

Pressing the Button for European Elections: Verifiable e-voting and public attitudes toward internet voting in Greece

Alex Delis, Konstantina Gavatha, Aggelos Kiayias, Charalampos Koutalakis, Elias Nikolakopoulos, Lampros Paschos, Mema Rousopoulou, Georgios Sotirellis, Panos Stathopoulos, Pavlos Vasilopoulos, **Thomas Zacharias**, Bingsheng Zhang

The FINER Research Team
Department of Political Science and Public Administration &
Department of Informatics and Telecommunications
University of Athens



HELLENIC REPUBLIC
National and Kapodistrian
University of Athens

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Motivation

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- Acceptance by voters is a necessary parameter for the development of e-voting.
- The literature related to evaluating attitudes toward e-voting (particularly in Europe) remains scarce.
 - **Latin America:** Alvarez *et al.* [2009]
 - **United States:** Sherman *et al.* [2010]
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 - **United States:** Sherman *et al.* [2010]
 - **Norway:** Baldersheim *et al.* [2012]
- Deployment of an end-to-end verifiable e-voting system in a real-world setting.

Greece as a case of study

- Greece is ranked low among European countries in familiarity with internet use and technology literacy (especially in the older age groups).

Age cohort	Daily		Often		Never	
	EU	Greece	EU	Greece	EU	Greece
15-24	86	81	12	19	2	0
25-39	77	78	18	18	5	4
40-54	61	42	24	31	15	27
55+	40	16	21	19	39	65

Table: Frequency of internet use in EU and Greece (2012).
The entries are in percent form.

- Greece serves as an ideal example that adds to the research on evaluating attitudes toward electronic voting in Europe.

Our contribution

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- (ii). We investigate the impact of three key components of acceptance of an e-voting system:
 - (a) the perceived easiness of the e-voting system,
 - (b) participants' willingness to see the system being adopted for national elections (trust in the e-voting system) and
 - (c) participants' attitudes towards casting their vote remotely via an e-voting system.

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 - (a) the perceived easiness of the e-voting system,
 - (b) participants' willingness to see the system being adopted for national elections (trust in the e-voting system) and
 - (c) participants' attitudes towards casting their vote remotely via an e-voting system.
- (iii). We present an ordinary least squares (OLS) regression analysis of our results.

Overview of the e-voting system Demos

- Demos is a remote code-voting system.
- In order to support **end-to-end verifiability** and **voter privacy**, Demos utilizes
 - 1 the *double ballot* idea,
 - 2 *perfectly binding homomorphic commitments* and
 - 3 suitably designed *zero-knowledge (ZK) proofs*.

Overview of the e-voting system Demos: Setup

- An **election authority** (EA) generates ballots that have a unique serial number and consist of two equivalent parts (A and B) containing the list of candidates associated with a randomly generated **vote-code**, paired with a **vote-code recording receipt**.

Candidate	Vote-code	Receipt
Alice	AAAA-1111	REC1
Bob	BBBB-2222	REC2
Charlie	CCCC-3333	REC3
David	DDDD-4444	REC4

Ballot No.100(A)

Candidate	Vote-code	Receipt
Alice	EEEE-5555	REC5
Bob	FFFF-6666	REC6
Charlie	GGGG-7777	REC7
David	HHHH-8888	REC8

Ballot No.100(B)

- The double ballots are distributed in paper form randomly, so that the serial numbers are in no way linked with the voters.

Overview of the e-voting system Demos: Setup

Σειριακός αριθμός: 117 Σειριακός αριθμός: 117

Πολιτικό κόμμα	Κωδικός Α	Απόδειξη Α	Πολιτικό κόμμα	Κωδικός Α	Απόδειξη Α
Ε. Αντάρτικο	JUTS-R CD- TMOH	T89J00	ΑΝΤΑΡΞΙΑ	04P0-J CV- PCK0	598V2M
ΟΚΔΕ	H02>-EDP- B85C	C Q8A4B	Α.Σ.Κ.Ε.	QLOM-5TQ7-0E1V	38P05P
Σ.Εθν.Ενωτ.	4W4H-80KE-49V6	G0N89X	Κοινωνία	YH6D-6JVS-VY72	20332I
Κ.Ε.ΑΝ.	5K0V-8H4G-ZDCT	G2E3H1	Κ.Κοινωνία	463S-8M5P-0J5I	9U654B
Α.Α.Ο.Σ.	ADY9-FCBJ-M79C	N0E3EH	Ε.Μετα. Κοινότη.	8E2S-88S5-#75H	74LW84A
ΚΚΕ	5QYV-6E7P-QDOR	C8E4B1	Το Ποτάμι	0L4F-FQI5-6LWE	H0204I
Χρυσή Άνοιξη	5QMT-0F8G-ARJ2	QHFV98	Χρυσή Άνοιξη	KD5P-5QK3-R6P1	2M0J8B
Γεωργικός	UC5A-HL8P-9JUS	8LL318	Ε.ΕΚ. Τροφικ.	Q8Z7-1548-229P	U03C9P
Αισιό	HT8V-CZCZ-R9XG	QF3OM3	Βιολογ. Οκ.	AK3X-54Y5-T9M6	16J984
ΕΓΝΩ	MUXC-C6LJ-Z858	K115QW	Ο.Α.Κ.ΚΕ.	4W2Z-2R05-7Q25	52C37E
Ελευθερία	3V8Z-3UKC-QQ2I	F0894D	Δ.Η.Μ.ΑΡ.	ΔΥVJ-LYMF-HM8	CW656F
Εθν.Μεταπο	JH0B-8H6Q-6NEP	Q5743Q	Ελλά	POZ3-C70M-8T1Q	4L00Q3
Πρόοδος	00KE-0ZDZ-8827	50862S	Μ.Α.Κ.ΚΕ.	888X-LPFS-Y1VC	H0MHO7
ΝΔ	49WM-877A-GQZ3	78CJ0M	Κοινωνία	0M7P-7UKH-FF7H	1Y647P
Επίσης Πολιτ.	DP2V-0M6D-4P8H	SJN8L0	ΗΩΡΟΠΟΥΛΩ ΟΤΩ6	G055QP	
Αρσίνη	28VQ-0J5Z-864J	HN8ZR2	Οκ. Πρ. Περ.	HNQZ-39AQ-94EX	6H464F
Ε.Βιολογ.Στοιμ.	512R-7UKH-PPFS	G2O333	Ε.Υ.Περ.Αισιό	3UAE-C4S1-G0W4	40SU12
Συμβίοθ	0MT-AN7D-SQDQ	WY9P9S	Συνεκ.Κιμ.	AMH-850V-882R	6L54P0
Β3.Ε.εργ.Πολ.	K03H-0F8D-4D56	DVMFPM	ΣΥΡΙΖΑ	4E1V-JN2D-RGCD	8T7HCJ
Κοινων. Αδελφ.	500E-5870-966Q	8P396C	ΑΚΡΕΛΑ	89H-C-0H8-MP0C	08P50A
Ε.Α.Α.Α.Σ.	28KE-AK10-F96QM	FK131FO	ΑΝ.Ε.ΛΑ	DAT3-QNHQ-300K	TAL3U6A



A

Εξυπηρητητής Ψηφοδελτίου FINER <http://tal.di.uoa.gr/finerabb/1B/>

Παρακαλούμε χρησιμοποιήστε οπισθοπίση από τις δύο πλευρές αυτού του φύλλου.

Σειριακός αριθμός: 117 Σειριακός αριθμός: 117

Πολιτικό κόμμα	Κωδικός Β	Απόδειξη Β	Πολιτικό κόμμα	Κωδικός Β	Απόδειξη Β
Ε. Αντάρτικο	CY9-EQW3-1CV2	GHTP53	ΑΝΤΑΡΞΙΑ	YV7T-ANQJ-6P8E	30KQ5L
ΟΚΔΕ	C3C5-ZOQP-RM07	F38J4H	Α.Σ.Κ.Ε.	8WJ0-HU8Z-E1AS	024L8R
Σ.Εθν.Ενωτ.	5285-L96Z-4EP	35GL9H	Κοινωνία	PPUP-AS2V-396	Z7H8Z2
Κ.Ε.ΑΝ.	30EH-79MM-F8D1	V5ZM9E	Κ.Κοινωνία	UEEP-AJQF-6Z0G	3F06EX
Α.Α.Ο.Σ.	686X-3APV-T3E2	P4L48R	Ε.Μετα. Κοινότη.	3P9U-858K-GZ8R	7C35U6
ΚΚΕ	X3UN-T804-VK7K	F7Y74L	Το Ποτάμι	M6XC-AYTP-AF4X	3FV46I
Χρυσή Άνοιξη	5VCB-K7QZ-3PQ2	05UC0P	Χρυσή Άνοιξη	8F0E-80XJ-K0XQ	DH058H
Γεωργικός	MQ3F-DL8C-8E55	AT2X31	Ε.ΕΚ. Τροφικ.	8Y9V-683B-S46C	PF0M7N
Αισιό	YH0Q-009P-RF2J	E4W6N9	Βιολογ. Οκ.	FR8G-8WVC-51Y5	NF0FHD
ΕΓΝΩ	0CD-8F95-K48D	BYS12Z	Ο.Α.Κ.ΚΕ.	30MP-WA3P-XF59	LMPZDE
Ελευθερία	8K8S-0T35-26X6	C08DKY	Δ.Η.Μ.ΑΡ.	H0K4-6L2S-Q4P0	3LRJ3N
Εθν.Μεταπο	8WNA-88P0-87E3	PTAJOT	Ελλά	3E2X-0ZUS-020K	LNEJLU
Πρόοδος	57DZ-3P7F-639H	U0EQXQV	Μ.Α.Κ.ΚΕ.	CSAO-FL7B-G246	H8P8H1
ΝΔ	08H-QC58-4Y8R	AAQJ3U	Κοινωνία	J0CA-8W8Q-86DH	G2X5AN
Επίσης Πολιτ.	UPV7-36Q6-VE4R	38W46L	ΠΑΝ.ΚΙ.	FR9V-V5DT-MY87	TUT45E
Αρσίνη	CAAD-HY0D-VK0N	3DE827	Οκ. Πρ. Περ.	D5Q5-H0H4-8M0W	H7L8QZ
Ε.Βιολογ.Στοιμ.	98TF-H09M-G2U5	0UJ5Y7	Ε.Υ.Περ.Αισιό	80T3-Y8C8-589X	HSYJ0C
Συμβίοθ	3648-Y2V5-7M65	F4F4QJ	Συνεκ.Κιμ.	N8D4-SH0T-7H QV	3E496R
Β3.Ε.εργ.Πολ.	LDGQ-5YF6-QQ27	39P3M7	ΣΥΡΙΖΑ	8C0E-8FUC-030K	FR653W
Κοινων. Αδελφ.	27E7-N08H-09M0	M4UJ3M	ΑΚΡΕΛΑ	FLUC-8K8H-TUEE	026V87
Ε.Α.Α.Α.Σ.	0333-M160-522F	C9P02W	ΠΑΝ.Ε.Λ.	NP0D-28CF-R00P	7M85TH



B

Εξυπηρητητής Ψηφοδελτίου FINER <http://tal.di.uoa.gr/finerabb/1B/>

Παρακαλούμε χρησιμοποιήστε οπισθοπίση από τις δύο πλευρές αυτού του φύλλου.

Overview of the e-voting system Demos: Setup

- The EA uses the commitment scheme to tabulate all ballots in committed form along with ZK proofs for the correct formation of the ballots. It posts all the audit information on a **public bulletin board** (BB).
- EA provides a **bulletin board authority** (BBA) with the list of pairs of vote-codes and vote-code recording receipts.
- EA provides a **keyholder** (a distributed authority) with the decommitment information needed that will be used for audit on the BB.
- At the end of the setup phase, the working tape of the EA is destroyed.

Overview of the e-voting system Demos: Vote-casting

Candidate	Vote-code	Receipt
Alice	AAAA-1111	REC1
Bob	BBBB-2222	REC2
Charlie	CCCC-3333	REC3
David	DDDD-4444	REC4

Ballot No.100(A)

Candidate	Vote-code	Receipt
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Ballot No.100(B)



BBA

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Ballot No.100(B)



AAAA-1111

Open (B)

(1 bit)

BBA

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Ballot No.100(B)



REC1

BBA

Overview of the e-voting system Demos: Tally and result announcement

- The KH provides BBA with the de-commitment information and ZK proof information.
- BBA opens all the vote-code commitments and marks as “voted” all encoded candidate commitments that are associated with cast vote-codes.
- BBA adds (homomorphically) all the marked commitments and opens their sum, which is the election result in encoded form.
- BBA opens all information for the ballot parts that were used for auditing.

Overview of the e-voting system Demos: Tally and result announcement

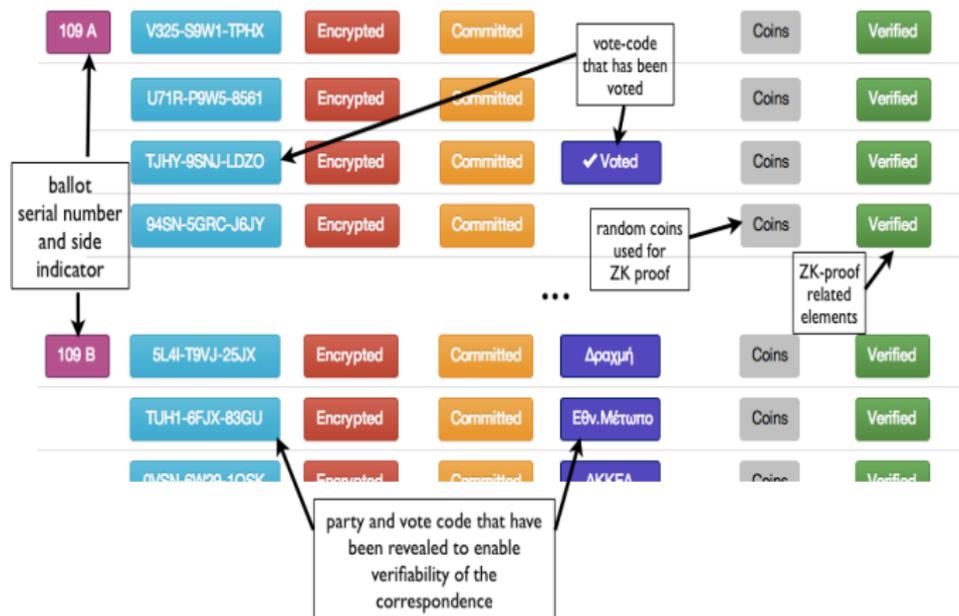


Figure: Ballot information on the BB after tally and result announcement.

Overview of the e-voting system Demos: Verification

- 1 Any party can **compute the election result**.
- 2 Any party can verify that **the ballots are well-formed**.
- 3 **Ballot auditing**: the voter can verify that her ballot was not altered by a malicious party by checking that the opening of the ballot part used for auditing matches the one that she has obtained.

Overview of the e-voting system Demos: E2E verifiability (against complete corruption of authorities)

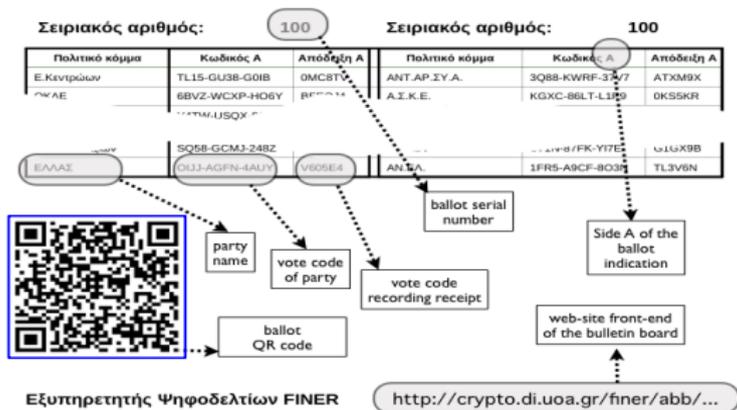
- The adversary cannot inject multiple votes via invalid encodings (except from some negligible soundness error of the ZK proofs).
- The adversary cannot know in advance which side the voter is going to use, so any malicious behaviour will be detected with probability $1/2$ by the voter.
- If the adversary attempts to alter t ballots, it will be caught with $1 - (1/2)^t$ probability.
- Assuming a large enough number of voters, we verify that almost all votes have been counted correctly with high probability.

Overview of the e-voting system Demos: Voter privacy (against a threshold of malicious authorities)

- The working tape of the EA is destroyed after setup.
- The KH is distributed.
- The distribution of the ballots is random.
- The only information that the voter keeps from the used ballot part is the vote-code she submitted.
- Opening the whole information of the unused ballot part does not reveal how the voter has voted.

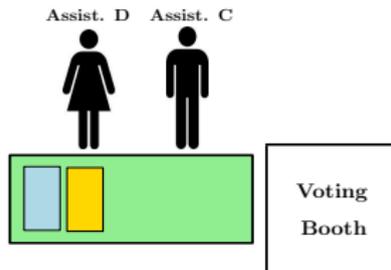
The pilot experiment: Implementation of Demos

Each participant received a paper ballot where in each facet, besides the lists of candidates, vote-codes and vote-code recording receipts, there was a QR code.

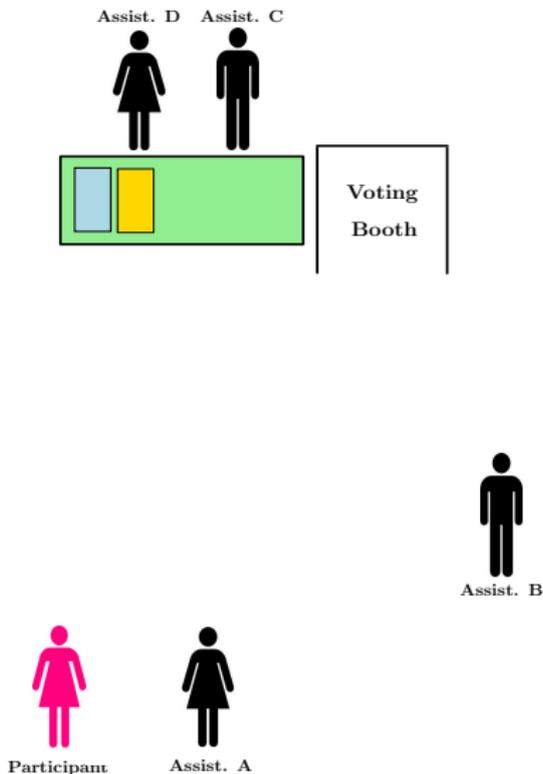


Voters used tablets with cameras to scan the paper ballots and voted electronically through a *web interface*.

The pilot experiment: Setup of the polling stations

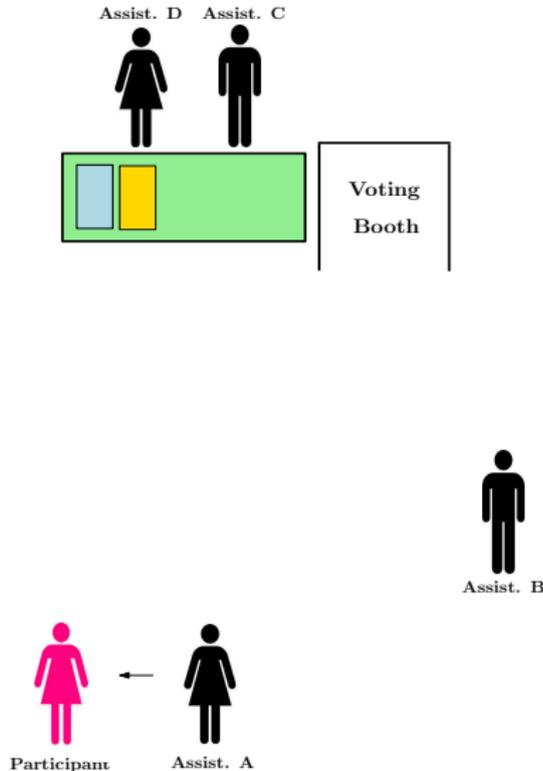


The pilot experiment: Run of the experiment



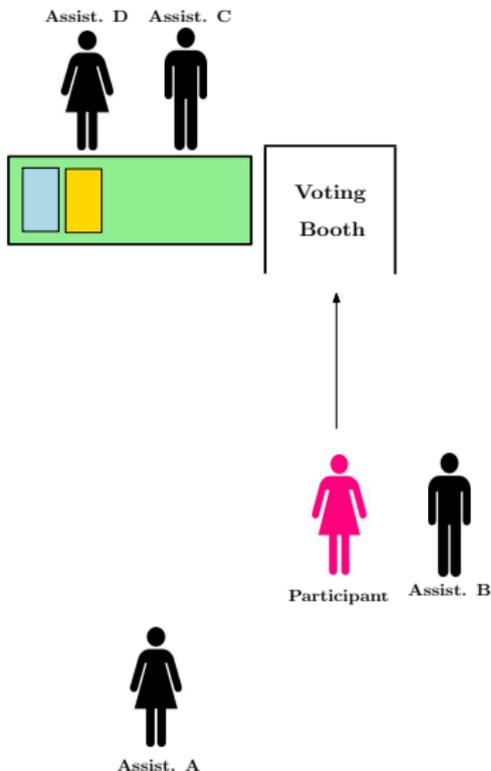
Assistant A was responsible for calling one out of every four voters that had already participated in the conventional elections, to participate in the e-voting procedure.

The pilot experiment: Run of the experiment



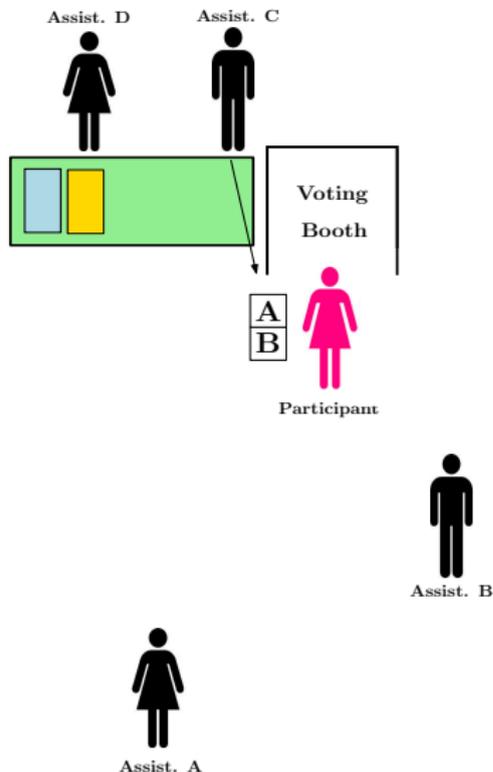
Assistant A was responsible for calling one out of every four voters that had already participated in the conventional elections, to participate in the e-voting procedure.

The pilot experiment: Run of the experiment



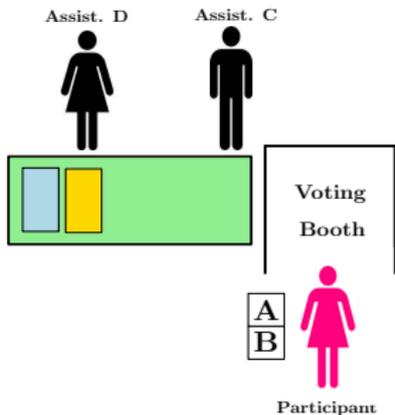
Assistant B accompanied the participant to the desks with the tablets.

The pilot experiment: Run of the experiment



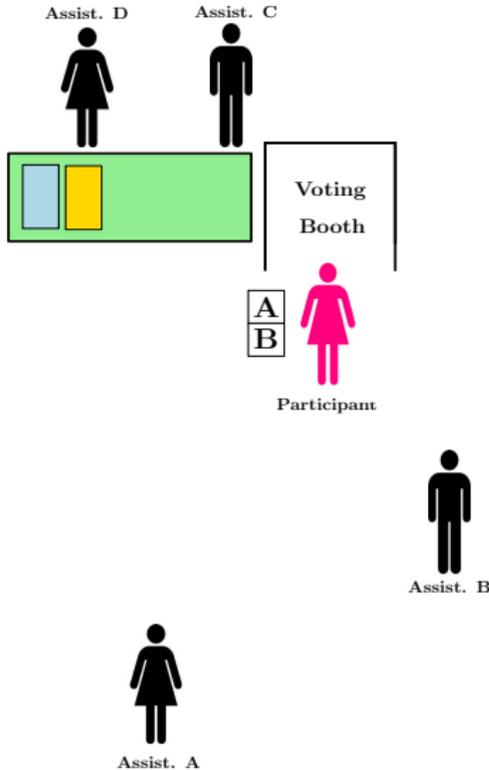
Assistant C or Assistant D were helping the participant to randomly pick a ballot from a stack and to explain to her how she could vote via our setting.

The pilot experiment: Run of the experiment



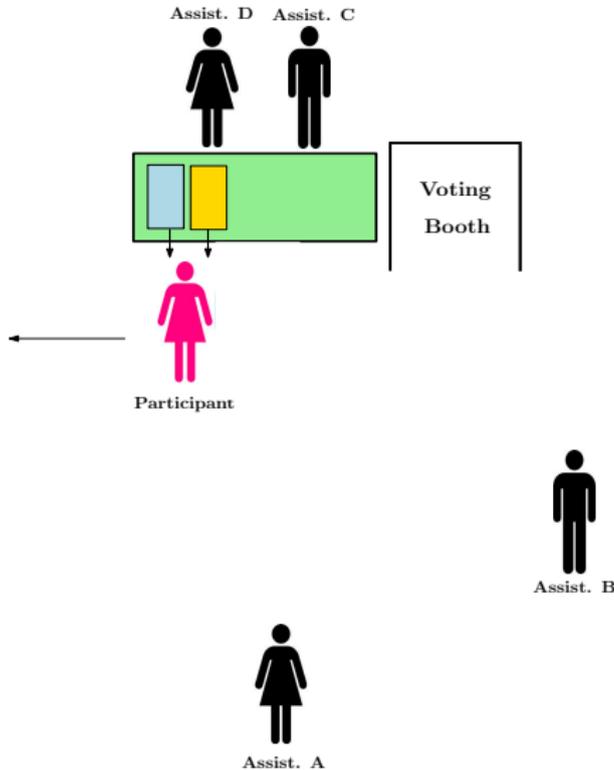
The participant used the device to scan the QR code on her paper ballot.

The pilot experiment: Run of the experiment



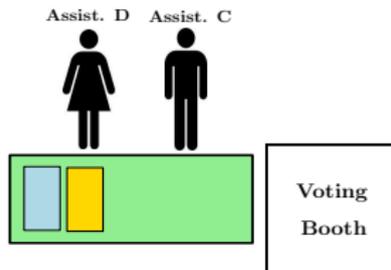
The participant used the device to scan the QR code on her paper ballot. Next, she was prompted to a website where she could (optionally) complete a questionnaire online.

The pilot experiment: Run of the experiment



Before leaving, the participant was given two leaflets containing (i) information about the e-voting system function and (ii) directions for successful verification.

The pilot experiment: Run of the experiment

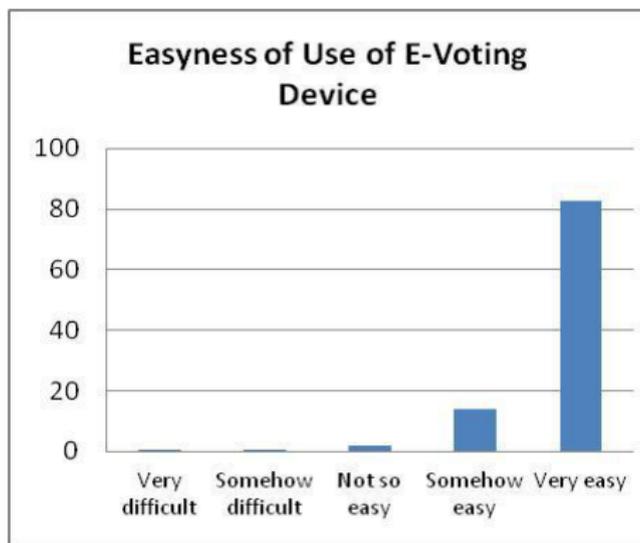


Results

Results: Participation

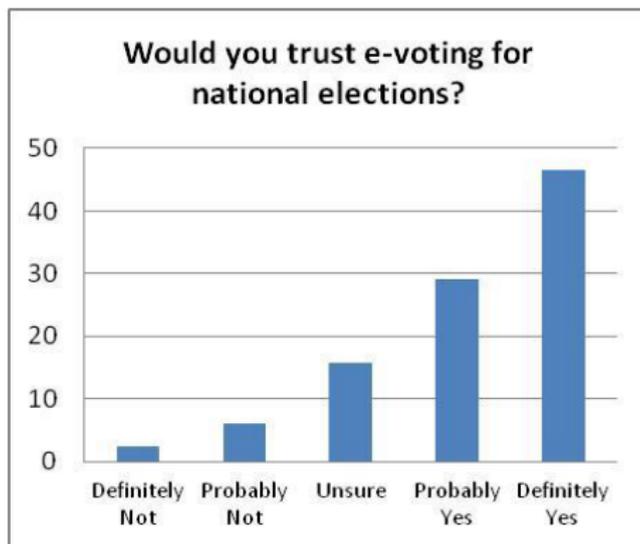
- A total of **747** people participated in the e-voting trial. The average participation rate was **61.5%** in both polling stations.
- **648** of the **747** participants filled in the online questionnaire that followed the actual e-voting procedure.
- The website of the project, received **231** unique visits the next two days.
- **21** participants chose to make use of the verifiability process.

Results: Easiness of use of the e-voting device



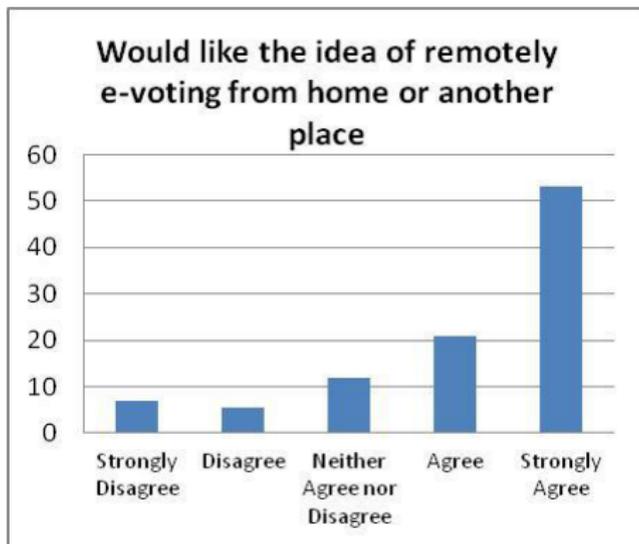
82.7% of respondents found the use of the e-voting device “very easy”, while only **1.2%** answered that they faced problems using the device.

Results: Trust toward the adoption of e-voting for national elections



47% of respondents would trust an e-voting device for the conduction of European elections, while **8.6%** appeared negative toward such an implementation.

Results: Attitude towards remote e-voting



75% of respondents were somehow or very positive toward the prospect of remote e-voting, whereas **12.4%** appeared dismissive toward this prospect.

Results: OLS regression analysis

	Easiness of use		Trust		Attitude towards remote e-voting	
	b	S.E.	b	S.E.	b	S.E.
Male	0.00	0.04	0.01	0.08	-0.07	0.09
Age cohort						
15-24						
25-34	-0.05	0.08	0.50***	0.14	0.53**	0.17
35-44	0.05	0.07	0.73***	0.13	0.60***	0.16
45-54	-0.09	0.07	0.79***	0.13	0.66***	0.16
55-64	-0.08	0.08	1.02***	0.14	0.67***	0.18
65+	-0.30**	0.11	1.17***	0.20	0.83**	0.24
Education	0.03**	0.02	-0.01	0.03	-0.01	0.04
No internet access	-0.42***	0.10	-0.07	0.18	-0.09	0.22
Easiness of use			0.59***	0.07	0.69***	0.09
Adj. R^2	0.12		0.16		0.11	
No. of respondents	624		620		618	

Results: OLS regression analysis - Easiness of use

	Easiness of use		Trust		Attitude towards remote e-voting	
	b	S.E.	b	S.E.	b	S.E.
Male	0.00	0.04	0.01	0.08	-0.07	0.09
Age cohort						
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25-34	-0.05	0.08	0.50***	0.14	0.53**	0.17
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55-64	-0.08	0.08	1.02***	0.14	0.67***	0.18
65+	-0.30**	0.11	1.17***	0.20	0.83**	0.24
Education	0.03**	0.02	-0.01	0.03	-0.01	0.04
No internet access	-0.42***	0.10	-0.07	0.18	-0.09	0.22
Easiness of use			0.59***	0.07	0.69***	0.09
Adj. R²	0.12		0.16		0.11	
No. of respondents	624		620		618	

- 1 Educated respondents found it easier to use the device.

Results: OLS regression analysis - Easiness of use

	Easiness of use		Trust		Attitude towards remote e-voting	
	b	S.E.	b	S.E.	b	S.E.
Male	0.00	0.04	0.01	0.08	-0.07	0.09
Age cohort						
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25-34	-0.05	0.08	0.50***	0.14	0.53**	0.17
35-44	0.05	0.07	0.73***	0.13	0.60***	0.16
45-54	-0.09	0.07	0.79***	0.13	0.66***	0.16
55-64	-0.08	0.08	1.02***	0.14	0.67***	0.18
65+	-0.30**	0.11	1.17***	0.20	0.83**	0.24
Education	0.03**	0.02	-0.01	0.03	-0.01	0.04
No internet access	-0.42***	0.10	-0.07	0.18	-0.09	0.22
Easiness of use			0.59***	0.07	0.69***	0.09
Adj. R^2	0.12		0.16		0.11	
No. of respondents	624		620		618	

- 1 Educated respondents found it easier to use the device.
- 2 Difficulty was significantly increased for respondents aged over 65 years and those who do not use the Internet.

Results: OLS regression analysis - Trust on e-voting

	Easiness of use		Trust		Attitude towards remote e-voting	
	b	S.E.	b	S.E.	b	S.E.
Male	0.00	0.04	0.01	0.08	-0.07	0.09
Age cohort						
15-24						
25-34	-0.05	0.08	0.50***	0.14	0.53**	0.17
35-44	0.05	0.07	0.73***	0.13	0.60***	0.16
45-54	-0.09	0.07	0.79***	0.13	0.66***	0.16
55-64	-0.08	0.08	1.02***	0.14	0.67***	0.18
65+	-0.30**	0.11	1.17***	0.20	0.83**	0.24
Education	0.03**	0.02	-0.01	0.03	-0.01	0.04
No internet access	-0.42***	0.10	-0.07	0.18	-0.09	0.22
Easiness of use			0.59***	0.07	0.69***	0.09
Adj. R^2	0.12		0.16		0.11	
No. of respondents	624		620		618	

- 1 Easiness of use of the e-voting device is associated with general trust toward e-voting.

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- 1 Easiness of use of the e-voting device is associated with general trust toward e-voting.
- 2 Older aged cohorts appear significantly more trustful.

Results: OLS regression analysis - Trust on e-voting

	Easiness of use		Trust		Attitude towards remote e-voting	
	b	S.E.	b	S.E.	b	S.E.
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Easiness of use			0.59***	0.07	0.69***	0.09
Adj. R^2	0.12		0.16		0.11	
No. of respondents	624		620		618	

- 1 Easiness of use of the e-voting device is associated with general trust toward e-voting.
- 2 Older aged cohorts appear significantly more trustful.
- 3 Level of education is not associated with trust toward electronic voting.

Results: OLS regression analysis - Attitude towards e-voting

	Easiness of use		Trust		Attitude towards remote e-voting	
	b	S.E.	b	S.E.	b	S.E.
Male	0.00	0.04	0.01	0.08	-0.07	0.09
Age cohort						
15-24						
25-34	-0.05	0.08	0.50***	0.14	0.53**	0.17
35-44	0.05	0.07	0.73***	0.13	0.60***	0.16
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Education	0.03**	0.02	-0.01	0.03	-0.01	0.04
No internet access	-0.42***	0.10	-0.07	0.18	-0.09	0.22
Easiness of use			0.59***	0.07	0.69***	0.09
Adj. R^2	0.12		0.16		0.11	
No. of respondents	624		620		618	

- Older respondents appear more positive toward remote electronic voting.

Results: OLS regression analysis - Attitude towards e-voting

	Easiness of use		Trust		Attitude towards remote e-voting	
	b	S.E.	b	S.E.	b	S.E.
Male	0.00	0.04	0.01	0.08	-0.07	0.09
Age cohort						
15-24						
25-34	-0.05	0.08	0.50***	0.14	0.53**	0.17
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No internet access	-0.42***	0.10	-0.07	0.18	-0.09	0.22
Easiness of use			0.59***	0.07	0.69***	0.09
Adj. R^2	0.12		0.16		0.11	
No. of respondents	624		620		618	

- 1 Older respondents appear more positive toward remote electronic voting.
- 2 Participants who found the e-voting device easy to use were significantly more willing to vote remotely.

Results: OLS regression analysis - Explanatory power of all three models

	Easiness of use		Trust		Attitude towards remote e-voting	
	b	S.E.	b	S.E.	b	S.E.
Male	0.00	0.04	0.01	0.08	-0.07	0.09
Age cohort						
15-24						
25-34	-0.05	0.08	0.50***	0.14	0.53**	0.17
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Easiness of use			0.59***	0.07	0.69***	0.09
Adj. R^2	0.12		0.16		0.11	
No. of respondents	624		620		618	

The adjusted R^2 is rather low, meaning that there exist additional latent factors that account for variation in attitudes toward electronic voting in Greece.

Conclusions

- 1 Acceptance of e-voting could be fairly high in the general population.

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- 2 The aggregate distribution of preferences toward e-voting masks significant individual-level variation.

Conclusions

- 1 Acceptance of e-voting could be fairly high in the general population.
- 2 The aggregate distribution of preferences toward e-voting masks significant individual-level variation.
- 3 Sociodemographic characteristics and familiarity with technology account only for a small portion of the total variation in acceptance of electronic voting.

Future research

- Study the pattern of attitudes toward e-voting from a comparative perspective considering many countries.
- Investigate latent parameters that may have an impact on attitudes toward e-voting.

Thank you!

Please visit our website:

<http://www.demos-voting.org>

Pressing the Button for European Elections: Verifiable e-voting and public attitudes toward internet voting in Greece

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The FINER Research Team
Department of Political Science and Public Administration &
Department of Informatics and Telecommunications
University of Athens



HELLENIC REPUBLIC
National and Kapodistrian
University of Athens

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