# Coverage Bias in European Telephone Surveys: Developments of Landline and Mobile Phone Coverage across Countries and over Time

**Survey Methods: Insights from the Field**

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**Abstract :** With the decrease of landline phones in the last decade, telephone survey methodologists face a new challenge to overcome coverage bias. In this study we investigate coverage error for telephone surveys in Europe over time and compare two situations: classical surveys that rely on landline only with surveys that also include mobile phones. We analyzed Eurobarometer data, which are collected by means of face-to-face interviews and contain information on ownership of landline and mobile phones. We show that for the period 2000-2009, time has a significant effect on both mobile phone penetration and coverage bias. In addition, the countries' development significantly affects the pace of these changes.

## Introduction

The first decennium of the 21st century has been marked by fast-paced technological changes that influence survey methods and survey quality. The main challenge for telephone surveys arose with the development of mobile phones. Traditionally, telephone surveys relied on available lists of telephone numbers or random digit dialing (RDD) to avoid undercoverage of unlisted numbers. This technology was developed for fixed landline telephones (see Lepkowski, 1988). Mobile phone numbers are usually not listed and have a different numbering system (e.g., in mobile numbers, as opposite to the landline phone numbers, the prefix does not represent an area coding) making RDD techniques difficult (Tortora, Groves, & Peytcheva, 2008). Especially, the mobile-phone-only population poses a coverage problem to survey research (Tucker & Lepkowski, 2008).

Telephone surveying started in the early 1970's in market research in the USA, in reaction to the growing costs of face-to-face surveys and was made possible by an increase in households with landline telephones (Nicholls, 1988; Nathan, 2001). From a new method it soon developed into the heir apparent of face-to-face interviews and was seen as the most prominent data collection method in the USA in the late 1980's (Dillman, 2002; Tucker & Lepkowski, 2008). This was partly due to a growing body of methodological studies that reassured survey researchers about issues in data quality and interviewer effects (for an overview, see De Leeuw & Van der Zouwen, 1988; Groves, 1989, chap. 8).

The start of regular telephone-based interviewing followed years of concerns about low telephone coverage and the potential for biased estimates as a result of ignoring non telephone households, defined at that point as those without landline service. In those years, fixed landline phones were not yet fully integrated in society and a household either had landline telephone service or not (Tucker & Lepkowski, 2008). Researchers argued that if the fraction of households without a telephone is large and distinctive in its characteristics, telephone surveys may provide misleading information (e.g., Massey, 1988). In the late eighties of the previous century, studies into telephone coverage showed a high penetration of landline telephones in the USA (Thornberry & Massey, 1988), but technological developments in Europe differed from those in North America and the coverage rates for landline telephones ranged from around 16 percent of households in Hungary to 94% in Finland and 99 percent in Sweden (Trewin & Lee, 1988). Furthermore, those without a landline phone differed on several key demographic variables (Trewin & Lee, 1988; Thornberry & Massey, 1988). Since then, substantial portions of the general population in Europe acquired landline telephone access (Busse and Fuchs, 2012), although countries still differ. For instance, Blyth (2008) reports over the year 2005 coverage rates for landline telephones of 52% for Finland, 64% for Hungary, and 100% for Sweden.

The difference between Finland and Sweden clearly illustrates a new problem in telephone surveys: the increase of mobile phones and mobile-phone only households. In both countries almost the total population can be reached by phone, but one has to use different technologies. In December 2005, in both countries over 94% of the households had a mobile phone, but in Sweden the percentage mobile-phone only households was less than 1%, while in Finland it was 47% (Blyth 2008).

Sweden and Finland are extreme cases, but both Blyth (2008) and Busse & Fuchs (2012) point out that the number of mobile phones and mobile phone-only is increasing over time and that the pattern differs greatly from country to country. Furthermore, several studies found differences on key demographics, like age and education, between those with and without a mobile phone (Busse & Fuchs, 2009; Blyth, 2008; Link, Battaglia, Frankel, Osborn, & Mokdad, 2007; Peytchev, Carley-Baxter, & Black, 2010; Vicente, Reis, & Santos, 2009). There is also some indication that American mobile phone owners are slightly more liberal or Democratic in their views (Mokrzycki, Keeter, & Kennedy, 2009) and differ on a variety of health and life style variables (Blumberg & Luke, 2010). So, more then twenty years later we have come full circle, survey researchers worry about telephone coverage again, this time due to the decrease of landline phone connections in favor of mobile phone-only use. Undercoverage due to the decrease in landline phones and the increase of mobile-only households is one of the main concerns for the validity of conclusions based on traditional landline telephone surveys (Blumberg, Luke, Cynamon & Frankel, 2008; Kuusela, Callegaro, & Vehovar, 2008; Tucker & Lepkowski, 2008), and not including mobile phones in the sampling scheme may result in coverage bias in the estimation of substantive variables of interest in a study (Blumberg, Luke, Ganesh, Davern, Boudreauw, & Soderberg, 2011).

In this study we investigate the consequences of restricting telephone surveys to landline phones and not including mobile phones in telephone surveys for Europe. With the use of Eurobarometer data, which are based on *face-to-face* surveys and provide us with mobile and landline telephone coverage figures over time for most European countries, we investigate trends over time. We analyze three key demographic variables: sex, age, and length of education, and two substantive variables: political left-right self-placement and life satisfaction. We mimic the standard survey practice of the past by looking at coverage bias when owners of landline telephone connections are investigated. We compare this to a new approach where all telephone owners are interviewed, either by landline phone or by mobile phone. The coverage bias for the traditional landline telephone surveys is expected to increase over time, whereas a bias decrease is expected for the 'any-phone' surveys. The analysis will cover the period between the years 2000, when the question about mobile-phone ownership was included in the Eurobarometer questionnaire

for the first time, and 2009.

In the next sections, we first describe the available data and the analysis methods used. We then give an overview of trends in landline and mobile phone coverage and the resulting coverage bias for available demographic variables and socio-political variables. This is followed by a multilevel analysis to model changes over time and the influence of socio-economical development on these trends. We end with a critical discussion and implications for research.

# Methods

A more detailed description of the Eurobarometer, the data, the bias indices and the analysis method used, can be found in Methodological Background.

## Available Data

In terms of coverage of the household population, face-to-face interviews are often viewed as the gold standard by which other modes are compared (e.g., Groves, Fowler, Couper, Lepkowski, Singer, & Tourangeau, 2009; De Leeuw, 2008). Since 2000 the Eurobarometer, which is based on *face-to-face* interviews, contains a question about mobile phone ownership. This provides an opportunity to analyze landline and mobile phone coverage figures across European countries and over time. In this study, the total Eurobarometer group is regarded as a proxy for the target population to which two telephone subgroups are compared. The first subgroup, which mimics traditional RDD telephone surveys, consists of those with a landline connection (i.e., landline-only households and households with access to both a landline and a mobile phone). The second subgroup mimics a new situation when households without landline phones are *not* excluded from the survey, the any-phone group (i.e., landline only, landline + mobile, *and mobile-only*).

The Eurobarometer collects data for the European Community across EU members and applicant countries through face-to-face interviews. For each standard Eurobarometer survey new and independent samples are drawn; since October 1989 the basic sampling design is a multi-stage probability sample (for more details, see Gesis Eurobarometer Survey series, 2012). In 2000 seventeen countries were part of the Eurobarometer. Sixteen new countries joined in the year 2004. The core questionnaire contains trend questions about socio-political orientation and standard demographic questions. Besides type of telephone, (face-to-face) interview data on the following variables were available for all countries: sex, age, length of education, political left-right self-placement and life satisfaction; also the year of data collection was recorded. For the question wording, see Questions as Asked in Eurobarometer. To assess coverage bias, we analyzed the available demographic variables.

The demographic variables age, gender, and education are available for all countries in the Eurobarometer. Previous research has shown that, especially age and to a lesser extent gender and education,  are associated with mobile phone-only use in Europe (e.g., Busse & Fuchs, 2012; Kuusela, Calllegaro, & Vehovar, 2008). Furthermore age, sex, and education correlate with many substantive variables typically assessed in academic or market research surveys (Fuchs & Busse, 2009). Therefore, these variables are of extreme interest in investigating coverage bias. In addition, the substantive variables political left-right self-placement and life satisfaction offer an opportunity to directly investigate the influence of undercoverage on the assessment of two major socio-political indicators.

All the data were downloaded in February and March 2011, at which point Eurobarometer data were fully available for the years 2000 to 2009. Hence, our analysis will cover this ten year period. Unfortunately, no detailed information on response rates is made available publicly and on a regular basis by the European Commission's Eurobarometer unit, also no systematic nonresponse studies are available. However, the Eurobarometer data *do* include integrated design and post-stratification weights to adjust the realized samples to EUROSTAT population data. These weights are used in estimating the coverage bias indicators.

**Additional country-level variables**

The data from the Eurobarometer are individual level data, collected through face-to-face interviews in each country. The countries involved in the Eurobarometer differ on socio-economic variables that may influence landline and mobile telephone coverage (Vagliasindi, Güney, & Taubman, 2006; Rice & Katz, 2003). To model this, we collected socio-economic country level data from Eurostat, the World Bank, and the Human Development Report for each year in the period 200-2009. Contextual country level variables are: life expectancy at birth (in years), country's educational index, duration of primary and secondary education (in years), and urbanization (the percentage of urban population). Economic indices on country level are the percentage of employed (labor force), the Gini coefficient, which measures income inequality, the Gross Domestic Product growth (GDP), and inflation. For a description of these variables and the data sources including the URL, see Contextual Variables at Country Level.

## Indicators of Coverage Bias

To assess the amount of bias, we use two indices: the relative bias and the absolute relative bias (Busse & Fuchs, 2012; Groves & Peytcheva, 2008). The relative coverage bias is used for descriptive purposes, as its sign indicates over- or undercoverage of specific groups (e.g., if more men than women have mobile-phone-only in a certain year and in a certain country). However, when modeling changes over time and across countries, positive and negative values for relative coverage can cancel each other out and the resulting regression coefficients may falsely give the impression that the overall coverage error is small. Therefore, in our multilevel analyses we use the absolute relative coverage bias.

The relative and absolute relative coverage bias are defined as

Relative coverage bias:

(1) $$\frac{\bar{Y}_{Phone(i)} - \bar{Y}_{EB}}{\bar{Y}_{EB}},$$

and

Absolute relative coverage bias:

(2) $$\left|\frac{\bar{Y}_{Phone(i)} - \bar{Y}_{EB}}{\bar{Y}_{EB}}\right|,$$

where $\mathrm{Phone(i)}$ represents the specific telephone subgroup and $\mathrm{EB}$ the complete face-to-face surveyed Eurobarometer group, which is viewed as our target population. Analogous $\bar{Y}_{\mathrm{Phone(i)}}$ and $\bar{Y}_{\mathrm{EB}}$ represent the means of the telephone subpopulations and the full Eurobarometer target population on the variable $y$.

We compare two telephone subgroups with the Eurobarometer target population: (1) landline-phone (i.e., landline-only households and households with access to both a landline and a mobile phone) and (2) the any-phone group (i.e., landline only, landline + mobile, *and mobile-only*). Differences between the two telephone groups and the total Eurobarometer group indicate the bias due to undercoverage if a traditional (landline) telephone survey would have been implemented instead of a face-to-face survey versus if mobile phones would have been included in the telephone survey too.

## Analysis

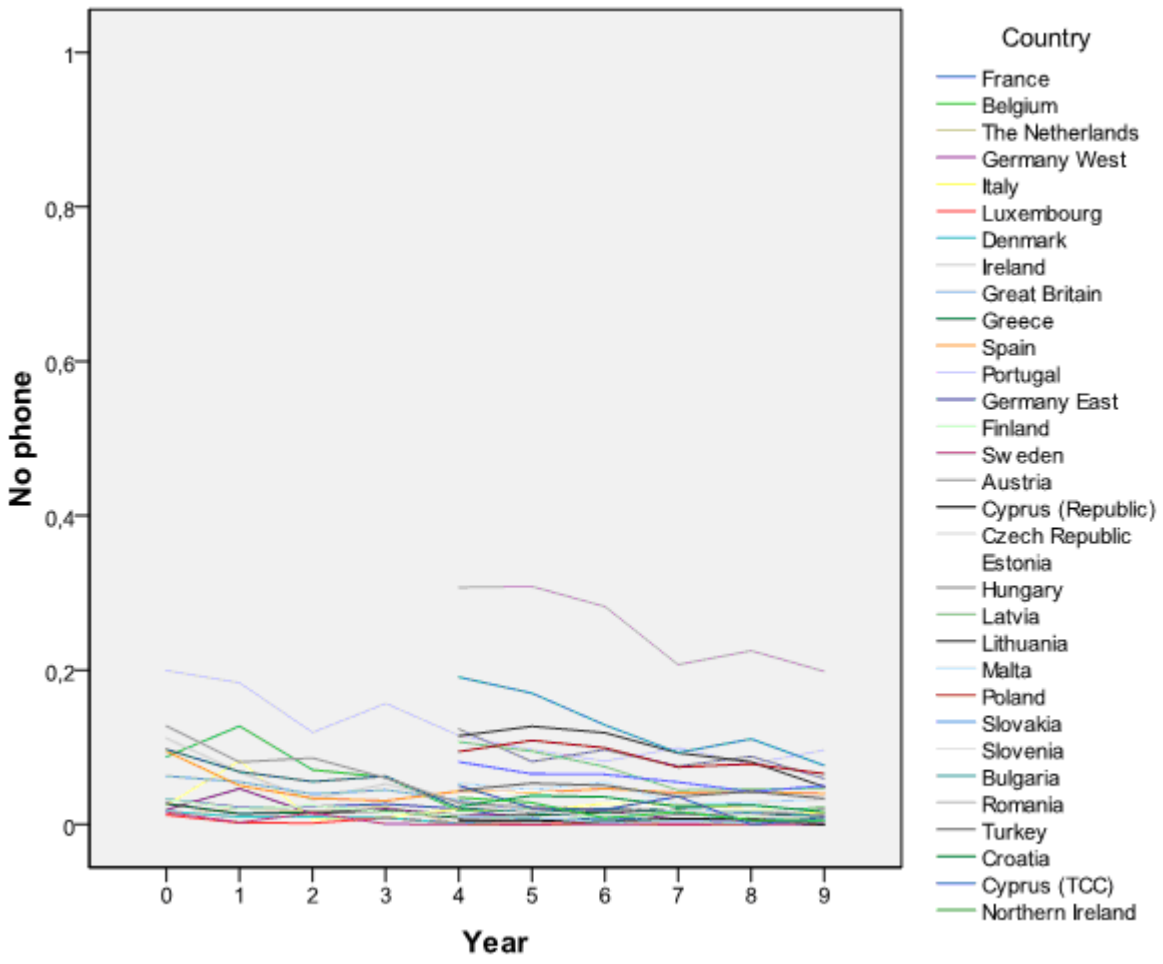
The relative coverage bias is used for descriptive analyses over countries and time. Positive values indicate that estimates from different types of telephone surveys are too high, whereas negative values indicate that these are too low. Multilevel analysis on the absolute relative coverage bias is used to model and explain trends over time and country for all bias indicators (sex, age, length of education, political left-right self-placement and life satisfaction). For ease of interpretation the absolute relative coverage bias is expressed as percentage points. In the multilevel model, the lowest level represents the years, indicated by a time variable coded 2000=0, 2001=1, et cetera. Analysis details are given in Methodological Background.

# Results

## Coverage trends in European countries over time

When we look at the figures for no-phone households across Europe for the period 2000-2009, we see that this clearly decreases over all countries. This is illustrated in *Figure 1*. *Figure 1* shows the trend for a total of 33 countries;note that sixteen mainly former Eastern-European countries joined the Eurobarometer in 2004. Most countries have a no phone rate below 5% in 2009; Romania is an exception with a no-phone rate of 20%. Other countries with a relatively high no-phone rate (between 5 and 10 %) are Latvia, Lithuania, Slovakia, Hungary, Poland, Bulgaria, and Portugal.

*Figure 1: No-phone households across Europe 2000-2009, based on the Eurobarometer's weighted data. Year is coded 0=2000,...,9=2009.*




From a coverage point of view, this seems an almost ideal picture: telephone penetration is very high all over Europe; and even in countries with a relative low telephone penetration the trend clearly shows a reduction of no-phone households. But, a different picture emerges, when we are looking at the development of mobile-phone only households all over Europe as can be seen in *Figure 2*, which clearly shows a rapid increase of mobile-phone-only households in many countries.

*Figure 2: Mobile-phone-only households across Europe 2000-2009, based on the Eurobarometer's weighted data. Year is coded 0=2000,...,9=2009.*

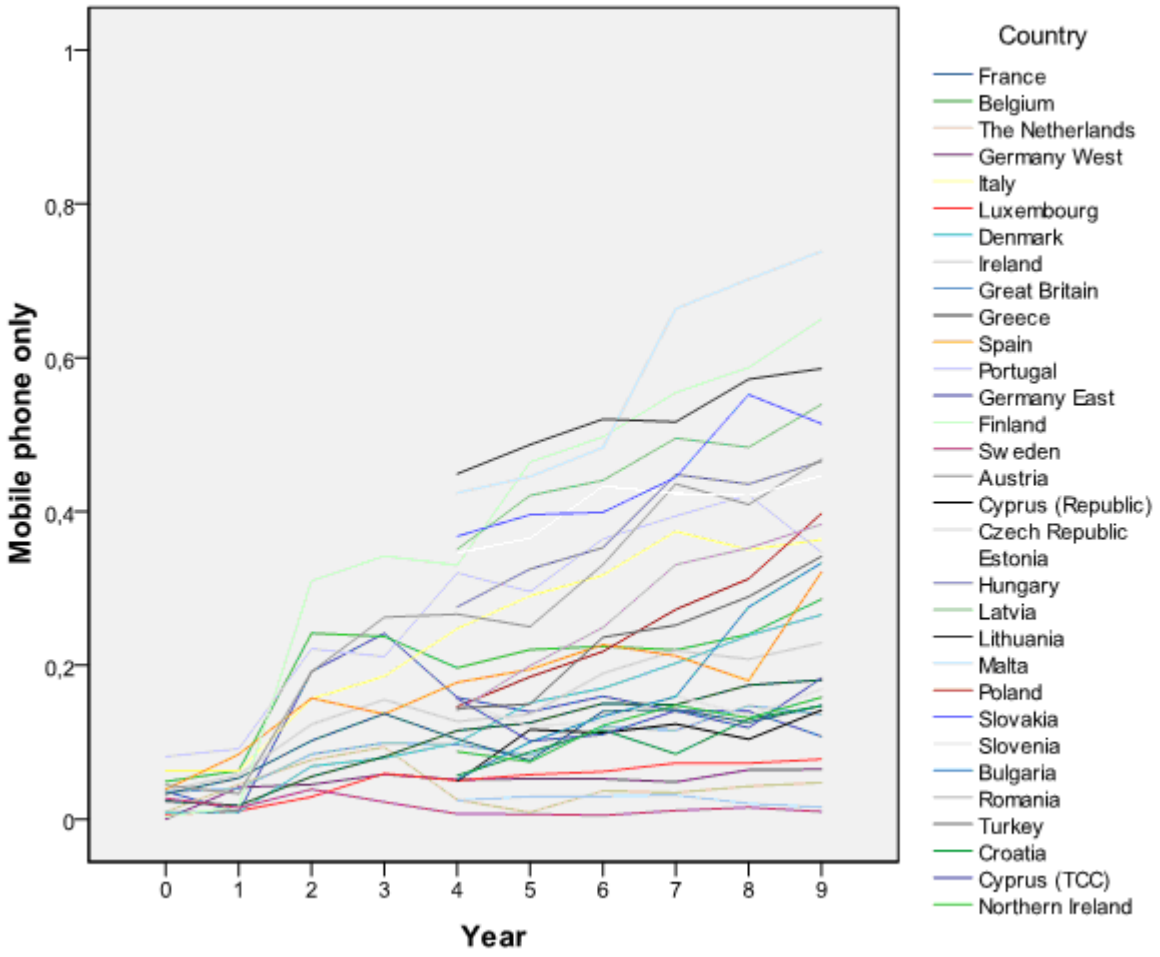



*Figure 2* indicates that when mobile phones are excluded from telephone surveys, a substantive part of the population in certain countries will not be reached. For instance, in 2009 Finland had a mobile-phone only population of 74%. The other countries with a mobile phone only rate higher than 50 % are Slovakia (51%), Latvia (54%), Lithuania (59%), and the Czech Republic (74%). These figures reflect two different trends: in some Western European countries (e.g., Finland) people abandon their landline connection in favor of a mobile phone, while in some former Eastern European countries (e.g. Czech republic) no-phone households opt for a mobile phone instead of a landline phone. The latter trend can be explained by the high expense and unreliability of landline connections in these countries (Vagliasindi, Güney, & Taubman, 2006).

Excluding mobile phones from telephone surveys could lead to biased estimates, due to coverage error. This is indicated by the relative coverage bias (*Equation 1*). Tables for the relative coverage bias for landline surveys and any phone surveys (including mobiles), per country and per year are given in Relative Coverage Bias in Europe.

The general trend for all variables in these tables is that the relative coverage bias shows an increasing trend when traditional landline surveys are employed. The relative coverage bias is in the direction of more males, older respondents, higher educated, and an overrepresentation of political right and persons more satisfied with life. These trends appear to differ across countries. When mobile phones would be included in a telephone survey, the biases are smaller and do not show an upward trend over time. In the next sections, these apparent trends are modeled explicitly using multilevel analysis.

## Changes in coverage bias over time

The analysis reported here is carried out over the full set of countries for all available years (see Methodological Background for details). The change in coverage bias over time is analyzed using multilevel analysis, with years (coded 2000=0, ..., 2009=9) nested within countries. This allows us to test if the change over time is significant and to test if country level variables can explain changes over time. The analysis showed that the effect of time squared was never significant, and therefore only the linear trend of time is included in the model. Table 1 presents the parameter estimates for each bias indicator for two models: a model for the absolute relative bias of estimates based on landline telephone surveys, and a model for the absolute relative bias of estimates based on telephone surveys employing landline plus mobile phones (any phone).

*Table 1. Estimates of multilevel model for absolute relative bias over time 2000-2009*

| | Sex | | Age | | Educ | | Left-Right | | Life Satis. | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Fixed** | LL | Any | LL | Any | LL | Any | LL | Any | LL | Any |
| Intercept | 0.54 | 0.33 | 1.21 | 1.24 | 1.07 | 1.13 | 0.64 | 0.36 | 1.13 | 1.02 |
| Year | 0.05 | -.02 | 0.58 | -.04$^{ns}$ | -.01$^{ns}$ | -.08 | 0.08 | -.01$^{ns}$ | 0.10 | -.05 |
| **Random** | | | | | | | | | | |
| Residual | 0.29 | 0.04 | 2.23 | 0.18 | 0.24 | 0.06 | 0.60 | 0.10 | 0.76 | 0.12 |
| Intercept | 0.06 | 0.02 | 0.90 | 1.30 | 1.22 | 1.91 | 0.37 | 0.15 | 0.20$^{ns}$ | 0.54 |
| Year | 0.004 | ns | 0.26 | 0.01 | 0.01 | 0.002 | 0.003 | ns | 0.01 | ns |

*LL indicates estimates based on (traditional) landline telephone surveys, Any indicates estimates based on telephone surveys including both landline and mobile-phone-only owners; ns indicates nonsignificance.*

The bias in landline telephone surveys show a trend over time that is either positive, indicating increasing bias, or in a few cases not significant. Including mobile phones in the survey leads to a trend that is always negative, indicating decreasing bias, or not significant. Thus, if mobile phones are excluded, there is an increasing overrepresentation of female and older respondents, and an increasing overestimation of respondents that place themselves on the political right and that are more satisfied with their lives. With one exception (landline estimates for life satisfaction) there is always variance between countries in amount of bias. Furthermore, for the landline-only estimates, the trend over time varies across countries. This means that in some countries the increase in bias is faster than in other countries. After including mobile phone-only (any phone estimates), the trend over time varies less across countries, and is significant only for estimates of age and education.

## Coverage bias and country differences

There are differences between countries in coverage bias and for some variables in the rate of decrease of the bias over time. These differences may be modeled by country level variables. Country level variables available for each country are: life expectancy at birth, educational index, duration of primary and secondary education, urbanization, employment, Gini index, GDP growth rate, and inflation (see Contextual Variables at Country Level). The differences in bias between countries are modeled by the direct effects of the country level variables; the differences in rate of decrease are modeled by

interactions of these variables with the time indicator. Table 2 presents the parameter estimates for each bias indicator for two models: a model for the absolute relative bias of estimates based on landline telephone surveys, and a model for the absolute relative bias of estimates based on telephone surveys employing landline plus mobile phones (any phone). The explanatory variables secondary education, GDP-growth rate, and inflation were never significant and are omitted entirely from the model and hence the table. Empty cells in Table 2 indicate incidental insignificant effects removed from both the model and the table.

*Table 2. Estimates of multilevel model with contextual variables for absolute relative bias over time 2000-2009*

| | Sex | | Age | | Educ | | Left-Right | | Life Satis. | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Fixed** | LL | Any | LL | Any | LL | Any | LL | Any | LL | Any |
| Intercept | 0.44 | 0.33 | 1.21 | 0.86 | 0.70 | 1.03 | 0.64 | 0.23 | 0.97 | 1.02 |
| Year | 0.07 | -.02 | 0.58 | $0.01^{ns}$ | $0.02^{ns}$ | -.07 | 0.08 | $0.01^{ns}$ | 0.13 | -.01 |
| LifeExp | -.32 | -.08 | | -.52 | -.89 | | | -.19 | -.50 | -.51 |
| Urban | | | | -.31 | | -.66 | | | | |
| GendPay | | | | | 0.38 | | | | | |
| Gini | | | | | | | | | | .13 |
| **Random** | | | | | | | | | | |
| Residual | 0.28 | 0.03 | 2.23 | 0.18 | 0.20 | 0.06 | 0.60 | 0.10 | 0.79 | 0.12 |
| Intercept | 0.03 | 0.01 | 0.90 | 0.70 | 0.62 | 1.57 | 0.37 | 0.09 | 0.28 | 0.15 |
| Year | 0.003 | ns | 0.26 | 0.01 | 0.02 | 0.01 | 0.003 | ns | ns | ns |

*LL indicates estimates based on (traditional) landline telephone surveys, Any indicates estimates based on telephone surveys including both landline and mobile-phone-only owners; ns indicates nonsignificance.*

Adding the significant country level variables to the model does not change the conclusions based on the model with only the time trends. The only variable that predicts bias with some consistency is life expectancy at birth. Countries with a higher general life expectancy show less bias. High life expectancy is generally considered a development indicator, so we may conclude that higher developed countries tend to have less biased estimates. The scattered significant regression coefficients for urbanicity, gender gap in earnings (GendPay in the Table) and the Gini coefficient point in the same direction. There are some bias indicators that show a significant variance for the regression slope of year, meaning that the countries differ in the rate of decrease of the bias. This variation in the slopes may be explained by introducing interactions of the variable *year* with country level variables. In our case, there are no significant interaction effects, meaning that the available country level variables do not predict the variation in the slopes of the predictor variable *year*. However, there is a general trend that the variation in slopes is larger for the landline surveys, if mobile phone only owners are added the slope variation is always very small or insignificant.

## Conclusion and Discussion

Our results (*Figure 2*) show that mobile-phone-only ownership is increasing in all European countries

included in the Eurobarometer, but that overall mobile-phone-only penetration and increase differs sharply across countries.

When we inspect coverage bias across countries, both the trends in the detailed tables (Relative coverage bias in Europe) and the results of the multilevel analyses reported above clearly show that omitting mobile phones from telephone surveys increases bias in both demographic and substantive variables. This bias becomes larger over time for all variables studied. When mobile phones are included, the bias is generally decreasing over time. These results supports concerns voiced by, among others, Blumberg, Luke, Cynamon, & Frankel (2008), Blyth (2008), Busse & Fuchs (2012), Kuusela et al. (2008) and Tucker & Lepkowski (2008). Not including mobile phones in the sampling scheme is likely to result in coverage bias in the estimation of substantive variables of interest in a study.

For all variables except life satisfaction, the trends over time vary across countries. This variation can be explained by interactions of the time variable with country level contextual variables. However, for the available country level variables, there were no significant interactions with time, meaning that the available country level variables can not predict the differences in amount of bias decrease. When we examined the size of the regression coefficients for time, and the amount of variance at the country level, an interesting pattern emerged. For all four bias indicators with a significant effect of time, we find that adding country level variables to the model decreases both the size of the regression coefficient for time and the variance across countries. Thus, part of the effect of time is the result of changes over time in country level variables. The signs of the regression coefficients for the country variables suggest that in general bias decreases when education, employment, life expectancy, and urbanicity increase. Bias increases when the income distribution is more unequal. Our interpretation is that in more developed countries, and with development over time, bias in telephone surveys tends to become smaller, provided that mobile phones are included.

Our research has its limitations. The conclusions are based only on countries that participate in the Eurobarometer, and only for a limited set of variables that were available for the selected time and country range. Also, we employed a secondary analysis, which per definition relies both on question formulation as well as data collection procedures used in the primary study. In addition, the Eurobarometer also suffers from nonresponse. The Eurobarometer data include integrated design and post-stratification weights, and these have been used in estimating the bias indicators. As comparative surveys evolve over time and their methodology and documentation improve, it would be highly informative to replicate this study over a larger number of topics and variables. For instance, the ESS has recently introduced questions about mobile phone use and Internet access, which will create an excellent resource for further study.

Nonetheless, standard telephone surveys, only sampling from a population of households that have at least one working landline telephone, is from a coverage point of view not advisable for many European countries. If and how mobile phones should be included in the sample depends on the situation in the country of interest. In Europe, the number assignment for mobile phones varies between countries, and also between telephone providers within countries, while in the US, the mobile phone numbering system follows the landline telephones and including mobile phones in a US telephone survey is comparatively more feasible (Kuusela et al, 2008). Also, the availability of good list-based sampling frames makes a difference, for instance, in Finland general population telephone surveys contain mobile and landline numbers (Steeh, 2008). In other cases more complicated dual frame sampling schemes should be employed.

Of course, including mobile phones in telephone surveys also complicates the survey process from a total survey error perspective (cf. AAPOR cell phone task force, 2010). Survey costs are likely to increase when mobile phones are incorporated. In Europe a call to a mobile phone is more expensive than to a landline phone. Also, more elaborated screening procedures are needed, adding to the data collection costs (e.g., is the respondent in a safe place to respond to an interview and not driving a bicycle or car, is the respondent not abroad as this will lead to considerable financial costs for the respondent, is the respondent of eligible age as many young children have a mobile phone). Finally, more complicated analysis procedures, especially for weighting, are needed. Still leaving out mobile phones is no longer an option. How to implement this across Europe remains a challenge for international survey methodologists, and more international comparative studies are needed.

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