Introducing Web in a Telephone Employee Survey: A Mode Design Experiment

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Contents

1 Introduction

Social sciences face a key challenge due to the impracticality of directly measuring human behavior, attitudes, and beliefs. Therefore, surveys serve as an essential research tool for systematically collecting data on various topics, including public health indicators, employment trends, educational outcomes, social attitudes, political preferences, environmental issues, and housing conditions (Fowler 2014; Dillman 2020). The notion of a survey relates to a method of interviewing a random sample of the target population using standardized questionnaires (de Leeuw et al. 2008; Stoop and Harrison 2012).

The first probability-based sampling surveys emerged in the 1930s and 1940s (Groves 2011). Until the 1970s, face-to-face surveys were the predominant data collection method (Fowler 2014). During the 1970s, landline telephone technology became widely available in private households, supplanting face-to-face surveys as a more cost-effective data collection method (de Leeuw et al. 2008; Steeh 2008). Since the 1990s, the emergence of new technologies such as telephone answering machines, caller identification, surveillance cameras, and the prevalence of fenced properties, coupled with the increasing number of unlisted telephone numbers, have presented growing obstacles to reaching sampled households and individuals in interviewer-administered surveys (Groves 2011; Häder and Sand 2019). These challenges contributed to declining response rates and escalating survey costs, especially in telephone surveys (Rossi et al. 2013; Czajka and Beyler 2016; Kennedy and Hartig 2019). Over the last three decades, a new and widely adopted cost-efficient technology emerged: the internet, providing a novel research possibility—web surveys (Callegaro et al. 2015; Biffignandi and Bethlehem 2021). Mixed-mode surveys, which begin with the web mode and follow up with interviewer-administered modes for nonrespondents, became an opportunity to reduce survey costs, nonresponse, and noncoverage rates (Dillman 2017; de Leeuw 2018; Olson et al. 2021). However, while some

methodical research has investigated the consequences of introducing the web mode in an ongoing face-to-face survey (Lüdtke and Schupp 2017; Bianchi et al. 2017; Cernat and Revilla 2021), the effects of incorporating the web mode in a traditional telephone single-mode survey remain under-researched, particularly in the context of employee surveys.

Employee surveys enable policymakers to make informed decisions by proactively addressing emerging challenges, such as skill shortages, and tailoring interventions that resonate with the evolving needs of the employed population (Swiss Federal Statistical Office 2021; German Federal Ministry of Labour and Social Affairs 2019). Examples of employee surveys are the China Employer-Employee Survey (CEES) (Li et al. 2022), and the German Digitalization and Change in Employment Survey (Arntz et al. 2020). Several reasons highlight why supplementing or replacing telephone with web data collection may be beneficial in employee surveys. First, telephone surveys tend to underestimate the share of employees (Yan et al. 2004; Kreuter et al. 2010; Lugtig et al. 2011; Voorpostel et al. 2020), as employed individuals are more likely to be occupied during the day compared to nonworking individuals (Knabe et al. 2010). Second, employees are more likely to have internet access at home than more general populations (German Federal Office of Statistics 2022; US Census Bureau 2022). Third, in contrast to telephone surveys, web surveys can be conducted at any time and any place, which could be especially beneficial for busy employee subgroups (e.g., commuters and full-time workers). Fourth, introducing the web in a conventional telephone-only survey allows employees with outdated or missing telephone numbers (in the sampling frame) to be included in the fielded sample. Summarized, introducing the web in a traditional telephone employee survey can potentially increase the response rate for employees, especially for those who are difficult to reach via telephone (de Leeuw 2018). Moreover, cost savings can be achieved by pushing employees to the cost-effective web starting mode (Dillman 2017).

On the other hand, introducing a web starting mode in an ongoing telephone panel survey may entail drawbacks, especially for employees who are used to being interviewed over the telephone. These panelists might not feel motivated to switch to the web mode. In addition, interviewer-administration may have served as a motivating factor for initial survey enrollment and sustained participation. Following web nonrespondents up with the original telephone mode may mitigate the risk of nonresponse during the transition.

However, the effects of introducing the web into a previously telephone-only survey of the employed population remain an understudied issue. To address this research gap and shed light on the impacts of introducing a web starting mode in a traditional telephone employee survey, particularly regarding response rates, coverage, and survey costs, I analyze a mode design experiment (described in more detail later) conducted within a traditional employee telephone survey. As prior research demonstrates diverse effects of introducing a web mode in a traditional interviewer-administered survey on panelists and refreshment cases (Jäckle et al. 2015), I address each group separately. I structured my dissertation as follows. Chapter 1 provides a thorough overview of key aspects, such as survey modes, while identifying research gaps and situating my dissertation within the broader research context. Chapter 2 describes the methodologies, and findings of my three dissertation contributions, each addressing different effects of introducing the web starting mode in a conventional telephone single-mode survey, shown in Chapters 3, 4, and 5. My first contribution (Chapter 3; refreshment sample) and my second contribution (Chapter 4; panel sample) investigate the impact of introducing the web in a traditional employee telephone survey on nonresponse (rates and bias) and survey costs. Additionally, my second contribution reports on an invitation letter experiment conducted in the panel sample. My third contribution (Chapter 5; refreshment sample) focuses on known telephone number coverage (bias), nonresponse (bias), and total selection bias before and

after introducing the web in a traditional telephone survey. Chapter 6 discusses the results, scientific contributions, limitations, and practical implications of my dissertation.

1.1 Survey lifecycle from a quality perspective

The main goal of a survey is to generate unbiased estimators with low variance for values in the population (e.g., voting behavior) by interviewing a sample of the target population. However, this objective is jeopardized by various potential errors that can occur over the survey lifecycle (de Leeuw et al. 2008; Groves et al. 2009).

In Figure 1, Groves et al. (2009) depict the steps involved in conducting a survey (white rectangles) and potential errors that may occur during the survey process (blue boxes at the margins). The graphic categorizes the survey life cycle into two main sections: the measurement side and the representation side. The measurement section includes errors that arise from the creation of the questionnaire to the editing of the responses. An example is the measurement error that occurs when, for instance, respondents systematically underestimate their working time in the survey (Fowler and Cosenza 2009). The representation section highlights errors that arise from defining the population over the sampling process and up to the responses. An example of such an error is the sampling error, which arises from drawing a sample instead of interviewing the entire population (Lohr 2008).

Three points are crucial for understanding survey errors and their impact on data quality. First, the listed errors include a systematic component, referred to as bias, as well as an unsystematic component, referred to as variance. While the bias denotes the systematic deviation of an estimator from the true value (Groves et al. 2009), the unsystematic component arises when a survey is conducted multiple times, and a sample unit participates in one round while refusing to participate in another (Groves 2005). Since the bias is the

focus of survey research, my dissertation prioritizes the systematic aspect, while disregarding variance. In my dissertation, bias and error consistently refer to systematic deviations from the true values. Second, individual errors do not necessarily result in biases, but when errors collectively exhibit a systematic direction, they result in biases. If, for instance, respondents consistently underestimate their income in a survey, the data are affected by measurement error, which is not the case if respondents randomly over- or underestimate their income. Third, the errors are variable-dependent, meaning that while one variable might be influenced by an error, others could remain unaffected by the same error. For instance, in an employee survey, we might observe an overrepresentation of highly educated employees among respondents compared to the sample (nonresponse bias), while there might be no nonresponse bias concerning the gender distribution. My dissertation focuses on two potential errors on the representation side, namely, nonresponse and coverage error, which will be described in the following sections. I note that while both terms—coverage bias and noncoverage bias—appear in scientific publications, I will use the term coverage bias in my dissertation due to its greater recognition in the survey research field.

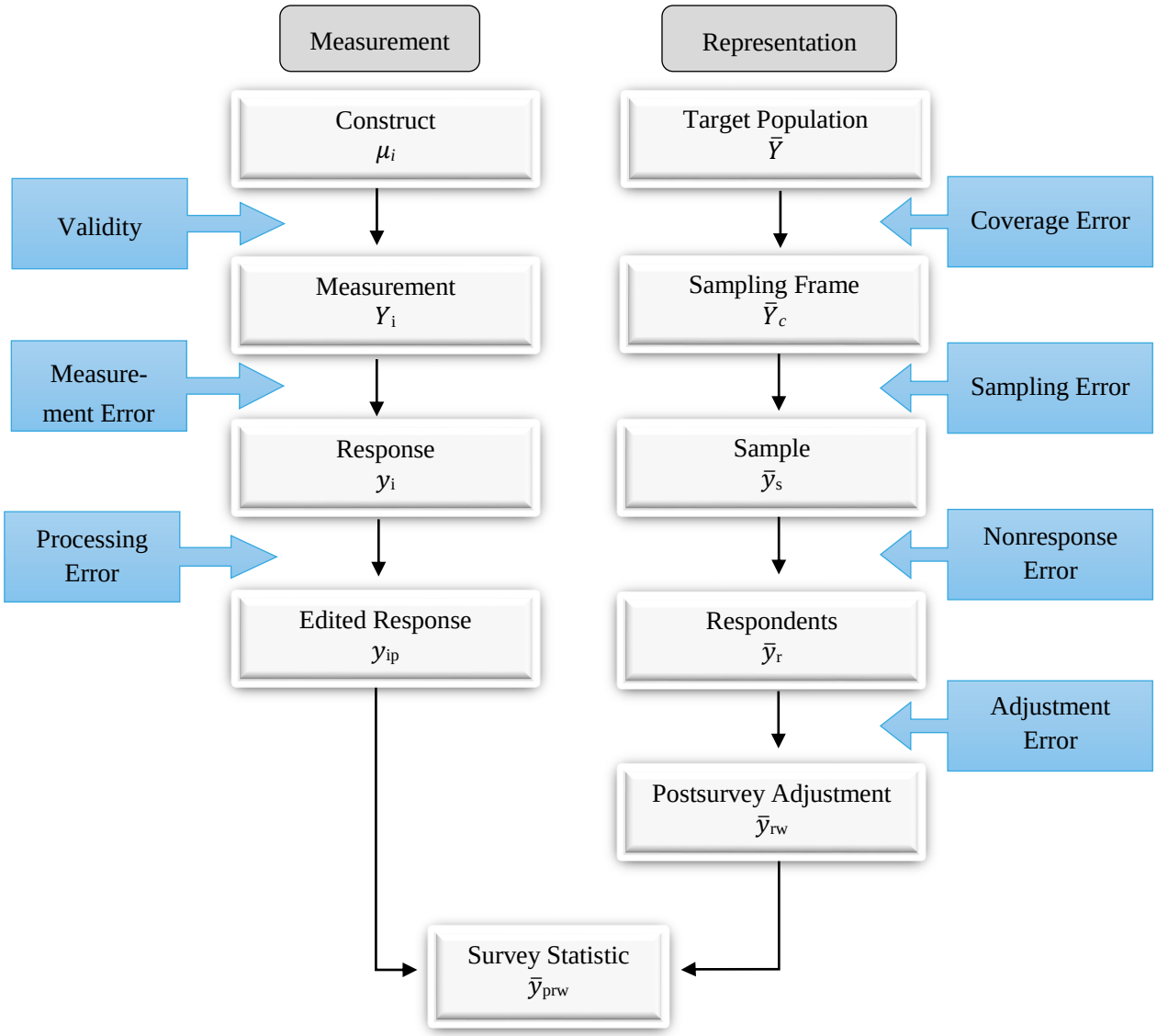


Figure 1. Survey life cycle from a quality perspective (Groves et al. 2009)

1.1.1 Coverage (Bias)

The coverage rate in a survey represents the percentage of individuals in the sampling frame eligible for participation, free from hindrances like lacking internet access in web surveys. A concern in survey research is the coverage bias, which emerges when the sampling frame inadequately represents the entire target population and noncovered individuals differ from those covered in the sample frame on specific variables measured in the survey. The inadequate representation of the target population in the sampling frame can occur due to two reasons. First, some members of the target population are missing in the

sampling frame. Second, the sampling frame includes incomplete information (e.g., missing postal addresses) for some members of the target population (Lohr 2008). My dissertation emphasizes the second case of inadequate representation, specifically addressing the absence of telephone numbers in the sampling frame. For simplicity, I use the term coverage bias, which refers to the known telephone number coverage bias.

Consider an example of coverage bias, where researchers aim to estimate the proportion of employees who work from home at least one day per week via a telephone survey. The researcher may draw a simple random sample from a list of all employees in Germany. This list may lack telephone numbers for some employees. If employees who work from home are more likely to have a listed telephone number than employees who do not work from home (e.g., 90% vs. 70%), telecommuters would be overrepresented in the sampling frame (coverage bias).

The coverage bias for a sample mean relates to the proportion of the target population not covered by the sampling frame and the difference in means of the covered and uncovered population and can be expressed as follows:

$$\bar{y}_C - \bar{y} = \frac{U}{N}\left(\bar{y}_C - \bar{y}_U\right) \quad (1)$$

with $\bar{y}$, $\bar{y}_C$ and $\bar{y}_U$ denoting the target population, the covered, and the uncovered target population, respectively. N refers to the total number of members in the target population, and U describes the total number of members in the target population uncovered by the sampling frame.

1.1.2 Nonresponse (Bias)

Nonresponse refers to missing information on specific variables (item nonresponse) and the complete absence of survey participation (unit nonresponse). Both item and unit non-

response can introduce nonresponse biases (Weisberg 2009), which occur when the values of the respondents on a particular survey item deviate from those of the nonrespondents (Groves and Peytcheva 2008). My dissertation focuses on unit nonresponse, subsequently referred to as nonresponse throughout this document.

Consider the earlier example (Section 1.1.1), where researchers aim to assess the prevalence of telecommuting using a list-based telephone survey. If telecommuters are more inclined to participate in the survey (e.g., 50%) compared to non-telecommuters (e.g., 10%) due to their higher contactability, the survey would result in an overestimation (nonresponse bias) of telecommuting prevalence among the employed population. Moreover, the overestimation of the telecommuting prevalence would be compounded by the coverage bias (previous example). Thus, both errors addressed in my dissertation (coverage and nonresponse) could either offset or reinforce each other.

The nonresponse bias (NB) for a sample mean is the product of the nonresponse rate and the disparity between the respondent and nonrespondent mean and can be expressed as follows:

$$\bar{y}_r - \bar{y}_s = \frac{m_s}{n_s}\left(\bar{y}_r - \bar{y}_m\right) \quad (2)$$

where $\bar{y}_s$ is the mean of the sample, $\bar{y}_r$ is the mean of the respondents and $\bar{y}_m$ refers to the mean of the nonrespondents. The terms n_s and m_s refer to the total number of sample members and the total number of nonrespondents, respectively.

1.1.3 Outcome Rates and Biases

Over the past few decades, survey response rates, which generally represent the proportion of obtained interviews from the selected sample (AAPOR 2023), have steadily declined (de Leeuw and de Heer 2002; Czajka and Beyler 2016; Luiten et al. 2020). This trend raises concerns as the nonresponse bias is often assumed to be lower when the response rate is higher (Koch and Blohm 2015; Schnell 2019; Kantar 2023). However, an examination of the nonresponse bias calculation (Equation 1) reveals that the response rate can only indicate the potential for nonresponse bias. The higher the response rate, the lower the risk for nonresponse bias. But, even with a low response rate, the nonresponse bias may be small, especially if nonresponse occurs at random.

Meta-analyses by Groves (2006, n = 30 publications), Groves and Peytcheva (2008, n = 47 publications), and Dickson et al. (2023, n = 149 publications) address the relationship between response rates and nonresponse bias. The main finding from all meta-analyses is that the response rate alone is a weak predictor of the magnitude of nonresponse bias in a specific variable.

Equation 2 (coverage bias) shows that an increasing coverage rate decreases the risk of coverage bias. As coverage bias is closely related to sampling frames (Weisberg 2009), meta-analyses on the connection between coverage rates and coverage bias are sparse. The next section elaborates on methodologies for identifying nonresponse and coverage errors.

1.1.4 Assessing Nonresponse Bias and Coverage Bias

Various methods for estimating coverage and nonresponse bias are established in the literature (Groves 2006). I will concentrate on the most used ones and discuss their application in my dissertation.

A primary method for estimating nonresponse biases is the comparison of different subgroups, such as early and late respondents, respondents and converted refusals, or respondents of the main questionnaire and participants of the refusal questionnaire. The underlying premise of this approach is that late respondents, converted refusals, and respondents of the refusal questionnaire would have been nonrespondents without additional efforts (such as increased contact attempts or refusal conversion) (Schnell 1997; Groves and Couper 1998; Stoop 2005; Billiet et al. 2009; Weinhardt and Liebig 2015). The differentiation between early and late respondents can be based on the a) number of contact attempts, and b) field time (e.g., days) until the interview is completed (Yan et al. 2004). However, it remains unclear to what extent a) late respondents, b) converted refusals, or c) participants in a refusal questionnaire resemble final nonrespondents. Assuming a continuum of nonresponse, the difference between respondents and a) converted refusals or b) participants of a refusal questionnaire on survey items can be interpreted as the lower limit of nonresponse bias (Lin and Schaeffer 1995; Schnell 1997; Billiet et al. 2007; Kaminska et al. 2010).

Nonresponse bias can also be assessed by contrasting survey results with comparable information from more reliable sources, such as census data. The nonresponse bias is then determined by examining the disparity between the distribution of the external data and the distribution of the survey data. Weaknesses of this method include the frequent limitation of external data to a few variables and the possible divergent target populations and

data collection methods of survey data and external data (Schnell 1997; Groves 2006; Billiet et al. 2009; Stoop et al. 2010).

Assessing nonresponse bias may entail comparing the characteristics of respondents and nonrespondents using individual non-survey data, such as the sampling frame or external sources. Moreover, when the sampling frame covers the entire target population but lacks specific information (e.g., telephone numbers) for certain cases, this approach facilitates estimating coverage bias by contrasting cases with known telephone numbers (covered) and those with unknown numbers (noncovered). The strength of this method lies in the availability of individual sampling frames or external data for the entire sample, enabling precise estimations of nonresponse and coverage bias. If there is a suspected link between the survey and individual non-survey data, the differences between respondents and nonrespondents or covered and noncovered cases indicate potential biases in the survey variables (Schnell 1997; Groves 2006; Stoop et al. 2010). In my dissertation, I utilize sampling frame and external data of the Institute for Employment Research (IAB), the German Federal Office of Statistics (DESTATIS), and the German Federal Ministry of Transport and Digital Infrastructure (BMVI) to estimate nonresponse and coverage bias. The following section delves into the data collection methods employed in my dissertation.

1.2 Data Collection

Survey data can be gathered through interviewer-administered (telephone and face-to-face) or self-administered (web and mail) data collection methods. Since telephone and web data collection methods are used in my dissertation, this chapter focuses on these methods.

1.2.1 Telephone

Telephone surveys are an interviewer-administered data collection method where interviewers, often stationed in telephone studios, ask questions to respondents via telephone (whether mobile or landline). Responses are usually recorded using specialized telephone survey software (Biffignandi and Bethlehem 2021; Dutwin and Buskirk 2021). Telephone survey samples can be drawn by using random-digit dialing (RDD) and list-based methods. RDD telephone surveys entail calling randomly generated telephone numbers, whereas list-based surveys rely on sampling frames that include telephone numbers (Lavrakas 2010). In my dissertation, all telephone surveys utilized a dual-frame approach (including both mobile and landline numbers), with samples selected from an employee list that included telephone numbers.

Telephone surveys gained prominence as the primary data collection method in various research fields across the USA and Europe by the 1980s. This transition was largely motivated by their cost-effectiveness compared to face-to-face interviews (Lavrakas 2010; Groves 2011). Recent decades have seen telephone surveys facing growing challenges due to technological advancements, such as answering machines, caller identification, and call-blocking, which contributed to increased survey costs and nonresponse rates by necessitating more contact attempts to reach sampling units (Kempf and Remington 2007; Steeh 2008; Groves 2011). Besides the decreasing survey costs (Olson 2021; Olson et al. 2021) and declining response rates (Czajka and Beyler 2016; Kennedy and Hartig 2019; Luiten et al. 2020), telephone surveys also face growing coverage issues, mainly due to two main developments. First, in the early 1990s, many European countries ceased the requirement for mandatory registration of telephone numbers (Beukenhorst 2012; Stähli 2012; Kuusela and Simpanen 2012). Subsequently, the decline in listed telephone numbers has resulted in sampling frames with missing telephone numbers and higher survey

costs due to the need for additional telephone number research (Lipps et al. 2015; Dal Grande et al. 2016; Häder and Sand 2019). Second, the worldwide transition from landline to mobile telephone adoption (Worldbank 2023a, b) represented another challenge for telephone surveys as mobile numbers are often changed, and rarely listed in public telephone directories (Kempf and Remington 2007; Häder and Sand 2019). To counteract the outlined challenges, many telephone surveys have switched completely to a web single-mode or introduced the web as an additional data collection method (Olson et al. 2021). However, the effects of introducing the web mode in a traditional telephone single-mode survey (e.g., on nonresponse and survey costs) remain insufficiently researched and constitutes a focal point of my dissertation.

1.2.2 Web

Web surveys are a self-administered data collection method where respondents answer a programmed questionnaire on a computer screen (e.g., classical computer or smartphone) without the presence of an interviewer (Groves 2011; Biffignandi and Bethlehem 2021). All web surveys utilized in my dissertation were conducted using traditional computers and smartphones, with responses stored in the web survey software.

By the 1980s, the expansion of the internet—an electronic network of computers—facilitated the adoption of internet data collection methods (e.g., email surveys and downloadable questionnaires). The rising spread of the 1989 launched World Wide Web (abbreviated as web) pushed internet surveys further by offering computers connected to the internet access to websites. With rising internet penetration, web surveys have become the most important data collection method over the internet (Couper 2000; Couper and Bosnjak 2010).

Web surveys present three significant advantages over interviewer-administered methods. First, the absence of interviewer costs makes web data collection an appealing option

for cost savings (Dillman 2017; Olson et al. 2021). Second, participation in web surveys is not restricted to the working hours of interviewers, a feature particularly advantageous for employees with long work schedules. Third, despite historical concerns regarding limited internet coverage impacting web survey feasibility (Zillien and Hargittai 2009; Mohorko et al. 2013; Haight et al. 2014; Couper et al. 2018), recent advancements have seen a notable increase in global internet accessibility, particularly among employed populations (German Federal Office of Statistics 2022; US Census Bureau 2022).

These advantages of web surveys (compared to interviewer-administered ones) prompt the potential for pure web surveys. Conversely, previous research indicates that web single-mode surveys produce more specific samples than telephone single-mode surveys (e.g., highly educated samples) (Lugtig et al. 2011; Laaksonen and Heiskanen 2014; Lesser et al. 2023; Szeitl et al. 2023). Thus, utilizing a combination of survey modes, such as starting with the web and following web nonrespondents by telephone, could address the diverse preferences of participants and potentially decrease nonresponse (rates and bias) as well as survey costs (Dillman 2017; de Leeuw 2018; Olson et al. 2021).

1.2.3 Mixing Telephone and Web

In a mixed-mode survey, two or more data collection modes are employed (Dillman and Edwards 2016). This includes, for instance, variations in survey modes across questions, such as using self-administered modes for sensitive questions in an otherwise interviewer-administered survey or surveying different respondents via different modes by using a sequential or concurrent mixed-mode design (de Leeuw 2018). Concurrent mixed-mode designs offer two or more modes (e.g., web and telephone) at the same time, while sequential mixed-mode designs present different survey modes one after another (Couper 2011; de Leeuw 2018; Biffignandi and Bethlehem 2021). In my dissertation, I utilize a

sequential mixed-mode approach, initially inviting participants to respond via the web and following the web nonrespondents by telephone.

Until the 21st century, most surveys used a single-mode design. However, single-mode surveys are facing rising challenges as declining response rates and rising survey costs (Dillman and Messer 2010; Dillman 2017; Olsen et al. 2021). In response to these challenges, sequential mixed-mode designs are increasingly used to reduce survey costs by pushing respondents to an inexpensive mode (e.g., web) and increase response rates through following nonrespondents by more expensive interviewer-administered modes (e.g., telephone) (de Leeuw et al. 2008; Groves 2011; Callegaro et al. 2015; Dillman 2017).

However, while some conventional telephone surveys have incorporated the web mode (Olsen et al. 2021; Voorpostel et al. 2021), the actual effects of introducing the web on outcome rates (response, coverage), biases (nonresponse, coverage, and total selection), and survey costs remain unexplored. The next chapter summarizes the main findings of my three dissertation contributions, which aim to address these research gaps.

References

American Association for Public Opinion Research (AAPOR; 2023), *Standard Definitions: Final Dispositions of Case Codes and Outcome Rates for Surveys* (10th ed.), AAPOR: Oakbrook Terrace, IL.

Arntz, M., Dengler, K., Dorau, R., Gregory, T., Hartwig, M., Helmrich, R., Lehmer, F., Matthes, B., Tisch, A., Wischniewski S., and Zierahn, U. (2020), "Digitalisierung und Wandel der Beschäftigung (DiWaBe)," Mannheim, pp. 1–92.

Beukenhorst, D. (2012), "The Netherlands," in *Telephone Surveys in Europe*, eds. S. Häder, M. Häder and M. Kühne, Heidelberg: Springer, pp. 17–24.

Bianchi, A., Biffignandi, S., and Lynn, P. (2017), "Web-Face-to-Face Mixed-Mode Design in a Longitudinal Survey: Effects on Participation Rates, Sample Composition, and Costs," *Journal of Official Statistics*, 33, 385–408.

Biffignandi, S., and Bethlehem, J. G. (2021), *Handbook of Web Surveys* (2nd ed.), Hoboken: John Wiley & Sons.

Billiet, J., Philippens, M., Fitzgerald, R., and Stoop, I. (2007), "Estimation of Nonresponse Bias in the European Social Survey: Using Information from Reluctant Respondents," *Journal of Official Statistics*, 23, 135–162.

Billiet, J., Matsuo, H., Beullens, K., and Vehovar, V. (2009), "Non-Response Bias in Cross-National Surveys: Designs for Detection and Adjustment in the ESS," *ASK. Research and Methods*, 18, 3–43.

Callegaro, M., Manfreda, K. L., and Vehovar, V. (2015), *Web Survey Methodology*, London: Sage.

Cernat, A., and Revilla, M. (2021), "Moving from Face-to-Face to a Web Panel: Impacts on Measurement Quality," *Journal of Survey Statistics and Methodology*, 9, 745–763.

Couper, M. P. (2000), "Review: Web Surveys: A Review of Issues and Approaches," *Public Opinion Quarterly*, 64, 464–494.

Couper, M. P., and Bosnjak, M. (2010), "Internet Surveys," in *Handbook of Survey Research,* eds. P. V. Marsden and J. D. Wright, Bingley: Emerald Group Publishing, pp. 527–550.

Couper, M. P. (2011), "The Future of Modes of Data Collection," *Public Opinion Quarterly*, 75, 889–908.

Couper, M. P., Gremel, G., Axinn, W., Guyer, H., Wagner, J., and West, B. T. (2018), "New options for national population surveys: The implications of internet and smartphone coverage," *Social Science Research*, 73, 221–235.

Czajka, J. L., and Beyler, A. (2016), *Declining Response Rates in Federal Surveys: Trends and Implications*, Washington, DC: Mathematica Policy Research.

Dal Grande, E., Chittleborough, C. R., Campostrini, S., and Taylor, A. W. (2016), "Bias of health estimates obtained from chronic disease and risk factor surveillance systems using telephone population surveys in Australia: results from a representative face-to-face survey in Australia from 2010 to 2013," *BMC medical research methodology*, 16, 1–13.

de Leeuw, E. D., Dillman, D. A., and Hox, J. (2008), "The Cornerstones of Survey Research," in *International Handbook of Survey Methodology,* eds. E. D. de Leeuw, J. Hox and D. A. Dillman, New York: Routledge, pp. 1–17.

de Leeuw, E. D. (2018), "Mixed-Mode: Past, Present, and Future," *Survey Research Methods*, 12, 75–89.

de Leeuw, E. D., and Heer, W. D. (2002), "Trends in household survey nonresponse: A longitudinal and international comparison," in *Survey Nonresponse*, eds. R. M.

Groves, D. A. Dillman, J. L. Eltinge and R. J. A. Little, New York: Wiley, pp. 41–54.

Dickson, S., Lugtig, P., Struminskaya, B., Timmers, A., Henneveldt, C., van Kessel, K., Peytcheva, E., and Groves, R. (2023), "The Relation Between Nonresponse Rates and Nonresponse Bias. An Update and Extension of Groves and Peytcheva (2008)," ESRA Conference, 17–21 June 2023, Milan.

Dillman, D. A. (2017), *The promise and challenge of pushing respondents to the Web in mixed-mode surveys. Survey Methodology*, Statistics Canada, Catalogue No. 12-001-X, 43(1), available at https://www150.statcan.gc.ca/n1/en/pub/12-001-x/2017001/article/14836-eng.pdf?st=f2oBpwDP.

Dillman, D. A. (2020), "Three Decades of Advancing Survey Methodology," in *A Meeting Place and More…: A History of the American Association for Public Opinion Research*, ed. T. W. Smith, pp. 95–116.

Dillman, D. A., and Edwards, M. (2016), "Designing a mixed-mode survey," in *The SAGE Handbook of Survey Methodology*, eds. C. Wolf, D. Joye, T. W. Smith, and Y. Fu, Thousand Oaks: SAGE Publications, pp. 255–268.

Dillman, D. A., and Messer, B. L. (2010), "Mixed-Mode Surveys," in *Handbook of Survey Research*, eds. P. V. Marsden and J. D. Wright, Bingley, Emerald Group Publishing Limited, pp. 551–574.

Dutwin, D., and Buskirk, T. D. (2021), "Telephone Sample Surveys: Dearly Beloved or Nearly Departed? Trends in Survey Errors in the Era of Declining Response Rates," *Journal of Survey Statistics and Methodology*, 9, 353–380.

Fowler, F. J. (2014), *Survey Research Methods* (5th ed.), Thousand Oaks: SAGE Publications.

Fowler, F. J., and Cosenza, C. (2009), "Design and Evaluation of Survey Questions," in *The SAGE Handbook of Applied Social Research Methods* (2nd ed.), eds. L. Bickman and D. J. Rog, Los Angeles: Sage, pp. 375–412.

German Federal Ministry of Labour and Social Affairs (2019), *Zwischenbilanz: Arbeitsqualität Und Wirtschaftlicher Erfolg: Die bisherigen Ergebnisse auf einen Blick*, available at https://www.bmas.de/DE/Service/Publikationen/Broschueren/a892-zwischenbilanz-arbeitsqualitaet-und-wirtschaftlicher-erfolg.htm.

German Federal Office of Statistics (2022), *Wirtschaftsrechnungen: Laufende Wirtschaftsrechnungen: Ausstattung privater Haushalte mit ausgewählten Gebrauchsgütern*, Fachserie 15 (Reihe 2).

Groves, R. M., and Couper, M. P. (1998), *Nonresponse in Household Interview Surveys*, New York: John Wiley & Sons.

Groves, R. M. (2005), "Survey Errors and Survey Costs," New York: Wiley.

Groves, R. M. (2006), "Nonresponse Rates and Nonresponse Bias in Household Surveys," *Public Opinion Quarterly*, 70, 646–675.

Groves, R. M., and Peytcheva, E. (2008), "The Impact of Nonresponse Rates on Nonresponse Bias: A Meta-Analysis," *Public Opinion Quarterly*, 72, 167–189.

Groves, R. M., Fowler, F. J., Couper, M., Lepkowski, J. M., Singer, E., and Tourangeau, R. (2009), *Survey Methodology* (2nd ed), Hoboken: John Wiley & Sons.

Groves, R. M. (2011), "Three Eras of Survey Research," *Public Opinion Quarterly*, 75, 861–871.

Häder, S., and Sand, M. (2019), "Telefonstichproben," in *Telefonumfragen in Deutschland*, eds. S. Häder, M. Häder, and P. Schmich, Wiesbaden: VS Verlag für Sozialwissenschaften, pp. 113–151.

Haight, M., Quan-Haase, A., and Corbett, B. A. (2014), "Revisiting the digital divide in Canada: the impact of demographic factors on access to the internet, level of online activity, and social networking site usage," *Information, Communication & Society*, 17, 503–519.

Jäckle, A., Lynn, P., and Burton, J. (2015), "Going Online with a Face-to-Face Household Panel: Effects of a Mixed Mode Design on Item and Unit Non-Response," *Survey Research Methods*, 9, 57–70.

Kaminska, O., McCutcheon, A. L., and Billiet, J. (2010), "Satisficing Among Reluctant Respondents in a Cross-National Context," *Public Opinion Quarterly*, 74, 956–984.

Kantar (2023), *The magic number: how to optimise and improve your survey response rate*, available at https://www.kantar.com/inspiration/research-services/what-is-a-good-survey-response-rate-pf#:~:text=A%20high%20response%20rate%2C%20for,the%20reliability%20of%20the%20findings.

Kempf, A. M., and Remington, P. L. (2007), "New challenges for telephone survey research in the twenty-first century," *Annual review of public health*, 28, 113–126.

Kennedy, C., and Hartig, H. (2019), *Response rates in telephone surveys have resumed their decline*, available at https://www.pewresearch.org/fact-tank/2019/02/27/response-rates-in-telephone-surveys-have-resumed-their-decline/.

Knabe, A., Rätzel, S., Schöb, R., and Weimann, J. (2010), "Dissatisfied with Life but Having a Good Day: Time-use and Well-being of the Unemployed," *The Economic Journal*, 120, 867–889.

Koch, A., and Blohm, M. (2015), "Nonresponse Bias (Version 1.1)," GESIS Survey Guidelines, Mannheim: GESIS -Leibniz-Institut für Sozialwissenschaften.

Kreuter, F., Müller, G., and Trappmann, M. (2010), "Nonresponse and Measurement Error in Employment Research: Making Use of Administrative Data," *Public Opinion Quarterly*, 74, 880–906.

Kuusela, V., and Simpanen, M. (2012), "Finland," in *Telephone Surveys in Europe*, eds. S. Häder, M. Häder and M. Kühne, Heidelberg: Springer, pp. 37–45.

Laaksonen, S., and Heiskanen, M. (2014), "Comparison of Three Modes for a Crime Victimization Survey," *Journal of Survey Statistics and Methodology*, 2, 459–483.

Lavrakas, P. J. (2010), "Telephone Surveys," in *Handbook of Survey Research*, eds. P. V. Marsden, and J. D. Wright, Bingley: Emerald Group Publication, pp. 471–498.

Lesser, V., Newton, L., and Robinson, J. (2023), "Choosing a Web-Push or a Web-Only Survey," ESRA Conference, 17–21 June 2023, Milan.

Li, Q., Hu, D., and Li, T. (2022), "The Innovation of Family Firms in China: New Evidence from the China Employer-Employee Survey," *China Economic Review*, 72, 1–19.

Lin, I. F., and Schaeffer, N. C. (1995), "Using Survey Participants to Estimate the Impact of Nonparticipation," *Public Opinion Quarterly*, 59, 236–258.

Lipps, O., Pekari, N., and Roberts, C. (2015), "Undercoverage and Nonresponse in a List-sampled Telephone Election Survey," *Survey Research Methods*, 9, 71–82.

Lohr, S. L. (2008), "Coverage and Sampling," in *International Handbook of Survey Methodology*, eds. E. D. de Leeuw, J. Hox and D. Dillman, New York: Routledge, pp. 97–112.

Lüdtke, D., and Schupp, J. (2017), "Wechsel von persönlichen Interviews zu webbasierten Interviews in einem laufenden Haushaltspanel," in *Methodische Probleme von Mixed-Mode-Ansätzen in der Umfrageforschung*, eds. S. Eifler and F. Faulbaum, Wiesbaden: Springer, pp. 141–160.

Lugtig, P., Lensvelt-Mulders, G. J. L. M., Frerichs, R., and Greven, A. (2011), "Estimating Nonresponse Bias and Mode Effects in a Mixed-Mode Survey," *International Journal of Market Research*, 53, 669–686.

Luiten, A., Hox, J., and de Leeuw, E. D. (2020), "Survey Nonresponse Trends and Fieldwork Effort in the 21st Century: Results of an International Study Across Countries and Surveys," *Journal of Official Statistics*, 36, 469–487.

Mohorko, A., de Leeuw, E., and Hox, J. (2013), "Internet Coverage and Coverage Bias in Europe: Developments Across Countries and Over Time," *Journal of Official Statistics*, 29, 609–622.

Moser, C. A., and Kalton, G. (2017), *Survey Methods in Social Investigation* (2nd ed.), New York: Routledge.

Olson, K. (2021), "Unpacking the black box of survey costs," *Research in Social and Administrative Pharmacy*, 17, 1342–1346.

Olson, K., Smyth, J. D., Horwitz, R., Keeter, S., Lesser, V., Marken, S., Mathiowetz, N. A., McCarthy, J. S., O'Brien, E., Opsomer, J. D., Steiger, D., Sterrett, D., Su, J., Suzer-Gurtekin, Z. T., Turakhia, C., and Wagner, J. (2021), "Transitions from Telephone Surveys to Self-Administered and Mixed-Mode Surveys: AAPOR Task Force Report," *Journal of Survey Statistics and Methodology*, 9, 381–411.

Peytchev, A., and Neely, B. (2013), "RDD Telephone Surveys: Toward a Single-Frame Cell-Phone Design," *Public Opinion Quarterly*, 77, 283–304.

Rossi, P. H., Wright, J. D., and Anderson, A. B. (2013), "Chapter 1 - Sample Surveys: History, Current Practice, and Future Prospects," in *Handbook of Survey Research*, eds. P. H. Rossi, J. D. Wright and A. B. Anderson, New York: Academic Press, pp. 1–20.

Schnell, R. (1997), *Nonresponse in Bevölkerungsumfragen: Ausmaß, Entwicklung und Ursachen*, Wiesbaden: VS Verlag für Sozialwissenschaften.

Schnell, R. (2019), *Survey-Interviews: Methoden standardisierter Befragungen* (2nd ed.), Wiesbaden: Springer.

Stähli, M. E. (2012), "Switzerland," in *Telephone Surveys in Europe*, eds. S. Häder, M. Häder and M. Kühne, Heidelberg: Springer, pp. 25–36.

Steeh, C. (2008), "Telephone Surveys," in *International Handbook of Survey Methodology*, eds. E. D. de Leeuw, J. Hox and D. Dillman, New York: Routledge, pp. 211–238.

Stoop, I. (2005), *The Hunt for the Last Respondent: Nonresponse in Sample Surveys*, The Hague: Social and Cultural Planning Office of the Netherlands.

Stoop, I., Billiet, A., Koch, A., and Fitzgerald, R. (2010), *Improving Survey Response: Lessons learned from the European Social Survey*, Chichester: John Wiley & Sons.

Stoop, I., and Harrison, E. (2012), "Classification of Surveys," in *Handbook of Survey Methodology for the Social Sciences*, eds. Gideon, L., New York: Springer, pp. 7–21.

Swiss Federal Statistical Office (2021), *SAKE in Kürze 2021*, available at https://dam-api.bfs.admin.ch/hub/api/dam/assets/22687494/master.

Szeitl, B., Messing, V., and Ságvári, B. (2023), "The risk of nonresponse bias in online and hybrid surveys," ESRA Conference, 17–21 June 2023, Milan.

US Census Bureau (2022), *S2802: Types of internet subscriptions by selected characteristics*, available at https://data.census.gov/table/ACSST5Y2020.S2802?q=S2802.

Vicente, P., and Reis, E. (2009), "The Mobile-only Population in Portugal and Its Impact in a Dual Frame Telephone Survey," *Survey Research Methods*, 3, 105–111.

Voorpostel, M., Kuhn, U., Tillmann, R., Monsch, G. A., Antal, E., Ryser, V. A., Lebert, F., Klaas, H. S., and Dasoki, N. (2020), "Introducing web in a refreshment sample of the Swiss Household Panel: Main findings from a pilot study," *FORS Working Paper Series* No. paper 2020-2, Lausanne: FORS.

Voorpostel, M., Lipps, O., and Roberts, C. (2021), "Mixing Modes in Household Panel Surveys: Recent Developments and New Findings," in *Advances in Longitudinal Survey Methodology*, ed. P. Lynn, Hoboken: John Wiley & Sons, pp. 204–226.

Weinhardt, M., and Liebig, S. (2015), "Teilnahmeverhalten und Stichprobenverzerrung in der deutschen Stichprobe des European Social Survey," in *Nonresponse Bias*, eds. J. Schupp and C. Wolf, Wiesbaden: Springer, pp. 47–84.

Weisberg, H. F. (2009), *The Total Survey Error Approach: A Guide to the New Science of Survey Research*, Chicago: University of Chicago Press.

Worldbank (2023a), *Fixed telephone subscriptions (per 100 people)*, available at https://data.worldbank.org/indicator/IT.MLT.MAIN.P2.

Worldbank (2023b), *Mobile cellular subscriptions (per 100 people)*, available at https://data.worldbank.org/indicator/IT.CEL.SETS.P2.

Yan, T., Tourangeau, R., and Arens, Z. (2004), *When Less is More: Are Reluctant Respondents Poor Reporters?* Proceedings of the Section on Survey Research Methods of the American Statistical Association.

Zillien, N., and Hargittai, E. (2009), "Digital Distinction: Status-Specific Types of Internet Usage," *Social Science Quarterly*, 90, 274–291.

2 Summary of Dissertation Contributions

Table 1 shows the research topics covered in my three dissertation contributions, which all explore different effects of introducing the web starting mode in a traditional employee telephone panel survey: the Linked Personnel Panel (LPP). I use the terms contribution and study simultaneously to denote my research contributions. The main effects of introducing web, studied in my first contribution "Introducing Web in a Telephone Employee Survey: Effects on Nonresponse and Costs", and second contribution "Transitioning an Employee Panel Survey from Telephone to Online and Mixed-Mode Data Collection", were nonresponse (rates and bias), and survey costs. In addition to focusing on wave 4 refreshment cases in my first contribution and on wave 4 panel cases in my second contribution, an invitation letter experiment was conducted in the latter to assess how mentioning upcoming telephone follow-ups in the web invitation impacts response rates and respondent composition. My third contribution "Going Online with a Telephone Employee Survey: Effects on Coverage, Nonresponse and Total Selection Bias", focused on known telephone number coverage (bias), nonresponse (bias) and total selection bias as well as on survey costs in the refreshment samples before (wave 1 to 3) and after (wave 4 to 5) introducing the web. To simplify, I use the term coverage bias to describe the known telephone number coverage bias.

My three contributions employed an experimental design (conducted during waves 4 and 5 in the LPP), assigning refreshment (Contribution 1 and 3) and panel employees (Contribution 2) to either a single-mode (telephone) or a sequential mixed-mode (web-telephone) design, as illustrated in Figure 1. To disentangle the effects of the web starting mode from the full web-telephone mixed-mode design and to evaluate single-mode comparisons, the analyses include a single-mode comparison: telephone from the single-mode

design vs. web starting mode from the mixed-mode design, and a mode design comparison: single-mode telephone vs. sequential web-telephone mixed-mode. Note that telephone follow-up respondents of the web-telephone mixed-mode design were treated as nonrespondents in the web starting mode. I use the terms web starting mode and web single-mode to denote the web phase of the mixed-mode design. Additionally, the terms web-telephone and web-to-telephone are used in different dissertation chapters to describe the sequential mixed-mode design, where the survey begins with the web mode and follows up with telephone for web nonrespondents. To address my research questions, I utilized extensive administrative data, including information from the Institute for Employment Research (IAB), the German Federal Office of Statistics (DESTATIS), and the German Federal Ministry of Transport and Digital Infrastructure (BMVI), as well as previous survey responses and paradata (shown in Table 2).

Joe Sakshaug and I collaborated on my three dissertation contributions. The first (Chapter 3) is published in the Journal of Survey Statistics and Methodology (Mackeben and Sakshaug 2023a), the second (Chapter 4) in the Statistical Journal of the IAOS (Mackeben and Sakshaug 2023b), and the third (Chapter 5) was submitted to the Journal of Survey Statistics and Methodology (Mackeben and Sakshaug 2024) on April 11, 2024.

Table 1. Research Questions Addressed in my Dissertation Contributions

	Outcome Rates		Regression Models		Data Quality			Survey Features	
	Coverage Rates	Response Rates	Known Tel. Number	Survey Response	Coverage Bias	Nonresponse Bias	Selection Bias	Survey Costs	Inv. Letter Experiment
Study 1		x (R)		x (R)		x (R)		x (R)	
Study 2		x (P)		x (P)		x (P)		x (P)	x (P)
Study 3	x (R)	x (R)	x (R)		x (R)	x (R)	x (R)	x (R)	

Notes: Tel = telephone, R = refreshment sample, P = panel sample, Inv = invitation.

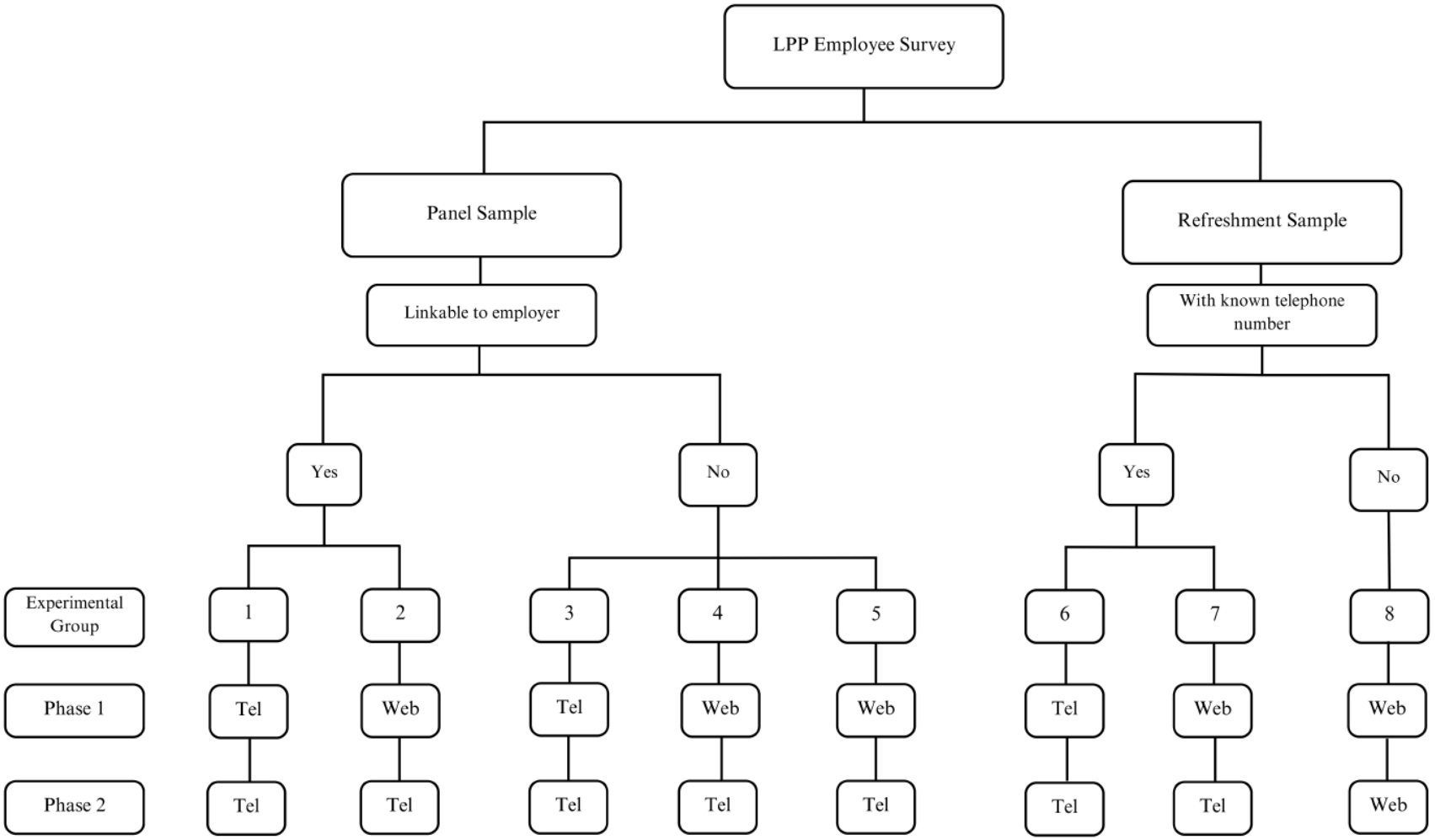


Figure 1. The Mode Design Experiment Conducted in Waves 4 and 5 of the LPP Employee Survey

Note: Tel = telephone. The invitation letter sent to groups 2, 4, 7 did not mention telephone follow-ups, while the invitations sent to group 5 did mention telephone follow-ups.

Table 2. Variables used in my Dissertation Contributions

Variables	Study 1	Study 2	Study 3
Demographics			
Sex	X	X	X
Age	X	X	X
German citizenship	X	X	X
Secondary education	X	X	X
Higher education	X	X	X
Employment			
Employment contract	X	X	X
Daily earnings	X	X	X
Occupation	X	X	X
Years working for employer	X	X	X
Benefit			
Benefits last 10 years	X	X	X
Job seeking last 10 years	X	X	X
Job seeking days last 10 years	X		
Geodata			
Region	X	X	X
Urbanicity	X	X	X
Commute	X	X	
Fast internet	X	X	
LPP Survey data			
Teleworking		X	
General trust		X	
Household size		X	
Big Five: Openness		X	
Big Five: Extraversion		X	
Big Five: Agreeableness		X	
Big Five: Conscientiousness		X	
Big Five: Neuroticism		X	
Employee linkage consent		X	
LPP Paradata			
Contact attempts wave 3		X	
First interview wave		X	
Item nonresponse wave 3		X	
Employer linkage		X	

2.1 Introducing Web in a Telephone Employee Survey: Effects on Nonresponse and Costs

My first dissertation contribution examines the effects of introducing the web mode in the refreshment sample of a traditional employee telephone single-mode survey on response rates, nonresponse bias, and survey costs. Newly drawn employees with known telephone numbers were randomly allocated to two groups: a single-mode telephone design (n = 7,197) and a sequential web-telephone mixed-mode design (n = 7,196) to address the following research questions:

1. To what extent do response rates differ between telephone and web modes, and between a single-mode telephone design and a sequential web-telephone mixed-mode design for an employee survey?
2. Does nonresponse bias vary between telephone and web modes, and between a single-mode telephone design and a sequential web-telephone mixed-mode design?
3. Do certain types of employees (e.g., commuters, full-time workers) vary in their likelihood to participate via a web starting mode or a sequential web-telephone mixed-mode design versus a single-mode telephone design?
4. To what extent do survey costs differ between a single-mode telephone design and a sequential web-telephone mixed-mode design?

The results can be summarized into four points. First, the inclusion of a web starting mode (9.85%) or a full web-telephone sequence (13.04%) significantly increased the response rates compared to using the traditional telephone single-mode design (5.88%). Second, both the web starting mode (highest) and full web-telephone design (second highest) showed a higher aggregate nonresponse bias than the telephone single-mode design.

Third, the likelihood of participation varied among employee subgroups. Full-time employees and employees working in business or administrative occupations were significantly more likely to participate via the web than by telephone. Fourth, the costs per respondent were lowest in the web starting mode, followed by the web-telephone mixed mode design, and highest in the telephone single-mode. Overall, the study suggests that introducing a web starting mode in the refreshment sample of an employee telephone survey can improve response rates and cost efficiency but increase nonresponse bias.

2.2 Transitioning an Employee Panel Survey from Telephone to Online and Mixed-Mode Data Collection

My second dissertation contribution investigates the impact of incorporating the web into a traditional telephone employee panel survey, focusing on response rates, nonresponse bias, and survey costs. All panel cases were randomly divided into two groups: a telephone single-mode design (n = 2,062) and a web-telephone mixed-mode design (n = 3,056). In an additional invitation letter experiment, 997 employees allocated to the mixed-mode design received an invitation letter that did not mention upcoming telephone calls, while a second subgroup of employees (n = 996) in the mixed-mode group received invitations that mentioned upcoming telephone calls. The primary research questions addressed are as follows:

1. Does mentioning the planned telephone follow-ups in the invitation letter affect web take-up rates and participation in the mixed-mode design?
2. Does switching from a single-mode telephone design to a sequential web-telephone mixed-mode design in an ongoing employee panel survey affect response rates in the initial wave of the switch?

3. Are there differences in nonresponse bias between the telephone-only design and either a) the web starting mode or b) the full sequential web-telephone mixed-mode design?

4. Does the likelihood of participation vary for specific employee subgroups (e.g., full-time workers) across both modes and mode designs?

5. Does the mixed-mode design yield potential cost savings (on a per-respondent basis) relative to the single-mode design?

The study reveals five main findings. First, invitation letter variations, whether mentioning telephone follow-ups or not, did not significantly affect response rates and respondent composition for the web starting mode and the full web-telephone sequences. Second, the sequential web-telephone design yielded a higher response rate than the single-mode telephone design. Third, although aggregate nonresponse bias was larger in the web starting mode compared to the telephone single-mode, conducting telephone follow-ups with web nonrespondents reduced the aggregate nonresponse bias to a level that is comparable to that of the telephone single-mode design. Fourth, high conscientiousness individuals were significantly more likely to participate via the web starting mode, while past job seekers were less likely to respond via the web starting mode compared to the telephone single-mode. None of the other variable categories affected the likelihood of participating in the web starting mode vs. telephone single-mode and in the web-telephone mixed-mode design vs. the telephone single-mode design significantly. Fifth, the web starting mode (lowest) and the web-telephone design (second lowest) demonstrated a cost advantage over the telephone single-mode design. In summary, the study demonstrates that transitioning a telephone employee panel survey to a sequential web-telephone mixed-mode design reduces nonresponse rates and survey costs, without impacting nonresponse bias for panel cases.

2.3 Going Online with a Telephone Employee Survey: Effects on Coverage, Nonresponse, and Total Selection Bias

My third contribution focuses on three different aspects. First, known telephone number coverage in the refreshment samples of the LPP employee survey was examined over the course of the survey (wave 1: n = 43,616, wave 2: n = 38,191, wave 3: n = 31,374, wave 4: n = 24,840, wave 5: n = 24,416). Second, known telephone number coverage, nonresponse, and total selection bias in the refreshment samples of the LPP employee survey were explored during exclusive telephone survey periods (waves 1 to 3). Third, experiments were conducted to understand the effects of introducing web in a traditional telephone single-mode survey on total selection bias and survey costs in waves 4 and 5. For the experiment, employees with a known telephone number (wave 4: n = 14,393, wave 5: n = 16,274) and those with an unknown telephone number (wave 4: n = 10,477, wave 5: n = 8,142) were randomly allocated between a traditional telephone single-mode and a sequential web-telephone mixed-mode design. In the single-mode telephone group, employees with unknown telephone number were treated as noncovered, while in the web-to-telephone mixed-mode group these cases were treated as covered by the web mode, which was the only feasible mode of interview. The following research questions were addressed:

1. To what extent has the known telephone number coverage rate changed over the first five waves (8 years) of the LPP survey?
2. Are specific employee subgroups more (or less) likely to have a known telephone number? Have these subgroup coverage patterns changed over time?
3. How large are known telephone number coverage biases in the first three waves of the LPP survey, i.e., before introducing the web mode?

4. What is the magnitude of total selection bias (noncoverage and nonresponse bias) in the first three waves of the LPP, i.e., before introducing the web mode? Do coverage and nonresponse biases offset or reinforce each other?
5. Does total selection bias differ between a single-mode telephone and a sequential web-to-telephone mixed-mode design? Is there a trade-off between coverage and nonresponse rates and bias?
6. What is the impact of introducing the web mode on survey costs and potential cost savings?

Addressing the research questions resulted in six main findings. First, known telephone number coverage rates generally declined over the survey waves. Second, some employee subgroups (e.g., high-income earners and non-German citizens) were significantly less likely to have a known telephone number compared to their reference groups. Third, coverage bias was prevalent and increased before the adoption of the web mode. Fourth, coverage bias and nonresponse bias offset each other for most variable categories, resulting in selection bias that lies between nonresponse and coverage bias for most variable categories in the exclusive telephone survey data collections. Fifth, the web-telephone mixed-mode design yielded—despite increasing response rates and eliminating coverage bias—a higher aggregate a) nonresponse bias and b) total selection bias compared to the traditional telephone single-mode. Sixth, introducing the web resulted in cost savings per interview compared to the telephone single-mode. Overall, the study found that introducing the sequential web-telephone design reduced nonresponse rates and survey costs but increased total selection bias compared to the traditional telephone single-mode.

References

Mackeben, J., and Sakshaug, J. W. (2023a), "Introducing Web in a Telephone Employee Survey: Effects on Nonresponse and Costs," *Journal of Survey Statistics and Methodology*, 11, 1054–1088.

Mackeben, J., and Sakshaug, J. W. (2023b), "Transitioning an Employee Panel Survey from Telephone to Online and Mixed-mode Data Collection," *Statistical Journal of the IAOS*, 39, 213–232.

Mackeben, J., and Sakshaug, J. W. (2024), "Going Online with a Telephone Employee Survey: Effects on Coverage, Nonresponse and Total Selection Bias," Unpublished manuscript.

3 Introducing Web in a Telephone Employee Survey: Effects on Nonresponse and Costs

Abstract

Policy decisions in business and economic fields are often informed by surveys of employees. Many employee surveys use costly interviewer-administered modes to reach this special population. However, certain employee subgroups may be especially hard to reach using these modes. Thus, besides high administration costs, nonresponse bias is a concern. To reduce costs and potential nonresponse bias, some employee surveys have introduced web as part of a sequential mixed-mode design. However, the impact of introducing web on response rates, nonresponse bias, and costs in employee surveys is understudied. The present study addresses this research gap by analyzing a mode design experiment in which employees selected for a national survey in Germany were randomly assigned to a single-mode telephone design or a sequential web-telephone mixed-mode design. The study revealed four main findings. First, introducing the web mode significantly increased the response rate compared to the telephone single-mode design. Second, despite the higher response rate, aggregate nonresponse bias was higher in the mixed-mode design than in the single-mode design. Third, the likelihood of web participation varied across certain employee subgroups, including occupation type and employment contract. Lastly, potential cost savings were evident under the mixed-mode design.

3.1 Introduction

In recent decades, surveys worldwide have experienced declining response rates (Luiten et al. 2020), with telephone surveys experiencing particularly steep declines (Brick and Williams 2013; Czajka and Beyler 2016). For example, the Pew Research Center, a major contributor of telephone surveys in the United States, reported a mean telephone response rate of 36 percent in 1997 and just 6 percent in 2018 (Kennedy and Hartig 2019). Telephone surveys in other countries, including Germany, have also been affected by declining response rates (Häder and Häder 2019). The decreasing number of households with landline telephones and the use of screening technologies (e.g., answering machines, caller identification) may have partially contributed to diminishing telephone survey response rates (Dillman 2017). Meanwhile, internet coverage has increased rapidly in western countries (Ryan 2017; Eurostat 2020; German Federal Office of Statistics 2020a), which has contributed to the growth of web surveys in these countries (Baker et al. 2010; ADM 2021).

A significant advantage of web surveys is that they offer more cost-effective and timely data collection compared to telephone surveys (Galesic et al. 2006; Tourangeau 2017; de Leeuw 2018). Cost savings can also occur in sequential mixed-mode surveys when sample units are "pushed" to the less-expensive web mode while more expensive modes (e.g., telephone) are used only for nonresponse follow-up (Dillman 2017). The potential for cost savings has likely contributed to many surveys transitioning from primarily interviewer-administered modes to web-first sequential mixed-mode designs. For example, the UK Household Longitudinal Study adopted a web-to-face-to-face sequential mixed-mode design from wave 7 to replace a primarily face-to-face design (Kantar 2017). Further examples are the labor force surveys of the Netherlands and Lithuania. Both surveys

transitioned from interviewer-administered designs to a web-first sequential mixed-mode design, with nonrespondents followed up by face-to-face or telephone (Eurostat 2018a).

Introducing web as part of a mixed-mode design can also reduce errors of nonobservation, such as nonresponse (de Leeuw and Hox 2011; Dillman et al. 2014; de Leeuw 2018), especially in surveys where certain subgroups of the population may be difficult to reach via interviewer-administration. This is particularly relevant for employee surveys which several countries use to study characteristics of their workforce (Statistics Canada 2017; Eurostat 2018a). The employed population differs from the general population on key aspects which may influence take-up of the web mode in a mixed-mode design. First, the employed population is primarily an age-truncated subgroup of the general population, which underrepresents the oldest age groups who are less likely to use the web (Zillien and Hargittai 2009; Haight et al. 2014). Second, employed persons have a higher likelihood of having internet access at home than the general population (US Census Bureau 2019; German Federal Office of Statistics 2020a). Third, employees are more difficult to reach via interviewer-administration (Yan et al. 2004; Asef and Riede 2006; Kreuter et al. 2010; Guzy 2015), as they are more likely to be occupied during the day or evenings Knabe et al. 2010). Given these factors, the employed population may benefit the most from being offered an online mode as opposed to an interviewer-administered one.

In this article, we study the effects of introducing a web starting mode on participation in a national employee telephone survey. Specifically, this study uses an experimental design where employees were randomly assigned to a single-mode (telephone) or a sequential mixed-mode (web-telephone) design. Extensive administrative data are used to evaluate indications of nonresponse bias and identify subgroups that are differentially affected by the two individual modes and both mode designs. The following research questions are addressed:

1. To what extent do response rates differ between telephone and web modes, and between a single-mode telephone design and a sequential web-telephone mixed-mode design for an employee survey?
2. Does nonresponse bias vary between telephone and web modes, and between a single-mode telephone design and a sequential web-telephone mixed-mode design?
3. Do certain types of employees (e.g., commuters, full-time workers) vary in their likelihood to participate via a web starting mode or a sequential web-telephone mixed-mode design versus a single-mode telephone design?
4. To what extent do survey costs differ between a single-mode telephone design and a sequential web-telephone mixed-mode design?

The remainder of the article is organized as follows. Section 3.2 provides a detailed literature review on mixed-mode surveys with a focus on telephone and web modes. Section 3.3 describes the mode experiment, data sources, and variables used in the analysis. The methodology and analysis procedures are introduced in Section 3.4. The study results are presented in Section 3.5 and a discussion of the results and their implications for survey practice is provided in Section 3.6.

3.2 Background

3.2.1 Mixed-Mode Surveys

Mixed-mode surveys can either be implemented concurrently or sequentially (Couper 2011). A concurrent design offers multiple modes simultaneously, whereas in a sequential design the modes are introduced in phases. In the first phase, all sampled units are offered

the same initial mode, whereas in the second phase, remaining nonrespondents are followed up with a secondary mode. Some designs implement additional phases and modes for nonresponse follow-up. As stated earlier, a key advantage of sequential mixed-mode surveys is that sample units may be pushed to the more cost-effective (usually self-administered) mode, which is typically offered in the first phase (de Leeuw 2018). For this reason, telephone surveys transitioning to a mixed-mode design tend to favor the sequential variant over the concurrent one (Olson et al. 2020a).

In the context of the present study, a sequential web-telephone design has other potential advantages over a single-mode telephone design. In addition to potential cost savings (Dillman 2009), it can reduce coverage bias (de Leeuw and Hox 2011). For example, in telephone surveys, a list frame may contain outdated or missing telephone numbers. Offering a web mode overcomes this coverage problem, if postal or email addresses are available, by allowing sampled units with invalid telephone numbers to participate online via the provided link. Further, introducing the web mode can potentially increase the response rate for certain subgroups that are difficult to reach via interviewer-administration (de Leeuw 2018). This could be especially important for the employed population who are often unavailable during the days or evenings. While telephone calls are restricted to certain times of day, the web mode offers the convenience of participating at any time. Moreover, employees who work in occupations that rely heavily on using an internet-enabled computer, such as business and administration, may participate in the survey during work hours. We expect these occupations to have higher web take-up rates compared to occupations which are less reliant on internet-enabled computer use, such as production. In short, introducing web in a sequential mixed-mode design may facilitate employee survey participation to a greater extent than a single-mode telephone design.

3.2.2 Effects of Telephone Versus Web on Survey Participation

In line with rising internet penetration, the number of studies comparing web and traditional survey modes has also risen. Early studies, focusing on special populations with high internet coverage (e.g., university students), found no difference in response rates between web and telephone (Christian 2007; Smyth et al. 2008). More recent mode comparison studies, involving general population samples, found a higher response rate for telephone compared to web (Schouten et al. 2013; Laaksonen and Heiskanen 2014; Lipps and Pekari 2016). As noted in the introduction, employed persons differ on certain characteristics from the general population that may make them more amenable to web survey participation. Consistent with this notion, Lugtig et al. (2011) found in an experimental mode comparison study that the web mode produced a higher share of employed respondents than the telephone mode. Greene et al. (2008) experimentally compared two sequential mixed-mode designs in the second wave of an employee survey—web-telephone and telephone-web—and found that the web starting mode yielded a higher response rate than the telephone starting mode. However, this result was likely influenced by the fact that the first wave was conducted entirely online and participants were already accustomed to the web survey, which is unlikely to be the case for a general population sample of employees.

Apart from the response rate, research has shown that web and telephone modes bring in different types of respondents (Revilla 2010; Lugtig et al. 2011; Laaksonen and Heiskanen 2014; Kappelhof 2015; Klausch et al. 2015). For example, experimental mode comparison studies have shown that the web mode produces a higher share of highly educated respondents compared to other modes (Link and Mokdad 2005; Lugtig et al. 2011; Laaksonen and Heiskanen 2014). This result could be partially explained by the fact that higher educated individuals are more likely to have internet access at home than

lower educated ones (Eurostat 2018b), and internet activity and digital affinity increase with education (Zillien and Hargittai 2009; Haight et al. 2014; Herzing and Blom 2019). Greene et al. (2008) found no demographic differences between respondents of the web and telephone starting modes in their employee panel survey. Again, this result could be due to all employees being interviewed online in the previous wave. With respect to the employee population, other characteristics besides demographics may play a role in the decision to participate via web or telephone, such as those that are correlated with internet access (e.g., occupation) and availability to be contacted by an interviewer (e.g., working hours, commuting distance), which are explored less in the mixed-mode literature.

3.2.3 Effects of Single-Mode Telephone Versus Sequential Web-Telephone Designs on Survey Participation

Aside from comparing individual modes, there is little research studying the impacts of a single-mode telephone design and a sequential web-telephone design on response rates and nonresponse bias. The sparse research shows that following up web nonrespondents by telephone increases the response rate in surveys of employees (Greene et al. 2008) and more general populations (Dillman et al. 2009), and that a web-telephone sequence may yield a higher response rate than a single-mode telephone design among employees (Greene et al. 2008). The fact that web and telephone modes tend to bring in different types of respondents also suggests that mixing web and telephone modes may potentially reduce nonresponse bias relative to a single-mode design. However, estimates of nonresponse bias are seldom reported in the literature.

In summary, there are only few studies comparing single-mode telephone and sequential web-telephone designs with respect to response rates and nonresponse bias, and even fewer that specifically target the employee population. Moreover, as noted earlier, some comparison studies are limited in their ability to compare the different mode designs. Our

contribution to the literature provides results from a mode design experiment embedded within a survey of the employed population in Germany, where sampled employees were randomized to a single-mode telephone or a sequential web-telephone design. The evaluation of the experiment makes use of extensive administrative employee data to generate proxy estimates of nonresponse bias and identify subgroups that vary in their likelihood to participate in either mode or mode design. The results of this analysis will inform practitioners on the possible cost and data quality implications of introducing web in a telephone survey of employees. We note that data quality can also be affected by differential measurement error caused by mixing modes (de Leeuw 2005, 2018). Although this is an important problem, we do not address measurement effects in the present study.

3.3 Mode Experiment and Data Sources

The data used in this study come from the cross-sectional sample of the fourth wave of the Linked Personnel Panel (LPP) employee survey and administrative data from the Institute for Employment Research (IAB), the German Federal Office of Statistics (DESTATIS), and the German Federal Ministry of Transport and Digital Infrastructure (BMVI).

3.3.1 LPP Employee Survey

The LPP is a linked employer–employee panel survey in Germany, which is designed for research on personnel economics by simultaneously observing the employer and employee perspectives (Ruf et al. 2020). The study is sponsored by the IAB and the German Federal Ministry of Labour and Social Affairs (BMAS). The first component of the LPP is a face-to-face employer panel survey that covers topics related to digitalization, human resource development, and structural features. Its sampling frame comprises all establishments that participated in a preceding survey—the IAB Establishment Panel (IAB-EP).

The IAB-EP is a representative employer survey of all establishments in Germany with at least one employee subject to social insurance contributions. Establishments excluded from the target population are (a) those with less than 50 employees subject to the social insurance system, (b) agricultural, fishing, forestry, and public sectors, and (c) nonprofit, charitable, or church institutions. The first wave (2012) of the LPP employer survey consisted of a random sample of establishments that completed an IAB-EP interview in 2011. Responding LPP establishments were re-contacted in the second (2014), third (2016), and fourth (2018) waves. In reaction to panel attrition, refreshment samples were drawn in the third and fourth waves.

The LPP employee panel survey forms the second component of the LPP and covers topics related to employee health and working conditions. In the first wave (2013), three months after the end of the LPP employer survey, a random sample of employees subject to social insurance was drawn from the responding establishments and recontacted in three subsequent waves. Due to panel attrition, refreshment samples of employees were drawn in waves 2 (2015), 3 (2017), and 4 (2019) from the responding establishments in these waves. Data collection was conducted solely via telephone through wave 3. In the wave 4 refreshment sample, a mode design experiment was carried out by introducing web into the telephone design (described in more detail later).

The telephone numbers used in the LPP originate from two sources. The first source are employees who provided their telephone number to the German Federal Employment Agency (BA). These are, for instance, persons who were registered as job seekers in the past. These numbers, with additional information about the sample units (name, address), are sent to the survey institute in every wave. The second source are the results of telephone number research conducted by the survey institute for the entire sample. The telephone number research is conducted by merging the names and addresses of the sample

units to the German Postal Directory, which includes registered telephone numbers (German Post 2021a). In 1992, the obligation to register every telephone number in Germany had been lifted, which led to a rapid decline of listed telephone numbers from 30.7 million in April 2000 (Häder et al. 2009) to 16.7 million in July 2016 (Häder and Sand 2019). In wave 3, about 22 percent of the LPP refreshment sample could be linked to a registered telephone number (infas 2018). If the telephone research and the BA search yield different telephone numbers, the number from the telephone research is used first. Due to data security and contractual regulations, it is not possible to distinguish employees who are contacted by a number from the BA or telephone research.

3.3.1.1 Transition to Mixed-Mode in Wave Four

At the beginning of the fourth wave, a number of developments prompted the LPP team to consider whether a single-mode telephone design was still an appropriate way of recruiting and interviewing employees. It is important to mention that the LPP telephone number sources mainly consist of landline numbers and the distribution of landline telephones has decreased steadily in Germany and rapidly among the younger population (German Federal Office of Statistics 2017, 2020a). The percentage of employees who were excluded from the LPP refreshment samples because of an unknown telephone number had increased over the first three waves (infas 2015, 2018). Moreover, as stated earlier, telephone surveys are facing declining response rates worldwide and this is also the case for the LPP, with observed response rates of 24.5 percent, 14.8 percent, and 12.1 percent in each of the respective waves (infas 2015, 2016, 2018). Meanwhile, the internet coverage for households in Germany increased from 79.4 percent in 2012 to 93.5 percent in 2019 (German Federal Office of Statistics 2017, 2020a). These developments motivated the LPP team to experiment with introducing a web starting mode as part of a sequential web-telephone mixed-mode design.

3.3.1.2 Mode Design Experiment

To evaluate the effect of introducing web as a starting mode followed by traditional telephone data collection, a mode design experiment was conducted in the refreshment sample of the fourth wave of the LPP employee survey. The refreshment sample consisted of 24,840 employees (from 689 establishments) in total and 14,393 employees (from 679 establishments) with a known telephone number. The majority (83.4 percent) of these employees could be linked to a BA telephone number. No information is available on the exact percentage of employees that were linked to a telephone number from the survey institute's research, or the extent of the overlap between these two sources.

Employees with an unknown telephone number were excluded from the experiment and interviewed online. We exclude this group from the analysis. Employees with a known telephone number were randomly allocated to either the traditional single-mode telephone design (n = 7,197) or a sequential web-telephone mixed-mode design (n = 7,196) with web used as the starting mode. Advance letters were mailed to both design groups on May 23, 2019, introducing the LPP survey, its main topics, data protection, the survey institute, and the sponsor. For the single-mode group, the invitation letter announced upcoming contact attempts via telephone. For the mixed-mode group, the advance letter only included a link and password for the online survey. Members of the mixed-mode group who did not complete the online survey within the first two weeks were sent one reminder on June 6, 2019. This reminder included once more the password and link to the web survey and announced upcoming telephone contact attempts if the online survey was not completed soon.

Web nonrespondents, including those who logged in but did not complete the online questionnaire, were contacted by telephone one week after they received the reminder. Web

answers were saved and transferred to the telephone system in the case of partial completion. The web survey system remained open throughout the field period (May 23, 2019–October 6, 2019) but interviewers did not mention this during the telephone follow-ups. The average number of telephone contact attempts was 5.8 in the single-mode design and 5.9 in the telephone follow-up stage of the mixed-mode design. The average interview duration was 39.6 minutes in the web survey and 50.3 minutes in the telephone survey. All data collection was carried out by the Institute for Applied Social Sciences (infas). A detailed description of the fourth wave of the LPP employee survey can be found in infas (2020).

3.3.2 Administrative Data

To evaluate the selectivity of participation by mode and mode design, nonresponse bias analysis is carried out using employee characteristics from multiple non-survey data sources available for the drawn sample. The first source consists of individual-level administrative data drawn from the Integrated Employment Biographies (IEB) of the IAB (Antoni et al. 2019). The IEB data are allocated into three summary variable groups: demographics, employment, and benefits. The demographics group consists of five variables: sex, age (in years; <36, 36–54, 55+), German citizenship (yes, no), secondary education (less than university entrance qualification, university entrance qualification), and higher education (less than university degree, university degree). The main difference between secondary education and higher education is that secondary education refers to the time pupils spend in basic education after primary schooling but before starting tertiary (i.e., higher) education leading to award of an academic degree. In Germany, both forms of education are measured independently in surveys as it is possible to pursue higher education without receiving a university entrance qualification during secondary

education. Likewise, not all pupils who receive a university entrance qualification during their secondary studies pursue higher education or receive a university degree.

The employment group has four variables: employment contract (full-time, part-time), daily earnings (in Euros; <121, 121–173, 174+), occupation (production, business or administration, other), and years working for current employer (<5, 5–11, 12+). The benefits group has three variables: received unemployment benefits at least once in the last 10 years (yes, no), registered as a job seeker with the BA at least once in the last 10 years (yes, no), and the number of days registered as job seeking with the BA during the last 10 years (0, 1–150, 151+).

The second set of administrative data originate from the Community Directory (CD) of the German Federal Office of Statistics. The CD includes information on the number of inhabitants, the postal code, and longitude and latitude of every municipality in Germany. These data are used to generate an urbanicity and commuting distance variable. The IAB possesses the postal code of the working and living place of each employee. The data protection legal team of the IAB approved the merging of this information to the CD by using the postal codes and in some cases the names of the cities. For the commuting variable, we used the R-package gmapsdistance to calculate the fastest distance by car between the mean longitude and latitude of the working and living place (postal code). For the urbanicity variable, we used the number of inhabitants of the living place (city).

The third set of administrative data stem from the Broadband Atlas of the German Federal Ministry of Transport and Digital Infrastructure. The Broadband Atlas includes data about internet quality at the postal code level (German Federal Ministry of Transport and Digital Infrastructure 2020). After merging these data to the LPP using the postal codes, we generated the variable “fast internet,” which measures the proportion of households within a postal code having access to at least 100 megabits per second. The variables constructed

from the CD and Broadband Atlas data sources comprise the fourth summary variable group: geodata. The geodata group consists of four variables: region (north, west, south, east), urbanicity (population; <13,000, 13,000–119,999, 120,000+), commuting distance (kilometers; <17, 17+), and fast internet (percent; <40; 40–100). Table 1 displays the distribution of each variable used in the analysis. The distributions are similar in both mode design groups, indicating that the randomization was successful.

These 16 variables were selected for two main reasons. First, they are closely related to the variables collected in the LPP survey. For example, all administrative demographic (age, sex, gender, secondary education, higher education) and substantive (income, occupation, job contract, years working for employer) variables are similarly measured in the LPP survey. Given their likely correlation with the actual survey items and potential interaction with mode (design), these administrative variables serve as suitable proxies for nonresponse bias. And second, the selected variables have been used in previous substantive and methodological research on employee samples. Sociodemographic characteristics are commonly used to study mode effects and nonresponse bias (Greene et al. 2008; Dillman et al. 2009; Lugtig et al. 2011; Laaksonen and Heiskanen 2014; Klausch et al. 2015; Lipps and Pekari 2016). Employment characteristics are also used to study nonresponse and other errors of nonobservation (Gesell et al. 2007; Warnke 2015; Sakshaug et al. 2017; Sakshaug and Eckman 2017a, 2017b; Sakshaug et al. 2020). Commuting distance is a prime example of a variable that is correlated to many topics gathered in the LPP, including general life satisfaction and job satisfaction (Fordham et al. 2018; Clark et al. 2020), mental and physical well-being (Gimenez-Nadal and Molina 2019; Clark et al. 2020), and the number of sick days (Künn-Nelen 2016). A new variable is the availability of high-speed internet at the municipality level, which is likely to be related to uptake of the web survey. Similarly, inhabitants of more-populated areas tend to have higher

response rates in web surveys compared to less populated areas (Brøgger et al. 2007; Laaksonen and Heiskanen 2014).

Table 1. Variable Distributions, by Mode and Mode Design

	Single-Mode Telephone		**Mixed-Mode Web-Telephone**			
Administrative variable	Sample (%)	Resp. (%)	Sample (%)	Resp. Web (%)	Resp. Web-Tel. (%)	**χ^2 test of samples, *p*-value**
Demographics						
Sex						
Male	74.98	73.52	74.96	76.73	74.20	0.981
Female	25.02	26.48	25.04	23.27	25.80	
Age						
<36	32.71	26.71	31.95	25.67	25.05	
36–54	48.73	48.70	49.65	50.63	49.57	0.517
55+	18.56	24.59	18.40	23.70	25.37	
German citizenship						
Yes	92.77	95.51	92.38	96.90	96.59	0.372
No	7.23	4.49	7.62	3.10	3.41	
Secondary education						
Less than university entrance	65.99	54.85	66.51	47.53	50.43	0.507
University entrance	34.01	45.15	33.49	52.47	49.57	
Higher education						
Less than university degree	77.92	67.38	78.50	61.50	63.22	0.399
University degree	22.08	32.62	21.50	38.50	36.78	
Employment						
Employment contract						
Full-time	89.04	86.05	88.80	92.10	90.41	0.650
Part-time	10.96	13.95	11.20	7.90	9.59	
Daily earnings						
<121	41.27	37.12	40.63	28.35	31.56	
121–173	34.33	27.90	34.71	30.18	29.85	0.742
174+	24.40	34.99	24.65	41.47	38.59	
Occupation						
Production	52.27	49.88	53.22	49.37	49.36	
Business / Administration	21.59	25.30	21.33	32.30	29.74	0.497
Other	26.14	24.82	25.44	18.34	20.90	
Years working for employer						
<5	25.82	25.53	25.25	18.90	19.08	0.731

5–11	39.96	33.57	40.37	40.90	42.11	
12+	34.22	40.90	34.38	40.20	38.81	
Benefits						
Benefits last 10 years						
No	67.53	71.87	68.58	80.68	77.19	0.176
Yes	32.47	28.13	31.42	19.32	22.81	
Job seeking last 10 years						
No	48.52	49.41	49.39	60.65	57.46	0.297
Yes	51.48	50.59	50.61	39.35	42.54	
Job seeking days last 10 years						
0	67.26	70.45	67.82	77.72	74.52	
1–150	15.95	15.84	15.81	12.41	13.33	0.749
151+	16.78	13.71	16.37	9.87	12.15	
Geodata						
Region						
North	34.11	31.44	34.92	32.16	31.56	
West	15.46	17.97	15.36	14.39	15.03	0.281
South	30.07	32.15	30.60	36.39	34.75	
East	20.36	18.44	19.12	17.07	18.66	
Urbanicity						
<13,000	39.20	43.97	38.60	38.79	39.23	
13,000–119,999	33.39	30.73	32.28	31.31	31.56	0.069
120,000+	27.41	25.30	29.11	29.90	29.21	
Commute						
<17	50.22	54.85	51.25	50.35	50.53	0.214
17+	49.78	45.15	48.75	49.65	49.47	
Fast internet						
<40	10.57	10.64	9.06	6.91	7.68	0.002
40-100	89.43	89.36	90.94	93.09	92.32	
N	7,197	423	7,196	709	938	

3.4 Methodology

The evaluation of the mode design experiment is structured into four parts, each addressing the corresponding research question. First, participation outcomes are compared between the two individual modes: telephone from the single-mode design vs. web from the mixed-mode design, and between the two mode design groups: single-mode telephone vs. sequential web-telephone mixed-mode. Second, (proxy) nonresponse bias is estimated across the administrative variables and the four summary variable groups. Third, multilevel logistic regressions are fitted to estimate interactions between mode (design) and employee characteristics on the likelihood of survey participation. Lastly, survey costs are analyzed for each mode (design) to provide a rough approximation of the extent of potential cost savings incurred by introducing the web starting mode. Each analysis is carried out separately for the direct mode comparison (single-mode telephone vs. web starting mode) and the full mode design comparison (single-mode telephone vs. web-telephone mixed-mode).

3.4.1 Response Rate Definition

Completed interviews in the LPP are defined as cases that answered every item of the questionnaire, including “don’t know” and “refuse” answers. Item skips were not allowed. The web survey response rate is calculated over the entire field period. That is, employees who voluntarily participated via web before or after the telephone follow-up phase had started are coded as web respondents. For the latter cases telephone follow-up attempts ceased on the same day as the web completion. The final disposition codes for the experimental groups are available in the appendix (see Table A1).

We adopt the AAPOR (2016) Response Rate 1 definition, which is the proportion of sampled cases that completed the interview:

$$\text{Response Rate} = \frac{\text{Interviews}}{\text{Interviews} + \text{Noncontacts} + \text{Refusals}} \quad (1)$$

For a more detailed comparison of the telephone outcome rates, we additionally calculate the contact and cooperation rates separately for the single-mode telephone design and the telephone phase of the web-telephone design. The contact rate measures the proportion of sampled cases in which the target person or at least one household member was successfully contacted:

$$\text{Contact Rate} = \frac{\text{Interviews} + \text{Refusals}}{\text{Interviews} + \text{Noncontacts} + \text{Refusals}} \quad (2)$$

The cooperation rate is the proportion of all successfully contacted cases which completed the interview:

$$\text{Cooperation Rate} = \frac{\text{Interviews}}{\text{Interviews} + \text{Refusals}} \quad (3)$$

As we do not know whether web nonrespondents were refusals or noncontacts, the contact and cooperation rates are calculated only for the telephone phase of the mixed-mode design. All web nonrespondents who were eligible for the telephone follow-up phase comprise the base for these calculations.

3.4.2 Nonresponse Bias Analysis

To analyze the second research question, nonresponse bias (NB) is calculated for all estimates of the administrative variables. Nonresponse bias for a specific variable category $c = (1, 2, .., C)$ is calculated as the difference between the estimated proportion derived from the respondents ($\bar{y}_{c,r}$) and the corresponding proportion derived from the sample ($\bar{y}_{c,s}$):

$$\text{Nonresponse Bias } (\bar{y}_c) = \bar{y}_{c,r} - \bar{y}_{c,s} \quad (4)$$

For example, if the estimated proportion of males in the sample is 0.5, and 0.4 among the respondents, the resulting estimate of nonresponse bias would be -0.1, which would indicate a 10-percentage point underestimation of males in the survey.

To facilitate comparisons of nonresponse bias, the absolute nonresponse bias (ANB) values are also reported:

$$\text{Absolute Nonresponse Bias } (\bar{y}_c) = \left|\bar{y}_{c,r} - \bar{y}_{c,s}\right| \tag{5}$$

To assess the relative magnitude of nonresponse bias, we also present the absolute relative nonresponse bias (ARNB), which is the ratio of the absolute nonresponse bias relative to the sample proportion ($\bar{y}_{c,s}$) (Groves 2006):

$$\text{Absolute Relative Nonresponse Bias } (\bar{y}_c) = \left|\frac{\bar{y}_{c,r} - \bar{y}_{c,s}}{\bar{y}_{c,s}}\right| \tag{6}$$

Following the previous example, the absolute relative nonresponse bias for the estimate of males would be 0.2 (or 20 percent), which means that the magnitude of nonresponse bias in the survey estimate, relative to the sample estimate, is 20 percent.

To summarize nonresponse bias, we further calculate the average absolute nonresponse bias (AANB) and the average absolute relative nonresponse bias (AARNB) for each of the four summary variable groups and overall. These aggregate measures are simply calculated by dividing the sums of the absolute and absolute relative nonresponse bias estimates by the total number of variable categories *C* within a given variable group:

$$\text{Average Absolute Nonresponse Bias} = \frac{\sum_{c=1}^{C} |\bar{y}_{c,r} - \bar{y}_{c,s}|}{C} \tag{7}$$

$$\text{Average Absolute Relative Nonresponse Bias} = \frac{\sum_{c=1}^{C} \left|\frac{\bar{y}_{c,r} - \bar{y}_{c,s}}{\bar{y}_{c,s}}\right|}{C} \tag{8}$$

We note that alternative measures of sample representativeness exist that assess the balance of respondent characteristics relative to the sample, including the R-indicator and

the coefficient of variation of the response propensities (Schouten et al. 2009; Moore et al. 2018). However, as our main focus is on estimating the magnitude of nonresponse bias for specific variables that proxy those collected in the LPP survey, and not on assessing variations in response propensities, we do not consider these alternative measures further.

3.4.3 Modeling Survey Participation

To analyze interactions between employee characteristics and mode (design) on the likelihood of survey participation, two sets of multilevel (random intercept) logistic regression models are estimated by accounting for employees nested within establishments. The first set of multilevel logistic regressions focus on the individual mode comparisons, revealing whether some employee subgroups are more (or less) likely to participate via the web starting mode in the mixed-mode design compared to telephone in the single-mode design. The second set of multilevel logistic regressions focus on the mode design comparisons, showing whether some employee subgroups are more (or less) likely to participate via the sequential web-telephone mixed-mode design compared to the single-mode telephone design. Both sets of multilevel logistic regressions include a main effects model and an interactions model. The main effects model contains all administrative employee variables described in Section 3.3.2 and a mode (design) indicator variable. The interactions model includes the mode (design) indicator interacted with all employee characteristics. The mode (design) indicator variable is equal to 0 for employees allocated to the single-mode (telephone) design and 1 for those allocated to the sequential mixed-mode (web-telephone) design. The dependent variable in all logistic regression models is the response indicator (0 = nonresponse, 1 = response).

The multilevel (random intercept) logistic regression model can be expressed as follows:

$$\log\left(\frac{p_{ij}}{1 - p_{ij}}\right) = \alpha + X_{ij}\beta + Z_{ij}\gamma + X_{ij}\, Z_{ij}\tau + \mu_j \qquad (9)$$

where p_{ij} is the probability of participation for the i^{th} employee within the j^{th} establishment and α is the model intercept. The coefficient for the mode (design) indicator X_{ij} is represented by β. The term γ refers to the coefficients corresponding to the administrative employee variables Z_{ij}. The coefficients representing the interactions of the employee characteristics Z_{ij} and the mode (design) indicator X_{ij} are represented by τ. The random effect term (denoted by μ_j) is assumed to be normally distributed with variance σ_u^2.

Given that the focus of the study is on randomization rather than representation, all analyses are reported unweighted. Therefore, the (proxy) nonresponse bias estimates reported below may not generalize to the full population of employees in Germany. However, our main interest lies in assessing the relative effects of the experimental mode (design) manipulations rather than the level of nonresponse bias in the population. All analyses were performed using Stata 16 (multilevel logistic regressions) (Stata Corp 2019) and R 4.0 (nonresponse bias estimation) (R Core Team 2021).

3.4.4 Cost Analysis

To address the fourth research question, we compare the costs associated with each mode and mode design (Olson et al. 2020b). As the actual survey costs are unknown, only hypothetical (yet realistic) values informed by the survey institute are used. The costs of the web mode include sending the invitation letter (0.95 EUR) and up to two reminders (0.80 EUR/ reminder) (German Post 2021b). We added 0.05 Euro per letter for printing, envelope, and handling. The costs of the telephone mode include the invitation letter and interviewer labor, including the hourly gross earnings (11.12 EUR; Indeed 2021) and the incidental wage cost (27 percent of the gross earnings; German Federal Office of Statistics 2020b). Thus, the hourly labor cost of one telephone interviewer is: 14.12 EUR [=11.12 EUR + (11.12 EUR x 0.27)]. We assumed that one telephone contact attempt

(e.g., dialing the telephone number, setting the status) would take on average one minute. For generating the cost of a telephone interview, we used the mean telephone interview duration (50.3 minutes). The estimated cost of a completed telephone interview and a telephone contact are as follows:

$$\text{Cost of telephone interview} = 14.12 \text{ x } \frac{50.3}{60} = €11.84 \quad (10)$$

$$\text{Cost of telephone contact attempt} = 14.12 \text{ x } \frac{1}{60} = €0.24 \quad (11)$$

Of course, web and telephone surveys also include fixed costs (e.g., programming the questionnaire). However, these costs are excluded as we do not have realistic cost information for them.

3.5 Results

3.5.1 Response Rates

Table 2 addresses the first research question by showing the response rates between the different modes and mode designs (Research Question 1). Out of 7,197 employees assigned to the single-mode telephone design, 423 (5.88 percent) completed the interview. For the 7,196 employees assigned to the sequential web-telephone mixed-mode design, 882 (12.25 percent) logged into the web questionnaire at least once but only 709 (9.85 percent) completed the web survey, and a further 229 (3.18 percent) completed the survey in the follow-up telephone mode for a total of 938 (13.04 percent) respondents in the mixed-mode design. The response rates for both the web starting mode and the web-telephone design were significantly higher than the single-mode telephone design, indicating that introducing the web starting mode had an overall positive effect on the response rate. The telephone contact rate did not significantly differ between the mixed-mode (61.80 percent) and single-mode (63.33 percent) groups. The telephone cooperation rate

was lower in the mixed-mode group (5.78 percent) than in the single-mode (9.28 percent) group, reflecting the more difficult-to-interview cases in the nonresponse follow-up phase of the field period.

Table 2. Response Rates by Mode and Mode Design

	Single-Mode	Mixed-Mode	
	Telephone	Web	Web-Telephone
Sample size	7,197	7,196	7,196
Respondents (total)	423	709	938
Telephone	423	0	229
Web	0	709	709
Response (%)	5.88	9.85	13.04
Contact (%)	63.33	N/A	61.80
Cooperation (%)	9.28	N/A	5.78

Notes: 46 out of 709 web respondents completed the web survey after at least one telephone contact was attempted. The response rate differs significantly between the single-mode telephone and web starting mode groups: $\chi^2 = 78.47$; $p < 0.001$. The response rate differs significantly between the single-mode telephone and mixed-mode web-telephone groups: $\chi^2 = 215.31$; $p < 0.001$. The contact rate does not differ significantly between the single-mode telephone and mixed-mode web-telephone groups: $\chi^2 = 3.41$; $p = 0.065$. The cooperation rate differs significantly between the single-mode telephone and mixed-mode web-telephone groups: $\chi^2 = 36.67$; $p < 0.001$.

3.5.2 Nonresponse Bias

Although the web starting mode and the full web-telephone sequence yielded higher response rates than the single-mode telephone design, what is still unclear is whether the higher response rates were accompanied by lower nonresponse biases (Research Question 2). We address this question by comparing aggregate (proxy) nonresponse bias between the mode (design) groups. Table 3 presents the AANB and the AARNB for each of the four administrative variable groups and overall. The table yields two key findings. First, despite the lower response rate, overall average nonresponse bias is lower for the single-mode telephone design than for the web starting mode and the full web-telephone mixed-mode design. The same pattern is apparent for the demographics, employment, and benefits variable groups. Only the geodata variable group has lower average nonresponse bias in the web starting mode and web-telephone groups compared to the single-mode

telephone design. And second, following up web nonrespondents by telephone reduces the average nonresponse bias in all variable groups. In summary, the results indicate that introducing the web mode in the LPP survey increased the response rate, but this did not correspond to a lower overall nonresponse bias relative to the single-mode telephone design.

Individual estimates of nonresponse bias and absolute relative nonresponse bias for each administrative variable are presented in the appendix (Table A2). For 22 out of 31 variable categories, the ARNB is higher in the web starting mode than in the single-mode telephone group. The differences are particularly large for employees (a) with university degree, (b) working in business or administration, and (c) who were registered as job seeker with the BA during the last 10 years. Conversely, the web starting mode produces a considerably smaller ARNB than the single-mode telephone group for employees who live in municipalities with less than 13,000 inhabitants and have a commuting distance of at least 17 kilometers.

Regarding the mode design comparison, implementing the telephone follow-ups reduces the ARNB for nearly all variables in the mixed-mode group. However, the single-mode telephone design still yields lower nonresponse bias than the mixed-mode web-telephone design for 20 out of 31 variable categories. To give some examples, single-mode telephone yields an appreciably lower ARNB for the following variable categories: occupation (working in business and administration) and higher education (university degree). There are more exceptions than in the single-mode comparisons. For instance, web-telephone yields lower nonresponse bias for the following subgroups: employment contract (full-time), region (west), and commuting (17 + kilometers).

Table 3. Average Absolute Nonresponse Bias (AANB) and Average Absolute Relative Nonresponse Bias (AARNB), by Variable Group and Overall

	Single-Mode		Mixed-Mode			
	Telephone		Web		Web-Telephone	
Variable group	AANB (%)	AARNB (%)	AANB (%)	AARNB (%)	AANB (%)	AARNB (%)
Demographics	5.42	25.01	7.83	36.07	7.18	33.86
Employment	4.49	13.90	7.16	24.52	5.86	20.09
Benefits	2.32	7.76	8.63	27.30	6.02	18.94
Geodata	2.60	8.69	1.84	8.41	1.32	5.42
Overall	3.80	13.90	6.00	22.90	4.87	18.57

3.5.3 Modeling Survey Participation

To understand whether certain employee subgroups are more (or less) likely to respond in different modes or mode designs (Research Question 3), this section analyzes the interaction between employee characteristics and mode (design) on participation in the LPP. The results will be presented separately for the single-mode comparisons (telephone vs. web starting mode) and the mode design comparisons (single-mode telephone vs. mixed-mode web-telephone). Since employees are nested within establishments, multilevel (random intercept) logistic regression results are presented accounting for the establishment grouping variable. All administrative variables described in Section 3.3.2 available for both respondents and nonrespondents are included simultaneously as covariates in the fitted logistic regression models.

3.5.3.1 Survey Participation: Single-Mode Telephone vs. Web Starting Mode

The estimated coefficients for the likelihood of participation in the LPP for the single-mode telephone versus web starting mode comparison are shown in Table 4 (left panel). Column 2 shows the results from the main effects model, while column 3 shows the re-

sults of the model with mode interactions. The main effects model reveals several statistically significant results with the most relevant being that employees assigned to the web starting mode are more likely to respond compared to those assigned to the single-mode telephone design. The interactions model additionally reveals some notable findings. First, full-time employees assigned to the web starting mode are significantly ($p < 0.01$) more likely to participate than those assigned to the single-mode telephone design. Additionally, employees working in business or administration occupations and between 5 and 11 years for their employer are significantly (both $p < 0.05$) more likely to participate via the web starting mode compared to the single-mode telephone design, while employees registered as job seekers at least once during the last 10 years are significantly ($p < 0.05$) more likely to participate via single-mode telephone compared to the web starting mode. Plots of the predicted probabilities of the significant interactions are provided in the appendix (Figures A1: Occupation, A2: Job seeking last 10 years, and A3: Employment contract). All other variables do not interact with mode.

3.5.3.2 Survey Participation: Single-Mode Telephone vs. Mixed-Mode Web-Telephone

The next set of multilevel logistic regressions model the likelihood of participation among the single-mode telephone and sequential web-telephone mixed-mode designs. The results are also reported in Table 4 (right panel). Column 4 shows the results of the main effects model, while column 5 displays the results of the interactions model. The results of the main effects model are largely consistent with the single-mode comparisons. Most relevant is the highly significant main effect ($p < 0.001$) of mode design, indicating that employees assigned to the mixed-mode group are more likely to respond than those assigned to the single-mode group. Turning to the interactions model, one can see that fol-

lowing up web nonrespondents via telephone generally reduces the size of most interaction terms identified in the previous single-mode comparisons. As before, full-time employees and employees working between 5 and 11 years for their current employer are more likely to participate via the mixed-mode design compared to the single-mode telephone design, and employees who were registered as job seeker at least once within the last 10 years are more likely to respond via the single-mode design compared to the mixed-mode design. However, employee occupation is no longer statistically significant. Plots of the predicted probabilities of these interactions are provided in the appendix (Figure A1: Occupation, Figure A2: Job seeking last 10 years, and Figure A3: Employment contract).

Table 4. Log-Odds Ratios of Survey Participation: Single-Mode Telephone vs. Web Starting Mode and Single-Mode Telephone vs. Mixed-Mode Web-Telephone

	Tel. vs. Web		**Tel. vs. Web-Tel.**	
	MEM Estimate (SE)	IM Estimate (SE)	MEM Estimate (SE)	IM Estimate (SE)
Intercept	-6.57(.47)***	-2.58(.28)***	-8.68(.45)***	-2.61(.28)***
Experimental group (EG)				
(Ref. Single-Mode Telephone)				
Web Starting Mode	0.57(.06)***	-0.42(.37)	0.90(.06)***	-0.16(.35)
Sex				
(Ref. Male)				
Female	-0.01(.09)	-0.02(.14)	0.09(.08)	0.01(.14)
Age				
(Ref. <36)				
36–54	0.16(.08)*	0.11(.13)	0.18(.08)*	0.12(.13)
55+	0.47(.10)***	0.41(.16)**	0.57(.09)***	0.42(.16)**
German citizenship				
(Ref. Yes)				
No	-0.61(.17)***	-0.50(.25)*	-0.60(.15)***	-0.50(.25)*
Secondary education				
(Ref. Less than university entrance)				
University entrance	0.44(.10)***	0.30(.16)	0.36(.09)***	0.31(.16)
Higher education				
(Ref. Less than university degree)				
University degree	0.27(.11)*	0.25(.18)	0.34(.10)***	0.25(.18)
Employment contract				
(Ref. Part-time)				
Full-time	-0.05(.12)	-0.40(.18)*	-0.07(.11)	-0.40(.18)*
Daily earnings				
(Ref. <121)				
121–173	0.15(.10)	0.13(.15)	0.14(.09)	0.11(.15)
174+	0.43(.12)***	0.51(.18)**	0.41(.11)***	0.48(.18)**
Occupation				

(Ref. Production)				
Business/Administration	0.16(.08)*	-0.06(.14)	0.12(.08)	-0.05(.14)
Other	-0.10(.09)	-0.08(.13)	-0.05(.08)	-0.07(.13)
Years working for employer				
(Ref. <5)				
5–11	-0.01(.09)	-0.25(.14)	0.08(.08)	-0.25(.14)
12+	0.09(.10)	0.05(.16)	0.12(.10)	0.05(.16)
Benefits last 10 years				
(Ref. No)				
Yes	-0.40(.14)**	-0.20(.21)	-0.35(.13)**	-0.20(.21)
Job seeking last 10 years				
(Ref. No)				
Yes	0.08(.09)	0.33(.14)*	0.08(.08)	0.33(.14)*
Job seeking days last 10 years				
(Ref. 0)				
1–150	0.16(.14)	0.09(.22)	0.17(.13)	0.09(.22)
151+	0.11(.17)	-0.05(.25)	0.18(.15)	-0.05(.25)
Region				
(Ref. North)				
West	0.05(.12)	0.17(.17)	0.12(.11)	0.20(.17)
South	0.03(.11)	-0.06(.15)	0.08(.10)	-0.03(.15)
East	0.02(.11)	-0.01(.17)	0.10(.10)	0.01(.17)
Urbanicity				
(Ref. <13,000)				
13,000–119,999	-0.07(.08)	-0.24(.13)	-0.07(.08)	-0.23(.13)
120,000+	-0.17(.09)	-0.34(.14)*	-0.17(.08)*	-0.34(.14)*
Commute				
(Ref. <17)				
17+	-0.17(.07)*	-0.29(.11)**	-0.16(.06) *	-0.30(.11)**
Fast internet				
(Ref. 40–100)				
<40	-0.13(.12)	-0.01(.18)	-0.10(.11)	-0.01(.18)
Interactions	Estimate (SE)	Estimate (SE)	Estimate (SE)	Estimate (SE)
Sex x EG				
(Re. Male)				
Female	--	-0.05(.17)	--	0.11(.17)
Age x EG				
(Ref. <36)				
36–54	--	0.07(.17)	--	0.09(.16)
55+	--	0.09(.20)	--	0.23(.19)
German citizenship x EG				
(Ref. Yes)				
No	--	-0.21(.34)	--	-0.16(.31)
Secondary education x EG				
(Ref. Less than University entrance)				
University entrance	--	0.22(.20)	--	0.09(.19)
Higher education x EG				
(Ref. Less than University degree)				
University degree	--	0.04(.22)	--	0.15(.22)
Employment contract x EG				
(Ref. Part-time)				
Full-time	--	0.64(.24)**	--	0.52(.22)*
Daily earnings x EG				
(Ref. <121)				
121–173	--	0.02(.19)	--	0.02(.18)
174+	--	-0.15(.22)	--	-0.12(.21)
Occupation x EG				
(Ref. Production)				
Business/Administration	--	0.37(.17)*	--	0.26(.16)

Other	--	-0.04(0.18)	--	0.03(.17)
Years working for employer x EG				
(Ref. <5)				
5–11	--	0.39(.18)*	--	0.50(.17)**
12+	--	0.07(.21)	--	0.12(.20)
Benefits last 10 years x EG				
(Ref. No)				
Yes	--	-0.36(.28)	--	-0.24(.27)
Job seeking last 10 years x EG				
(Ref. No)				
Yes	--	-0.40(.18)*	--	-0.37(.17)*
Job seeking days last 10 years x EG				
(Ref. 0)				
1–150	--	0.10(.29)	--	0.11(.27)
151+	--	0.28(.34)	--	0.36(.32)
Region x EG				
(Ref. North)				
West	--	-0.21(.21)	--	-0.13(.20)
South	--	0.16(.17)	--	0.17(.16)
East	--	0.04(.21)	--	0.12(.20)
Urbanicity x EG				
(Ref. <13,000)				
13,000–119,999	--	0.28(.17)	--	0.23(.16)
120,000+	--	0.28(.18)	--	0.25(.17)
Commute x EG				
(Ref. <17)				
17+	--	0.20(.14)	--	0.21(.13)
Fast internet x EG				
(Ref. 40–100)				
<40	--	-0.23(.24)	--	-0.14(.22)
N	14,393	14,393	14,393	14,393
AIC	7602.66	7592.8	8516.64	8519.60
BIC	7807.18	7979.1	8721.15	8905.9
Wald-Test (x^2)	356.05	423.97	501.56	559.77
Wald-Test (p-value)	0.0000	0.0000	0.0000	0.0000
Random effect (establishment; SE)	0.018(0.019)	0.017(0.019)	0.009(0.014)	0.008(0.014)
ICC (empty model)	0.041	0.041	0.032	0.032

Significance level: *** 0.001; ** 0.01; * 0.05

Note: The results are obtained from fitting multilevel logistic regressions accounting for nesting of employees within establishments. MEM = main effects model, IM = interactions model, SE = standard error, ICC = intraclass correlation.

3.5.4 Cost Analysis

Table 5 presents the results of the cost analysis. The estimated total costs for the telephone interviews were 5,007.16 EUR in the single-mode design and 2,710.73 EUR in the mixed-mode design. The total costs were highest in the web-telephone (€24,720.49) design, followed by the single-mode telephone (€22,200.18) design and the web starting mode (€13,238.65). Dividing the total costs by the number of respondents yields an average cost per completed interview that is substantially smaller for the web starting mode

(€18.67) and the web-telephone (€26.35) design, compared to the single-mode telephone design (€52.48). Thus, by introducing the web starting mode the LPP achieved a (hypothetical) cost savings of about 50 percent per respondent in the mixed-mode design.

Table 5. Cost Analysis by Mode and Mode Design

	Single-Mode	Mixed-Mode	
	Telephone	Web	Web-Telephone
Invitation letters	€7,197	€7,196	€7,196
Reminder letters	N/A	€6,042.65	€6,042.65
Interviews	€5,007.16	N/A	€2,710.73
Contact attempts	€9,996.02	N/A	€8,771.11
Total costs	€22,200.18	€13,238.65	€24,720.49
Interviews (N)	423	709	938
Avg. cost per interview	€52.48	€18.67	€26.35

3.6 Discussion

The present study analyzed the effects of experimentally introducing a web starting mode on participation in a telephone employee survey. The results can be summarized into four main findings. First, the web starting mode and the full web-telephone sequence produced higher response rates (9.85 percent and 13.04 percent, respectively) compared to the traditional single-mode telephone design (5.88 percent). Second, despite the lower response rate, aggregate nonresponse bias was lower in the telephone single-mode design compared to the web starting mode and the full web-telephone design. However, following up the web nonrespondents with telephone was effective in reducing initial nonresponse bias. Third, the likelihood of survey participation differed between both modes and mode designs for some employee subgroups. In particular, employees working full-time were significantly more likely to participate in the web starting mode or in the web-telephone sequence compared to the single-mode telephone design. Employees working in business or administrative occupations were significantly more likely to participate via the web

starting mode compared to the single-mode telephone design. Business and administration workers were similarly likely to participate in the telephone single-mode and web-telephone mixed-mode designs. Lastly, average (estimated) survey costs per respondent were significantly (about 50 percent) lower in the mixed-mode design compared to the telephone single-mode design.

This work has several practical implications. Perhaps most significant, introducing a web mode into a telephone survey of the employed population can yield potential cost savings and increase the response rate relative to the single-mode alternative. However, these advantages must be weighed against a potential increase in nonresponse bias, as indicated by our results. Although following-up web nonrespondents via telephone seems to reduce nonresponse bias, this did not push the level of aggregate nonresponse bias below that of the single-mode design. Nonetheless, we recommend using an interviewer-administered mode, such as telephone, as a follow-up to web if the researcher's budget allows.

Moreover, our results indicate that employees working full-time or in business or administrative occupations are more likely to respond via web compared to telephone. If these employee subgroups are a high priority for analysis or represent a large share of the target population, then introducing web either as a starting mode in a mixed-mode sequence or as an exclusive mode could be beneficial in terms of reaching these groups while reducing survey costs. Lastly, there were several employee characteristics that did not interact with mode or mode design, including sociodemographic and economic characteristics. Thus, for surveys which focus on measuring these attributes, there seems to be little difference in which mode (design) is used. As such, they can be measured more cost-effectively by using the web mode as part of a single-mode or sequential mixed-mode (with telephone follow-up) design.

This study is not without limitations. First, the study's target population are employees subject to social insurance in Germany. According to the definition of the International Labour Organization (ILO), 45.3 million individuals were employed in Germany in 2019. Out of these, 33.4 million (73.73 percent) employees were subject to social insurance (German Federal Office of Statistics 2021). Thus, generalizations to other employed populations, such as self-employed and civil servants should be met with caution. Second, adjustment weights were unavailable for the experiment. Such weights could correct for some of the nonresponse biases reported here. Third, because of the large number of comparisons in the interactions model (Table 4), it is possible that some of the interactions were statistically significant due to chance alone (i.e., Type 1 error). Fourth, the combination of web and telephone in a sequential mixed-mode design may also introduce unintended effects on observational errors, such as differential measurement error (de Leeuw and Hox 2011; Dillman et al. 2014; de Leeuw 2018). Although measurement mode effects were outside the scope of the present study, they should also be considered when deciding whether to mix modes. This is particularly the case for panel studies, such as the LPP, where respondents may switch modes between waves, which could introduce bias in longitudinal estimates of change (Cernat and Sakshaug 2021). This issue will be studied in future waves of the LPP. Despite these limitations, this study made use of a randomized mode design experiment and extensive administrative data, which is particularly rare in telephone and web surveys and especially rare for employee surveys.

In conclusion, we identified clear advantages of introducing web in a telephone survey in terms of increasing response rates and reducing costs in a population of employees. However, introducing the web starting mode did lead to a modest increase in aggregate nonresponse bias. Thus, the advantages of introducing web should be weighed against the possibility of higher nonresponse bias and the particular employee subgroups of interest

to the researcher. Future research is needed to determine whether these results are transferable to other countries and employee populations. In the current situation of costly interviewer-administered designs and declining response rates, it is important that alternative mode designs are studied to better inform potential tradeoffs between costs and data quality.

Appendix

Table A1. Final Disposition Codes, by Mode Design

Final Disposition Code	Mode Design			
	Single-Mode Telephone		Mixed-Mode Web-Telephone	
	Freq.	Percent	Freq.	Percent
Completed Interview	423	5.88	938	13.04
Refusal				
Respondent-level				
Respondent refusal (T/C)	2,386	33.15	2,114	29.38
Language problem (T/C)	71	0.99	75	1.04
Broken appointment (T)	1,151	15.99	1,109	15.41
Partial Interview (T/W)	79	1.10	84	1.17
New invitation letter requested (T)	16	0.22	14	0.19
Out of the target group (e.g., retired) (T/W/C)	109	1.51	162	2.25
Household-level				
Household-level refusal (T)	279	3.88	217	3.02
Household level language problem (T)	22	0.31	28	0.39
Respondent deceased (T/C)	9	0.13	7	0.10
Respondent Moved (T/C)	13	0.18	0	0.00
Noncontact				
Always busy (T)	143	1.99	112	1.56
No answer (T)	67	0.93	64	0.89
Invitation returned undelivered (T/W)	391	5.43	144	2.00
Fax data line (T)	24	0.33	19	0.26
Non-working number (T)	897	12.46	911	12.66
Wrong number (T)	342	4.75	299	4.16
Telephone answering device (T)	775	10.77	899	12.49
N	7,197	100	7,196	100

Notes: Most final disposition codes are available only for the telephone (T) mode. Three disposition codes are also available for the web (W) mode. Some sample units and household members contacted the survey institute or the IAB after they received the invitation letter or reminder (C). These employee contacts are assigned to the phase in which they occurred.

Table A2. Estimates of Nonresponse Bias (NB) and Absolute Relative Nonresponse Bias (ARNB) for Each Variable Category

Administrative variable	Single-Mode		Mixed-Mode			
	Telephone		Web		Web-Telephone	
	NB (%)	ARNB (%)	NB (%)	ARNB (%)	NB (%)	ARNB (%)
Sex						
Female	1.46	5.83	-1.77	7.06	0.76	3.03
Age						
<36	-6.00	18.33	-6.28	19.66	-6.90	21.59
36–54	-0.03	0.06	0.98	1.98	-0.08	0.15
55+	6.03	32.47	5.30	28.78	6.97	37.90
German citizenship						
No	-2.74	37.87	-4.52	59.28	-4.21	55.23
Secondary education						
University entrance	11.14	32.77	18.98	56.67	16.08	48.02
Higher education						
University degree	10.54	47.75	17.00	79.09	15.28	71.07
Employment contract						
Full-time	-2.99	3.36	3.30	3.72	1.61	1.81
Daily earnings						
<121	-4.15	10.07	-12.28	30.22	-9.07	22.33
121–173	-6.43	18.74	-4.53	13.04	-4.86	14.00
174+	10.59	43.39	16.82	68.22	13.94	56.56
Occupation						
Production	-2.39	4.57	-3.85	7.24	-3.86	7.25
Business / Administration	3.71	17.16	10.97	51.43	8.41	39.45
Other	-1.32	5.04	-7.10	27.93	-4.54	17.86
Years working for employer						
<5	-0.29	1.12	-6.35	25.15	-6.17	24.42
5–11	-6.39	15.99	0.53	1.32	1.74	4.31
12+	6.68	19.52	5.82	16.92	4.43	12.87
Benefits last 10 years						
Yes	-4.34	13.36	-12.10	38.50	-8.61	27.39
Job seeking last 10 years						
Yes	-0.89	1.73	-11.26	22.25	-8.07	15.95
Job seeking days last 10 years						
0	3.19	4.74	9.90	14.59	6.70	9.88
1–150	-0.11	0.69	-3.40	21.49	-2.48	15.71
151+	-3.07	18.29	-6.50	39.69	-4.22	25.76
Region						
North	-2.67	7.82	-2.76	7.91	-3.36	9.63
West	2.51	16.22	-0.97	6.34	-0.33	2.14

South	2.08	6.92	5.79	18.92	4.15	13.58
East	-1.92	9.43	-2.05	10.74	-0.46	2.42
Urbanicity						
<13,000	4.77	12.17	0.19	0.48	0.63	1.64
13,000–119.000	-2.66	7.96	-0.97	3.00	-0.72	2.24
120,000+	-2.11	7.71	0.79	2.72	0.10	0.35
Commute						
17+	-4.63	9.29	0.90	1.84	0.72	1.47
Fast internet						
<40	0.07	0.65	-2.15	23.72	-1.38	15.28

Figure A1. Marginal Predicted Response Probability: Occupation, by Mode (left panel) and Mode Design (right panel)

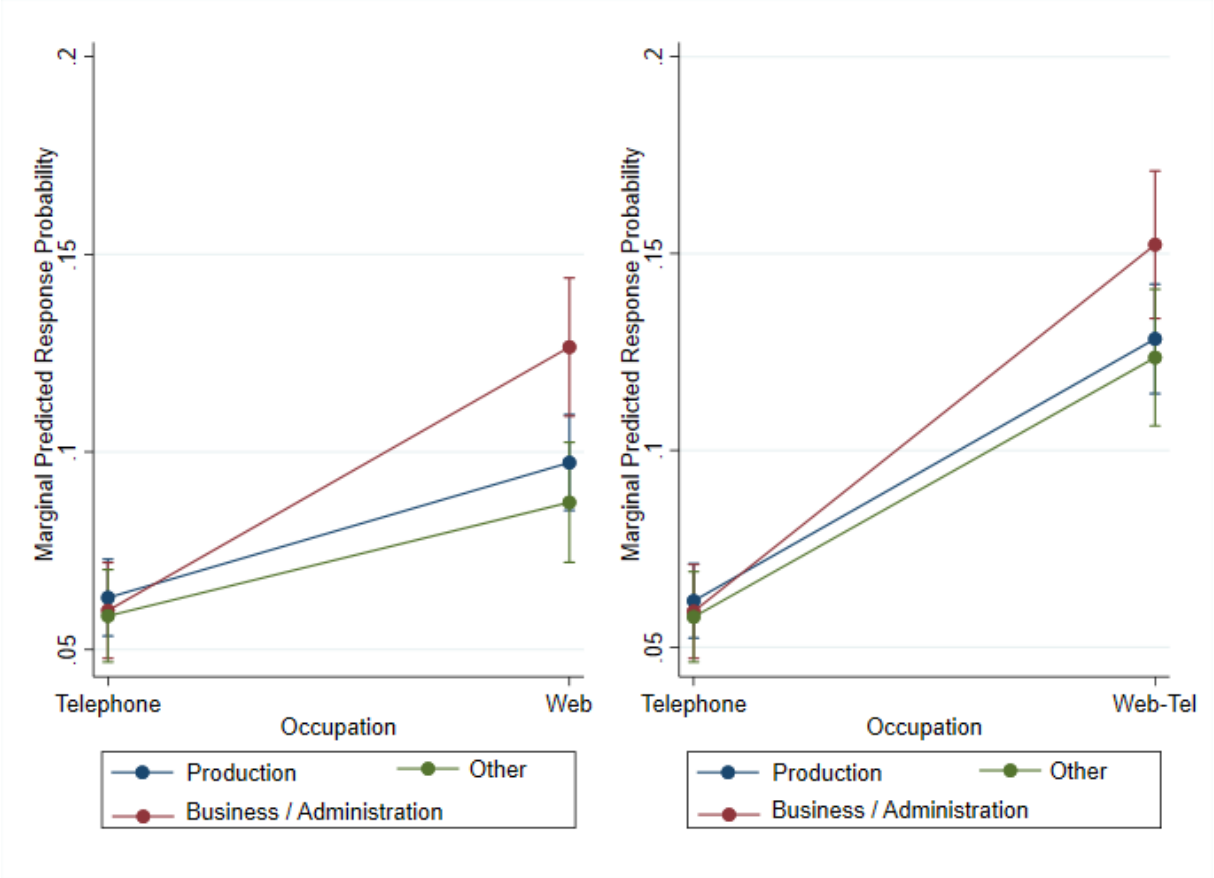


Figure A2. Marginal Predicted Response Probability: Job seeking last 10 years, by Mode (left panel) and Mode Design (right panel)

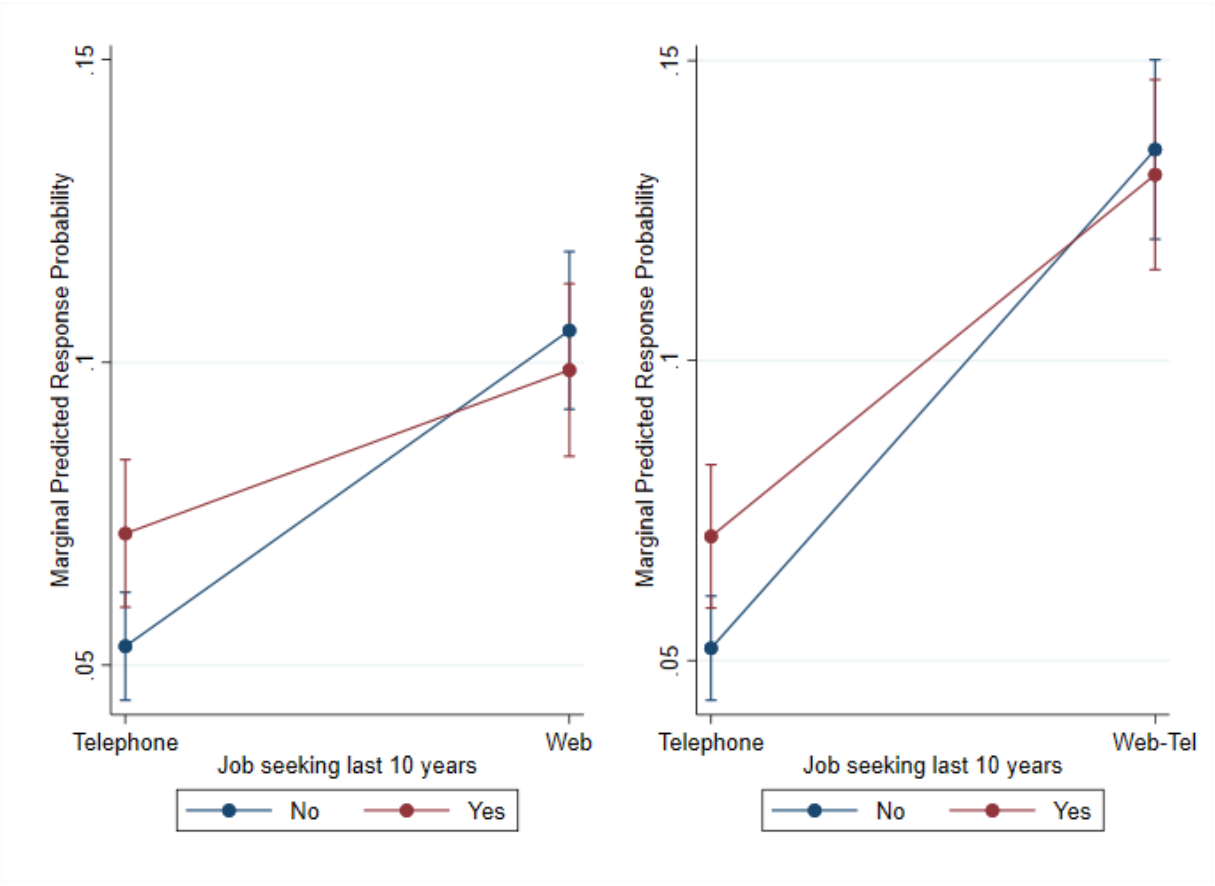
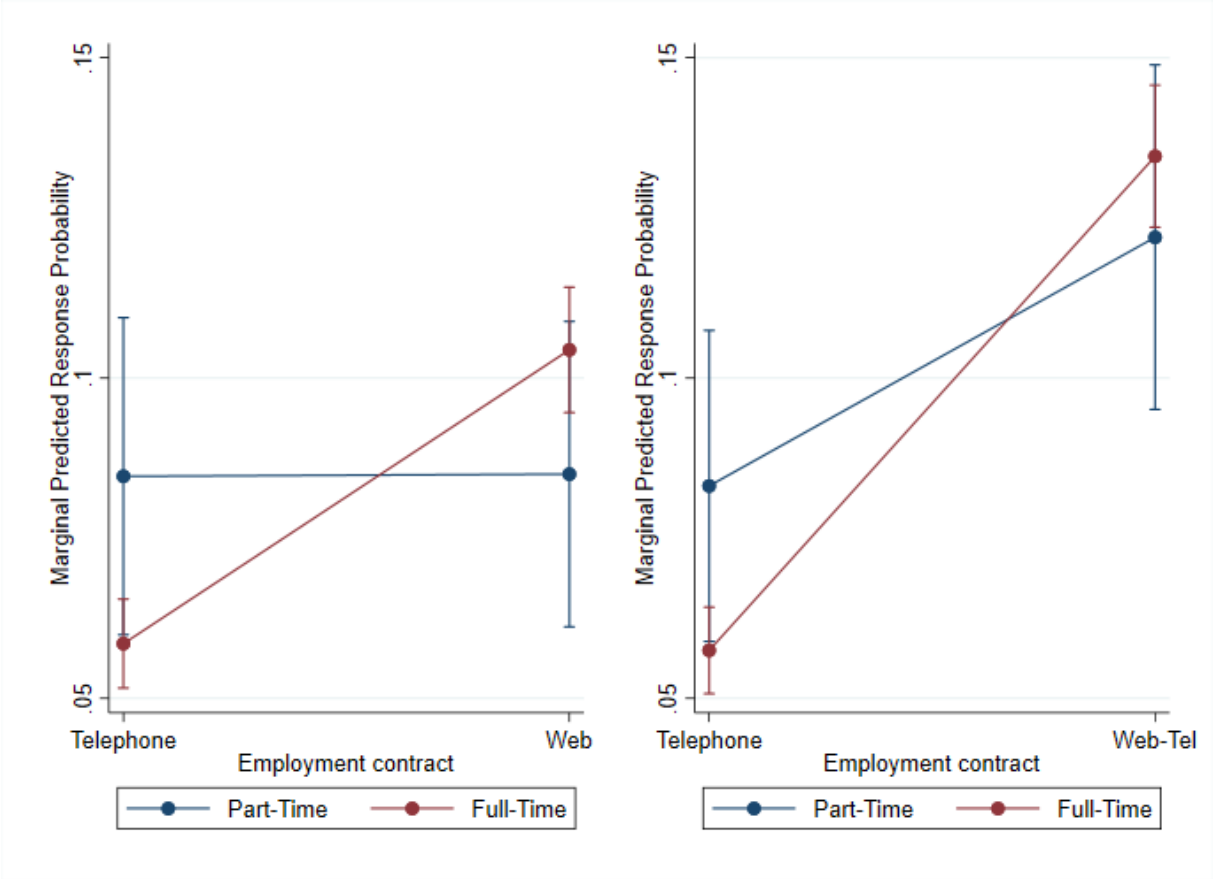


Figure A3. Marginal Predicted Response Probability: Employment contract, by Mode (left panel) and Mode Design (right panel)



References

Arbeitskreis Deutscher Markt- und Sozialforschungsinstitute (ADM; 2021), *Marktforschung in Zahlen*, available at https://www.adm-ev.de/die-branche/mafo-zahlen/.

American Association for Public Opinion Research (AAPOR; 2016), *Standard Definitions: Final Dispositions of Case Codes and Outcome Rates for Surveys* (9th ed.), AAPOR: Oakbrook Terrace, IL.

Antoni, M., Schmucker, A., Seth, S., and vom Berge, P. (2019), *Sample of Integrated Labour Market Standard Biographies (SIAB) 1975-2017*, Research Data Centre (FDZ), FDZ-Datenreport, 02/2019 (en), Nuremberg.

Asef, D., and Riede, T. (2006), "Kontaktzeit in einer Telefonerhebung – wie beeinflussen sie die Messung der Erwerbstätigkeit," in *Wirtschaft und Statistik*, ed. Statistisches Bundesamt Wiesbaden: Statistisches Bundesamt, pp. 581–586.

Baker, R., Blumberg, S. J., Brick J. M., Couper, M. P., Courtright, M., Dennis, J. M., Dillman, D., Frankel, M. R., Garland, P., Groves, R. M., Kennedy, C., Krosnick, J., Lavrakas, P. J., Lee, S., Link, M., Piekarski, L., Rao, K., Thomas, R. K., and Zahs, D. (2010), "Research synthesis: AAPOR report on online panels," *Public Opinion Quarterly*, 74, 711–781.

Brick, J. M., and Williams, D. (2013), "Explaining Rising Nonresponse Rates in Cross-Sectional Surveys," *Annals of the American Academy of Political Science*, 645, 36–59.

Brøgger, J., Nystad, W., Cappelen, I., and Bakke, P. (2007), "No Increase in Response Rate by Adding a Web Response Option to a Postal Population Survey: A Randomized Trial," *Journal of Medical Internet Research*, 9, 1–9.

Cernat, A., and Sakshaug J. W. (2021), "Estimating the Measurement Effects of Mixed Modes in Longitudinal Studies: Current Practice and Issues," in *Advances in Longitudinal Survey Methodology*, ed. P. Lynn, Hoboken: John Wiley & Sons, pp. 227–249.

Christian, L. M. (2007), *How Mixed-Mode Surveys are Transforming Social Research: The Influence of Survey Mode on Measurement in Web and Telephone Surveys*, Washington State University, Department of Sociology, Washington.

Clark, B., Chatterjee, K., Martin, A., and Davis, A. (2020), "How commuting affects subjective wellbeing," *Transportation*, 47, 2777–2805.

Couper, M. P. (2011), "The Future of Modes of Data Collection," *Public Opinion Quarterly*, 75, 889–908.

Czajka, J. L., and Beyler, A. (2016), *Declining Response Rates in Federal Surveys: Trends and Implications*, Washington, DC: Mathematica Policy Research.

de Leeuw, E. D. (2005), "To Mix or Not to Mix Data Collection Modes in Surveys," *Journal of Official Statistics*, 21, 233–255.

de Leeuw, E. D. (2018), "Mixed-Mode: Past, Present, and Future," *Survey Research Methods*, 12, 75–89.

de Leeuw, E. D., and Hox, J. J. (2011), "Internet Surveys as Part of a Mixed-Mode Design," in *Social and Behavioral Research and the Internet*, eds. M. Das, P. Ester and L. Kaczmirek, New York: Taylor & Francis Group, pp. 45–76.

Dillman, D. A. (2009), *Mail and Internet surveys: The Tailored Design Method*, Hoboken: John Wiley & Sons.

Dillman, D. A. (2017), *The promise and challenge of pushing respondents to the Web in mixed-mode surveys. Survey Methodology*, Statistics Canada, Catalogue No. 12-

001-X, 43(1), available at https://www150.statcan.gc.ca/n1/en/pub/12-001-x/2017001/article/14836-eng.pdf?st=f2oBpwDP.

Dillman, D. A., Phelps, G., Tortora, R., Swift, K., Kohrell, J., Berck, J., and Messer, B. I. (2009), "Response rate and measurement differences in mixed-mode surveys using mail, telephone, interactive voice response (VCR) and the Internet," *Social Science Research*, 38, 1–18.

Dillman, D. A., Smyth, J. D., and Christian, L. M. (2014), *Internet, Mail, and Mixed-Mode Surveys: The Tailored Design Method* (44th ed.), Hoboken: John Wiley & Sons.

Eurostat (2018a), *Labour Force Survey in the EU, candidate and EFTA countries: Main characteristics of national surveys 2017*, European Union, Luxembourg.

Eurostat (2018b), *Archive: Internet access and use statistics – households and individuals*, available at https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Archive:Internet_access_and_use_statistics_-_households_and_individuals&oldid=379591.

Eurostat (2020), *Households with broadband access*, available at https://ec.europa.eu/eurostat/databrowser/view/tin00073/default/table?lang=en.

Fordham, L., van Lierop, D., and El-Geneidy, A. (2018), "Examining the Relationship Between Commuting and its Impact on Overall Life Satisfaction," in *Quality of Life and Daily Travel. Applying Quality of Life Research (Best Practices)*, eds. M. Friman, D. Ettema and L. E. Olsson, Cham: Springer, pp. 157–181.

Galesic, M., Tourangeau, R., and Couper, M. P. (2006), "Complementing Random-Digit-Dial Telephone Surveys with Other Approaches to Collecting Sensitive Data," *American Journal of Preventive Medicine*, 31, 437–443.

German Federal Ministry of Transport and Digital Infrastructure (2020), *Bericht zum Breitbandatlas*, available at https://www.bmvi.de/SharedDocs/DE/Anlage/DG/Digitales/bericht-zum-breitbandatlas-ende-2019-ergebnisse.pdf?__blob=publicationFile.

German Federal Office of Statistics (2017), *Wirtschaftsrechnungen: Laufende Wirtschaftsrechnungen: Ausstattung privater Haushalte mit ausgewählten Gebrauchsgütern*, Fachserie 15 (Reihe 2).

German Federal Office of Statistics (2020a), *Wirtschaftsrechnungen: Laufende Wirtschaftsrechnungen: Ausstattung privater Haushalte mit ausgewählten Gebrauchsgütern*, Fachserie 15 (Reihe 1).

German Federal Office of Statistics (2020b), *Arbeitskosten in der EU 2019: Deutschland an siebter Stelle*, available at https://www.destatis.de/DE/Presse/Pressemitteilungen/2020/04/PD20_142_624.html.

German Federal Office of Statistics (2021), *Eckzahlen zum Arbeitsmarkt, Deutschland,* available at https://www.destatis.de/DE/Themen/Arbeit/Arbeitsmarkt/Erwerbstaetigkeit/Tabellen/eckwerttabelle.html;jsessionid=82C9339C3527EB001935FA2A2EE35D39.live711.

German Post (2021a), *Addressfactory: Cleansing and enriching customer addresses*, available at https://www.deutschepost.de/en/d/deutsche-post-direkt/addressfactory.html.

German Post (2021b), *Preisänderungen zum 01.07.2019*, available at https://www.deutschepost.de/de/b/briefe-in-deutschland.html.

Gesell, S. B., Drain, M., and Sullivan, M. P. (2007), "Test of a Web and Paper Employee Satisfaction Survey: Comparison of Respondents and Non-Respondents," *International Journal of Internet Science*, 2, 45–58.

Gimenez-Nadal, I., and Molina, J. (2019), "Daily feelings of US workers and commuting time," *Journal of Transport & Health,* 12, 21–33.

Greene, J., Speizer, H., and Wiitala, W. (2008), "Telephone and Web: Mixed-Mode Challenge," *Health Services Research,* 43, 230–248.

Groves, R. M. (2006), "Nonresponse Rates and Nonresponse Bias in Household Surveys," *Public Opinion Quarterly*, 70, 646–675.

Guzy, N. (2015), "Nonresponse Bias in telefonischen Opferbefragungen. Forschungsstand und Ergebnisse einer Nonresponseanalyse," in *Nonresponse Bias*, eds. J. Schupp, and C. Wolf, Wiesbaden: Springer, pp. 161–208.

Häder, S., Gabler, S., and Heckel, C. (2009), "Stichprobenziehung für die CELLA-Studie," in *Telefonbefragungen über das Mobilfunknetz,* eds. M. Häder and S. Häder, Wiesbaden: VS Verlag für Sozialwissenschaften, pp. 21–50.

Häder, S., and Häder, M. (2019), "Einleitung und Motivation," in *Telefonumfragen in Deutschland*, eds. S. Häder, M. Häder, and P. Schmich, Wiesbaden: VS Verlag für Sozialwissenschaften, pp. 35–43.

Häder, S., and Sand, M. (2019), "Telefonstichproben," in *Telefonumfragen in Deutschland,* eds. S. Häder, M. Häder, and P. Schmich, Wiesbaden: VS Verlag für Sozialwissenschaften, pp. 113–151.

Haight, M., Quan-Haas, A., and Corbett, B. A. (2014), "Revisiting the digital divide in Canada: the impact of demographic factors on access on the internet, level of online activity, and social networking site usage," *Information, Communication & Society*, 17, 503–519.

Herzing, J. M. E., and Blom, A. G. (2019), "The Influence of a Person's Digital Affinity on Unit Nonresponse and Attrition in an Online Panel," *Social Science Computer Review*, 37, 404–424.

Indeed (2021), *Gehälter pro Stunde bei infas*, available at https://de.indeed.com/cmp/Infas-Institut-F%C3%BCr-Angewandte-Sozialwissenschaft-Gmbh/salaries/Telefoninterviewer-(m-w).

infas (2015), *IAB-Beschäftigtenbefragung: Projekt Arbeitsqualität und wirtschaftlicher Erfolg: Panelstudie zu Entwicklungsverläufen in deutschen Betrieben – Personenbefragung*, Research Data Centre (FDZ), FDZ-Methodenreport, 02/2015 (de), Nuremberg.

infas (2016), *IAB-Beschäftigtenbefragung: Projekt Arbeitsqualität und wirtschaftlicher Erfolg: Panelstudie zu Entwicklungsverläufen in deutschen Betrieben – Personenbefragung, 2. Erhebungswelle*, Research Data Centre (FDZ), FDZ-Methodenreport, 02/2016 (de), Nuremberg.

infas (2018), *IAB-Beschäftigtenbefragung: Projekt Arbeitsqualität und wirtschaftlicher Erfolg: Panelstudie zu Entwicklungsverläufen in deutschen Betrieben – Personenbefragung, 3. Erhebungswelle*, Research Data Centre (FDZ), FDZ-Methodenreport, 11/2018 (de), Nuremberg.

infas (2020), *IAB-Beschäftigtenbefragung: Projekt Arbeitsqualität und wirtschaftlicher Erfolg: Panelstudie zu Entwicklungsverläufen in deutschen Betrieben – Personenbefragung, 4. Erhebungswelle*, Research Data Centre (FDZ), FDZ-Methodenreport 04/2020 (de), Nuremberg.

Kantar (2017), *UK Household Longitudinal Study: Wave 7 technical report*. Kantar Public, London.

Kappelhof, J. W. S. (2015), "Face-to-Face or Sequential Mixed-Mode Surveys Among Non-Western Minorities in the Netherlands: The Effect of Different Survey Designs on the Possibility of Nonresponse Bias," *Journal of Official Statistics*, 31, 1–30.

Kennedy, C., and Hartig, H. (2019), *Response rates in telephone surveys have resumed their decline*, available at https://www.pewresearch.org/fact-tank/2019/02/27/response-rates-in-telephone-surveys-have-resumed-their-decline/.

Klausch, T., Hox, J., and Schouten, B. (2015), "Selection error in single- and mixed mode surveys of the Dutch general population," *Journal of the Royal Statistical Society*, 178, 945–961.

Knabe, A., Rätzel, S., Schöb, R., and Weimann, J. (2010), "Dissatisfied with Life but Having a Good Day: Time-use and Well-being of the Unemployed," *The Economic Journal*, 120, 867–889.

Kreuter, F., Müller, G., and Trappmann, M. (2010), "Nonresponse and Measurement Error in Employment Research: Making Use of Administrative Data," *Public Opinion Quarterly*, 74, 880–906.

Künn-Nelen, A. (2016), "Does Commuting Affect Health," *Health Economics*, 25, 984–1004.

Laaksonen, S., and Heiskanen, M. (2014), "Comparison of three Modes for a Crime Victimization Survey," *Journal of Survey Statistics and Methodology*, 2, 459–483.

Link, M. W., and Mokdad, A. H. (2005), "Alternative Modes for Health Surveillance Surveys: An Experiment with Web, Mail, and Telephone," *Epidemiology*, 16, 701–704.

Lipps, O., and Pekari, N. (2016), "Sample Representation and Substantive Outcomes Using Web With and Without Incentives Compared to Telephone in an Election Survey," *Journal of Official Statistics*, 32, 165–186.

Lugtig, P., Lensvelt-Mulders, G. J. L. M., Frerichs, R., and Greven, A. (2011), "Estimating Nonresponse Bias and Mode Effects in a Mixed-Mode Survey," *International Journal of Market Research*, 53, 669–686.

Luiten, A., Hox, J., and de Leeuw, E. (2020), "Survey Nonresponse Trends and Fieldwork Effort in the 21st Century: Results of an International Study across Countries and Surveys," *Journal of Official Statistics*, 36, 469–487.

Moore, J. C., Durrant, G. B., and Smith, P. W. (2018), "Data Set Representativeness During Data Collection in the Three UK Social Surveys: Generalizability and the Effects of Auxiliary Covariate Choice," *Journal of the Royal Statistical Society: Series A (Statistics in Society)*, 181, 229–248.

Olson, K., Smyth, J. D., Horwitz, R., Keeter, S., Lesser, V., Marken, S., Mathiowetz, N., McCarthy, J., O'Brien, E., Opsomer, J., Steiger, D., Sterrett, D., Su, J., Suzer-Gurtekin, Z. T., Turakhia, C., and Wagner, J. (2020a), *Transition from Telephone Surveys to Self-Administered and Mixed-Mode Surveys*, available at https://www.aapor.org/Education-Resources/Reports/Transitions-from-Telephone-Surveys-to-Self-Adminis.aspx.

Olson, K., Wagner, J., and Anderson, R. (2020b), "Survey Costs: Where are We and What is The Way Forward," *Journal of Survey Statistics and Methodology*, 9, 921–945.

R Core Team (2021), *R: A language and environment for statistical computing* [Computer software manual], available at https://www.R-project.org/.

Revilla, M. (2010), "Quality in Unimode and Mixed-Mode Designs: A Multitrait-Multimethod Approach," *Survey Research Methods*, 4, 151–164.

Ruf, K., Mackeben, J., Haepp, T., Wolter, S., and Grunau P. (2020), *LPP – Linked Personnel Panel 1819. Quality of work and economic success: longitudinal study in German establishments*. FDZ-Datenreport 11/2020 (en), Nuremberg.

Ryan, C. (2017), *Computer and Internet Use in the United States: 2016*. American Community Survey Reports, ACS-39, U.S. Census Bureau: Washington DC.

Sakshaug, J. W., and Eckman, S. (2017a), "Are Survey Nonrespondents Willing to Provide Consent to Use Administrative Records? Evidence from a Nonresponse Follow-Up Survey in Germany," *Public Opinion Quarterly,* 81, 495–522.

Sakshaug, J. W., and Eckman, S. (2017b), "Following Up with Nonrespondents via Mode Switch and Shortened Questionnaire in an Economic Survey: Evaluating Nonresponse Bias, Measurement Error Bias, and Total Bias," *Journal of Survey Statistics and Methodology,* 5, 454–479.

Sakshaug, J. W., Hülle, S., Schmucker, A., and Liebig, S. (2017), "Exploring the Effects of Interviewer- and Self-Administered Survey Models on Record Linkage Consent Rates and Bias," *Survey Research Methods*, 11, 171–188.

Sakshaug, J. W., Hülle, S., Schmucker, A., and Liebig, S., (2020), "Panel Survey Recruitment with or Without Interviewers? Implications for Nonresponse, Panel Consent, and Total Recruitment Bias," *Journal of Survey Statistics and Methodology*, 8, 540–565.

Schouten, B., Cobben, F., and Bethlehem, J. (2009), "Indicators for the Representativeness of Survey Response," *Survey Methodology*, 35, 101–113.

Schouten, B., van den Brakel, J., Buelens, B., van der Laan, J., and Klausch, T. (2013), "Disentangling mode-specific selection and measurement bias in social surveys," *Social Science Research*, 42, 1555–1570.

Smyth, J. D., Christian, L. M., and Dillman, D. A. (2008), "Does "Yes or No" on the Telephone Mean the Same as "Check-All-That-Apply" on the Web," *Public Opinion Quarterly*, 72, 103–113.

Stat Corp (2019), *Stata Statistical Software: Release 16,* College Station, TX: StataCorp LLC.

Statistics Canada (2017), *Methodology of the Canadian Labour Force Survey*. Catalogue no. 71-526-X. Ottawa.

Tourangeau, R. (2017), "Mixing Models: Tradeoffs Among Coverage, Nonresponse, and Measurement Error," in *Total Survey Error in Practice*, eds. P. P. Biemer, E. de Leeuw, S. Eckman, B. Edwards, F. Kreuter, L. E. Lyberg, N. C. Tucke and B. T. West, Hoboken: John Wiley & Sons, pp. 115–132.

US Census Bureau (2019), *Types of Internet Subscriptions by Selected Characteristics*, available at https://data.census.gov/table/ACSST1Y2019.S2802?q=internet&hidePreview=false.

Warnke, A. J. (2015), "Verzerrung durch selektive Stichproben: Untersuchung eines verknüpften Arbeitgeber-Arbeitnehmer Datensatzes mit Zugang zu administrativen Quellen," in *Nonresponse Bias*, eds. J. Schupp and C. Wolf, Wiesbaden: Springer, pp. 305–327.

Yan, T., Tourangeau, R., and Arens, Z. (2004), *When Less is More: Are Reluctant Respondents Poor Reporters?* Proceedings of the Section on Survey Research Methods of the American Statistical Association.

Zillien, N., and Hargittai, E. (2009), "Digital Distinction: Status-Specific Types of Internet Usage," *Social Science Quarterly*, 90, 274–291.

4 Transitioning an Employee Panel Survey from Telephone to Online and Mixed-Mode Data Collection

Abstract

Employee panel surveys, which are essential for measuring ongoing labor market developments, are facing significant challenges of respondent recruitment and retention. Even interviewer-administered panel surveys, historically considered the gold standard form of data collection, are facing high costs and nonresponse issues that threaten their sustainability and inferential capabilities. Supplementing interviewer-administration with online data collection is a popular method of reducing costs and may improve contactability and reduce nonresponse in employee surveys. However, the effects of introducing online data collection in an ongoing panel survey of the employed population have received little attention. We address this research gap by analyzing a mode design experiment embedded in the fourth wave of a German employee panel survey. Individuals were randomly assigned to the standard telephone-only design, or a sequential web-telephone mixed-mode design. An invitation letter experiment was also conducted to test the effect of mentioning the telephone follow-ups in the web survey invitation. Introducing the mixed-mode design led to a higher response rate (59.9% vs. 50.1%), similar levels of nonresponse bias, and lower costs compared to the single-mode design. Mentioning the telephone follow-ups had no effect on participation in the web starting mode or the full mixed-mode design. Implications of these findings for survey practice are discussed.

4.1 Introduction

As a nation's economic success depends on its employed population, many developed nations and research institutions conduct employee panel surveys that follow the same employees over time and measure individual-level changes in their attitudes, behaviors, and working conditions (Haunberger 2011; Toepoel 2012). Examples of large surveys covering the employed population are the labor force surveys of Canada (Statistics Canada 2017), the UK (UK Office for National Statistics 2022), the European Union, candidate and European Free Trade Association nations (Eurostat 2019), and the Further Training as a Part of Lifelong Learning study in Germany (Huber and Schmucker 2012). Employee panel surveys are often collected for purposes of industry classification, comparisons between and within nations, and political decision-making (Eurostat 2022a). Such surveys have gained increasing importance in employment research (Fernandez et al. 2015; Mackeben et al. 2020; Frodermann et al. 2021a), especially due to shifts in labor market behavior caused by the COVID-19 pandemic (Sakshaug et al. 2020; Haas et al. 2021).

However, a major concern of panel surveys is nonresponse and attrition, which reduce sample sizes and can lead to biased estimates if respondents differ from nonrespondents on the key survey variables (de Leeuw and Lugtig 2015). As nonresponse accumulates over time, the risk of nonresponse bias increases, highlighting the importance of strategies to minimize nonresponse and/or attrition in panel studies (Lugtig et al. 2014; Sakshaug and Huber 2016; Stöckinger et al. 2018; Müller and Castiglioni 2020). The mode of data collection plays a major role in panel surveys. Historically, interviewer-administered modes (e.g., telephone, face-to-face) have been the gold-standard mode for maximizing recruitment and retention in panel surveys. However, with rising survey costs and the difficulty of reaching certain subgroups—including employed individuals—interviewer-

administered modes are often supplemented (or replaced) with less-expensive, self-administered modes, such as web surveys (Kantar 2017; German Federal Office of Statistics 2020a; Olson et al. 2021).

In the context of employee panel surveys, there are multiple reasons why supplementing or replacing interviewer-administration with online data collection may be advantageous. First, for telephone panel surveys, panelists without a valid telephone number (due to number change or telephone disconnection) but with a known postal (or email) address can continue to be reached (e.g., by invitation letter with accompanying login information for the online survey) as opposed to being excluded due to the inability of establishing telephone contact. It might also be possible to match panelists with unknown telephone number to official telephone lists, however, the amount of listed telephone numbers (mobile and landline) has decreased rapidly over the years and listed numbers are likely to be selective (Beukenhorst 2012; Stähli 2012). Second, introducing a web mode offers greater flexibility to panelists, especially those who are busy and work full-time, enabling them to complete the survey at their own convenience. Panelists who work on internet-enabled computers or other devices as part of their employment duties may even prefer to complete the web survey during business hours (e.g., during their lunch break), which saves time for other activities outside of work.

On the other hand, transitioning to online data collection in the middle of an ongoing panel survey may also have drawbacks. For example, panelists have become accustomed to being interviewed in their usual interviewer-administered mode and do not anticipate this changing in the future. In fact, interviewer-administration may have been the primary motivator for initially joining the panel and continuing to participate. Thus, it may come as a shock when they are pushed to the web as part of a cost-cutting move, which may reduce their motivation to participate further. Offering a sequential mixed-mode design

in which web nonrespondents are followed up with the original interviewer-administered mode may mitigate the risk of nonresponse during the transition, although this may depend on whether panelists are explicitly informed from the outset that their usual interviewer mode will be offered later if they do not engage with the web mode.

Against this backdrop, the current study assesses the initial effects of transitioning from telephone-only to online and mixed-mode data collection on participation in an ongoing national employee panel survey in Germany. Specifically, we report the results of a mode design experiment in which panelists in the fourth wave of the survey were randomly assigned to the traditional telephone-only design, or a sequential mixed-mode design with web starting mode and telephone follow-ups. A random subsample of employees assigned to the mixed-mode design were also explicitly informed about the planned telephone follow-ups in the invitation letter to determine whether this knowledge affected their participation in the survey. In addition to assessing response rate effects, we utilize rich administrative data to assess the impacts of introducing the mixed-mode design on nonresponse bias and explore whether certain subgroups (e.g., full-time workers) differentially participate in the web starting mode and the full sequential mixed-mode design relative to the telephone-only design. Potential cost savings are also assessed. Specifically, we address the following research questions:

1. Does mentioning the planned telephone follow-ups in the invitation letter affect web take-up rates and participation in the mixed-mode design?

2. Does switching from a single-mode telephone design to a sequential web-telephone mixed-mode design in an ongoing employee panel survey affect response rates in the initial wave of the switch?

3. Are there differences in nonresponse bias between the telephone-only design and either the a) the web starting mode or b) the full sequential web-telephone mixed-mode design?
4. Does the likelihood of participation vary for specific employee subgroups (e.g., full-time workers) across both modes and mode designs?
5. Does the mixed-mode design yield potential cost savings (on a per-respondent basis) relative to the single-mode design?

4.2 Background

4.2.1 Mixed-Mode Panel Surveys

Panel surveys gained increasing importance at a time when interviewer-administration was the primary data collection method. Many panel surveys introduced during these times continue to use telephone or face-to-face interviewing as their primary mode of data collection. Examples include the Panel Study of Income Dynamics (PSID) (Institute for Social Research 2022), the German Socio-Economic Panel (SOEP) (Schupp 2012), and the Swiss Household Panel (SHP) (Tillmann et al. 2016), although some panels were forced to scale back certain forms of interviewer-administration (e.g., face-to-face interviewing) to comply with lockdown restrictions imposed during the COVID-19 pandemic (Burton et al. 2020; Gummer et al. 2020; Sakshaug et al. 2020; Sastry et al. 2020).

Unlike face-to-face panel surveys, telephone panel surveys have had to cope with several widespread technological developments, such as declining penetration of landline telephones (World Bank 2021a), increasing use of telephone screening devices (Dillman 2017), and the rise of mobile-only households (German Federal Office of Statistics 2021). Additionally, households may change their telephone number or disconnect their service

without informing the survey organization. These developments have contributed to declining telephone participation and very low response rates in telephone surveys (Brick and Williams 2013; Czajka and Beyler 2016). To illustrate this point, response rates of US telephone surveys conducted by the Pew Research Center have declined from around 28% in 2001 to around 6% in 2018 (Kennedy and Hartig 2019).

To counter these trends, many surveys supplement (or mix) interviewer-administration with online data collection given high rates of internet coverage in many countries (Eurostat 2020; World Bank 2021b). A popular mixed-mode strategy is to deploy multiple modes sequentially, typically starting with the least-expensive, usually self-administered mode, and following up initial nonrespondents with a more expensive interviewer-administered (e.g., telephone or face-to-face) mode (Dillman 2017). Sequential mixed-mode designs have greater potential for cost savings compared to concurrent mixed-mode designs as all sample units are "pushed" to the less-expensive mode from the outset (Dillman 2017; Tourangeau 2017; de Leeuw 2018), often not knowing that a more expensive interviewer-administered mode will be offered later if they do not engage with the initial mode(s). In addition to potential cost savings, introducing a self-administered mode in an otherwise interviewer-administered panel survey may afford particular benefits to panelists. Specifically, offering the web mode provides panelists with the opportunity to participate at their convenience. This is an essential feature for many working professionals, and especially full-time workers, who participate in panel studies but are difficult to reach with traditional interviewer modes. Employees who use computers at their workplace or work from home can flexibly participate in the web survey during the day without relying on an interviewer to contact them.

However, changing the data collection mode in a panel survey can also have potential negative effects. For example, panelists who have developed a good rapport with their

usual interviewer may lose interest in participating if the study is pushing them to complete the survey online. Further, panelists with lower digital affinity may be put off by the mode switch and become reluctant to adopt the web mode, which could reduce their likelihood of further participation in the panel. Low digital affinity is, however, less of an issue in western nations where the share of internet usage in the population is high (e.g., Netherlands: 95%, Germany: 91%, Spain: 94%, France: 92%) (Eurostat 2022b).

Considering these potential strengths and drawbacks, it is important to evaluate the effect of introducing web on response rates, nonresponse bias, and the likelihood of continued participation in ongoing employee panel surveys. The present study addresses this understudied area of research.

We note that altering the mode design can also have implications for measurement mode effects (Dillman et al. 2009; Allum et al. 2018; Biemer et al. 2021a; Biemer et al. 2021b; Cernat and Revilla 2021). While we acknowledge the importance of measurement effects, this topic is not considered further and is left to future work.

4.2.2 Effects of Introducing Web in Panel Surveys

A small set of large-scale population-based panel studies have experimentally assessed the participatory effects of introducing a web mode as part of a sequential mixed-mode design. In the fifth wave of the UK Household Longitudinal Study Innovation Panel (UKHLS-IP), panelists and refreshment cases were randomly allocated to a sequential mixed-mode design with web starting mode and face-to-face follow-ups, or the usual face-to-face designs; unconditional incentives were used in both mode designs. Switching panelists to the mixed-mode design in the fifth wave did not have a statistically significant effect on response rates among fourth wave respondents (mixed-mode: 81%, face-to-face: 84%; $p = 0.31$) nor for the fourth wave nonrespondents (mixed-mode: 36%, face-to-face: 33%; $p = 0.69$) (Jäckle et al. 2015). However, from wave 6 onward, the mixed-mode

design began to outperform the single-mode design in terms of response rates for both wave 4 respondents and nonrespondents (Gaia 2016). Regression analyses revealed no demographic differences in the likelihood of participation between the two mode designs in the fifth wave. However, several subgroups (especially rural citizens and unemployed persons) were more likely to participate via face-to-face compared to web (Jäckle et al. 2015). Potential cost savings were also observed in the mixed-mode design (Bianchi et al. 2017), which led to the same sequential mixed-mode design being implemented in wave 7 of the main UKHLS survey to replace a primarily face-to-face design (Kantar 2017).

The US National Longitudinal Study of Adolescent to Adult Health (Add Health) experimentally tested a mixed-mode design in its fifth wave (2016–2018). Panelists were randomly allocated to either a web/mail choice protocol followed by face-to-face follow-ups for a subsample of initial nonrespondents, or the traditional face-to-face single-mode design. The mode design experiment was crossed with incentive experiments. The mixed-mode design achieved a slightly lower response rate (69%) than the single-mode design (72%), with a relatively high take-up rate for the web/mail modes (50%). Overall, the mixed-mode design achieved considerable cost savings in comparison to the single-mode design (Biemer et al. 2021a; Biemer et al. 2021b).

In 2014, the SOEP, an annual primarily face-to-face panel survey, explored the effects of introducing web on response rates by experimenting with households that had previously participated in at least four waves of the face-to-face panel survey "Families in Germany" (FiD). In 2014, funding for the FiD study expired and the panelists were integrated into the SOEP core study. The FiD sample consisted of a cohort and a screening sample. The main difference between the samples was that all cohort households had children under 8 years, while all screening households had children under 18 years (infas 2020). The

screening sample was assigned to a sequential web-face-to-face mixed-mode design, while the cohort sample was allocated to a face-to-face single-mode design. The mixed-mode design had a negative effect on the response rate (face-to-face: 82%, web-face-to-face: 70%), but lowered costs relative to the single-mode design (Lüdtke and Schupp 2017). However, these results could be influenced by the aforementioned differences in household composition.

The SHP, an annual telephone panel survey, conducted an extensive mode (design) experiment over two waves in 2018 and 2019. Unconditional incentives were used in all experimental groups. Here, we describe only a side experiment in which Swiss households were interviewed primarily by telephone or face-to-face (in the case of unknown telephone number) in 2018, while these respondents were randomly allocated to telephone and face-to-face (in case of missing telephone numbers) (70% of households) or a web single-mode design (30% of households) in 2019. Households assigned to the web mode yielded a similar response rate (75%) compared to those assigned to the interviewer-administered mode (77%), which was not a statistically significant difference (Voorpostel et al. 2020; Voorpostel et al. 2021), suggesting that the switch to web did not have an immediate negative effect on participation in the panel.

The US Panel Study of Income Dynamics (PSID), a biennial telephone survey, evaluated the implementation of self-administered modes in 2014. Individuals who completed the 2013 wave of the PSID were invited by mail to complete a supplemental study in 2014. All individuals who reported in the 2013 wave that they had connected to the internet at home in the past year (73%) were assigned to a web-only design, while the remaining individuals were assigned to a web-mail sequential mixed-mode design. The invitation letter sent to the mixed-mode group stated that the survey could be completed via a paper questionnaire that would be mailed to them if they did not complete the web survey within

two weeks. Response rates were presented for three randomly allocated prepaid incentive groups ($0, $5, $10). Response rates in all three incentives groups were higher in the web-only design ($0: 16%; $5: 26%; $10: 30%) compared to the web-mail design ($0: 9%; $5: 16%; $10: 21%) (McGonagle and Freedman 2017), suggesting that mentioning the follow-up paper mode had a negative effect on the response rate and may have given the impression that individuals were free to choose between either mode, akin to a concurrent mixed-mode design, as opposed to being ”pushed” to the web mode.

The PSID additionally conducted a targeted invitation letter experiment in 2016 with panel members at least 30 years of age by assigning the whole sample to a sequential web-paper mixed-mode design. The experiment made use of two invitation letter variations. While the first variation (mentioning group) informed the individuals that a paper questionnaire would be sent in two weeks if they did not complete the web survey, the second invitation letter variation (hiding group) did not mention the paper follow-up stage. Panel members with a predicted web response probability greater than 70% were assigned to the hiding group, while individuals with a web response probability less than 30% were allocated to the mentioning group. Panel members with a predicted web response probability between 30% and 70% were randomly allocated to both invitation letter variations. Both invitation letter variations produced similar response rates for individuals with web response probability between 30% and 70% (hiding group: 68% vs. mentioning group: 71%; $p = 0.49$). For cases with the highest web response probability (> 70%), the hiding group invitation letter variation yielded a response rate of 78%. For cases with the lowest web response probability (< 30%), the mentioning group invitation letter variation yielded a response rate of 75% (Freedman et al. 2018).

4.2.3 Summary of Previous Findings and Research Gaps

Some conclusions can be drawn from the aforementioned literature on introducing a web-first phase in an interviewer-administered panel survey. First, the literature suggests that introducing a web-first phase in a traditional interviewer-administered panel survey does not always increase the response rate in the wave the web mode was introduced. Second, the literature suggests that introducing a web-first phase in a traditional interviewer-administered panel survey reduces survey costs (Lüdtke and Schupp 2017; Bianchi et al. 2017; Biemer et al. 2021b).

However, nearly all of these results are gathered from general population surveys and some of these studies used incentives. Further, not all of these studies tested for statistically significant differences between response rates. Thus, it is unclear if results from these studies can be transferred to other surveys, including employee surveys that do not use incentives. For instance, as previously mentioned, employees may be more likely to participate via web compared to the general population as they are busier during the day and may use internet-enabled devices during work hours. Thus, studies are needed to experimentally test the effects of introducing web in a telephone employee panel survey. Not only are effects on response rates important, but also nonresponse bias and whether certain employee subgroups (e.g., full-time workers, commuters) differ in their likelihood to participate via web and/or mixed-mode design, compared to single-mode interviewer-administration.

What is also unknown is the effect of mentioning the follow-up interviewer-administered mode in the invitation letter. Keeping in mind that all panel cases were originally recruited and responded at least once in the interviewer-administered mode, they may be more inclined to stand pat and wait for this mode to be offered if it is mentioned in the invitation letter, which may reduce the likelihood of taking up the web starting mode and negate the

intended effects of the "push-to-web" design. Given that one of the intended effects of a push-to-web design is to reduce costs, it is important to test whether mentioning the follow-up mode from the outset affects web survey participation.

4.3 Data and Methods

4.3.1 Study Design

A mode design experiment was carried out in the fourth wave of the German employer-employee panel survey, the Linked Personnel Panel (LPP). The first part of the LPP is a biennial employer survey (conducted by the survey institute Kantar) that started in 2012 and covers topics related to human resources and digitalization. The second part is an employee survey that started in 2013 and collects biennial data on topics related to employment and human resource issues, financial aspects, and physical and mental well-being. The employee sample is drawn from establishments that once participated in the LPP employer survey. All employee interviews of the first three waves (2013, 2015, 2017) were conducted via telephone by the Institute of Applied Social Sciences (infas). The LPP employee survey is representative of all employees subject to social insurance in Germany who work in private establishments with at least 50 employees excluding the agricultural, fishing, and forestry sectors. As our focus is on the employee survey, we use the term LPP to refer exclusively to the LPP employee survey.

To address issues of declining response and coverage (infas 2015; infas 2016; infas 2018), the LPP experimentally implemented a sequential mixed-mode design in its fourth wave (2019). A total of 5,118 panelists from 1,662 establishments were randomly allocated to either a telephone single-mode design or a sequential mixed-mode design with web starting mode and telephone follow-ups. Figure 1 shows the experimental design. At the first stage, the employee panel sample can be distinguished between employees whose survey

data can be linked to the LPP employer survey (n = 2,128) and those that cannot be linked (n = 2,990). Panel employees are classified as non-linkable if: 1) their employer did not respond to the previous wave employer survey, or 2) the employee did not consent to link their data to the employer survey in the previous wave (employers were not asked for linkage consent).

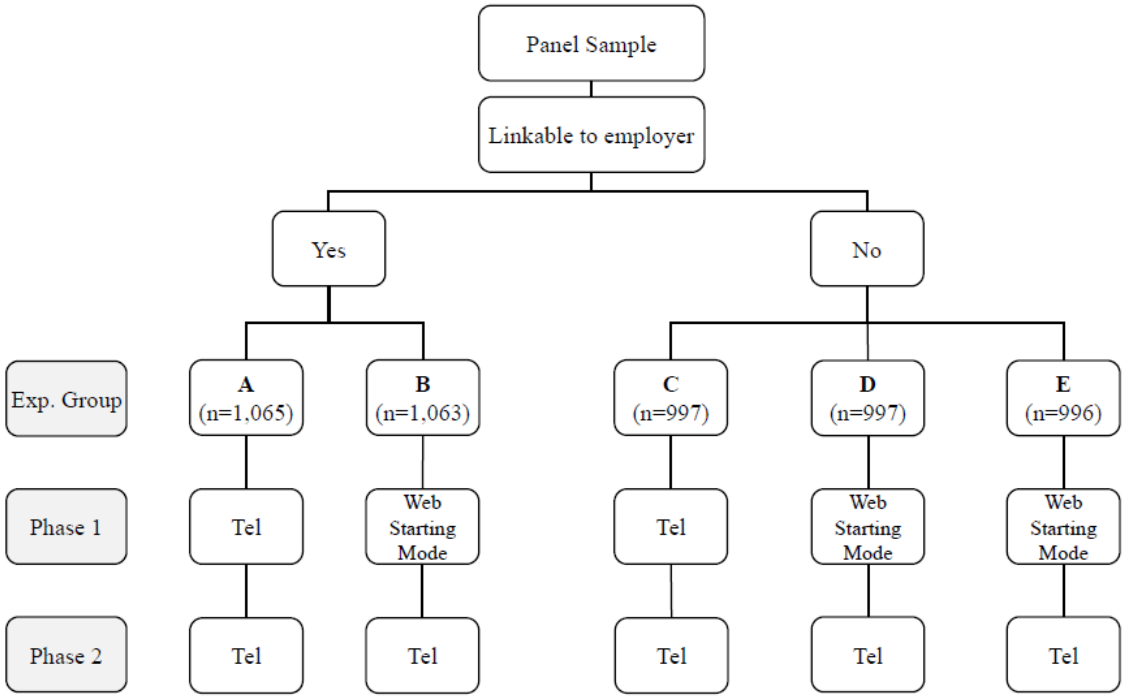


Figure 1. Diagram of The Mode Design Experiment
Note: The invitation letter sent to groups B and D did not mention planned telephone follow-ups, whereas the invitation letter sent to group E did mention the telephone follow-ups.

The mode design experiment was conducted separately for the linkable employees (randomly allocated into experimental groups A, B) and non-linkable employees (randomly allocated to experimental groups C, D, E) to control for possible differences between these two sets of employees. Employees were randomly allocated to either the sequential web-telephone mixed-mode design (groups B, D, E) or the conventional single-mode telephone design (groups A, C). Postal letters were mailed to the home addresses of the panel members on the 16th of April 2019. No email addresses were available. While the postal letter informed the single-mode groups about upcoming telephone calls, non-linkable members of the mixed-mode design (groups D, E) received one of two invitation

letter variations as part of an invitation letter experiment (sample size considerations prevented the same experiment from being implemented in the linkable mixed-mode group). Both invitation letter variations included a link and password for the web survey, but only the second variation (group E) mentioned that telephone contact attempts would start in three weeks if the online survey was not completed by then. There was no variation in the envelope design between the experimental groups nor did the envelope design differ from previous waves. No incentives were offered to panelists.

All mixed-mode groups that did not complete the survey using the web starting mode within the first two weeks were sent one reminder on the 30th of April 2019. The reminder mentioned that telephone follow-up contact attempts would start in one week if the web survey was not answered during that time. Completing the survey online was possible for the entire field period, even after the telephone follow-up phase started. Infas conducted on average 11.6 and 12.9 calls per panelist in the single-mode telephone design and the telephone follow-up stage of the mixed-mode design, respectively. The mean interview duration was shorter in the web starting mode (31.5 minutes) than in the telephone mode (37.4 minutes).

4.3.2 Data

To aid in evaluating the mode design experiment, including estimating nonresponse bias and determinants of survey participation, five external data sources are used. Table 1 provides an overview of the data sources, variables used, and variable coding and labeling.

The first data source consists of administrative data from the German Institute for Employment Research (IAB) (reference year 2019) available for all employees subject to the German social insurance system (Frodermann et al. 2021b). From these first administrative data source, three variable groups can be formed: demographics, employment, and benefits. The demographics variable group consists of sex, age (in years; <40, 40–55,

56+), German citizenship (yes, no), secondary education (less than university entrance qualification, university entrance qualification), and higher education (less than university degree, university degree). The employment variable group consists of employment contract (full-time, part-time), daily earnings (in Euros; <93, 93–141, 142+), occupation (production, business or administration, other), and years working for current employer (<10, 10–19, 20+). The benefits variable group comprises receipt of unemployment benefits at least once in the last 10 years (yes, no) and being registered as a job seeker with the German Federal Employment Agency (BA) at least once in the last 10 years (yes, no).

The second data source is the Community Directory (CD) of the German Federal Office of Statistics (reference year 2019), which includes geodata (e.g., mean longitude and latitude, population size) of each German municipality. The CD data are used to generate variables on urbanicity (number of inhabitants in the city of residence) and commuting distance to work. Commuting distance (fastest way by car between the geographic center of the employer's and employee's residence postal code) was calculated using the R-package `gmapsdistance`.

The third data source is the Broadband Atlas (BAT) (German Federal Ministry of Transport and Digital Infrastructure 2020) (reference year 2019) of the German Federal Ministry of Transport and Digital Infrastructure, which contains data about internet quality and speed at the postal code level. These data are used to generate the percentage of households within the employee's residential postal code that have access to fast internet speeds of at least 100 megabits per second. The CD and BAT data comprise the geodata variable group consisting of region (north, west, south, east), urbanicity (population count; <13,000, 13,000–119,999, 120,000+), commute (kilometers; <17, 17+), and fast internet (percent; <50, 50–100).

The fourth data source consists of LPP survey data collected from previous waves. We use the following variables: whether the employee teleworks (yes, no), level of general trust (low, high), household size (1, 2, 3+ person), the Big Five personality traits (the Big Five is a well-known taxonomy of personality groupings) (John et al. 1991; John and Srivastava 1999): extraversion, agreeableness, openness, conscientiousness, neuroticism (each coded low, medium, high), and employee linkage consent (yes, no).

The fifth data source is the LPP paradata collected during the third wave. These data include the variables: number of item nonresponse in wave 3 (0, 1–2, 3+), number of contact attempts in wave 3 (<4, 4–8, 9+), first wave of participation (wave 1, wave 2, wave 3), and employer linkage (yes, no) in wave 3. While the employer linkage variable is coded as yes if the employer participated in wave 3 (and no if not), the employee linkage consent is coded as yes if the employee gave linkage consent in wave 4 (and no if not). The correlation between the employer linkage consent and employee linkage consent is very low (correlation coefficient = 0.04), suggesting there is no risk of multicollinearity between these two outcomes.

Question wordings and response options (translated to English) for each survey variable (Table A1), information about coding and handling of missing values for each survey variable (Table A2), as well as descriptive statistics and distributions of each survey and administrative variable (Table A3) are available in the online appendix.

Table 1. Variables, Data Sources, and Variable Categories

Variables	Value labels
Demographics (source: IEB)	
Sex	Male, Female
Age	Years: <40, 40–55, 56+
German citizenship	Yes, No
Secondary education	Less than university entrance qualification, University entrance qualification
Higher education	Less than university degree, University degree
Employment (source: IEB)	
Employment contract	Full-time, Part-time
Daily earnings	Euros: <93, 93–141, 142+
Occupation	Production, Business/Administration, Other
Years working for employer	<10, 10–19, 20+
Benefits (source: IEB)	
Benefits last 10 years	Yes, No
Job seeking last 10 years	Yes, No
Geodata (Source CD, BA)	
Region	North, West, South, East
Urbanicity	Population: <13,000, 13,000–119,999, 120,000+
Commute	Kilometers: <17, 17+
Fast internet	% of households with 100 or more Mbit/s: <50, 50–100
LPP Survey	
Teleworking	Yes, No
General trust	Low, High
Household size	1, 2, 3+ Person
Big Five: Openness	Low, Medium, High
Big Five: Extraversion	Low, Medium, High
Big Five: Agreeableness	Low, Medium, High
Big Five: Conscientiousness	Low, Medium, High
Big Five: Neuroticism	Low, Medium, High
Employee linkage consent	Yes, No
LPP Paradata	
Contact attempts wave 3	<4, 4–8, 9+
First interview wave	Wave 1, Wave 2, Wave 3
Item nonresponse wave 3	0, 1–2, 3+
Employer linkage	Yes, No

All of these variables were selected based on their prior usage in methodological research on nonresponse, mode effects, and employee samples, as well as their potential interactions with the mode design on survey participation. Sociodemographic characteristics (e.g., age, gender and education) are commonly used to study panel attrition (Lugtig 2014;

Lynn et al. 2014; Müller and Castiglioni 2015; Stöckinger et al. 2018) and mode effects on nonresponse (Dillman et al. 2009; Kappelhof 2015; Felderer et al. 2019; Voorpostel et al. 2020). Employment characteristics are also used to study nonresponse and other errors of non-observation (Kreuter et al. 2010; Sakshaug and Eckman 2017a, 2017b; Büttner et al. 2021; Sakshaug et al. 2017, 2020).

Research has identified paradata (Pickery et al. 2001; Bristle et al. 2014; Bianchi and Biffignandi 2018) and Big Five personality traits (Lugtig 2014; Salthouse 2014; Hansson et al. 2018; Cheng et al. 2020) as predictors of panel attrition. These variables could also interact with the mode design indicator. For instance, difficult to reach employees requiring many telephone contact attempts in wave 3 could be more likely to participate via web compared to telephone. In addition, employees with high scores on the Big Five personality trait openness could also be more likely to participate via web compared to telephone, as these individuals are likely to adopt changes more quickly (i.e., introduction of new techniques like mobile telephones) (John et al. 1991; John and Srivastava 1999). We note that all administrative demographic, employment, and benefit variables are measured similarly in the LPP employee survey and thus serve as suitable proxies for estimating nonresponse bias.

4.4 Methodology

This chapter describes the methodology used to analyze the mode design experiment and invitation letter experiment. The key outcomes of interest are response rates, nonresponse bias, predictors of survey participation (including interactions with mode and mode design), and survey costs. This section describes how these outcomes were calculated.

All analyses of the mode (design) experiment are presented separately for the telephone single-mode design, the web starting mode (treating telephone follow-up respondents as

nonrespondents), and the full web-telephone sequential mixed-mode design. Note that the web starting mode is simply the first phase of the full web-telephone sequential mixed-mode design, with the telephone follow-ups conducted in the second phase. Decomposing both phases of the mixed-mode design allows for: 1) disentangling the effects of the web starting mode from the full mixed-mode sequence; and 2) performing single-mode comparisons between the web starting mode of the mixed-mode design and the telephone mode of the single-mode design.

Employees that answered every question are classified as respondents. As web interviews were possible during the entire field period, we classified employees who responded via the web starting mode after the telephone follow-up phase had started as web respondents in the forthcoming analysis. The appendix includes the final disposition codes for both mode designs (see Table A4).

As the main focus of this study is on randomization rather than representation and because nonresponse adjustment weights were not available for the experiment, all analyses are performed unweighted using Stata 16 (Stata Corp 2019) and R (R Core Team 2021).

4.4.1 Outcome Rate Calculations

Response rates are calculated using the AAPOR (2016) Response Rate 1 definition, which is the proportion of the fielded sample that completed the interview:

$$\text{Response Rate} = \frac{\text{Interviews}}{\text{Interviews} + \text{Noncontacts} + \text{Refusals}} \quad (1)$$

Contact and cooperation rates are also reported but only for the telephone-only design and the telephone follow-up stage of the mixed-mode design, as we have no definitive information about contacts and refusals for the web starting mode. The contact rate is calculated as the proportion of the fielded sample that was successfully contacted (target

person or household) and the cooperation rate is the proportion of successfully contacted employees who completed the interview:

$$\text{Contact Rate} = \frac{\text{Interviews} + \text{Refusals}}{\text{Interviews} + \text{Noncontacts} + \text{Refusals}} \tag{2}$$

$$\text{Cooperation Rate} = \frac{\text{Interviews}}{\text{Interviews} + \text{Refusals}} \tag{3}$$

4.4.2 Estimating Nonresponse Bias

Nonresponse bias is estimated for the following administrative variable groups: demographics, employment, benefits, and geodata. Estimates of nonresponse bias are constructed by calculating the difference between the proportion of a variable category (c) based on the respondents ($\bar{y}_{c,r}$) and the corresponding proportion based on the full sample ($\bar{y}_{c,s}$):

$$\text{Nonresponse Bias } (\bar{y}_c) = \bar{y}_{c,r} - \bar{y}_{c,s} \tag{4}$$

The absolute nonresponse is also reported which simplifies comparisons between different variable categories:

$$\text{Absolute Nonresponse Bias } (\bar{y}_c) = \left|\bar{y}_{c,r} - \bar{y}_{c,s}\right| \tag{5}$$

In addition, we report the absolute relative nonresponse bias, which assesses the magnitude of nonresponse bias in the survey estimate relative to the full sample estimate (Groves 2006):

$$\text{Absolute Relative Nonresponse Bias } (\bar{y}_c) = \left|\frac{\bar{y}_{c,r} - \bar{y}_{c,s}}{\bar{y}_{c,s}}\right| \tag{6}$$

As summary measures of nonresponse bias, we present the average absolute nonresponse bias (AANB) and the average absolute relative nonresponse bias (AARNB) by dividing the sum of the absolute (and absolute relative) nonresponse bias estimates by the number of total bias estimates computed across all variable categories (C):

$$\text{Average Absolute Nonresponse Bias} = \frac{\sum_{c=1}^{C} \left| \bar{y}_{c,r} - \bar{y}_{c,s} \right|}{C} \tag{7}$$

$$\text{Average Absolute Relative Nonresponse Bias} = \frac{\sum_{c=1}^{C} \left| \frac{\bar{y}_{c,r} - \bar{y}_{c,s}}{\bar{y}_{c,s}} \right|}{C} \tag{8}$$

These summary measures are calculated separately for each variable group and overall across all variables. These aggregate estimates are used to facilitate the comparisons between the different mode designs.

4.4.3 Modeling Survey Participation

Logistic regression models are used to examine predictors of survey participation, including the mode design indicator, all employee characteristics described in the data section, and interactions between both. The regression models are fitted separately for the single-mode comparisons (telephone-only vs. web starting mode) and mode design comparisons (telephone-only vs. web-telephone), where the single-mode comparison involving the web starting mode treats the telephone follow-up respondents as nonrespondents. Both a main effects model and an interactions model are fitted to test for mode (design) effects for specific subgroups and overall. All variables described in Section 4.3.2 are included as predictors of survey participation (0 = nonresponse, 1 = response) along with a mode (design) indicator variable (0 = telephone-only, 1 = web starting mode, mixed-mode). Multilevel models are used to account for employees nested within establishments. The regression model can be expressed as:

$$\log\left(\frac{p_{ij}}{1 - p_{ij}}\right) = \alpha + X_{ij}\beta + Z_{ij}\gamma + X_{ij}\, Z_{ij}\tau + \mu_j \tag{9}$$

where p_{ij} denotes the probability of participation for employee i nested within establishment j. The model intercept is denoted by α. The coefficient of the mode (design) indica-

tor X_{ij} is represented by β. γ refers to a vector of coefficients corresponding to the individual variables Z_{ij}, the interaction coefficients of the individual characteristics Z_{ij} and the mode (design) indicator X_{ij} are represented by the vector τ. The random effect term μ_j is normally distributed with mean 0 and variance σ_u^2.

4.4.4 Estimating Survey Costs

Survey costs are estimated per respondent for the telephone single-mode design, the web starting mode, and the full web-telephone mixed-mode design. Though the true costs are unknown, hypothetical (yet realistic) values informed by the survey institute are applied. The web starting mode comprises mainly postal communication costs, which are 0.95 Euro for one invitation letter and 0.80 Euro for one reminder letter (German Post 2021). Printing, enveloping, and letter handling are assumed to cost 0.05 Euro per letter. The telephone mode costs consist of the aforementioned postal communication costs plus interviewer expenses, including interviewer hourly payment (11.12 EUR) (Indeed 2021) and the incidental wage cost (27% of the gross earnings; German Federal Office of Statistics 2020b). Based on this information, the labor cost of one telephone interviewer per hour is approximately 14.12 EUR (= 11.12 EUR + (11.12 EUR x 0.27)). Assuming that one telephone contact attempt takes on average one minute, the cost of one completed telephone interview (by using the mean telephone interview duration of 37.4 minutes) and one contact attempt is as follows:

$$\text{Cost of telephone interview} = 14.12 * \frac{37.4}{60} = €8.8 \quad (10)$$

$$\text{Cost of telephone contact attempt} = 14.12 * \frac{1}{60} = €0.24 \quad (11)$$

We note that both survey modes (web starting mode and telephone) also include fixed costs (e.g., questionnaire programming) which are not accounted for in these cost calculations. As we have no realistic information about fixed costs our focus lies solely on the variable costs.

4.5 Results

Before we present the results of the experiment, we note that we did not find substantial differences between the linkable and non-linkable groups when analyzed separately. The separated results are available as tables in the appendix (outcome rates: A5 and A6; nonresponse bias: A7, A8, A9, and A10; participation effects: A11 and A12). Thus, all mode (design) analyses are based on the comparison of the combined single-mode telephone groups (A and C) vs. the combined sequential mixed-mode (web starting mode followed by telephone) groups (B, D, and E).

4.5.1 Effect of Mentioning Follow-Up Mode in Invitation Letter

The results of the invitation letter experiment conducted in mixed-mode design groups D (telephone follow-ups not mentioned) and E (telephone follow-ups mentioned) are shown in Table 2. In short, there are no significant differences between the two groups with respect to response rates in the web starting mode (Group D: 32.50%; Group E: 30.92%) or the full web-telephone sequence (Group D: 58.17%; Group E: 59.94%), or the contact (Group D: 86.87%; Group E: 86.93%) and cooperation rates (Group D: 46.63%; Group E: 50.52%) of the telephone follow-ups.

The same conclusions were drawn when stratifying the analysis by wave of joining the panel. Table A13 shows that the respondent compositions were also similar in both invitation letter groups. Given the lack of differences between the two invitation letter groups, we combine both groups in all subsequent analyses.

Table 2. Outcome Rates for Web Starting Mode and Full Web-Telephone Design, by Invitation Letter Version

	Experimental Group D (Telephone mode not mentioned)		**Experimental Group E (Telephone mode mentioned)**	
	Web starting mode	Web-Telephone	Web starting mode	Web-Telephone
Sample size	997	997	996	996
Respondents (total)	324	580	308	597
Telephone	0	256	0	289
Web	324	324	308	308
Response (%)	32.50	58.17	30.92	59.94
Contact (%)	N/A	86.87	N/A	86.93
Cooperation (%)	N/A	46.63	N/A	50.52

Notes: χ^2 tests were performed to compare the response, contact, and cooperation rates between experimental groups D and E. The response rates for the web starting mode in groups D and E did not significantly differ from each other ($\chi^2 = 0.57$; $p = 0.450$), and the same was true for the full mode sequences ($\chi^2 = 0.64$; $p = 0.423$). The contact rates ($\chi^2 = 0.00$; $p = 0.973$) and cooperation rates ($\chi^2 = 1.70$. $p = 0.192$) also did not significantly differ between the telephone follow-up stages of the mixed-mode design.

4.5.2 Outcome Rates

Table 3 shows the response, contact, and cooperation rates for the mixed-mode design (combined groups B, D, E) and the telephone-only design (combined groups A, C). There are three key results. First, the response rate of the web starting mode (32.46% including all login attempts that occurred before and after the telephone follow-up phase started) was significantly lower than the telephone-only design (50.10%), indicating that the web mode is an insufficient replacement for the conventional telephone single-mode design. However, implementing the full web-telephone sequence yielded a statistically significantly higher response rate (59.91%) compared to the single-mode telephone design. Second, the telephone contact rates for the web-telephone (87.51%) and telephone-only

(88.60%) designs were quite similar. Third, the telephone cooperation rate for the telephone-only design (56.54%) was higher than for the telephone follow-up stage of the mixed-mode design (48.47%), indicating that some employees with high willingness to participate already responded via the web starting mode. The same conclusions were drawn when stratifying the analysis by wave of joining the panel. In summary, we conclude that transitioning a telephone employee panel to a web-telephone sequential mixed-mode panel has a positive effect on response rates.

Table 3. Response Rates by Mode and Mode Design

	Single-Mode (Groups: A and C)	Mixed-Mode (Groups: B, D and E)	
	Telephone	Web	Web-Telephone
Sample size	2,062	3,056	3,056
Respondents	1,033	992	1,831
Telephone	1,033	0	839
Web	0	992	992
Response (%)	50.10	32.46	59.91
Tel. Contact (%)	88.60	N/A	87.51
Tel. Cooperation (%)	56.54	N/A	48.47

Notes: All employees (106 out of 992) who participated via web after at least one telephone follow-up contact attempt were classified as web respondents. Statistically significant response rate differences were evident between the telephone single-mode design and the web starting mode ($\chi^2 = 160.1586$; $p < 0.001$) and web-telephone design ($\chi^2 = 48.16$; $p < 0.001$). While telephone contact rate differences between the telephone single-mode and web-telephone designs were not evident ($\chi^2 = 1.14$; $p = 0.285$), telephone cooperation rates varied significantly between both designs ($\chi^2 = 23.23$; $p < 0.001$).

4.5.3 Nonresponse Bias

As a higher response rate decreases the risk of nonresponse bias (Groves 2006), one might assume that the web-telephone mixed-mode design yielded lower nonresponse bias, on average, than the telephone single-mode design. We now check this assumption by contrasting the mode designs on their average absolute nonresponse bias (AANB) and average absolute relative nonresponse bias (AARNB), overall and for each administrative variable group. The results, presented in Table 4, reveal two main findings. First, and unsurprisingly, aggregate nonresponse bias is higher in the web starting mode for each

variable group and overall (overall: AANB: 4.37%; AARNB: 16.70%) in comparison to the telephone single-mode design (overall: AANB: 1.72%; AARNB: 5.87%). Second, aggregate nonresponse bias is similar overall between the web-telephone design (overall; AANB: 1.70%; AARNB: 5.83%) and the telephone single-mode design. Differences between the mode designs for the individual variable groups are rather small. The AANB for the employment and benefits variable groups are slightly lower for the telephone single-mode design than for the web-telephone mixed-mode design, while the opposite is true for the demographic and geodata variable groups. Overall, we may conclude that the single- and mixed-mode designs yield comparable levels of aggregate nonresponse bias. Similar conclusions can be drawn from examining median nonresponse biases (Table A14).

Table 4. Average Absolute Nonresponse Bias (AANB) and Average Absolute Relative Nonresponse Bias (AARNB), by Variable Group and Overall

	Single-Mode (Groups A and C)		Mixed-Mode (Groups B, E and D)			
	Telephone		Web		Web-Telephone	
Variable group	AANB (%)	AARNB (%)	AANB (%)	AARNB (%)	AANB (%)	AARNB (%)
Demographics	2.37	8.71	4.93	24.58	1.99	7.53
Employment	1.54	4.32	4.99	15.61	1.78	5.41
Benefits	2.96	11.81	9.76	34.24	3.37	11.95
Geodata	1.11	4.06	2.04	7.88	1.02	3.62
Overall	1.72	5.87	4.37	16.70	1.70	5.83

Next, we examine nonresponse bias (NB), absolute nonresponse bias (ANB), and absolute relative nonresponse bias (ARNB) for specific variables between the mode (designs), presented in Table A15 of the appendix. The table reveals three main findings. First, the ANB is higher for 23 out of 28 administrative variables in the web starting mode compared to the telephone single-mode. The web starting mode yielded particularly higher ANB (than the telephone single-mode) for two categories (<93 Euros; 142+ Euros) of the

variable daily earnings and for individuals who were registered as job seekers in the past 10 years. In contrast, the ANB for full-time workers is a bit lower in the web starting mode compared to the telephone-only design. Second, introducing the telephone follow-up stage for web nonrespondents reduces the ANB (compared to the web-starting mode) for 24 out of 28 variable categories. The most substantial bias reduction can be seen for employees with university entrance degree as well as the lowest and highest daily earnings groups. This is contrasted by increasing nonresponse bias for 4 out of 28 variable categories with the largest increase for the middle earning category (93–141 Euros). Third, the web-telephone design yields a lower ANB for 14 out of 28 variable categories than the telephone single-mode. While the ANB for full-time work and employees with university degree is larger in the telephone single-mode (compared to the web-telephone design), the variable category of occupation (business/administration) and employees registered as job seeker in the past 10 years have, in contrast, a lower ANB in the telephone single-mode design than in the web-telephone design.

To recap, our results show that switching an employee telephone panel survey to a web-telephone design does not affect aggregate levels of nonresponse bias. However, for half of the variable categories (14 out of 28) the nonresponse bias is lower for the web-telephone mixed-mode design compared to the telephone single-mode design. While nonresponse bias estimates for demographic variables tended to be lower for the web-telephone mixed-mode design compared to the telephone single-mode design, the telephone single-mode produced lower nonresponse bias estimates (compared to the web-telephone mixed-mode design) on variables related to employment and benefits. For the geodata variables we did not observe a clear pattern.

4.5.4 Mode Effects on Survey Participation

In this section, we evaluate the likelihood of survey participation by mode (design) and its interaction with employee characteristics by presenting the multilevel modeling results. The results of the main effects and interaction effects models are presented separately for the telephone single-mode vs. web starting mode comparison and the telephone single-mode vs. web-telephone mixed-mode comparison.

4.5.5 Telephone-Only vs. Web Starting Mode

We start with the results of the telephone-only vs. web starting mode comparison, presented in Table 5. The most relevant finding of the main effects model (2nd column) is that employees assigned to the mixed-mode design are less likely to respond via the web starting mode than those assigned to the single-mode telephone design. The results of the interaction model (3rd column) reveal two significant results: employees with high conscientiousness scores are significantly more likely to participate via web than telephone, while past job seekers are more likely to respond via telephone compared to web. All other variables, including demographics, employment, geodata, and paradata do not interact with the mode indicator.

Table 5. Log-Odds Ratios of Survey Participation: Telephone Single-Mode vs. Web Starting Mode and Web-Telephone Mixed-Mode

	Telephone vs. Web Starting Mode		**Telephone vs. Web-Telephone**	
	Main effects model	Interaction model	Main effects model	Interaction model
	Estimate (SE)	Estimate (SE)	Estimate (SE)	Estimate (SE)
Intercept	0.04(.26)	0.68(.38)	0.62(.24)*	0.68(.38)
Experimental group (EG) (Ref. Telephone-Only)				
Web	-0.80(.06)***	-1.98(.52)***	0.41(.06)***	0.33(.50)
Sex (Ref. Male)				
Female	-0.04(.09)	0.09(.13)	0.02(.08)	0.09(.13)
Age (Ref. <40)				
40–55	0.33(.10)***	0.29(.14)*	0.26(.09)**	0.29(.14)*
56+	0.15(.10)	0.04(.16)	0.04(.10)	0.04(.16)
German citizenship (Ref. Yes)				
No	-0.39(.22)	-0.15(.30)	-0.08(.20)	-0.15(.30)
Secondary education (Ref. Less than university entrance)				
University entrance	0.31(.09)***	0.22(.14)	0.21(.09)*	0.22(.14)
Higher education (Ref. Less than university degree)				
University degree	0.20(.10)*	0.21(.16)	0.16(.10)	0.21(.16)
Employment contract (Ref. Part-time)				
Full-time	-0.17(.11)	-0.26(.17)	-0.15(.10)	-0.26(.17)
Daily earnings (Ref. <93)				
93–141	0.18(.08)*	0.05(.13)	0.02(.08)	0.05(.13)
142+	0.34(.10)***	0.24(.16)	0.23(.10)*	0.24(.16)
Occupation (Ref. Production)				
Business/Administration	0.07(.08)	-0.09(.13)	0.07(.08)	-0.09(.13)
Other	-0.03(.12)	0.01(.12)	0.04(.08)	0.01(.12)
Years working for employer (Ref. <10)				
10–19	-0.05(.09)	-0.17(.14)	-0.10(.09)	-0.17(.14)
20+	0.03(.10)	-0.07(.15)	-0.04(.10)	-0.07(.15)
Benefits last 10 years (Ref. No)				
Yes	-0.42(.11)***	-0.49(.16)**	-0.34(.10)***	-0.49(.16)**

Job seeking last 10 years				
(Ref. No)				
Yes	-0.03(.08)	0.16(.13)	0.03(.08)	0.16(.13)
Region				
(Ref. North)				
West	0.09(.10)	0.12(.15)	0.00(.09)	0.12(.15)
South	0.04(.10)	0.02(.15)	-0.06(.10)	0.02(.15)
East	-0.11(.11)	-0.12(.16)	-0.17(.10)	-0.12(.16)
Urbanicity				
(Ref. <13,000)				
13,000–119,999	0.01(.07)	0.04(.11)	0.06(.09)	0.04(.11)
120,000+	-0.05(.09)	-0.03(.14)	-0.01(.09)	-0.03(.14)
Commute				
(Ref. <17)				
17+	0.02(.09)	0.08(.10)	0.09(.06)	0.08(.10)
Fast internet				
(Ref. 50–100)				
<50	-0.10(.09)	-0.10(.14)	-0.05(.09)	-0.10(.14)
Teleworking				
(Ref. No)				
Yes	0.22(.08)**	0.07(.13)	0.11(.08)	0.07(.13)
General trust				
(Ref. Low				
High	0.06(.07)	-0.05(.10)	0.03(.06)	-0.05(.10)
Household size				
(Ref. 3+ Person)				
2 Person	0.05(.07)	-0.04(.11)	-0.15(.07)*	-0.04(.11)
Single	-0.04(.10)	-0.03(.15)	-0.14(.09)	-0.03(.15)
Openness				
(Ref. Low)				
Medium	0.11(.10)	0.01(.16)	-0.08(.10)	0.01(.16)
High	0.02(.12)	0.04(.18)	-0.07(.12)	0.04(.18)
Extraversion				
(Ref. Low)				
Medium	-0.25(.08)***	-0.18(.12)	-0.27(.08)***	-0.18(.12)
High	-0.27(.14)**	-0.16(.14)	-0.34(.09)***	-0.16(.14)
Agreeableness				
(Ref. Low)				
Medium	0.06(.09)	0.04(.14)	0.03(.09)	0.04(.14)
High	0.13(.09)	0.13(.14)	0.06(.09)	0.13(.14)
Conscientiousness				
(Ref. Low)				
Medium	-0.11(.11)	-0.32(.17)	-0.11(.11)	-0.32(.17)
High	-0.08(.10)	-0.29(.15)	-0.11(.10)	-0.29(.15)
Neuroticism				
(Ref. Low)				
Medium	-0.08(.07)	-0.06(.10)	-0.04(.07)	-0.06(.10)
High	0.03(.09)	0.02(.14)	0.05(.09)	0.02(.14)
Employee linkage consent				
(Ref. Yes)				
No	-0.28(.12)*	-0.42(.18)*	-0.33(.11)**	-0.42(.18)*
Item nonresponse wave 3				
(Ref. 0)				
1–2	-0.13(0.06)	-0.09(.10)	-0.11(.06)	-0.09(.10)
3	-0.23(.10)*	-0.22(.15)	-0.26(.10)**	-0.22(.15)
Contact attempts wave 3				
(Ref. <4)				

4–8	-0.19(.07**)	-0.29(.11)**	-0.23(.07)***	-0.29(.11)**
9+	-0.32(.08)***	-0.48(.12)***	-0.4(.08)***	-0.48(.12)***
First interview wave				
(Ref. Wave 1)				
Wave 2	-0.00(.08)	0.03(.12)	-0.01(.08)	0.03(.12)
Wave 3	-0.17(.08)*	-0.19(.12)	-0.27(.07)***	-0.19(.12)
Employer linkage				
(Ref. No)				
Yes	0.04(.06)	0.03(.10)	0.07(0.06)	0.03(.10)
Interactions	Estimate	Std. Error	Estimate	Std. Error
Sex x EG				
(Re. Male)				
Female		-0.21(.18)		-0.10(.17)
Age x EG				
(Ref. <40)				
40–55		0.08(.20)		-0.06(.19)
56+		0.18(.21)		-0.01(.20)
German citizen-ship x EG				
(Ref. Yes)				
No		-0.62(.47)		0.10(.40)
Secondary educa-tion x EG				
(Ref. Less than University en-trance)				
University en-trance		-0.16(.18)		-0.03(.18)
Higher education x EG				
(Ref. Less than University de-gree)				
University degree		0.02(.21)		-0.05(.21)
Employment con-tract x EG				
(Ref. Part-time)				
Full-time		0.14(.22)		0.19(.21)
Daily earnings x EG				
(Ref. <93)				
93–141		0.24(.18)		-0.06(.17)
142+		0.22(.21)		-0.00(.21)
Occupation x EG				
(Ref. Production)				
Business/Admin-istration		0.28(.17)		0.27(.17)
Other		-0.07(.16)		0.04(.16)
Years working for employer x EG				
(Ref. <10				
10–19		0.22(.19)		0.11(.18)
20+		0.20(.20)		0.05(.20)
Benefits last 10 years x EG				
(Ref. No)				
Yes		0.13(.22)		0.26(.20)
Job seeking last 10 years x EG				
(Ref. No)				

Yes	-0.34(.17)*	-0.22(.17)
Region x EG		
(Ref. North)		
West	-0.06(.20)	-0.19(.19)
South	-0.01(.20)	-0.14(.20)
East	-0.00(.21)	-0.08(.20)
Urbanicity x EG		
(Ref. <13,000)		
13,000–119,999	-0.06(.14)	0.03(.14)
120,000+	-0.02(.19)	0.03(.19)
Commute x EG		
(Ref. <17)		
17+	-0.10(.13)	0.02(.13)
Fast internet x EG		
(Ref. 50–100)		
<50	-0.01(.19)	0.08(.18)
Teleworking x EG		
(Ref. No)		
Yes	0.22(.17)	0.06(.17)
General trust x EG		
(Ref. Low		
High	0.21(.14)	0.12(.13)
Household size x EG		
(Ref. 3+ Person)		
2 Person	015(.14)	-0.18(.14)
Single	-0.07(.20)	-0.20(.19)
Openness x EG		
(Ref. Low)		
Medium	0.18(.21)	-0.15(.21)
High	-0.03(.25)	-0.19(.24)
Extraversion x EG		
(Ref. Low)		
Medium	-0.11(.16)	-0.15(.16)
High	-0.19(.19)	-0.33(.19)
Agreeableness x EG		
(Ref. Low)		
Medium	0.04(.18)	0.00(.18)
High	0.01(.19)	-0.12(.18)
Conscientiousness x EG		
(Ref. Low)		
Medium	0.39(.22)	0.36(.22)
High	0.40(.20)*	0.33(.20)
Neuroticism x EG		
(Ref. Low)		
Medium	-0.01(.14)	0.04(.13)
High	0.03(.19)	0.04(.18)
Employee linkage consent x EG		
(Ref. Yes)	0.25(0.24)	0.14(0.23)
No		
Item nonresponse wave 3 x EG		
(Ref. 0)		
1–2	-0.05(.13)	-0.03(.13)
3	-0.03(.21)	-0.05(.20)
Contact attempts wave 3 x EG		

(Ref. <4)				
4–8		0.15(.14)		0.09(.14)
9+		0.26(.16)		0.13(.16)
First interview wave x EG				
(Ref. Wave 1)				
Wave 2		-0.04(.16)		-0.06(.16)
Wave 3		0.04(.16)		-0.13(.16)
Employer linkage x EG				
(Ref. Yes)				
No		0.02(0.13)		0.08(0.13)
N	5,118	5,118	5,118	5,118
AIC	6471.4	6495.5	6804.8	6868.8
BIC	6772.3	7084.1	7105.6	7457.5
Wald-Test (x^2)	431.83	469.79	284.57	303.96
Wald-Test (p-value)	<0.00	<0.00	<0.00	<0.00
Random effect (establishment)	<0.00	<0.00	<0.00	<0.00
ICC (empty model)	0.04(.01)	0.04(.01)	0.02(.01)	0.02(.01)

Significance level: *** = 0.001, ** = 0.01, * = 0.05

4.5.6 Interaction Effects: Telephone vs. Web-Telephone

The results of the telephone single-mode vs. web-telephone mixed-mode comparison are presented next. The most important finding from the main effects model (Table 5, 4th column) is that assignment to the web-telephone mixed-mode design is associated with a significantly higher likelihood of survey participation compared to the telephone single-mode design. The interaction model (Table 5, 5th column) reveals no significant interactions between the mode design and employee characteristics. The nonexistence of interactions between the mode design and various employee characteristics is a key finding for survey practitioners, as it suggests that transitioning to a web-telephone sequential mixed-mode design does not alter the respondent composition in an ongoing employee panel survey.

4.5.7 Cost Comparison

The outcomes of the cost analysis (Table 6) reveal that the web-telephone mixed-mode design (€27,113.28) produces higher total costs than the telephone single-mode design (€16,359.72) and the web starting mode (€5,414.75). However, when looking at the costs

per respondent, a different picture emerges. The cost per respondent, calculated as the ratio of the total cost to the number of completed interviews, is lowest for the web starting mode (€5.46) followed by the web-telephone design (€14.81) and the telephone single-mode design (€15.85). Hence, the mixed-mode design yields a small potential cost savings (of about 7%) relative to the single-mode telephone design.

Table 6. Cost Analysis by Mode and Mode Design

	Single-Mode	Mixed-Mode	
	Telephone	Web	Web-Telephone
Invitation letters	€2,062	€3,056	€3,056
Reminder letters	0	€2,358.75	€2,358.75
Contact attempts	€4,193.63	0	€5,583.05
Interviews	€10,104.08	0	€16,115.49
Total costs	€16,359.72	€5,414.75	€27,113.28
Interviews (N)	1,032	992	1,831
Avg. cost per respondent	€15.85	€5.46	€14.81

4.6 Discussion

Telephone panel surveys are facing technical and societal changes that lead to rising survey costs and declining response rates. To compensate for this, some panel surveys have experimented with introducing online data collection. This paper reported on a mode (design) experiment conducted in the fourth wave of a German employee panel survey, where panel employees were randomly allocated to a telephone single-mode or a sequential mixed-mode design with web starting mode and telephone follow-ups. To our knowledge this is the first study that analyzed the effects of introducing a web starting mode in an ongoing telephone employee panel survey.

Our results can be summarized into five key findings. First, the different invitation letter variations (mentioning vs. not mentioning the telephone follow-ups) did not significantly affect response rates and respondent composition to the web starting mode or full mixed-

mode sequence, indicating that it makes no difference whether the interviewer-administered follow-up mode is disclosed in the web survey invitation letter. Second, introducing the sequential web-telephone design yielded a roughly 10-percentage point higher response rate compared to the traditional single-mode telephone design. Third, although aggregate nonresponse bias was higher in the web starting mode compared to the telephone single-mode design, following up the web nonrespondents with telephone reduced the aggregate nonresponse bias to a level that was comparable to the telephone single-mode design. The effect on the individual nonresponse bias estimates was split, with half of the estimates having a lower nonresponse bias in the telephone single-mode than in the web-telephone mixed-mode design, and the other half having a higher nonresponse bias in the telephone single-mode (compared to the web-telephone mixed-mode design). Fourth, only two employee subgroups were differentially affected by the web starting mode—employees with a high conscientiousness were significantly more likely to participate via the web starting mode, while past job seekers were less likely to respond via the web starting mode. None of the employee subgroups differed in their likelihood to participate in the web-telephone mixed-mode design or the telephone single-mode design. Finally, (estimated) per-respondent survey costs were about 7% lower in the web-telephone design compared to the telephone single-mode design, indicating a small potential cost savings of mixing modes.

We note that our results are in contrast to those reported in earlier mode (design) experiments conducted with general population samples, which found a higher response rate for the traditional interviewer-administered mode compared to the web-first mixed-mode design in the initial wave of the mode change (Jäckle et al. 2015; Lüdtke and Schupp 2017). The different results may be at least partially explained by the population under study. Employees (especially full-time workers and commuters) are a busy and hard-to-reach

group, who can benefit from the possibility of participating online independent of the time of day. However, we note that other study design features can also influence mode differences in other studies, such as the use of incentives, paper vs. email invitations, and the layout and wording of the invitations, among other features. Disentangling the effects of these specific design features in mode design experiments is a topic for future research. From a practical viewpoint, our results suggest that transitioning to a web-first mixed-mode design in the middle of a telephone employee panel can increase response rates and decrease survey costs with little to no effect on the recruitment of employee subgroups. The lack of subgroup effects suggests that there is little difference in which mode design is used. However, in an environment of declining response rates and increasing costs (Brick and Williams 2013; Czajka and Beyler 2016), the sequential web-telephone design may be preferred in ongoing employee panel surveys to address these concerns.

We acknowledge some limitations of the present study. First, the target population consisted of employees subject to social insurance in Germany excluding certain sectors (e.g., civil service, agricultural) and types of work (e.g., self-employed). Although we have no reason to believe the study conclusions would have changed without these exclusions, it would be prudent to replicate these findings with broader employee populations. Second, we examined the effects of transitioning to a mixed-mode design only for the initial wave of the transition to mixed-mode. An important topic for future research is to assess the long-term effects of the transition on nonresponse and attrition in subsequent waves of the LPP as the panel continues to mature. Another topic for future research is to study the measurement effects of mixing web and telephone modes (de Leeuw 2005). Such effects could affect panel analyses and estimates of change which may have consequences for substantive analyses (Cernat and Sakshaug 2021). Thus, any improvements in response

rates and costs should be weighed against the possible impacts of measurement mode effects.

In conclusion, we did not identify serious drawbacks of participation in the initial phase of the transition from a single-mode telephone design to a web-telephone sequential mixed-mode design in an ongoing employee panel survey, with some advantages in terms of response rates and costs. The current challenges faced by panel studies, such as declining participation and increasing survey costs, underscore the importance of researching alternative mode designs. While our results show promise in this regard, it is only a first step in evaluating the transition. More research is needed to identify the long-term impacts of introducing online and mixed-mode data collection on continuing survey participation and attrition, as well as consequences for measurement quality and panel data analyses, which are important points to be discussed with data users as part of the transition.

Appendix

Table A1. LPP Survey Questions used in the Mode (Design) Experiment

Variable	Question Text	Answer Categories
Teleworking	Do you work from home for your employer—even if only occasionally?	1: Yes 2: No
General trust	In general, one can trust people.	1: Fully applies 2: Largely applies 3: Neutral 4: Does rather not apply 5: Does not apply at all
Household size	How many people live in your household, children and yourself included?	Number: _____
Big Five categories	I see myself as someone who … A: does a thorough job B: is communicative, talkative C: is sometimes somewhat rude to others D: is original, comes up with new ideas E: worries a lot F: has a forgiving nature G: tends to be lazy H: is outgoing, sociable I: values artistic, aesthetic experiences J: gets nervous easily K: does things effectively and efficiently L: is reserved M: is considerate and kind to others N: has an active imagination O: is relaxed, handles stress well P: is eager for knowledge	1: Fully applies 2: Largely applies 3: Neutral 4: Does rather not apply 5: Does not apply at all
Employee linkage consent	To not have to query all your professional career information in the next interview again and not needlessly increase its length, we would like to include excerpts from other data in the analysis of the survey. These data are available at the Institute for Employment Research in Nuremberg. This is, for example, information about previous periods of employment. However, the inclusion of these data requires your agreement. For merging these data with the survey data, the Data Protection Law requires your agreement, for which I kindly ask you. When evaluating this information, it is certain that all data protection regulations are strictly adhered to. Of course, your agreement is voluntary. You can withdraw it at any time.	1: Yes, agreement granted 2: No, agreement not granted

Table A2. LPP Survey Questions Coding and Handling Information

Variable	**Information about coding and handling missing values**
Teleworking	The teleworking variable is sourced primarily from wave 3. If the teleworking variable is missing (n = 1) in wave 3, it is retrieved from either wave 2 or wave 1.
General trust	Due to limited usage of the low trust answer categories by respondents, the trust variable underwent recoding. Responses falling within the categories *neutral*, *does rather not apply*, and *does not apply at all* were recoded as low trust, while those response falling within the categories *fully applies* and *largely applies* were recoded as high trust. Additionally, one missing value in the general trust variable was imputed into the low trust category.
Household size	Missing values (n = 4) in the household variable, originally sourced from wave 3, were supplemented with responses from wave 2 and wave 1. Additionally, we modified the metric coding to three categories (household members; 1, 2, 3+) to assess nonresponse bias.
Big Five categories	The Big Five refer to a set of five personality traits: *Openness to Experience*, *Conscientiousness*, *Extraversion*, *Agreeableness*, and *Neuroticism*. This system was developed by psychologists (John et al. 1991; John and Srivastava 1999). Within the LPP survey, the Big Five traits are assessed using the BFI-S (Big Five Inventory-Short), which comprises up to four questions on a five-point scale (1 = *fully apply*; 5 = *does not apply at all*) for each trait (Gerlitz and Schupp 2005; Lang et al. 2011). The Big Five category scores were computed through a three-step process. First, missing values (each question contained between 1 and 23 missing values) were imputed using the R-package `mice`. The imputation models mirrored those utilized in the LPP weighting procedure (Mackeben et al. 2023). For example, if the third question pertaining to the Big Five trait *Openness* was missing, it was imputed using the first, second, and fourth questions on *Openness* as predictors. Second, all items were recoded to ensure consistency in directionality (some were negatively formulated while others were positively formulated). Third, the mean of the scores for relevant subdomains was calculated (John et al. 1991; Danner et al. 2019). All employees were categorized into one of three groups (low, medium, high) for each Big Five trait based on their scores on the respective scale. Notably, the distribution of responses varies across different questions within the Big Five. For example, many individuals may have high scores on *Openness* but low scores on *Neuroticism*. Consequently, unique classification criteria were developed for each trait. The categories were determined as follows: *Extraversion* (low: <10, medium: 10–12, high: 13+), *Agreeableness* (low: <11, medium: 11–12, high: 13+), *Openness* (low: <12, medium: 12–16, high: 17+), *Conscientiousness* (low: <12, medium: 12, high: 13+), and *Neuroticism* (low: <8, medium: 8–10, high: 11+).
Employee linkage consent	Responding to the employee linkage consent question is obligatory in the LPP employee survey. Based on their responses to the employee linkage consent question in wave 3 of the survey, employees were divided into two groups on the employee linkage consent variable: yes and no.

Table A3. Variable Distributions, by Mode and Mode Design

Administrative variable	Telephone-Only		Web-Telephone		
	Sample (%)	Resp. Tel. (%)	Sample (%)	Resp. Web (%)	Resp. Web-Tel. (%)
Demographics					
Sex					
Male	70.51	69.96	70.94	73.49	71.33
Female	29.49	30.04	29.06	26.51	28.67
Age					
<40	16.15	14.15	16.26	10.99	14.15
40–55	41.71	45.35	42.24	45.77	45.33
56+	42.14	40.50	41.49	43.25	40.52
German citizenship					
Yes	97.58	97.67	98.00	98.99	98.09
No	2.42	2.33	2.00	1.01	1.91
Secondary education					
Less than university entrance	62.03	57.27	62.93	51.71	58.87
University entrance	37.97	42.73	37.07	48.29	41.13
Higher education					
Less than university degree	77.55	73.55	76.05	66.83	72.86
University degree	22.45	26.45	23.95	33.17	27.14
Employment					
Employment contract					
Full-time	86.28	84.88	85.05	85.79	84.71
Part-time	13.72	15.12	14.95	14.21	15.29
Daily earnings					
<93	32.69	29.55	32.82	21.77	29.77
93–141	32.20	31.10	33.84	32.76	32.39
142+	35.11	39.34	33.34	45.46	37.85
Occupation					
Production	45.00	43.70	43.82	40.52	41.78
Business/Administration	30.31	31.59	30.20	37.00	32.66
Other	24.68	24.71	25.98	22.88	25.56
Years working for employer					
<10	24.64	23.55	23.79	17.94	22.01
10–19	36.81	36.43	38.35	38.81	38.61
20+	38.55	40.02	37.86	43.25	39.38
Benefits					
Benefits last 10 years					
No	79.78	83.33	78.34	87.10	81.49
Yes	20.22	16.67	21.66	12.90	18.51
Job seeking last 10 years					
No	61.11	63.47	61.62	72.38	65.21

Yes	38.89	36.53	38.38	27.62	34.79
Geodata					
Region					
North	14.26	14.34	14.95	14.21	15.46
West	29.63	30.23	28.53	31.05	28.89
South	30.41	32.85	31.28	35.38	32.99
East	25.70	22.58	25.23	19.35	22.67
Urbanicity					
<13,000	42.05	41.18	40.71	39.92	39.92
13,000–119,999	40.40	41.18	41.62	42.44	42.60
120,000+	17.56	17.64	17.67	17.64	17.48
Commute					
<17	55.72	54.55	55.73	53.93	54.12
17+	44.28	45.45	44.27	46.07	45.88
Fast internet					
<50	13.09	12.21	13.61	11.90	13.16
50–100	86.91	87.79	86.39	88.10	86.84
Survey data					
Teleworking					
No	79.10	76.45	78.30	69.76	75.59
Yes	20.90	23.55	21.70	30.24	24.41
General trust					
Low	32.49	31.98	34.13	28.43	32.22
High	67.51	68.02	65.87	71.57	67.78
Household size					
1	13.58	13.08	12.50	10.28	11.47
2	36.37	34.98	36.39	37.40	34.35
3+	50.05	51.94	51.11	52.32	54.18
Big Five: Extraversion					
Low	22.65	24.61	22.28	26.11	24.85
Medium	51.84	50.48	52.23	50.81	51.61
High	25.51	24.90	25.49	23.08	23.54
Big Five: Agreeableness					
Low	16.00	15.79	15.58	16.62	15.46
Medium	42.30	42.34	42.64	44.35	43.53
High	41.61	41.86	41.79	41.03	41.02
Big Five: Openness					
Low	9.99	9.98	9.75	8.87	10.38
Medium	67.60	67.54	69.08	72.48	69.31
High	22.41	22.48	21.17	18.65	20.32
Big Five: Conscientiousness					
Low	11.69	13.57	11.71	12.10	12.07
Medium	24.15	23.74	22.81	24.40	23.81
High	64.16	62.69	65.48	63.51	64.12

Big Five: Neuroticism					
Low	42.87	43.51	42.41	44.96	42.71
Medium	42.00	41.18	41.00	38.81	40.47
High	15.13	15.31	16.59	16.23	16.82
Employee linkage consent					
No	8.10	6.68	7.30	6.55	6.34
Yes	91.90	93.32	92.70	93.45	93.66
Paradata					
Contact attempts wave 3					
<4	41.61	45.74	43.19	45.16	45.33
4–8	35.21	33.62	34.59	33.67	33.97
<8	23.18	20.64	22.22	21.17	20.70
First interview wave					
Wave 1	40.49	37.89	37.96	33.47	34.52
Wave 2	33.32	33.72	33.48	33.06	33.59
Wave 3	26.19	28.39	28.57	33.47	31.90
Item nonresponse wave 3					
0	46.51	48.93	50.20	54.44	52.21
1–2	40.93	40.02	38.51	35.89	37.68
3+	12.56	11.05	11.29	9.68	10.10
Employer linkage wave 3					
No	48.35	48.31	65.22	63.71	64.28
Yes	51.65	51.69	34.78	36.29	35.72
N	2,062	1,032	3,056	992	1,831

Table A4. Final Disposition Codes, by Mode Design

Final Disposition Code	Mode-Design			
	Telephone-Only		Web-Telephone	
	Freq.	Percent	Freq.	Percent
Completed interview	1,033	50.10	1,831	59.91
Refusal				
Respondent-level				
Respondent refusal (T/C)	336	16.29	312	10.21
Language problem (T/C)	1	0.05	7	0.23
Broken appointment (T)	287	13.92	392	12.83
Partial Interview (T/W)	12	0.58	25	0.82
New invitation letter requested (T)	1	0.05	6	0.20
Out of the target group (e.g., retired) (T/W/C)	114	5.53	178	5.82
Household-level				
Household-level refusal (T)	25	1.21	30	0.98
Household level language problem (T)	11	0.53	16	0.52
Respondent deceased (T/C)	6	0.29	12	0.39
Respondent moved (T/C)	1	0.05		
Noncontact				
Always busy (T)	3	0.15		
No answer (T)	63	3.06	29	0.95
Invitation returned undelivered (T/W)	29	1.41	16	0.52
Fax data line (T)	3	0.15	5	0.16
Non-working number (T)	98	4.75	174	5.69
Wrong number (T)	29	1.41	19	0.62
Telephone answering device (T)	10	0.48	4	0.13
N	2,062	100	3,056	100

Notes: Most final disposition codes are available only for the telephone (T) mode. Three disposition codes are also available for the web (W) mode. Some sample units and household members contacted the survey institute or the IAB after they received the invitation letter or reminder (C). These employee contacts are assigned to the phase in which they occurred.

Table A5. Outcome Rates for Telephone-Single-Mode, Web Starting Mode and Full Web-Telephone Design, by Linkable Employees

	Single-Mode (Group A)	Mixed-Mode (Group B)	
	Telephone	Web	Web-Telephone
Sample size	1,065	1,063	1,063
Respondents	534	360	654
Telephone	534	0	294
Web	0	360	360
Response (%)	50.14	33.87	61.52
Contact (%)	88.45	N/A	88.70
Cooperation (%)	56.69	N/A	48.04

Notes: the response rates differ significantly (χ^2 tests: $p = 0.000$) between the telephone single-mode vs. web starting mode and the telephone single-mode vs. web-telephone mixed-mode design. While contact rate differences between the telephone single-mode and telephone follow-up stage of the mixed-mode design ($p = 0.875$) are not significant, the cooperation rate varies significantly between both designs ($p = 0.001$).

Table A6. Outcome Rates for Telephone-Single-Mode, Web Starting Mode and Full Web-Telephone Design, by Non-Linkable Employees

	Single-Mode (Group C)	Mixed-Mode (Group D and E)	
	Telephone	Web	Web-Telephone
Sample size	997	1,993	1,993
Respondents	499	360	1,177
Telephone	499	0	817
Web	0	360	360
Response (%)	50.05	31.71	59.06
Contact (%)	88.77	N/A	86.90
Cooperation (%)	56.69	N/A	48.04

Notes: the response rates differ significantly (χ^2 tests: $p = 0.000$) between the telephone single-mode vs. web starting mode and the telephone single-mode vs. web-telephone mixed-mode design. While contact rate differences between the telephone single-mode and telephone follow-up stage of the mixed-mode design ($p = 0.177$) are not significant, the cooperation rate varies significantly between both designs ($p = 0.001$).

Table A7. Average Absolute Nonresponse Bias (AANB) and Average Absolute Relative Nonresponse Bias (AARNB), by Variable Group and Overall (Linkable Employees)

	Single-Mode (Group A)		Mixed-Mode (Group B)			
	Telephone		Web		Web-Telephone	
Variable group	AANB (%)	AARNB (%)	AANB (%)	AARNB (%)	AANB (%)	AARNB (%)
Demographics	2.29	8.56	5.32	27.67	2.10	10.40
Employment	1.49	4.39	5.35	16.94	2.34	7.09
Benefits	2.10	9.99	7.08	35.45	3.00	15.63
Geodata	0.96	3.28	1.78	6.57	0.95	3.09
Overall	1.62	5.91	4.59	19.34	1.99	8.06

Table A8. Average Absolute Nonresponse Bias (AANB) and Average Absolute Relative Nonresponse Bias (AARNB), by Variable Group and Overall (Non-Linkable Employees)

	Single-Mode (Group C)		Mixed-Mode (Group D and E)			
	Telephone		Web		Web-Telephone	
Variable group	AANB (%)	AARNB (%)	AANB (%)	AARNB (%)	AANB (%)	AARNB (%)
Demographics	2.66	9.39	4.93	22.80	2.42	8.84
Employment	2.56	7.63	4.93	15.47	1.51	4.62
Benefits	2.43	12.07	7.08	27.80	2.12	7.77
Geodata	1.48	6.29	2.34	9.39	1.19	4.73
Overall	2.23	8.35	4.52	17.35	1.72	6.12

Table A9. Estimates of Nonresponse Bias (NB), Absolute Nonresponse Bias and Absolute Relative Nonresponse Bias (ARNB) for Each Variable Category (Linkable Employees)

Administrative variable	Single-Mode (Group A)		Mixed-Mode (Group B)			
	Telephone		Web		Web-Telephone	
	NB(ANB) (%)	ARNB (%)	NB(ANB) (%)	ARNB (%)	NB(ANB) (%)	ARNB (%)
Sex						
Female	-(0.54)	2.02	-(1.34)	5.20	-(0.09)	0.35
Age						
<40	-(2.11)	12.91	-(6.65)	40.62	-(3.07)	18.75
40–55	3.53	8.34	0.22	0.49	0.02	0.04
56+	-(1.42)	3.44	6.43	16.55	3.05	7.85
German citizenship						
No	-(0.10)	4.26	-(1.71)	60.64	-(0.53)	18.79
Secondary education						
University entrance	4.57	11.93	11.00	29.91	3.89	10.58
Higher education						
University degree	3.87	17.03	9.89	40.29	4.04	16.46
Employment contract						
Full-time	-(1.56)	1.77	0.20	0.23	-(0.63)	0.72
Daily earnings						
<93	-(3.16)	11.81	-(8.17)	32.89	-(2.82)	11.35
93–141	-(0.18)	0.57	-(3.40)	10.18	-(2.97)	8.89
142+	3.35	8.09	11.56	27.68	5.78	13.84
Occupation						
Production	0.43	0.91	-(5.67)	11.77	-(1.99)	4.13
Business/Administration	-(1.76)	6.42	7.61	26.70	2.69	9.44
Other	1.33	5.31	-(1.94)	8.32	-(0.70)	3.00
Years working for employer						
<10	-(0.44)	1.83	-(6.66)	29.25	-(2.28)	10.01
10–19	-(1.14)	2.98	-(0.83)	2.05	-(0.64)	1.58
20+	1.58	4.19	7.48	20.39	2.91	7.93
Benefits last 10 years						
Yes	-(2.77)	14.12	-(8.53)	46.74	-(3.72)	20.38
Job seeking last 10 years						
Yes	-(2.17)	5.53	-(11.00)	29.77	-(3.75)	10.20
Region						
North	0.52	3.26	-(1.80)	12.11	-(0.33)	2.22
West	1.60	5.36	3.04	9.94	0.93	3.04
South	0.20	0.72	1.27	4.14	0.37	1.21

East	-(2.32)	8.82	-(2.50)	10.46	-(0.95)	3.98
Urbanicity						
<13,000	-(0.78)	1.88	-(2.33)	5.58	-(1.71)	4.09
13,000–119.999	0.72	1.73	1.29	3.11	1.02	2.46
120,000+	0.04	0.24	1.03	6.15	0.68	4.06
Commute						
17+	2.13	4.93	2.50	6.04	2.49	6.02
Fast internet						
<50	0.34	2.55	-(0.22)	1.56	0.11	0.78

Table A10. Estimates of Nonresponse Bias (NB), Absolute Nonresponse Bias and Absolute Relative Nonresponse Bias (ARNB) for Each Variable Category (Non-Linkable Employees)

Administrative variable	**Single-Mode** (Group C)		**Mixed-Mode** (Group D and E)			
	Telephone		**Web**		**Web-Telephone**	
	NB(ANB) (%)	ARNB (%)	NB(ANB) (%)	ARNB (%)	NB(ANB) (%)	ARNB (%)
Sex						
Female	1.67	5.15	-(3.12)	10.13	-(0.48)	1.56
Age						
<40	-(1.72)	10.78	-(4.50)	27.76	-(1.60)	9.87
40–55	3.67	8.95	5.31	12.99	4.73	11.57
56+	-(1.95)	4.53	-(0.81)	1.89	-(3.14)	7.32
German citizenship						
No	-(0.11)	4.38	-(0.61)	39.10	0.14	8.97
Secondary education						
University entrance	5.08	13.51	11.35	30.49	4.15	11.15
Higher education						
University degree	4.08	18.40	8.81	37.28	2.71	11.47
Employment contract						
Full-time	-(1.18)	1.40	0.98	1.17	-(0.22)	0.26
Daily earnings						
<93	-(3.15)	8.07	-(12.4)	33.44	-(3.01)	8.12
93–141	-(2.14)	6.56	0.27	0.79	-(0.60)	1.76
142+	5.28	18.60	12.13	42.05	3.61	12.51
Occupation						
Production	-(3.65)	8.62	-(2.10)	5.06	-(2.16)	5.20
Business/Administration	5.08	15.21	6.39	20.54	2.36	7.59
Other	-(1.42)	5.85	-(4.30)	15.69	-(0.21)	0.77
Years working for employer						

<10	-(1.83)	7.24	-(5.35)	21.98	-(1.49)	6.12
10–19	0.36	1.02	1.11	2.99	0.71	1.91
20+	1.46	3.70	4.24	11.02	0.77	2.00
Benefits last 10 years						
Yes	-(4.23)	20.28	-(8.76)	37.31	-(2.75)	11.71
Job seeking last 10 years						
Yes	-(2.45)	6.36	-(10.60)	27.01	-(3.47)	8.84
Region						
North	-(0.42)	3.38	-(0.13)	0.87	0.97	6.47
West	3.28	10.58	4.73	14.94	2.15	6.79
South	1.18	3.75	3.14	11.46	0.30	1.09
East	-(4.04)	16.11	-(7.74)	29.84	-(3.43)	13.22
Urbanicity						
<13,000	-(1.05)	2.47	0.05	0.12	-(0.29)	0.72
13,000–119.999	0.96	2.45	0.55	1.32	0.95	2.28
120,000+	0.08	0.44	-(0.60)	3.30	-(0.66)	3.63
Commute						
17+	0.05	0.11	1.50	2.77	-(1.17)	2.16
Fast internet						
<50	-(2.22)	17.29	-(2.59)	19.40	-(0.78)	5.84

Table A11. Log-Odds Ratios of Survey Participation: Telephone Single-Mode vs. a) Web Starting Mode and b) Web-Telephone Mixed-Mode (Linkable Employees)

	Tel. vs. Web (Groups A vs. B)		**Tel. vs. Web-Tel.** (Groups A vs. B)	
	MEM Estimate (SE)	IM Estimate (SE)	MEM Estimate (SE)	IM Estimate (SE)
	Estimate (SE)	Estimate (SE)	Estimate (SE)	Estimate (SE)
Intercept	-0.09(.40)	0.71(.54)	0.59(.40)	0.71(.54)
Experimental group (EG)				
(Ref. Telephone-Only)				
Web	-0.75(.09)***	-2.66(.83)***	0.48(.09)***	0.18(.80)
Sex				
(Ref. Male)				
Female	-0.07(.14)	-0.02(.19)	0.01(.14)	-0.02(.19)
Age				
(Ref. <40)				
40–55	0.35(.15)*	0.31(.20)	0.24(.14)	0.31(.20)
56+	0.25(.16)	0.06(.22)	0.19(.15)	0.06(.22)
German citizenship				
(Ref. Yes)				
No	-0.49(.32)	-0.29(.43)	-0.27(.29)	-0.29(.43)
Secondary education				
(Ref. Less than university entrance)				
University entrance	0.28(.14)*	0.33(.19)	0.15(.14)	0.33(.19)
Higher education				
(Ref. Less than university degree)				
University degree	0.18(.16)	0.09(.22)	0.19(.16)	0.09(.22)
Employment contract				
(Ref. Part-time)				
Full-time	-0.31(.18)	-0.54(.25)*	-0.39(.18)*	-0.54(.25)*
Daily earnings				
(Ref. <93)				
93–141	0.22(.14)	0.21(.19)	0.11(.14)	0.21(.19)
142+	0.31(.16)	0.25(.22)	0.32(.16)*	0.25(.22)
Occupation				
(Ref. Production)				
Business/Administration +Other	-0.09(.13) 0.04(.12)	-0.46(.19)* 0.03(.17)	-0.16(.13) 0.01(.12)	-0.46(.19)* 0.03(.17)
Years working for employer				
(Ref. <10)				
10–19	-0.13(.14)	-0.34(.20)	-0.22(.14)	-0.34(.20)
20+	0.07(.16)	-0.14(.22)	-0.04(.15)	-0.14(.22)
Benefits last 10 years				
(Ref. No)				
Yes	-0.45(.16)**	-0.41(.22)	-0.45(.16)**	-0.41(.22)
Job seeking last 10 years				
(Ref. No)				
Yes	-0.03(.13)	0.08(.18)	0.06(.13)	0.08(.17)
Region				
(Ref. North)				
West	0.07(.15)	0.06(.20)	0.02(.14)	0.06(.20)
South	0.03(.15)	0.01(.21)	0.01(.15)	0.01(.21)
East	-0.01(.16)	-0.08(.22)	-0.01(.16)	-0.08(.22)
Urbanicity				
(Ref. <13,000)				
13,000–119,999	0.06(.11)	0.03(.15)	0.09(.11)	0.03(.15)

120,000+	0.07(.15)	-0.03(.20)	0.12(.14)	-0.03(.20)
Commute				
(Ref. <17)				
17+	0.10(.10)	0.18(.14)	0.18(.10)	0.18(.14)
Fast internet				
(Ref. 50–100)				
<50	0.14(.14)	0.13(.20)	0.14(.14)	0.13(.20)
Teleworking				
(Ref. No)				
Yes	0.37(.13)**	0.25(.18)	0.25(.13)	0.25(.18)
General trust				
(Ref. Low				
High	0.11(.10)	0.11(.14)	0.04(.10)	0.11(.14)
Household size				
(Ref. 3+ Person)				
2 Person	0.14(.11)	0.10(.15)	-0.03(.11)	0.10(.15)
Single	0.15(.16)	0.03(.22)	-0.04(.15)	0.03(.22)
Openness				
(Ref. Low)				
Medium	0.09(.16)	-0.06(.22)	-0.21(.16)	-0.06(.22)
High	0.16(.19)	0.13(.25)	-0.12(.18)	0.13(.25)
Extraversion				
(Ref. Low)				
Medium	-0.30(.12)**	-0.28(.17)	-0.28(.12)*	-0.28(.17)
High	-0.30(.14)*	-0.25(.20)	-0.43(.14)**	-0.25(.20)
Agreeableness				
(Ref. Low)				
Medium	0.09(.14)	0.24(.20)	0.23(.14)	0.24(.20)
High	0.20(.14)	0.39(.20)*	0.25(.14)	0.39(.20)*
Conscientiousness				
(Ref. Low)				
Medium	0.00(.17)	-0.24(.23)	-0.05(.17)	-0.24(.23)
High	-0.00(.15)	-0.26(.21)	-0.06(.15)	-0.26(.21)
Neuroticism				
(Ref. Low)				
Medium	-0.06(.10)	-0.09(.14)	-0.01(.10)	-0.09(.14)
High	0.10(.14)	0.01(.21)	0.01(.14)	0.01(.21)
Item nonresponse wave 3				
(Ref. 0)				
1–2	-0.10(.10)	-0.02(.14)	-0.04(.10)	-0.02(.14)
3	-0.41(.16)**	-0.35(.21)	-0.45(.15)**	-0.35(.21)
Contact attempts wave 3				
(Ref. <4)				
4–8	-0.19(.11)	-0.31(.15)	-0.26(.11)*	-0.31(.15)*
9+	-0.46(.12)***	-0.55(.17)**	-0.53(.12)***	-0.55(.17)**
First interview wave				
(Ref. Wave 1)				
Wave 2	-0.08(.13)	0.09(.18)	-0.08(.13)	0.09(.18)
Wave 3	-0.19(.12)	-0.25(.16)	-0.28(.11)*	-0.25(.16)
Interactions	Estimate	Std. Error	Estimate	Std. Error
Sex x EG				
(Re. Male)				
Female		-0.03(.29)		0.10(.28)
Age x EG				
(Ref. <40)				
40–55		0.12(.31)		-0.16(.29)
56+		0.49(.33)		0.33(.31)
German citizenship x EG				
(Ref. Yes)				
No		-0.54(.71)		0.11(.58)

Secondary education x EG		
(Ref. Less than University entrance)		
University entrance	-0.10(.29)	-0.39(.29)
Higher education x EG		
(Ref. Less than University degree)		
University degree	0.25(.32)	0.29(.32)
Employment contract x EG		
(Ref. Part-time)		
Full-time	0.43(.37)	0.27(.36)
Daily earnings x EG		
(Ref. <93)		
93–141	0.11(.29)	-0.19(.28)
142+	0.22(.33)	0.17(.32)
Occupation x EG		
(Ref. Production)		
Business/Administration	0.77(.26)**	0.66(.26)*
Other	-0.04(.25)	-0.11(.25)
Years working for employer x EG		
(Ref. <10		
10–19	0.48(.30)	0.23(.28)
20+	0.49(.33)	0.22(.31)
Benefits last 10 years x EG		
(Ref. No)		
Yes	-0.18(.35)	-0.06(.32)
Job seeking last 10 years x EG		
(Ref. No)		
Yes	-0.18(.26)	-0.02(.26)
Region x EG		
(Ref. North)		
West	0.01(.30)	-0.05(.30)
South	-0.02(.31)	0.02(.30)
East	0.06(.33)	0.13(.32)
Urbanicity x EG		
(Ref. <13,000)		
13,000–119,999	0.07(.22)	0.14(.22)
120,000+	0.24(.30)	0.34(.29)
Commute x EG		
(Ref. <17)		
17+	-0.13(0.20)	0.07(.20)
Fast internet x EG		
(Ref. 50–100)		
<50	-0.02(.29)	-0.03(.28)
Teleworking x EG		
(Ref. No)		
Yes	0.24(.26)	0.04(.27)
General trust x EG		
(Ref. Low		
High	0.00(.21)	-0.15(.20)
Household size x EG		
(Ref. 3+ Person)		
2 Person	0.02(.22)	-0.34(.22)
Single	0.18(.32)	-0.20(.31)
Openness x EG		
(Ref. Low)		

Medium		0.34(.33)		-0.35(.33)
High		0.10(.39)		-0.55(.38)
Extraversion x EG				
(Ref. Low)				
Medium		-0.05(.24)		-0.03(.24)
High		-0.16(.30)		-0.42(.29)
Agreeableness x EG				
(Ref. Low)				
Medium		-0.30(.29)		-0.04(.28)
High		-0.44(.29)		-0.34(.28)
Conscientiousness x EG				
(Ref. Low)				
Medium		0.55(.34)		0.46(.34)
High		0.66(.32)		0.51(.31)
Neuroticism x EG				
(Ref. Low)				
Medium		0.09(.21)		0.18(.21)
High		0.12(.29)		-0.01(.29)
Item nonresponse wave 3 x EG				
(Ref. 0)				
1–2		-0.09(.21)		0.02(.20)
3		-0.11(.33)		-0.22(.30)
Contact attempts wave 3 x EG				
(Ref. <4)				
4–8		0.25(.22)		0.12(.22)
9+		0.19(.25)		0.07(.25)
First interview wave x EG				
(Ref. Wave 1)				
Wave 2		-0.40(.27)		-0.35(.27)
Wave 3		0.11(.24)		-0.06(.23)
N	2,128	2,128	2,128	2,128
AIC	2776.793	2805.481	2846.729	2888.233
BIC	3025.962	3292.494	3095.898	3375.246
Wald-Test (x^2)	180.64	215.04	145.99	178.91
Wald-Test (p-value)	<0.00	<0.00	<0.00	<0.00
Random effect (establishment)	<0.00	<0.00	<0.00	<0.00
ICC (empty model)	0.02(.016)	0.02(.016)	0.02(.014)	0.02(.014)

Significance level: *** = 0.001, ** = 0.01, * = 0.05

Table A12. Log-Odds Ratios of Survey Participation: Telephone Single-Mode vs. a) Web Starting Mode and b) Web-Telephone Mixed-Mode (Non-Linkable Employees)

	Tel. vs. Web (Groups C vs. D, E)		**Tel. vs. Web-Tel.** (Groups C vs. D, E)	
	MEM Estimate (SE)	IM Estimate (SE)	MEM Estimate (SE)	IM Estimate (SE)
	Estimate (SE)	Estimate (SE)	Estimate (SE)	Estimate (SE)
Intercept	0.22(.34)	0.64(.55)	0.73(.32)*	0.64(.55)
Experimental group (EG)				
(Ref. Telephone-Only)				
Web	-0.83(.08)***	-1.57(.70)*	0.38(.08)***	0.48(.68)
Sex				
(Ref. Male)				
Female	-0.04(.11)	0.19(.18)	0.00(.11)	0.19(.18)
Age				
(Ref. <40)				
40–55	0.29(.13)*	0.25(.21)	0.26(.12)*	0.25(.21)
56+	0.05(.14)	0.06(.23)	-0.07(.13)	0.06(.23)
German citizenship				
(Ref. Yes)				
No	-0.30(.30)	-0.03(.43)	0.09(.29)	-0.03(.43)
Secondary education				
(Ref. Less than university entrance)				
University entrance	0.32(.12)**	0.19(.20)	0.24(.12)*	0.19(.20)
Higher education				
(Ref. Less than university degree)				
University degree	0.22(.13)	0.27(.23)	0.13(.13)	0.27(.23)
Employment contract				
(Ref. Part-time)				
Full-time	-0.08(.14)	0.06(.23)	-0.01(.13)	0.06(.23)
Daily earnings				
(Ref. <93)				
93–141	0.14(.11)	-0.15(.19)	-0.05(.11)	-0.15(.19)
142+	0.39(.14)**	0.22(.23)	0.17(.14)	0.22(.23)
Occupation				
(Ref. Production)				
Business/Administration	0.18(.11)	0.24(.19)	0.22(.11)*	0.24(.19)
Other	-0.06(.11)	-0.03(.18)	0.09(.10)	-0.03(.18)
Years working for employer				
(Ref. <10)				
10–19	0.03(.12)	0.02(.19)	0.00(.11)	0.02(.19)
20+	0.05(.13)	0.07(.22)	0.01(.13)	0.07(.22)
Benefits last 10 years				
(Ref. No)				
Yes	-0.39(.14)**	-0.60(.23)**	-0.27(.13)*	-0.60(.23)**
Job seeking last 10 years				
(Ref. No)				
Yes	-0.01(.12)	0.29(.19)	0.02(.11)	0.29(.19)
Region				
(Ref. North)				
West	0.08(.13)	0.19(.23)	-0.04(.13)	0.19(.23)
South	0.03(.13)	0.04(.23)	-0.14(.13)	0.04(.23)
East	-0.19(.14)	-0.18(.24)	-0.28(.13)*	-0.18(.24)
Urbanicity				
(Ref. <13,000)				
13,000–119,999	-0.02(.09)	0.03(.16)	0.04(.09)	0.03(.16)

120,000+	-0.13(.12)	-0.04(.21)	-0.11(.12)	-0.04(.21)
Commute				
(Ref. <17)				
17+	-0.02(.08)	0.01(.14)	0.04(.08)	0.01(.14)
Fast internet				
(Ref. 50–100)				
<50	-0.28(.13)	-0.34(.21)	-0.18(.12)	-0.34(.21)
Teleworking				
(Ref. No)				
Yes	0.09(.11)	-0.12(.19)	0.01(.11)	-0.12(.19)
General trust				
(Ref. Low				
High	0.02(.09)	-0.29(.15)	0.01(.08)	-0.29(.15)
Household size				
(Ref. 3+ Person)				
2 Person	-0.03(.09)	-0.23(.16)	-0.23(.09)**	-0.23(.16)
Single	-0.18(.13)	0.20(.21)	-0.22(.12)	-0.20(.21)
Openness				
(Ref. Low)				
Medium	0.11(.14)	0.07(.23)	-0.00(.13)	0.07(.23)
High	-0.11(.16)	-0.07(.27)	-0.06(.15)	-0.07(.27)
Extraversion				
(Ref. Low)				
Medium	-0.20(.11)	-0.03(.18)	-0.25(.10)*	-0.03(.18)
High	-0.23(.13)	0.02(.21)	-0.27(.12)*	0.02(.21)
Agreeableness				
(Ref. Low)				
Medium	0.05(.12)	-0.17(.20)	-0.11(.12)	-0.17(.20).
High	0.10(.12)	-0.19(.20)	-0.07(.12)	-0.19(.20)
Conscientiousness				
(Ref. Low)				
Medium	-0.20(.14)	-0.44(.25)	-0.15(.14)	-0.44(.25)
High	-0.14(.13)	-0.32(.22)	-0.14(.13)	-0.32(.22)
Neuroticism				
(Ref. Low)				
Medium	-0.09(.09)	-0.07(.15)	-0.06(.09)	-0.07(.15)
High	-0.04(.12)	-0.06(.20)	0.04(.12)	-0.06(.20)
Item nonresponse wave 3				
(Ref. 0)				
1–2	-0.13(.09)	-0.09(.15)	-0.16(.08)	-0.09(.15)
3	-0.13(.13)	-0.19(.21)	-0.15(.13)	-0.19(.21)
Contact attempts wave 3				
(Ref. <4				
4–8	-0.18(.09)	-0.22(.16)	-0.21(.09)*	-0.22(.16)
9+	-0.21(.10)*	-0.36(.17)*	-0.32(.10)**	-0.36(.17)*
First interview wave				
(Ref. Wave 1)				
Wave 2	0.03(.10)	-0.01(.16)	0.02(.09)	-0.01(.16)
Wave 3	-0.21(.11)	-0.22(.18)	-0.32(.10)***	-0.22(.18)
Interactions	Estimate	Std. Error	Estimate	Std. Error
Sex x EG				
(Re. Male)				
Female		-0.34(.23)		-0.25(.23)
Age x EG				
(Ref. <40)				
40–55		0.05(0.27)		0.02(.26)
56+		-0.04(.29)		-0.21(.28)
German citizenship x EG				
(Ref. Yes)				
No		-0.60(.64)		0.26(.59)

Secondary education x EG		
(Ref. Less than University entrance)		
University entrance	0.25(.25)	0.10(.25)
Higher education x EG		
(Ref. Less than University degree)		
University degree	-0.08(.29)	-0.21(.29)
Employment contract x EG		
(Ref. Part-time)		
Full-time	-0.19(.29)	-0.07(.28)
Daily earnings x EG		
(Ref. <93)		
93–141	0.46(.24)	0.16(.23)
142+	0.28(.30)	-0.06(.29)
Occupation x EG		
(Ref. Production)		
Business/Administration	-0.11(.23)	-0.06(.23)
Other	-0.06(.23)	0.16(.22)
Years working for employer x EG		
(Ref. <10)		
10–19	-0.01(.25)	-0.05(.24)
20+	-0.02(.27)	-0.09(.27)
Benefits last 10 years x EG		
(Ref. No)		
Yes	0.35(.29)	0.50(.28)
Job seeking last 10 years x EG		
(Ref. No)		
Yes	-0.50(.24)*	-0.41(.23)
Region x EG		
(Ref. North)		
West	-0.18(.28)	-0.34(.27)
South	-0.01(.28)	-0.27(.28)
East	-0.03(.30)	-0.16(.29)
Urbanicity x EG		
(Ref. <13,000)		
13,000–119,999	-0.09(.20)	-0.00(.19)
120,000+	-0.12(.26)	-0.11(.25)
Commute x EG		
(Ref. <17)		
17+	-0.05(.18)	0.04(.17)
Fast internet x EG		
(Ref. 50–100)		
<50	0.13(.27)	0.24(.26)
Teleworking x EG		
(Ref. No)		
Yes	0.28(.23)	0.17(.23)
General trust x EG		
(Ref. Low		
High	0.49(.19)***	0.44(.18)
Household size x EG		
(Ref. 3+ Person)		
2 Person	0.31(.20)	0.01(.20)
Single	-0.05(.27)	-0.04(.26)
Openness x EG		
(Ref. Low)		

Medium		0.10(.30)		-0.06(.29)
High		-0.01(.34)		0.06(.33)
Extraversion x EG				
(Ref. Low)				
Medium		-0.27(.22)		-0.32(.22)
High		-0.38(.26)		-0.45(.26)
Agreeableness x EG				
(Ref. Low)				
Medium		0.32(.25)		0.09(.24)
High		0.42(.26)		0.15(.25)
Conscientiousness x EG				
(Ref. Low)				
Medium		0.37(.31)		0.41(.30)
High		0.30(.28)		0.28(.27)
Neuroticism x EG				
(Ref. Low)				
Medium		-0.03(.19)		0.00(.18)
High		0.02(.26)		0,12(.25)
Item nonresponse wave 3 x EG				
(Ref. 0)				
1–2		-0.07(.18)		-0.09(.18)
3		0.08(.27)		0.08(.27)
Contact attempts wave 3 x EG				
(Ref. <4)				
4–8		0.03(.19)		0.01(.19)
9+		0.24(.22)		0,09(.21)
First interview wave x EG				
(Ref. Wave 1)				
Wave 2		0.08(.20)		0.05(.20)
Wave 3		0.01(.22)		-0.16(.22)
N	2,990	2,990	2,990	2,990
AIC	3745.28	3785.029	4003.557	4060.315
BIC	4009.413	4301.29	4267.691	4576.575
Wald-Test (x^2)	268.89	297.50	170.29	193.03
Wald-Test (p-value)	<0.00	<0.00	<0.00	<0.00
Random effect (establishment; SE)	<0.00	<0.00	<0.00	<0.00
ICC (empty model)	0.04(.017)	0.04(.017)	0.017(.014)	0.017(.014)

Significance level: *** = 0.001, ** = 0.01, * = 0.05

Table A13. Variable Distributions of the Advance Letter Experiment, by Mode and Mode Design

Administrative variable	Experimental Group D			Experimental Group E			χ^2 test (*p*-value)		
	Sample	Resp. Web	Resp. Web-Tel.	Sample	Resp. Web	Resp. Web-Tel.	Samples	Resp. Web	Resp. Web-Tel.
Demographics									
Sex									
Male	69.21	72.53	69.48	69.18	72.08	69.85	0.988	0.899	0.891
Female	30.79	27.47	30.52	30.82	27.92	30.15			
Age									
<40	15.15	12.35	15.17	17.27	11.04	14.07			
40–55	40.42	44.75	45.52	41.37	47.73	45.73	0.274	0.727	0.858
56+	44.43	42.90	39.31	41.37	41.23	40.20			
German citizenship									
Yes	98.19	99.07	97.93	98.69	99.03	98.66	0.367	0.950	0.333
No	1.81	0.93	2.07	1.31	0.97	1.34			
Secondary education									
Less than university entrance	61.79	50.31	57.41	63.76	52.60	59.80	0.363	0.565	0.406
University entrance	38.21	49.69	42.59	36.24	47.40	40.20			
Higher education									
Less than university degree	75.73	66.36	73.10	77.01	68.83	74.20	0.501	0.507	0.668
University degree	24.27	33.64	26.90	22.99	31.17	25.80			
Employment									
Employment contract									
Full-time	84.25	86.11	83.97	83.73	83.77	83.58	0.753	0.410	0.859
Part-time	15.75	13.89	16.03	16.27	16.23	16.42			
Daily earnings									
<93	37.11	25.00	33.79	37.05	24.35	34.34			
93–141	33.80	33.64	33.10	34.34	35.06	33.84	0.960	0.931	0.895
142+	29.09	41.36	33.10	28.61	40.58	31.83			
Occupation									
Production	41.42	42.59	39.31	41.57	36.04	39.36			
Business / Administration	30.39	34.88	32.41	31.83	40.26	34.51	0.675	0.219	0.643
Other	28.18	22.53	28.28	26.61	23.70	26.13			
Years working for employer									
<10	23.17	17.28	22.41	25.50	20.78	23.28	0.323	0.511	0.756

10–19	38.62	38.58	38.97	35.74	37.99	36.85			
20+	38.21	44.14	38.62	38.76	41.23	39.87			
Benefits									
Benefits last 10 years									
No	76.53	84.57	78.45	76.51	86.04	80.07	0.990	0.602	0.493
Yes	23.47	15.43	21.55	23.49	13.96	19.93			
Job seeking last 10 years									
No	61.08	69.44	62.93	60.44	73.38	65.49	0.769	0.274	0.359
Yes	38.92	30.56	37.07	39.56	26.62	34.51			
Geodata									
Region									
North	16.15	15.43	17.24	13.86	14.29	14.74			
West	26.18	28.09	26.72	28.61	33.12	28.64	0.294	0.502	0.584
South	32.50	36.73	34.31	30.82	36.04	33.33			
East	25.18	19.75	21.72	26.71	16.56	23.28			
Urbanicity									
<13,000	39.02	38.27	38.97	41.27	42.21	40.70			
13,000–119,999	42.63	43.83	43.10	40.76	40.58	42.21	0.582	0.593	0.819
120,000+	18.36	17.90	17.93	17.97	17.21	17.09			
Commute									
<17	52.46	50.31	50.34	55.92	55.19	55.61	0.120	0.219	0.070
17+	47.54	49.69	49.66	44.08	44.81	44.39			
Fast internet									
<50	13.64	12.04	13.62	13.05	9.42	11.56	0.699	0.288	0.286
50–100	86.36	87.96	86.38	86.95	90.58	88.44			
N	997	324	580	996	308	597			

Table A14. Median Absolute Nonresponse Bias (MANB) and Median Absolute Relative Nonresponse Bias (MARNB), by Variable Group and Overall

Variable Groups	**Single-Mode** (Groups A and C)		**Mixed-Mode** (Groups B, D and E)			
	Telephone		**Web Starting Mode**		**Web-Telephone**	
	MANB (%)	MARNB (%)	MANB (%)	MARNB (%)	MANB (%)	MARNB (%)
Demographics	2.00	8.73	3.53	30.27	2.11	7.32
Employment	1.29	3.61	4.35	13.08	1.65	4.47
Benefits	2.96	11.81	9.76	34.24	3.37	11.95
Geodata	0.87	2.07	1.71	4.95	0.79	3.31
Overall	1.23	3.85	3.20	12.25	1.57	4.39

Table A15. Estimates of Nonresponse Bias (NB), Absolute Nonresponse Bias and Absolute Relative Nonresponse Bias (ARNB) for Each Variable Category

Administrative variable	Single-Mode (Groups A and C)		Mixed-Mode (Groups B, D and E)			
	Telephone		Web		Web-Telephone	
	NB(ANB) (%)	ARNB (%)	NB(ANB) (%)	ARNB (%)	NB(ANB) (%)	ARNB (%)
Sex						
Female	(0.55)	1.87	-(2.55)	8.77	-(0.39)	1.34
Age						
<40	-(2.00)	12.38	-(5.27)	32.41	-(2.11)	12.98
40–54	(3.64)	8.73	(3.53)	8.36	(3.09)	7.32
56+	-(1.64)	3.89	(1.76)	4.24	-(0.97)	2.34
German citizenship						
No	-(0.09)	3.72	-(0.99)	49.50	-(0.09)	4.50
Secondary education						
University entrance	(4.76)	12.54	(11.22)	30.27	(4.06)	10.95
Higher education						
University degree	(4.00)	17.82	(9.22)	38.50	(3.19)	13.32
Employment contract						
Full-time	-(1.40)	1.62	(0.74)	0.87	-(0.34)	0.40
Daily earnings						
<93	-(3.14)	9.61	-(11.05)	33.67	-(3.05)	9.29
93–141	-(1.10)	3.42	-(1.08)	3.19	-(1.45)	4.28
142+	(4.23)	12.05	(12.12)	36.35	(4.51)	13.53
Occupation						
Production	-(1.30)	2.89	-(3.30)	7.53	-(2.04)	4.66
Business/Administration	(1.28)	4.22	(6.80)	22.52	(2.46)	8.15
Other	(0.03)	0.12	-(3.10)	11.93	-(0.42)	1.62
Years working for employer						
<10	-(1.09)	4.42	-(5.85)	24.59	-(1.78)	7.48
10–19	-(0.38)	1.03	(0.46)	1.20	(0.26)	0.68
20+	(1.47)	3.81	(5.39)	14.24	(1.52)	4.01
Benefits last 10 years						
Yes	-(3.55)	17.56	-(8.76)	40.44	-(3.15)	14.54
Job seeking last 10 years						
Yes	-(2.36)	6.07	-(10.76)	28.04	-(3.59)	9.35
Region						
North	(0.08)	0.56	-(0.74)	4.95	(0.51)	3.41
West	(0.60)	2.02	(2.52)	8.83	(0.36)	1.26
South	(2.44)	8.02	(4.10)	13.11	(1.71)	5.47
East	-(3.12)	12.14	-(5.88)	23.31	-(2.56)	10.15

Urbanicity						
<13,000	-(0.87)	2.07	-(0.79)	1.94	-(0.79)	1.94
13,000–119.999	(0.78)	1.93	(0.82)	1.97	(0.98)	2.35
120,000+	(0.08)	0.46	-(0.03)	0.17	-(0.19)	1.08
Commute						
17+	(1.17)	2.64	(1.80)	4.07	(1.61)	3.64
Fast internet						
<50	-(0.88)	6.72	-(1.71)	12.56	-(0.45)	3.31

References

Allum, N., Conrad, F., and Wenz, A. (2018), "Consequences of mid-stream mode-switching in a panel survey," *Survey Research Methods*, 12, 43–58.

American Association for Public Opinion Research (AAPOR; 2016), *Standard Definitions: Final Dispositions of Case Codes and Outcome Rates for Surveys* (9th ed.), AAPOR: Oakbrook Terrace, IL.

Beukenhorst, D. (2012), "The Netherlands," in *Telephone Surveys in Europe*, eds. S. Häder, M. Häder and M. Kühne, Heidelberg: Springer, pp.17–24.

Bianchi, A., and Biffignandi, S. (2018), "Social Indicators to Explain Response in Longitudinal Studies," *Social Indicators Research*, 141, 931–957.

Bianchi, A., Biffignandi, S., and Lynn, P. (2017), "Web-Face-to-Face Mixed-Mode Design in a Longitudinal Survey: Effects on Participation Rates, Sample Composition, and Costs," *Journal of Official Statistics*, 33, 385–408.

Biemer, P. P., Harris, K. M., Burke, B. J., Liao, D., and Halpern, C. T (2021a), "Transitioning a panel survey from in-person to predominantly web data collection: Results and lessons learned," *Journal of the Royal Statistical Society Series A: Statistics in Society*, 185, 798–821.

Biemer, P. P., Harris, K. M., Burke, B. J., Liao, D., and Halpern, C. T. (2021b), "Modeling mode effects for a panel survey in transition," in *Measurement Errors in Longitudinal Data*, eds. A. Cernat, J. W. Sakshaug, Oxford: University Press, pp. 63–87.

Brick, J. M., and Williams, D. (2013), "Explaining Rising Nonresponse Rates in Cross-Sectional Surveys," *Annals of the American Academy of Political Science*, 645, 36–59.

Bristle, J., Celidoni, M., Bianco, C.D., and Weber, G. (2014), "The contributions of para-data to panel co-operation in SHARE," *Share Working Paper Series (19-2014),* Munich: MEA, Max Planck Institute for Social Law and Social Policy.

Burton, J., Lynn, P., and Benzeval, M. (2020), "How Understanding Society: The UK Household Longitudinal Study adapted to the COVID-19 pandemic," *Survey Research Methods*, 14, 235–239.

Büttner, T. J., Sakshaug, J. W., and Vicari, B. (2021), "Evaluating the Utility of Linked Administrative Data for Nonresponse Bias Adjustment in a Piggyback Longitudinal Survey," *Journal of Official Statistics*, 37, 837–864.

Cernat, A., and Revilla, M. (2021), "Moving from Face-to-Face to a Web Panel: Impacts on Measurement Quality," *Journal of Survey Statistics and Methodology*, 9, 745–763.

Cernat, A., and Sakshaug, J. W. (2021), "Estimating the Measurement Effects of Mixed Modes in Longitudinal Studies: Current Practice and Issues," in *Advances in Longitudinal Survey Methodology*, ed. P. Lynn, Hoboken: John Wiley & Sons, pp. 227–249.

Cheng, A., Zamarro, G., and Orriens, B. (2020), "Personality as a Predictor of Unit Nonresponse in an Internet Panel," *Sociological Methods & Research*, 49, 672–698.

Czajka, J. L., and Beyler, A. (2016), *Declining Response Rates in Federal Surveys: Trends and Implications*, Washington, DC: Mathematica Policy Research.

Danner, D., Rammstedt, B., Bluemke, M., Lechner, C., Berres, S., Knopf, T., Soto, C. J., and John, O. P. (2019), "Das Big Five Inventar 2 Validierung eines Persönlichkeitsinventars zur Erfassung von 5 Persönlichkeitsdomänen und 15 Facetten," *Diagnostica*, 65, 121–132.

de Leeuw, E. D. (2005), "To Mix or Not to Mix Data Collection Modes in Surveys," *Journal of Official Statistics*, 21, 233–255.

de Leeuw, E. D. (2018), "Mixed-Mode: Past, Present, and Future," *Survey Research Methods*, 12, 75–89.

de Leeuw, E. D., and Lugtig, P. (2015), "Dropouts in Longitudinal Surveys," in Wiley *STATSREF: Statistics reference online*,1–6.

Dillman, D. A. (2017), *The promise and challenge of pushing respondents to the Web in mixed-mode surveys. Survey Methodology*, Statistics Canada, Catalogue No. 12-001-X, 43(1), available at https://www150.statcan.gc.ca/n1/en/pub/12-001-x/2017001/article/14836-eng.pdf?st=f2oBpwDP.

Dillman, D. A., Phelps, G., Tortora, R., Swift, K., Kohrell, J., Berck, J., and Messer, B. I. (2009), "Response rate and measurement differences in mixed-mode surveys using mail, telephone, interactive voice response (VCR) and the Internet," *Social Science Research*, 38, 1–18.

Eurostat (2019), *Labour Force Survey in the EU, candidate and EFTA countries: Main characteristics of national surveys 2018*, European Union, Luxembourg.

Eurostat (2020), *Level of internet access - households*, available at https://ec.europa.eu/eurostat/databrowser/view/tin00134/default/table?lang=en.

Eurostat (2022a), *Employment and Unemployment (LFS) – Overview*, available at https://ec.europa.eu/eurostat/web/lfs/overview.

Eurostat (2022b), *Internet use by individuals*, available at https://ec.europa.eu/eurostat/databrowser/view/tin00028/default/table?lang=en.

Felderer, B., Kirchner, A., and Kreuter, F. (2019), "The Effect of Survey Mode on Data Quality: Disentangling Nonresponse and Measurement Error Bias," *Journal of Official Statistics*, 35, 93–115.

Fernandez, S., Resh, W. G., Moldogaziev, T., and Oberfield, Z. W. (2015), "Assessing the Past and Promise of the Federal Employee Viewpoint Survey for Public Management Research: A Research Synthesis," *Public Administration Review*, 75, 382–394.

Freedman, V. A., McGonagle, K. A., and Couper, M. P. (2018), "Use of a Targeted Sequential Mixed Mode Protocol in a Nationally Representative Panel Study", *Journal of Survey Statistics and Methodology*, 6, 98–121.

Frodermann, C., Grunau, P., Hass, G. C., and Müller, D. (2021a),"Homeoffice in Zeiten von Corona: Nutzung, Hindernisse und Zukunftswünsche," *IAB-Kurzbericht*, 5/2021, Nuremberg.

Frodermann, C., Schmucker, A., Seth, S., and vom Berge, P. (2021b), *Sample of Integrated Labour Market Standard Biographies (SIAB) 1975-2019*, Research Data Centre (FDZ), FDZ-Datenreport, 01/2021 (en), Nuremberg.

Gaia, A. (2016), *The Effect of a Switch to a Mixed-Mode Design on Panel Attrition: Evidence from an Experiment of the Understanding Society Innovation Panel*, 5th Panel Survey Methods Workshop. Berlin.

Gerlitz, J. Y., and Schupp, J. (2005), "Zur Erhebung der Big-Five-basierten Persönlichkeitsmerkmale im SOEP (The measurement of the Big Five personality traits in the SOEP)," *Working paper*, DIW, Berlin: DIW.

German Federal Ministry of Transport and Digital Infrastructure (2020), *Bericht zum Breitbandatlas. Teil 1: Ergebnisse*, available at https://bmdv.bund.de/SharedDocs/DE/Anlage/DG/Digitales/bericht-zum-breitbandatlas-mitte-2020-ergebnisse.pdf?__blob=publicationFile.

German Federal Office of Statistics (2020a), *Die Neuregelung des Mikrozensus ab 2020*, available at https://www.destatis.de/DE/Themen/Gesellschaft-Umwelt/Bevoelkerung/Haushalte-Familien/Methoden/mikrozensus-2020.html.

German Federal Office of Statistics (2020b), *Arbeitskosten in der EU 2019: Deutschland an siebter Stelle*, available at https://www.destatis.de/DE/Presse/Pressemitteilungen/2020/04/PD20_142_624.html.

German Federal Office of Statistics (2021), *Wirtschaftsrechnungen: Laufende Wirtschaftsrechnungen: Ausstattung privater Haushalte mit ausgewählten Gebrauchsgütern*, Fachserie 15 (Reihe 2).

German Post (2021), *Addressfactory*, available at https://www.deutschepost.de/en/d/deutsche-post-direkt/addressfactory.html.

Groves, R. M. (2006), "Nonresponse Rates and Nonresponse Bias in Household Surveys," *Public Opinion Quarterly*, 70, 646–675.

Gummer, T., Schmiedeberg, C., Bujard, M., Christmann, P., Hank, K., Kunz, T., Lück, D., and Neyer. F. J. (2020), "The impact of COVID-19 on fieldwork efforts and planning in pairfam and FReDA-GGS," *Survey Research Methods*, 14, 223–227.

Haas, G. C., Müller, B., Osiander, C., Schmidtke, J., Trahms, A., Volkert, M., and Zins, S. (2021), "Development of a new COVID-19 panel survey: the IAB high-frequency online personal panel (HOPP)," *Journal for Labour Market Research*, 55, 1–14.

Hansson, I., Berg, A. I., and Thorvaldsson, V. (2018), "Can personality predict longitudinal study attrition? Evidence from a population-based sample of older adults," *Journal of Research in Personality*, 77, 133–136.

Haunberger, S. (2011), *Teilnahmeverweigerung in Panelstudien*, Wiesbaden: VS Verlag für Sozialwissenschaften.

Huber, M., and Schmucker A. (2012), "Panel Well. Arbeitnehmerbefragung für das Projekt Berufliche Weiterbildung als Bestandteil Lebenslangen Lernens," Research Data Centre, *FDZ-Datenreport*, 03/2012 (de), Nürnberg.

Indeed (2021), *Gehälter pro Stunde bei infas*, available at https://de.indeed.com/cmp/Infas-Institut-F%C3%BCr-Angewandte-Sozialwissenschaft-Gmbh/salaries.

infas (2015), *IAB-Beschäftigtenbefragung: Projekt Arbeitsqualität und wirtschaftlicher Erfolg: Panelstudie zu Entwicklungsverläufen in deutschen Betrieben – Personenbefragung*, Research Data Centre (FDZ), FDZ-Methodenreport, 02/2015 (de), Nuremberg.

infas (2016), *IAB-Beschäftigtenbefragung: Projekt Arbeitsqualität und wirtschaftlicher Erfolg: Panelstudie zu Entwicklungsverläufen in deutschen Betrieben – Personenbefragung, 2. Erhebungswelle*, Research Data Centre (FDZ), FDZ-Methodenreport, 02/2016 (de), Nuremberg.

infas (2018), *IAB-Beschäftigtenbefragung: Projekt Arbeitsqualität und wirtschaftlicher Erfolg: Panelstudie zu Entwicklungsverläufen in deutschen Betrieben – Personenbefragung, 3. Erhebungswelle*, Research Data Centre (FDZ), FDZ-Methodenreport, 11/2018 (de), Nuremberg.

infas (2020), "SOEP FiD – Familien in Deutschland 2013: Methodenbericht," *SOEP Survey Papers*, 906 (Series B).

Institute for Social Research (2022), *Panel Study of Income Dynamics*, available at https://psidonline.isr.umich.edu/Guide/default.aspx.

Jäckle, A., Lynn, P., and Burton, J. (2015), "Going Online with a Face-to-Face Household Panel: Effects of a Mixed Mode Design on Item and Unit Non-Response," *Survey Research Methods*, 9, 57–70.

John, O. P., Donahue, E. M., and Kentle, R. L. (1991), *Big Five Inventory (BFI)*, available at https://psycnet.apa.org/doiLanding?doi=10.1037%2Ft07550-000.

John, O. P., and Srivastava, S. (1999), "The Big Five Trait Taxonomy: History, Measurement, and Theoretical Perspectives," in *Handbook of Personality: Theory and research*, eds. L.A. Pervin and O. P. John, pp. 102–138, New York: Guilford Press.

Kantar (2017), *UK Household Longitudinal Study: Wave 7 technical report*. Kantar Public: London.

Kappelhof, J. W. S. (2015), "Face-to-Face or Sequential Mixed-Mode Surveys Among Non-Western Minorities in the Netherlands: The Effect of Different Survey Designs on the Possibility of Nonresponse Bias," *Journal of Official Statistics*, 31, 1–30.

Kennedy, C., and Hartig, H. (2019), *Response rates in telephone surveys have resumed their decline*, available at https://www.pewresearch.org/short-reads/2019/02/27/response-rates-in-telephone-surveys-have-resumed-their-decline/.

Kreuter, F., Müller, G., and Trappmann, M. (2010), "Nonresponse and Measurement Error in Employment Research: Making Use of Administrative Data," *Public Opinion Quarterly*, 74, 880–906.

Lang, F. R., John, D., Lüdtke, O., Schupp, J., Wagner, G. G. (2011), "Short assessment of the big five: robust across survey methods except telephone interviewing," *Behavior Research Methods*, 43, 548–567.

Lugtig, P., Das, J., and Scherpenzeel, A. (2014), "Nonresponse and attrition in a probability-based online panel for the general population," in *Online Panel Research: A Data Quality Perspective*, eds. M. Callegaro, R. P. Baker, J. Bethlehem, A. S. Goeritz, J. A. Krosnick and P. J. Lavrakas, pp. 135-153, Colchester: John Wiley & Sons.

Lugtig, P. (2014), “Panel Attrition: Separating Stayers, Fast Attriters, Gradual Attriters, and Lurkers,” *Sociological Methods & Research*, 43, 699–723.

Lüdtke, D., and Schupp, J. (2017), “Wechsel von persönlichen Interviews zu webbasierten Interviews in einem laufenden Haushaltspanel,” in *Methodische Probleme von Mixed-Mode-Ansätzen in der Umfrageforschung*, eds. S. Eifler and F. Faulbaum, Wiesbaden: Springer, pp. 141–160.

Lynn, P., Kaminska, O., and Goldstein, H. (2014), “Panel Attrition: How Important is Interviewer Continuity?,” *Journal of Official Statistics*, 30, 443–457.

Mackeben, J., Ruf, K., Wolter, S., and Grunau, P. (2023), LPP survey data linked with administrative data of the IAB (LPP-ADIAB) 1975–2021, FDZ-Datenreport, 11/2023 (en), Nuremberg.

Mackeben, J., Ruf, K., and Grunau, P. (2020), “Arbeitsqualität und wirtschaftlicher Erfolg: Betriebsbefragung 5. Welle,” *Zweiter Sachstandsbericht*.

McGonagle, K. A., and Freedman, V. A. (2017), “The Effects of a Delayed Incentive on Response Rates, Response Mode, Data Quality, and Sample Bias in a Nationally Representative Mixed Mode Study,” *Field Methods*, 29, 221–237.

Müller, B., and Castiglioni, L. (2015), “Attrition im Beziehungs- und Familienpanel pairfam,” in *Nonresponse Bias*, eds. J. Schupp and C. Wolf, pp. 383–408.

Müller, B., and Castiglioni, L. (2020), “Do Temporary Dropouts Improve the Composition of Panel Data? An Analysis of “Gap Interviews” in the German Family Panel pairfam,” *Sociological Methods & Research*, 49, 193–215.

Olson, K., Smyth, J. D., Horwitz, R., Keeter, S., Lesser, V., Marken, S., Mathiowetz, N. A., McCarthy, J. S., O’Brien, E., Opsomer, J. D., Steiger, D., Sterrett, D., Su, J.,

Suzer-Gurtekin, Z. T., Turakhia, C., and Wagner, J. (2021), "Transitions from Telephone Surveys to Self-Administered and Mixed-Mode Surveys: AAPOR Task Force Report," *Journal of Survey Statistics and Methodology*, 9, 381–411.

Pickery, J. A., Loosveldt, G., and Carton, A. N. (2001), "The Effects of Interviewer and Respondent Characteristics on Response Behavior in Panel Surveys," *Sociological Methods & Research*, 29, 509–523.

R Core Team (2021), *R: A language and environment for statistical computing*, available at https://www.r-project.org/.

Sakshaug, J. W., Beste, J., Coban, M., Fendel, T., Haas, G.-C., Hülle, S., Kosyakova, Y., König, C., Kreuter, F., Küfner, B., Müller, B., Osiander, C., Schwanhäuser, S., Stephan, G., Valliazdeh, E., Volkert, M., Wenzig, C., Westermeier, C., Zabel., Cordula., and Zins, S. (2020), "Impacts of the COVID-19 Pandemic on Labor Market Surveys at the German Institute for Employment Research," *Survey Research Methods*, 14, 229–233.

Sakshaug, J. W., and Eckman, S. (2017a), "Are Survey Nonrespondents Willing to Provide Consent to Use Administrative Records? Evidence from a Nonresponse Follow-Up Survey in Germany," *Public Opinion Quarterly*, 81, 495–522.

Sakshaug, J. W., and Eckman, S. (2017b), "Following Up with Nonrespondents via Mode Switch and Shortened Questionnaire in an Economic Survey: Evaluating Nonresponse Bias, Measurement Error Bias, and Total Bias," *Journal of Survey Statistics and Methodology*, 5, 454–479.

Sakshaug, J. W., and Huber, M. (2016), "An Evaluation of Panel Nonresponse and Linkage Consent Bias in a Survey of Employees in Germany," *Journal of Survey Statistics and Methodology*, 4, 71–93.

Sakshaug, J. W., Hülle, S., Schmucker, A., and Liebig, S. (2017), "Exploring the Effects of Interviewer- and Self-Administered Survey Modes on Record Linkage Consent Rates and Bias," *Survey Research Methods*, 11, 171–188.

Sakshaug, J. W., Hülle, S., Schmucker, A., and Liebig, S. (2020), "Panel Survey Recruitment with or Without Interviewers? Implications for Nonresponse, Panel Consent, and Total Recruitment Bias," *Journal of Survey Statistics and Methodology*, 8, 540–565.

Salthouse, T. A. (2014), "Selectivity of attrition in longitudinal studies of cognitive functioning," *Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, 69, 567–574.

Sastry, N., McGonagle, K., and Fomby, P. (2020), "Effects of the COVID-19 crisis on survey fieldwork: Experience and lessons from two major supplements to the U.S. Panel Study of Income Dynamics," *Survey Research Methods*, 14, 241–245.

Schupp, J. (2012), "Das Sozio-oekonomische Panel (SOEP)," *Bundesgesundheitsblatt – Gesundheitsforschung – Gesundheitsschutz*, 55, 767–774.

Stähli, M. E. (2012), "Switzerland," in Telephone Surveys in Europe, eds. S. Häder, M. Häder and M. Kühne, Berlin: Springer, pp 25–36.

Stata Corp. (2019), "Stata Statistical Software: Release 16," College Station, TX: Stata Corp LLC.

Statistics Canada (2017), *Methodology of the Canadian Labour Force Survey*. Catalogue no. 71-526-X, Ottawa.

Stöckinger, C., Kretschmer, S., and Kleinert, C. (2018), "Panel Attrition in NEPS Starting Cohort 6: A Description of Attrition Processes in Waves 2 to 7 with Regard to Nonresponse Bias," *NEPS Survey Paper*, 35.

Tillmann, R., Voorpostel, M., Antal, E., Kuhn, U., Lebert, F., Ryser, V. A., Lipps, O., and Wernli B. (2016), "The Swiss Household Panel Study: Observing social change since 1999," *Longitudinal and Life Course Studies*, 7, 64–78.

Toepoel, V. (2012), "Building Your Own Online Panel Via E-Mail and Other Digital Media," in *Handbook of Survey Methodology in Social Sciences*, ed. L. Gideon, New York: Springer, pp. 345–360.

Tourangeau, R. (2017), "Mixing Models: Tradeoffs Among Coverage, Nonresponse, and Measurement Error," in *Total Survey Error in Practice*, eds. P. P. Biemer, E. de Leeuw, S. Eckman, B. Edwards, F. Kreuter, L. E. Lyberg, N. C. Tucke and B. T. West, Hoboken: John Wiley & Sons, pp. 115–132.

UK Office for National Statistics (2022), *Labour Force Survey: Background and Methodology*, available at https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/employmentandemployeetypes/methodologies/labourforcesurveyuserguidance.

Voorpostel, M., Kuhn, U., Tillmann, R., Monsch, G. A., Antal, E., Ryser, V. A., Lebert, F., Klaas, H. S., and Dasoki, N. (2020), "Introducing web in a refreshment sample of the Swiss Household Panel: Main findings from a pilot study," FORS Working Paper Series No. paper 2020-2, Lausanne: FORS.

Voorpostel, M., Lipps, O., and Roberts, C. (2021), "Mixing Modes in Household Panel Surveys: Recent Developments and New Findings," in: *Advances in Longitudinal Survey Methodology*, ed. P. Lynn, Hoboken: John Wily & Sons, pp. 204–226.

World Bank (2021a), *Fixed telephone subscriptions (per 100 people)*, available at https://databank.worldbank.org/reports.aspx?source=2&series=IT.MLT.MAIN.P2.

World Bank (2021b), *Fixed broadband subscriptions (per 100 people)*, available at https://databank.worldbank.org/source/jobs/Series/IT.NET.BBND.P2#.

5 Going Online with a Telephone Employee Survey: Effects on Coverage, Nonresponse, and Total Selection Bias

Abstract

Telephone surveys have historically been a popular form of data collection in labor market research and continue to be used to this day. Yet, telephone surveys are confronted with many challenges, including imperfect coverage of the target population, low response rates, and rising data collection costs. To address these challenges, many telephone surveys have shifted to online and mixed-mode data collection to reduce costs and minimize the risk of coverage and nonresponse biases. However, empirical evaluations of the intended effects of introducing online and mixed-mode data collection in ongoing telephone surveys are lacking. We address this research gap by analyzing a telephone employee survey in Germany, the Linked Personnel Panel (LPP), which experimentally introduced a sequential web-to-telephone mixed-mode design in the fourth and fifth waves of the panel. By utilizing administrative data available for sampled individuals with and without known telephone numbers, we estimate the before-and-after effects of introducing the web mode on coverage and nonresponse rates and biases. We show that the LPP was affected by known telephone number coverage bias for various employee subgroups prior to introducing the web mode, though many of these biases were partially offset by nonresponse bias. Introducing the web-to-telephone design improved the response rate but increased total selection bias, on average, compared to the standard telephone single-mode design. This result was driven by larger nonresponse bias in the web-to-telephone design and partial offsetting of coverage and nonresponse biases in the telephone single-mode design. Significant cost savings (up to 50% per respondent) were evident in the web-to-telephone design.

5.1 Introduction

Labor market surveys focused on employed persons are essential for understanding workplace dynamics, improving labor conditions, and guiding policy decisions. These surveys collect data on various aspects, including employee demographics, wages, job satisfaction, benefits, career development, and work-life balance. This wealth of information empowers policymakers to forge effective labor regulations, aids organizations in optimizing employee engagement and well-being, and furnishes researchers with invaluable insights into evolving trends (German Federal Ministry of Labour and Social Affairs 2019; Statistics Denmark 2023). Despite substantial sociological and technological transitions in telephone usage patterns and contactability (Kempf and Remington 2007; Mohorko et al. 2013; Degryse 2016; Lovergine and Pellero 2018), many labor market surveys are conducted solely by telephone. Examples include the Swedish, Norwegian, and Swiss labor force surveys (Eurostat 2022) as well as the German Digitalization and Change in Employment Survey (DiWaBe) (Arntz et al. 2020) and the BIBB/BAuA Employment Survey conducted by the German Federal Institute for Vocational Education Training (BIBB) and the German Federal Institute for Occupational Safety and Health (BAuA) (Hall et al. 2020). However, like other interviewer-administered surveys, telephone surveys are hampered by low and declining response rates (Brick and Williams 2013; Czajka and Beyler 2016; Luiten et al. 2020), imperfect coverage of the target population (Kempf and Remington 2007; Lipps et al. 2015; Häder and Sand 2019), and rising survey costs (Couper 2017; Olson 2021; Olson et al. 2021a).

Introducing online or mixed-mode data collection in ongoing telephone labor market surveys offers the potential to address each of these challenges (Tourangeau et al. 2013; Couper 2017; Dillman 2017; de Leeuw 2018). First, utilizing an online mode addresses

the issue of coverage by allowing sampled households with unknown (or unlisted) telephone numbers to be included in the fielded sample. Known telephone number noncoverage is a particularly relevant concern in Europe, where it is common to draw address-based samples from population registers and match them to public telephone directories and commercial telephone lists, as opposed to implementing random-digit dialing (Lavrakas 2010). However, due to declining proportions of telephone number registrations, which are no longer mandatory, there is a growing risk of undercoverage due to unknown telephone number status (Lipps et al. 2015; Häder and Sand 2019). Second, labor market surveys are likely to benefit from inviting respondents to participate online as an alternative to telephone, as it provides employees the possibility of participating at their own convenience and from any location with internet access, including their workplace, thus potentially increasing the likelihood of participation and, in turn, response rates. Lastly, introducing online data collection in an ongoing telephone survey offers potential cost savings if a significant proportion of respondents use the online mode instead of the more expensive telephone mode (Berzelak et al. 2015; Dillman 2017; Sastry and McGonagle 2022).

However, the intended effects of introducing an online mode on coverage and nonresponse in an otherwise single-mode telephone employment survey have not been experimentally evaluated. We address this research gap by analyzing a mode design experiment embedded within a telephone employee panel survey in Germany—the Linked Personnel Panel (LPP). To reduce costs and address decreasing rates of known telephone number coverage, the LPP experimentally introduced a sequential web-to-telephone mixed-mode design in the fourth and fifth waves of the panel. Using extensive administrative data available for respondents and nonrespondents and those with and without known telephone numbers, we address the following research questions:

1. To what extent has the known telephone number coverage rate changed over the first five waves (8 years) of the LPP survey?
2. Are specific employee subgroups more (or less) likely to have a known telephone number? Have these subgroup coverage patterns changed over time?
3. How large are known telephone number coverage biases in the first three waves of the LPP survey, i.e., before introducing the web mode?
4. What is the magnitude of total selection bias (noncoverage and nonresponse bias) in the first three waves of the LPP, i.e., before introducing the web mode? Do coverage and nonresponse biases offset or reinforce each other?
5. Does total selection bias differ between a single-mode telephone and a sequential web-to-telephone mixed-mode design? Is there a trade-off between coverage and nonresponse rates and bias?
6. What is the impact of introducing the web mode on survey costs and potential cost savings?

Addressing these research questions will inform researchers on the implications of shifting away from telephone-only to online and mixed-mode data collection for employed populations from both a cost and error perspective. By examining multiple sources of selection bias (namely, coverage and nonresponse) over multiple rounds of data collection, researchers will come away with a better understanding of how these error sources have evolved over the last decade, their joint impact on total selection bias, and how they are affected before and after introducing the online mode. Such knowledge is crucial for identifying potential coverage and nonresponse disparities and trade-offs, and will provide survey practitioners and data users with a nuanced understanding of the accessibility

of different subgroups and their likelihood of being covered and participating under different mode designs. From a cost perspective, this research will inform survey planners the extent to which potential savings can be realized by shifting from telephone to online and mixed-mode data collection. While many studies have made claims about cost savings of shifting to online data collection, the present study provides estimated cost differentials that will inform researchers on the extent to which these claims hold and provide an empirical basis for evaluating the cost implications of shifting mode designs in their own surveys.

5.2 Background

5.2.1 Known Telephone Number Coverage

Telephone surveys became a prominent data collection method in the 1980s due to high landline coverage and low survey costs compared to face-to-face surveys (Häder et al. 2012; Couper 2017; Dillman 2017). Telephone surveys in Europe have been traditionally conducted by merging population register samples to public (mainly landline) telephone directories. This contrasts with telephone surveys in the US, which often use random-digit dialing (RDD) (Lavrakas 2010).

However, two major developments produced coverage challenges for European telephone surveys. First, the obligation to register every telephone number ended in 1992 for many European countries (Beukenhorst 2012; Kuusela and Simpanen 2012; Stähli 2012). Since then, the amount of listed telephone numbers has continuously declined, with Germany, for example, seeing a decrease from 28.6 million in 2005 to 16.7 million in 2016 (Häder and Sand 2019). This has led to a growing proportion of units with unknown telephone number in register-based samples and has also resulted in heightened survey costs due to the necessity of conducting additional telephone number research (Lipps et al. 2015; Dal

Grande et al. 2016). Second, the worldwide transition from landline to mobile telephone adoption (Lavrakas et al. 2017; Worldbank 2023a, b) represented another challenge for telephone surveys as mobile numbers are mostly unknown and rarely listed in public telephone directories (Kempf and Remington 2007). In Germany, the share of households with (at least) one landline telephone decreased from 95.1% in 2004 to 84.3% in 2021 (German Federal Office of Statistics 2004, 2021). In the US, the trend is even more pronounced with the share of adults living in households with landline access declining from 93.6% to 20.1% over the same period (Blumberg and Luke 2008, 2022). In contrast, the share of households in the US and Germany with at least one mobile telephone has increased to almost 100% since its market introduction in the 1990s (German Federal Office of Statistics 2021; Blumberg and Luke 2022).

The declining share of registered (landline and mobile) telephone numbers that can be matched to register-based samples calls into question the issue of coverage bias in telephone surveys. This issue has drawn some attention in the literature. For example, Gordoni et al. (2011) merged a random sample of individuals (n = 6,405) from the Israeli population register to a public telephone directory using name and postal address. Altogether, 77.9% of individuals could be merged to a telephone number (landline, mobile, or both). Differences between merged and non-merged individuals were rather small and mostly insignificant, suggesting no strong evidence of coverage bias due to known telephone number status.

Joye et al. (2012) analyzed landline telephone coverage in Switzerland by using the fourth round of the European Values Survey (EVS). The survey was conducted face-to-face and included a question on landline registration in public telephone directories. Differences

in sociodemographic and substantive characteristics between listed and non-listed landline owners were small, indicating no significant coverage bias due to listed telephone number status.

Sala and Lillini (2017) analyzed listed (landline) telephone number coverage bias using the Italian Everyday Living Survey, a cross-sectional face-to-face survey that included questions on landline registration in official telephone directories. The authors found significant differences on sociodemographic and substantive characteristics between listed and unlisted landline owners. For instance, unlisted landline owners were significantly less likely to be 45 and older and to be retired, and more likely to live in single-person households and to report better health conditions than listed landline owners.

Lipps et al. (2015) matched the Swiss Electoral Study 2011 sample to telephone numbers by using different matching procedures. In the initial step, 5,530 out of 8,162 individuals were matched to a listed telephone number by the Swiss Federal Statistical Office (SFSO). In a second step, 1,338 out of 2,632 non-matched cases could be merged to a telephone number using various methods, such as commercial matching software and marketing databases. In a third step, a postcard request was addressed to the remaining 1,294 unmatched cases, with an additional 124 employees providing a telephone number. The authors showed that both additional steps (commercial searches and postcard request) contributed to a reduction in coverage bias.

Our study builds on these previous studies by exploring changes in coverage rates over time to capture trends and variations in known telephone number status. Further, we utilize objective measures of known telephone number status, as opposed to relying on respondent self-reports. Furthermore, we extend the analysis beyond sociodemographic characteristics by incorporating a wide range of substantive administrative variables.

5.2.2 Nonresponse in Telephone Surveys

In addition to known telephone number coverage, telephone surveys have also experienced declining response rates over the last decades (Brick and Williams 2013; Czajka and Beyler 2016; Luiten et al. 2020; Dutwin and Buskirk 2021). To address this challenge, survey practitioners have employed methods such as offering incentives, reducing questionnaire length, and increasing contact attempts (Groves et al. 2009). Despite these methods, response rates in large telephone surveys are still declining for both landline (2008: 16%, 2015: 9%) and mobile (2008: 12%, 2015: 7%) samples, as evidenced from 15 survey research institutes in the USA, spanning years 2007 to 2015 (Dutwin and Lavrakas 2016). In line with this trend, the Pew Research Center, a US survey research organization, reported a decline in their telephone response rates from an average of 36% in 1997 to 6% in 2018 (Kennedy and Hartig 2019). These nonresponse and coverage issues, combined with rising survey costs, have led to a declining share of telephone-only surveys (compared to other survey modes) (Olson et al. 2021b; ADM 2023), raising concerns about the future of this survey mode.

A consequence of declining response rates is the increased risk of nonresponse bias in telephone survey estimates when respondents differ systematically from nonrespondents on key variables (Groves 2006). Previous empirical research has found evidence of nonresponse bias in single-mode telephone surveys. For example, younger individuals are often underrepresented (Dennis et al. 2005; Kreuter et al. 2010; Lugtig et al. 2011; Lipps et al. 2015) as are individuals with lower levels of education (Dennis et al. 2005; Dillman et al. 2009; Lugtig et al. 2011), inhabitants of large cities (Lipps and Pekari 2016), nonmarried individuals (Lugtig et al. 2011; Lipps and Pekari 2016), persons living alone (Dillman et al. 2009), and employed persons (Kreuter et al. 2010; Lugtig et al. 2011). However, very little is known about the relative contribution of both nonresponse bias

and known number coverage bias in telephone surveys, whether they offset or reinforce each other, and their joint impact on total selection bias—issues we explore in the present study.

5.2.3 Effects of Introducing Web in Telephone Surveys

While known telephone number coverage has declined in Europe, the share of households with internet access has constantly risen. For example, from 2010 to 2021, the internet penetration rate in the Netherlands, Spain, and Belgium increased from 80%, 56%, and 70% to 99%, 96%, and 92%, respectively (Eurostat 2023). Some sociodemographic subgroups tend to be more likely to have home internet access than others, including employed persons (German Federal Office of Statistics 2021; US Census Bureau 2022). Hence, introducing web in a telephone employee survey could be beneficial in terms of maximizing coverage due to the widespread availability of the internet for this population, but also for addressing declining response rates and minimizing costs.

Web is a commonly used mode in mixed-mode surveys as it is less costly than interviewer-administered modes. Cost savings can be maximized when implemented as part of a sequential web-first mixed-mode design (Dillman 2017), where sampled units are initially "pushed" to the web mode, and only offered a potentially more expensive alternative mode (e.g., face-to-face, telephone) during the nonresponse follow-up phase. Introducing a web mode can also increase the chances of reaching potential respondents (Dillman 2017; de Leeuw 2018; Biffignandi and Bethlehem 2021). Thus, it may overcome coverage biases in register-based telephone surveys as sampled units without a known telephone number can still be reached and invited to take part online. In the context of employment surveys, the web mode offers greater flexibility and convenience for working professionals who may be difficult to reach via an interviewer-administered mode.

However, reducing coverage biases in telephone surveys by introducing a web mode may be met with reduced overall response rates and a greater risk of nonresponse bias if those who are excluded from register samples due to having an unknown telephone number are less likely to participate via web. Previous studies comparing both modes experimentally have found that the web mode often yields lower response rates than the telephone mode (Schouten et al. 2013; Laaksonen and Heiskanen 2014; Keeter 2015; Woo et al. 2015; Lee et al. 2019; Gundersen et al. 2021; Voorpostel et al. 2021), but lower survey costs (Braunsberger et al. 2007; Berzelak et al. 2015; Lipps and Pekari 2016; Lee et al. 2019; Soullier et al. 2023).

Research has also shown that web and telephone modes generate different types of respondents (Dillman et al. 2009; Lugtig et al. 2011; Klausch et al. 2015; Lipps and Pekari 2016). For instance, individuals with middle and higher incomes (Dillman et al. 2009; Berzelak et al. 2015; Klausch et al. 2015) and employed individuals (Lugtig et al. 2011; Schouten et al. 2013; Voorpostel et al. 2021) are more likely to respond via web, possibly due to the aforementioned relationship between employment status and home internet access.

In the context of mixing modes, previous research has found that following-up web nonrespondents by telephone significantly increases response rates compared to a single-mode web design (Greene et al. 2008; Dillman et al. 2009; Soullier et al. 2023), but yields lower response rates compared to a single-mode telephone design (Legleye and Charrance 2021). Legleye and Charrance (2021) also found differences in respondent compositions (e.g., education levels) between both mode designs. Furthermore, Soullier et al. (2023) showed a nearly 40% lower cost-per-interview for a sequential web-to-telephone design compared to a telephone-only design (23 EUR vs. 39 EUR per respondent).

However, the effects of introducing web in a traditional telephone survey on total selection bias and potential trade-offs between coverage and nonresponse remain a gap in the literature. In the most severe case, efforts to reduce or eliminate coverage bias by introducing a web mode could lead to greater overall selection bias—an issue we explore in the forthcoming analysis by leveraging extensive individual-level administrative data available for both respondents and nonrespondents as well as sampled units with and without known telephone numbers.

5.3 Data

5.3.1 Linked Personnel Panel

This study uses data from the Linked Personnel Panel (LPP), a German employee panel survey. The LPP—sponsored by the German Federal Ministry of Labor and Social Affairs (BMAS) and the Institute for Employment Research (IAB)—is designed for labor market research by simultaneously observing the employer and employee perspectives (Ruf et al. 2022).

An employer panel survey, which covers topics related to human resources and digitalization, forms the first part of the LPP. The target population of the LPP employer survey comprises establishments with a minimum of 50 employees covered by social insurance, excluding those establishments in agriculture, fishing, public administration, publicly owned businesses, and non-profit or religious organizations. The target population of the LPP employer survey consists of companies that meet the specified criteria and had a valid interview in the IAB Establishment Panel (IEB-EP) in the year before. The IAB-EP is an annual survey representative of all establishments in Germany with at least one employee subject to social insurance. The sample is drawn from the business register of the German Federal Employment Agency (BA). Given that the above conditions applied to

only 2,222 employers, all employers in the LPP employer survey sample frame were surveyed starting in 2012. Participating employers were recontacted in subsequent waves (2: 2014, 3: 2016, 4: 2018, 5: 2020). Refreshment samples were drawn via simple random sampling in waves 3, 4, and 5 to counter panel attrition. All data collection was carried out by Kantar.

An employee survey, covering employees' working conditions, health, and personality traits, forms the second part of the LPP and is the focus of the present study. A simple random sample of employees (drawn from the establishments that participated in the first wave of the LPP employer survey) represents the starting point of the LPP employee survey, which began in 2013. This employee sample is drawn from the Integrated Employment Biographies, an administrative database of employees in Germany discussed in more detail below. Employees who gave panel consent at the end of their initial interview were recontacted in subsequent waves (2: 2015; 3: 2017; 4: 2019; 5: 2021). Refreshment samples were also drawn in these waves, which we use to address our research questions. All data collections were conducted by the Institute of Applied Social Sciences (infas).

Interviews were carried out solely by telephone during the first three waves of the LPP employee survey. Employee telephone numbers originate from past contacts with the BA (e.g., registration as a welfare benefit recipient or job seeker) and from commercial telephone number research conducted by the survey institute. For the refreshment samples, the telephone number research was carried out by merging names and addresses to the German Postal Directory, which contains telephone number registrations (German Post 2023). The numbers originating from the telephone number research are used first if they differ from the BA number. Due to data security regulations, the survey institute does not publish results of the telephone number research; thus, it is unclear how many individuals were contacted solely by a number supplied by the BA or the telephone number research.

5.3.2 Mode Design Experiment

A sequential web-to-telephone mixed-mode design was experimentally introduced in the refreshment samples of waves 4 and 5 of the LPP employee survey to evaluate the impacts of introducing web on coverage, nonresponse, and survey costs. The experimental design is depicted in Figure 1. Sampled employees with known telephone number were randomly allocated to two experimental groups: the standard single-mode telephone design used in previous waves of the LPP and a sequential web-to-telephone mixed-mode design. Employees with unknown telephone numbers were allocated to a (non-experimental) single-mode web design.

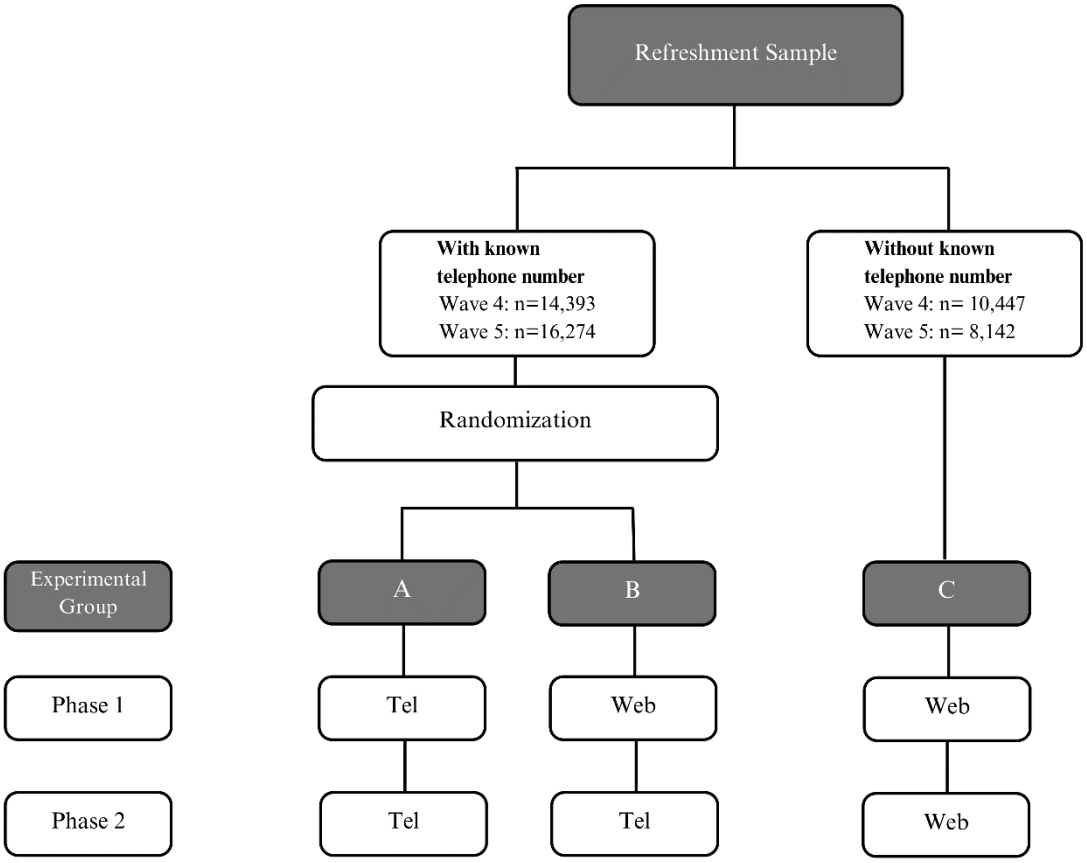


Figure 1. Diagram of the Mode Design Experiment for the Refreshment Samples of Waves 4 and 5 of the LPP Employee Survey

Invitation and reminder letters were sent in all mode designs. For the single-mode telephone design, the invitation letter announced upcoming contact attempts via telephone. For the web-to-telephone design, the invitation letter included a link and password to the online survey, with no mention of telephone follow-ups. One reminder was sent to initial nonrespondents after two weeks to encourage a web response and mentioning that telephone contact attempts would start within the next week if the web survey was not completed until then. All telephone contact attempts were carried out from Monday to Friday between 1pm–9pm and on Saturday between 10am–6pm. The web survey remained open throughout the entire field period. For the single-mode web design used for employees with unknown telephone number, up to two reminders were sent that included the same link and password to the online survey as included in the invitation letter.

5.3.3 Administrative Data

Two different administrative data sources are used for analyzing coverage and nonresponse bias: the Integrated Employment Biographies (IEB) (Schmucker et al. 2023) of the IAB and the Community Directory (CD) of the German Federal Office of Statistics. The IEB includes sociodemographic and employment information collected from 1975 onward for each employee subject to the German social insurance system. The IEB data are used to generate three variable groups: demographics, employment characteristics, and benefit receipt. The demographic variables include information on sex, age (in years; <30, 30–39, 40–49, 50–59, 60+), German citizenship (yes, no), secondary education (university entrance qualification; yes, no), and higher education (university degree; yes, no). The employment variable group is composed of employment contract (full-time, part-time), daily earnings (in Euros; <86, 86–131, 132+), occupation (production, business, or administration, other), and number of years working for current employer (<5, 5–9, 10–19, 20+). The benefits group includes two variables on whether, in the last 10 years, the

employee received social benefits (yes, no) or registered as a job seeker (yes, no) in order to receive non-monetary benefits, including job counseling and placement suggestions.

The CD provide geodata on the number of inhabitants, postal codes, and population size of every municipality in Germany. We use the CD data to derive a measure of urbanicity (population size: <5,000, 5,000–19,999, 20,000–99,999, 100,000–499,999, 500,000+) at the municipality level. This variable and region of residence (north, south, west, east) (collected from the IEB data) comprise the geodata variable group. All continuous variables are categorized into roughly-equal sized groups or arbitrary categories based on inspection of their distributions. Table 1 provides an overview of the administrative variables used in this study. Sample distributions for each variable are displayed in Table A1 of the appendix.

Table 1. Administrative Variables Used in Analysis

Variables	Categories
Demographics (source: IEB)	
Sex	Male, Female
Age	Years: <30, 30–39, 40–49, 50–59, 60+
German Citizenship	Yes, No
Secondary education	Less than university entrance qualification, University entrance qualification
Higher education	Less than university degree, University degree
Employment (source: IEB)	
Employment contract	Full-time, Part-time
Daily earnings	Euros: <86, 86–131, 132+
Occupation	Production, Business/Administration, Other
Years working for current employer	<5, 5–9, 10–19, 20+
Benefit receipt (source: IEB)	
Benefits last 10 years	Yes, No
Job seeking last 10 years	Yes, No
Geodata (source: CD/IEB)	
Region	North, West, South, East
Urbanicity	<5,000, 5,000–19,999, 20,000–99,999, 100,000–499,999, 500,000+

These 13 administrative variables are chosen for several reasons. First, they are available for all sampled employees regardless of whether they have a known telephone number or participated in the LPP survey. Second, many of the selected variables are closely related to those collected in the LPP survey, thus, they serve as suitable proxies for nonresponse and coverage bias in the published LPP datasets (Ruf et al. 2022; Mackeben et al. 2023). To give some examples, the LPP employee survey includes questions related to demographics (e.g., age, sex, education, German citizenship) and employment (e.g., occupation, part time, income). In addition, some administrative variables are directly measured in the LPP employee survey (Ruf et al. 2022). These include, for instance, longitudinal data on job seeking and benefit receipt. Third, the selected variables (e.g., age, sex, education, income, urbanicity) are commonly used in survey research to study coverage (Gordoni et al. 2011; Mohorko et al. 2013; Arcos et al. 2015; Lipps et al. 2015) and nonresponse bias (Keeter et al. 2006; Kreuter et al. 2010; Lugtig et al. 2011; Peytchev et al. 2011) in telephone surveys. The selected variables (e.g., sex, age, income, education, urbanicity) have also been used to study the effects of introducing web in traditional interviewer-administered surveys (Bianchi et al. 2017; Lüdtke and Schupp 2017; McGonagle and Freedman 2017; Voorpostel et al. 2020). Lastly, we chose variables that are also used in substantive employment research (e.g., Hausner et al. 2015; Stüber 2022; Dietrich and Patzina 2023) to demonstrate potential biases relevant to labor market research.

5.4 Methodology

The research questions are addressed using the cross-sectional (i.e., refreshment) samples of the LPP employee survey in combination with the linked administrative data. To address the first research question (coverage rates), we define the known telephone number coverage rate as the ratio of the number of employees with a known telephone number,

i.e., the covered units (c), and the drawn sample (n) in each wave. This is consistent with the definition of coverage used in official statistics (European Commission 2021):

$$\text{Known Telephone Number Coverage Rate} = \frac{c}{n} \tag{1}$$

To address the second research question (coverage patterns), we fit a multilevel logistic regression (accounting for employees nested within establishments) to model the existence of a known telephone number (0 = no, 1 = yes) on employee characteristics from the administrative data. The regression model is fitted separately for each wave of the LPP employee survey and is specified as follows:

$$\log\left(\frac{p_{ij}}{1-p_{ij}}\right) = \alpha + Z_{ij}\gamma + \mu_j \tag{2}$$

where the probability of having a known telephone number for individual i (working in establishment j) is represented by p_{ij}. The term α denotes the model intercept. A vector of coefficients corresponding to employee variables Z_{ij} is denoted by γ. The normally distributed (mean 0 and variance σ_u^2) random effect is represented by the term μ_j.

The third research question (coverage bias) is addressed using the first three waves of the LPP employee survey, before the introduction of the web mode. Coverage bias (CB) is estimated for every administrative variable category (excluding one category for binary variables) by calculating the difference between the proportion of a variable category (k) based on the covered employees (c) with known telephone number ($\bar{y}_{k,c}$) and the corresponding proportion based on the full sample ($\bar{y}_{k,n}$):

$$\text{Coverage Bias } (\bar{y}_k) = \bar{y}_{k,c} - \bar{y}_{k,n} \tag{3}$$

To simplify comparisons, we also report the absolute coverage bias (ACB):

$$\text{Absolute Coverage Bias } (\bar{y}_k) = \left|\bar{y}_{k,c} - \bar{y}_{k,n}\right| \tag{4}$$

As a summary measure, we further report the average absolute coverage bias (AACB) for each of the variable groups (demographics, employment, benefits, geodata) and overall. These estimates are generated by dividing the sum of the absolute coverage bias estimates by the total number of variable categories (K):

$$\text{Average Absolute Coverage Bias} = \frac{\sum_{k=1}^{K} |\bar{y}_{k,c} - \bar{y}_{k,n}|}{K} \tag{5}$$

The fourth research question (coverage, nonresponse, and total selection bias before introducing the web mode) is addressed using the first three waves of the LPP employee survey. In addition to coverage bias, we also present estimates of nonresponse bias (NB) and total selection bias (TSB) for all variable categories. Nonresponse bias is calculated by taking the difference between the proportion of a variable category (k) based on the respondents ($\bar{y}_{k,r}$) and the corresponding proportion based on the fielded cases with known telephone number ($\bar{y}_{k,c}$):

$$\text{Nonresponse Bias } (\bar{y}_k) = \bar{y}_{k,r} - \bar{y}_{k,c} \tag{6}$$

The absolute nonresponse bias (ANB) is also reported as:

$$\text{Absolute Nonresponse Bias } (\bar{y}_k) = \left|\bar{y}_{k,r} - \bar{y}_{k,c}\right| \tag{7}$$

We also generate the average absolute nonresponse bias (AANB) by dividing the sum of the ANB estimates by the total number of variable categories (K):

$$\text{Average Absolute Nonresponse Bias} = \frac{\sum_{k=1}^{K} \left|\bar{y}_{k,r} - \bar{y}_{k,c}\right|}{K} \tag{8}$$

Total selection bias is estimated in similar fashion by calculating the difference between the proportion of a category (k) based on the respondents ($\bar{y}_{k,r}$) and the corresponding proportion based on the full sample (covered and noncovered cases) ($\bar{y}_{k,n}$):

$$\text{Total Selection Bias } (\bar{y}_k) = \bar{y}_{k,r} - \bar{y}_{k,n} \tag{9}$$

We note that the total selection bias is essentially the sum of the nonresponse and coverage bias estimates. Like the other biases, we also report the absolute total selection bias (ATSB):

$$\text{Absolute Total Selection Bias } (\bar{y}_k) = \left|\bar{y}_{k,r} - \bar{y}_{k,n}\right| \tag{10}$$

and the average absolute total selection bias (AATSB):

$$\text{Average Absolute Total Selection Bias} = \frac{\sum_{k=1}^{K}\left|\bar{y}_{k,r} - \bar{y}_{k,n}\right|}{K} \tag{11}$$

For the fifth research question (coverage, nonresponse, and total selection bias after introducing the web mode), the mode design experiments in waves 4 and 5 of the LPP employee survey are analyzed. Like the previous research question, we consider the same outcome rates and bias measures for coverage, nonresponse, and total selection to compare the effects of each mode design. We also analyze the performance of the web starting mode (phase 1) relative to the full sequential web-to-telephone sequence (phases 1 and 2) in order to evaluate the before-and-after effects of implementing the telephone follow-ups. For purposes of the analysis, we randomly allocate employees without a known telephone number (and who were assigned to the non-experimental single-mode web design) between the single-mode telephone and web-to-telephone mixed-mode groups. In the single-mode telephone group, we treat these cases as noncovered with no telephone interview attempted and ignore their web survey invitation, whereas in the web-to-telephone mixed-mode group these cases are treated as covered by the web mode, which was the only feasible mode of interview. This modification allows us to mimic the real-world scenario in which employees without a known telephone number are part of the drawn sample, even if it is not possible for them to be recruited or participate in one or more of the offered modes.

The sixth research question investigates the potential cost impacts of introducing the web mode in the LPP survey. Since the exact survey expenses are unknown, we rely on hypothetical, yet realistic, cost values provided by the survey institute. The costs for the web mode include sending the invitation (0.95 EUR) and reminder (0.80 EUR) letters (German Post 2019) with an additional 0.05 Euro per letter to cover printing, envelope, and handling expenses. The telephone mode expenses encompass the invitation letter and interviewer labor, which includes hourly gross earnings of 11.12 EUR (Indeed 2021) and incidental wage costs equivalent to 27% of the gross earnings (German Federal Office of Statistics 2020). This results in a total hourly labor cost of 14.12 EUR for a single telephone interviewer. We assume that each telephone contact attempt, including actions such as dialing the telephone number and updating the status, has an average duration of one minute. To determine the cost of a completed telephone interview, we utilize the average interview duration (ID_w) for telephone interviews conducted in each refreshment sample (in minutes; wave 1: 30.3, wave 2: 39.2, wave 3: 39.3, wave 4: 50.3, wave 5: 51.4). The estimated expenses for a completed telephone interview and a single telephone contact attempt are computed as follows:

$$\text{Cost of telephone interview} = 14.12 \bullet \frac{ID_w}{60} = €11.84 \tag{12}$$

$$\text{Cost of telephone contact attempt} = 14.12 \bullet \frac{1}{60} = €0.24 \tag{13}$$

Although web and telephone surveys also involve fixed costs, such as questionnaire programming, these costs have been omitted due to the absence of any realistic cost data.

All analyses were conducted using Stata 16 (Stata Corp 2019). The LPP employee survey is based on a simple random sample and sampling probabilities are unavailable for the LPP employee parent surveys, the IAB-EP and the LPP employer survey. Thus, all analyses are performed unweighted. As a robustness check, we controlled for establishment

size and industry as covariates in the multilevel models. The main conclusions did not change (see Table A2 of the appendix), supporting the robustness of the findings.

5.5 Results

5.5.1 RQ1: Known Telephone Number Coverage Rates

Known telephone number coverage rates and overall response rates (Response Rate 1; AAPOR 2023) for waves 1 to 5 of the LPP employee survey are presented for all refreshment samples in Table 2. Out of 43,616 employees sampled in wave 1, 30,659 (or 70.29%) had a known telephone number. The coverage rate trended downward over time to 66.65% in wave 5, with the lowest coverage rate of 57.94% observed in wave 4. These coverage rates are significantly higher than the LPP response rates, which range from a high of 24.46% (wave 1) to a low of 12.10% (wave 3). The number of sampled employees with a known telephone number originating from the BA increased over the waves, from 51.48% in wave 1 to 72.00% in wave 3, with additional rises in waves 4 (83.36%) and five (87.27%). The highest proportion of known telephone numbers originating from the BA observed in wave 5 is at least partially due to the impact of the COVID-19 crisis. This sample was drawn in 2020 at a time when many employees registered as job seekers at the BA and provided their telephone number. Conversely, we observe a declining proportion of sampled employees with a known telephone number originating only from telephone number research conducted by the survey institute (infas), from 48.52% in wave 1 to only 12.73% in wave 5. This can be attributed to the increasing amount of telephone number registrations at the BA over time, but also the decreasing amount of listed telephone numbers in Germany (Häder and Sand 2019).

Table 2. Known Telephone Number Coverage and Overall Response Rates, by Wave

	Wave 1	**Wave 2**	**Wave 3**	**Wave 4**	**Wave 5**
Sample size	43,616	38,191	31,374	24,840	24,416
Known telephone number	30,659	26,989	20,463	14,393	16,274
Source: BA	15,783 (51.48%)	19,281 (71.44%)	14,733 (72.00%)	11,998 (83.36%)	14,203 (87.27%)
Source: infas	14,876 (48.52%)	7,708 (28.56%)	5,730 (28.00%)	2,395 (16.64%)	2,071 (12.73%)
Coverage Rate (%)	70.29	70.67	65.22	57.94	66.65
No. Respondents	7,499	4,000	2,477	3,260	3,331
Response Rate (%)	24.46	14.82	12.10	13.12	13.64

Note: Response rate calculated using Response Rate 1 definition (AAPOR 2023).

5.5.2 RQ2: Coverage Patterns

The results of the multilevel logistic regression model on the existence of a known telephone number (0 = no, 1 = yes), applied separately to each wave, are displayed in Table 3. All predictors demonstrate statistically significant associations with known telephone number coverage in at least one wave, except for employment contract and secondary education. For instance, employee characteristics associated with not having a known telephone number in every wave include non-German citizenship, daily earnings of at least 132 Euros, not receiving benefits and not registering as a job seeker in the last 10 years, living in a municipality with at least 20,000 residents, and having worked for their current employer at least 20 years. The negative associations with long-term employment, benefit receipt, and job seeking are likely driven by fewer interactions with the BA due to the lack of need to apply for unemployment or other benefit schemes. Other characteristics have only statistically significant effects in some survey waves. For instance, females (waves 1 to 4), employees with university degree (waves 3 to 5), employees with daily earnings between 86 and 131 Euros (waves 1 to 3), and employees living in municipalities with 5,000 to 19,999 inhabitants (waves 1 to 3) are significantly less likely to have a known telephone number in these waves compared to their respective reference groups. A few characteristics flip their effects across time. For example, the youngest employees (under 30 years) are negatively associated with a known telephone number in

odd waves and positively associated in even waves. Similarly, living in the eastern region of Germany is negatively associated with a known telephone number in wave one but positively associated in waves three to five. The Intra-Class Correlation (ICC) from the empty model, which represents the proportion of the total variance in the outcome of having a known telephone number that is attributable to differences between employers, is relatively small across all waves (range: 0.029–0.056), suggesting that there is relatively low variability between employers in terms of their impact on the presence of a known telephone number for their employees.

Given that there are different ways in which a known telephone number can manifest in the LPP survey, as an aside, we fitted a multilevel multinomial regression model predicting a known telephone number originating from the BA database or only from telephone number research carried out by the survey institute (infas) versus no known telephone number (Table A3: waves 1 to 3; Table A4: waves 4 to 5). The results point to some similarities and differences in known telephone number coverage patterns between both sources. For instance, younger employees are generally more likely to have a known telephone number originating from the BA database but are less likely to have a known number only from telephone research compared to the oldest age group. Non-German citizens are unlikely to have a known telephone number from either source. Earning the highest daily wage (at least 132 Euros) and working for their current employer at least 20 years tends to have a negative effect on the presence of a known BA number in most waves, but a positive effect on having a known number from telephone research only. Having a full-time employment contract tends to be positively associated with a known BA number, but negatively associated with a known number from telephone research only. As expected, receiving income benefits or registering as a job seeker in the last 10 years is positively associated with a known BA number, however, its effects on a known

number only from telephone research are mixed across the waves. Regarding urbanicity, the likelihood of having a known telephone number in either source decreases as population size increases. These results suggest that acquiring known telephone numbers from different sources can result in different coverage patterns, reinforcing coverage (or the lack thereof) for some groups and, in some cases, offsetting diverging patterns for groups that are over- and under-represented in the different sources.

To sum up this section, we find strong associations between employee characteristics and the presence of a known telephone number, indicating that certain employee groups were not fully covered in the LPP employee survey prior to the introduction of the web mode. In the next section, we analyze the magnitude of these coverage biases.

Table 3. Log-Odds Ratios of the Presence of a Known Telephone Number, by Wave

	Wave 1 Estimate (SE)	**Wave 2** Estimate (SE)	**Wave 3** Estimate (SE)	**Wave 4** Estimate (SE)	**Wave 5** Estimate (SE)
Intercept	4.04(.10)***	3.94(.10)***	4.03(.11)***	3.57(.14)***	3.72(.12)***
Sex					
(Ref. Male)					
Female	-0.25(.03)***	-0.31(.035)***	-0.22(0.04)***	-0.13(0.04)**	-0.08(.05)
Age					
(Ref. 60+)					
<30	-0.33(.07)***	0.27(.07)***	-0.42(0.07)***	0.58(0.09)***	-0.28(.08)***
30–39	-0.45(.05)***	-0.32(.05)***	-0.48(0.05)***	0.09(0.07)	-0.11(.06)
40–49	-0.25(.05)***	-0.34(.05)***	-0.23(0.05)***	0.03(0.06)	0.14(.06)*
50–59	-0.09(.05)	-0.12(.05)**	-0.13(0.05)**	-0.08(0.06)	0.00(.05)
German citizenship					
(Ref. Yes)					
No	-0.80(.05)***	-0.62(.05)***	-0.72(0.06)***	-0.78(0.07)***	-1.28(.06)***
Secondary education					
(Ref. Less than university entrance)					
University entrance	0.05(.04)	0.06(.04)	0.02(0.04)	-0.03(0.05)	0.03(.05)
Higher education					
(Ref. Less than university degree)					
University degree	-0.05(.05)	-0.07(.05)	-0.12(0.05)*	-0.29(0.06)***	-0.19(.06)**
Employment contract					
(Ref. Part-time)					
Full-time	-0.04(.04)	-0.05(.05)	-0.02(0.05)	0.10(0.07)	0.05(.06)
Daily earnings					
(Ref. <86)					
86–131	-0.14(.04)***	-0.20(.04)***	-0.23(0.04)***	-0.02(0.07)	-0.07(.05)
132+	-0.19(.05)***	-0.25(.05)***	-0.37(0.05)***	-0.20(0.07)**	-0.35(.06)***
Occupation					
(Ref. Production)					
Business/Administration	0.02(.04)	0.04(.04)	-0.08(0.04)*	-0.08(0.04)	-0.14(.05)**
Other	-0.12(.03)***	-0.01(.04)	-0.10(0.04)**	0.02(0.05)	-0.10(.05)*
Years working for current employer					

(Ref. <5)					
5–9	0.02(.05)	0.11(.05)*	0.12(0.05)*	0.31(0.06)***	0.26(.06)***
10–19	-0.08(.05)	0.02(.05)	0.08(0.05)	0.26(0.06)***	0.47(.06)***
20+	-0.16(.05)**	-0.27(.05)***	-0.51(0.05)***	-0.75(0.06)***	-0.68(.06)***
Benefits last 10 years					
(Ref. Yes)					
No	-1.37(.06)***	-0.97(.07)***	-1.33(0.07)***	-0.87(0.10)***	-1.09(.08)***
Job seeking last 10 years					
(Ref. Yes)					
No	-1.21(.04)***	-1.87(.05)***	-1.63(0.05)***	-2.54(0.07)***	-2.09(.06)***
Region					
(Ref. North)					
South	-0.07(.06)	0.07(.06)	0.03(0.06)	-0.11(0.08)	-0.02(.08)
West	-0.05(.06)	0.14(.05)*	0.15(0.06)*	-0.09(0.08)	-0.01(.07)
East	-0.25(.06)***	0.10(.06)	0.13(0.06)*	0.24(0.07)**	0.24(.07)**
Urbanicity					
(Ref. <5,000)					
5,000–19,999	-0.20(.04)***	-0.21(.04)***	-0.18(0.04)***	-0.03(0.05)	-0.10(.05)
20,000–99,999	-0.43(.04)***	-0.46(.04)***	-0.53(0.05)***	-0.25(0.06)***	-0.26(.06)***
100,000–499,999	-0.75(.05)***	-0.74(.05)***	-0.69(0.06)***	-0.44(0.05)***	-0.37(.07)***
500,000+	-0.95(.06)***	-0.80(.06)***	-0.80(0.06)***	-0.46(0.07)***	-0.51(.07)***
N	43,616	38,191	31,374	24,840	24,416
AIC	43416.34	37011.52	31937.84	24933.52	22965.59
BIC	43650.79	37242.39	32163.4	25152.77	23184.37
Wald-Test (x^2)	4343.95	4965.01	4394.76	4265.11	4002.30
Wald-Test (p-value)	<0.00	<0.00	<0.00	<0.00	<0.00
Random intercept (establishment)	.1950	.0988	.1095	.1688	.1702
ICC (empty model)	.0559	.0291	.0322	.0488	.0492

Significance level: *** p < 0.001, ** p < 0.01, * p < 0.05

5.5.3 RQ3: Coverage Bias

Table 4 (BA and infas columns) presents the aggregate summary measure of known telephone number coverage bias, i.e., the average absolute coverage bias (AACB), for the first three waves of the LPP employee survey which acquired known telephone numbers from both the BA database and external telephone research conducted by the survey institute (infas). Overall, across all administrative variables, the bias measures are relatively small across the waves with the AACB never exceeding 3% and with a slightly increasing trend over time. Larger average coverage biases are found for some variable groups. In particular, the benefits variable group stands out with AACB values ranging from 10.25–13.58%. This large bias may be explained by the increasing reliance on BA sources for acquiring telephone numbers, as previously discussed. The average coverage biases for the other variable groups, including employment (AACB range: 2.28–3.11%), demographics (AACB range: 0.90–1.25%), and geodata (AACB range: 1.28–1.49%) are relatively small in comparison and show a slightly increasing trend over time.

Given that known telephone numbers originated from two different sources: past interactions with the BA and additional telephone number research conducted by infas, as well as earlier analyses showing that coverage patterns are differentially affected by source (see Table A3: waves 1 to 3; Table A4: waves 4 and 5), as a side analysis we also present coverage bias estimates in Table 4 (BA only columns) assuming that only the BA database was used to acquire known telephone numbers. Here, we indicate whether using telephone number research as a supplement to BA number research has a positive or negative effect on coverage bias. Across all waves, the overall AACB is larger when the sample exclusively relies on BA numbers (range: 6.16–8.30%), compared to a design incorporating both BA numbers and numbers from the external telephone research (range:

2.10–2.77%). Remarkably, the average coverage biases are consistently larger for all variable categories in every wave when the sample solely relies on BA numbers, contrasting with a sample utilizing both BA numbers and externally acquired numbers. Thus, supplementing the BA numbers with external telephone research conducted by the survey institute leads to a reduction in aggregate coverage bias.

Table 4. Average Absolute Coverage Bias (AACB) in Percent, by Variable Group and Overall

Variable group	Wave 1		Wave 2		Wave 3	
	BA only	BA & infas	BA only	BA & infas	BA only	BA & infas
Demographics	4.26	0.90	3.72	1.25	3.25	1.22
Employment	10.21	2.28	7.77	2.60	7.46	3.11
Benefits	40.66	10.25	30.07	11.50	29.95	13.58
Geodata	2.81	1.28	2.35	1.15	2.21	1.49
Overall	8.30	2.10	6.46	2.36	6.16	2.77

Estimates of raw and absolute coverage bias for each individual variable can be found in the appendix (Table A5) with the absolute values discussed here for some variables. Here, we report the results based on the combination of both telephone number data sources. The ACB estimates differ widely across variables, with the highest values for benefit receipt (wave 1: 9.37%, wave 2: 9.81%, wave 3: 11.69%) and having registered as a job seeker (wave 1: 11.13%, wave 2: 13.19%, wave 3: 15.46%) in the last 10 years. Categories for daily earnings (<86 Euros: wave 1: 5.02%, wave 2: 5.30%, wave 3: 6.42%; 132+ Euros: wave 1: 3.72%, wave 2: 4.11%, wave 3: 5.57%) and years working for current employer (<5 years: wave 1: 3.55%, wave 2: 4.35%, wave 3: 3.75%; 20+ years: wave 1: 3.39%, wave 2: 5.02%, wave 3: 7.16%) show low-to-moderate coverage biases in all survey waves. In contrast, biases are relatively small for education and employment contract variables. ACB estimates increased for most variable categories with 19 out of 31 having higher ACB values in wave 3 than in the previous waves. Table A5 also presents coverage

biases under the assumption that the sample solely relies on sourcing BA telephone numbers. This hypothetical scenario shows a larger coverage bias for 24 (wave 1), 25 (wave 2), and 21 (wave 3) out of 31 variable categories compared to the actual scenario of sourcing numbers from both the BA database and external telephone number research. In summary, coverage biases are prevalent for many variable categories before the LPP employee survey introduced the web mode in wave 4. We also find that supplementing the BA database with external telephone number research generally reduces known telephone number coverage bias.

5.5.4 RQ4: Coverage, Nonresponse, and Total Selection Bias Before Introducing the Web Mode

Table 5 shows the average absolute coverage (taken from Table 4 to facilitate comparison), nonresponse, and total selection bias for each variable group and overall for the first three waves of the LPP employee survey. Overall, we can see that the AANB tends to be slightly higher than AACB for all waves, suggesting that nonresponse is the more dominant source of selection bias, on average. Both average biases tend to increase over time. The pattern is largely consistent for each variable group, apart from the benefits variables. For this variable group, coverage is the dominant source of selection bias, exceeding average nonresponse bias by roughly two-fold. This finding is particularly noteworthy given that the known telephone number coverage rate is significantly higher than the LPP response rate in each wave (see Table 2). Regarding average total selection bias, the AATSB values tend to lie between coverage and nonresponse bias, indicating potential offsetting of the two biases. Significant offsetting is apparent for some variable groups (e.g., employment, benefits), where the AATSB is lower than both the AACB and AANB.

Table 5. Average Absolute Nonresponse (AANB), Coverage (AACB), and Total Selection Bias (AATSB), by Variable Group and Overall

Variable group	Wave 1			Wave 2			Wave 3		
	AACB (%)	AANB (%)	AATSB (%)	AACB (%)	AANB (%)	AATSB (%)	AACB (%)	AANB (%)	AATSB (%)
Demographics	0.90	2.86	2.35	1.25	3.53	2.88	1.22	4.65	3.81
Employment	2.28	2.72	1.67	2.60	3.00	1.74	3.11	3.84	1.89
Benefits	10.25	6.38	3.88	11.50	5.43	6.08	13.58	7.84	5.74
Geodata	1.28	1.28	2.13	1.15	0.95	1.84	1.49	1.09	2.21
Overall	2.10	2.58	2.14	2.36	2.72	2.38	2.77	3.54	2.79

Taking a closer look at the individual coverage and nonresponse bias estimates, shown in Table A6, we can see that nearly all variables are jointly affected by both coverage and nonresponse bias to some extent. Some variables with the largest absolute nonresponse biases also tend to have the largest absolute coverage biases (as reported earlier), including benefit receipt in the last 10 years (ANB; wave 1: 6.67%, wave 2: 5.92%, wave 3: 8.31%), registered as job seeker in the last 10 years (ANB; wave 1: 6.08%, wave 2: 4.93%, wave 3: 7.37%), and the variable categories daily earnings (<86 Euros: ANB; wave 1: 6.80%, wave 2: 5.79%, wave 3: 7.30%; >132 Euros: ANB; wave 1: 7.02%, wave 2: 7.18%, wave 3: 8.50%), and years working for current employer (20+ years: ANB; wave 1: 3.89%, wave 2: 5.39%, wave 3: 6.29%). Some demographics variables tend to have larger absolute nonresponse bias relative to coverage bias, including secondary education (ANB; wave 1: 4.89%, wave 2: 5.92%, wave 3: 7.79%), higher education (ANB; wave 1: 3.88%, wave 2: 5.25%, wave 3: 7.28%), and age categories (30–39 years: ANB; wave 1: 4.49%, wave 2: 5.09%, wave 3: 5.93%; 50–59 years: ANB; wave 1: 5.59%, wave 2: 7.37%, wave 3: 9.73%). Other variables are mainly unaffected by coverage and nonresponse bias (e.g., sex, employment contract).

Absolute nonresponse bias has a larger effect on selection bias than absolute coverage bias for most variable categories: 17 (wave 1), 20 (wave 2), and 19 (wave 3) out of 31

total variable categories. The direction of the raw nonresponse and coverage biases differ for most variable categories (wave 1: 20, wave 2: 22, wave 3: 19 out of 31), pointing to an offsetting effect of both biases. In some cases, the offsetting effect is dramatic. For example, the variable category daily earnings (<86 Euros) has absolute coverage and nonresponse biases that exceed 5% in every wave, but the absolute total selection bias never exceeds 2%. Similarly, the absolute total selection bias for years working for current employer (20+ years) never exceeds 1% even though the absolute coverage and nonresponse biases exceed 5% in most waves. For the benefits group variables, which exhibited the largest coverage biases, the offsetting effects are significant. For example, the absolute total selection bias for the variable category benefit receipt in the last 10 years, which has absolute coverage biases up to around 12%, is below 4% in all waves. Registering as a job seeker in the last 10 years, which has absolute coverage biases up to 15%, yields an absolute total selection bias up to around 8%—a significant reduction but still a rather large selection bias. In contrast, nonresponse and coverage bias reinforce each other for the remaining number of variable categories (wave 1: 11, wave 2: 9, wave 3: 12 out of 31). However, these variables generally have relatively small absolute total selection biases, never exceeding 5%.

In summary, nonresponse and coverage biases tend to offset each other for many variable categories, sometimes rather significantly, yielding a significant reduction in the total selection bias. The next question is to what extent introducing the web mode affects these selection patterns.

5.5.5 RQ5: Coverage, Nonresponse, and Total Selection Bias After Introducing the Web Mode

In this section, we evaluate the impacts of introducing the web mode on coverage, nonresponse, and total selection bias relative to the single-mode telephone design in the LPP

employee survey. Here, we exploit the mode design experiment that was conducted in the refreshment samples of waves 4 and 5. We remind the reader that for this analysis we randomly allocated all sampled employees with unknown telephone number who received the single-mode web design between the single-mode telephone and web-to-telephone mixed-mode design groups. For the single-mode telephone design, we assume these cases are not covered and ignore their web recruitment. For the web-to-telephone design, we treat them as covered for the web mode only with no possibility of a telephone interview in the follow-up phase of the sequential mixed-mode design.

Table 6 displays the coverage and response rates for waves 4 and 5, respectively, for the telephone single-mode design and the sequential web-to-telephone mixed design (phases 1 and 2). The outcome rates of the web starting mode (phase 1) are also reported. The web starting mode (wave 4: 12.10%, wave 5: 11.84%) and full web-to-telephone sequence (wave 4: 13.95%, wave 5: 14.40%) both exhibit higher response rates than the telephone single-mode design (wave 4: 5.87% and wave 5: 7.96%), suggesting that introducing the web mode and eliminating known telephone number noncoverage does not adversely affect the response rate and increases it significantly.

Table 6. Known Telephone Number Coverage Rates and Response Rates, by Mode Design and Wave

	Wave 4			Wave 5		
	Single-Mode	Mixed-Mode		Single-Mode	Mixed-Mode	
	Tel.	Web Starting Mode	Web-Tel.	Tel.	Web Starting Mode	Web-Tel.
Sample size	12,420	12,420	12,420	12,209	12,207	12,207
Known telephone number	7,197	7,196	7,196	8,138	8,136	8,136
Source: BA	6,019 (83.63%)	5,963 (82.87%)	5,963 (82.87%)	7,103 (87.28%)	7,094 (87.19%)	7,094 (87.19%)
Source: infas	1,178 (16.37%)	1,233 (17,13%)	1,233 (17,13%)	1,035 (12.72%)	1,042 (12.81%)	1,042 (12.81%)
Coverage Rate (%)	57.95	100.00	100.00	68.14	100.00	100.00
No. Respondents	423	1,503	1,732	617	1,445	1,758
Response Rate (%)	5.87	12.10	13.95	7.96	11.84	14.40

Note: Response rate calculated using Response Rate 1 definition (AAPOR 2023).

The average absolute coverage, nonresponse, and total selection bias estimates are presented in Tables 7 (wave 4) and 8 (wave 5). A key question is whether there is a trade-off between eliminating known telephone number coverage bias and potentially increasing nonresponse bias when introducing the web starting mode as part of a sequential web-to-telephone design. When looking at the performance of the web starting mode (AATSB; wave 4: 5.09%, wave 5: 5.80%) and the full web-to-telephone sequence (AATSB; wave 4: 4.10%, wave 5: 4.95%) in both waves, we can see that the overall average selection bias is larger than for the telephone single-mode design (AATSB; wave 4: 3.57%, wave 5: 3.71%), suggesting that the elimination of coverage bias indeed leads to greater total selection bias, on average, which is driven by larger nonresponse bias in the mixed-mode design and partial offsetting of coverage and nonresponse biases in the single-mode telephone design.

There is some variation in the results across the variable groups and waves. For instance, the benefits variable group exhibits contrasting effects whereby the AATSB is smaller

under the sequential web-to-telephone mixed-mode design in wave 4 (7.03%) but larger in wave 5 (10.23%) relative to their corresponding single-mode telephone designs (wave 4: 11.54%, wave 5: 5.45%). This is mainly driven by the job seeker variable. In wave 4, the category of not registering as a job seeker in the last 10 years has a large negative coverage bias (-19.39%) and a relatively small positive nonresponse bias (3.13%) under the single-mode telephone design, resulting in a partially offset selection bias of -16.26%, which is significantly larger than the total selection bias (due to nonresponse only) under the web-to-telephone design (7.23%). In wave 5, the amount of offsetting under the single-mode telephone is greater for this variable, which has a large negative coverage bias (-16.24%) countered by a relatively large positive nonresponse bias (8.31%), resulting in a total selection bias of -7.93% compared to 10.04% in the web-to-telephone design. Thus, the performance of the web-to-telephone design relative to the single-mode telephone design is considerably impacted by the amount of offsetting between coverage and nonresponse bias in the latter design. Other variable groups exhibit more modest variation between waves. For the demographics group, the AATSB is slightly larger under the web-to-telephone design (5.96%) in wave 4 but slightly smaller in wave 5 (5.77%) compared to their respective single-mode telephone designs (wave 4: 3.93%, wave 5: 6.48%). The employment variable group consistently has larger AATSB in the web-to-telephone design (wave 4: 4.34%, wave 5: 6.47%) relative to the single-mode telephone design (wave 4: 3.01%, wave 5: 2.98%), whereas the geodata group always has smaller AATSB in the sequential mixed-mode design (wave 4: 1.31%, wave 5: 1.10%) compared to the single-mode design (wave 4: 2.12%, wave 5: 1.43%). For all variable groups and waves, the average total selection bias for the full web-to-telephone design is always smaller than that of the web starting mode, which speaks to the benefit of using telephone as a follow-up mode to web.

Table 7. Average Absolute Nonresponse Bias (AANB), Coverage (AACB), and Selection Bias (AATSB) in percentages, by Variable Group and Overall, Wave 4

	Single-Mode			**Mixed-Mode**					
	Telephone			**Web Starting Mode**			**Web-Telephone**		
Variable group	AACB (%)	AANB (%)	AATSB (%)	AACB (%)	AANB (%)	AATSB (%)	AACB (%)	AANB (%)	AATSB (%)
Demographics	2.59	5.02	3.93	0.00	6.61	6.61	0.00	5.96	5.96
Employment	4.52	3.09	3.01	0.00	5.72	5.72	0.00	4.34	4.34
Benefits	15.97	4.43	11.54	0.00	10.76	10.76	0.00	7.03	7.03
Geodata	1.66	1.56	2.12	0.00	1.53	1.53	0.00	1.31	1.31
Overall	3.87	3.29	3.57	0.00	5.09	5.09	0.00	4.10	4.10

Table 8. Average Absolute Nonresponse Bias (AANB), Coverage (AACB), and Selection Bias (AATSB) in percentages, by Variable Group and Overall, Wave 5

	Single-Mode			**Mixed-Mode**					
	Telephone			**Web Starting Mode**			**Web-Telephone**		
Variable group	AACB (%)	AANB (%)	AATSB (%)	AACB (%)	AANB (%)	AATSB (%)	AACB (%)	AANB (%)	AATSB (%)
Demographics	1.57	7.47	6.48	0.00	6.08	6.08	0.00	5.77	5.77
Employment	3.15	5.21	2.98	0.00	7.67	7.67	0.00	6.47	6.47
Benefits	14.28	8.82	5.45	0.00	13.83	13.83	0.00	10.23	10.23
Geodata	1.09	1.36	1.43	0.00	1.44	1.44	0.00	1.10	1.10
Overall	2.81	4.98	3.71	0.00	5.80	5.80	0.00	4.95	4.95

The individual bias estimates for each of the 31 variable categories are shown in Tables A7 (wave 4) and A8 (wave 5) of the appendix. The results generally coincide with the patterns discussed above. The single-mode telephone design produces smaller nonresponse biases for most variable categories (19 in wave 4, 20 in wave 5) compared to the web-to-telephone mixed-mode design. Implementing the telephone follow-up mode reduces nonresponse bias relative to the web starting mode for most variable categories (26 in wave 4, 21 in wave 5). In the telephone single-mode design, there is a significant amount of offsetting between coverage and nonresponse bias that affects most variable categories (21 in wave 4, 23 in wave 5), which lessens the magnitude of total selection bias. Coupled with the tendency of larger nonresponse biases in the mixed-mode design,

the result is smaller total selection bias in the telephone design for most variable categories (19 in wave 4; 22 in wave 5).

In summary, we show that introducing a sequential web-to-telephone design, while eliminating known telephone number coverage bias, does not necessarily lead to smaller total selection bias compared to a single-mode telephone design for most variables due to the diverging effects of coverage and nonresponse bias between the two mode designs.

5.5.6 RQ6: Cost Analysis

Table 9 presents the results of the cost analysis for each survey wave and mode design. Total costs were €208,973.75 in wave 1, €150,194.68 in wave 2, and €85,013.73 in wave 3, with corresponding average per-interview costs of €27.87, €37.55, and €34.32. In waves 4 and 5, the cost per telephone interview was notably higher at €52.48 and €54.25, respectively, when compared to waves 1 to 3, mainly due to the extended interview duration. However, introducing the web-to-telephone mixed-mode design in waves 4 and 5 effectively reduced the cost per interview (wave 4: €21.92, wave 5: €25.58) by around 50%, demonstrating its cost-effectiveness in comparison to the traditional telephone single-mode design in both waves.

Table 9. Cost Analysis, by Wave and Mode Design (in Euros)

	Wave 1	Wave 2	Wave 3	Wave 4			Wave 5		
	Telephone	Telephone	Telephone	Telephone	Web Starting Mode	Web-Tel.	Telephone	Web Starting Mode	Web-Tel.
Invitation letters (in €)	30,659	26,989	20,463	7,197	12,420	12,420	8,138	12,207	12,207
Reminder letters (in €)	N/A	N/A	N/A	N/A	4,071.75	14,071.75	N/A	12,971	12,971
Tel. interviews (in €)	53,295.39	36,900	22,909.77	5,007.16	N/A	2,710.73	7,465.7	N/A	3,787.3
Tel. contact attempts (in €)	125,019.36	86,305.68	41,640.96	9,996.02	N/A	8,771.11	17,868.24	N/A	14,243.52
Total costs (in €)	208,973.75	150,194.68	85,013.73	22,200.18	26,491.75	37,973.59	33,471.94	25,178.00	43,208.82
Interviews (N)	7,499	4,000	2,477	423	1,503	1,732	617	1,445	1,758
Avg. tel. int. duration (in min)	30.3	39.2	39.3	50.3	--	50.3	51.4	--	51.4
Avg. cost per interview (in €)	27.87	37.55	34.32	52.48	17.62	21.92	54.25	17.42	25.58

5.6 Discussion

The present study investigated the impact of replacing a single-mode telephone design with a sequential web-to-telephone mixed-mode design on survey costs and errors (namely, known telephone number coverage, nonresponse, and total selection bias) in the refreshment samples of waves 4 and 5 of a German employee panel (i.e., the LPP). The study unfolded in three phases. First, we examined trends and patterns in known telephone number coverage across the first five waves of the LPP employee survey spanning eight years (2013 to 2021). Subsequently, we explored known telephone number coverage bias, nonresponse bias, and total selection bias during the exclusive telephone survey waves (waves 1 to 3). Finally, we analyzed mode design experiments in waves 4 and 5 to understand the impact of introducing a sequential web-to-telephone mixed-mode design as a replacement to the standard single-mode telephone design on total selection bias (coverage and nonresponse) and survey costs.

The key findings can be summarized as follows. First, the proportion of sampled employees who could be merged to a known telephone number generally declined over the waves, with an increasing share of merged telephone numbers originating from administrative records from the German Federal Employment Agency (BA) and a decreasing share that could only be merged through telephone number research conducted by the survey institute (infas), which is in line with the existing literature on the declining amount of publicly listed telephone numbers (Tucker et al. 2002; Häder and Sand 2019; Werbewoche 2021). Second, we found that some employee characteristics were significantly related to the lack of a known telephone number, including non-German citizenship, high income earners, inhabitants of larger populated cities, those who have had stable employment with their current employer, and who haven't registered for benefits or as a job seeker in the last 10 years. These subgroups appear to be the most difficult to

merge to a known telephone number, given their fewer interactions with the federal employment system. Third, known telephone number coverage biases were prevalent but relatively small, on average, with a slightly increasing trend prior to the introduction of the web-to-telephone design. Benefit receipt and registering as a job seeker exhibited the largest absolute coverage biases, with relatively smaller biases for employment, demographics, and geodata characteristics. There was evidence that sourcing telephone numbers from both the BA database and external telephone number research conducted by infas produced less known telephone number coverage bias compared to using only the BA database. Fourth, nonresponse bias tended to be the dominant source of total selection bias, on average, apart from the aforementioned benefit receipt and job seeker variables where coverage bias was the dominant error source. The average total selection bias tended to lie between average nonresponse and coverage bias, which pointed to offsetting of the two error sources for most variables. Offsetting was significant for some variable groups (e.g., employment, benefits), where the average total selection bias was smaller than the average of both of its error components. Fifth, we showed that the web starting mode and the full sequential web-to-telephone mixed-mode design yielded higher response rates compared to the standard LPP single-mode telephone design. This finding stands in contradiction to previous research which showed that telephone produces higher response rates than web designs (Laaksonen and Heiskanen 2014; Lee et al. 2019; Gundersen et al. 2021). The contradictory findings may be explained by the fact that previous studies used more general populations, while this study sampled employees, who are more likely to have internet access compared to the general population (German Federal Office of Statistics 2021). However, despite increasing response rates and eliminating known telephone number coverage bias, the web-to-telephone design resulted in larger total selection bias, on average, compared to the single-mode telephone design. This counterintuitive result was driven by larger (average) nonresponse bias in the mixed-

mode design and partial offsetting of coverage and nonresponse biases in the single-mode telephone design. Lastly, we found evidence of significant cost savings under the web-to-telephone design, which effectively reduced the cost-per-interview by around 50% compared to the standard telephone-only design. These results are in line with previous research, which showed that a web single-mode (Lipps and Pekari 2016; Lee et al. 2019; Soullier et al. 2023) and a sequential web-telephone mixed-mode design (Soullier et al. 2023) produce lower costs than a telephone single-mode design.

Our research has identified significant challenges in telephone surveys that rely on merging telephone numbers to register-based samples regarding the potential noncoverage (bias) that can arise due to unknown telephone numbers. These challenges persist even when supplementing commercial telephone research with administrative records from official sources, as our research showed. This underscores the trend of introducing online data collection in telephone surveys as part of a mixed-mode design to eliminate this form of noncoverage while also reducing costs. However, we note the potential for other error trade-offs when introducing web in a telephone survey. As we showed, introducing the web-to-telephone design increased average nonresponse bias to a level that exceeded the average total selection bias in the single-mode telephone design. It is interesting to know that this effect was exacerbated by the partial offsetting of coverage and nonresponse biases which occurred for most estimates in the telephone-only design. Thus, eliminating one source of error may have the unintended effect of increasing another. This suggests that survey practitioners must carefully weigh the trade-off between costs and multiple sources of error, as well as their unintended consequences, to determine the most effective mode design for their specific study.

While our research provides important insights, it is necessary to acknowledge certain limitations that may affect the generalizability and interpretation of the findings. For instance, our study employs a sampling frame comprising current addresses (rarely older than one year), with telephone numbers that often predate the addresses. Moreover, the LPP employee survey is in a unique position, benefiting from access to telephone numbers provided by the German Federal Employment Agency in addition to commercial telephone research conducted by the survey institute. The generalizability of our findings beyond this survey may be limited. In addition, the study focused on the subpopulation of employees based in Germany. The identified challenges and findings may vary across other populations and geographical areas. Moreover, the results are not universally applicable to all employees in Germany, as some sectors, such as the public sector and all establishments with fewer than 50 socially insured employees, were excluded from the target population. In addition, we cannot identify whether employees with a known BA telephone number also have a known number from external research conducted by infas. Furthermore, in cases where infas found a telephone number for employees who also had a known BA number, we lack information on which number (or both) was utilized during the field period.

Looking ahead to future research, our study points to further avenues of exploration in several key areas. First, there is a need to investigate the applicability and effectiveness of sequential web-to-telephone mixed-mode designs in diverse survey contexts and populations. Second, it is crucial to explore innovative strategies aimed at addressing the challenges identified in telephone surveys, including how telephone numbers are sourced and the implications of mixing different sources. Although we showed that using multiple sources reduces known telephone number coverage bias, this finding may not be univer-

sally applicable in all surveys. Furthermore, future research should delve into the implications of introducing web modes on measurement quality and response patterns in mixed-mode telephone surveys. Analyzing potential mode effects and assessing the comparability of results across telephone and web modes would contribute to a more nuanced understanding of the strengths and limitations inherent in each approach. In addition, it would enable the analysis of a more complete set of error sources, contributing to a deeper understanding of their individual and joint effects and potential trade-offs from a Total Survey Error perspective.

Appendix

Table A1. Variable Distributions in Percentages, by Wave

Administrative Variables	Wave 1		Wave 2		Wave 3		Wave 4		Wave 5	
	Sam	Cov	Sam	Cov	Sam	Cov	Sam	Cov	Sam	Cov
Sex										
Female	28.74	28.32	29.72	29.24	29.94	29.56	24.12	25.03	29.01	29.06
Male	71.26	71.68	70.28	70.76	70.06	70.44	75.88	74.97	70.99	70.94
Age										
<30	11.26	12.76	11.60	14.12	9.73	11.22	10.10	13.66	11.97	12.96
30–39	19.63	20.19	20.51	22.16	21.94	23.85	24.92	30.10	24.50	27.10
40–49	30.34	29.00	27.30	25.23	24.71	23.86	24.99	23.80	22.59	22.93
50–59	31.32	30.56	31.25	29.53	31.78	29.87	32.08	25.63	28.69	25.99
60+	7.45	7.50	9.35	8.97	11.83	11.20	7.91	6.81	12.25	11.02
German Citizenship										
Yes	94.18	95.47	93.52	94.38	92.68	93.54	92.40	92.78	88.39	90.45
No	5.82	4.53	6.48	5.62	7.32	6.46	7.60	7.22	11.61	9.55
Secondary Education										
Less than university entrance	72.66	73.67	71.66	72.34	68.81	70.28	64.41	65.89	66.20	67.53
University entrance	27.34	26.33	28.34	27.66	31.19	29.72	35.59	34.11	33.80	32.47
Higher education										
Less than university degree	84.64	85.77	84.48	85.35	82.38	83.90	75.02	77.72	81.64	83.53
University degree	15.36	14.23	15.52	14.65	17.62	16.10	24.98	22.28	18.36	16.47
Employment contract										
Full-time	85.60	85.25	86.60	86.19	86.30	85.77	89.30	88.92	83.81	82.70
Part-time	14.40	14.75	13.40	13.81	13.70	14.23	10.70	11.08	16.19	17.30
Daily earnings										
<86	38.00	43.02	35.01	40.31	37.78	44.20	17.70	23.21	32.40	37.40
86–131	36.67	35.37	37.03	35.86	33.99	33.13	20.74	23.54	31.84	33.38
132+	25.34	21.62	27.95	23.84	28.24	22.67	61.56	53.25	35.77	29.22
Years employer										

<5	19.94	23.49	22.42	26.77	18.51	22.26	19.34	25.64	29.69	34.00
5–9	23.22	26.00	22.51	25.52	22.80	27.04	21.72	28.36	24.64	28.14
10–19	32.55	29.61	30.00	27.65	31.39	30.55	25.27	26.23	24.00	24.55
20+	24.29	20.90	25.08	20.06	27.31	20.15	33.67	19.76	21.67	13.32
Occupation										
Production	45.56	46.33	43.69	43.94	43.80	44.53	52.48	52.05	40.73	41.39
Business/Administration	25.06	24.06	26.67	25.25	26.56	24.14	24.38	22.05	24.72	22.68
Other	29.38	29.61	29.64	30.82	29.64	31.32	23.14	25.91	34.55	35.93
Benefits last 10 years										
No	72.48	63.11	72.04	62.23	74.39	62.70	81.22	68.83	71.84	59.81
Yes	27.52	36.89	27.96	37.77	25.61	37.30	18.78	31.17	28.16	40.19
Job seeking last 10 years										
No	60.98	49.85	59.21	46.02	60.73	45.27	69.03	49.75	58.61	42.40
Yes	39.02	50.15	40.79	53.98	39.27	54.73	30.97	50.25	41.39	57.60
Region										
North	15.90	16.66	14.90	15.05	16.09	15.83	36.89	34.48	24.19	24.12
West	33.14	31.56	35.04	33.26	27.03	25.61	15.15	15.37	26.99	26.36
South	25.47	24.92	25.54	25.02	30.63	29.59	32.14	30.37	23.74	21.21
East	25.48	26.86	24.53	26.67	26.24	28.97	15.82	19.78	25.09	28.31
Urbanicity										
<5,000	16.58	18.21	15.89	17.11	15.37	17.10	15.65	15.58	16.52	17.12
5,000–19,999	33.65	35.65	32.92	34.56	33.11	35.36	31.88	33.66	31.73	32.57
20,000–99,999	25.76	25.75	26.38	25.91	26.50	25.61	20.08	21.03	24.77	24.73
100,000–499,999	12.75	11.00	14.16	12.69	13.14	11.50	22.70	19.86	13.50	12.57
500,000+	11.26	9.39	10.66	9.73	11.88	10.43	9.68	9.87	13.48	13.01
N	43,616	30,659	38,191	26,989	31,374	20,463	24,840	14,393	24,416	16,274

Notes: Sam = Sample, Cov = Covered.

Table A2. Log-Odds Ratios of the Presence of a Known Telephone Number after Controlling for Establishment Size and Sector, by Wave

	Wave 1 Estimate (SE)	Wave 2 Estimate (SE)	Wave 3 Estimate (SE)	Wave 4 Estimate (SE)	Wave 5 Estimate (SE)
Intercept	4.16(.10)***	3.94(.10)***	3.94(.10)***	3.51(.13)***	3.79(.11)***
Sex					
(Ref. Male)					
Female	-0.25(.03)***	-0.32(.03)***	-0.24(.04)***	-0.14(.04)**	-0.10(.04)*
Age					
(Ref. 60+)					
<30	-0.44(.06)***	0.28(.07)***	-0.37(.07)***	0.62(.08)***	-0.26(.07)***
30–39	-0.54(.05)***	-0.30(.05)***	-0.43(.05)***	0.13(.07)	-0.09(.06)
40–49	-0.30(.05)***	-0.33(.05)***	-0.20(.05)***	0.06(.06)	0.16(.06)**
50–59	-0.13(.05)**	-0.12(.04)**	-0.12(.04)**	-0.07(.06)	0.01(.05)
German citizenship					
(Ref. Yes)					
No	-0.86(.05)***	-0.64(.05)***	-0.71(.06)***	-0.80(.07)***	-1.32(.06)***
Secondary education					
(Ref. Less than university entrance)					
University entrance	0.04(.04)	0.06(.04)	-0.01(.04)	-0.05(.05)	0.03(.05)
Higher education					
(Ref. Less than university degree)					
University degree	-0.11(.05)*	-0.09(.05)	-0.09(.05)	-0.26(.06)***	-0.19(.06)***
Employment contract					
(Ref. Part-time)					
Full-time	-0.02(.04)	-0.05(.05)	-0.01(.05)	0.09(.06)	-0.00(.05)
Daily earnings					
(Ref. <86)					
86–131	-0.17(.03)***	-0.23(.04)***	-0.23(.04)***	-0.04(.06)	-0.08(.05)
132+	-0.33(.04)***	-0.29(.05)***	-0.38(.04)***	-0.18(.07)**	-0.36(.05)***
Occupation					
(Ref. Production)					
Business/Administration	0.04(.03)	0.05(.04)	-0.07(.04)	-0.08(.04)	-0.12(.05)**
Other	-0.18(.03)***	-0.01(.04)	-0.08(.04)*	0.03(.04)	-0.10(.04)*
Years working for current employer					

(Ref. <5)					
5–9	0.03(.04)	0.09(.05)*	0.13(.05)**	0.32(.06)***	0.27(.05)***
10–19	-0.10(.04)**	0.01(.04)	0.09(.05)	0.28(.06)***	0.44(.05)***
20+	-0.28(.05)***	-0.25(.05)***	-0.46(.05)***	-0.72(.06)***	-0.64(.06)***
Benefits last 10 years					
(Ref. Yes)					
No	-1.32(.06)***	-0.99(.07)***	-1.34(.07)***	-0.86(.10)***	-1.13(.08)***
Job seeking last 10 years					
(Ref. Yes)					
No	-1.21(.04)***	-1.86(.05)***	-1.65(.04)***	-2.51(.07)***	-2.09(.06)***
Region					
(Ref. North)					
South	-0.12(.04)**	0.07(.04)	0.12(.04)**	-0.07(.04)	-0.05(.05)
West	-0.13(.04)***	0.10(.04)*	0.18(.04)***	-0.12(.05)*	-0.04(.05)
East	-0.33(.04)***	0.06(.05)	0.16(.05)***	0.25(.06)***	0.15(.05)**
Urbanicity					
(Ref. <5,000)					
5,000–19,999	-0.18(.04)***	-0.20(.04)***	-0.18(.04)***	-0.03(.05)	-0.08(.05)
20,000–99,999	-0.42(.04)***	-0.46(.04)***	-0.53(.05)***	-0.27(.05)***	-0.27(.05)***
100,000–499,999	-0.83(.05)***	-0.80(.05)***	-0.78(.05)***	-0.42(.05)***	-0.44(.06)***
500,000+	-1.06(.05)***	-0.86(.05)***	-0.89(.06)***	-0.49(.07)***	-0.52(.06)***
N	41,901	38,191	31,374	24,840	24,416
AIC	42717.18	37163.81	32073.4	24986.61	23168.05
BIC	42950.54	37394.67	32307.3	25205.85	23386.83
Wald-Test (x^2)	5006.74	5353.88	4778.87	4469.25	4413.67
Wald-Test (p-value)	<0.00	<0.00	<0.00	<0.00	<0.00
Random intercept (establishment)	.0114	.0058	.0052	.0172	.0161
ICC (empty model)	.0061	.0018	.0025	.0052	.0049

Significance level: *** 0.001; ** 0.01; * 0.05

Note: The results are obtained from fitting multilevel logistic regressions accounting for nesting of employees within establishments controlling for establishment-level variables (establishment size and sector). SE = standard error, ICC = intraclass correlation.

Table A3. Multinomial Log-Odds Ratios of the Presence of a Known Telephone Number Originating from the BA or infas vs. No Known Telephone Number (waves 1 to 3)

	Wave 1		Wave 2		Wave 3	
	BA-Number	infas-Number	BA-Number	infas-Number	BA-Number	infas-Number
	Estimate (SE)	Estimate (SE)	Estimate (SE)	Estimate (SE)	Estimate (SE)	Estimate (SE)
Intercept	3.67(.13)***	2.04(.11)***	4.26(.15)***	0.05(.17)	3.60(.14)***	-0.42(.16)**
Sex						
(Ref. Male)						
Female	-0.16(.05)***	-0.27(.04)***	-0.25(.05)***	-0.39(.04)***	-0.09(.05)	-0.28(.05)***
Age						
(Ref. 60+)						
<30	0.26(.09)**	-0.91(.07)***	1.06(.10)***	-0.77(.10)***	-0.06(.11)	-0.90(.10)***
30–39	0.04(.08)	-0.74(.06)***	0.39(.08)***	-1.06(.07)***	0.02(.08)	-1.27(.08)***
40–49	-0.02(.07)	-0.33(.05)***	0.05(.07)	-0.58(.05)***	0.22(.07)**	-0.58(.06)***
50–59	0.07(.07)	-0.16(.05)***	0.08(.07)	-0.22(.05)***	0.01(.06)	-0.24(.05)***
German citizenship						
(Ref. Yes)						
No	-0.59(.07)***	-0.95(.07)***	-0.57(.09)***	-0.81(.07)***	-0.60(.10)***	-0.86(.10)***
Secondary education						
(Ref. Less than university entrance)						
University entrance	0.15(.06)**	-0.02(.04)	0.15(.06)**	0.00(.05)	0.57(.06)	-0.07(.05)
Higher education						
(Ref. Less than university degree)						
University degree	-0.08(.06)	-0.00(.05)	-0.08(.06)	-0.08(.05)	-0.13(.06)	.0.04(.07)
Employment contract						
(Ref. Part-time)						
Full-time	0.03(.06)	-0.06(.05)	0.21(.07)**	-0.30(.06)***	0.13(.07)	-0.18(.07)*
Daily earnings						
(Ref. <86)						
86–131	-0.30(.05)***	-0.09(.04)*	-0.35(.06)***	-0.00(.05)	-0.26(.05)***	-0.11(.05)*
132+	-0.75(.07)***	-0.06(.05)	-0.91(.07)***	0.16(.06)**	-0.80(.07)***	0.01(.06)
Occupation						
(Ref. Production)						
Business/Administration	-0.11(.05)*	0.05(.04)	-0.06(.05)	0.08(.04)	-0.14(.05)**	-0.02(.05)
Other	-0.17(.05)**	-0.15(.03)***	0.03(.05)	-0.07(.04)	-0.09(.05)	-0.15(.05)**

Years working for current employer						
(Ref. <5)						
5–9	-0.02(.06)	0.15(.05)**	0.16(.07)*	0.20(.07)**	0.16(.07)*	0.18(.09)*
10–19	-0.30(.06)***	0.14(.05)**	-0.09(.06)	0.24(.06)***	0.12(.07)	0.27(.08)***
20+	-1.53(.09)***	0.24(.06)***	-1.73(.08)***	0.45(.07)***	-1.94(.08)***	0.46(.08)***
Benefits last 10 years						
(Ref. Yes)						
No	-1.50(.07)***	-0.66(.07)***	-1.24(.10)***	0.41(.14)**	-1.23(.08)***	0.60(.13)***
Job seeking last 10 years						
(Ref. Yes)						
No	-2.42(.06)***	-0.18(.05)***	-3.08(.07)***	0.08(.08)	-2.45(.06)***	0.13(.07)
Region						
(Ref. North)						
South	-0.04(.09)	-0.09(.07)	-0.07(.09)	0.20(.07)**	-0.09(.08)	0.24(.08)**
West	-0.19(.08)*	-0.02(.06)	-0.07(.08)	0.28(.07)***	0.03(.08)	0.32(.08)***
East	0.18(.08)*	-0.50(.07)***	0.52(.09)***	-0.28(.08)***	0.48(.08)***	-0.30(.09)***
Urbanicity						
(Ref. <5,000)						
5,000–19,999	-0.14(.05)**	-0.23(.04)***	-0.16(.06)**	-0.22(.05)***	-0.12(.06)	-0.24(.05)***
20,000–99,999	-0.30(.06)***	-0.50(.05)***	-0.26(.06)***	-0.61(.05)***	-0.32(.06)***	-0.72(.06)***
100,000–499,999	-0.52(.07)***	-0.92(.06)***	-0.53(.08)***	-0.97(.06)***	-0.32(.08)***	-1.09(.07)***
500,000+	-0.74(.08)***	-1.15(.07)***	-0.50(.08)***	-1.16(.07)***	-0.49(.09)***	-1.24(.07)***
N	43,616		38,191		31,374	
AIC	65827.33		48823.01		42674.87	
BIC	66296.22		49284.73		43125.97	
Wald-Test (x^2)	9109.07		7943.71		9513.26	
Wald-Test (p-value)	0.000		0.000		0.000	
ICC (empty model)	0.05		0.01		0.02	

Significance level: *** 0.001; ** 0.01; * 0.05

Note: The results are obtained from fitting multinomial regressions accounting for nesting of employees within establishments. Controlled for Establishment number. SE = standard error, ICC = intraclass correlation.

Table A4. Multinomial Log-Odds Ratios of the Presence of a Known Telephone Number Originating from the BA or infas vs. No Known Telephone Number (waves 4 to 5)

	Wave 4		Wave 5	
	BA-Number	infas-Number	BA-Number	infas-Number
	Estimate (SE)	Estimate (SE)	Estimate (SE)	Estimate (SE)
Intercept	3.14(.15)***	-1.06(.34)**	3.36(.12)***	-1.42(.24)***
Sex				
(Ref. Male)				
Female	-0.33(.06)	-0.27(.06)***	-0.31(.05)	-0.12(.07)
Age				
(Ref. 60+)				
<30	1.16(.16)***	-0.62(.12)***	-0.07(.10)	-0.58(.12)***
30–39	0.68(.11)***	-1.19(.09)***	0.21(.09)*	-1.09(.11)***
40–49	0.61(.10)***	-0.64(.06)***	0.52(.08)***	-0.74(.09)***
50–59	0.07(.08)	-0.20(.06)***	0.12(.08)	-0.21(.07)**
German citizenship				
(Ref. Yes)				
No	-0.86(.10)***	-0.70(.11)***	-1.29(.09)***	-1.49(.15)***
Secondary education				
(Ref. Less than university entrance)				
University entrance	-0.03(.10)	-0.14(.08)	0.03(.06)	-0.03(.08)
Higher education				
(Ref. Less than university degree)				
University degree	-0.35(.18)	-0.09(.09)	-0.22(.06)**	-0.01(.09)
Employment contract				
(Ref. Part-time)				
Full-time	0.20(.07)**	-0.20(.07)**	0.15(.07)*	-0.21(.08)
Daily earnings				
(Ref. <86)				
86–131	0.05(.08)	-0.04(.10)	-0.05(.07)	0.05(.09)
132+	-0.19(.15)	0.14(.10)	-0.55(.08)***	0.24(.09)*
Occupation				
(Ref. Production)				

Business/Administration	-0.17(.05)**	0.03(.05)	-0.15(.06)**	-0.16(.07)*
Other	0.06(.07)	-0.11(.05)*	-0.11(.06)	-0.21(.07)**
Years working for current employer				
(Ref. <5)				
5–9	0.37(.08)***	0.29(.13)*	0.30(.07)***	0.27(.11)*
10–19	0.35(.10)***	0.27(.09)**	0.54(.09)***	0.44(.11)***
20+	-1.58(.12)***	0.52(.09)***	-1.31(.09)***	0.52(.11)***
Benefits last 10 years				
(Ref. Yes)				
No	-0.68(.13)***	-0.22(.42)	-1.01(.10)***	0.47(.24)
Job seeking last 10 years				
(Ref. Yes)				
No	-3.12(.12)***	0.38(.18)*	-2.40(.08)***	0.10(.14)
Region				
(Ref. North)				
South	-0.21(.03)***	0.30(.09)**	-0.07(.09)	0.43(.09)***
West	-0.30(.08)***	0.24(.09)***	-0.13(.08)	0.39(.10)***
East	0.43(.11)***	-0.47(.12)***	0.38(.08)***	-0.26(.11)**
Urbanicity				
(Ref. <5,000)				
5,000–19,999	0.06(.11)	-0.12(.11)	-0.07(.06)	-0.10(.06)
20,000–99,999	-0.06(15)	-0.58(.15)***	-0.09(.06)	-0.63(0.8)***
100,000–499,999	-0.12(.11)	-0.94(.13)***	-0.11(.07)	-1.14(.10)***
500,000+	-0.29(.09)**	-0.87(.16)***	-0.29(.09)**	-1.24(.12)***
N	24,840		24,416	
AIC	31377.01		29842.40	
BIC	31815.50		30279.96	
Wald-Test (x^2)	13635.70		5068.75	
Wald-Test (p-value)	0.000		0.000	
ICC (empty model)	0.00		0.02	

Significance level: *** 0.001; ** 0.01; * 0.05

Note: The results are obtained from fitting multinomial regressions accounting for nesting of employees within establishments. Controlled for Establishment number. SE = standard error, ICC = intraclass correlation.

Table A5. Estimates of Coverage Bias (CB), Absolute Coverage Bias (ACB) for Each Variable Category and Different Telephone Number Sources (wave 1 to 3)

Administrative variables	Wave 1				Wave 2				Wave 3			
	BA only		BA & infas		BA only		BA & infas		BA only		BA & infas	
	CB (%)	ACB (%)	CB (%)	ACB (%)	CB (%)	ACB (%)	CB (%)	ACB (%)	CB (%)	ACB (%)	CB (%)	ACB (%)
Sex												
Female	1.93	1.93	-0.42	0.42	1.53	1.53	-0.48	0.48	1.23	1.23	-0.38	0.38
Age												
<30	8.90	8.90	1.50	1.50	7.30	7.30	2.52	2.52	4.38	4.38	1.49	1.49
30–39	8.39	8.39	0.56	0.56	7.96	7.96	1.65	1.65	8.39	8.39	1.91	1.91
40–49	-5.52	5.52	-1.34	1.34	-3.73	3.73	-2.07	2.07	-0.53	0.53	-0.85	0.85
50–59	-9.32	9.32	-0.76	0.76	-8.45	8.45	-1.72	1.72	-8.21	8.21	-1.91	1.91
60+	-2.45	2.45	0.05	0.05	-3.10	3.10	-0.38	0.38	-4.02	4.02	-0.63	0.63
German citizenship												
No	-0.03	0.03	-1.29	1.29	0.16	0.16	-0.86	0.86	0.37	0.37	-0.86	0.86
Secondary education												
University entrance	-0.17	0.17	-1.01	1.01	0.23	0.23	-0.68	0.68	-0.44	0.44	-1.47	1.47
Higher education												
University degree	-1.67	1.67	-1.13	1.13	-1.00	1.00	-0.87	0.87	-1.67	1.67	-1.52	1.52
Employment contract												
Full-time	-1.43	1.43	-0.35	0.35	-1.07	1.07	-0.41	0.41	-1.12	1.12	-0.53	0.53
Daily earnings												
<86	20.61	20.61	5.02	5.02	14.91	14.91	5.30	5.30	14.14	14.14	6.42	6.42
86–131	-5.98	5.98	-1.30	1.30	-1.96	1.96	-1.17	1.17	-1.06	1.06	-0.86	0.86
132+	-14.64	14.64	-3.72	3.72	-12.94	12.94	-4.11	4.11	-13.09	13.09	-5.57	5.57
Occupation												
Production	-0.28	0.28	0.77	0.77	-1.09	1.09	0.25	0.25	-0.39	0.39	0.73	0.73

Business/Administration	-4.74	4.74	-1.00	1.00	-3.60	3.60	-1.42	1.42	-4.80	4.80	-2.42	2.42
Other	5.02	5.02	0.23	0.23	4.69	4.69	1.18	1.18	5.19	5.19	1.68	1.68
Years working for employer												
<5	17.23	17.23	3.55	3.55	13.68	13.68	4.35	4.35	10.15	10.15	3.75	3.75
5–10	12.59	12.59	2.78	2.78	8.94	8.94	3.01	3.01	10.96	10.96	4.24	4.24
10–19	-10.41	10.41	-2.94	2.94	-4.24	4.24	-2.35	2.35	-0.49	0.49	-0.84	0.84
20+	-19.40	19.40	-3.39	3.39	-18.38	18.38	-5.02	5.02	-20.64	20.64	-7.16	7.16
Benefits last 10 years												
No	-37.11	37.11	-9.37	9.37	-25.78	25.78	-9.81	9.81	-25.78	25.78	-11.69	11.69
Job seeking last 10 years												
No	-44.20	44.20	-11.13	11.13	-34.36	34.36	-13.19	13.19	-34.11	34.11	-15.46	15.46
Region												
North	0.97	0.97	0.76	0.76	1.44	1.44	0.15	0.15	0.61	0.61	-0.26	0.26
West	-7.26	7.26	-1.58	1.58	-5.98	5.98	-1.78	1.78	-3.98	3.98	-1.42	1.42
South	-4.19	4.19	-0.55	0.55	-3.35	3.35	-0.52	0.52	-4.84	4.84	-1.04	1.04
East	10.48	10.48	1.38	1.38	7.88	7.88	2.14	2.14	8.21	8.21	2.73	2.73
Urbanicity												
<5,000	-0.54	0.54	1.63	1.63	-0.59	0.59	1.22	1.22	0.23	0.23	1.73	1.73
5,000–19,000	0.34	0.34	2.00	2.00	0.24	0.24	1.64	1.64	0.50	0.50	2.25	2.25
20,000–99,000	-0.19	0.19	-0.01	0.01	-0.01	0.01	-0.47	0.47	-0.33	0.33	-0.89	0.89
100,000–499,000	-0.45	0.45	-1.75	1.75	-0.67	0.67	-1.47	1.47	-0.80	0.80	-1.64	1.64
500,000+	0.84	0.84	-1.87	1.87	1.03	1.03	-0.93	0.93	0.41	0.41	-1.45	1.45

Table A6. Estimates of Coverage Bias (CB), Nonresponse Bias (NB) and Total Selection Bias (TSB) for Each Variable Category (wave 1 to 3)

Administrative Variables	**Wave 1**						**Wave 2**						**Wave 3**					
	Sam	Cov	Res	CB	NB	TSB	Sam	Cov	Res	CB	NB	TSB	Sam	Cov	Res	CB	NB	TSB
Sex																		
Female	28.74	28.32	27.76	-0.42	-0.56	-0.98	29.72	29.24	29.95	-0.48	0.71	0.23	29.94	29.56	30.08	-0.38	0.52	0.14
Age																		
<30	11.26	12.76	9.88	1.50	-2.88	-1.38	11.60	14.12	10.57	2.52	-3.55	-1.00	9.73	11.22	7.95	1.49	-3.27	-1.80
30–39	19.63	20.19	15.70	0.56	-4.49	-3.93	20.51	22.16	17.07	1.65	-5.09	-3.40	21.94	23.85	17.92	1.91	-5.93	-4.00
40–49	30.34	29.00	30.39	-1.34	1.39	0.05	27.30	25.23	25.48	-2.07	0.25	-1.80	24.71	23.86	21.52	-0.85	-2.34	-3.20
50–59	31.32	30.56	36.15	-0.76	5.59	4.83	31.25	29.53	36.90	-1.72	7.37	5.65	31.78	29.87	39.60	-1.91	9.73	7.82
60+	7.45	7.50	7.88	0.05	0.38	0.43	9.35	8.97	9.97	-0.38	1.00	0.62	11.83	11.20	13.00	-0.63	1.80	1.17
German citizenship																		
No	5.82	4.53	2.88	-1.29	-1.65	-2.94	6.48	5.62	2.98	-0.86	-2.64	-3.50	7.32	6.46	3.27	-0.86	-3.19	-4.10
Secondary education																		
University entrance	27.34	26.33	31.22	-1.01	4.89	3.88	28.34	27.66	33.58	-0.68	5.92	5.24	31.19	29.72	37.51	-1.47	7.79	6.32
Higher education																		
University degree	15.36	14.23	18.11	-1.13	3.88	2.75	15.52	14.65	19.90	-0.87	5.25	4.38	17.62	16.10	23.38	-1.52	7.28	5.76
Employment contract																		
Full-time	85.60	85.25	85.54	-0.35	0.29	-0.06	86.60	86.19	85.45	-0.41	-0.74	-1.10	86.30	85.77	85.39	-0.53	-0.38	-0.90
Daily earnings																		
<86	38.00	43.02	36.22	5.02	-6.80	-1.78	35.01	40.31	34.52	5.30	-5.79	-0.50	37.78	44.20	36.90	6.42	-7.30	-0.90
86–131	36.67	35.37	35.14	-1.30	-0.23	-1.53	37.03	35.86	34.45	-1.17	-1.41	-2.60	33.99	33.13	31.93	-0.86	-1.20	-2.10
132+	25.34	21.62	28.64	-3.72	7.02	3.30	27.95	23.84	31.02	-4.11	7.18	3.07	28.24	22.67	31.17	-5.57	8.50	2.93
Occupation																		
Production	45.56	46.33	46.51	0.77	0.18	0.95	43.69	43.94	43.33	0.25	-0.61	-0.40	43.80	44.53	45.98	0.73	1.45	2.18
Business/ Administration	25.06	24.06	27.39	-1.00	3.33	2.33	26.67	25.25	28.82	-1.42	3.57	2.15	26.56	24.14	28.83	-2.42	4.69	2.27
Other	29.38	29.61	26.10	0.23	-3.51	-3.28	29.64	30.82	27.85	1.18	-2.97	-1.80	29.64	31.32	25.19	1.68	-6.13	-4.50
Years working for employer																		
<5	19.94	23.49	20.15	3.55	-3.34	0.21	22.42	26.77	23.80	4.35	-2.97	1.38	18.51	22.26	18.77	3.75	-3.49	0.26
5–9	23.22	26.00	25.07	2.78	-0.93	1.85	22.51	25.52	24.52	3.01	-1.00	2.01	22.80	27.04	25.07	4.24	-1.97	2.27
10–19	32.55	29.61	29.99	-2.94	0.38	-2.56	30.00	27.65	26.23	-2.35	-1.42	-3.80	31.39	30.55	29.71	-0.84	-0.84	-1.70
20+	24.29	20.90	24.79	-3.39	3.89	0.50	25.08	20.06	25.45	-5.02	5.39	0.37	27.31	20.15	26.44	-7.16	6.29	-0.90

Benefits last 10 years																	
No	72.48	63.11	69.78	-9.39	6.67	-2.70	72.04	62.23	68.15	-9.81	5.92	-3.90	74.39	62.70	71.01	-11.69	8.31	-3.40
Job seeking last 10 years																	
No	60.98	49.85	55.93	-11.13	6.08	-5.05	59.21	46.02	50.95	-13.19	4.93	-8.30	60.73	45.27	52.64	-15.46	7.37	-8.10
Region																	
North	15.90	16.66	15.96	0.76	-0.70	0.06	14.90	15.05	13.38	0.15	-1.67	-1.50	16.09	15.83	14.98	-0.26	-0.85	-1.10
West	33.14	31.56	31.22	-1.58	-0.34	-1.92	35.04	33.26	33.63	-1.78	0.37	-1.40	27.03	25.61	25.43	-1.42	-0.18	-1.60
South	25.47	24.92	26.66	-0.55	1.74	1.19	25.54	25.02	25.60	-0.52	0.58	0.06	30.63	29.59	31.25	-1.04	1.66	0.62
East	25.48	26.86	26.16	1.38	-0.70	0.68	24.53	26.67	27.40	2.14	0.73	2.87	26.24	28.97	28.34	2.73	-0.63	2.10
Urbanicity																	
<5,000	16.58	18.21	20.50	1.63	2.29	3.92	15.89	17.11	19.73	1.22	2.62	3.84	15.37	17.10	18.41	1.73	1.31	3.04
5,000–19,999	33.65	35.65	37.40	2.00	1.75	3.75	32.92	34.56	34.42	1.64	-0.14	1.50	33.11	35.36	37.30	2.25	1.94	4.19
20,000–99,999	25.76	25.75	24.14	-0.01	-1.61	-1.62	26.38	25.91	25.25	-0.47	-0.66	-1.10	26.50	25.61	23.62	-0.89	-1.99	-2.90
100,000–499,999	12.75	11.00	10.05	-1.75	-0.95	-2.70	14.16	12.69	11.75	-1.47	-0.94	-2.40	13.14	11.50	10.78	-1.64	-0.72	-2.40
500,000+	11.26	9.39	7.91	-1.87	-1.48	-3.35	10.66	9.73	8.85	-0.93	-0.88	-1.80	11.88	10.43	9.89	-1.45	-0.54	-2.00
N	43,616	30,659	7,499				38,191	26,989	4,000				31,374	20,463	2,477			

Note: Sam = Sample, Cov = Covered, Res = Respondents, CB = Coverage Bias, NB = Nonresponse Bias, TSB = Total Selection Bias.

Table A7. Estimates of Coverage Bias (CB), Nonresponse Bias (NB) and Total Selection Bias (TSB) for Each Variable Category and Survey Design (telephone single-mode vs. web starting mode and web-telephone mixed-mode design, wave 4)

Administrative Variables	Telephone single-mode						Web starting mode						Web-telephone mixed-mode design					
	Sam	Cov	Res	CB	NB	TSB	Sam	Cov	Res	CB	NB	TSB	Sam	Cov	Res	CB	NB	TSB
Sex																		
Female	24.04	25.02	26.48	0.98	1.46	2.44	24.20	24.20	21.56	0	-2.64	-2.64	24.20	24.20	23.15	0	-1.05	-1.05
Age																		
<30	10.23	13.84	7.33	3.61	-6.51	-2.90	9.98	9.98	6.85	0	-3.13	-3.13	9.98	9.98	6.93	0	-3.05	-3.05
30–39	24.94	30.23	29.08	5.29	-1.15	4.14	24.90	24.90	21.42	0	-3.48	-3.48	24.90	24.90	21.88	0	-3.02	-3.02
40–49	24.80	23.57	21.28	-1.23	-2.29	-3.52	25.19	25.19	22.95	0	-2.24	-2.24	25.19	25.19	22.92	0	-2.27	-2.27
50–59	32.15	25.76	34.28	-6.39	8.52	2.13	32.00	32.00	39.59	0	7.59	7.59	32.00	32.00	38.80	0	6.80	6.80
60+	7.89	6.60	8.04	-1.29	1.44	0.15	7.93	7.93	9.18	0	1.25	1.25	7.93	7.93	9.47	0	1.54	1.54
German citizenship																		
No	7.41	7.00	4.49	-0.41	-2.51	-2.92	7.79	7.79	3.13	0	-4.66	-4.66	7.79	7.79	3.35	0	-4.44	-4.44
Secondary education																		
University entrance	35.81	34.38	45.15	-1.43	10.77	9.34	35.37	35.37	53.29	0	17.92	17.92	35.37	35.37	51.62	0	16.30	16.25
Higher education																		
University degree	25.27	22.61	33.10	-2.66	10.49	7.83	24.69	24.69	41.25	0	16.56	16.56	24.69	24.69	39.95	0	15.26	15.26
Employment contract																		
Full-time	89.32	89.04	86.05	-0.28	-2.99	-3.27	89.28	89.28	92.02	0	2.74	2.74	89.28	89.28	91.11	0	1.83	1.83
Daily earnings																		
<86	17.71	23.26	20.09	5.55	-3.17	2.38	17.70	17.70	8.05	0	-9.65	-9.65	17.70	17.70	10.05	0	-7.65	-7.65
86–131	20.80	23.65	21.75	2.85	-1.90	0.95	20.68	20.68	17.30	0	-3.38	-3.38	20.68	20.68	18.07	0	-2.61	-2.61
132+	61.50	53.09	58.16	-8.41	5.07	-3.34	61.62	61.62	74.65	0	13.03	13.03	61.62	61.62	71.88	0	10.26	10.26
Occupation																		
Production	52.48	52.12	49.17	-0.36	-2.95	-3.31	52.48	52.48	49.17	0	-3.31	-3.31	52.48	52.48	49.02	0	-3.46	-3.46
Business/ Administration	24.24	21.98	25.77	-2.26	3.79	1.53	24.53	24.53	33.47	0	8.94	8.94	24.53	24.53	32.22	0	7.69	7.69
Other	23.29	25.90	25.06	2.61	-0.84	1.77	22.99	22.99	17.37	0	-5.62	-5.62	22.99	22.99	18.76	0	-4.23	-4.23
Years working for employer																		
<5	19.64	25.97	25.53	6.33	-0.44	5.89	19.04	19.04	13.31	0	-5.73	-5.73	19.04	19.04	14.15	0	-4.89	-4.89
5–9	21.47	27.80	23.88	6.33	-3.92	2.41	21.98	21.98	19.56	0	-2.42	-2.42	21.98	21.98	21.88	0	-0.10	-0.10
10–19	25.56	26.62	24.35	1.06	-2.27	-1.21	24.98	24.98	27.61	0	2.63	2.63	24.98	24.98	26.50	0	1.52	1.52
20+	33.33	19.61	26.24	-13.72	6.63	-7.09	34.00	34.00	39.52	0	5.52	5.52	34.00	34.00	37.47	0	3.47	3.47

Benefits last 10 years																	
No	81.04	68.50	74.23	-12.54	5.73	-6.81	81.40	81.40	91.28	0	9.88	9.88	81.40	81.40	88.22	0	6.82	6.82
Job seeking last 10 years																	
No	68.74	49.35	52.48	-19.39	3.13	-16.26	69.33	69.33	80.97	0	11.64	11.64	69.33	69.33	76.56	0	7.23	7.23
Region																	
North	36.47	33.99	31.21	-2.48	-2.78	-5.26	37.31	37.31	36.39	0	-0.92	-0.92	37.31	37.31	35.62	0	-1.69	-1.69
West	15.36	15.44	17.97	0.08	2.53	2.61	14.94	14.94	13.31	0	-1.63	-1.63	14.94	14.94	13.80	0	-1.14	-1.14
South	31.92	30.12	32.15	-1.80	2.03	0.23	32.35	32.35	35.60	0	3.25	3.25	32.35	32.35	34.82	0	2.47	2.47
East	16.24	20.45	18.68	4.21	-1.77	2.44	15.39	15.39	14.70	0	-0.69	-0.69	15.39	15.39	15.76	0	0.37	0.37
Urbanicity																	
<5,000	15.70	15.85	17.26	0.15	1.41	1.56	15.60	15.60	14.84	0	-0.76	-0.76	15.60	15.6	15.07	0	-0.53	-0.53
5,000–19,999	31.80	33.46	34.52	1.66	1.06	2.72	31.97	31.97	31.80	0	-0.17	-0.17	31.97	31.97	32.39	0	0.42	0.42
20,000–99,999	20.59	21.80	20.57	1.21	-1.23	-0.02	19.58	19.58	19.83	0	0.25	0.25	19.58	19.58	19.75	0	0.17	0.17
100,000–499,999	22.52	19.31	18.68	-3.21	-0.63	-3.84	22.88	22.88	26.28	0	3.40	3.40	22.88	22.88	25.35	0	2.47	2.47
500,000+	9.40	9.57	8.98	0.17	-0.59	-0.42	9.96	9.96	7.25	0	-2.71	-2.71	9.96	9.96	7.45	0	-2.51	-2.51
N	12,420	7,197	423				12,420	12,420	1,503				12,420	12,420	1,732			

Note: Sam = Sample, Cov = Covered, Res = Respondents, CB = Coverage Bias, NB = Nonresponse Bias, TSB = Total Selection Bias.

Table A8. Estimates of Coverage Bias (CB), Nonresponse Bias (NB) and Total Selection Bias for Each Variable Category and Survey Design (telephone single-mode vs. web starting mode and web-telephone mixed-mode design, wave 5)

Administrative Variables	Telephone single-mode						Web starting mode						Web-telephone mixed-mode design					
	Sam	Cov	Res	CB	NB	TSB	Sam	Cov	Res	CB	NB	TSB	Sam	Cov	Res	CB	NB	TSB
Sex																		
Female	28.94	28.64	30.96	-0.30	2.32	2.02	29.09	29.09	31.14	0	2.05	2.05	29.09	29.09	30.89	0	1.80	1.80
Age																		
<30	12.11	13.17	8.59	1.06	-4.58	-3.52	11.83	11.83	7.27	0	-4.56	-4.56	11.83	11.83	7.45	0	-4.38	-4.38
30–39	24.63	27.37	20.42	2.74	-6.95	-4.21	24.36	24.36	22.35	0	-2.01	-2.01	24.36	24.36	21.73	0	-2.63	-2.63
40–49	22.79	23.02	23.34	0.23	0.32	0.55	22.38	22.38	22.42	0	0.04	0.04	22.38	22.38	22.30	0	-0.08	-0.08
50–59	28.28	25.61	35.66	-2.67	10.05	7.38	29.11	29.11	34.67	0	5.56	5.56	29.11	29.11	35.32	0	6.21	6.21
60+	12.18	10.84	11.99	-1.34	1.15	-0.19	12.32	12.32	13.29	0	0.97	0.97	12.32	12.32	13.20	0	0.88	0.88
German citizenship																		
No	11.61	9.45	1.94	-2.16	-7.51	-9.67	11.62	11.62	4.15	0	-7.47	-7.47	11.62	11.62	3.75	0	-7.87	-7.87
Secondary education																		
University entrance	33.43	31.90	50.89	-1.53	18.99	17.46	34.16	34.16	52.32	0	18.16	18.16	34.16	34.16	50.11	0	15.95	15.95
Higher education																		
University degree	18.16	16.10	31.44	-2.06	15.34	13.28	18.55	18.55	32.46	0	13.91	13.91	18.55	18.55	30.72	0	12.17	12.17
Employment contract																		
Full-time	83.99	83.15	82.98	-0.84	-0.17	-1.01	83.62	83.62	85.54	0	1.92	1.92	83.62	83.62	85.44	0	1.82	1.82
Daily earnings																		
<86	32.87	37.91	28.69	5.04	-9.22	-4.18	31.92	31.92	17.51	0	-14.41	-14.41	31.92	31.92	19.40	0	-12.52	-12.52
86–131	31.53	33.13	31.44	1.60	-1.69	-0.09	32.15	32.15	28.17	0	-3.98	-3.98	32.15	32.15	29.47	0	-2.68	-2.68
132+	35.60	28.96	39.87	-6.64	10.91	4.27	35.93	35.93	54.33	0	18.40	18.40	35.93	35.93	51.14	0	15.21	15.21
Occupation																		
Production	39.92	40.70	37.12	0.78	-3.58	-2.80	41.53	41.53	37.77	0	-3.74	-3.74	41.53	41.53	37.77	0	-3.76	-3.76
Business/ Administration	25.03	23.03	32.41	-2.00	9.38	7.38	24.41	24.41	34.67	0	10.26	10.26	24.41	24.41	33.16	0	8.75	8.75
Other	35.05	36.27	30.47	1.22	-5.80	-4.58	34.05	34.05	27.54	0	-6.51	-6.51	34.05	34.05	29.07	0	-4.98	-4.98
Years working for employer																		
<5	29.68	34.05	27.07	4.37	-6.98	-2.61	29.69	29.69	19.38	0	-10.31	-10.31	29.69	29.69	21.22	0	-8.47	-8.47
5–9	24.52	28.04	26.74	3.52	-1.30	2.22	24.76	24.76	22.49	0	-2.27	-2.27	24.76	24.76	22.53	0	-2.23	-2.23
10–19	24.05	24.44	26.09	0.39	1.65	2.04	23.95	23.95	28.72	0	4.77	4.77	23.95	23.95	28.27	0	4.32	4.32
20+	21.75	13.47	20.10	-8.28	6.63	-1.65	21.59	21.59	29.41	0	7.82	7.82	21.59	21.59	27.99	0	6.40	6.40

Benefits last 10 years																	
No	71.38	59.07	68.40	-12.31	9.33	-2.98	72.30	72.30	85.40	0	13.10	13.10	72.30	72.30	82.71	0	10.41	10.41
Job seeking last 10 years																	
No	58.50	42.26	50.57	-16.24	8.31	-7.93	58.73	58.73	73.29	0	14.56	14.56	58.73	58.73	68.77	0	10.04	10.04
Region																	
North	23.96	23.83	24.96	-0.13	1.13	1.00	24.42	24.42	22.42	0	-2.00	-2.00	24.42	24.42	21.96	0	-2.46	-2.46
West	26.93	26.33	30.15	-0.60	3.82	3.22	27.04	27.04	27.13	0	0.09	0.09	27.04	27.04	27.36	0	0.32	0.32
South	23.97	21.31	20.26	-2.66	-1.05	-3.71	23.51	23.51	28.65	0	5.14	5.14	23.51	23.51	27.47	0	3.96	3.96
East	25.15	28.53	24.64	3.38	-3.89	-0.51	25.03	25.03	21.80	0	-3.23	-3.23	25.03	25.03	23.21	0	-1.82	-1.82
Urbanicity																	
<5,000	16.40	16.97	17.67	0.57	0.70	1.27	16.64	16.64	15.85	0	-0.79	-0.79	16.64	16.64	16.55	0	-0.09	-0.09
5,000–19,999	31.80	32.53	32.74	0.73	0.21	0.94	31.67	31.67	31.56	0	-0.11	-0.11	31.67	31.67	32.08	0	0.41	0.41
20,000–99,999	25.04	25.25	24.15	0.21	-1.10	-0.89	24.49	24.49	24.15	0	-0.34	-0.34	24.49	24.49	24.18	0	-0.31	-0.31
100,000–499,999	13.56	12.55	12.80	-1.01	0.25	-0.76	13.43	13.43	14.26	0	0.83	0.83	13.43	13.43	13.71	0	0.28	0.28
500,000+	13.20	12.71	12.64	-0.49	-0.07	-0.56	13.76	13.76	14.19	0	0.43	0.43	13.76	13.76	13.48	0	-0.28	-0.28
N	12,209	8,138	617				12,207	12,207	1,445				12,207	12,207	1,758			

Note: Sam = Sample, Cov = Covered, Res = Respondents, CB = Coverage Bias, NB = Nonresponse Bias, TSB = Total Selection Bias.

References

American Association for Public Opinion Research (AAPOR; 2023), *Standard Definitions: Final Dispositions of Case Codes and Outcome Rates for Surveys* (10th ed.), AAPOR: Oakbrook Terrace, IL.

Arbeitskreis Deutscher Markt- und Sozialforschungsinstitute (ADM; 2023), *Marktforschung in Zahlen*, available at https://www.adm-ev.de/die-branche/mafo-zahlen/.

Arcos, A., del Mar Rueda, M., Trujillo, M., and Molina, D. (2015), "Review of Estimation Methods for Landline and Cell Phone Surveys," *Sociological Methods & Research*, 44, 458–485.

Arntz, M., Dengler, K., Dorau, R., Gregory, T., Hartwig, M., Helmrich, R., Lehmer, F., Matthes, B., Tisch, A., Wischniewski S., and Zierahn U. (2020), "Digitalisierung und Wandel der Beschäftigung (DiWaBe): Eine Datengrundlage für die interdisziplinäre Sozialpolitikforschung," Mannheim, pp. 1–92.

Berzelak, N., Vehovar, V., and Manfreda, K. L. (2015), "Web mode as part of mixed-mode surveys of the general population: An approach to the evaluation of costs and errors," *Advances in Methodology and Statistics*, 12, 45–68.

Beukenhorst, D. (2012), "The Netherlands," in *Telephone Surveys in Europe*, eds. S. Häder, M. Häder and M. Kühne, Heidelberg: Springer, pp. 17–24.

Bianchi, A., Biffignandi, S., and Lynn, P. (2017), "Web-Face-to-Face Mixed-Mode Design in a Longitudinal Survey: Effects on Participation Rates, Sample Composition, and Costs," *Journal of Official Statistics*, 33, 385–408.

Biffignandi, S., and Bethlehem, J. G. (2021), *Handbook of Web Surveys* (2nd ed.), Hoboken: John Wiley & Sons.

Blumberg, S. J., and Luke, J. V. (2008), *Wireless substitution: early release of estimates based on data from the National Health Interview Survey, July-December 2007.* National Center for Health Statistics.

Blumberg, S. J., and Luke, J. V. (2022), *Wireless substitution: early release of estimates based on data from the National Health Interview Survey, January-June 2022.* National Center for Health Statistics.

Braunsberger, K., Wybenga, H., and Gates, R. (2007), "A comparison of reliability between telephone and web-based surveys," *Journal of Business Research*, 60, 758–764.

Brick, J. M., and Williams, D. (2013), "Explaining Rising Nonresponse Rates in Cross-Sectional Surveys," *Annals of the American Academy of Political Science*, 645, 36–59.

Couper, M. P. (2017)," New Developments in Survey Data Collection," *Annual Review of Sociology*, 43, 121–145.

Czajka, J. L., and Beyler, A. (2016), *Declining Response Rates in Federal Surveys: Trends and Implications*, Washington, DC: Mathematica Policy Research.

Dal Grande, E., Chittleborough, C. R., Campostrini, S., and Taylor, A. W. (2016), "Bias of health estimates obtained from chronic disease and risk factor surveillance systems using telephone population surveys in Australia: results from a representative face-to-face survey in Australia from 2010 to 2013," *BMC medical research methodology*, 16, 1–13.

Degryse, C. (2016), *Digitalisation of the economy and its impact on labour markets.* Retrieved March 01, 2023, available at https://www.etui.org/publications/working-papers/digitalisation-of-the-economy-and-its-impact-on-labour-markets.

de Leeuw, E. D. (2018), "Mixed-Mode: Past, Present, and Future," Survey Research Methods, 12, 75–89.

Dennis, J. M., Chatt, C., Li, R., Motta-Stanko, A., and Pulliam, P. (2005), *Data collection mode effects controlling for sample origins in a panel survey: Telephone versus internet*, available at https://www.academia.edu/download/48535585/Research-0105.pdf.

Dietrich, H., and Patzina, A. (2023), "Erwerbsverläufe von Personen mit allgemeiner Hochschulreife: Auf den Abschluss kommt es an - Universität im Vergleich zu anderen Hochschulen," *IAB-Kurzbericht*, 2/2023, Nuremberg.

Dillman, D. A. (2017), *The promise and challenge of pushing respondents to the Web in mixed-mode surveys. Survey Methodology*, Statistics Canada, Catalogue No. 12-001-X, 43, available at https://www150.statcan.gc.ca/n1/en/pub/12-001-x/2017001/article/14836-eng.pdf?st=f2oBpwDP.

Dillman, D. A., Phelps, G., Tortora, R., Swift, K., Kohrell, J., Berck, J., and Messer, B. I. (2009), "Response rate and measurement differences in mixed-mode surveys using mail, telephone, interactive voice response (VCR) and the Internet," *Social Science Research*, 38, 1–18.

Dutwin, D., and Buskirk, T. D. (2021), "Telephone Sample Surveys: Dearly Beloved or Nearly Departed? Trends in Survey Errors in the Era of Declining Response Rates," *Journal of Survey Statistics and Methodology*, 9, 353–380.

Dutwin, D., and Lavrakas, P. J. (2016), "Trends in Telephone Outcomes, 2008–2015," *Survey Practice*, 9, 1–9.

European Commission (2021), "European Statistical System Handbook for Quality and Metadata Reports (2021 re-edition)", Luxembourg: Publications Office of the European Union.

Eurostat (2022), "Labour Force Survey in the EU, candidate and EFTA countries: Main characteristics of national surveys 2021," European Union, Luxembourg.

Eurostat (2023), *Level of internet access - households*, available at https://ec.europa.eu/eurostat/databrowser/view/isoc_ci_it_h__custom_11542358/default/table?lang=en.

German Federal Ministry of Labour and Social Affairs (2019), *Zwischenbilanz: Arbeitsqualität Und Wirtschaftlicher Erfolg: Die bisherigen Ergebnisse auf einen Blick*, available at https://www.bmas.de/DE/Service/Publikationen/Broschueren/a892-zwischenbilanz-arbeitsqualitaet-und-wirtschaftlicher-erfolg.htm.

German Federal Office of Statistics (2004), "Ausstattung mit Gebrauchsgütern und Wohsituation privater Haushalte – Ergebnisse der Einkommens- und Verbrauchsstichprobe 2003," *Wirtschaft und Statistik*, 2, 209–227.

German Federal Office of Statistics (2020), *Arbeitskosten in der EU 2019: Deutschland an siebter Stelle*, available at https://www.destatis.de/DE/Presse/Pressemitteilungen/2020/04/PD20_142_624.html.

German Federal Office of Statistics (2021), *Wirtschaftsrechnungen: Laufende Wirtschaftsrechnungen: Ausstattung privater Haushalte mit ausgewählten Gebrauchsgütern*, Fachserie 15 (Reihe 2).

German Post (2019), *Preisänderungen zum 01.07.2019*, available at https://www.deutschepost.de/de/b/briefe-in-deutschland.html.

German Post (2023), *Addressfactory*, available at https://www.deutschepost.de/en/d/deutsche-post-direkt/addressfactory.html.

Gordoni, G., Oren, A., and Shavit, Y. (2011), "Coverage Bias in Telephone Surveys in Israel," *Field Methods,* 23, 188–203.

Greene, J., Speizer, H., and Wiitala, W. (2008), "Telephone and Web: Mixed-Mode Challenge," *Health Services Research,* 43, 230–248.

Groves, R. M., Fowler, F. J., Couper, M., Lepkowski, J. M., Singer, E., and Tourangeau, R. (2009), *Survey Methodology* (2nd ed), Hoboken: John Wiley & Sons.

Groves, R. M. (2006), "Nonresponse Rates and Nonresponse Bias in Household Surveys," *Public Opinion Quarterly*, 70, 646–675.

Gundersen, D. A., Wivagg, J., Young, W. J., Yan, T., and Delnevo, C. D. (2021), "The Use of Multimode Data Collection in Random Digit Dialing Cell Phone Surveys for Young Adults: Feasibility Study," *Journal of medical Internet research*, 23, e31545.

Häder, S., Häder, M., and Kühne, M. (2012), "Introduction: Telephone Surveys in Europe," in *Telephone Surveys in Europe*, eds. S. Häder, M. Häder and M. Kühne, Heidelberg: Springer, pp. 17–24.

Häder, S., and Sand, M. (2019), "Telefonstichproben," in *Telefonumfragen in Deutschland,* eds. S. Häder, M. Häder, and P. Schmich, Wiesbaden: VS Verlag für Sozialwissenschaften, pp. 113–151.

Hall, A., Hünefeld, L., and Rohrbach-Schmidt, D. (2020), "BIBB/BAuA-Erwerbstätigenbefragung 2018 - Arbeit und Beruf im Wandel. Erwerb und Verwertung beruflicher Qualifikationen (SUF)," Bonn: Bundesinstitut für Berufsbildung; Bundesanstalt

für Arbeitsschutz und Arbeitsmedizin; Forschungsdatenzentrum im Bundesinstitut für Berufsbildung (BIBB-FDZ).

Hausner, K. H., Söhnlein, D., Weber, B., and Weber, E. (2015), "Qualifikation und Arbeitsmarkt: Bessere Chancen mit mehr Bildung," *IAB-Kurzbericht*, 11/2015, Nuremberg.

Indeed (2021), *Gehälter pro Stunde bei infas*, available at https://de.indeed.com/cmp/Infas-Institut-F%C3%BCr-Angewandte-Sozialwissenschaft-Gmbh/salaries.

Joye, D., Pollien, A., Sapin, M., and Stähli, M. E. (2012), "Who Can Be Contacted by Phone? Lessons from Switzerland," in *Telephone Surveys in Europe*, eds. S. Häder, M. Häder, and M. Kühne, Heidelberg: Springer, pp. 85–102.

Keeter, S. (2015), *From Telephone to the Web: The Challenge of Mode of Interview Effects in Public Opinion Polls*, available at https://www.pewresearch.org/methods/2015/05/13/from-telephone-to-the-web-the-challenge-of-mode-of-interview-effects-in-public-opinion-polls/.

Keeter, S., Kennedy, C., Dimock, M., Best, J., and Craighill, P. (2006), "Gauging the Impact of Growing Nonresponse on Estimates from a National RDD Telephone Survey," *Public Opinion Quarterly*, 70, 759–779.

Kempf, A. M., and Remington, P. L. (2007), "New challenges for telephone survey research in the twenty-first century," *Annual review of public health*, 28, 113–126.

Kennedy, C., and Hartig, H. (2019), *Response rates in telephone surveys have resumed their decline*, available at https://www.pewresearch.org/fact-tank/2019/02/27/response-rates-in-telephone-surveys-have-resumed-their-decline/.

Klausch, T., Hox, J., and Schouten, B. (2015), "Selection error in single- and mixed mode surveys of the Dutch general population," *Journal of the Royal Statistical Society*, 178, 945–961.

Kreuter, F., Müller, G., and Trappmann, M. (2010), "Nonresponse and Measurement Error in Employment Research: Making Use of Administrative Data," *Public Opinion Quarterly*, 74, 880–906.

Kuusela, V., and Simpanen, M. (2012), "Finland," in *Telephone Surveys in Europe*, eds. S. Häder, M. Häder and M. Kühne, Heidelberg: Springer, pp. 37–45.

Laaksonen, S., and Heiskanen, M. (2014), "Comparison of Three Modes for a Crime Victimization Survey," *Journal of Survey Statistics and Methodology*, 2, 459–483.

Lavrakas, P. J. (2010), "Telephone Surveys," in *Handbook of Survey Research*, eds. P. V. Marsden, and J. D. Wright, Bingley: Emerald Group Publication, pp. 471–498.

Lavrakas, P. J., Benson, G., Blumberg, S., Buskirk, T., Cervantes, I. F., Christian, L., Dutwin, D., Fahimi, M., Fienberg, H., Guterbock, T., Keeter, S., Kelly, S., Kennedy, C., Peytchev, A., Piekarski, L., and Shuttles, C. (2017), "*The Future of U.S. General Population Telephone Survey Research*," AAPOR Task Force, 1–74.

Lee, H., Kim, S., Couper, M. P., and Woo, Y. (2019), "Experimental Comparison of PC Web, Smartphone Web, and Telephone Surveys in the New Technology Era," *Social Science Computer Review*, 37, 234–247.

Legleye, S., and Charrance, G. (2021), "Sequential and Concurrent Internet-Telephone Mixed-Mode Designs in Sexual Health Behavior Research," *Journal of Survey Statistics and Methodology*, 11, 75–99.

Lipps, O., Pekari, N., and Roberts, C. (2015), "Undercoverage and Nonresponse in a List-sampled Telephone Election Survey," *Survey Research Methods*, 9, 71–82.

Lipps, O., and Pekari, N. (2016), "Sample Representation and Substantive Outcomes Using Web With and Without Incentives Compared to Telephone in an Election Survey," *Journal of Official Statistics*, 32, 165–186.

Lovergine, S., and Pellero, A. (2018), "This Time it Might be Different: Analysis of the Impact of Digitalization on the Labour Market," *European Scientific Journal ESJ, 14*, 68–82.

Lüdtke, D., and Schupp, J. (2017), "Wechsel von persönlichen Interviews zu webbasierten Interviews in einem laufenden Haushaltspanel," in *Methodische Probleme von Mixed-Mode-Ansätzen in der Umfrageforschung*, eds. S. Eifler and F. Faulbaum, Wiesbaden: Springer, pp. 141–160.

Lugtig, P., Lensvelt-Mulders, G. J. L. M., Frerichs, R., and Greven, A. (2011), "Estimating Nonresponse Bias and Mode Effects in a Mixed-Mode Survey," *International Journal of Market Research*, 53, 669–686.

Luiten, A., Hox, J., and de Leeuw, E. (2020), "Survey Nonresponse Trends and Fieldwork Effort in the 21st Century: Results of an International Study across Countries and Surveys," *Journal of Official Statistics*, 36, 469–487.

Mackeben, J., Ruf, K., Wolter, S., and Grunau, P. (2023), *LPP survey data linked with administrative data of the IAB (LPP-ADIAB) 1975–2021*, FDZ-Datenreport, 11/2023 (en), Nuremberg.

McGonagle, K. A., and Freedman, V. A. (2017), "The Effects of a Delayed Incentive on Response Rates, Response Mode, Data Quality, and Sample Bias in a Nationally Representative Mixed Mode Study," *Field Methods*, 29, 221–237.

Mohorko, A., Hox, J., and de Leeuw, E. D. (2013), "Coverage Bias in European Telephone Surveys: Developments of Landline and Mobile Phone Coverage across Countries and over Time," Survey *Methods: Insights from the Field*,1–13.

Olson, K. (2021), "Unpacking the black box of survey costs," *Research in Social and Administrative Pharmacy*, 17, 1342–1346.

Olson, K., Wagner, J., and Anderson, R. (2021a), "Survey Costs: Where are We and What is The Way Forward," *Journal of Survey Statistics and Methodology*, 9, 921–945.

Olson, K., Smyth, J. D., Horwitz, R., Keeter, S., Lesser, V., Marken, S., Mathiowetz, N. A., McCarthy, J. S., O'Brien, E., Opsomer, J. D., Steiger, D., Sterrett, D., Su, J., Suzer-Gurtekin, Z. T., Turakhia, C., and Wagner, J. (2021), "Transitions from Telephone Surveys to Self-Administered and Mixed-Mode Surveys: AAPOR Task Force Report," Journal of Survey Statistics and Methodology, 9, 381–411.

Peytchev, A., Carley-Baxter, L. R., and Black, M. C. (2011), "Multiple Sources of Nonobservation Error in Telephone Surveys: Coverage and Nonresponse," *Sociological Methods & Research*, 40, 138–168.

Ruf, K., Mackeben, J., Wolter, S., and Grunau P. (2022), *LPP – Linked Personnel Panel 1221. Quality of work and economic success: longitudinal study in German establishments*. FDZ-Datenreport 06/2022 (en), Nuremberg.

Sala, E., and Lillini, R. (2017), "Undercoverage Bias in Telephone Surveys in Europe: The Italian Case," *International Journal of Public Opinion Research*, 29, 133–156.

Sastry, N., and McGonagle, K. A. (2022), "Switching from Telephone to Web-First Mixed-Mode Data Collection: Results from the Transition into Adulthood Supplement to the US Panel Study of Income Dynamics," *Journal of the Royal Statistical Society, Series A, (Statistics in Society),* 185, 933–954.

Schmucker, A., Seth, S., and vom Berge, P. (2023), *Sample of Integrated Labour Market Biographies (SIAB) 1975-2021.* FDZ-Datenreport 02/2023 (en), Nuremberg.

Schouten, B., van den Brakel, J., Buelens, B., van der Laan, J., and Klausch, T. (2013), "Disentangling mode-specific selection and measurement bias in social surveys," *Social Science Research,* 42, 1555–1570.

Soullier, N., Garras, L., Houot, M., and Pilorget, C. (2023), "Pushing to Web Populations less prone to answer: An adaptive Design in a french Survey on Professional Careers," ESRA Conference, 17–21 June 2023, Milan.

Stata Corp (2019), Stata Statistical Software: Release 16. College Station, TX: Stata Corp LLC.

Stähli, M. E. (2012), "Switzerland," in Telephone Surveys in Europe, eds. S. Häder, M. Häder and M. Kühne, Berlin: Springer, pp. 25–36.

Statistics Denmark (2023), *Labour Force Survey (LFS),* available at https://www.dst.dk/en/Statistik/dokumentation/metode/aku-arbejdskraftundersoegelsen.

Stüber, H. (2022), "Berufsspezifische Lebensentgelte: Ein Studium garantiert nicht immer das höchste Lebensentgelt," *IAB-Kurzbericht,* 18/2022, Nuremberg.

Tourangeau, R., Conrad, F. G., and Couper, M. P. (2013), "Summary and Conclusions," in *The science of Web surveys,* eds. R. Tourangeau, F. G. Conrad, and M. Couper, Oxford: Oxford Univ. Press, pp. 151–172.

Tucker, C., Lepkowski, J. M., and Piekarski, L. (2002), "The Current Efficiency of List-Assisted Telephone Sampling Designs," *Public Opinion Quarterly*, 66, 321–338.

US Census Bureau (2022), *Types of Internet Subscriptions by Selected Characteristics*, available at https://data.census.gov/table?q=S2802&tid=ACSST5Y2020.S2802.

Voorpostel, M., Kuhn, U., Tillmann, R., Monsch, G. A., Antal, E., Ryser, V. A., Lebert, F., Klaas, H. S., and Dasoki, N. (2020), "Introducing web in a refreshment sample of the Swiss Household Panel: Main findings from a pilot study," *FORS Working Paper Series* No. paper 2020-2, Lausanne: FORS.

Voorpostel, M., Lipps, O., and Roberts, C. (2021), "Mixing Modes in Household Panel Surveys: Recent Developments and New Findings," in: *Advances in Longitudinal Survey Methodology*, ed. P. Lynn, Hoboken: John Wily & Sons, pp. 204–226.

Werbewoche (2021), *Printed telephone directory to be discontinued after 142 years - "Yellow Pages" to re-main*, available at https://www.werbewoche.ch/en/medien/mediennutzung/2022-09-14/gedrucktes-telefonbuch-wird-nach-142-jahren-eingestellt-gelbe-seiten-bleiben/.

Woo, Y. J., Kim, S. W., and Couper, M. P. (2015), "Comparing a cell phone survey and a Web survey of university students," *Social Science Computer Review*, 33, 399–410.

Worldbank (2023a), *Fixed telephone subscriptions (per 100 people)*, available at https://data.worldbank.org/indicator/IT.MLT.MAIN.P2.

Worldbank (2023b), *Mobile cellular subscriptions (per 100 people)*, available at https://data.worldbank.org/indicator/IT.CEL.SETS.P2.

6 Conclusion

Following the presentation of my three contributions, this chapter provides a comprehensive conclusion of my dissertation. The central motivation for my dissertation arises from the challenges inherent in telephone surveys: rising survey costs coupled with decreasing coverage and response rates, which heighten the likelihood of coverage and nonresponse biases in the collected data. Table 1 shows the main findings of my dissertation. For clarification, I use the term coverage bias, which refers to the known telephone number coverage bias. As my three dissertation contributions are located several pages above, I will summarize their contents in the following pages. Subsequently, I will discuss the contributions of my dissertation to the existing literature and survey practices, while also addressing important limitations.

Table 1. Main Findings of My Dissertation

		Single-Mode	Mixed-Mode		Study
		Tel	Web	Web-Tel	
Response rates	R	-	+	++	1 & 3
	P	+	-	++	2
Coverage Rates	R	-	++	++	3
Nonresponse Bias	R	++	-	+	1 & 3
	P	++	-	++	2
Coverage Bias	R	-	++	++	3
Selection Bias	R	++	-	+	3
Survey Costs	R	-	++	+	1 & 3
	P	-	++	+	2

Notes: ++ = best performance, + = intermediate performance, - = worst performance, Tel = telephone, R = refreshment sample, P = panel sample.

6.1 First Contribution

My first contribution analyzes the effects of introducing a web starting mode in the wave 4 refreshment sample of an employee telephone survey on nonresponse (rates and bias) and survey costs. 14,393 newly drawn employees with known telephone numbers were randomly allocated to a traditional telephone single-mode (n = 7,197) or a sequential web-telephone mixed-mode design (n = 7,196). By merging the response indicator (0 = no, 1 = yes) to external data of the Institute for Employment Research (IAB), the German Federal Office of Statistics (DESTATIS), and the German Federal Ministry of Transport and Digital Infrastructure (BMVI), we made four main findings. First, the sequential web-telephone mixed-mode design produced the highest response rate, followed by the web starting mode, and the telephone single-mode. Second, aggregate nonresponse bias was highest in the web starting mode, followed by the sequential web-telephone mixed-mode design, and lowest in the telephone single-mode. Third, the likelihood of survey participation varied between a) the telephone and web (single-modes) and b) the telephone single-mode and the web-telephone sequential mixed-mode design for some employee subgroups. For instance, full-time workers were significantly more likely to participate in the web starting mode compared to the telephone single-mode design. Fourth, the web starting mode, followed by the web-telephone mixed-mode design, produced the lowest costs per respondent, while the telephone single-mode had the highest costs.

6.2 Second Contribution

My second contribution examines the effects of introducing a web starting mode into a traditional telephone employee panel survey on nonresponse and survey costs, by randomly dividing wave 4 panel cases to a telephone single-mode design (n = 2,062) and a web-telephone mixed-mode design (n = 3,056). Additionally, my second contribution

conducted an invitation letter experiment by randomly splitting a subgroup of panel cases of the mixed-mode design into two groups (first: *n* = 997, second: *n* = 996). While both groups received invitation letters with links and QR codes, only the second group was informed that telephone calls would start in three weeks if the web survey remained incomplete. By linking the response indicator (0 = no, 1 = yes) to individual data of the IAB, the DESTATIS, and the BMVI, we made five main findings. First, mentioning vs. not mentioning the telephone follow-ups in the invitation letter did not significantly affect response rates and respondent composition in the web starting mode and the web-telephone mixed-mode design. Second, the web-telephone mixed-mode design yielded the highest response rates, followed by the telephone single-mode, and the web starting mode. Third, aggregate nonresponse bias was similar in the telephone single-mode and the web-telephone mixed-mode design and highest in the web single-mode. Fourth, high conscientiousness employees were significantly more likely to respond via web than telephone, whereas former job seekers were more likely to respond via telephone compared to web. None of the other variable categories significantly influenced the likelihood of telephone vs. web and telephone vs. web-telephone participation. Fifth, survey costs per interview were lowest in the web starting mode, followed by the web-telephone mixed-mode design, and highest in the telephone single-mode.

6.3 Third Contribution

My third contribution starts with an examination of known telephone number coverage in the refreshment samples of the LPP employee survey (wave 1: *n* = 43,616, wave 2: *n* = 38,191, wave 3: *n* = 31,374, wave 4: *n* = 24,840, wave 5: *n* = 24,416). Afterwards, my contribution addresses coverage and nonresponse (both rates and bias), total selection bias, and survey costs before (waves 1 to 3) and after (waves 4 to 5) introducing web in

the LPP employee survey. The effects of introducing the web mode into a traditional telephone survey were analyzed by randomly assigning wave 4 and 5 refreshment cases to a telephone single-mode or a web-telephone mixed-mode design. In the single-mode telephone group, employees with unknown telephone numbers were treated as noncovered cases, whereas in the web-telephone mixed-mode design, they were classified as covered by the web mode. By merging the response (0 = no, 1 = yes) and known telephone number indicator (0 = no, 1 = yes) with external data from the IAB and the DESTATIS, three main findings were made. First, known telephone coverage generally declined over the waves and varied across employee subgroups. For instance, individuals not registered as job seekers during the last 10 years and those residing in larger cities were less likely to have a known telephone number compared to their reference groups. Second, for most variable categories in the telephone single-mode, coverage bias and nonresponse bias tended to offset each other, yielding a total selection bias that lies between nonresponse and coverage bias. Third, introducing the web decreased nonresponse rates and survey costs, removed coverage bias, but increased nonresponse bias and total selection bias compared to the telephone single-mode.

6.4 Contribution to the Literature

Despite that a growing number of traditional telephone surveys recently introduced or switched to the web (Olson et al. 2021), only a few studies addressed the effects of introducing the web in an ongoing telephone panel survey (Voorpostel et al. 2020; Biemer et al. 2021). However, none of these studies compared a single-mode telephone survey with a) a web starting mode and b) a sequential web-telephone mixed-mode design in an experimental setting conducted within a traditional employee panel survey. My three dis-

sertation contributions close this research gap by addressing diverse aspects of introducing the web in a telephone panel survey. This chapter relates three primary outcomes of my dissertation to the existing literature.

First, previous studies on refreshment samples (Manfreda et al. 2008; Laaksonen and Heiskanen 2014; Woo et al. 2015; Lipps and Pekari 2016; Lee et al. 2019; Daikeler et al. 2020; Voorpostel et al. 2020; Gundersen et al. 2021) found that web mode yields lower or similar response rates compared to telephone mode. Contrarily, my dissertation shows higher response rates for the refreshment sample (Contributions 1 and 3) in the web starting mode compared to the telephone single-mode. Additionally, research on panel cases has indicated that the traditional interviewer-administered mode has a higher response rate than the web-first mixed-mode design during the initial wave of the mode change (Jäckle et al. 2015; Lüdtke and Schupp 2017). My second contribution reveals a higher response rate for panel cases in the initial wave of the mode change in the web-telephone mixed-mode design compared to the traditional telephone single-mode. The varying outcomes may, in part, be attributed to the population under study. While preceding studies primarily target broader populations, my dissertation concentrates on employees. Employees, especially those who work full-time or commute regularly, represent a busy and hard-to-reach group. They can benefit from the flexibility of online participation regardless of their schedule. Additionally, employees are more likely to have internet access at home compared to the general population (German Federal Office of Statistics 2022; US Census Bureau 2022).

Second, the literature demonstrates differences in respondent composition between telephone and web modes, as shown by Dillman et al. (2009), Revilla (2010), Laaksonen and Heiskanen (2014), Kappelhof (2015), Klausch et al. (2015), and Lipps and Pekari (2016). For example, the web mode produces a higher share of a) employed individuals (Lugtig

et al. 2011; Voorpostel et al. 2020) and b) higher educated individuals (Fricker et al. 2005; Lugtig et al. 2011; Laaksonen and Heiskanen 2014) compared to the telephone mode. My three contributions also showed variations in sample composition between the web single-mode and the telephone single-mode in the refreshment sample (Contribution 1 and 3) and panel sample (Contribution 2). In my three contributions, the distinct sample compositions resulted in a higher overall absolute nonresponse bias in the web single-mode compared to the telephone single-mode. Following web nonrespondents by telephone reduced the overall absolute nonresponse bias in all three contributions, but only in the wave 4 panel sample (Contribution 2) to a similar amount compared to the telephone single-mode.

Third, earlier results indicate that introducing the web in an interviewer-administered survey has the potential to decrease survey costs, mainly driven by the absence of an interviewer (Berzelak et al. 2015; Lipps and Pekari 2016; Lüdtke and Schupp 2017; Bianchi et al. 2017; Lee et al. 2019; Soullier et al. 2023). My three dissertation contributions support this finding. The web single-mode had the lowest cost per interview, followed by the web-telephone mixed-mode design, and then the telephone single-mode, across both the refreshment (Contributions 1 and 3) and panel sample (Contribution 2). The contributions of my dissertation to survey praxis will be discussed in the next section.

6.5 Practical Implications

My dissertation provides three main practical implications. First, replacing a traditional telephone single-mode with a web single-mode decreases survey costs (refreshment and panel sample), coverage bias and noncoverage rates (refreshment sample), and nonresponse rates (refreshment sample), but increases nonresponse rates (panel sample), non-

response bias (refreshment and panel sample), and total selection bias (refreshment sample). These results were considered when the IAB and the Federal Ministry of Labour and Social Affairs discussed the potential of transitioning the LPP employee survey to an exclusive web mode.

Second, although following web nonrespondents via telephone increases response rates (refreshment and panel sample), this did only push the level of aggregate nonresponse bias in the panel sample to a level comparable to that of the telephone single-mode design. Additionally, the web-telephone mixed-mode design produces lower survey costs (refreshment and panel sample) and noncoverage rates and coverage bias (refreshment sample) than the telephone single-mode. Based on my dissertation findings, the decision has been made to adopt the sequential web-telephone mixed-mode design for the entire sample (refreshment and panel cases) of the LPP employee survey starting from wave 7 onwards. In addition, my results informed a team of the University of Bielefeld and the IAB to start a new employee survey (project: Zeit vs. Geld) in a sequential web-telephone mixed-mode design in 2023. Third, the survey weights included in the LPP employee survey contain a separate coverage and nonresponse adjustment step for the refreshment and panel sample. The coverage adjustment was done in the waves prior to the mode change, while the nonresponse adjustment was done in all survey waves. The adjustment steps include the variables sex, age (groups), income (groups), state of the working place, and a full-time vs. part-time indicator. My results show that variables related to past contacts to the Federal Employment Agency (BA) (e.g., registered as a job seeker or income benefit receiver within the last 10 years) have the strongest relation among all tested variables on the existence of a known telephone number and are also related to survey variables (own calculations), which lead to my suggestion to update the wave 1 to wave 3 coverage adjustment by using these variables. Moreover, my results show that certain

variables used in the nonresponse adjustment, such as sex and region, have minimal impact on survey response, while others (e.g., education, survey mode, urbanicity, and personality traits) demonstrate stronger correlations with survey participation. As the education (Lott 2020; Denzer and Grunau 2021; Yang et al. 2023), personality traits (Bellmann and Hübler 2021; Herr et al. 2021; Laible and Brezel 2021) urbanicity (own calculations) and survey mode (Saar and Mackeben 2023) are also related to survey variables in the LPP, I suggested to add these variables to the nonresponse adjustment step. While my dissertation offers practical implications, it is not without limitations, which I will outline in the following section.

6.6 Limitations and Future Research

To my knowledge, my dissertation has four major overarching limitations. First, the target population of my dissertation is employees subject to social insurance contributions in Germany. The monthly income threshold for social insurance is 520 Euros in 2023 (German Federal Employment Agency 2023). Employees working in establishments with a) less than 50 employees subject to social insurance, and b) establishments belonging to the fishing, agricultural, and public sectors do not belong to the target population. Future research should address whether my dissertation results are generalizable to other employed or more general populations. Second, my dissertation employs a specific sampling frame, comprising telephone numbers derived from previous interactions with the BA or listings in public telephone directories, both sources potentially spanning multiple years. In contrast, addresses are typically no older than one year, being supplied annually to the BA by employers. Future research is warranted to ascertain the extent to which my dissertation results can be extrapolated to other sampling frames. Third, the differentiation between web (computer) and web (smartphone) (e.g., in terms of questionnaire design

and sample composition) has recently become an important topic in survey research (de Bruijne et al. 2013; Lee et al. 2019; Biffignandi and Bethlehem 2021; Čehovin and Vehovar 2023; Knapp and Blanke 2023). While I could not distinguish between smartphone and computer responses in my dissertation, upcoming waves of the LPP employee survey will facilitate the differentiation between smartphone and computer participation. Fourth, survey design features (e.g., use of incentives, the layout and wording of the invitation letters, and the number of telephone contact attempts) can affect the outcome rates and biases (Kreuter et al. 2010; Kaplowitz et al. 2012; Lipps and Pekari 2016; McGonagle and Freedman 2017). Thus, my results may be at least partly influenced by the survey design features, making it a topic for future research. Additionally, future research should address the long-term effects of introducing web in a traditional telephone survey on continuing survey participation, and differential measurement error (de Leeuw 2018).

Despite these limitations, extensive individual administrative data were used in my dissertation to analyze a randomized mode design experiment. I found clear advantages of replacing a traditional telephone single-mode with a sequential web-telephone mixed-mode design in terms of response rates, known telephone coverage (rates and bias) as well as survey costs. However, these advantages must be weighed against increasing nonresponse bias and total selection bias in the refreshment samples.

References

Bellmann, L., and Hübler, O. (2022), "Personality traits, working conditions and health: an empirical analysis based on the German Linked Personnel Panel 2013–2017," *Review of Managerial Science*, 16, 283–318.

Berzelak, N., Vehovar, V., and Manfreda, K. L. (2015), "Web mode as part of mixed-mode surveys of the general population: An approach to the evaluation of costs and errors," *Advances in Methodology and Statistics*, 12, 45–68.

Bianchi, A., Biffignandi, S., and Lynn, P. (2017), "Web-Face-to-Face Mixed-Mode Design in a Longitudinal Survey: Effects on Participation Rates, Sample Composition, and Costs," *Journal of Official Statistics*, 33, 385–408.

Biemer, P. P., Harris, K. M., Burke, B. J., Liao, D., and Halpern, C. T. (2021), "Transitioning a panel survey from in-person to predominantly web data collection: Results and lessons learned," *Journal of the Royal Statistical Society Series A: Statistics in Society*, 185, 798–821.

Čehovin, G., and Vehovar, V. (2023), "Grid Questions in PC and Smartphone Surveys: Alternative Layouts and Implications for Data Quality and Survey Estimates," ESRA Conference, 17–21 June 2023, Milan.

Daikeler, J., Bošnjak, M., and Manfreda, K. L. (2020), "Web Versus Other Survey Modes: An Updated and Extended Meta-Analysis Comparing Response Rates," *Journal of Survey Statistics and Methodology*, 8, 513–539.

de Bruijne, M., and Wijnant, A. (2013), "Comparing Survey Results Obtained via Mobile Devices and Computers: An Experiment With a Mobile Web Survey on a Heterogeneous Group of Mobile Devices Versus a Computer-Assisted Web Survey," *Social Science Computer Review*, 31, 482–504.

de Leeuw, E. D. (2018), "Mixed-Mode: Past, Present, and Future," *Survey Research Methods*, 12, 75–89.

Denzer, M., and Grunau, P. (2021), "The Impacts of Working from Home on Individual Health and Well-being," *Gutenberg School of Management and Economics & Research Unit "Interdisciplinary Public Policy" Discussion Paper Series*, 2106, 1–27.

Dillman, D. A., Phelps, G., Tortora, R., Swift, K., Kohrell, J., Berck, J., and Messer, B. I. (2009), "Response rate and measurement differences in mixed-mode surveys using mail, telephone, interactive voice response (VCR) and the Internet," *Social Science Research*, 38, 1–18.

Fricker, S., Galesic, M., Tourangeau, R., and Yan, T. (2005), "An Experimental Comparison of Web and Telephone Surveys," *Public Opinion Quarterly*, 69, 370–392.

German Federal Office of Statistics (2022), Wirtschaftsrechnungen: Laufende Wirtschafts-rechnungen: Ausstattung privater Haushalte mit ausgewählten Gebrauchsgütern, Fachserie 15 (Reihe 2).

German Federal Employment Agency (2023), *Beschäftigung - Sozialversicherungspflichtige Bruttomonatsentgelte*, available at https://statistik.arbeitsagentur.de/DE/Statischer-Content/Grundlagen/Methodik-Qualitaet/Methodische-Hinweise/BST-MethHinweise/Entgelt-meth-Hinweise.

Grunau, P., Mackeben, J., Ruf, K., Walz, H., Wolter, S., and Hauschka, G. (2022), "Endbericht im Projekt Arbeitsqualität und wirtschaftlicher Erfolg", Institut für Arbeitsmarkt- und Berufsforschung (IAB).

Gundersen, D. A., Wivagg, J., Young, W. J., Yan, T., and Delnevo, C. D. (2021), "The Use of Multimode Data Collection in Random Digit Dialing Cell Phone Surveys

for Young Adults: Feasibility Study," *Journal of medical Internet research*, 23, e31545.

Herr, R. M., van Vianen, A. E. M., Bosle, C., and Fischer, J. E. (2023), "Personality type matters: Perceptions of job demands, job resources, and their associations with work engagement and mental health," *Current Psychology*, 42, 2576–2590.

Jäckle, A., Lynn, P., and Burton, J. (2015), "Going Online with a Face-to-Face Household Panel: Effects of a Mixed Mode Design on Item and Unit Non-Response," *Survey Research Methods*, 9, 57–70.

Kaplowitz, M. D., Lupi, F., Couper, M. P., and Thorp, L. (2012), "The effect of invitation design on web survey response rates," *Social Science Computer Review*, 30, 339–349.

Kappelhof, J. W. S. (2015), "Face-to-Face or Sequential Mixed-Mode Surveys Among Non-Western Minorities in the Netherlands: The Effect of Different Survey Designs on the Possibility of Nonresponse Bias," *Journal of Official Statistics*, 31, 1–30.

Klausch, T., Hox, J., and Schouten, B. (2015), "Selection error in single- and mixed mode surveys of the Dutch general population," *Journal of the Royal Statistical Society*, 178, 945–961.

Knapp, D., and Blanke, K. (2023), "Mobile Questionnaire Design: Learnings from Redesigning the Online Data Collection at Destatis," ESRA Conference, 17–21 June 2023, Milan.

Kreuter, F., Müller, G., and Trappmann, M. (2010), "Nonresponse and Measurement Error in Employment Research: Making Use of Administrative Data," *Public Opinion Quarterly*, 74, 880–906.

Laaksonen, S., and Heiskanen, M. (2014), "Comparison of three Modes for a Crime Victimization Survey," *Journal of Survey Statistics and Methodology*, 2, 459–483.

Laible, M.-C., and Brenzel, H. (2022), "Does Personality Matter? Noncognitive Skills and the Male Migrant Wage Gap in Germany," *International Migration Review*, 56, 376–409.

Lee, H., Kim, S., Couper, M. P., and Woo, Y. (2019), "Experimental Comparison of PC Web, Smartphone Web, and Telephone Surveys in the New Technology Era," *Social Science Computer Review*, 37, 234–247.

Lipps, O., and Pekari, N. (2016), "Sample Representation and Substantive Outcomes Using Web With and Without Incentives Compared to Telephone in an Election Survey," *Journal of Official Statistics*, 32, 165–186.

Lott, Y. (2020), " Work-Life Balance im Homeoffice: Was kann der Betrieb tun?," *WSI Report*, 54, 1–17.

Lüdtke, D., and Schupp, J. (2017), "Wechsel von persönlichen Interviews zu webbasierten Interviews in einem laufenden Haushaltspanel," in *Methodische Probleme von Mixed-Mode-Ansätzen in der Umfrageforschung*, eds. S. Eifler and F. Faulbaum, Wiesbaden. Springer, pp. 141–160.

Lugtig, P., Lensvelt-Mulders, G. J. L. M., Frerichs, R., and Greven, A. (2011), "Estimating Nonresponse Bias and Mode Effects in a Mixed-Mode Survey," *International Journal of Market Research*, 53, 669–686.

Manfreda, K. L., Bosnjak, M., Berzelak, J., Haas, I., and Vehovar, V. (2008), "Web Surveys versus other Survey Modes: A Meta-Analysis Comparing Response Rates," *International Journal of Market Research*, 50, 79–104.

McGonagle, K. A., and Freedman, V. A. (2017), "The Effects of a Delayed Incentive on Response Rates, Response Mode, Data Quality, and Sample Bias in a Nationally Representative Mixed Mode Study," *Field Methods*, 29, 221–237.

Olson, K., Smyth, J. D., Horwitz, R., Keeter, S., Lesser, V., Marken, S., Mathiowetz, N. A., McCarthy, J. S., O'Brien, E., Opsomer, J. D., Steiger, D., Sterrett, D., Su, J., Suzer-Gurtekin, Z. T., Turakhia, C., and Wagner, J. (2021), "Transitions from Telephone Surveys to Self-Administered and Mixed-Mode Surveys: AAPOR Task Force Report," *Journal of Survey Statistics and Methodology*, 9, 381–411.

Revilla, M. (2010), "Quality in Unimode and Mixed-Mode Designs: A Multitrait-Multimethod Approach," *Survey Research Methods*, 4, 151–164.

Saar, X., and Mackeben, J. (2023), "Telefon oder Web: Moduspräferenz und modusbedingtes Antwortverhalten in einer Beschäftigtenerhebung", Research Data Centre (FDZ), FDZ-Datenreport, 04/2023 (de), Nuremberg.

Soullier, N., Garras, L., Houot, M., and Pilorget, C. (2023), "Pushing to Web Populations less prone to answer: An adaptive Design in a french Survey on Professional Careers," ESRA Conference, 17–21 June 2023, Milan.

US Census Bureau (2022), *Types of internet subscriptions by selected characteristics*, available at https://data.census.gov/table?q=S2802&tid=ACSST5Y2020.S2802.

Voorpostel, M., Kuhn, U., Tillmann, R., Monsch, G. A., Antal, E., Ryser, V. A., Lebert, F., Klaas, H. S., and Dasoki, N. (2020), "Introducing web in a refreshment sample of the Swiss Household Panel: Main findings from a pilot study," *FORS Working Paper Series* No. paper 2020-2, Lausanne: FORS.

Woo, Y. J., Kim, S. W., and Couper, M. P. (2015), "Comparing a cell phone survey and a Web survey of university students," *Social Science Computer Review*, 33, 399–410.

Yang, D., Kelly, E. L., Kubzansky, L. D., and Berkman, L. (2023), “Working from Home and Worker Well-being: New Evidence from Germany,” *ILR Review*, 76, 504–531.