The Impact of Public e-Services

Statistical modeling, prediction,
anomaly detection, auto-generated data

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Digital Signature

Digital signature enables secure, legally-binding, electronic document signing

e-Law

Allows public access to every piece of draft law that has been submitted since February 2003

e-Prescription

A centralized, paperless system for issuing and handling medical prescriptions

e-School

Allow students, teachers and parents to collaborate in the learning process

e-Tax

e-Tax has drastically reduced the time spent by individuals and entrepreneurs on filing taxes

Electronic Health Record

Integrates data from healthcare providers into a national record for each patient

Electronic ID Card

e-ID acts as definitive proof of ID in secure electronic environments

Electronic Land Register

A one-of-a-kind information system for storing real estate and land data

i-Voting

i-Voting allows voters to cast their ballots over the internet, from anywhere in the world

m-Parking

Allows drivers to pay for city parking using a mobile phone

Mobile-ID

Allows a client to use a mobile phone as a form of secure electronic ID

Mobile Payment

Enables payment for goods and services using mobile phones

Population Register

The state database for basic information about each person living in Estonia

Social Welfare e-Services

The social welfare benefit system is accessible by a convenient, online environment

State e-Services Portal

A one-stop-shop for the hundreds of e-services offered by government institutions

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What is their impact?

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Voter turnout

Mobilization

Political bias

Trust and vote verification

Usage and diffusion

Components of Estonia's e-governance ecosystem

National identification system
Unique identifier for all residents
Digital Population Register
Legislative framework

↓

Digital identification

↓

Digital ID card
Mobile ID
other forms of digital identification

Unified and decentralized middleware for data exchange

↓

Data exchange layer

↓

client authentication, registry services, query design, data entry, secure data exchange, logging, query tracking, visualization, monitoring

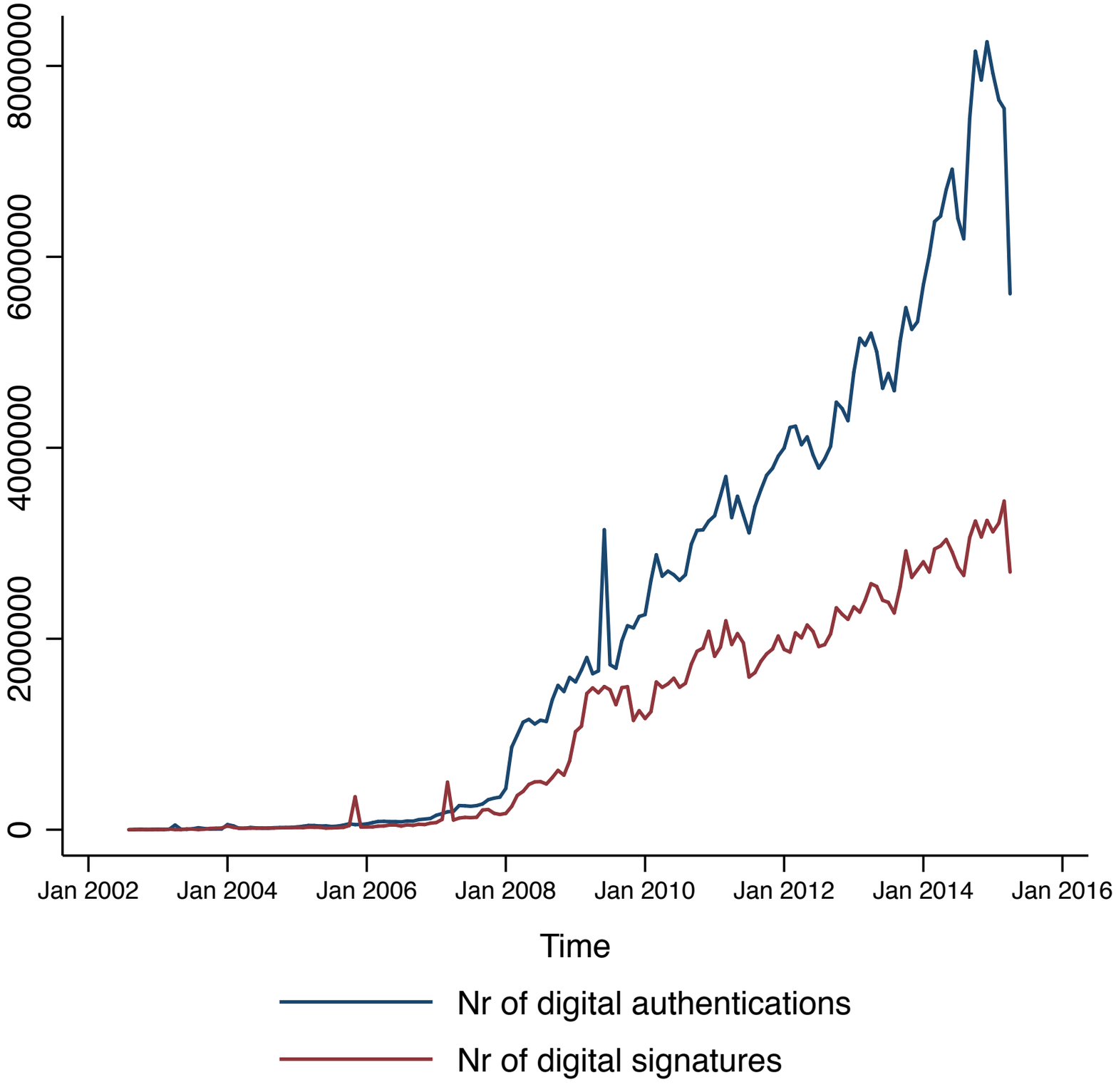
Integrated applications developed independently by state institutions following a unified set of principles procedures

↓

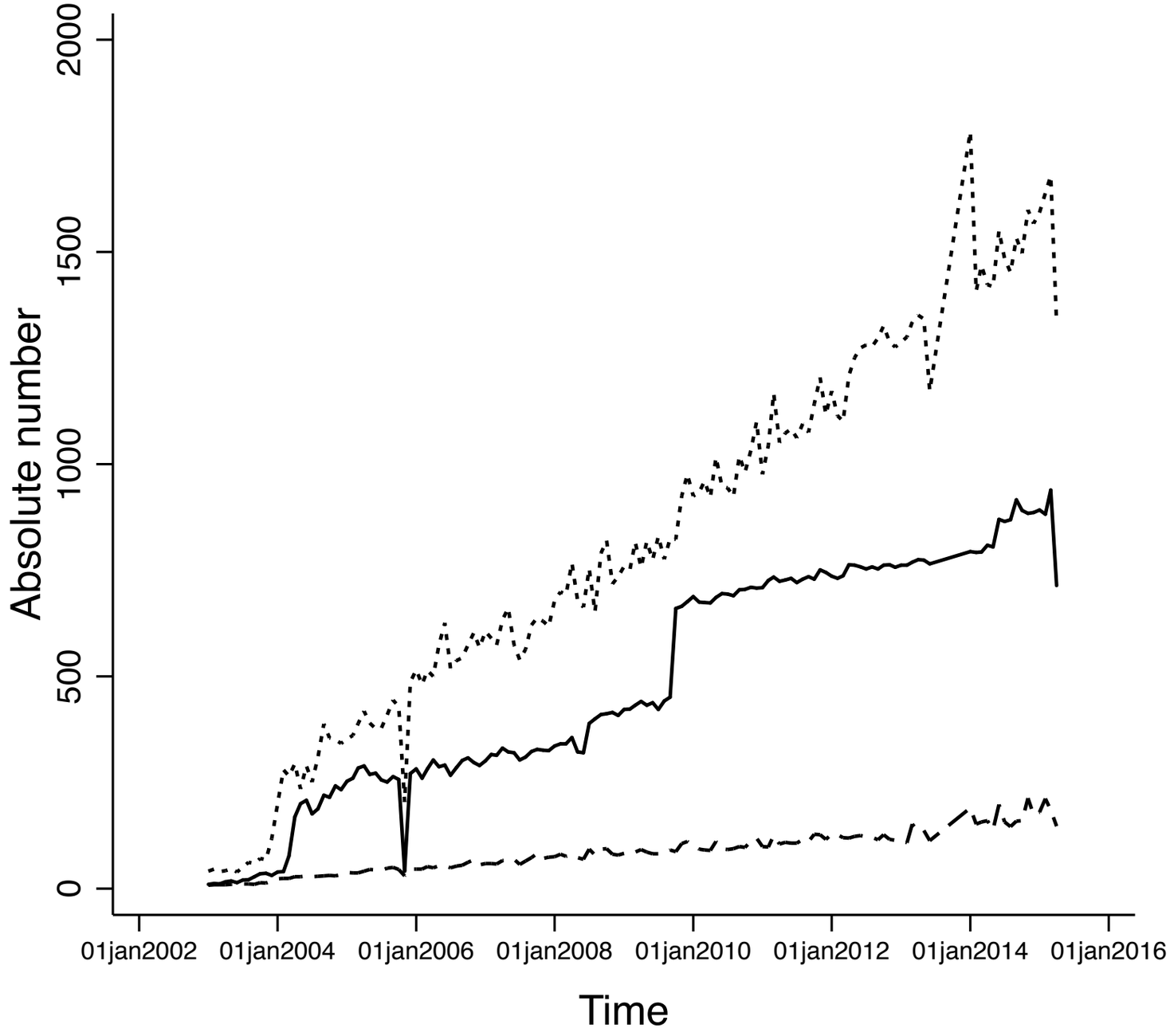
Application's layer

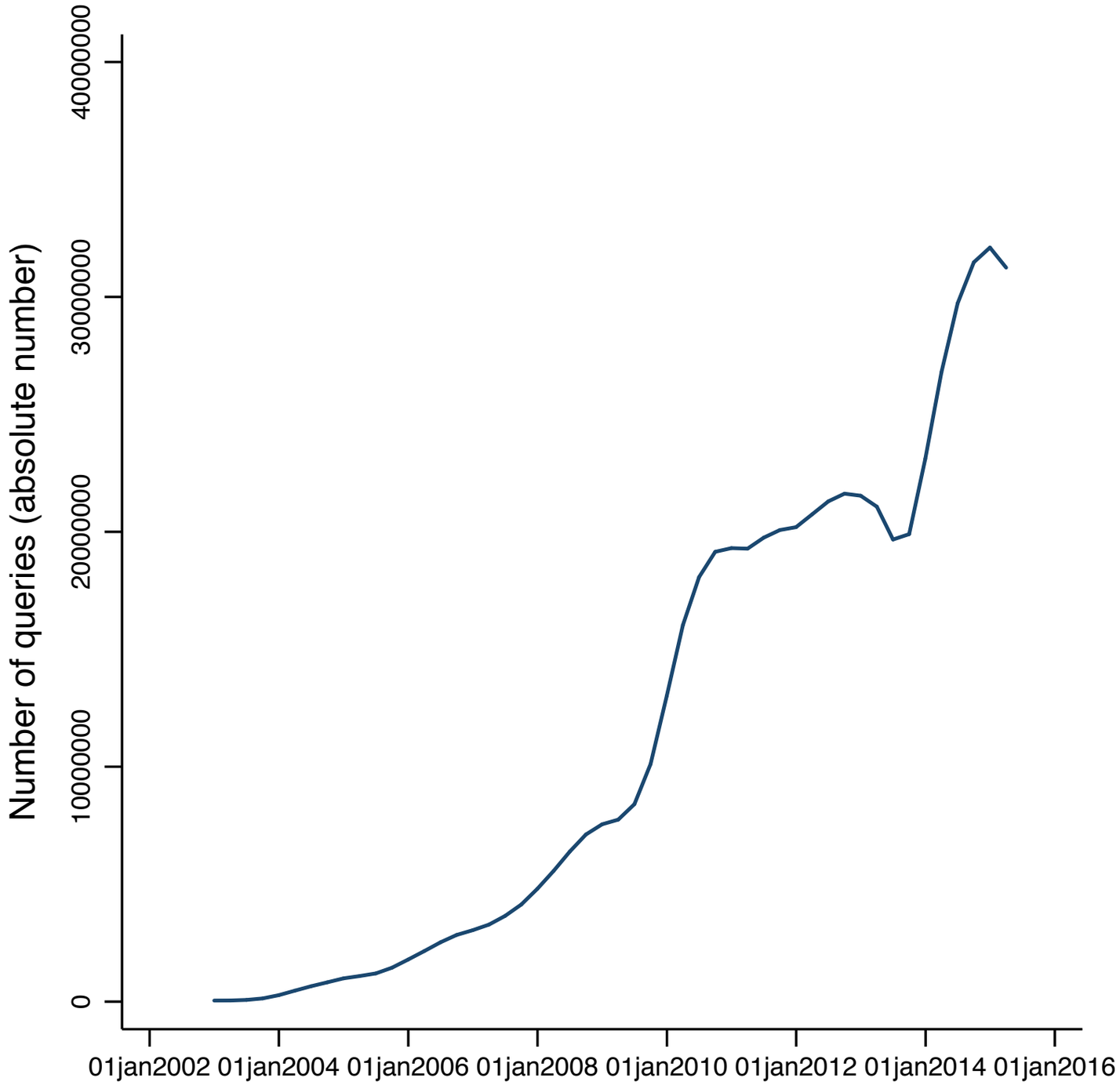
↓

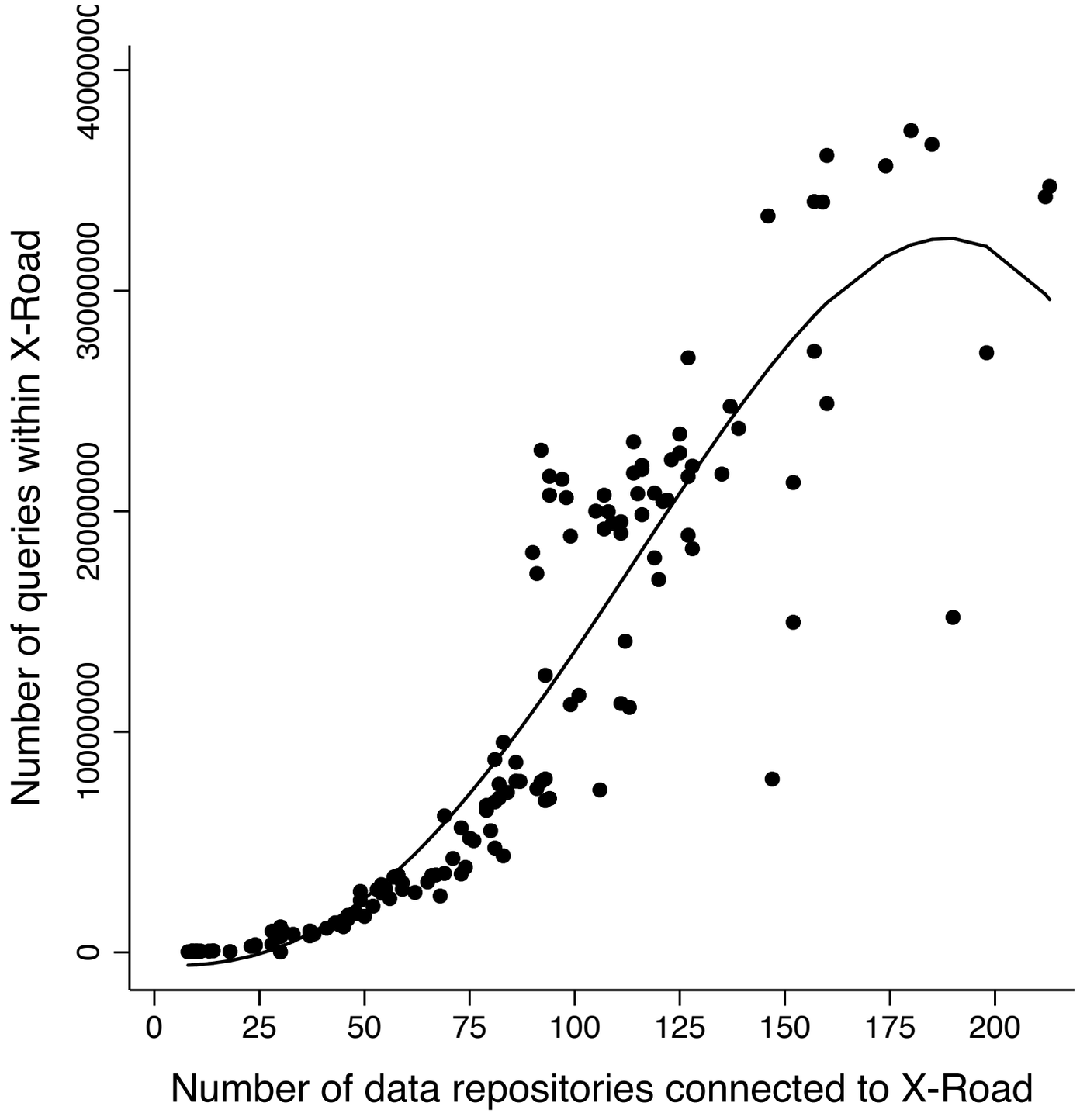
e-business register, e-police, internet voting, e-prescription, e-school, e-health, e-tax, social welfare services, etc.


8000000
6000000
4000000
2000000
0
Jan 2002
Jan 2004
Jan 2006
Jan 2008
Jan 2010
Jan 2012
Jan 2014
Jan 2016
Time
Nr of digital authentications
Nr of digital signatures

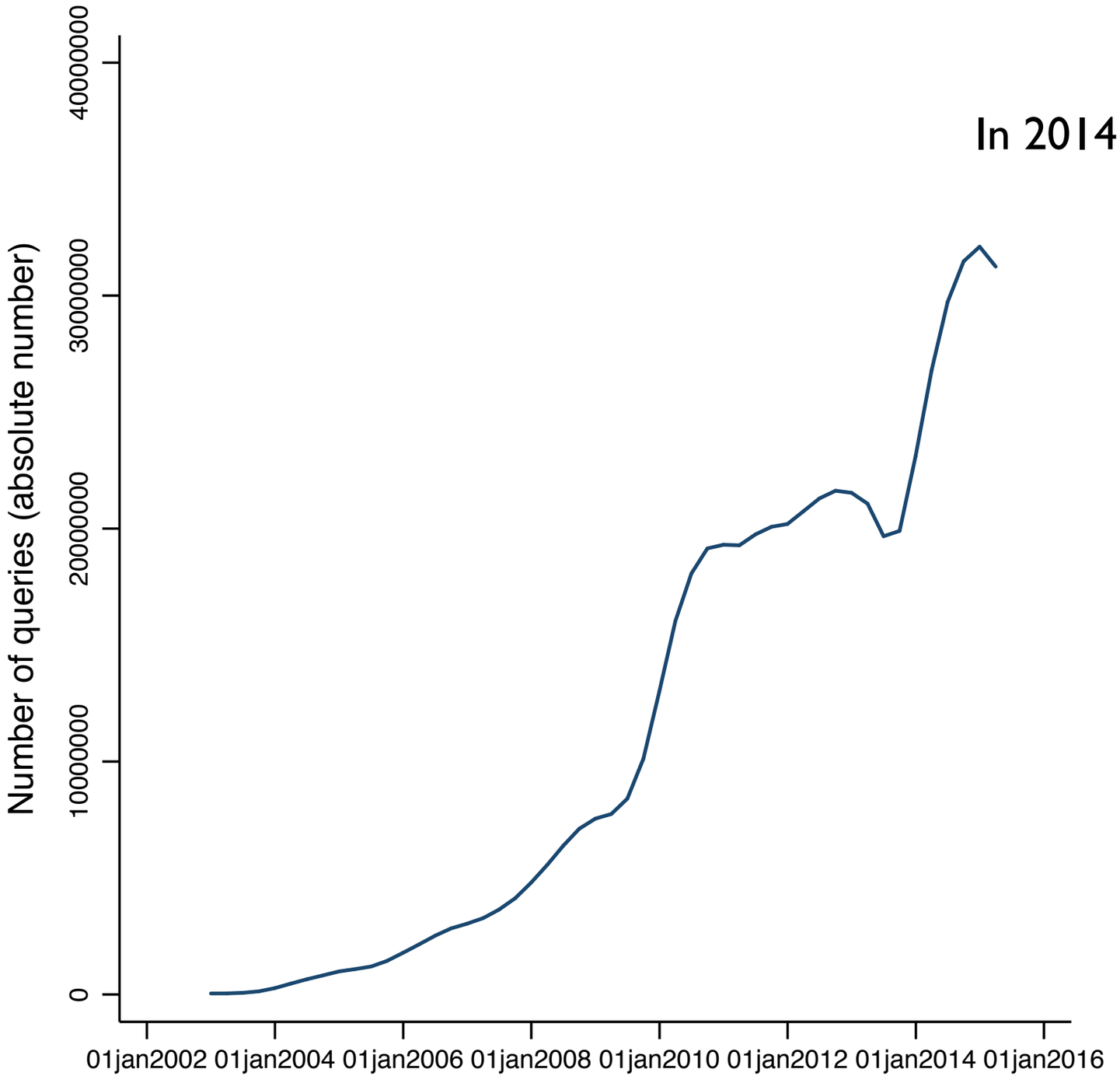
X-Road

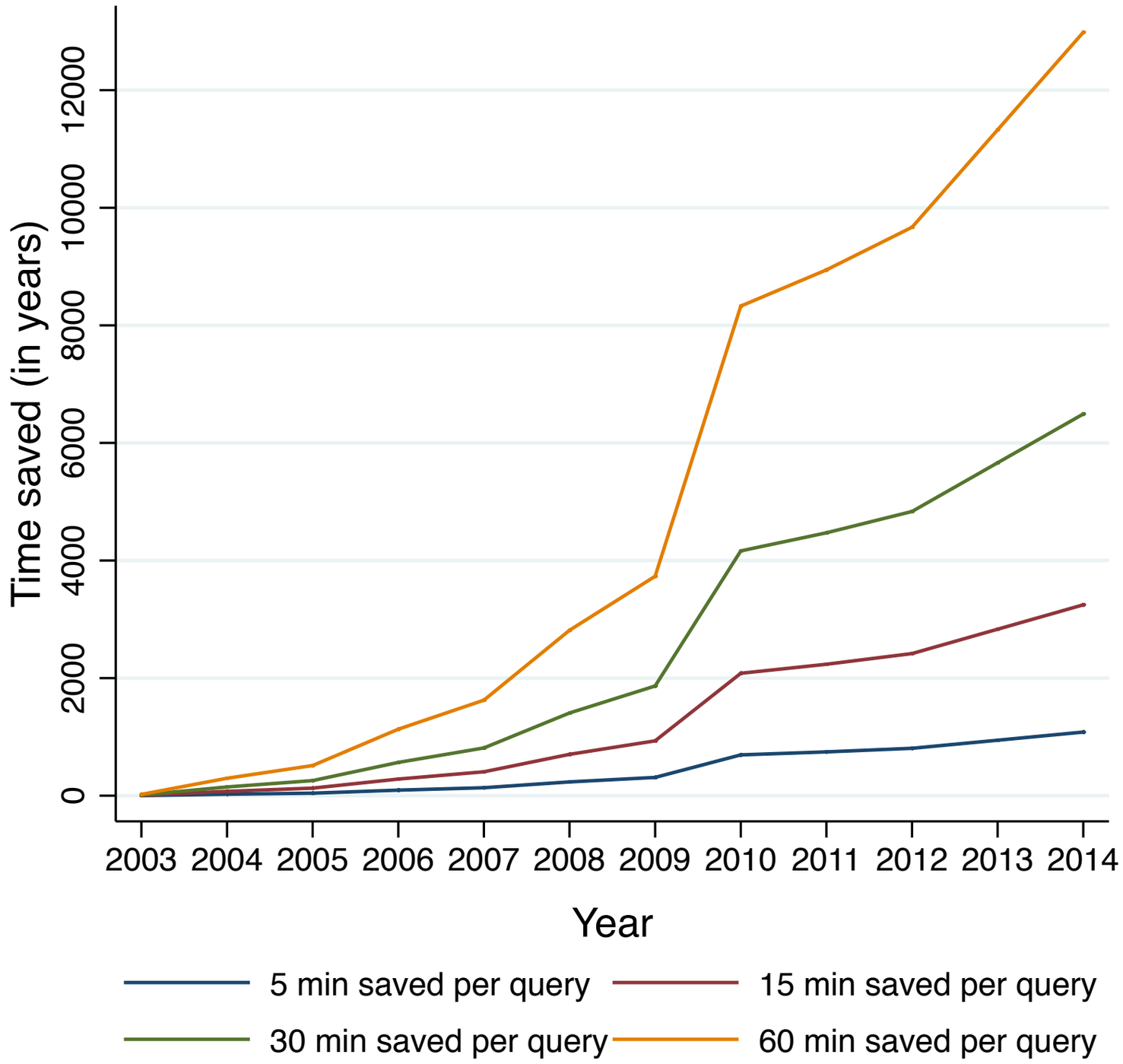

Absolute number
0
500
1000
1500
2000
01jan2002
01jan2004
01jan2006
01jan2008
01jan2010
01jan2012
01jan2014
01jan2016
Time
Institutions
Services
Data repositories


Number of queries (absolute number)
0
10000000
20000000
30000000
40000000
01jan2002
01jan2004
01jan2006
01jan2008
01jan2010
01jan2012
01jan2014
01jan2016

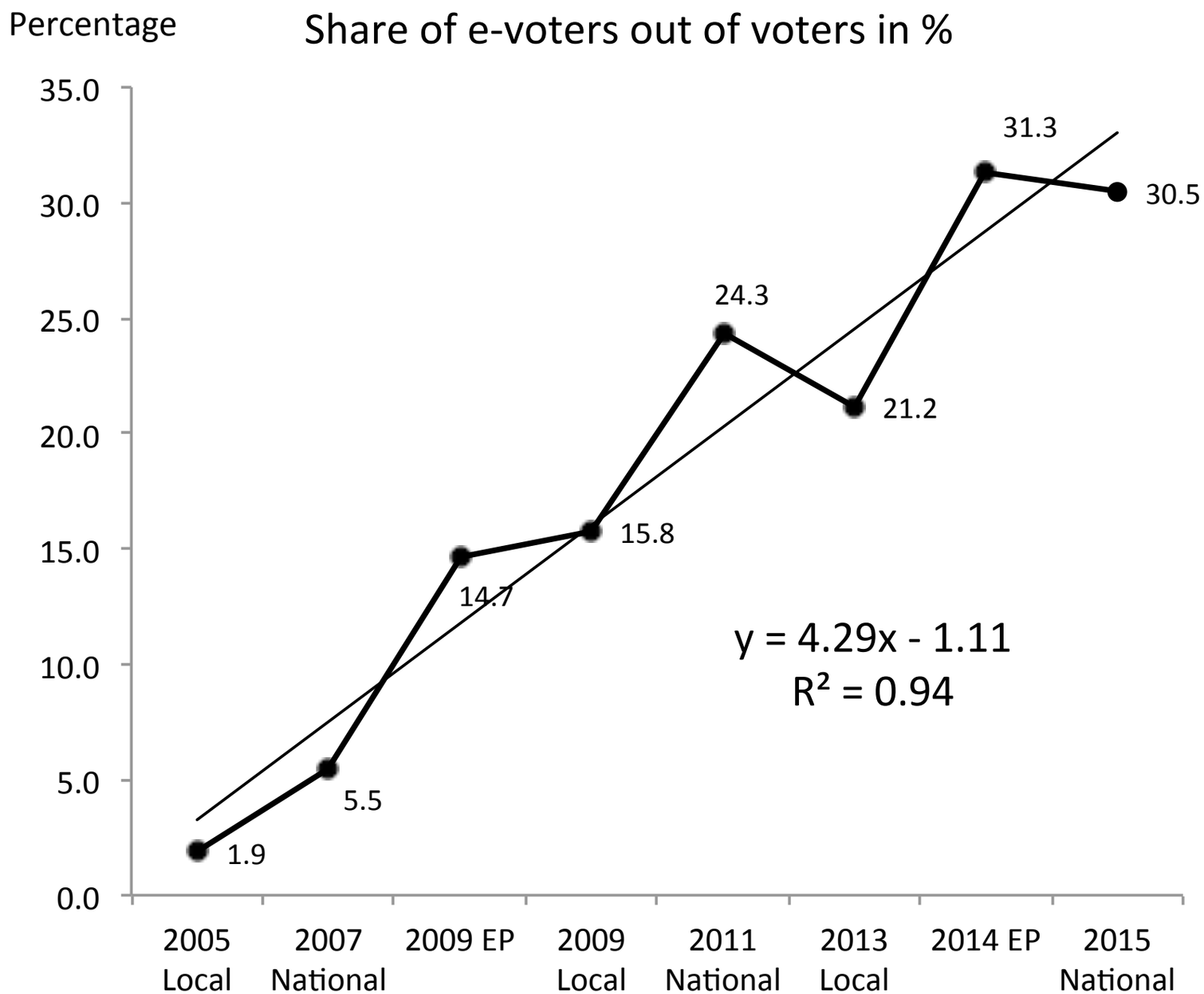

Number of queries within X-Road
0
10000000
20000000
30000000
40000000
0
25
50
75
100
125
150
175
200
Number of data repositories connected to X-Road

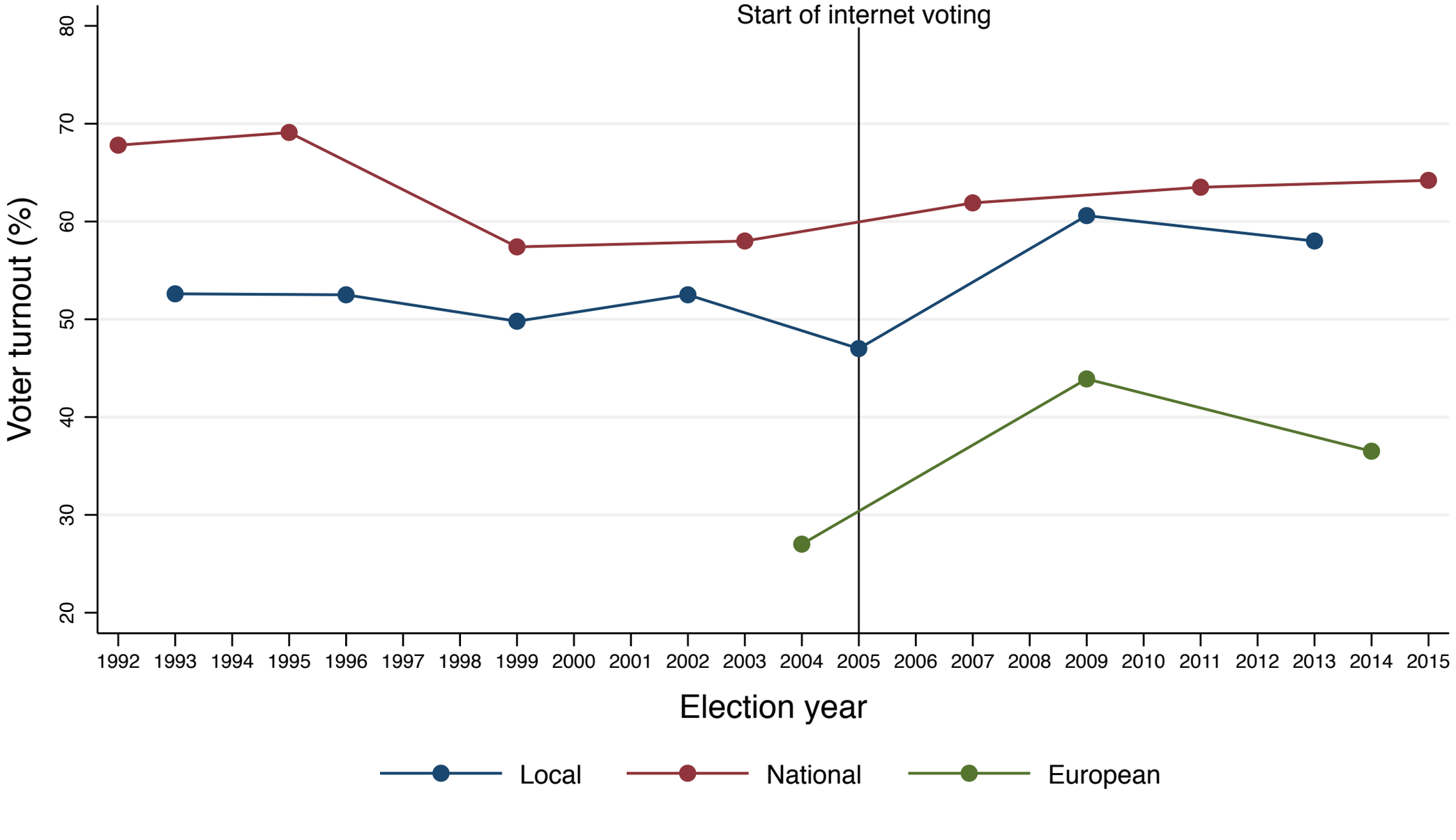
A third of all queries are human interaction
In 2014 113 mil queries
Every query saves 15 min
In 2014 a total of 2.8 mil hrs was saved
Which amounts to 3225 years

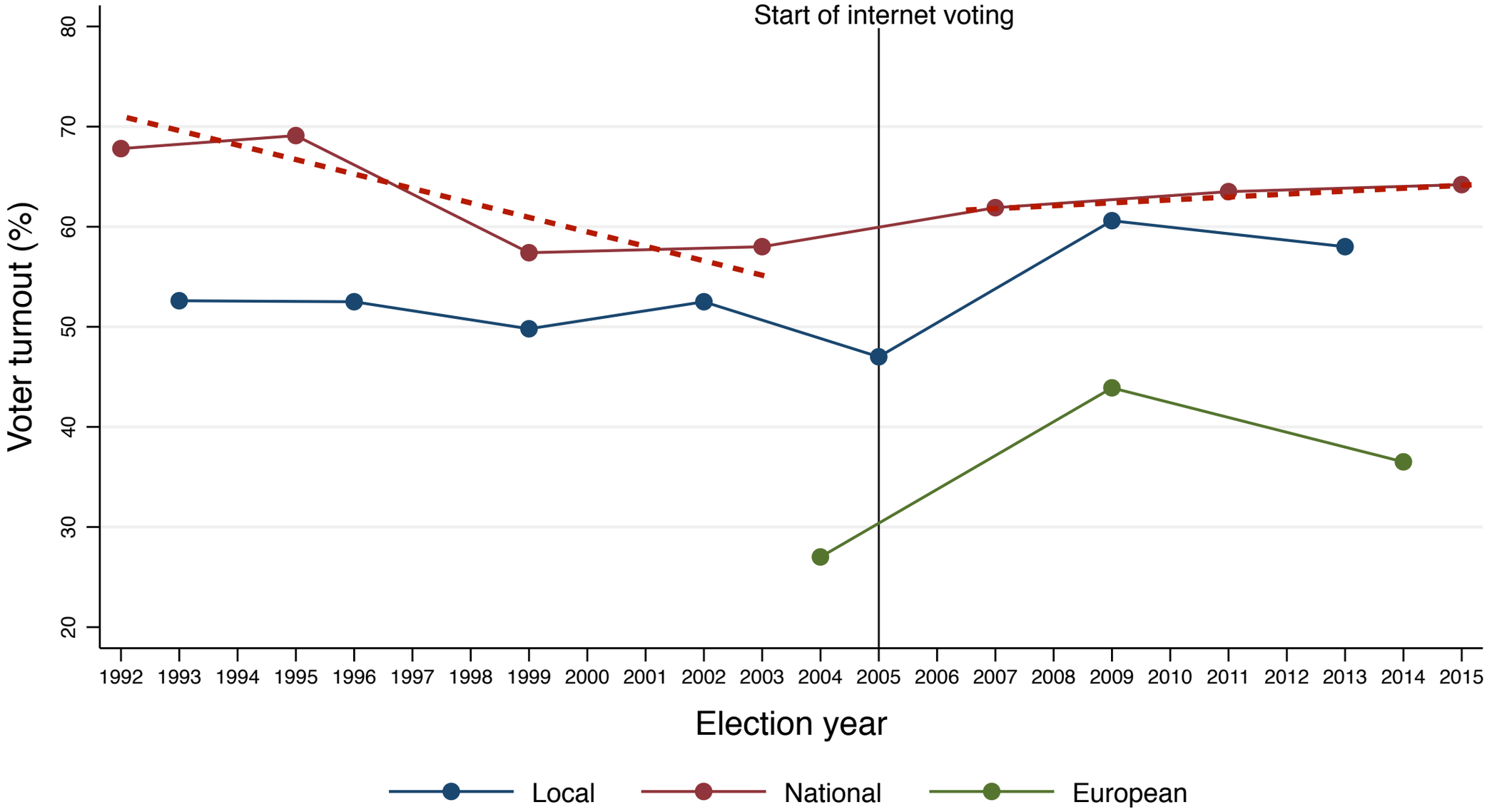


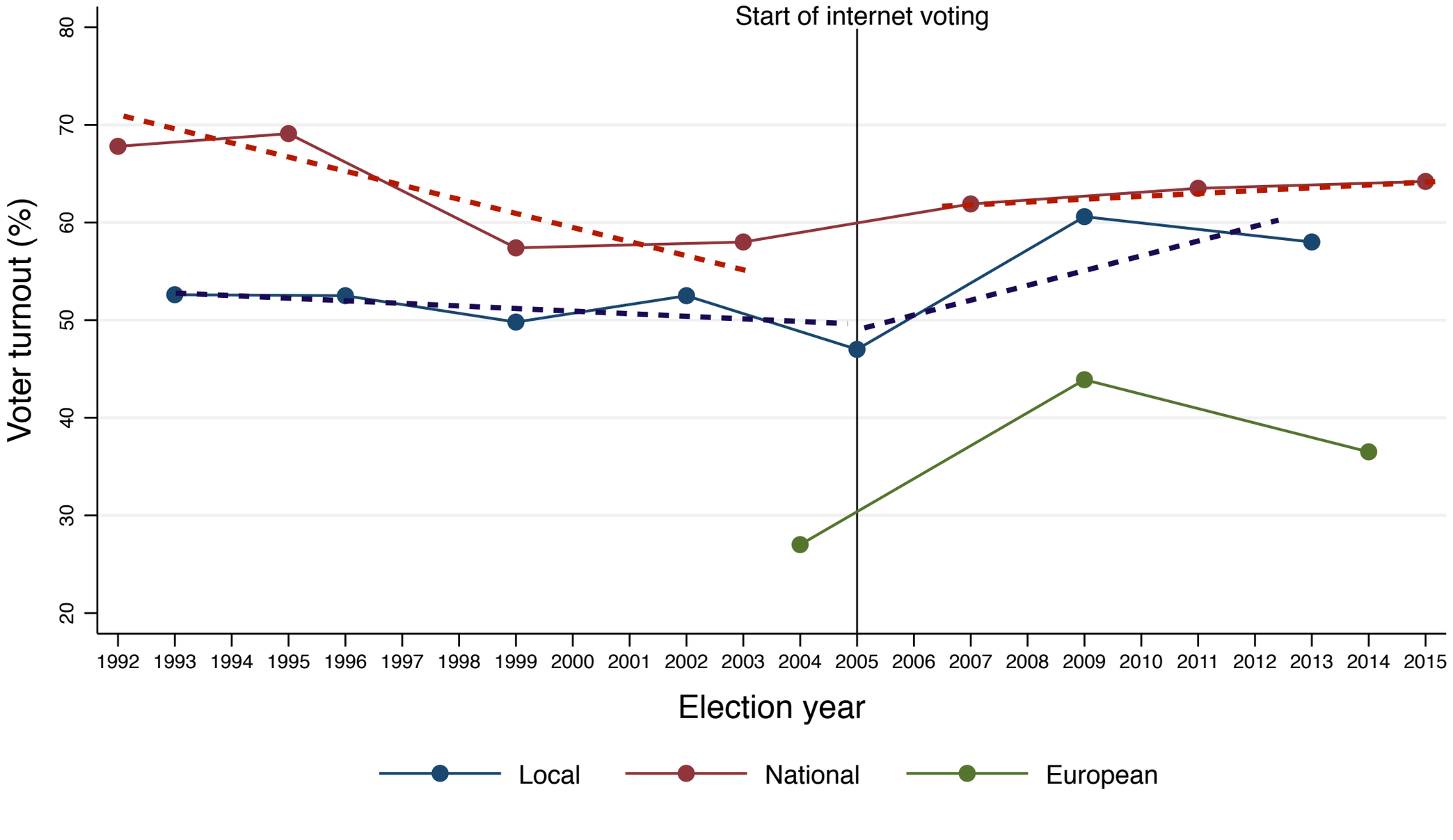

Time saved (in years)
0
2000
4000
6000
8000
10000
12000
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
Year
5 min saved per query
15 min saved per query
30 min saved per query
60 min saved per query

Internet voting


Percentage
Share of e-voters out of voters in %
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
1.9
5.5
14.7
15.8
24.3
21.2
31.3
30.5
y = 4.29x - 1.11
R² = 0.94
2005 Local
2007 National
2009 EP
2009 Local
2011 National
2013 Local
2014 EP
2015 National


Start of internet voting
Voter turnout (%)
80
70
60
50
40
30
20
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Election year
Local
National
European


Start of internet voting
Voter turnout (%)
80
70
60
50
40
30
20
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Election year
Local
National
European

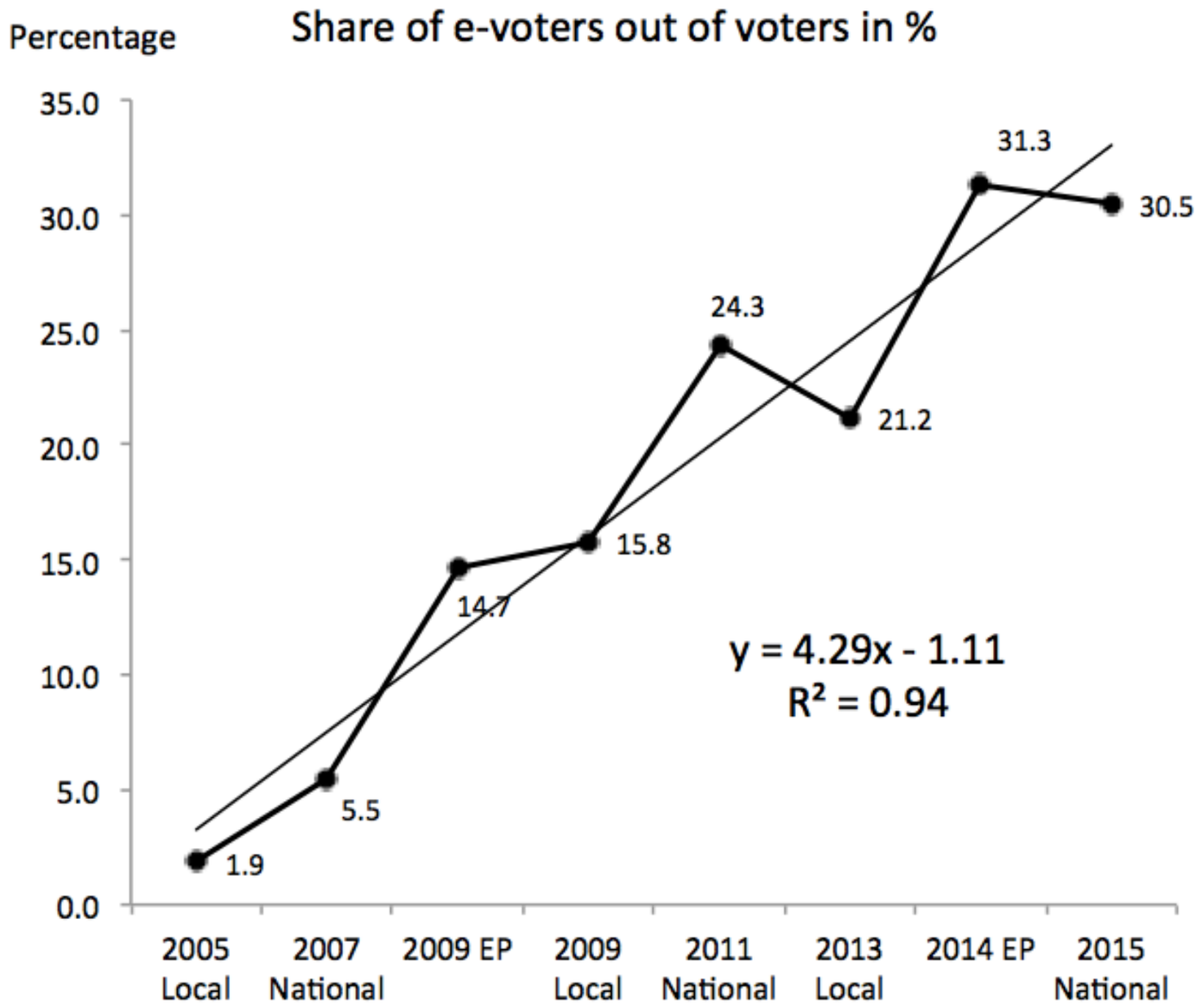

Start of internet voting
Voter turnout (%)
80
70
60
50
40
30
20
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Election year
Local
National
European

Diffusion of internet voting

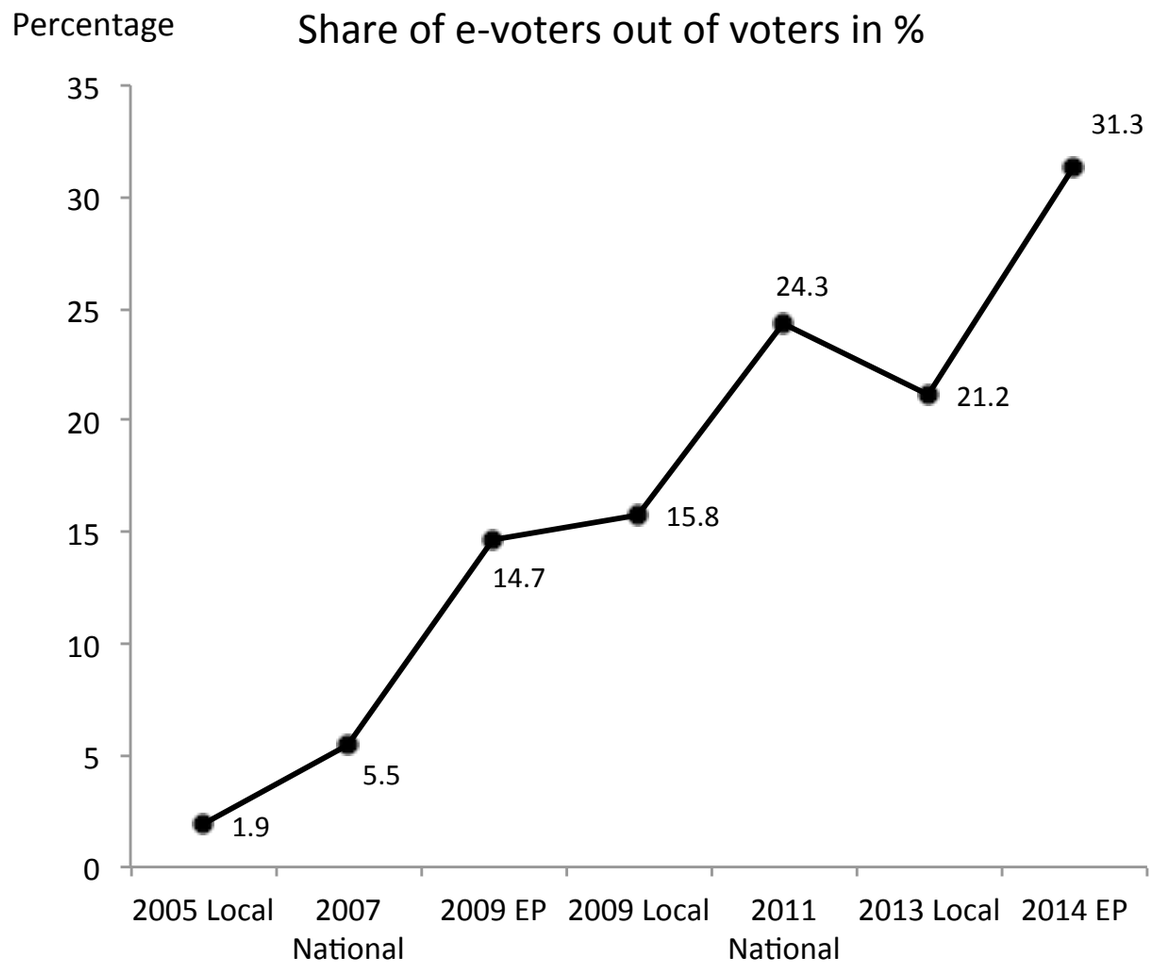
Who votes online?

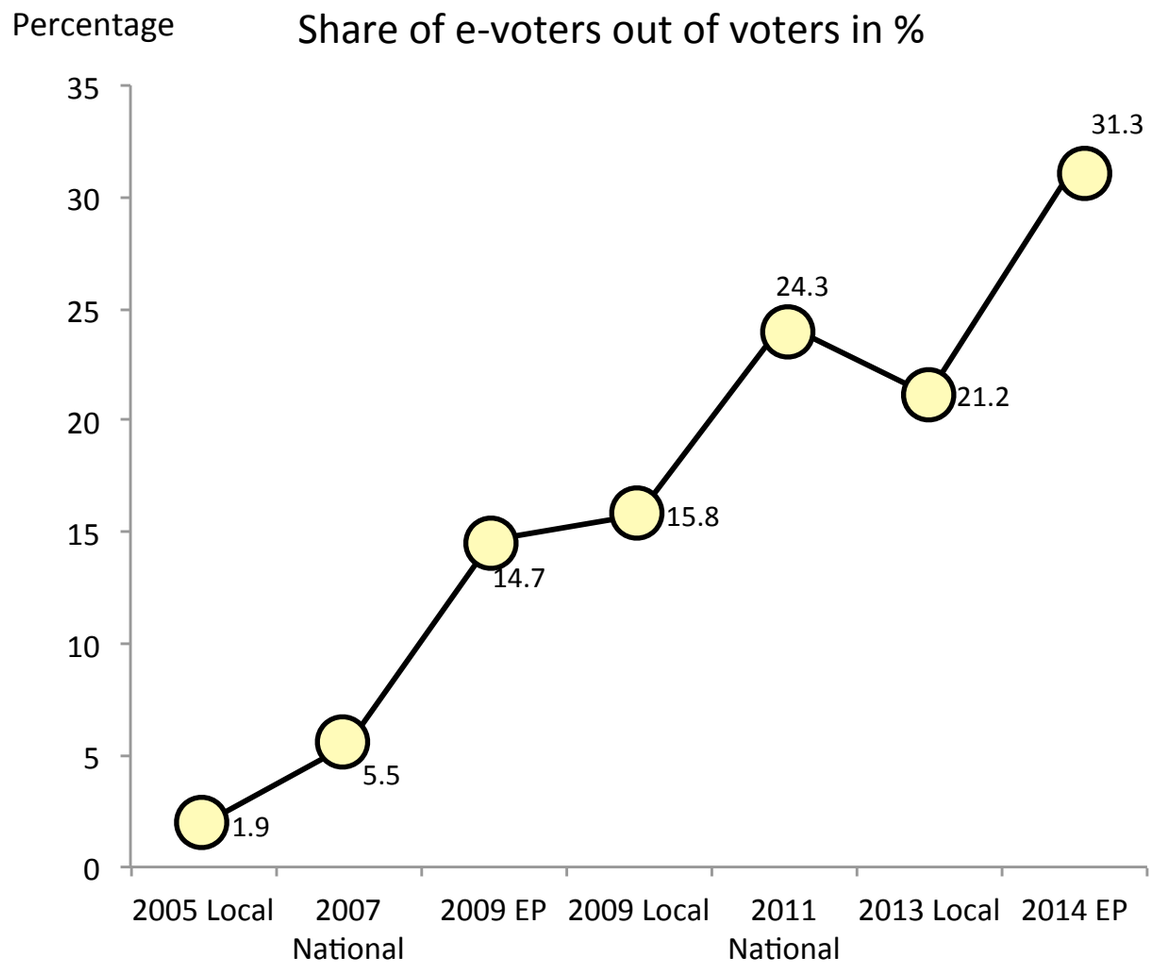
Does the profile of e-voters change?

Has the usage of e-voting diffused?

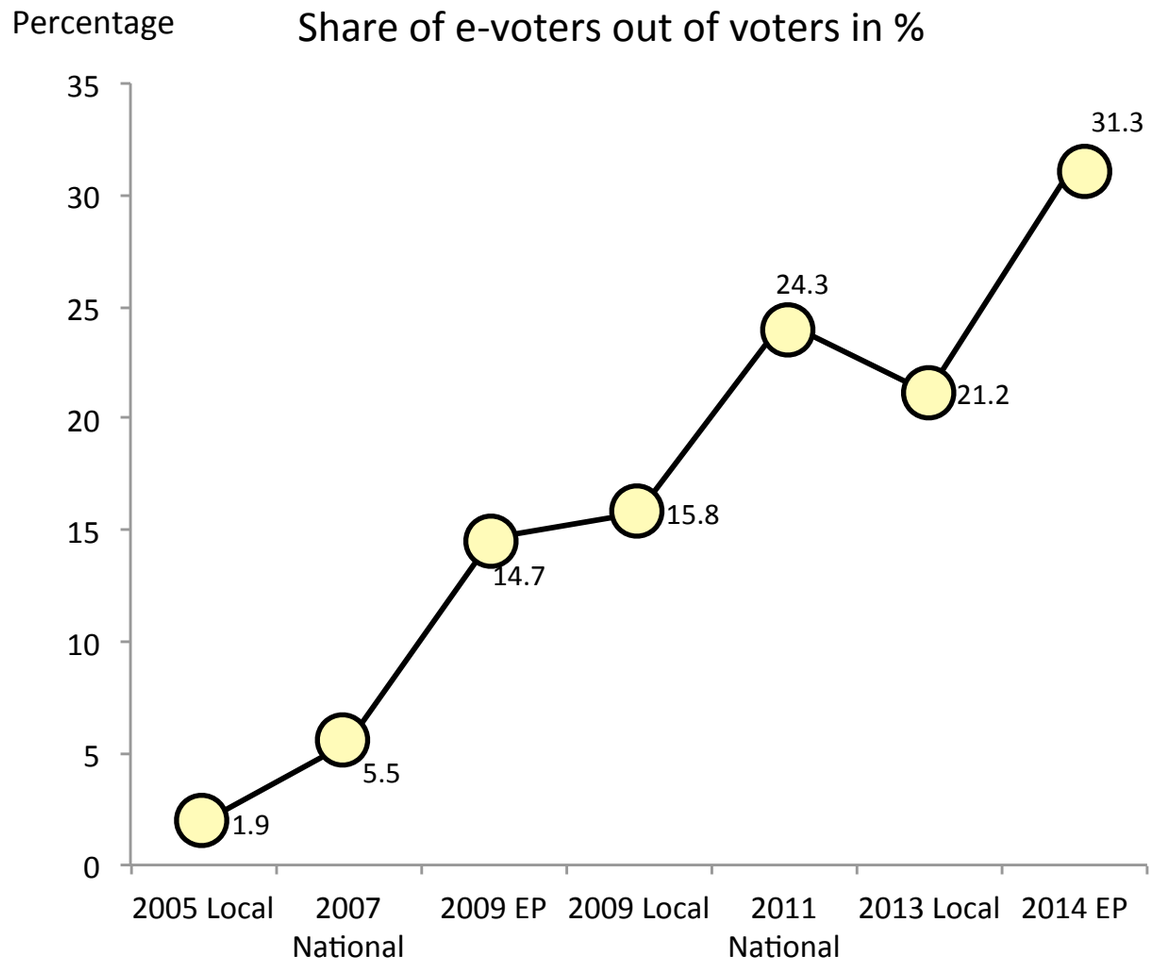


Does internet voting diffuse among the electorate?


Share of e-voters out of voters in %
Percentage
35
30
25
20
15
10
5
0
1.9
5.5
14.7
15.8
24.3
21.2
31.3
2005 Local
2007 National
2009 EP
2009 Local
2011 National
2013 Local
2014 EP

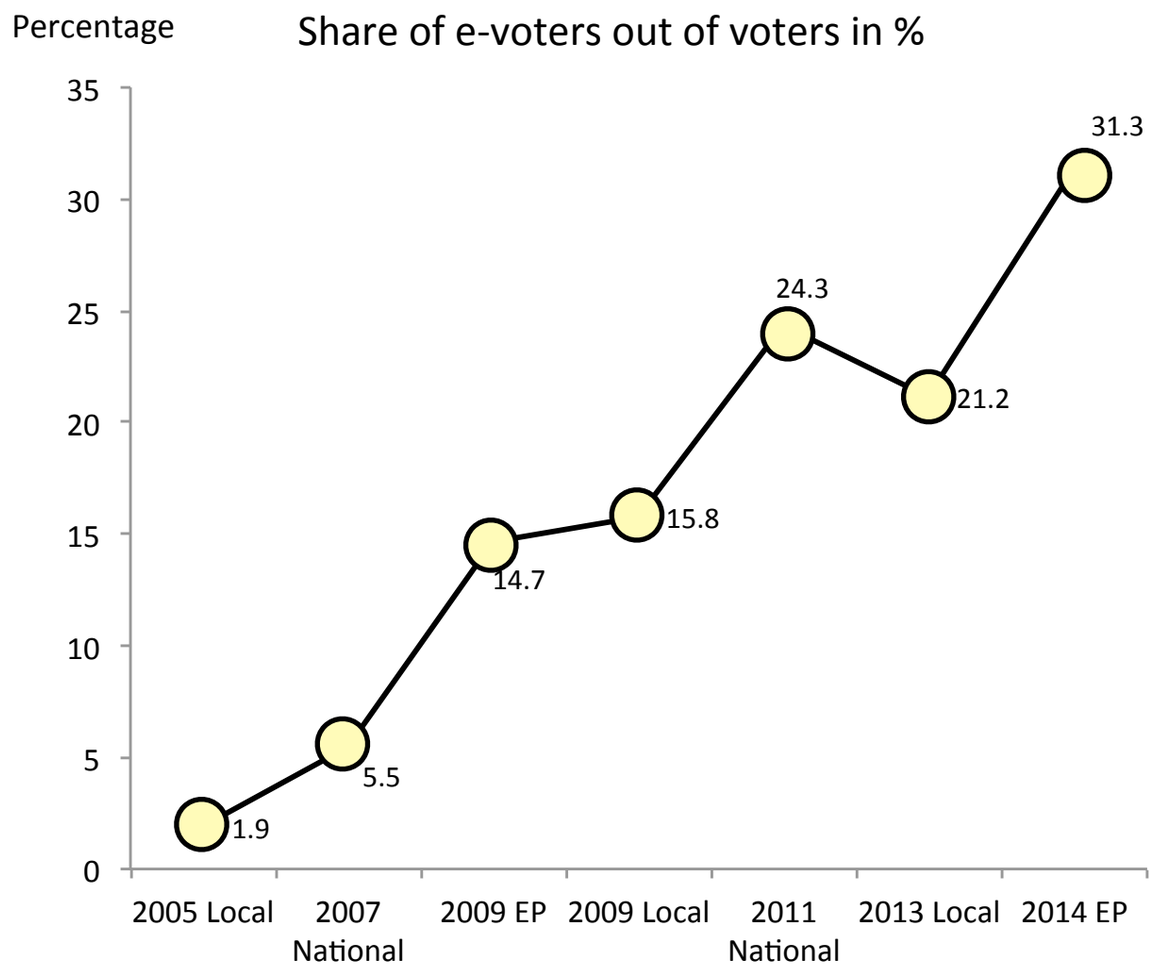

Share of e-voters out of voters in %
Percentage
35
30
25
20
15
10
5
0
1.9
5.5
14.7
15.8
24.3
21.2
31.3
2005 Local
2007 National
2009 EP
2009 Local
2011 National
2013 Local
2014 EP

Sample of about 1000



Sample of about 1000

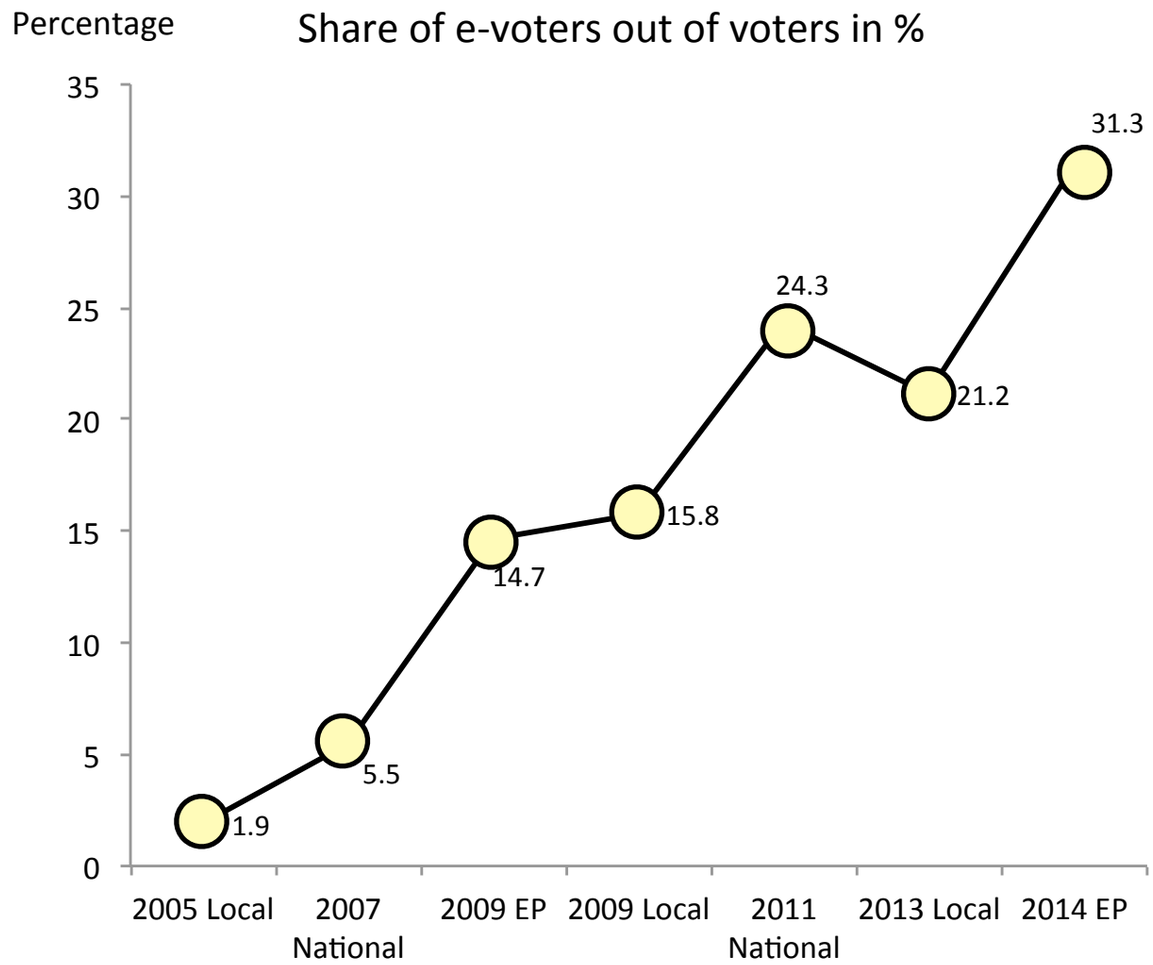
E-voters
Normal voters 2005-2011
Non-voters

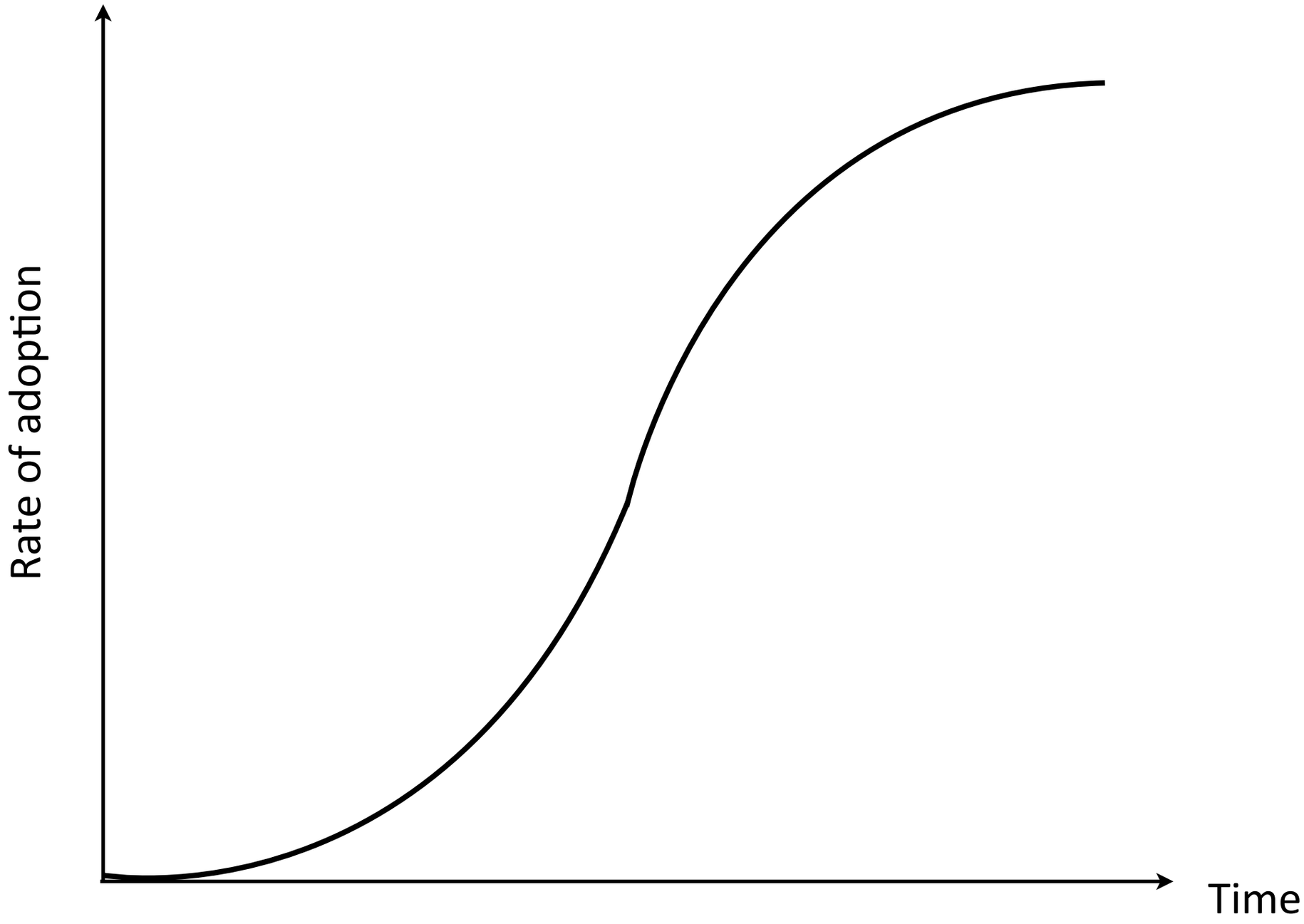


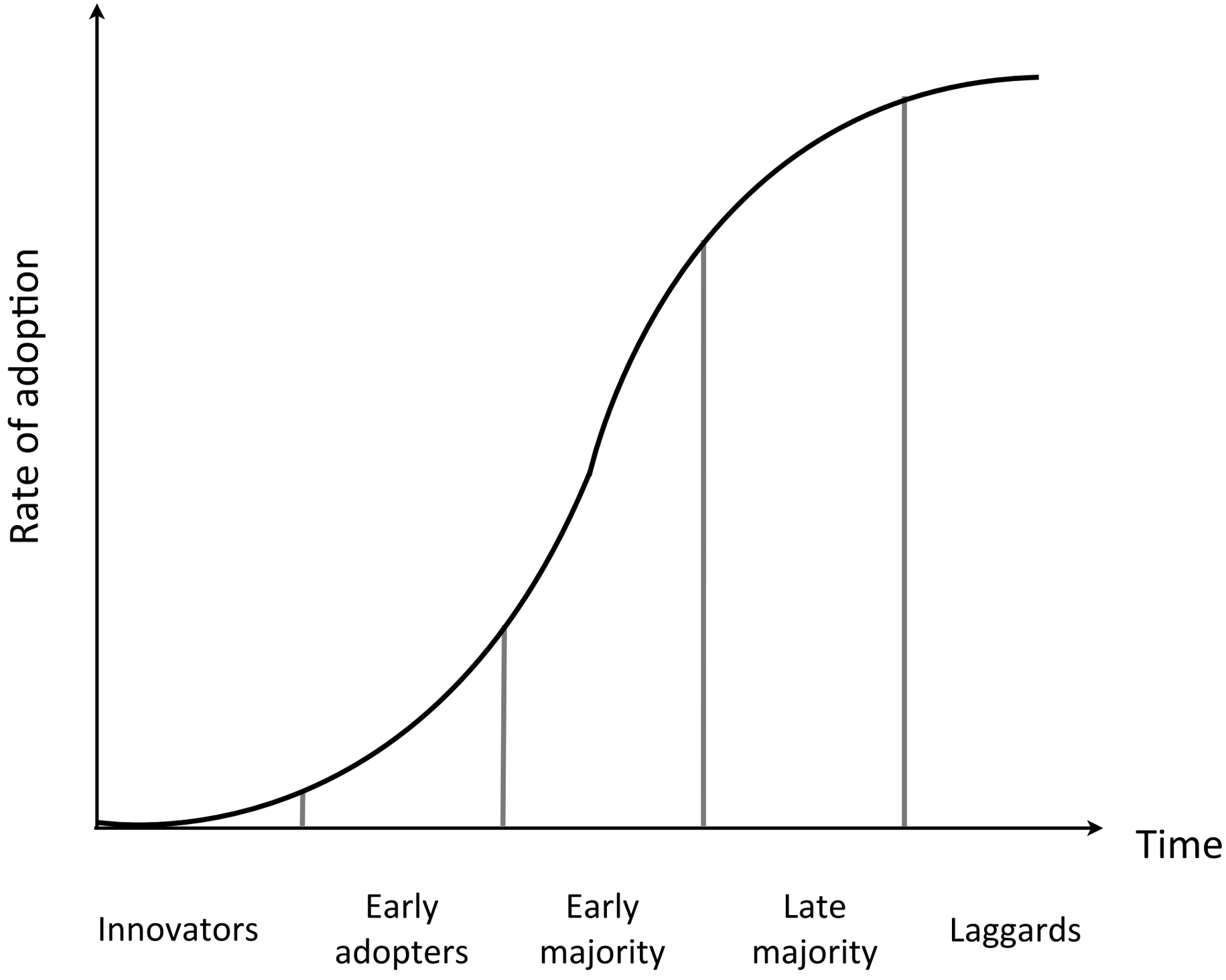
Sample of about 1000

E-voters
Normal voters 2005-2011
Non-voters

Random probability sample in 2013, 2014 and 2015

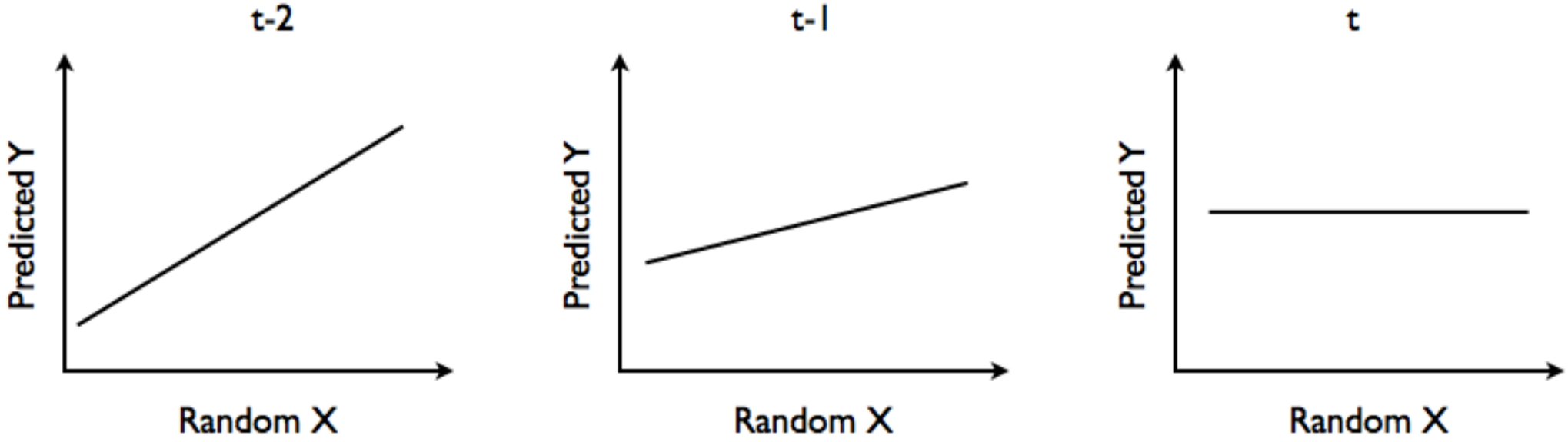



Rate of adoption
Time

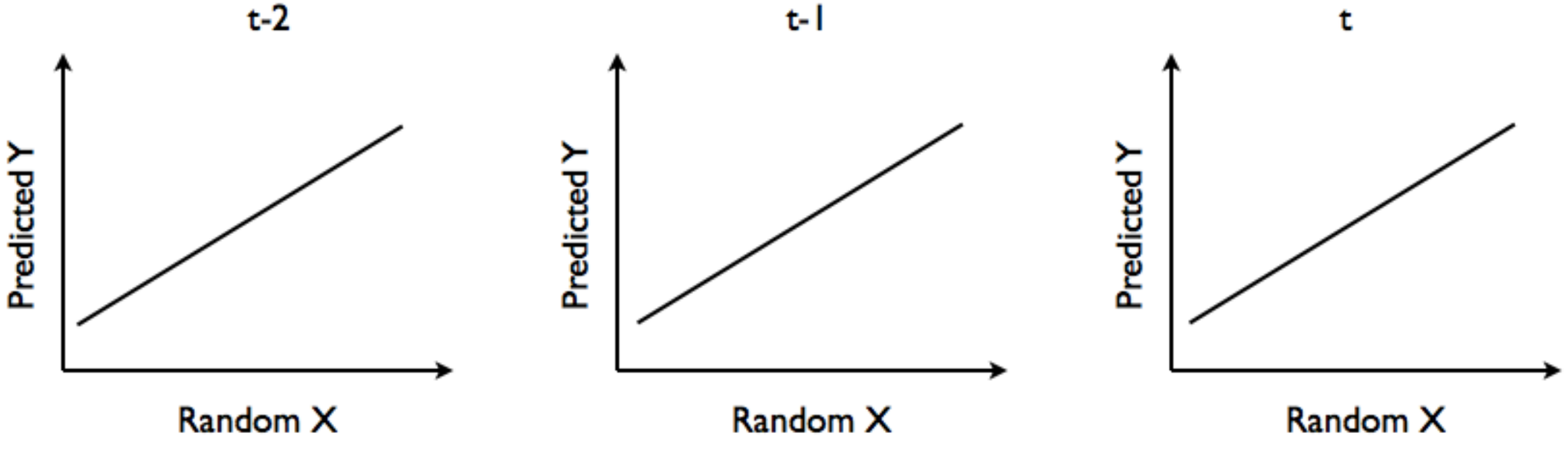

Rate of adoption
Time
Innovators
Early adopters
Early majority
Late majority
Laggards

I

Characteristics that explain e-voting during the first e-enabled elections *lose* their predictive power over time



2 Characteristics that explain e-voting during the first e-enabled elections *retain* their predictive power over time



y	1st time e-voter = 1 Normal voter = 0

y	1st time e-voter = 1 Normal voter = 0

age, age2, male, estonian ethnicity, higher education, secondary education, income decile, urban residence

y

1st time e-voter = 1

Normal voter = 0

age, age2, male, estonian ethnicity, higher education, secondary education, income decile, urban residence

voting habit, good PC-literacy, average PC-literacy, trust in e-voting system, LR self-position, political talk

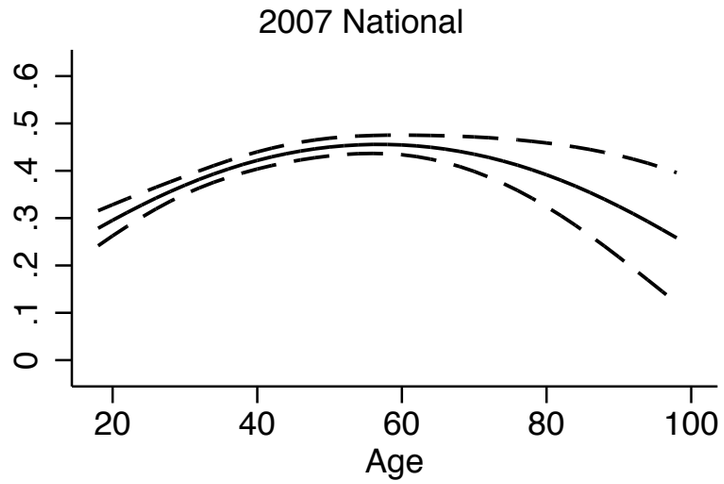
y	1st time e-voter = 1 Normal voter = 0

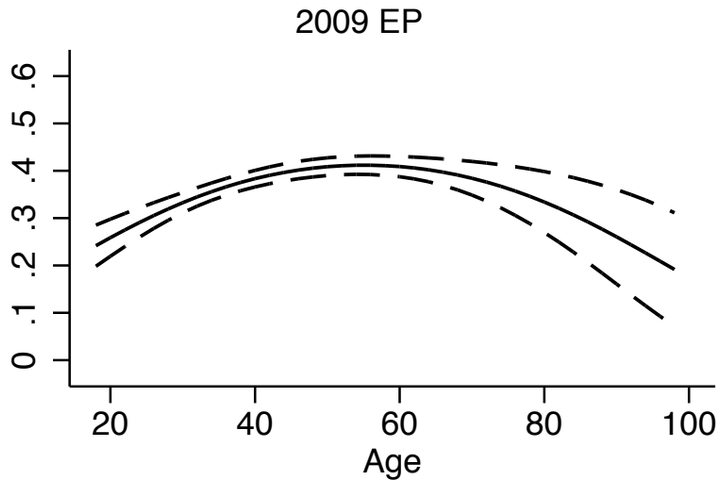
age, age2, male, estonian ethnicity, higher education, secondary education, income decile, urban residence

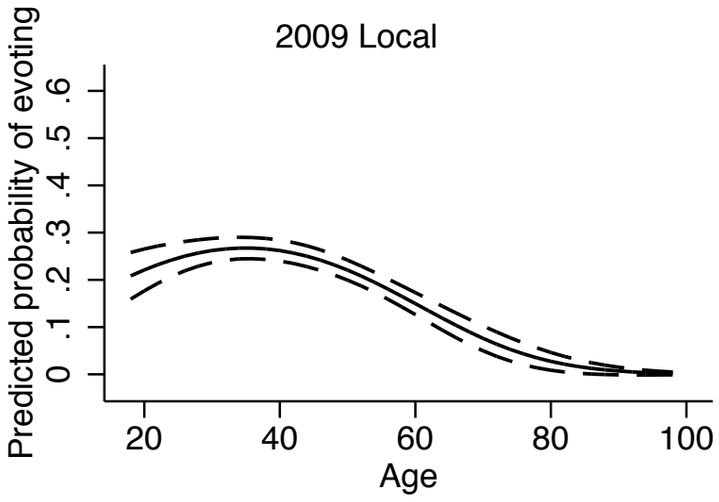
voting habit, good PC-literacy, average PC-literacy, trust in e-voting system, LR self-position, political talk

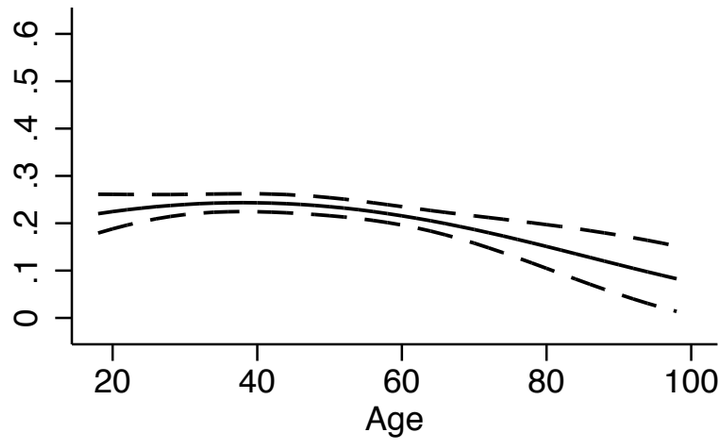
$$\ln\left\{\frac{\Pr(evote = 1)}{1 - \Pr(evote = 1)}\right\} = \beta_0 + \beta_i X_i$$

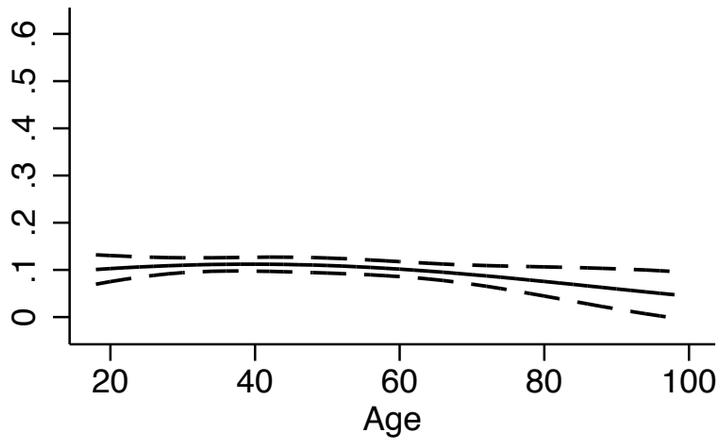

2005 Local
Predicted probability of evoting
0 .1 .2 .3 .4 .5 .6
20 40 60 80 100
Age

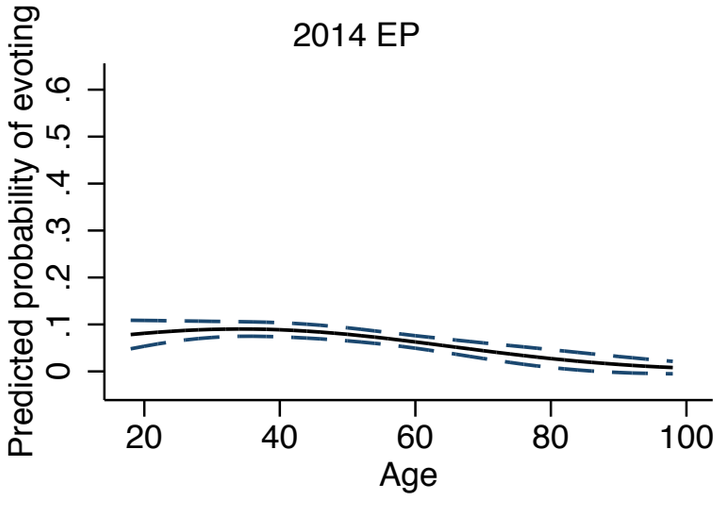

2007 National
0 .1 .2 .3 .4 .5 .6
20 40 60 80 100
Age


2009 EP
0 .1 .2 .3 .4 .5 .6
20 40 60 80 100
Age

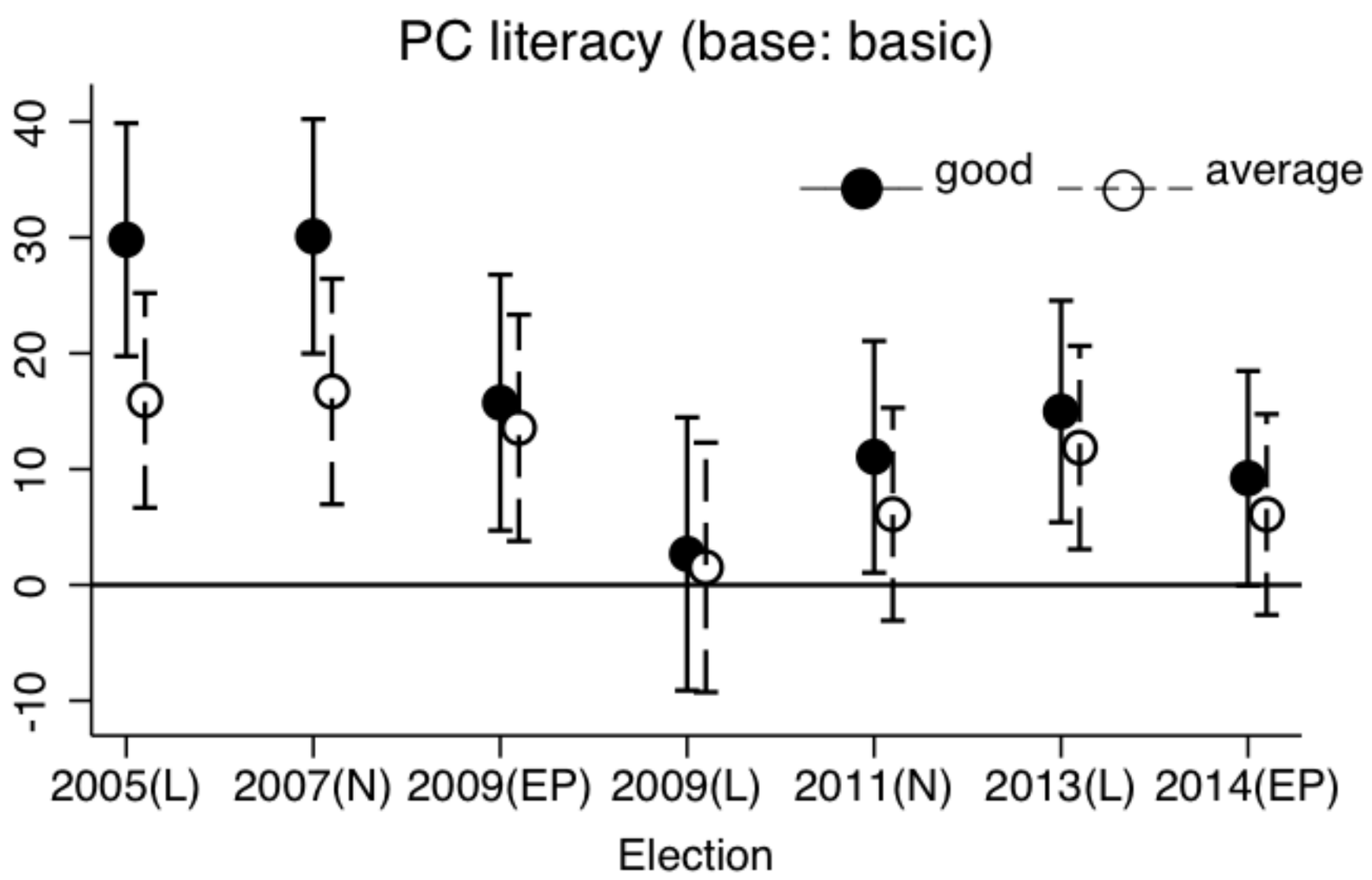

2009 Local
Predicted probability of evoting
0 .1 .2 .3 .4 .5 .6
20 40 60 80 100
Age

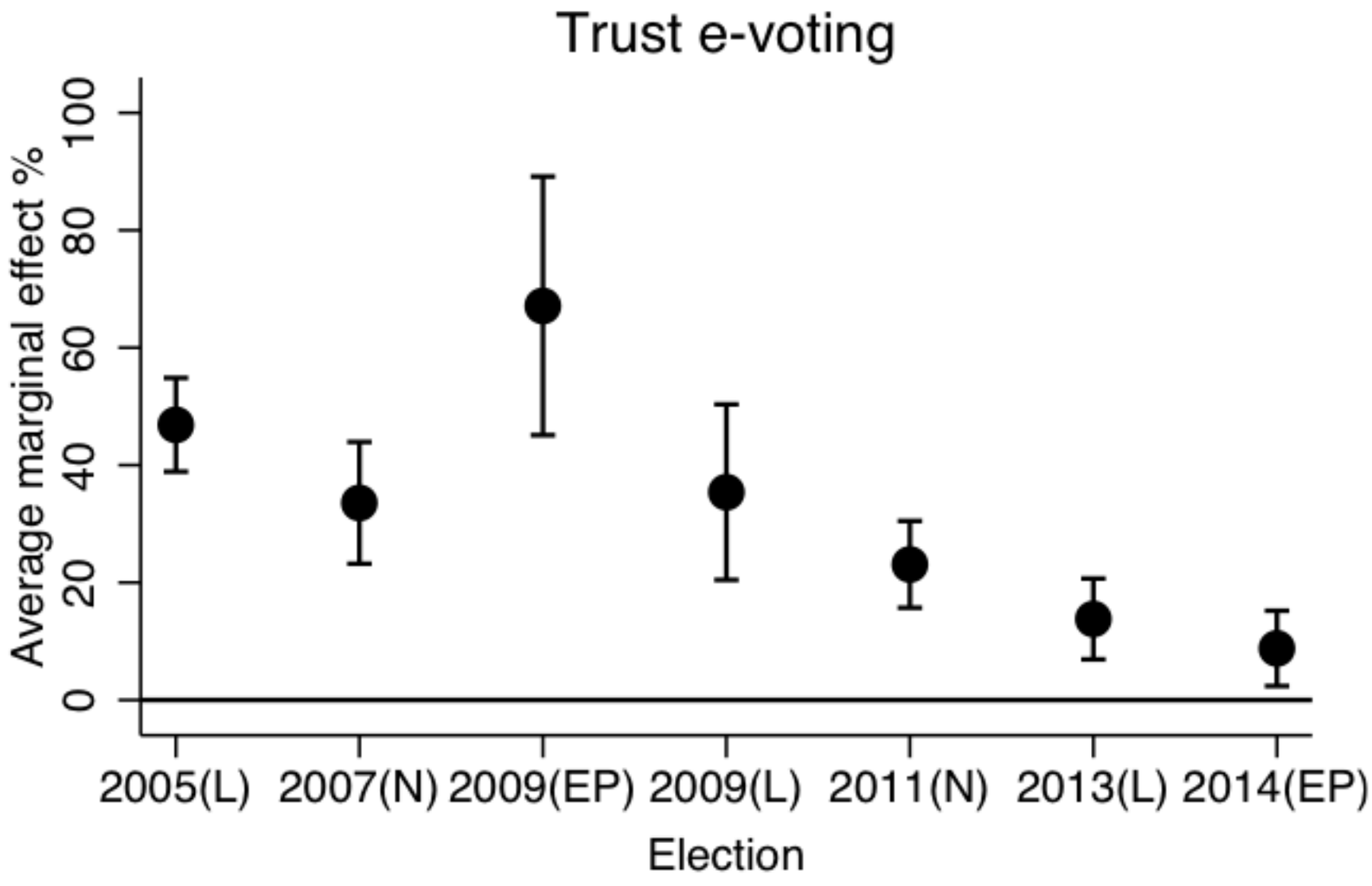

2011 National
0 .1 .2 .3 .4 .5 .6
20 40 60 80 100
Age


2013 Local
0 .1 .2 .3 .4 .5 .6
20 40 60 80 100
Age

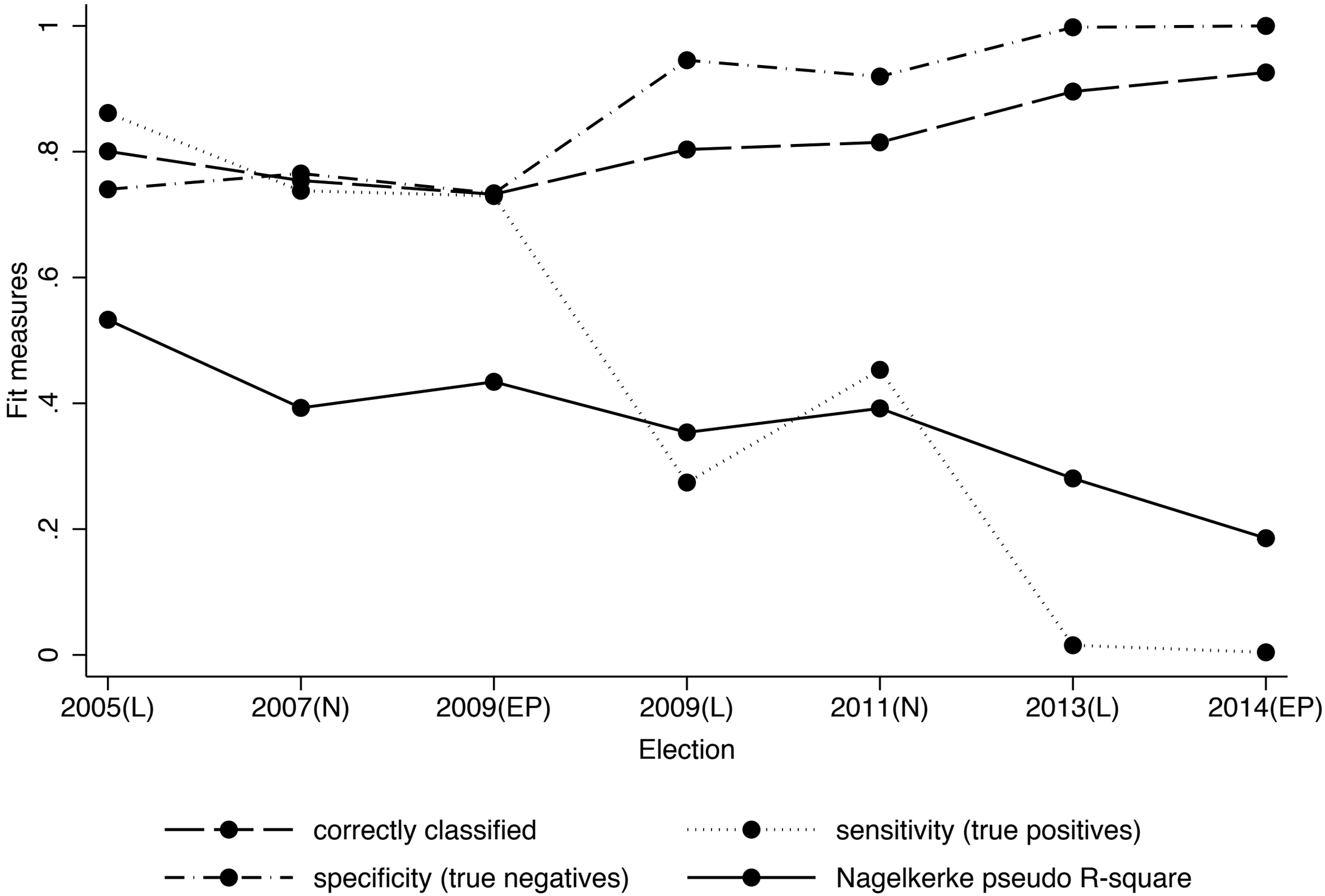

2014 EP
Predicted probability of evoting
0 .1 .2 .3 .4 .5 .6
20 40 60 80 100
Age

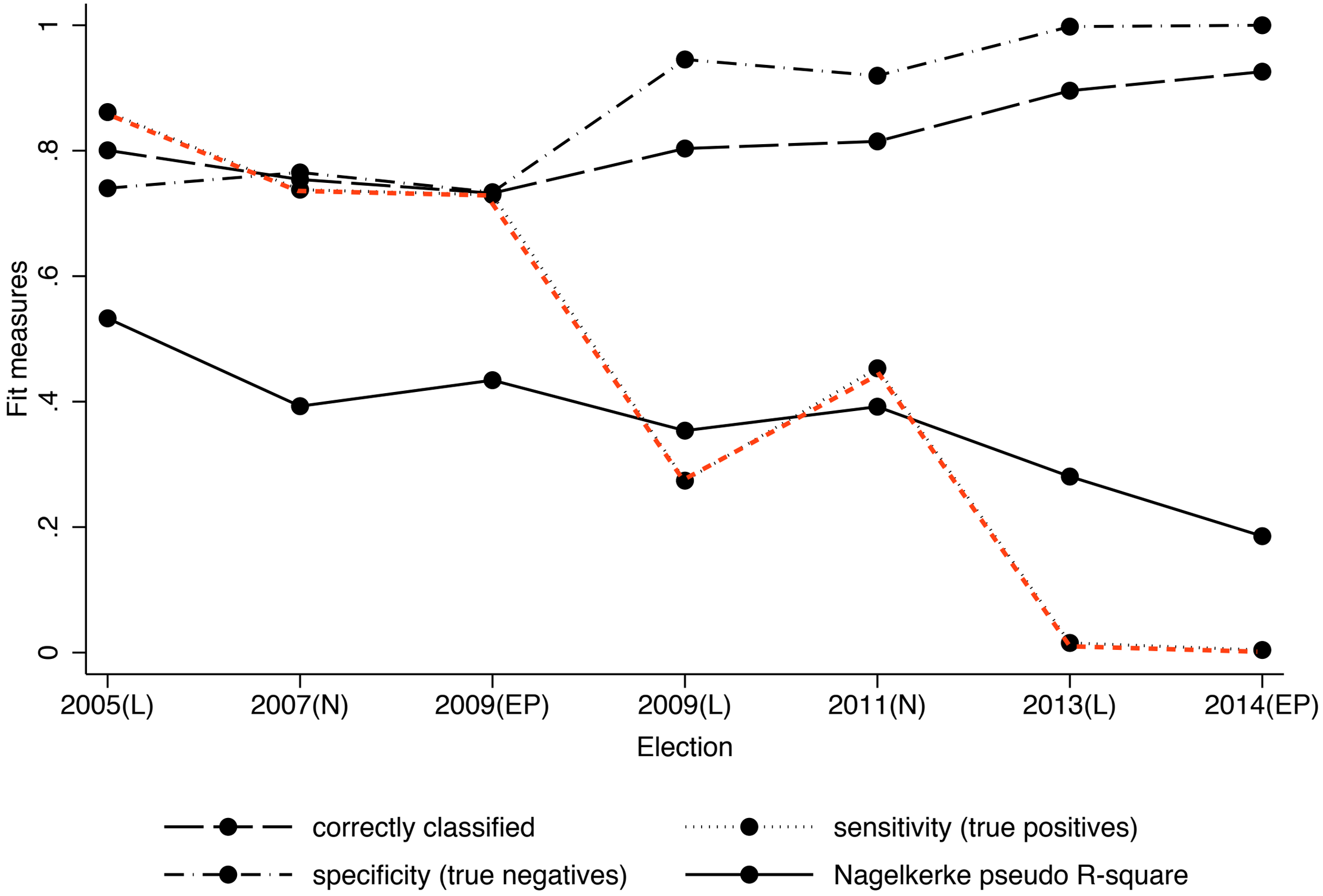

Ethnicity (Estonia)
60
40
20
0
2005(L)
2007(N)
2009(EP)
2009(L)
2011(N)
2013(L)
2014(EP)
Election

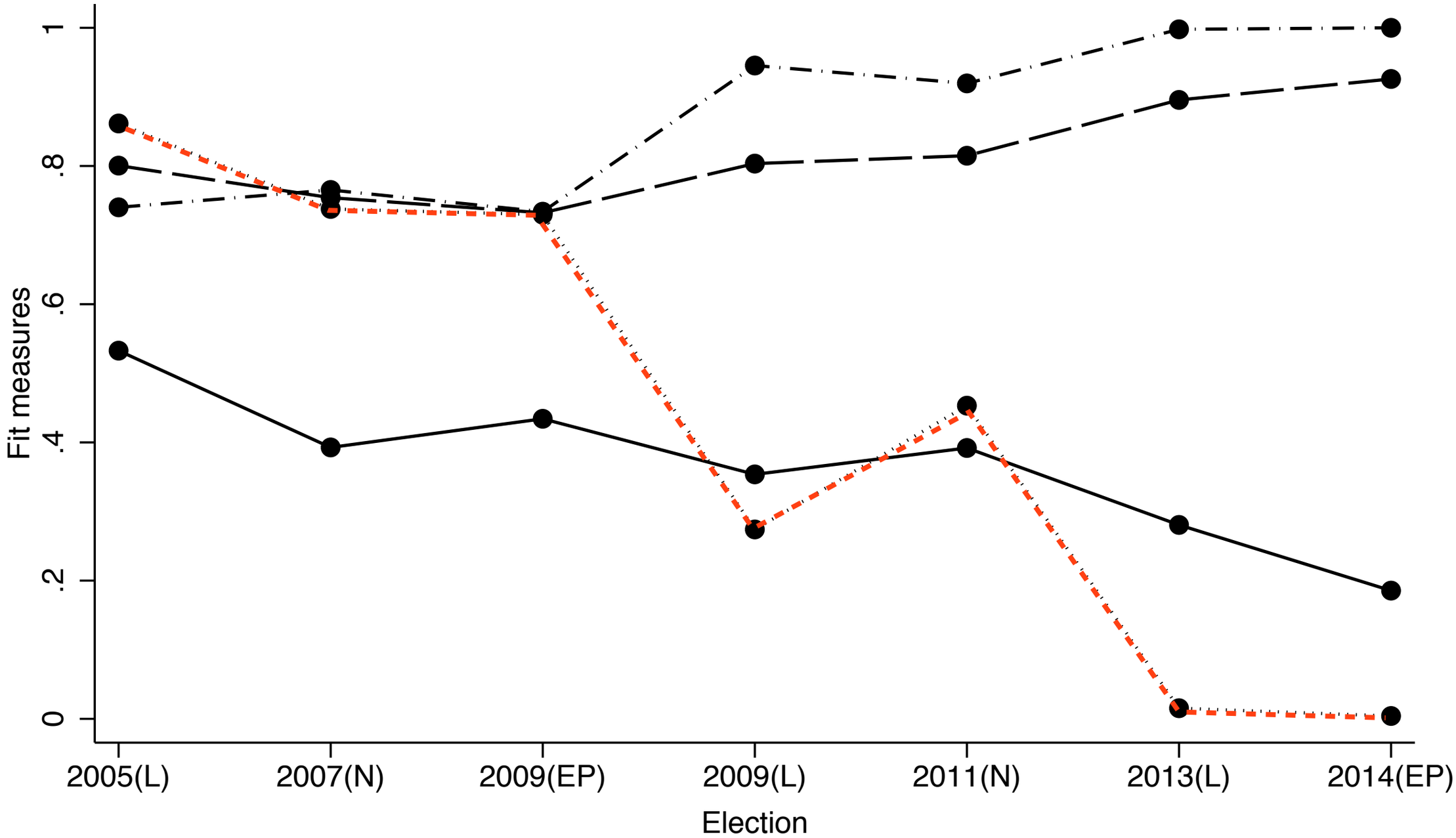

PC literacy (base: basic)
good
average
40
30
20
10
0
-10
2005(L)
2007(N)
2009(EP)
2009(L)
2011(N)
2013(L)
2014(EP)
Election


Trust e-voting
Average marginal effect %
0
20
40
60
80
100
2005(L)
2007(N)
2009(EP)
2009(L)
2011(N)
2013(L)
2014(EP)
Election


Left-right self-position
3
2
1
0
-1
-2
2005(L)
2007(N)
2009(EP)
2009(L)
2011(N)
2013(L)
2014(EP)
Election


Fit measures
0
.2
.4
.6
.8
1
2005(L)
2007(N)
2009(EP)
2009(L)
2011(N)
2013(L)
2014(EP)
Election
correctly classified
specificity (true negatives)
sensitivity (true positives)
Nagelkerke pseudo R-square


Fit measures
0
.2
.4
.6
.8
1
2005(L)
2007(N)
2009(EP)
2009(L)
2011(N)
2013(L)
2014(EP)
Election
correctly classified
specificity (true negatives)
sensitivity (true positives)
Nagelkerke pseudo R-square



The model fails to correctly predict e-voters

I

We find evidence of the diffusion of internet voting

1 We find evidence of the diffusion of internet voting

2 Three electoral cycles required for diffusion to begin

Publication

Diffusion of Internet Voting

Usage Patterns of Internet Voting in Estonia Between 2005-2013

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University of Tartu

R. Michael Alvarez
California Institute of Technology

Priit Vinkel
Tallinn Technical University

Thad Hall
University of Utah

72nd Annual Midwest Political Science Association Conference
April 3-6, 2014, Chicago

Internet voting log-data

Data

Session level data

2013 Local Elections and 2014 EP elections

Automatically generated by e-voters

Logged by the system of e-voting

2013	2014
1:47	1:29
Estonia	Estonia
Windows	Windows
ID-card	ID-card
age 43 years	age 45 years
8am-10pm	8am-10pm

	KOV2013		EP2014	
Times voted	N	%	N	%
0	4,070	2.95	1,303	1.25
1	131,221	95.18	101,404	97.09
2	2,348	1.70	1,595	1.53
3	186	0.13	100	0.10
4 and more	41	0.04	42	0.03
Total	137,866	100.00	104,444	100.00

2 Global index of non-normality

Available *ex ante*

Parametric

Compliant with normality

Available *ex ante*

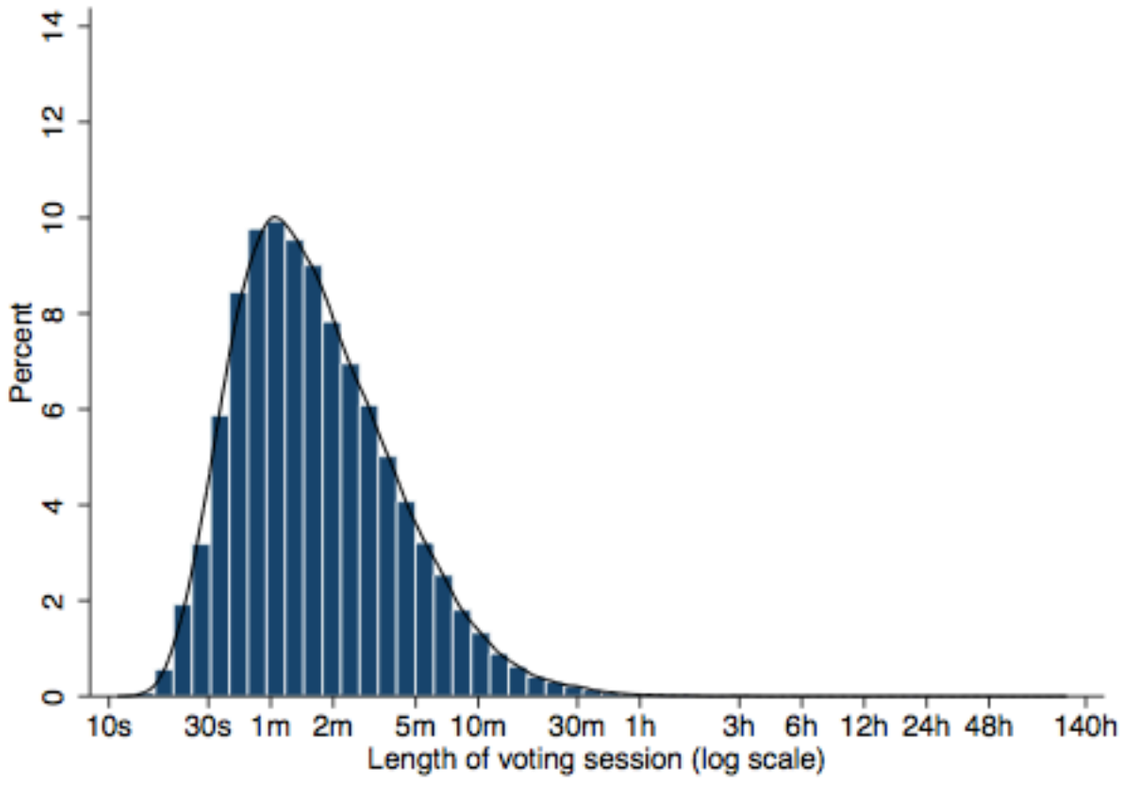
Parametric

Compliant with normality

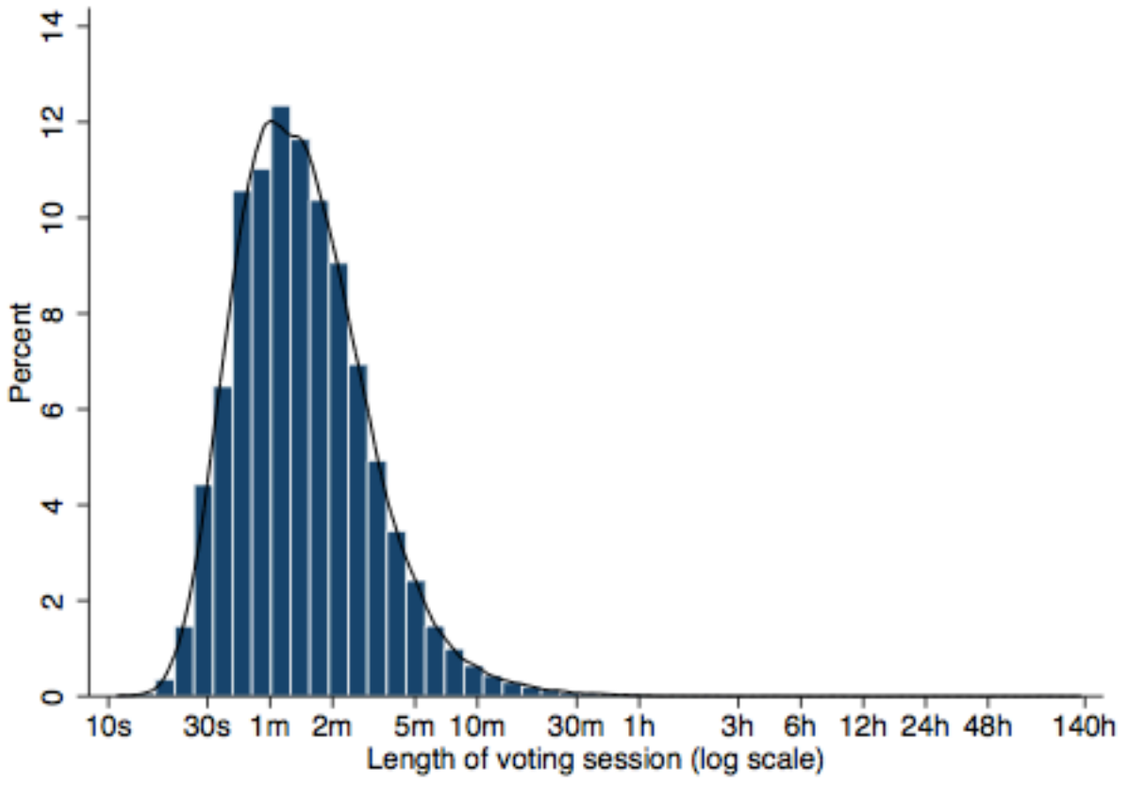
c_1 Session length

c_2 Number of votes

c_3 Number of sessions

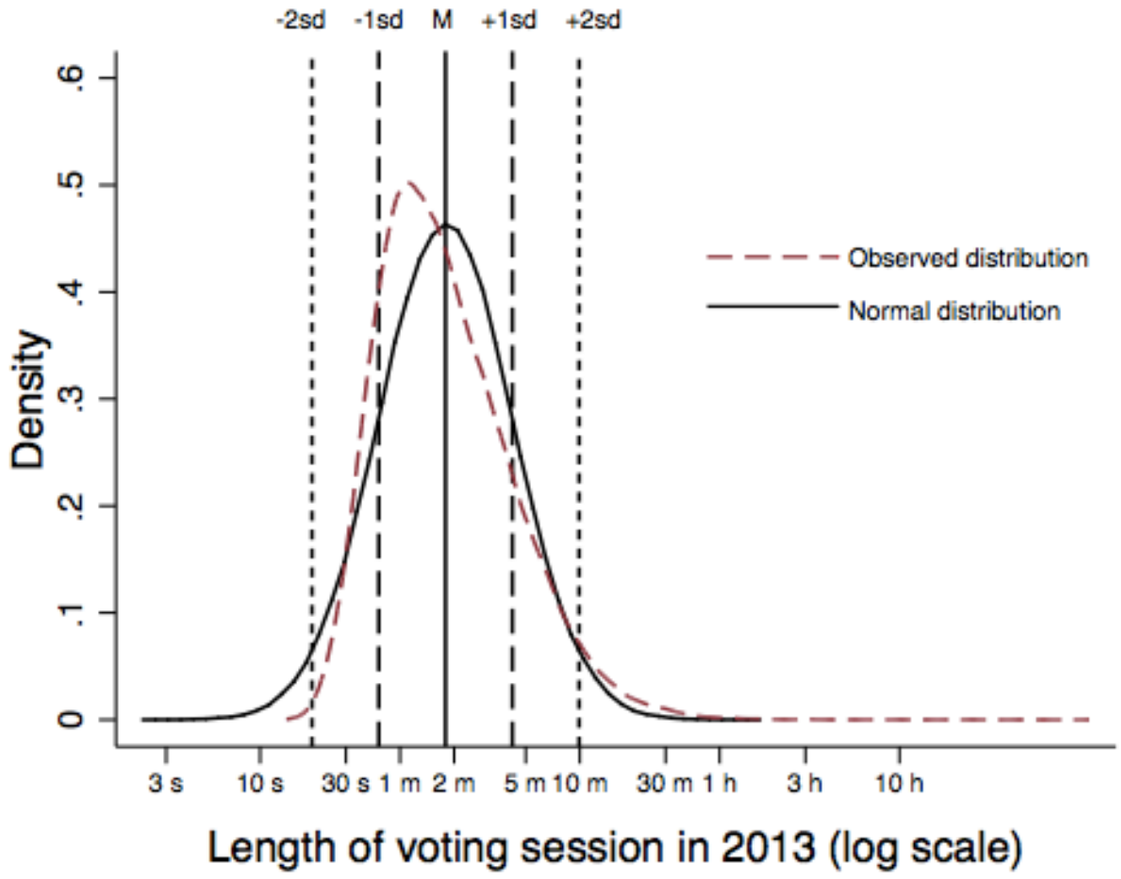


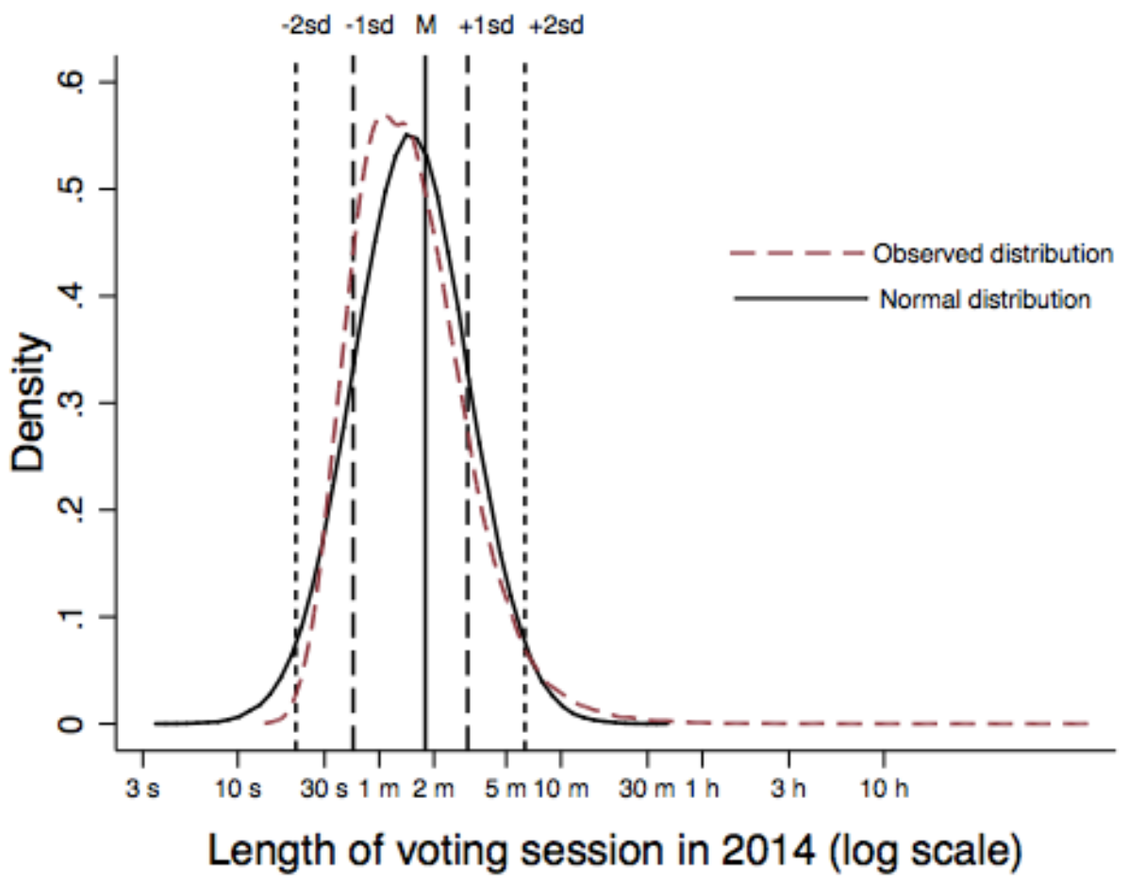
(a) 2013



(b) 2014

Figure 3.1: Voting session length distributions


-2sd
-1sd
M
+1sd
+2sd
Density
0
.1
.2
.3
.4
.5
.6
Observed distribution
Normal distribution
3 s
10 s
30 s
1 m
2 m
5 m
10 m
30 m
1 h
3 h
10 h
Length of voting session in 2013 (log scale)


-2sd
-1sd
M
+1sd
+2sd
Density
0
.1
.2
.3
.4
.5
.6
Observed distribution
Normal distribution
3 s
10 s
30 s
1 m
2 m
5 m
10 m
30 m
1 h
3 h
10 h
Length of voting session in 2014 (log scale)

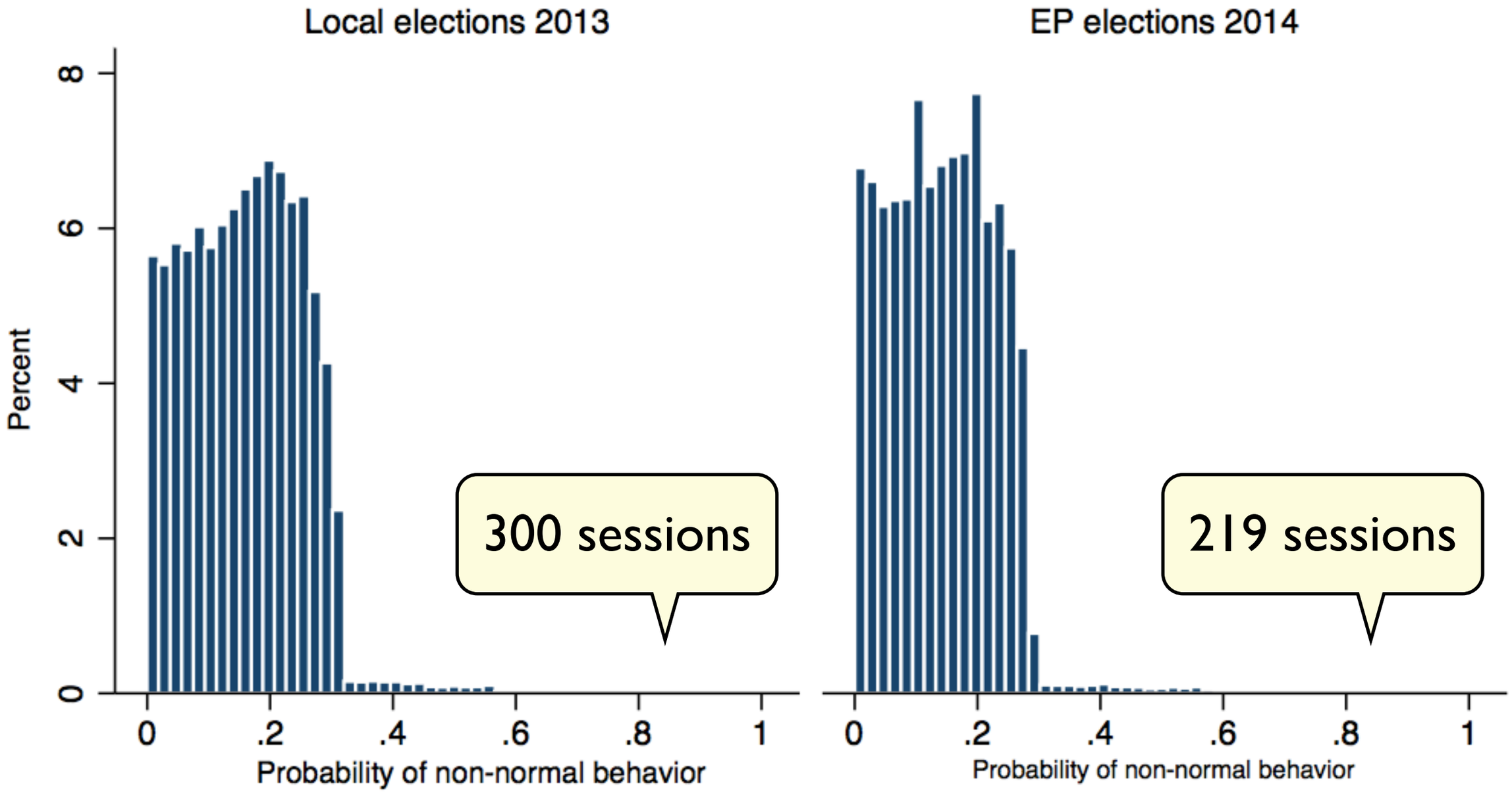
$$z = \frac{x - \bar{x}}{stdv(x)}$$

$$c_1 = 1 - Pr(z) = 1 - \frac{e^{-\frac{1}{2}z^2}}{\sqrt{2\pi}}$$

$$c_2 = 1 - Pr(x) = 1 - \frac{\mu^x e^{-\mu}}{x!}, \quad x = 0, 1, 2, ...$$

$$c_3 = 1 - Pr(x|x > 0) = 1 - \frac{\mu^x}{(e^\mu - 1)x!} \quad x = 1, 2, 3, ...$$

$$g = c_1 * c_2 * c_3$$


Local elections 2013
EP elections 2014
Percent
0
2
4
6
8
0
.2
.4
.6
.8
1
Probability of non-normal behavior
300 sessions
219 sessions
Global non-normality index

Digital Signature

Digital signature enables secure, legally-binding, electronic document signing

e-Law

Allows public access to every piece of draft law that has been submitted since February 2003

e-Prescription

A centralized, paperless system for issuing and handling medical prescriptions

e-School

Allow students, teachers and parents to collaborate in the learning process

e-Tax

e-Tax has drastically reduced the time spent by individuals and entrepreneurs on filing taxes

Electronic Health Record

Integrates data from healthcare providers into a national record for each patient

Electronic ID Card

e-ID acts as definitive proof of ID in secure electronic environments

Electronic Land Register

A one-of-a-kind information system for storing real estate and land data

i-Voting

i-Voting allows voters to cast their ballots over the internet, from anywhere in the world

m-Parking

Allows drivers to pay for city parking using a mobile phone

MOBIIL

Mobile-ID

Allows a client to use a mobile phone as a form of secure electronic ID

Mobile Payment

Enables payment for goods and services using mobile phones

Population Register

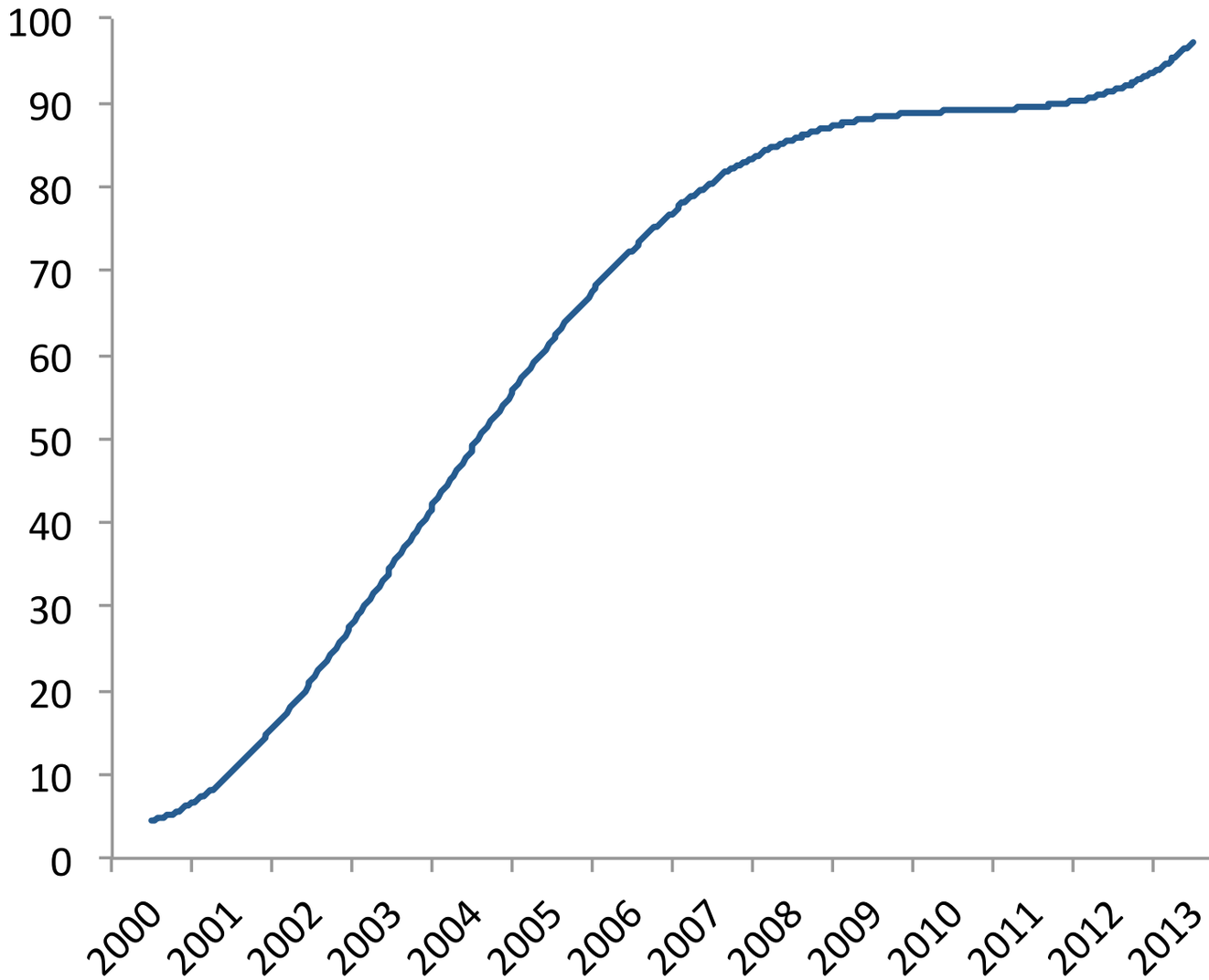
The state database for basic information about each person living in Estonia

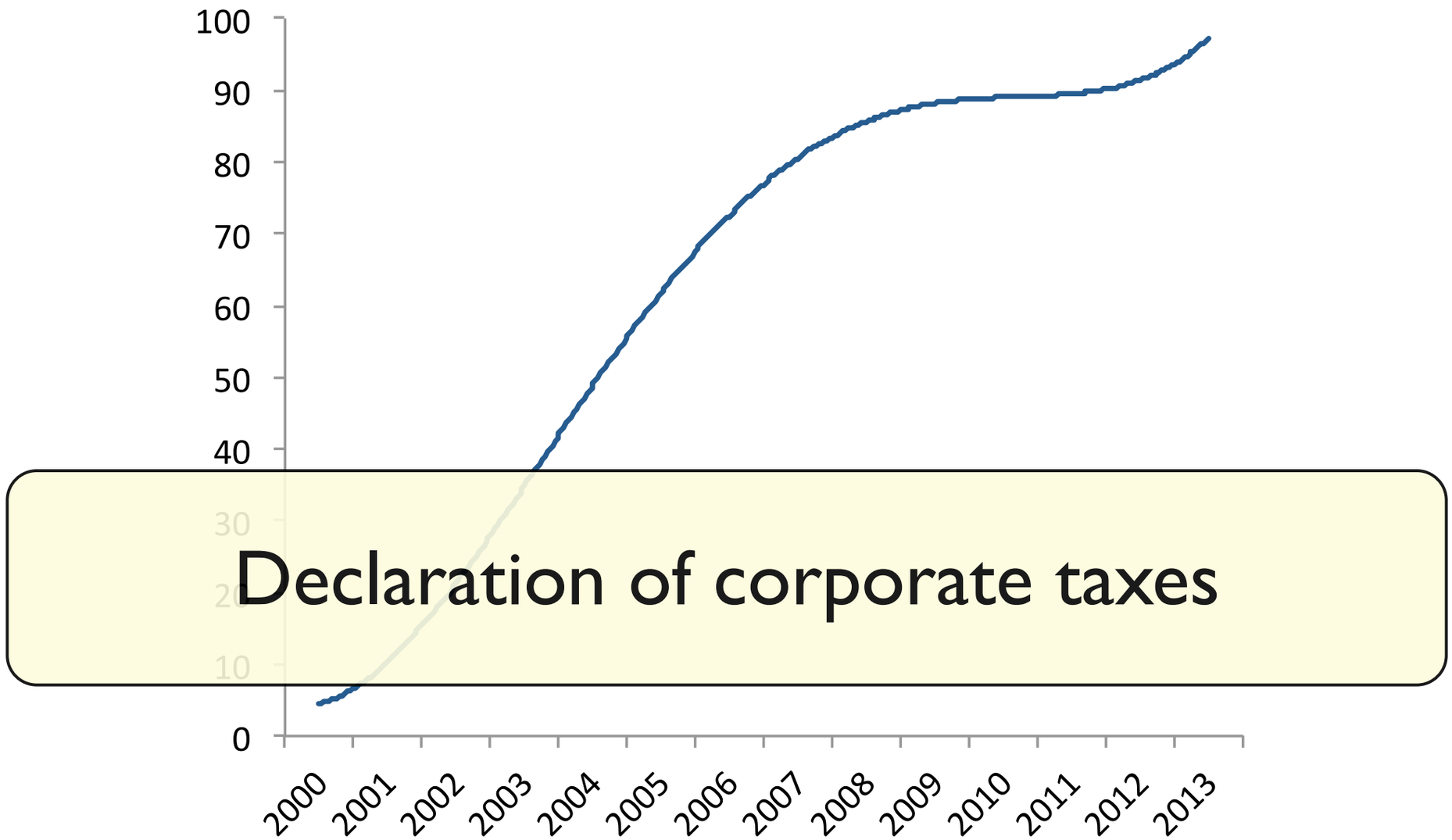
Social Welfare e-Services

The social welfare benefit system is accessible by a convenient, online environment

State e-Services Portal

A one-stop-shop for the hundreds of e-services offered by government institutions


100
90
80
70
60
50
40
30
20
10
0
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013


100
90
80
70
60
50
40
30
20
10
0
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
Declaration of corporate taxes

Estimate the likelihood of
failure to pay the taxes

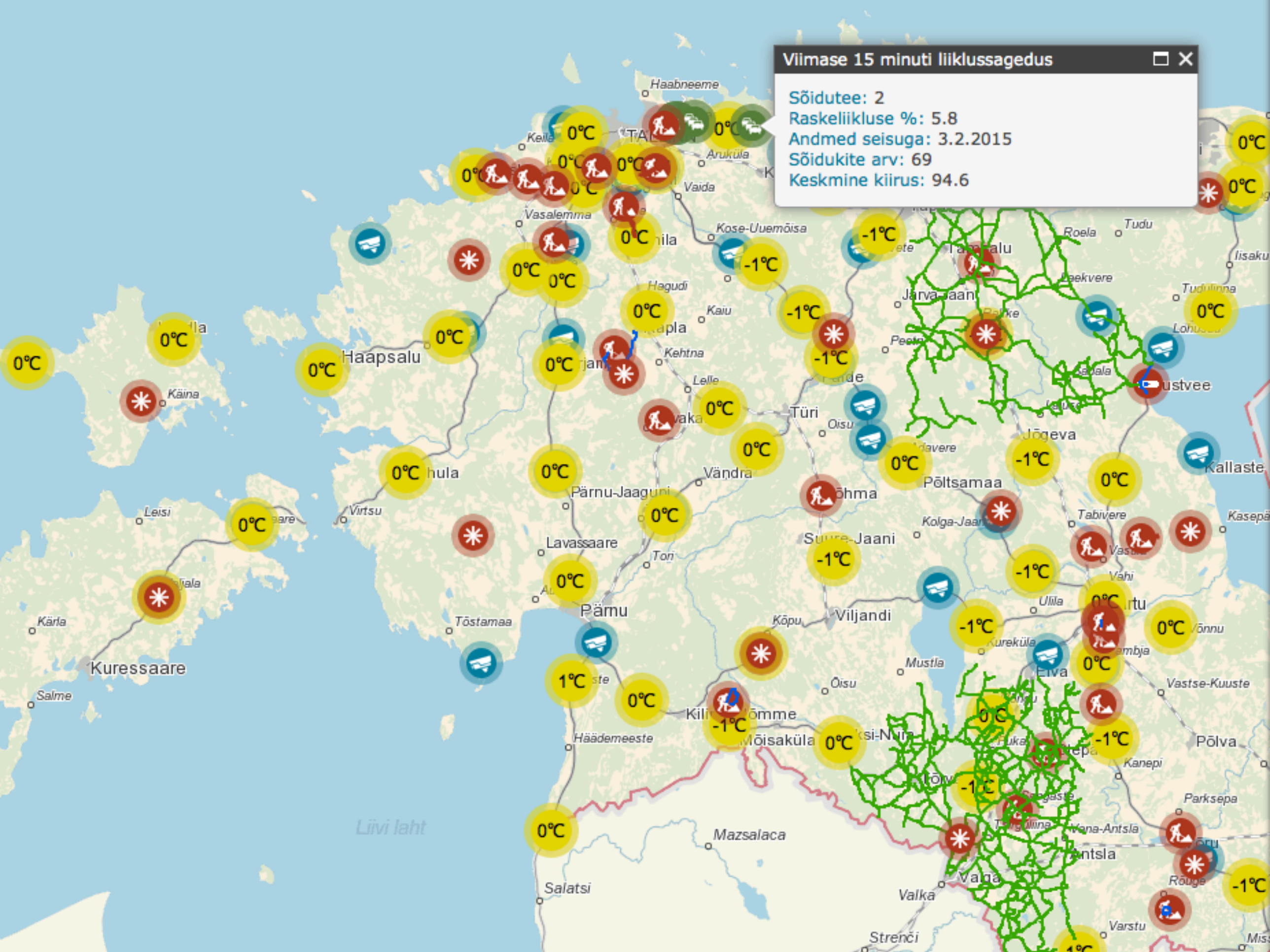
Estimate the likelihood of
failure to pay the taxes

Estimate the size of the potential
debt outstanding

Estimate the likelihood of
failure to pay the taxes

Estimate the size of the potential
debt outstanding

Estimate the recovery probability


Viimase 15 minuti liiklussagedus
Sõidutee: 2
Raskeliikluse %: 5.8
Andmed seisuga: 3.2.2015
Sõidukite arv: 69
Keskmine kiirus: 94.6
Haabneeme
Keila
Aruküla
Vaida
Vasalemma
Kose-Uuemõisa
Roela
Tudu
Järva-Jaani
Tapa
Tudulinna
Lohusuu
Hagudi
Kaiu
Haapsalu
Kehtna
Lelle
Türi
Oisu
Jõgeva
Põltsamaa
Kallaste
Tabivere
Kasepää
Kolga-Jaani
Suure-Jaani
Vahi
Ulila
Tartu
Virtsu
Pärnu-Jaagupi
Vändra
Lavassaare
Tori
Leisi
Kärla
Kuressaare
Salme
Tõstamaa
Pärnu
Viljandi
Kõpu
Mustla
Eivere
Vastse-Kuuste
Põlva
Kanepi
Häädemeeste
Mõisaküla
Mazsalaca
Liivi laht
Salatsi
Valka
Valga
Parksepa
Rõuge
Varstu
Strenči

Viimase 15 minuti liiklussagedus

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Sõidukite arv: 69
Keskmine kiirus: 94.6








The Impact of Public e-Services

Statistical modeling, prediction,
anomaly detection, auto-generated data

Kristjan Vassil
University of Tartu