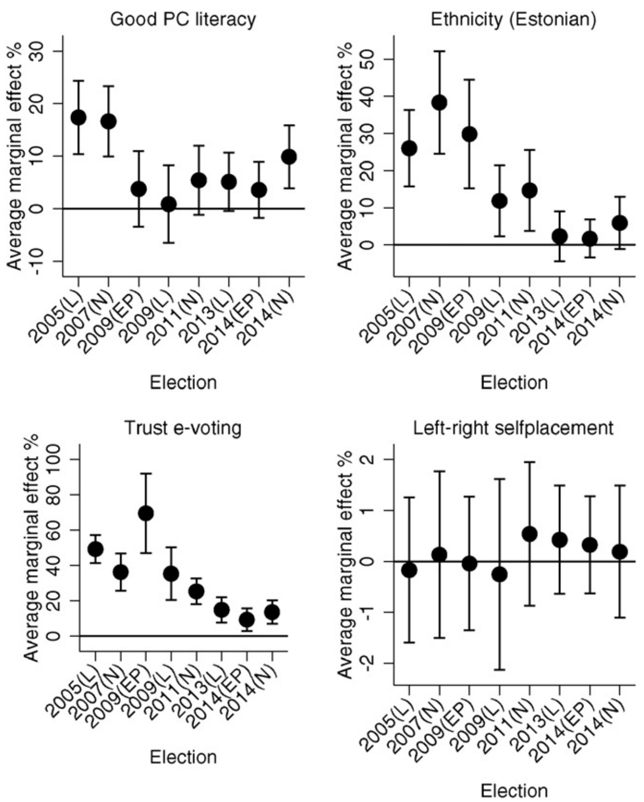

Fig. 3. Impact of computer literacy, ethnicity, trust and ideological auto-position on the likelihood of internet voting. Whiskers represent 95% confidence intervals. (L – local, N – national, EP – European Parliament election.).

accurately predict (*only*) on-paper voters, this further supporting the evidence on diffusion.

5. Discussion

E-voting has become a widely used voting mode in Estonia. However, the aggregate number of e-voters might disguise a situation where the technology has not diffused across societal boundaries, but instead is only being increasingly used by a distinct subpopulation of well-resourced, technologically savvy voters. Real diffusion over time would mean that voters from a broad cross-section of the population, regardless of their social status or level of resources, use e-voting.

Following the expectations derived from Rogers' diffusion of innovation, we examined the profile of first time e-voters over the course of eight e-enable elections (a period of ten years, 2005–2015), to determine to what degree usage of this new voting technology has been adopted by the wider voter population. The aggregate number of e-voters increased sizably over time, with every third vote being cast online during the past two elections. At the level of the individual, we found that the characteristics of first time e-voters became more similar to the characteristics of traditional paper ballot voters over time. E-voters used to be Estonian-speakers from a distinct age group, who have good computer literacy and trust in the system of internet voting. However, this was only the case for the first three elections in which e-voting was used. From the fourth election onward, we consistently saw that these characteristics were only weakly, if at all, associated with the choice to vote online. As a result, our model's ability to predict and correctly classify first-time e-voters based only on socio-demographic and attitudinal data, becomes increasingly limited. Our results show that e-voting has diffused among the overall voter population, and not just remained an activity of the privileged few. Importantly, we found that the process of diffusion did not occur immediately, but was shown via a plateau effect, by which diffusion became visible only after the first three elections.

We focused on elections in one temporal sequence, irrespective of their type. Alternatively, one could focus on electoral cycles by separating them by type. We chose not to do so, because we modelled the diffusion of e-voting in one country, where eligible voters substantially overlap from one election to another. However, if one did focus on electoral cycles, the evidence provided in this paper should also point toward the diffusion. Namely, some of the effects already started to disappear after the second, and others after the third, electoral cycle.

As a result of our findings, we draw two main conclusions. First, technology has the potential to bridge societal divisions and ease political participation, not only for the already connected and resourceful, but also for the less privileged, who have fewer resources and remain at the periphery of using modern technologies. Similarly, internet voting may appeal to those finding conventional voting to cumbersome. As a more convenient mode of participation e-voting may also have the potential to ease participation for those who are connected and engaged but may still abstain due to the inconveniences related to on-

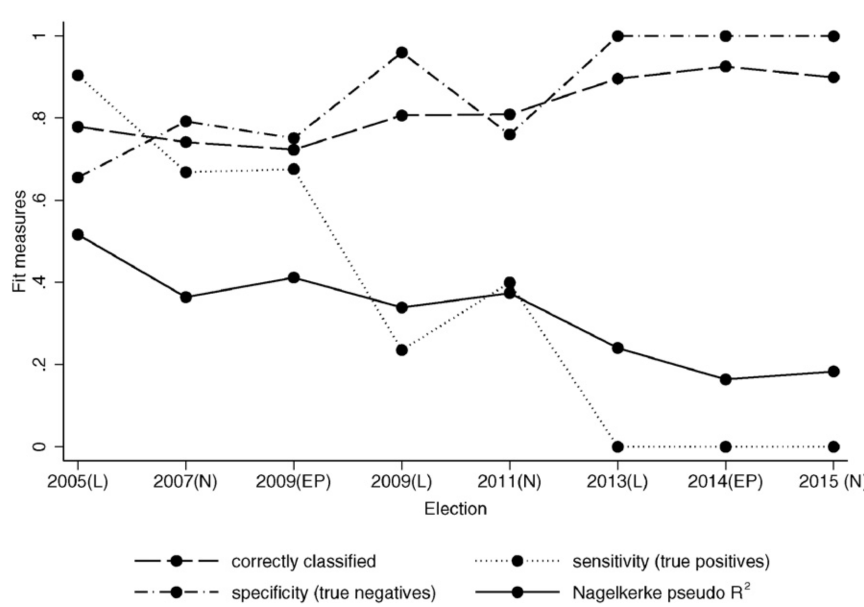

Fig. 4. Model fit diagnostics (L – local, N – national, EP – European Parliament election).

paper voting. The experience of e-voting usage in Estonia shows that technology should not be considered as a hurdle, but as an enabler for political participation. The caveat is that technology only provides an efficient mode for participation; structural hurdles that inhibit participation in general, regardless of the mode voting, will most likely stay unaffected. However, what we have demonstrated in this paper is that technology itself does not seem to exclude anybody, as the skeptics have suggested.

The second conclusion is that the potential enabling effects did not surface immediately in the electoral realm after the introduction of the new voting technology, but required a period of at least three elections to appear. Adoption among a select subgroup can happen immediately, but this is limited to people who already have the resources and skills to use new technologies. A wider public benefit can only be realized once usage has diffused and this does take time. Policymakers are well advised not to expect immediate results following the introduction of new voting technologies, but should recognize that different subgroups of the electorate adopt and use new technologies at different rates. From a positive perspective, our evidence showed the process to be fairly quick; characteristics that used to predict internet voting started to lose their predictive power after only three separate elections within four years. What seemed to matter most was not time as such, but the frequency of being exposed to the possibility of casting their vote over the internet.

Regarding the generalizability of the three-election argument to other contexts, we point out that Estonia was an early adopter of internet voting. Ten years ago internet penetration, broadband communications, and the use of social media, was markedly lower than today. In countries where such factors are higher, the rate of diffusion of internet voting may be substantially accelerated following its introduced.

Taken together, we found evidence that e-voting has diffused among a wide and heterogeneous group of Estonian voters, and has not just become an exclusive form of participation for a privileged few. That Estonian e-voters are a widespread and heterogeneous group was convincingly shown by the model fit, which went from excellent to extremely poor in just over the course of eight elections. Therefore, we are confident that new voting technologies are not necessarily exclusive, as early studies on e-voting have suggested, but are inclusive for a wide range of voter types.

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