Methodological Background

1. Available Data

1.1. Eurobarometer

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 et al., 2009). Since 2000 the Eurobarometer, which is based on *face-to-face* interviews, contains a question about both landline and mobile phone ownership. This provides us with a unique data set to analyze landline and mobile phone coverage figures across European countries and over time.

The Eurobarometer regularly collects data for the European Community across EU members and applicant countries through face-to-face interviews. The Eurobarometer has a separate data collection for East and West Germany, Republic of Cyprus and the Turkish Republic of Northern Cyprus, and Great Britain and Northern Ireland. In 2000 seventeen countries were part of the Eurobarometer, namely Austria, Belgium, Denmark, Finland, France, Germany (East and West), Great Britain, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, and Sweden. Sixteen new countries joined in the year 2004, namely Bulgaria, Croatia, Cyprus (Republic of Cyprus and Turkish Republic of Northern Cyprus), Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Northern Ireland, Poland, Romania, Slovakia, Slovenia, and Turkey. We have analyzed all available data, see the analysis section for details.

Each wave of the Eurobarometer consists of *face-to-face* interviews with adults aged 18+ and includes a core questionnaire plus an additional questionnaire with special topics. 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).

The core questionnaire contains trend questions about socio-political orientation and standard demographic questions and since 2000 also a question on the ownership of a mobile-phone and a landline phone, allowing us to estimate telephone coverage and the resulting coverage bias. Besides type of telephone, interview data on the following variables were available for all countries: sex, age, length of education, political left-right

self-placement and life satisfaction (see Questions as Asked in Eurobarometer for the question wording used); also the year of data collection was recorded. All the data were downloaded in February and March 2011, at which point Eurobarometer data were available for the years 2000 to 2009. Hence, our analysis covers this ten year period. To assess coverage bias, we analyze three demographic variables: sex, age, and length of educational, and two substantive variables: political left-right self-placement and life satisfaction. Especially age and to a lesser extent gender and education have been found to be associated with mobile phone-only use in Europe (e.g., Busse and Fuchs, 2012; Kuusela, Calllegaro, and Vehovar, 2008). Furthermore age, sex, and education correlate with many substantive variables typically assessed in academic or market research surveys (Fuchs and Busse, 2009). The substantive variables political left-right self-placement and life satisfaction give us a unique opportunity to directly investigate the influence of undercoverage on the assessment of two major socio-political indicators.

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.

1.2. 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, besides in landline- and mobile phone- penetration, also on socio-economic variables, which may influence landline and mobile telephone coverage (Vagliasindi, Güney, & Taubman, 2006; Rice and Katz, 2003). To model this, we collected socio-economic country level data from Eurostat, the World Bank, and the Human Development Report. 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. It should be noted that these variables are measured at the country level, but they are available for each year, hence they are time-varying predictors.

2. Coverage and Indicators of Coverage Bias

A common definition of coverage error is given by Groves (1989, p. 11): 'coverage error exists because some persons are not part of the list or frame (or equivalent materials) used to identify members of the population. Because of this they never can be measured whether a complete census of the frame is attempted or a sample studied.' In other words: coverage error arises from the failure to give a nonzero probability of sample selection to some individuals in the population. Coverage error can be seen as the nonobservational gap between the target population and the sampling frame. When those covered differ from those not covered on the variables of interest in the study, coverage bias occurs (Lohr, 2008).

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 and Frankel, 2008; Kuusela et al., 2008; Tucker and Lepkowski, 2008). To investigate coverage problems in telephone interviews we compare the responses of *two* subgroups (landline-phone and any-phone with those of the total group of Eurobarometer respondents. The selection of the two subgroups groups is based on the following research question: *how would results of a telephone survey differ if the data collection would not be carried out only through samples of landline phones (as done traditionally) but would also incorporate mobile phones*?. The first subgroup, which mimics traditional telephone surveys, consists of those with a landline connection, which includes landline-only households and households with access to both a landline and a mobile phone. The second subgroup mimics the new situation when households without landline phones are *not* excluded, the any-phone group (landline only, landline + mobile, and mobile-only). Since the Eurobarometer was conducted face-to-face in all countries and face-to-face surveys have the least coverage problems (Groves et al, 2009, p. 163; De Leeuw, 2008, p. 125), the

total Eurobarometer group in this study is regarded as a proxy for the Target population. Differences between the two telephone groups and the total Eurobarometer group give an indication of 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 were included in the telephone survey too.

To assess the amount of bias, we use two indices: the relative bias and the absolute relative bias (Busse and Fuchs, 2012; Groves and Peytcheva, 2008). The relative coverage bias is used for descriptive purposes, as the sign of this estimate indicates the 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

$$\text{Relative coverage bias} = \frac{\bar{y}_{Phone(i)} - \bar{y}_{EB}}{\bar{y}_{EB}}, \qquad [1]$$

and

$$\text{Absolute relative coverage bias} = \left| \frac{\bar{y}_{Phone(i)} - \bar{y}_{EB}}{\bar{y}_{EB}} \right|, \qquad [2]$$

where *Phone(i)* represents the specific telephone subgroup and *EB* the complete face-to-face surveyed Eurobarometer group, which is viewed as our target population. Analogous $\bar{y}_{Phone(i)}$ and $\bar{y}_{EB}$ 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 provide an indication of 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.

3. Statistical Analyses

The relative coverage bias is used for descriptive analyses over countries and time. Positive values indicate that surveys that are exclusively conducted via landline telephone will result in estimates that are too high, whereas negative values indicate that these will result in estimates that are too low. Analogously, positive values indicate that surveys that do not exclude mobile phones will result in estimates that are too high, whereas negative values indicate that these will result in estimates that 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.

The statistical analysis is carried out in two steps. First, separate analyses are carried out for the initial 17 countries with data available for the years 2000-2003 and for the full set of 33 countries with data available for the years 2004-2009. The results are very similar, so in a second step we carry out an analysis over all available countries for the entire range of 2000-2009.

To estimate change over time, we analyze a null model that always includes the linear effect of time, and test whether the variance component for the slope of time is significant. If this random component is not significant using a likelihood ratio test, it is removed from the null model. Since the plots for the effect of time in Figure 1 and 2 indicate possible non-linearity, we test for nonlinear effects by analyzing the quadratic effect of time. If the quadratic term is not significant at the conventional 5% level, it is removed from this model; the linear term for time is always retained in the null model.

Next, we add country level socio-economic variables. Country level variables model initial differences in bias between countries in the starting year 2000. Since the

country level variables vary across time, they may also explain change over time. Because the country level variables are correlated with time, adding them to the model may replace (part of) the explanatory power of the time variable as estimated in the null model.

Finally, differences between countries in the rate of change over the years, as indicated by variation in the slopes of the time variable, are modeled as interactions of country level variables with the time variable. Again, effects that are not significant are removed from the model. A two-sided significance level of alpha = 0.05 is used throughout.