JeDEM 17(4): 1-42, 2025
ISSN 2075-9517
http://www.jedem.org
Date of submission: 04.03.2025
Date of acceptance: 13.10.2025
Article DOI: 10.29379/jedem.v17i4.1024

Pandemic-proof elections: Did COVID-19 increase the use of Internet voting?

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Abstract: COVID-19 forced governments to postpone elections, potentially jeopardizing the functionality of democratic societies by delaying regime legitimization. However, theoretically, Internet voting, as a mode of absentee voting, can easily overcome the pandemic circumstances by reducing the electorate's voting costs, yet the connection was not discovered. Hence, in this research, we decided to shed light on how COVID-19 affected voting costs and Internet voting usage, especially across at-risk groups. As a result, we explored that in the state with homogeneous i-voting diffusion, COVID-19 did not impact paper-voting and i-voting turnout, in general, and amidst the elderly population as well. First of all, these findings illustrate the existence of a saturation point in the technology acceptance rate. Additionally, the article discusses the theoretical-empirical conceptualization of voting costs and the causal mechanism of the pandemic and turnout.

Keywords: Absentee voting, COVID-19, Estonia, Internet voting, Voting costs

1. Introduction

COVID-19 has cast a very long shadow over democratic elections worldwide. An estimated 80 elections globally were postponed due to COVID (IDEA, 2022), and the polls held during the pandemic seem to have suffered a statistically significant decrease in turnout (Constantino et al., 2021; Justinus et al., 2020; Stancea & Muntean, 2024) and an increase in absentee voting (Yoder et al., 2021). It affected voter opinion formation (Bol et al., 2021; Bruin et al., 2020; Craig et al., 2022; Dal & Tokdemir, 2022; Ollerenshaw, 2022) and immediate election outcomes (Algara et al., 2022; Baccini et

al., 2021). It might also have negative, long-lasting structural effects by causing unequal interest representation (Eady & Rasmussen, 2022) and strengthening otherwise fringe conspiracy theorists at ideological extremes (Bierwiaczonek et al., 2022; Imhoff & Lamberty, 2022; Pummerer et al., 2022; Rieger & Wang, 2022). On the bright side, depending on effective crisis response, overall trust in the government might actually have increased (Goldfinch et al., 2021; Liu & Lo, 2022; Mansoor, 2021).

The dilemma of holding elections while simultaneously mandating the population to stay at home brought a renewed urgency to introduce remote voting options. It re-invigorated interest in Internet voting (the terms Internet voting, i-voting, and online voting are used interchangeably) as one viable option to make elections possible also during the pandemic (IDEA, 2020; James, 2021; R. Krimmer et al., 2020, 2021). Do voters flock to Internet voting when going to the polling station is risky? Do older people who face heightened health risks simply switch to casting their vote on the Internet? Answers to these questions remain speculative until we examine cases that held elections with the Internet voting option during the pandemic. Such cases are, however, few and far between. The most popular remote voting option in use globally is still postal voting, and remote Internet voting, proposed as a future way of voting in the late 1990s and early 2000s (Norris, 2001, 2003), has been in actual usage since mid-2000, mainly in Estonia, Switzerland, and the provinces of Canada.

Given that lockdown and social-distancing rules caused societies to take up digital tools to keep functioning while minimizing population risk, doing the equivalent with voting did not seem such a far-fetched idea anymore. Setting up an Internet voting system that at the same time ensures integrity, transparency, and confidentiality cannot be done quickly, let alone during an ongoing pandemic. It is also unclear if such a voting channel would constitute pandemic-proof elections unless we observe this empirically.

This paper tries to answer the broader question by outlining how COVID-19 affected the cost of voting and if and to what degree increased usage of remote Internet voting in a country already heavily using this voting channel. Specifically, it examines whether Internet voting usage increased during elections held under high COVID-19 infection levels in the fall of 2021 in Estonia and whether more at-risk groups were more likely to switch to using this voting channel to avoid health risks. It lays out a theoretical model of why and how COVID-19 affected voting cost calculus and tests the hypotheses using post-election survey data.

The case of Estonia is especially suitable for this research as it is a pioneer of unlimited Internet voting usage, with user rates reaching 51% in the latest national election of 2023; we can hence argue that this voting channel has been normalized, and pandemic-induced usage differences would be more easily detectable.

The research in question has a two-fold relevance. The academic salience of the research stems from the measurement of the shift in voter behavior due to external crises: did people opt for the mode of voting, which has lower voting costs? Is this trend observable only for particular age groups? Also, the theoretical backbone of the article is constructed from Downs' theory, which was applied to the COVID-embedded elections and has not yet been tested. Moreover, the article has a methodological undertone, encompassing the operationalization of participation risk through the 'age' variable.

Apart from the academic relevance, the article has a hypothetical societal impact. Within the research, we explore whether Internet voting might be adopted in the context where it has existed for almost two decades due to the exogenous shock, e.g., COVID-19. In theory, the findings might be extrapolated to similar scenarios, for instance, natural disasters, which might also affect the functionality of democracies. In other words, this is not just another COVID article; instead, we perceive the pandemic as a circumstance that has unique features and should change voter behavior.

The rest of the paper proceeds as follows: the second section outlines the theoretical rationale for how and why COVID-19 should affect voter behavior, followed by the third section on the study design, methods, and data used; the fourth section presents the results; finally, the fifth section concludes the research.

2. Theoretical expectations

The theoretical model specifies how costs affect turnout, how COVID-19 affects costs, and how switching to Internet voting should result from the resulting cost differential of different voting channels.

2.1. Cost of voting, turnout, and COVID-19

The minimalist Downsian explanation of individual turnout has been criticized for its inability to explain the level of turnout we see in elections (Aldrich, 1993; Feddersen, 2004), but it seems to do a better job of explaining the differences in levels of changes in turnout. Part of the latter comes from its simplicity, summarized as follows:

$$turnout = \begin{cases} yes & if\ p \times U > C \\ no & if\ p \times U < C \end{cases}$$

, with U designating the utility of the most preferred option, p the probability of participation making a difference, and C the costs associated with the voting (Downs, 1957, pp. 36–50). Turnout occurs when the utilities outweigh the costs and not when vice versa (Woller et al., 2022). Given that even small costs should outweigh the utilities if the latter is weighted with a minuscule p in mass elections, we should never observe turnout at the level we regularly do. This same model does provide a set of testable hypotheses of what happens to turnout when either p, U, or C changes with everything else held constant. There is ample aggregate-level evidence that turnout is indeed higher when voting costs are comparatively lower (Geys, 2006), and individual-level evidence also points to this logic holding — people with lower voting costs are turning out at higher levels (Smets & van Ham, 2013). For example, the availability of convenience voting modes reducing voting costs has been shown to positively affect turnout (Germann, 2021; Goodman & Smith, 2017; Nemcok & Peltoniemi, 2021; Sheppard & Beauregard, 2018). This simple cost model hence predicts that, given an increase in the cost of voting, turnout should go down.

The primary way COVID-19 affected individual behavior was by changing the cost calculation of participation. Voting in person implies close social contact, which increases infection risks; hence, it introduces a heightened cost in terms of an increased health or even mortality risk attached to this

behavior. The growing body of literature on COVID-19 and voting does show clear associations along those lines. Turnout tended to decrease from a relatively small 0.5 percentage points in Italy during the 2020 elections (Picchio & Santolini, 2022) to a sizeable 8.7 points decrease in the US presidential elections (Morris & Miller, 2021). Second, higher participation rates led to an increased number of infections (Cipullo & Le Moglie, 2022; Cotti et al., 2020; Flanders et al., 2020; Picchio & Santolini, 2022). The higher the infection levels or/and the number of confirmed cases around the polling station, the lower the willingness of voters to risk their health by participating (Fernandez-Navia et al., 2021; Haute et al., 2021; Noury et al., 2021; Santana et al., 2020; Vázquez-Carrero et al., 2020).

Remote voting options, such as voting-by-mail, became more popular with absentee voting by nearly tripling in the US (Yoder et al., 2020, p. 2), and typical in-person voters switched to mail voting in great numbers (Thompson et al., 2020; Yoder et al., 2020, 2021).

Finally, the core argument of the research is that i-voting might be the way to maintain democratic functionality despite external crises. This thesis resonates with already published articles on the elections and turnout during the COVID pandemic: Daniel Scheller found out that there is an effect of risk aversion and voting abstention for the on-site voters increasing with age (Scheller, 2021); a similar effect was also observed in French local elections (Haute et al., 2021); additionally, in some countries, COVID was neglected in favor of domestic politics (Dulani et al., 2021). In this sense, Internet voting could be a golden mean, which would enable adequate political participation via elections yet also allow citizens to take care of their health and well-being since COVID is just a mere example of an exogenous shock that is not regular in comparison to the natural disasters, which also could be alleviated via Internet voting. Nevertheless, we are not stating that i-voting has features of a 'silver bullet'; rather, we imply that the pandemic should not undermine the functionality of a democratic state, and there are means for that.

Based on the theory and the observed behavior, with increased infection risk, the attached personal health risk of in-person voting increases. Internet voting, however, does not involve any in-person interactions during voting; hence, the health cost should not change with increased infection risk. A study on Estonian Internet voting has shown that an i-vote takes the voter an average of 2,5 minutes to cast, with the median i-voting speed hovering around 90 seconds (Solvak & Vassil, 2016). Compared to a roughly 30-minute median round trip for the paper voting (Solvak & Vassil, 2016), it makes for a drastic 20-fold time differential. Just like regular paper voting, it is also available universally for all voters and requires no separate voter registration.

Returning to the Downsian turnout model, Internet voting should hence have decreased voting cost C compared to in-person voting in general $C_{in-person} > C_{internet}$.

But this cost differential should grow as (personal health) risks increase with COVID-19 to: $C_{in-person} \gg C_{internet}$. Figure 1 shows this expectation graphically.

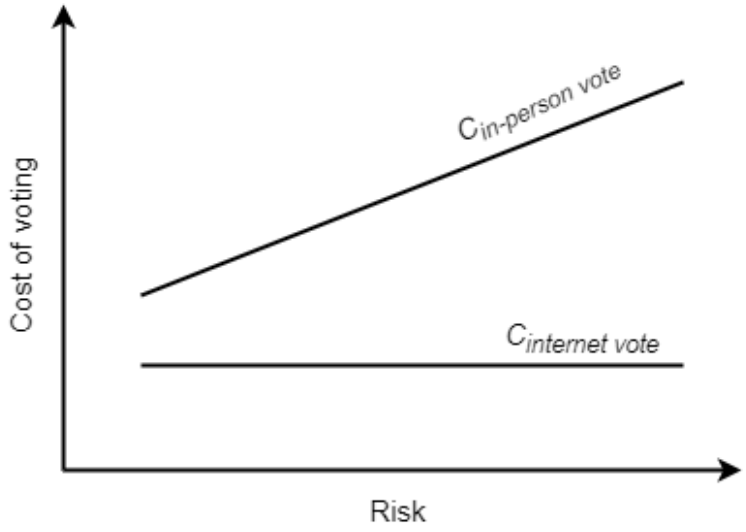

Figure 1. Theoretical risk-induced cost differential for in-person and Internet voting

Source: Authors' calculations

The final question is for whom is the COVID-19-induced voting cost differential more significant? We know that risk avoidance behavior was mandated and increased during higher COVID-19 infection levels (Engle et al., 2020; Kashima & Zhang, 2021). Especially, a heightened mortality risk induced a change of behavior to reduce exposure to this risk (Hammitt, 2020). This readiness to change behavior was comparatively stronger in older age groups (Hall et al., 2020) reduced their mobility more (Bonaccorsi et al., 2020; Canning et al., 2020; Cepaluni et al., 2021), and they were more willing to comply with restrictive containment measures (Brankston et al., 2021; Charoenwong et al., 2020; Clark et al., 2020; Daoust, 2020; Lin et al., 2021; Painter & Qiu, 2020; Wirz et al., 2020). Given that the elderly were objectively more at risk of getting infected and having more severe symptoms (Calderón-Larrañaga et al., 2020; Carrieri et al., 2020; Niu et al., 2020), their behavior showed that objective differences in risk levels led to behavioral differences. Though this risk-aversion and connected behavior changed during the pandemic as societies became more knowledgeable, it still depended (non-linearly) on the risk level (Tsutsui & Tsutsui-Kimura, 2022), and it was noted that the danger of COVID-19 tended to be actually overestimated (Akesson et al., 2022; Bundorf et al., 2021). All this suggests that higher risk aversion leads to risk avoidance behavior, especially among the factually more at-risk population, and the overestimation of risk levels should amplify the avoidance behavior even more. For voting, it was indeed observed that the probability of not participating increased with age (Haute et al., 2021; Joe, 2022; Noury et al., 2021; Scheller, 2021), which is actually atypical for voting otherwise, as age tends to have a strong curvilinear association with turnout. This means a marked change in behavior as the inverted U-shaped age association with turnout is something that has been observed almost universally across very different countries over time (Bhatti et al., 2012). COVID-19 hence changed how age and voting behavior associate; we presume something similar can hold for the usage of Internet voting.

Now, we can formulate the final theoretical expectations in connecting COVID-19 and turnout with the help of the voting cost model — the infection risk increases the individual cost of in-person participation, which, ceteris paribus, decreases turnout. However, the increase in in-person voting costs due to the virus should result in a cost differential that is more favorable to Internet voting and a subsequent usage increase. The larger the individual cost-differential for Internet voting based on the individual risk level, the more likely the usage should become. These cost differentials should be more pronounced depending on age, and we should see marked differences compared to normal times in how age is associated with the usage of these voting channels. We hence derive the following hypotheses from the above discussion:

H1: During COVID-19, the probability of turnout increases with age at a lower rate than pre-pandemic

H2: During COVID-19, the probability of Internet voting usage decreases with age at a lower rate than pre-pandemic

H3: Switching from on-site voting to Internet voting increases with age, conditional on perceived risk

Hypotheses 1 and 2 are graphically represented in Figure 2 — COVID-19 should reduce participation but increase usage of a cost-efficient remote voting option. Hypothesis 3 is shown in Figure 3 — switching to Internet voting to keep on participating should be more likely for individuals for whom the risk is higher and who are more risk-averse.

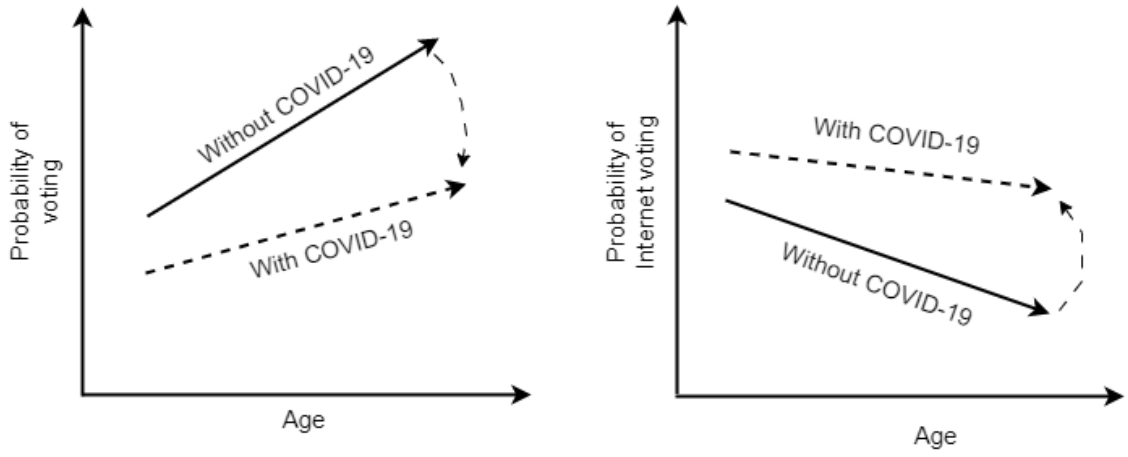

Figure 2. Hypotheses on voting and Internet voting usage under COVID-19

Source: Authors' calculations

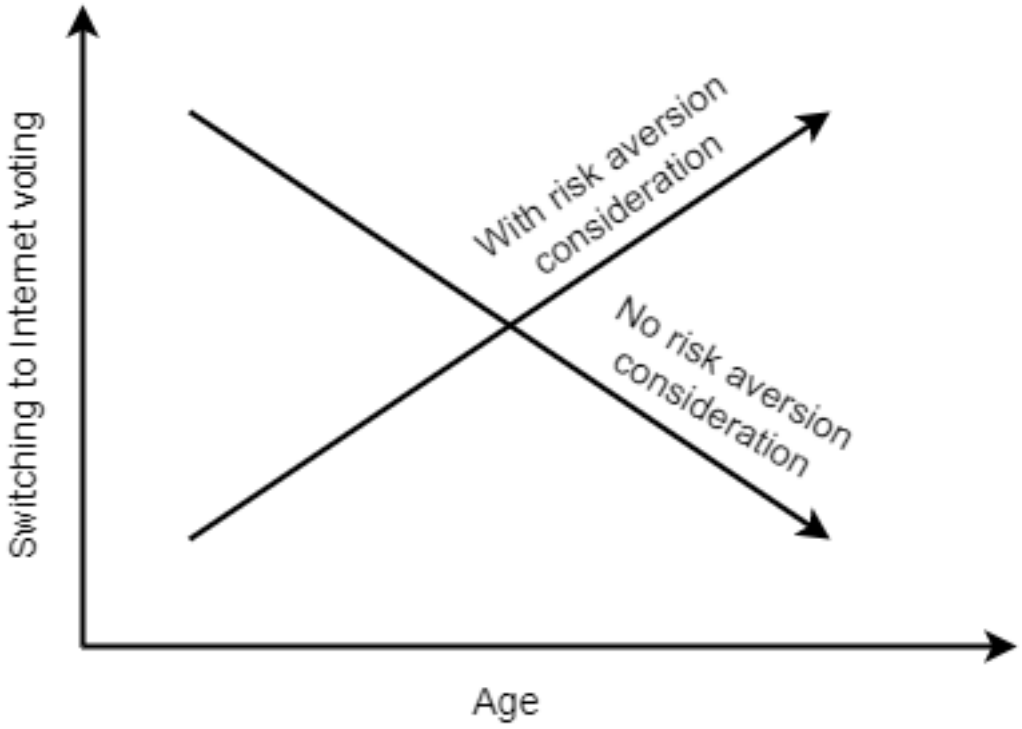

Figure 3. Hypothesis on switching to Internet voting usage under COVID-19

Source: Authors' calculations

Before examining the data and results, the next section briefly discusses why the case of Estonia is particularly suitable to test these expectations.

2.2. Internet voting and COVID-19 infection rates in Estonia

Estonia introduced remote Internet voting in 2005 in a "big bang" manner for all eligible voters at the same time. As of March 2023, a total of 13 elections with this option have been held, and usage of Internet voting has grown to a record of 46.9% in local elections of 2021 and 51% in national elections of 2023.

Over the years, the typical i-voter has become very similar to a regular paper voter (Ehin et al., 2022; Vassil et al., 2016), which presents an even better test setting for COVID-19 effects in a mature Internet voting country: usage has normalized, novelty effects have worn off, and the acceptance rate is homogeneous. This also means that changes observed during the pandemic should be more than just due to other trends of technology diffusion or voting channel popularity growth over time. In order to ensure the latter, we also expand the pre-pandemic period included in the study over multiple years and election types.

Another two arguments in favor of Estonia being a valid case study for the effect of COVID-19 as an exogenous shock on the Internet voting usage rate are lowered acceptance barriers and the limited pool of countries employing Internet voting in general.

Firstly, Estonia represents a unique context where Internet voting has been fully integrated into the democratic process for nearly two decades. This long-term exposure has resulted in lowered adoption barriers, including high levels of public familiarity, trust, and operational stability in the voting system (Ehin et al., 2022; Vassil et al., 2016). The widespread normalization of Internet voting means that voters face fewer obstacles (e.g., technological, logistical, or psychological), when switching to the online mode of voting. During the pandemic, this context provides an opportunity to observe whether such pre-existing infrastructure and trust facilitate behavioral shifts under crisis conditions. In essence, Estonia allows us to test whether a mature Internet voting environment can act as a buffer against external shocks like COVID-19, preserving electoral participation even during a public health crisis.

Secondly, according to the International Project IDEA, Internet voting is available for all citizens in only one democracy – in Estonia (*Use of E-Voting Around the World*, 2023). Another country where it is used on a constant basis in a legally binding format is the autocratic United Arab Emirates, which entails its own limitations in terms of access to the data and its integrity. Once more democracies (Switzerland, Canada, and Australia) expand their scope of Internet voting, the Estonian case could be perceived as some sort of baseline value, which can serve as an angle for comparative research. Hence, acknowledging the high degree of Internet voting diffusion, which might reduce the theoretically expected effect sizes, does not imply that the effects are nonexistent, especially in such a unique case of the pandemic outbreak, which undermines the efficiency of conventional voting methods. Within this research, we are working with democracy, providing its citizens with an electoral solution that mitigates the hazardous effects of the pandemic and enables them to participate in the elections.

That is why we examine specifically voting behavior during the local election of 2021, which took place on the 17th of October 2021. Estonian local elections are held nationwide in all municipalities at the same time, so Election Day is shared for all voters across the country.

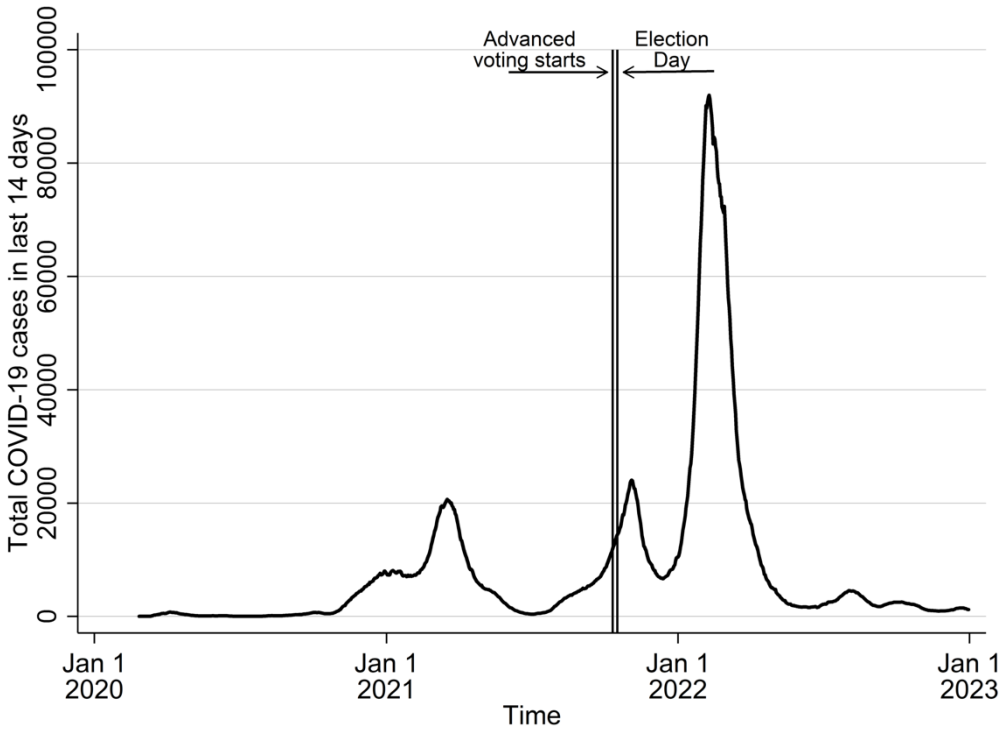

Figure 4. Running 14-day total COVID-19 infections in Estonia (2020-2023).

*Source: Estonian Covid-19 open-data portal. (*Estonian Covid-19 Open-Data Portal*, n.d.)*

Figure 4 shows that this day was in the middle of a steep upsurge of infections, which peaked two weeks after Election Day. Advance voting in polling stations, which was used by close to 25% of all who voted, and Internet voting started a week before Election Day. On election day, the infections per 100 thousand stood at 1086, with the peak reaching 1808 two weeks later, and the number of hospitalized patients stood at 430, peaking at 665 two weeks later. The number of daily COVID-19 deaths stood at 5 per day (running a 7-day average), with a record peak of 12 a day (running a 7-day average) reached two weeks later (*Estonian Covid-19 Open-Data Portal*, n.d.). A day before Election Day on 16th October 2021, Estonia was 8th in the world for confirmed cases and 2nd in the world for hospital admissions relative to the population size (*Our World in Data: Coronavirus (COVID-19) Cases*, n.d.).

Whichever statistics one looks at, the elections happened during the onset of the second wave of COVID-19 in the country. Though worse was to come in terms of the number of infections in early 2022, the number of deaths peaked during that second wave and did not reach close levels ever again. Though the vaccination rates with the first dose stood at 79% for the 70+ group at that time, it is still safe to say that objectively, risk aversion and subsequent risk avoidance behavior should have been at peak values during the active voting period and Election Day, given the apprehension around the start of a projected major second wave and steady climbing hospitalization, death rates. Estonia's 2021 local elections should hence be a perfect time and place to see if Internet voting is pandemic-proof voting.

3. Research design and Methods

3.1. Internet voting and COVID-19 infection rates in Estonia

Even though our main interest is to see if and how behavior changed during the election held under pandemic conditions, we examine the hypotheses using aggregate data on turnout and Internet voting and individual-level survey data from 7 elections in total over the period from 2013 to 2023. Expanding the period under study is needed for two reasons. First, it is a pragmatic reason to be able to have enough different types of elections to compare with — the selected period includes three parliamentary, two European Parliament, and three local elections. Second, past research shows that Internet voting usage has a certain pattern, such as voters slowly converting to Internet voting (Vassil et al., 2016) and having vote habit-inducing effects, which might affect turnout over time (Solvak & Vassil, 2016). An expanded comparison period will allow us to tell if the possible changes observed in 2021 are continued trends in voting technology usage by voters or more abrupt changes associated with the COVID-19 pandemic and health risks at that time. All used studies were cross-sectional post-election surveys representative of the voting-eligible population regarding age, gender, ethnicity, education, and region; see Appendix A for a detailed description of the actor responsible for data collection, mode of data collection, sample size, as well as other crucial details regarding the database.

We use three different outcome variables; see Appendix B for detailed question-wording. First, turnout with non-voters as the reference group. Second, Internet voting with paper voting as the reference group. Third, switching from paper voting to Internet voting in the given election, with repeated Internet voting as the reference group. This last variable was created based on a question of voting channels in prior elections, asked as a recall for the previous and second to previous elections between 2013 and 2019, and as a question of whether the voter has ever voted on the Internet in the past in 2021.

Our primary explanatory variable is the age group of the voter with the following categories: 18-49, 50-59, 60-69, and 70+. This grouping logic was created based on the official at-risk group classification, which was widely communicated and formed the basis for the COVID-19 response, like age group-dependent vaccination roll-out and general risk-mitigating behavioral suggestions.[1]

The second main explanatory variable would be a self-reported evaluation of COVID-19 considerations that played a role in choosing Internet voting. The exact question wording is to what degree did COVID-19-related health risks influence your decision to vote via the Internet rather than in the polling station? and this was only asked of respondents who reported having Internet voted in the given election in 2021. We use this variable to test if COVID-19 perceived risk had a larger role in switching from paper to Internet voting for the more at-risk voter groups.

[1] For Estonian national guidelines see: "COVID-19 Trükised Ja Juhendmaterjalid | Terviseamet." 2023. https://www.terviseamet.ee/et/koroonaviirus/koroonaviiruse-haigus-covid-19-trukised-ja-juhendmaterjalid. For an overview of WHO-issued global and regional guidelines see: "Guidance for Specific Populations, High Risk Groups." 2023. https://www.who.int/westernpacific/emergencies/covid-19/technical-guidance/specific-populations-high-risk-groups.

Given that Internet voting also requires minimal familiarity and willingness to use ICT in vote casting, and these skills tend to be partially age-dependent (Friemel, 2016; Poynton, 2005), we also include self-reported PC literacy level as a control variable. In the Swiss case, ICT skills have actually been shown to be more important than age in explaining Internet voting uptake, so much so that including ICT eliminates age effects (Serdült, 2010; Serdült et al., 2015). As we use age as a proxy for being at risk of COVID-19, getting a PC skill-controlled age effect is essential.

Continuing the same reasoning, we also add gender, education level, ethnicity, income, and urban or rural residency as controls, both because they tend to affect the turnout (Smets & van Ham, 2013; van der Eijk & Franklin, 2009), as well as early studies of Internet voting usage show uptake to be dependent on those factors (Serdült, 2010; Serdült et al., 2015; Solvak & Vassil, 2016, 2018; Vassil et al., 2016; Vassil & Weber, 2011). Finally, for models on Internet voting and switching voting mode, we also include the party choice as a control, as using Internet voting is affected by party identification (Bochsler, 2009). The effects of the control variables are not reported but have been included in all regression models used in the paper.

3.2. Methods

We compare marginal and average marginal effects across logit regression models to identify the above-outlined behavioral differences. This is preferable to comparing logit coefficients or odds ratios as these are affected by the unobserved heterogeneity of the separate models (Mize et al., 2019; Mood, 2010).

The voting likelihood of the first hypothesis will be tested by estimating the following logit models for each election separately:

$$\ln\left\{\left(\frac{\Pr(vote=1)}{1-\Pr(vote=1)}\right)\right\} = \beta_0 + \beta_{1(age50to59)} + \beta_{2(age60to69)} + \beta_{3(age70andmore)} + \beta_{4controls}$$

, where we expect the β_1 to β_3 values to be positive, significant as well as in an increasing order prior to 2021, but to have comparatively clearly lower values in 2021.

The Internet voting likelihood of the second hypothesis will be tested by estimating the following logit models for each election separately:

$$\ln\left\{\left(\frac{\Pr(ivote=1)}{1-\Pr(ivote=1)}\right)\right\} = \beta_0 + \beta_1 age50to59 + \beta_2 age60to69 + \beta_3 age70andmore + \beta_4 PCliteracy + \beta_5 controls$$

, where we expect the β_1 to β_3 values to be negative, significant as well as the in a negatively increasing order prior to 2021, but to have comparatively clearly higher values in 2021.

The third hypothesis will be tested by estimating the following logit model for the 2021 study:

$$\ln\left\{\left(\frac{\Pr(switch=1)}{1-\Pr(switch=1)}\right)\right\} = \beta_0 + \beta_1(age50to59 \times COVID19) + \beta_2(age60to69 \times COVID19) + \beta_3(age70andmore \times COVID19) + \beta_4 PCliteracy + \beta_5 controls$$

, where we expect β_1 to β_3 values to be significant and show a positive association with increased age when COVID-19 has been deemed a consideration in switching to Internet voting and a negative association with increased age when not.

Additionally, to provide a comprehensive examination of age-specific effects in 2021 compared to other years, we included a pooled model with interaction terms in Appendix C.

4. Results

4.1. Aggregate-level evidence

We examine the aggregate level picture first. Our two variables of interest are shares of Internet voters and turnout across the elections at the aggregate level; the third outcome comes from survey data. From Figure 5, we see that turnout depends a lot on the type of election, with European Parliament (EP) elections showing, as a rule, the lowest and the national parliamentary elections the highest figures. For local elections, turnout tends to be around 53-58%. The 2021 local election, held during the onset of a second wave of COVID-19 and a public vaccination drive, does not stand out in terms of the lower turnout; in fact, it shows higher levels than the previous election of the same type. The usage of Internet voting, however, was record-breaking in 2021, but only when compared to the previous pre-pandemic election for the 2019 European Parliament. The record-breaking effect of 2021 fades with the 2023 results in the picture – the Estonian electoral field witnessed a situation in which more than 50 percent of votes were given via Internet voting.

In order to get the first gauge of whether the election at the time of COVID-19 stood out, we examine the Internet voting shares graphically, including the very first instances since 2005, to get a better picture of the trend. Additionally, we have predicted the expected share of the Internet votes for the year 2021 using the linear model. Figure 5 shows how the share of Internet voters out of all votes cast has increased across different elections over time; the average growth rate has been 5% per election. We see, however, that for 2021, when the infection rate was rapidly increasing, the share of Internet voters is slightly lower than what could have been expected based on the trend of previous elections alone. However, one can also see that this seems to be a typical pattern, with Internet voting share in local elections almost always slightly below the overall trend. A look at the trend in local elections, only in Figure 6, shows that 2021 did stand out with a slightly higher share compared to the expected share based on the growth trend for local elections, but this is within the confidence interval of the projected trend. So, the aggregate picture is mixed, leaning toward a null effect, and a detailed look at the micro level is needed.

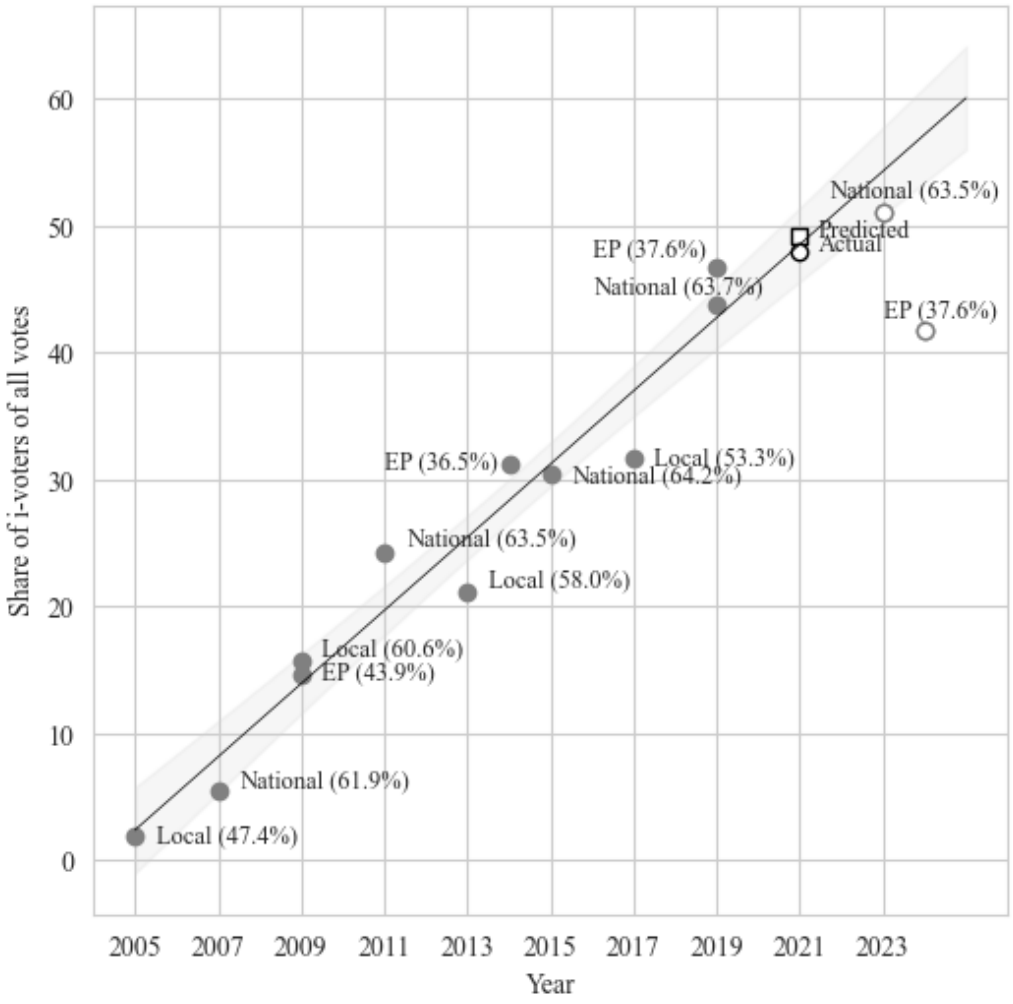

Figure 5. Share of Internet voters 2005-2024 with a superimposed trendline and predicted 2021 i-voter share based on the data for 2005 to 2019 with turnout depicted in the parentheses. Values for 2023 and 2024 are not included in the training data and are presented for the overall trend.

Source: Valimised | Elections in Estonia. (2024). Retrieved December 4, 2024, from https://www.valimised.ee/

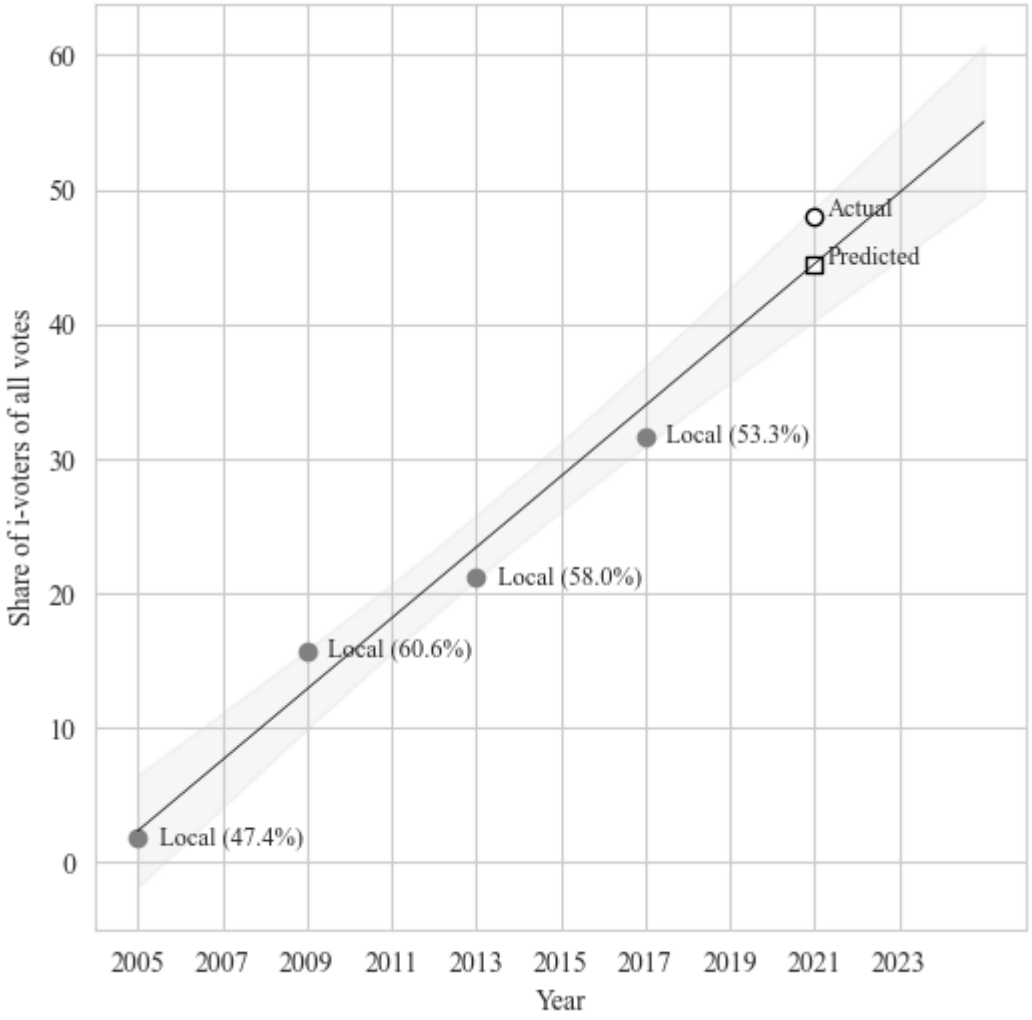

Figure 6. Share of Internet voters 2005-2024 with a superimposed trendline and predicted 2021 i-voter share based on the data for 2005 to 2019 with turnout depicted in the parentheses. Values for 2023 and 2024 are not included in the training data and are presented for the overall trend.

Source: Valimised | Elections in Estonia. (2024). Retrieved December 4, 2024, from https://www.valimised.ee/

4.2. Micro-level associations

Moving to the micro level, we hypothesized that voting as such should become less likely among the at-risk group, while choosing to vote over the Internet should become more likely. The former is not confirmed. Table 1 shows the oldest age group to have consistently the highest voting probabilities in every election under study. In 2021, the 70+-year-olds were 14 percent more likely to vote, and the 60-69-year-olds were 11 percent more likely to vote than the 18-49-year-old reference group. These are sizable differences, and although compared to other years, the age differences in turnout probabilities seem less pronounced in 2021, it is not sufficient evidence to claim dampened

turnout among at-risk groups, especially as the post-pandemic election of 2023 shows even smaller effects for the oldest voter groups.

Table 1. Effects on voting (2013-2023) (reference category: not voting)

Source: Authors' calculations

	2013 local	**2014 EP**	**2015 national**	**2017 local**	**2019 national**	**2019 EP**	**2021 local**	**2023 national**
Age: 50-59	6.00	13.48*	9.77*	8.06	6.72	10.85	6.34	8.55*
(ref: 18-49)	(4.44)	(5.34)	(4.04)	(3.75)	(4.06)	(4.39)	(3.42)	(3.82)
Age: 60-69	10.83*	35.40***	11.77**	9.39*	12.72***	23.02***	11.15***	6.85*
(ref: 18-49)	(4.36)	(4.81)	(3.87)	(3.82)	(3.56)	(4.40)	(3.16)	(3.54)
Age:70+	20.03***	30.05***	14.28***	8.96*	16.47***	25.32***	13.99***	12.29***
(ref: 18-49)	(3.83)	(4.73)	(3.64)	(4.28)	(3.43)	(4.17)	(2.93)	(3.18)
Pseudo R2	0.36	0.25	0.16	0.28	0.24	0.19	0.11	0.14
Observations	888	653	796	827	844	858	1058	858

Average marginal effects in percentages with standard errors in parentheses. Controls include gender, nationality, education, income level, urban residency, effects not shown.

* p<0.05, ** p<0.01, *** p<0.00

Table 2 shows the effects of age groups on Internet voting probability. Three things stand out. First, age does not have a significant and consistent effect in any year. Second, though not significant, the coefficients have negative signs, which means the older the group, the less likely they are to pick Internet voting over paper voting when compared with the younger voters. Third, the COVID-19-dominated 2021 is a year where 60-69-year-olds show a significantly lower probability of voting over the Internet compared to the younger reference group, but so does the pre-pandemic year of 2015. All in all, the evidence so far points towards no tangible change in behavior for the at-risk group.

Table 2. Effects on Internet voting (2013-2023) (reference category: voting on paper)

Source: Authors' calculations

	2013 local	**2014 EP**	**2015 national**	**2017 local**	**2019 national**	**2019 EP**	**2021 local**	**2023 National**
Age: 50-59	-4.16	-0.04	-0.97	0.06	2.55	-3.26	-8.32	-14.10***
(ref: 18-49)	(4.12)	(4.90)	(4.45)	(4.56)	(4.81)	(5.54)	(4.95)	(4.98)
Age: 60-69	-4.43	4.77	11.70*	-9.88	0.74	-3.03	14.62**	-3.19
(ref: 18-49)	(4.54)	(5.93)	(5.10)	(5.40)	(5.39)	(6.14)	(5.31)	(5.17)
Age:70+	-9.20	0.65	3.46	-12.86	-1.14	-4.97	-7.74	-4.69
(ref: 18-49)	(4.71)	(8.22)	(5.78)	(6.78)	(6.60)	(6.75)	(5.16)	(5.67)
PC literacy: v. good or good	13.80***	6.38	11.83***	18.08***	21.41***	12.26	21.78***	26.51***
(ref: poor or basic)	(3.78)	(4.46)	(3.59)	(6.17)	(5.27)	(7.32)	(6.64)	(5.77)
PC literacy: average	18.41***	28.66***	29.94***	33.93***	37.64***	27.92***	36.88***	35.30***
(ref: poor or basic)	(4.55)	(6.54)	(4.71)	(6.62)	(6.06)	(7.83)	(6.82)	(6.05)
Pseudo R2	0.39	0.36	0.25	0.34	0.33	0.30	0.21	0.311
Observations	634	394	637	642	675	547	846	699

Average marginal effects in percentages with standard errors in parentheses. Controls include gender, nationality, education, income level, urban residency and party choice in elections, effects not shown.

* p<0.05, ** p<0.01, *** p<0.00

Let us turn to switching from paper voting to Internet voting; Table 3 depicts the share of respondents who reported having paper-voted previously and Internet-voted in the given election for the first time. We see that in 2021, switching from paper to i-voting was indeed comparatively high at 8%, a figure that is the highest for all local elections in the observed period; the next election in 2023 does not show a similarly high switching rate. However, this share does not stand out either, as a very similar number was observable in the 2019 national election.

Table 3. Share of self-reported voters who switched from paper voting to Internet voting (2013-2023).

Source: Valimised | Elections in Estonia. (n.d.). Retrieved March 4, 2025, from https://www.valimised.ee/

Election	Share out of voters (%)
2013 local	6.82
2014 EP	5.16
2015 national	6.00
2017 local	2.86
2019 national	8.02
2019 EP	4.28
2021 local	8.13
2023 national	6.46

How much less or more likely this switching was among the different age groups is shown in Table 4. It is clear that the data do not support the expectation; the 70+ age group is almost 14 percentage points, the 60-69 year-olds are roughly 18 percentage points, and 50-59 year-olds 17 percentage points less likely to switch from paper to Internet voting compared to the reference group. No other election under investigation shows such strong patterns across all the age groups. We can only conclude that a general switch towards Internet voting among the more at-risk group did not occur.

Table 4. Effects for switching from paper voting to Internet voting (2013-2023) (reference category: voting on paper)

Source: Authors' calculations

	2013 local	**2014 EP**	**2015 national**	**2017 local**	**2019 national**	**2019 EP**	**2021 local**	**2023 national**
Age: 50-59	-11.27**	-0.84	0.82	-21.49*	1.11	3.52	-15.35*	-18.31***
(ref: 18-49)	(3.91)	(9.41)	(3.90)	(8.65)	(5.89)	(5.87)	(6.17)	(5.23)
Age: 60-69	-7.55	9.11	8.39	-16.44	3.05	-5.47	-15.16*	-10.73
(ref: 18-49)	(4.70)	(11.71)	(4.91)	(9.37)	(6.76)	(6.42)	(6.51)	(6.63)
Age:70+	-7.93	24.07	0.26	-21.13*	-0.68	1.10	-12.63	-10.44
(ref: 18-49)	(4.66)	(26.24)	(4.18)	(8.87)	(6.91)	(6.41)	(6.83)	(7.60)
PC literacy: v. good or good	6.23	-	4.97	0.37	12.29**	0.18	3.75	5.06
(ref: poor or basic)	(3.55)	-	(2.87)	(4.69)	(4.22)	(6.60)	(6.19)	(4.56)
PC literacy: average	12.01*	-	17.65**	14.84*	24.79***	10.51	13.10	17.87
(ref: poor or basic)	(4.87)	-	(5.71)	(7.14)	(5.91)	(7.79)	(7.19)	(6.04)
Pseudo R2	0.29	0.33	0.19	0.39	0.30	0.37	0.21	0.31
Observations	393	113	416	176	303	207	343	275

Average marginal effects in percentages with standard errors in parentheses. Controls include gender, nationality, education, income level, urban residency and party choice in elections, effects not shown.

* p<0.05, ** p<0.01, *** p<0.00

We also estimated the same set of models from Tables 1 and 2 with age as a continuous variable and age squared for 2021 separately to see how the qualitative differences between age groups seen in the tables appear as finer quantitative differences across the full range of age. This is shown in Figure 7, and the contrast is dramatic; the older one is consistently lower in Internet voting and switching to Internet voting, with the switching outcome standing out with a steeper negative age effect compared to voting or Internet voting.

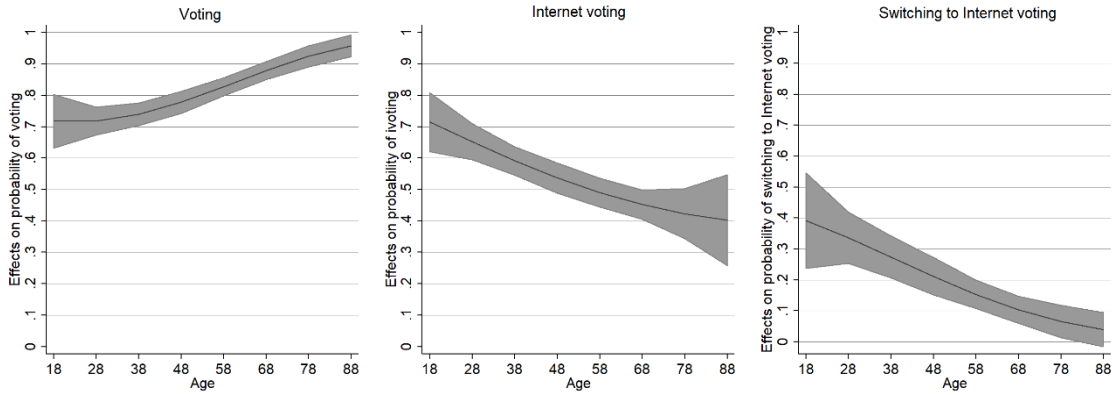

Figure 7. Age effect on voting, Internet voting, and switching to Internet voting probabilities (2021)

Source: Authors' calculations

Finally, to check the conditionality hypothesis, we examine if the at-risk group was more likely to state COVID-19 risks as a consideration, causing the switch from paper to Internet voting. The distribution of the variable itself is shown in Figure 8. For an overwhelming share of Internet voters, this did not seem to be an issue at all; in fact, only a total of 11.1% stated that it was either clearly or very clearly an influence in their Internet voting. We code this variable into a dummy, 'not at all' and 'not clearly' (0) vs. 'clearly' and 'very clearly' (1), and examine it further descriptively and with regression models. The distribution of this variable already suggests that the effects we are looking to test for might not be substantial.

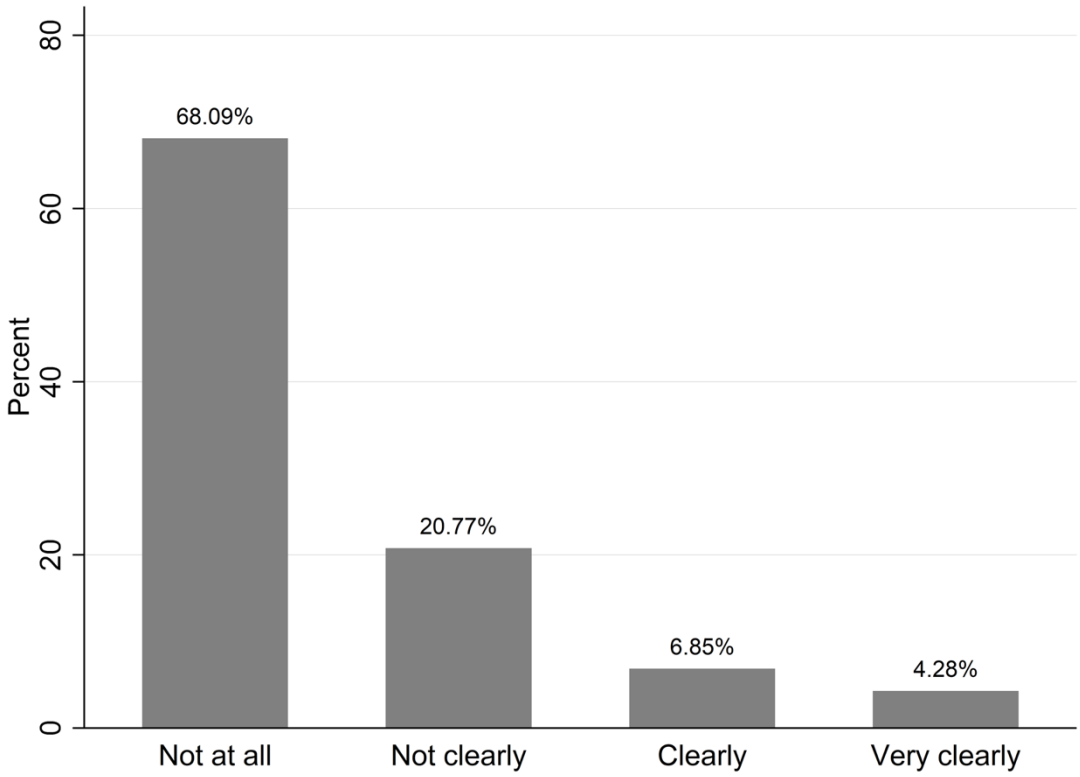

Figure 8. Importance of COVID-19 consideration in choosing Internet voting (2021).

Question-wording: "To what degree did COVID-19-related health risks influence your decision to vote via the Internet rather than in the polling station?"

Source: Authors' calculations

Interestingly, Table 5 Model 1 shows that stating COVID-19 as a reason for using Internet voting does not make it more likely to switch from paper to Internet voting; it also leads to age group effects disappearing, which indicates that the COVID-19 consideration is not systematically age dependent, as the bivariate picture indicated, nor driving vote mode switching, after including other controls. This is quite surprising. A further examination of the interaction between COVID-19 and age groups in Model 2 confirms this. We extracted adjusted predictions for both the COVID-19 variable independently and for all age groups from the models in Figure 8 to better make sense of the coefficients. As one can see, the switching probabilities are a bit higher for those for whom COVID-19 was a consideration, and these differences grow bigger in older age groups, but the differences are not significant.

Table 5. Effects for switching to Internet voting (2021) (reference category: voting on paper)

Source: Authors' calculations

	Model 1	**Model 2**
Age: 50-59	-1.09*	-1.21*
(ref: 18-49)	(0.56)	(0.61)
Age: 60-69	-0.67	-0.19
(ref: 18-49)	(0.58)	(0.58)
Age:70+	-0.87	-1.26*
(ref: 18-49)	(0.53)	(0.63)
COVID-19 consideration	0.24	-0.01
	(0.43)	(0.56)
PC literacy: v. good or good	-1.48*	-1.76*
(ref: poor or basic)	(0.75)	(0.78)
PC literacy: average	-1.71*	-1.90*
(ref: poor or basic)	(0.75)	(0.77)
COVID-19 consideration * Age:50-59	-	1.21
	-	(1.46)
COVID-19 consideration * Age:60-69	-	-
	-	-
COVID-19 consideration * Age:70+	-	1.77
	-	(1.08)
Pseudo R2	0.26	0.29
Observations	439	433

Logit coefficients with standard errors in parentheses. Controls include gender, nationality, education, income level, urban residency and party choice in elections, effects not shown.

* p<0.05, ** p<0.01, *** p<0.00

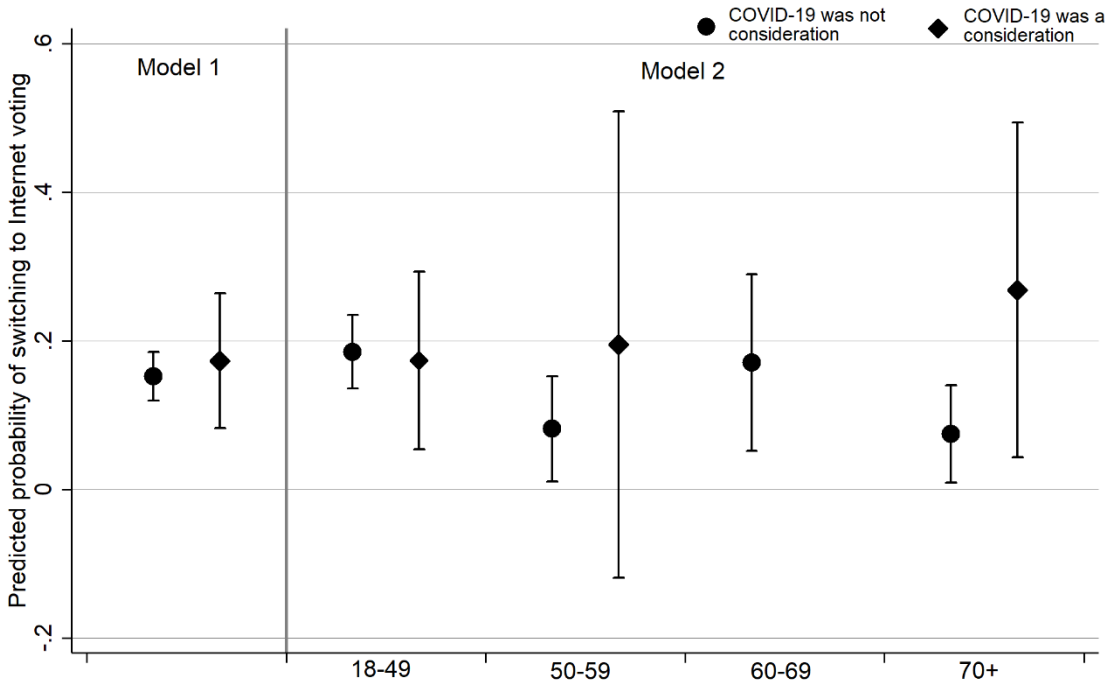

Figure 9. Adjusted predictions of switching to Internet voting from models in Table 5.

Source: Authors' calculations

Finally, we also estimated a model with age as a continuous variable interacted with the COVID-19 consideration; it also mitigates the problem that, due to multicollinearity, we could not estimate the interaction effect for the 60-69-year-old group. The result is shown in Figure 10, older age and stating COVID-19 as a consideration for Internet voting made switching from paper to Internet voting more likely and vice versa when COVID-19 was not stated as a consideration, as we originally expected based on the theory. Nevertheless, again, the effects are not pronounced enough to be significantly different from each other.

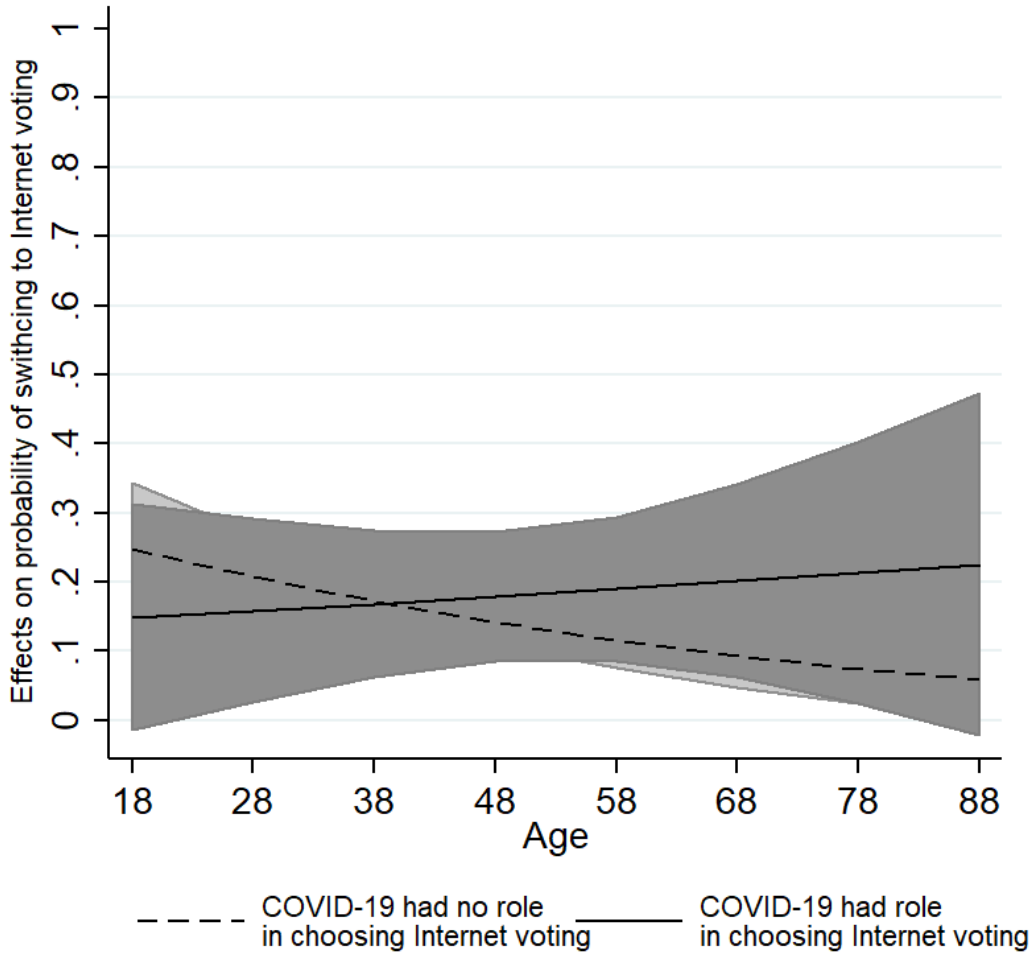

Figure 10. The age-conditioned effect of stating COVID-19 as important in choosing to Internet vote on the probability of switching from paper to Internet voting.

Source: Authors' calculations

5. Discussion

The empirical evidence does not support the hypotheses that COVID-19-induced heightened risk led to a decrease in turnout but an increase in Internet voting usage. This is not observable at the aggregate level, nor does it hold on the individual voter level. Switching to Internet voting among the elderly, who had objectively higher infection risks, also did not become more likely. Switching to Internet voting across age, conditional on perceived COVID-19 risk, did take place, but not to a statistically significant degree after introducing control variables.

All in all, the evidence shows that Internet voting enabled elections at times of the pandemic to proceed in the decidedly usual way, and the typical age associations observed in the past usage also repeated themselves during peak COVID-19 times. What to make of this?

First, it might simply mean that the health-related voting cost increases are not strong enough to cause certain voters to pick up Internet voting if they are otherwise reluctant to use this channel. It could, therefore, be that the voting cost theory is not fitting to explain Internet voting usage or non-usage during COVID-19, or alternatively, pandemic-induced cost differential for Internet and in-person voting was not yet sufficient to lead to voting channel switching for those who had not already done so during normal times.

Secondly, if there is an optimum point from what risk level onward, any inhibiting factors, such as low trust in Internet voting or inability to use a technology-intensive voting channel, will be outweighed by the to-be-avoided risks, which are difficult to determine with the data at hand. The fact that we did not see any age-dependent changes, even with plentiful evidence from other sources that older age groups did change their behavior in other settings, suggests that age itself is not the best proxy for perceived risk level. Older age, in combination with a stated risk-aversion motivation, did suggest some switching to the less risky Internet voting took place, which suggests that age simply accentuated the perceived risk, but not enough to lead to substantial Internet voting uptake. We did test additional interaction effects to see if a low PC skill level or trust among the older age groups were at values that inhibited Internet voting usage, i.e., to see if the heightened risk was strong enough to overrule other barriers of usage, but the evidence was not conclusive, and not all combinations could be estimated with this data. However, even our limited data raises the nuance of trust, both political and technological: elderly citizens could distrust the technology of i-voting and trust the government, which could take all the necessary precautions while organizing the procedures at the polling stations. This might be one of the potential vectors for further studies.

Similarly to the age being a suboptimal variable for the operationalization of perceived risk level, a further limitation concerns the simplifying assumptions embedded in the theoretical model of voting costs. In our framework, the cost differential between Internet and in-person voting was primarily conceptualized in terms of time expenditure, which is indeed a salient dimension in Estonia, where digital infrastructure and access are nearly universal (Ehin & Solvak, 2021; Vassil et al., 2016). However, in other contexts, and even for some groups within Estonia, additional cost components may play a role, such as the cognitive or technical effort required to navigate online authentication, the need for reliable Internet access and suitable devices, or the perceived psychological costs linked to unfamiliar technology, which brings us back to the notion of trust when it comes to the Internet voting usage (Romanov et al., 2025). It could be the case that due to the digital divide, which would serve as an increased transactional barrier, and low trust in the political institutions, those who are susceptible to COVID-19 did not switch from paper voting to Internet voting.

Thirdly, and as a counter-argument to the previous point, we already alluded to the fact that Internet voting is normal, if not the norm, of voting in Estonia now. When voting technology usage by voters has reached a possible saturation level through a normal diffusion process over time, additional uptake increases become less likely. This indicates two explanations for the largely null findings we saw. On the one hand, it might simply mean that those for whom COVID-19 was an issue were already in the Internet voting camp and simply kept on using this voting channel, even when they did report that they did so because of COVID-19 risks to in-person voting. On the other hand, ceteris paribus, this does not mean it is unreasonable to expect some switching to Internet

voting among the paper voting segment, but the level of this is probably a function of how widespread Internet voting already is.

Three explanations of the obtained results revolve around the acceptance and usage of Internet voting, while neglecting the alternative modes of voting that were improved during the COVID-19 pandemic and before that —these improvements were made to traditional, in-person paper-based voting. During both the 2021 and 2023 elections, the Estonian State Electoral Office introduced extensive measures to make polling stations COVID-secure, including enforced distancing, protective equipment for staff, and separate spaces for high-risk voters (COVID-19 and Elections | Elections in Estonia, n.d.). At the same time, the introduction of the electronic voter registry substantially simplified the administrative side of voting, reduced queues since voters could vote from any of the polling stations, and improved the accessibility of polling places (Parliamentary Elections, 5 March 2023, n.d.). With the subsequent development of the electronic voter registry, the polling stations were opened in pop-up tents in both the 2021 and 2023 elections (H. W. ERR ERR News |., 2021; From Monday to Thursday, You Can Vote in 31 Polling Places in Tallinn | Tallinn, 2021), and in 2023, citizens could cast votes at supermarkets, in parallel to other daily chores (A. R. ERR ERR |., 2023). These institutional and logistical adjustments effectively lowered the perceived and actual costs of voting in person, offsetting the pandemic-related health risks that might otherwise have driven voters toward the Internet channel, as illustrated in Figure 8. Hence, the stability in turnout and the lack of additional Internet voting adoption may partly reflect the success of these election management interventions in maintaining the attractiveness and safety of polling-station voting even under pandemic conditions.

6. Conclusion

This study examined whether the COVID-19 pandemic influenced the use of Internet voting in Estonia by increasing its adoption among voters, particularly those at higher risk due to age. Using aggregate election data and individual-level survey responses from multiple elections spanning from 2013 to 2023, the study tested the hypothesis that heightened health risks would lead to a decrease in turnout and an increase in Internet voting adoption, particularly among elderly voters. The findings, however, indicate no significant changes in voter behavior attributable to the pandemic. Turnout remained stable, and while Internet voting usage continued to increase, it did so as part of an existing long-term trend rather than as a direct response to COVID-19 concerns. The study highlights the normalization of Internet voting in Estonia and suggests that the saturation point for its adoption may have been reached, making external shocks like the pandemic less likely to drive additional uptake. While Internet voting ensured that elections proceeded without disruption, the research underscores that it is not a universal solution for maintaining electoral participation during crises. The study calls for further investigation into the specific conditions under which risk perceptions influence voting behavior, particularly among demographics that are less inclined to adopt digital voting methods.

This leads back to our starting question: Is Internet voting "pandemic-proof" for democratic elections? It seems it has already been done in Estonia, as voting remotely via the Internet is normal. So much so that a major societal disruption like a pandemic does not seem to affect voter behavior at all. Nevertheless, even under these conditions, holding everything else constant, some segments of the yet-to-be Internet-vote citizens should be observed switching to using this voting channel, given the possible health risks at polling stations. The fact that we saw very little evidence for this leads to the conclusion that Internet voting is no panacea when in-person voting is potentially disrupted.

At the very least, more empirical research on what level of perceived risk would lead to the uptake of Internet voting among the less technology-inclined voters is needed. What our largely null finding does show, however, is that the wide availability of Internet voting results in a largely unaffected electoral process with no dampening of turnout at the individual level, or any unusual uptake of remote voting among voters – in other words, the functionality of digitalized democracy was not affected in the slightest.

7. Disclosure statement

No potential conflict of interest was reported by the authors.

8. Funding

The work was supported by the European Union's Horizon 2020 research and innovation program under grant agreement No 857622 "ERA Chair in EGovernance and Digital Public Services - ECePS".

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Author Contributions

First Author is the paper lead responsible for writing a literature review, methodology, visualizations, and resources.

Second Author is a significant contributor, who generated the draft research design, who later became in charge of statistical analysis, visualization preparation, and final review of the manuscript.

All authors have read and agreed to the published version of the manuscript.

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Appendix

Appendix A

All surveys are post-election surveys, with fieldwork conducted over 30 days after the election date. The surveys use stratified random samples and are representative of eligible voters in terms of age, gender, citizenship and language, settlement type, and region. The sampling frame was the Estonian Population Registry, which holds demographic data for the whole population, as well as their phone and email addresses. The sampling and surveying were conducted by professional survey companies. Table A1 lists the interview methods and the number of respondents for all the surveys used in this study.

Table A1. Description of post-election surveys used in the study

Post-election survey	Sampling method	Interview method	Number of respondents
2013 local	stratified random sample	CAPI	1042
2014 EP	stratified random sample	CAPI	1001
2015 parliamentary	stratified random sample	CAPI	1007
2017 local	stratified random sample	CATI	1000
2019 parliamentary	stratified random sample	CATI	1000
2019 EP	stratified random sample	CATI	1002
2021 local	stratified random sample	CATI(30%)/CAWI(70%)	1153
2023 parliamentary	stratified random sample	CATI(20%)/CAWI(80%)	1001

Note: CAPI – computer-assisted personal interview, CATI – computer-assisted telephone interview, CAWI – computer-assisted web interview.

Appendix B. Question Wording

Table B1. Question wording and recoding of the main variables of interest

Variable	Question	Note
Turnout	Did you vote in [current] election? 1. Yes 2. No 3. Refusal 4. DK	Recoded as: 1. → 1. Yes 2. → 0. No
Internet voting	How did you vote? 1. Voted on the election day 2. Voted in an advance polls at polling station 3. Voted in an advance polls by Internet 4. Other 5. Refusal 6. DK	Recoded as: 1. → 0. No 2. → 0. No 3. → 1. Yes
Switching	(2013-2019) How did you vote in the [previous election] in [year]? 1. Voted on the election day 2. Voted in an advance polls at polling station 3. Voted in an advance polls by Internet 4. Other 5. Refusal 6. DK (2021-2023) Have you ever e-voted? 1. Yes, I have e-voted in the past 2. No, I have never e-voted 3. Refusal 4. DK	The variable was created by coding people who previously voted on paper and in the current election via the Internet as switchers (1) and the ones who voted via the Internet and did so also in the current election as repeat Internet voters (0).
Age	What is your age?	No transformation
COVID-19 consideration in voting	To what degree did COVID-19-related health risks influence your decision to vote via the Internet rather than in the polling station? 1. Not at all 2. Not clearly 3. Clearly 4. Very clearly 5. Refusal 6.DK	Recoded for model in Table 6 as: 1. to 2. → 0. No 3. to 4. → 1. Yes
PC literacy	How do You evaluate Your computer skills? Are they: 1. Very good 2. Good 3. Average 4. Basic 5. Poor or no computer skills 6. Refusal 7. DK	Recoded as: 1. to 2. → 1. Good, very good 3. → 2. Average 4. → 3. Basic or poor 5. → 3. Basic or poor

Appendix C. Pooled model

Table C1. Effects on voting (2013-2023) (reference category: not voting). The coefficient values are rounded to two decimals.

Category	Coef.	Std. Err.	P>z
age_group3 (ref: 18-49)			
Age: 50-59	.69***	.1110414	0.000
Age: 60-69	1.11***	.1182674	0.000
Age:70+	1.82***	.136988	0.000
election			
2014 EP	-.69***	.022861	0.000
2015 national	.56***	.0085298	0.000
2017 local	.33***	.072735	0.000
2019 national	.34***	.0732031	0.000
2019 EP	-.57***	.0677094	0.000
2021 local	.52***	.0170609	0.000
2023 national	.60***	.0373908	0.000
age_group3#election (ref: 18-49×2013 local)			
Age: 50-59×2014 EP	.12*	.0487442	0.011
Age: 50-59×2015 national	.05	.0595113	0.411
Age: 50-59×2017 local	-.04	.066046	0.581
Age: 50-59×2019 national	-.11	.0964731	0.242
Age: 50-59×2019 EP	-.22*	.0685005	0.001
Age: 50-59×2021 local	-.05	.1044608	0.662
Age: 50-59×2023 national	.11	.1102073	0.338
Age: 60-69×2014 EP	.86***	.0297357	0.000
Age: 60-69×2015 national	-.16***	.0422705	0.000
Age: 60-69×2017 local	-.33***	.0208686	0.000
Age: 60-69×2019 national	.11*	.0329068	0.001
Age: 60-69×2019 EP	.005	.0370654	0.886
Age: 60-69×2021 local	-.13*	.0429327	0.002
Age: 60-69×2023 national	-.48***	.0762766	0.000
Age:70+×2014 EP	-.09*	.0370292	0.013
Age:70+×2015 national	-.63***	.0559159	0.000
Age:70+×2017 local	-.98***	.0430788	0.000
Age:70+×2019 national	-.16***	.0355956	0.000
Age:70+×2019 EP	-.41***	.0437721	0.000
Age:70+×2021 local	-.36***	.0873554	0.000
Age:70+×2023 national	-.52***	.0747613	0.000
pclit_ordinal_1			
2	.33***	.0883318	0.000
3	.56***	.1039562	0.000
male	.08	.0493806	0.101
estonian	.66**	.2267588	0.004

educ_high	1.34***	.1056108	0.000
educ_secondary	.69***	.1250426	0.000
educ_vocational	.77***	.0972003	0.000
income_deciles	.05**	.019706	0.009
urban	.12	.1006458	0.229
_cons	-1.49***	.3257133	0.000
Pseudo R2	0.111		
Observations	6733		

Logit coefficients with standard errors clustered by election in parentheses. Controls include gender, nationality, education, income level, and urban residency; effects not shown.

* p<0.05, ** p<0.01, *** p<0.00

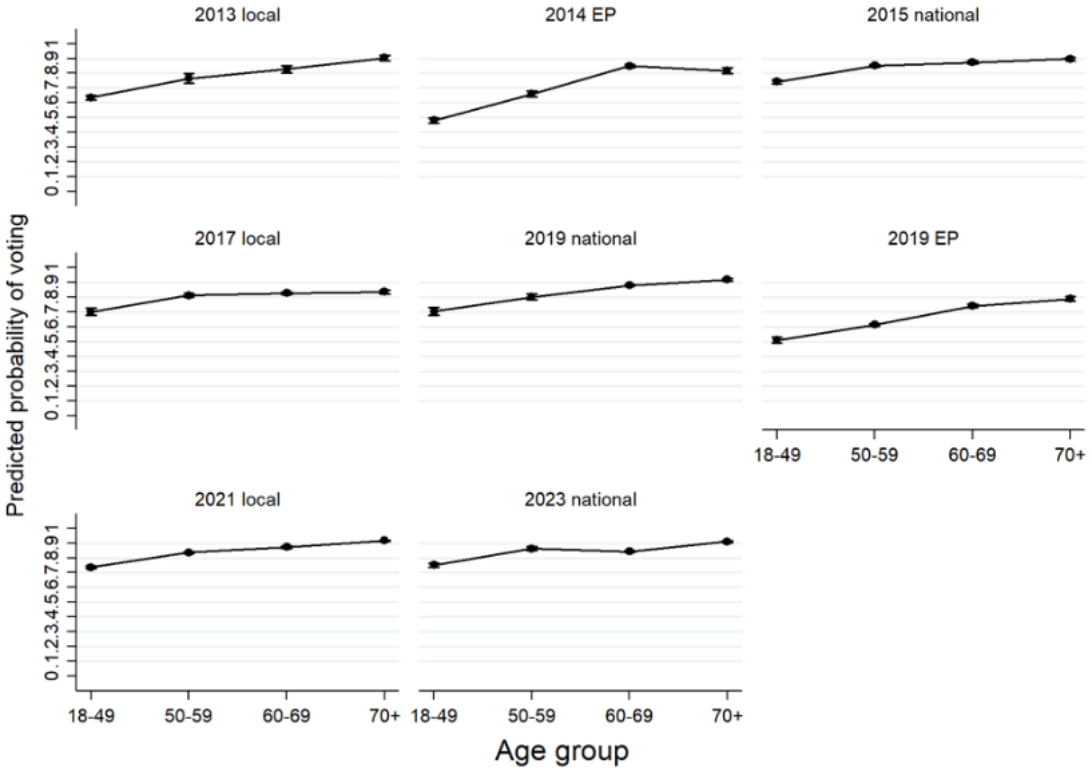

Figure C1. Predicted probability of voting for age groups conditional on year (pooled model 2013 to 2023 with age group interacted with the election).

Table C2: Effects on Internet voting (2013-2023) (reference category: voting on paper). The coefficient values are rounded to two decimals

Category	Coef.	Std. Err.	P>z
age_group3 (ref: 18-49)			
Age: 50-59	-0.23***	0.0458025	0.000
Age: 60-69	-0.18**	0.0675085	0.008
Age:70+	-0.51***	0.0892253	0.000
election			
2014 EP	-0.11***	0.0292908	0.000
2015 national	-0.10***	0.024733	0.000
2017 local	0.61***	0.0460336	0.000
2019 national	0.66***	0.054069	0.000
2019 EP	1.03***	0.0347083	0.000
2021 local	1.38***	0.0704952	0.000
2023 national	1.02***	0.0865954	0.000
age_group3#election			
Age: 50-59×2014 EP	0.01***	0.0201437	0.600
Age: 50-59×2015 national	0.03	0.0214107	0.153
Age: 50-59×2017 local	0.22***	0.0216668	0.000
Age: 50-59×2019 national	0.38***	0.0317497	0.000
Age: 50-59×2019 EP	0.08*	0.0276812	0.005
Age: 50-59×2021 local	-0.07	0.0375931	0.051
Age: 50-59×2023 national	-0.46***	0.06039	0.000
Age: 60-69×2014 EP	-0.07*	0.0311362	0.018
Age: 60-69×2015 national	0.62***	0.0214544	0.000
Age: 60-69×2017 local	-0.43***	0.0246875	0.000
Age: 60-69×2019 national	0.11***	0.0171432	0.000
Age: 60-69×2019 EP	0.12***	0.0313991	0.000
Age: 60-69×2021 local	-0.41***	0.0377316	0.000
Age: 60-69×2023 national	0.12*	0.0463887	0.012
Age:70+×2014 EP	-0.31***	0.0421562	0.000
Age:70+×2015 national	0.36***	0.042079	0.000
Age:70+×2017 local	-0.27***	0.0363273	0.000
Age:70+×2019 national	0.39***	0.0584572	0.000
Age:70+×2019 EP	0.29***	0.0478835	0.000
Age:70+×2021 local	0.33***	0.0570151	0.000
Age:70+×2023 national	0.49***	0.0717976	0.000
pclit_ordinal_1			
2	1.19	0.0976701	0.000
3	1.88***	0.0935771	0.000
male	0.29**	0.1053026	0.005
estonian	0.83***	0.153234	0.000
educ_high	0.79***	0.1983125	0.000
educ_secondary	0.33**	0.1192597	0.005
educ_vocational	0.29	0.1855754	0.106

income_deciles	0.03	0.0205776	0.146
urban	-0.12	0.0669409	0.078
votechoice			
Reform	0.91***	0.1020658	0.000
ProPatria_Resp	0.567**	0.215591	0.009
Pseudo R2	0.256		
Observations	5074		

Logit coefficients with standard errors clustered by election in parentheses. Controls include gender, nationality, education, income level, urban residency, and party choice; effects not shown.

* p<0.05, ** p<0.01, *** p<0.00

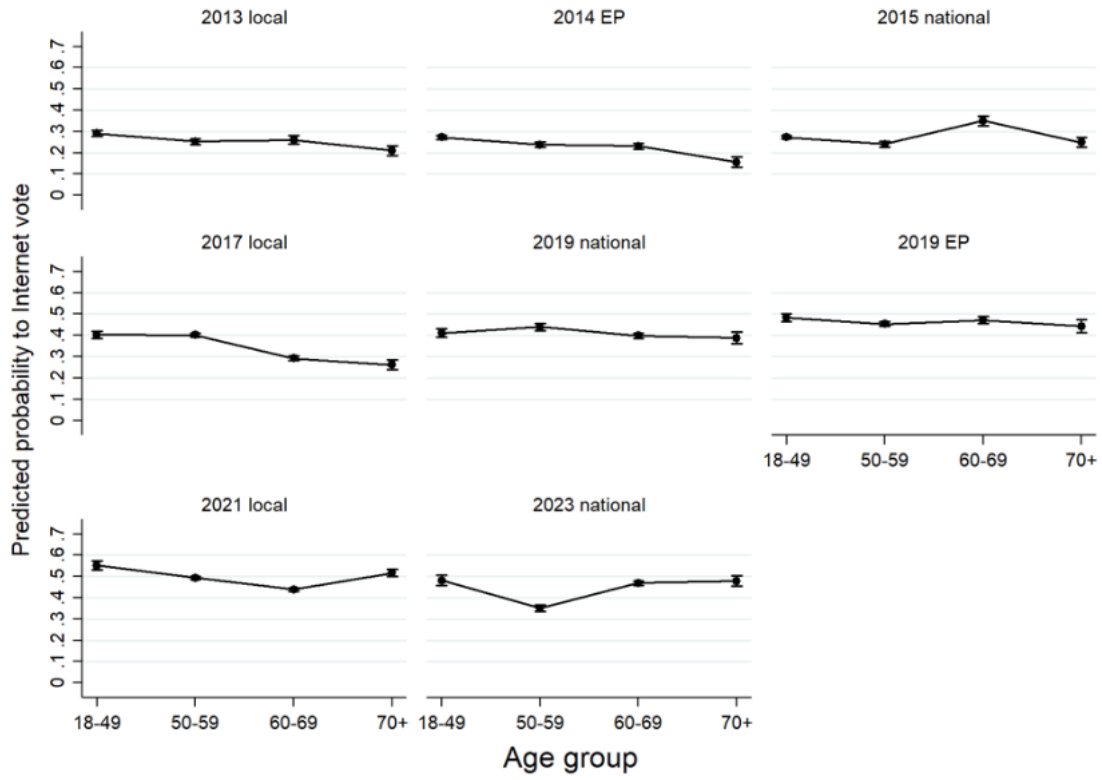

Figure C2. Predicted probability of casting an Internet vote for age groups, conditional on year (pooled model 2013 to 2023 with age group interacted with the election).

Table C3: Effects for switching from paper voting to Internet voting (2013-2023) (reference category: paper voter). The coefficient values are rounded to two decimals.

Category	**Coef.**	**Std. Err.**	**P>z**

age_group3 (ref: 18-49)			
Age: 50-59	-1.40***	0.11	0.00
Age: 60-69	-0.55***	0.13	0.00
Age:70+	-0.43*	0.16	0.01
election			
2014 EP	-0.63***	0.06	0.00
2015 national	-0.77***	0.04	0.00
2017 local	-0.18	0.14	0.19
2019 national	0.12	0.13	0.37
2019 EP	-0.36***	0.10	0.00
2021 local	0.64***	0.13	0.00
2023 national	0.29	0.15	0.06
age_group3#election			
Age: 50-59×2014 EP	1.01***	0.11	0.00
Age: 50-59×2015 national	1.50***	0.09	0.00
Age: 50-59×2017 local	-0.57***	0.12	0.00
Age: 50-59×2019 national	1.47***	0.08	0.00
Age: 50-59×2019 EP	1.75***	0.10	0.00
Age: 50-59×2021 local	0.45***	0.08	0.00
Age: 50-59×2023 national	-0.55***	0.12	0.00
Age: 60-69×2014 EP	0.27**	0.11	0.02
Age: 60-69×2015 national	1.53***	0.06	0.00
Age: 60-69×2017 local	-0.48***	0.08	0.00
Age: 60-69×2019 national	0.30***	0.04	0.00
Age: 60-69×2019 EP	-0.77***	0.08	0.00
Age: 60-69×2021 local	-0.32***	0.09	0.00
Age: 60-69×2023 national	-0.16	0.16	0.31
Age:70+×2014 EP	-0.62	0.11	0.00
Age:70+×2015 national	0.67***	0.08	0.00
Age:70+×2017 local	-0.78***	0.09	0.00
Age:70+×2019 national	0.35***	0.10	0.00
Age:70+×2019 EP	0.15	0.11	0.19
Age:70+×2021 local	-0.48***	0.15	0.00
Age:70+×2023 national	-0.39***	0.13	0.00
pclit_ordinal_1			
2	1.01***	0.19	0.00
3	1.91***	0.28	0.00
male	0.14	0.19	0.48
estonian	0.29	0.34	0.39
educ_high	0.57*	0.25	0.02
educ_secondary	0.39*	0.19	0.04
educ_vocational	0.16	0.33	0.63
income_deciles	-0.02	0.03	0.46

urban	-0.20	0.22	0.36
votechoice			
Reform	0.58	0.32	0.07
ProPatria_Resp	0.28	0.31	0.37
Social Democrats	0.55*	0.22	0.01
EKRE	-0.70	0.54	0.19
Estonia 200	1.10***	0.26	0.00
Other	0.01	0.35	0.98
_cons	-3.50	0.51	0.00
Pseudo R2	0.12		
Observations	2406		

Logit coefficients with standard errors clustered by election in parentheses. Controls include gender, nationality, education, income level, urban residency, and party choice; effects not shown.

* p<0.05, ** p<0.01, *** p<0.00

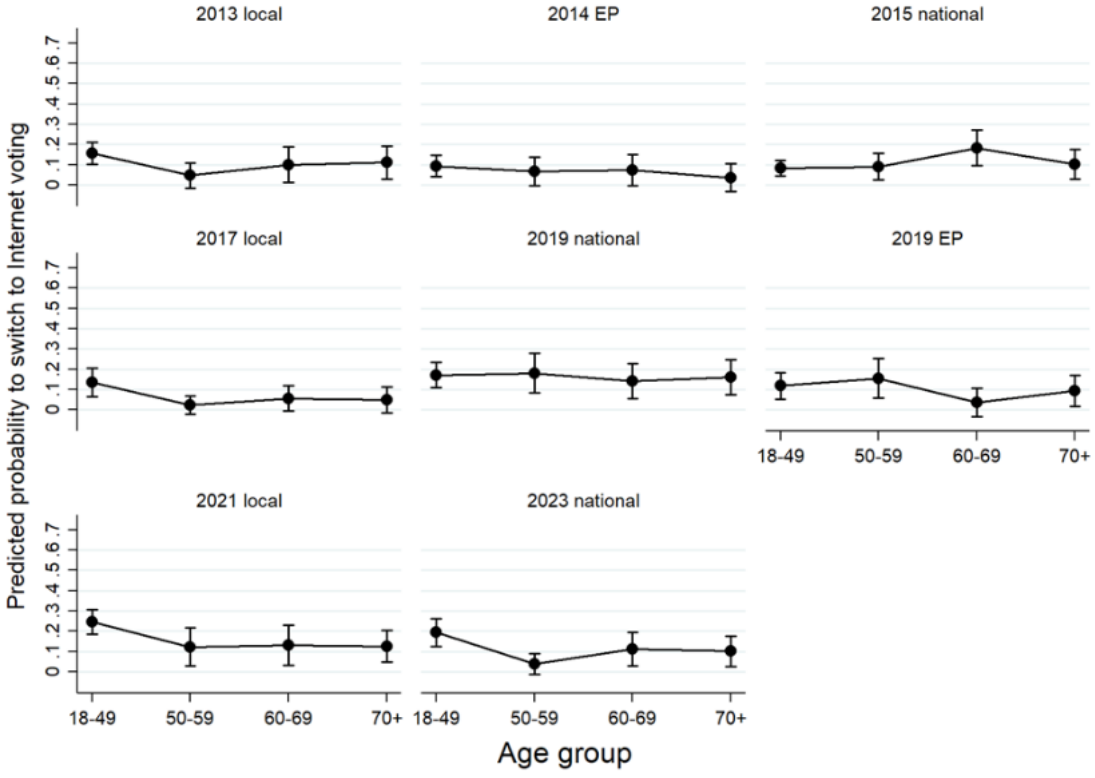

Figure C3. Predicted probability to switch to Internet voting for age groups, conditional on year (pooled model 2013 to 2023 with age group interacted with election).

