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**CAN I USE A PANEL?
PANEL CONDITIONING AND ATTRITION BIAS IN PANEL
SURVEYS**

By Marcel Das, Vera Toepoel, Arthur van Soest

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TILBURG ◆ UNIVERSITY

Can I Use a Panel?
Panel Conditioning and Attrition Bias in Panel Surveys[1]

Marcel Das[*], Vera Toepoel[*], and Arthur van Soest[**]

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Abstract

Over the past decades there has been an increasing use of panel surveys at the household or individual level, instead of using independent cross-sections. Panel data have important advantages, but there are also two potential drawbacks: attrition bias and panel conditioning effects. Attrition bias can arise if respondents drop out of the panel non-randomly, i.e., when attrition is correlated to a variable of interest. Panel conditioning arises if responses in one wave are influenced by participation in the previous wave(s). The experience of the previous interview(s) may affect the answers of respondents in a next interview on the same topic, such that their answers differ systematically from the answers of individuals who are interviewed for the first time. The literature has mainly focused on estimating attrition bias; less is known on panel conditioning effects.

In this study we discuss how to disentangle the total bias in panel surveys due to attrition and panel conditioning into a panel conditioning and an attrition effect, and develop a test for panel conditioning allowing for non-random attrition. First, we consider a fully nonparametric approach without any assumptions other than those on the sample design, leading to interval identification of the measures for the attrition and panel conditioning effect. Second, we analyze the proposed measures under additional assumptions concerning the attrition process, making it possible to obtain point estimates and standard errors for both the attrition bias and the panel conditioning effect.

We illustrate our method on a variety of questions from two-wave surveys conducted in a Dutch household panel. We found a significant bias due to panel conditioning in knowledge questions, but not in other types of questions. The examples show that the bounds can be informative if the attrition rate is not too high. Point estimates of the panel conditioning effect do not vary a lot with the different assumptions on the attrition process.

[*]CentERdata, Tilburg University

[**]Department of Econometrics and Operations Research, Faculty of Economics and Business Administration, Tilburg University

1   Introduction

One of the most important developments in the social sciences over the past decades has been the increasing use of panel surveys at the household or individual level. Panel data have important advantages for research, such as creating the possibility to analyze changes at the micro-level, to disentangle permanent from transitory characteristics, to distinguish between causal effects and individual heterogeneity, etc. (see, e.g., Baltagi (2001) or Lee (2002)). Two potential drawbacks compared to, e.g., independent cross-sections are attrition bias and panel conditioning effects (see, e.g., Shariot (1991) or Trivellato (1999)).

Attrition bias can arise if respondents drop out of the panel non-randomly, i.e., when attrition is correlated to a variable of interest. Panel attrition has been studied extensively, usually without discussing the possibility of panel conditioning effects. See, e.g., Fitzgerald et al. (1998), Vella (1998), and Nicoletti (2006). Hirano et al. (2001) show how a refreshment sample can be used to relax the assumptions under which attrition can be identified. Their first model makes the assumption that the observations in the second period are missing at random (MAR, Rubin (1976)). Their second model is closely related to the model of Hausman and Wise (1979), allowing the probability of attrition to depend on second period variables, but not on first period variables. With a refreshment sample, the distinction between these two models can be non-parametrically identified.

Panel conditioning arises if responses in one wave are influenced by having participated in the previous wave(s). The experience of the previous interview(s) may affect the answers of respondents in a next interview on the same topic, such that their answers differ systematically from the answers of individuals who are interviewed for the first time. This may be a good thing and reduce measurement error, if respondents learn how to interpret questions and make fewer errors. On the other hand, experienced respondents may become strategic and learn, e.g., that answering

"no" reduces the burden of their task, avoiding follow up questions (see, e.g., Meurs et al. 1989). Sturgis et al. (2007) expand on the main theory behind panel conditioning: the cognitive stimulus hypothesis. Questions asked about certain topics may induce respondents to reflect more closely on them after the interview has ended, and possibly to talk about them with friends and relatives or to acquire additional information through the media. This should particularly lead to a difference between knowledge or attitudes reported at the first and second interview. They find some empirical evidence in favor of this, but have to ignore attrition effects as well as time trends. Brannen (1993) asked explicit questions on the effects of survey participation and also found that respondents became more aware of and interested in the research issues (child behavior and parental roles).

Panel conditioning has been studied in many social sciences, with mixed findings. While Williams (1970), Williams and Mallows (1970), and Meurs et al. (1989) showed that systematic biases occur in panel data sets, due to attrition as well as panel conditioning, Coombs (1973) found differences in knowledge due to re-interviewing, i.e., panel conditioning, but little impact on behavior or attitudes. Waterton and Lievesley (1989) found some evidence that respondents are influenced by re-interviewing, especially respondents with low knowledge scores. On the other hand, Dennis (2001) and Clinton (2001) found little evidence for attrition or panel conditioning in the Knowledge Networks' panel (an online panel that is representative of the entire US population). Mathiowetz and Lair (1994) found evidence of panel conditioning in the measurement of functional health limitations, which can be explained by strategic behavior: by not reporting limitations, follow-up questions can be avoided. Van der Zouwen and Van Tilburg (2001) showed that most of their evidence of panel conditioning for measurement of personal network size in repeated personal interviews could be attributed to behavior of the interviewers. Sharpe and Gilbert (1998) find that repeated testing (interrupted by a 1 week interval) increases the scores on the Beck depression scale and attribute this to socially desirable responding, mood-congruent associative processing, or self-monitoring, triggered by the first interview. Similar effects, called "testing effects" in this

context, were found within the same experimental session by Chan and McDermott (2007).

In practice, it is difficult to separate the effects of panel conditioning from those of other changes between waves (Kalton et al. 1989). Many studies on panel effects do not explicitly distinguish between attrition and panel conditioning and only look at the total bias induced by both, see, e.g., Bartels (1999) on campaign interest and turnout at national elections, Lohse et al. (2000) on consumer buyer behavior, Wang et al. (2000) who found some significant panel effects in a set of 32 variables on use of medical care and social security, or Golob (1990) who found panel effects on reported travel time expenditures.

In this paper we aim at disentangling panel conditioning from attrition bias, with the goal of testing for panel conditioning while controlling for attrition bias. We extend the framework of Hirano et al. (2001) incorporating the possibility of panel conditioning effects, emphasizing the usefulness of a refreshment sample. The setup, with an initial sample interviewed once (in case of attrition) or twice (non-attrition) and a refreshment sample interviewed once, is described in Section 2. Section 3 proposes two measures for the attrition bias and the panel conditioning effect. Without further assumptions these measures are not point-identified. We then consider two approaches. First, we follow Manski (1989, 1995) and derive bounds on the panel conditioning and attrition effects, without making further assumptions. Second, we discuss several sets of additional assumptions on the attrition process under which we can obtain point estimates and standard errors for the attrition and panel conditioning effects. In Section 4 we illustrate our method for several repeated measurements conducted in the CentERpanel, a representative panel of Dutch households. We find evidence of panel conditioning in knowledge questions, but not in questions on behavior or attitudes. Section 5 concludes.

2 Setup

We consider the case of two interview times, time 1 and time 2, with the same population (assumed to be the same at both points in time). For notational convenience we work with binary questions. Our approach can straightforwardly be extended to any other finite number of categories. We are interested in the following (population) variables. The variable $Z_1 \in \{0, 1\}$ denotes the answer to the question of interest at time 1. $Z_2(1) \in \{0, 1\}$ is the answer to the same question given at time 2 that the respondent (would) give(s) if the interview at time 2 is her first interview. The variable $Z_2(2) \in \{0, 1\}$ denotes the time-2-answer that the respondent (would) give(s) if the interview at time 2 is her second interview. Finally, the variable W takes value 1 if the respondent, if interviewed at time 1, also responds at time 2 ("panel observation"), and takes value 0 otherwise ("attrition"). Compared to the setup of Hirano et al. (2001) we incorporate panel conditioning, i.e., we allow for the possibility that the answer to the question at time 2 can be affected by being interviewed at time 1, i.e. $Z_2(1) \neq Z_2(2)$. The parameters of interest that we consider in this paper are all functions of the population distribution of $(Z_1, Z_2(1), Z_2(2), W)$, described by 16 parameters $\Pr(Z_1 = a, Z_2(1) = b, Z_2(2) = c, W = d)$, $a, b, c, d \in \{0, 1\}$.

The sample design is as follows. At time 1 a random sample of size N_1 is drawn from the population of interest, Sample 1. We assume throughout the paper that there is no initial (unit or item) non-response (or that initial non-response is MAR). The respondents in Sample 1 answer the question of interest and their answers are denoted by $Z_{i,1}$, $i = 1, \ldots, N_1$. At time 2, all Sample 1 individuals are approached for a second interview. If respondent i responds, then $W_i = 1$ and $Z_{i,2}(2)$ is observed. If respondent i does not respond, we only observe $W_i = 0$. Hence, $N_P = \sum_{i=1}^{N_1} W_i$ is the number of respondents in Sample 1 that stay in the panel ("panel members") and $N_A = N_1 - N_P$ is the number of respondents that attrite.

At time 2, a refreshment sample is available. This is a (new) random sample ("Sample 2") of

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size N_R from the population of interest (to be precise: the population excluding the respondents in Sample 1, but we assume the population is infinitely large). We assume there is no non-response in this sample (or that non-response is MAR). Since the respondents are interviewed for the first time, this sample yields observations $Z_{i,2}(1)$, $i = 1, \ldots, N_R$.

In summary, at time 1, we only have respondents interviewed for the first time (attrition and panel sample, the union of them is a simple random sample, Sample 1). At time 2, we have respondents interviewed for the second time (panel part of Sample 1), respondents who are interviewed for the first time (refreshment sample Sample 2, again a simple random sample), and respondents who do not respond at time 2 (attrition part of Sample 1).

Parameters identified without further assumptions

The sample design implies that eight functions of the sixteen population parameters are identified and can be estimated consistently without further assumptions. From Sample 1 we can consistently estimate six probabilities using corresponding sample analogues: the two probabilities $\Pr(Z_1 = z_1, W = 0)$, $z_1 \in \{0, 1\}$, and the four probabilities $\Pr(Z_1 = z_1, Z_2(2) = z_2, W = 1)$, $z_1, z_2 \in \{0, 1\}$.

Similarly, the refreshment sample can be used to consistently estimate the two probabilities $\Pr(Z_2(1) = z_2)$, $z_2 \in \{0, 1\}$ using their sample analogues.

This is obviously not enough to estimate the complete joint distribution of the four variables $Z_1, Z_2(1), Z_2(2)$ and W. For example, we only know the marginal distribution of $Z_2(1)$, and nothing about how $Z_2(1)$ relates to the other three variables, since $Z_2(1)$ is never observed jointly with any of the other three. Similarly, we know nothing of the distribution of $Z_2(2)$ when $W = 0$. The latter is the familiar problem of identification under selective attrition, as in Hirano et al. (2001). The difference with Hirano et al. (2001) is that we want to allow for arbitrary panel conditioning effects, implying that we do not impose any restrictions on the relation between $Z_2(1)$ and $Z_2(2)$. The

refreshment sample is informative about the distribution of $Z_2(1)$ but not about the distribution of $Z_2(2)$.

3 Measures for attrition and panel conditioning bias

This section introduces several parameters of interest that are functions of the 16 population parameters describing the distribution of $(Z_1, Z_2(1), Z_2(2), W)$. The (true) *trend effect* (taking outcome 1 as the reference level) is given by $TE = \Pr(Z_2(1) = 1) - \Pr(Z_1 = 1)$. The second term can be estimated consistently from Sample 1. Typically, ignoring possible effects of attrition and panel conditioning and not using a refreshment sample, one would estimate the first term by

$$\frac{1}{N_P} \sum_{i=1}^{N_1} Z_{i,2}(2) W_i.$$

This is a consistent estimator of $\Pr(Z_2(2) = 1 | W = 1)$, which, in general, differs from $\Pr(Z_2(1) = 1)$. Using it to estimate TE would thus induce the asymptotic "total bias" TB given by:

$$TB = \Pr(Z_2(2) = 1 | W = 1) - \Pr(Z_2(1) = 1).$$

With the refreshment sample, $\Pr(Z_2(1) = 1)$ can be estimated consistently in a straightforward way. Thus TB is identified (without additional assumptions) and can be estimated consistently by

$$\hat{TB} = \hat{\Pr}(Z_2(2) = 1 | W = 1) - \hat{\Pr}(Z_2(1) = 1)$$

$$= \frac{1}{N_P} \sum_{i=1}^{N_1} Z_{i,2}(2) W_i - \frac{1}{N_R} \sum_{i=1}^{N_R} Z_{i,2}(1).$$

Inference on TB is straightforward, because samples 1 and 2 are independent of each other. Thus, for example, a test for the null hypothesis $H_0 : TB = 0$ (versus the alternative $H_1 : TB \neq 0$) can

be based upon the difference between two independent sample fractions.

3.1 Decompositions

The main point of our paper is to decompose the total bias into two components that give an attrition bias (AB) and a panel conditioning effect (PC). This can be done in two ways, depending on the order.

Decomposition 1

In decomposition 1 the total bias is decomposed in the following way:

$$
\begin{aligned}
TB = PC_1 &\qquad\qquad\qquad\qquad\qquad\qquad\qquad + AB_1 \\
&= [\Pr(Z_2(2) = 1|W = 1) - \Pr(Z_2(1) = 1|W = 1)] + [\Pr(Z_2(1) = 1|W = 1) - \Pr(Z_2(1) = 1)].
\end{aligned}
$$

Without additional assumptions, we cannot identify AB_1 and PC_1, because $\Pr(Z_2(1) = 1|W = 1)$ is not identified. However, we can derive bounds on this probability, following Manski (1989, 1995). First, note that this probability equals

$$
\Pr(Z_2(1) = 1|W = 1) = \frac{\Pr(Z_2(1) = 1, W = 1)}{\Pr(W = 1)}.
$$

The denominator is identified. The numerator is not - we can identify the marginal probabilities $\Pr(Z_2(1) = 1)$ and $\Pr(W = 1)$ but other than that, the data are not informative about the joint probability. Thus it is straightforward to show that sharp lower and upper bounds on $\Pr(Z_2(1) = 1, W = 1)$ are given by:

$$
\max(0, 1 - \Pr(Z_2(1) = 0) - \Pr(W = 0)) \le \Pr(Z_2(1) = 1, W = 1) \le \min(\Pr(Z_2(1) = 1), \Pr(W = 1))
$$

This immediately implies the following bounds on PC_1 and AB_1: $\ell \leq PC_1 \leq r$, with

$$\ell = \Pr(Z_2(2) = 1 | W = 1) - \min\left(\frac{\Pr(Z_2(1) = 1)}{\Pr(W = 1)}, 1\right),$$

$$r = \Pr(Z_2(2) = 1 | W = 1) - \max\left(0, 1 - \frac{\Pr(Z_2(1) = 0)}{\Pr(W = 1)}\right),$$

and $\ell \leq AB_1 \leq r$ with,

$$\ell = \max\left(0, 1 - \frac{\Pr(Z_2(1) = 0)}{\Pr(W = 1)}\right) - \Pr(Z_2(1) = 1),$$

$$r = \min\left(\frac{\Pr(Z_2(1) = 1)}{\Pr(W = 1)}, 1\right) - \Pr(Z_2(1) = 1).$$

All expressions in these bounds can be estimated straightforwardly, replacing probabilities by their sample analogues. Note that the distance between upper and lower bound is bounded by $\Pr(W = 0)/\Pr(W = 1)$ for both effects. Thus the bounds are informative if attrition is low, i.e., if $\Pr(W = 0)$ is small.

Decomposition 2

In decomposition 2 the total bias is decomposed as follows:

$$TB = AB_2 \qquad\qquad + PC_2$$

$$= [\Pr(Z_2(2) = 1 | W = 1) - \Pr(Z_2(2) = 1)] + [\Pr(Z_2(2) = 1) - \Pr(Z_2(1) = 1)].$$

Without additional assumptions, we cannot identify AB_2 or PC_2, because $\Pr(Z_2(2) = 1)$ is not identified (since we have no observations on $Z_2(2)$ if $W = 0$). Decomposing $\Pr(Z_2(2) = 1) = \Pr(Z_2(2) = 1, W = 1) + \Pr(Z_2(2) = 1 | W = 0)\Pr(W = 0)$, the following sharp bounds can be

derived straightforwardly:

$$PC_2 \in [\Pr(Z_2(2) = 1, W = 1) - \Pr(Z_2(1) = 1),$$

$$\Pr(Z_2(2) = 1, W = 1) - \Pr(Z_2(1) = 1) + \Pr(W = 0)];$$

$$AB_2 \in [\Pr(Z_2(2) = 1 | W = 1) - \Pr(Z_2(2) = 1, W = 1) - \Pr(W = 0),$$

$$\Pr(Z_2(2) = 1 | W = 1) - \Pr(Z_2(2) = 1, W = 1)].$$

The bounds can be estimated consistently by replacing probabilities by their sample analogues. Again, the distance between the bounds depends on the attrition probability – it is given by $\Pr(W = 0)$.

3.2 Additional assumptions

The previous section shows that further assumptions are needed to obtain point identification of the panel conditioning effect and the attrition bias. In this section we discuss several possibilities.

Attrition is not associated with time 2 answers

Assumption 1a (before panel conditioning):

$$\Pr(W = 1 | Z_2(1) = a) = \Pr(W = 1), \quad a \in \{0, 1\}.$$

Assumption 1b (after panel conditioning):

$$\Pr(W = 1 | Z_2(2) = a) = \Pr(W = 1), \quad a \in \{0, 1\}.$$

Both assumptions are similar to the assumption that wave 2 non-response is missing completely at random (CMAR, cf. Little and Rubin 2002). They are rather strong, since they do not condition on the wave 1 answer. So it seems better to introduce a third and a fourth version, replacing CMAR by MAR, missing at random, conditional on observables, in this case the time 1 answer Z_1:[1]

Assumption 1c (before panel conditioning):

$$\Pr(W = 1|Z_1 = z_1, Z_2(1) = z_2) = \Pr(W = 1|Z_1 = z_1) \ (z_1, z_2 \in \{0.1\}).$$

Assumption 1d (after panel conditioning):

$$\Pr(W = 1|Z_1 = z_1, Z_2(2) = z_2) = \Pr(W = 1|Z_1 = z_1) \ (z_1, z_2 \in \{0.1\}).$$

Assumption 1c does not help in identifying the components in decomposition 1, since $Z_2(1)$ and Z_1 are never observed jointly. In the remainder, we therefore do not consider CMAR Assumption 1c.

Attrition has the same effect at times 1 and 2

Assumption 2a (before panel conditioning):

$$\Pr(Z_1 = a|W = 1) - \Pr(Z_1 = a) = \Pr(Z_2(1) = a|W = 1) - \Pr(Z_2(1) = a), \quad a \in \{0, 1\}.$$

Assumption 2b (after panel conditioning):

$$\Pr(Z_1 = a|W = 1) - \Pr(Z_1 = a) = \Pr(Z_2(2) = a|W = 1) - \Pr(Z_2(2) = a), \quad a \in \{0, 1\}.$$

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[1]Fitzgerald et al. (1998) and others refer to this as no selection on unobservables.

Both of these assume, in different senses, stationarity of the attrition bias.

Point estimation under additional assumptions

How can the additional assumptions discussed above be used to obtain point estimates? All our point estimates are based on sample analogues of unconditional or conditional probabilities.

Assumption 1a

Under Assumption 1a W and $Z_2(1)$ are independent and hence $\Pr(Z_2(1) = 1|W = 1) = \Pr(Z_2(1) = 1)$. Thus under this assumption $AB_1 = 0$ and $PC_1 = TB$, and AB_1 and PC_1 are identified since TB is identified.

Assumption 1b

Under Assumption 1b, W and $Z_2(2)$ are independent and hence $\Pr(Z_2(2) = 1|W = 1) = \Pr(Z_2(2) = 1)$. Thus under this assumption $AB_2 = 0$ and $PC_2 = TB$, and AB_2 and PC_2 are identified.

Assumption 1d

Under Assumption 1d we have

$$\Pr(Z_1 = z_1, Z_2(2) = 1) = \frac{\Pr(Z_1 = z_1, Z_2(2) = 1, W = 1)}{\Pr(W = 1|Z_1 = z_1)}, z_1 \in \{0, 1\}$$

and hence

$$\Pr(Z_2(2) = 1) = \frac{\Pr(Z_1 = 0, Z_2(2) = 1, W = 1)}{\Pr(W = 1|Z_1 = 0)} + \frac{\Pr(Z_1 = 1, Z_2(2) = 1, W = 1)}{\Pr(W = 1|Z_1 = 1)}.$$

The four probabilities on the right hand side can all directly be estimated with their sample analogues, so under Assumption 1d, AB_2 and PC_2 are identified.

Assumption 2a

Under Assumption 2a we have

$$\Pr(Z_2(1) = 1|W = 1) = \Pr(Z_2(1) = 1) - \Pr(Z_1 = 1) + \Pr(Z_1 = 1|W = 1),$$

and all three probabilities on the right hand side can be directly estimated with their sample analogues. Thus AB_1 and PC_1 are identified.

Assumption 2b

Under Assumption 2b we have

$$\Pr(Z_2(2) = 1) = \Pr(Z_2(2) = 1|W = 1) + \Pr(Z_1 = 1) - \Pr(Z_1 = 1|W = 1),$$

and the probabilities on the right hand side can be estimated directly by their sample analogues, so that AB_2 and PC_2 are identified.

It is straightforward to check that Assumptions 2a and 2b give the same expression for AB_1 and AB_2 (and thus also for PC_1 and PC_2). The estimators based upon sample analogues will therefore also be the same.

4   Empirical Results

In this section we use the bounds and point estimates of the previous section to compute estimates of panel conditioning effects and attrition bias (for the two decompositions) in several examples.

We make use of the CentERpanel, an Internet panel representative of the Dutch population ages 16 and over, administered by CentERdata, Tilburg University. Because not everyone owns a personal computer or has access to Internet, CentERdata provides a set-top box for people who do not have a computer, enabling them to complete the questionnaires online. The setup is similar to the one chosen by Knowledge Networks in the US.

Respondents of the CentERpanel are asked to fill out a questionnaire every week. We selected various binary variables in several two-wave research projects. Details of the questions and the results are presented in Appendix A. Standard errors for the estimates were calculated using the Central Limit Theorem and the Delta-method.

The hypothesis that the *total bias* is equal to zero is rejected for only a few of the variables we analyzed. In particular, this only happened if the question referred to knowledge. For other question types, referring to actual behavior or actual circumstances, attitudes and opinions, or future expectations, no significant bias was found. The fact that knowledge questions are the most sensitive to panel conditioning is consistent with the literature (cf. Section 1).

Table 1 summarizes the results for the three knowledge questions for which we find a significant *total bias*: "Do you know what campylobacter is?", "Do you know what cross-infection is?", and "Have you ever heard of a foundation named "Stichting Pensioenkijker?". The first two stem from a survey module on hygiene knowledge, fielded in November 2003 and November 2005. The third question is from a survey module on pensions and pension knowledge, held in February 2004 and February 2005. Stichting Pensioenkijker is a Dutch non-profit organization that aims at increasing the Dutch population's knowledge about pensions and to help them prepare financially for retirement. Their main instrument is a web site (http://www.pensioenkijker.nl).

Consider the first example - knowledge of campylobacter. At time 1, 19.3% report they know what this is. Among panel observations, this increases to 28.1% at time 2, whereas in the refreshment sample, it increases much less – to 21.9%. The difference is the estimate of total bias,

6.17%-points, due to panel conditioning, attrition, or both. Without making further assumptions, the estimates on the lower and upper bound of the panel conditioning component of the total bias are 1.10 and 24.27 %-points according to decomposition 1 and 0.90 and 19.70%-points for decomposition 2. Neither the 1.10 nor the 0.90 are significantly different from 0 (standard errors are 2.16 and 1.76, respectively). Thus in this example, without making further assumptions, there is no significant evidence of panel conditioning.

This changes if additional assumptions are made on the nature of attrition. Under all additional assumptions we consider, Ass. 1a (or 1b, which gives the same as 1a – $PC = TB$), Ass. 1d or Ass. 2a (or 2b, which gives the same as 2a) we find that all or almost all of the total bias can be attributed to panel conditioning, with estimates of the panel conditioning effect that are 6.17%-points, 5.85%-points and 5.96%-points, respectively, all significantly different from zero.

In the second example, on knowing the meaning of cross-infection, the results are similar. The total bias is estimated to be 6.71%-points, and under the additional assumptions that allows for point estimation, most or all of this is panel conditioning (6.71, 5.88 or 6.31%-points, all significantly different from zero). The only difference with the first example is that the point estimates of the lower bound of the panel conditioning effect are negative so that the estimated interval contains zero, making a test whether the lower bound is significantly different from zero unnecessary – the fact that the lower bound is negative and the upper bound is positive already implies that without additional assumptions on attrition, there is no evidence of panel conditioning.

The third example, on knowing "Stichting Pensioenkijker", gives the strongest evidence of panel conditioning. At time 1, 7.55% of respondents have heard of this organization. For panel respondents, this rises to 16.47% one year later. In the refreshment sample drawn at the same time, 11.27% report they know "Stichting Pensioenkijker." The difference of 5.20%-points is statistically significant. Without further assumptions, the implied lower bound on the panel conditioning effect is 3.85 or 3.44%-points (for decompositions 1 and 2, respectively), and both are significantly positive

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(standard errors are 1.64 and 1.47, respectively). Thus even without making further assumptions, we find significant evidence of panel conditioning. The main reason why we find this here and not in the example on campylobacter is the lower attrition rate – 10.7% versus 18.8%. Under additional assumptions 1a, 1d or 2a, the point estimates of the panel conditioning effect are always 5.2%-points (and, as expected, significantly larger than zero).

Table 1: Panel Conditioning in Three Knowledge Questions

	Campylobacter	Cross-infection	Stichting Pensioenkijker
Size Sample 1	1510	1510	1734
Attrition rate (%)	18.8	18.8	10.7
Size Sample 2	891	891	701
Total Bias (%-points)	6.17*	6.71*	5.20*
Panel Conditioning Effect			
Interval estimates			
Decomposition 1	[1.10; 24.27*]	[-7.92; 15.24*]	[3.85*; 15.87*]
Decomposition 2	[0.90; 19.70*]	[-6.43; 12.38*]	[3.44*; 14.16*]
Panel Conditioning Effect			
Point estimates			
Ass. 1d, Decomp. 2	5.96*	6.31*	5.20*
Ass. 2a/b, Decomp. 1/2	5.85*	5.88*	5.20*

*=significant at 5% level

5 Conclusion

In this paper we have analyzed panel conditioning effects on the estimates of binary outcome probabilities in two-wave panel surveys, using a refreshment sample and allowing for selective attrition. We introduced two definitions of a panel conditioning effect, based upon different decompositions of the total bias induced by estimating the time 2 distribution of the variable of interest into a panel conditioning effect and an attrition bias. We have shown that without additional assumptions, point identification of the panel conditioning effect (or the attrition bias) is not possible, but the panel conditioning effect is identified up to a bounding interval. We also introduced several additional assumptions on the attrition process, and showed how they guarantee point identification of

the panel conditioning effect.

Applying our method to various empirical examples, we found that the problem of panel conditioning plays a role in knowledge questions, and not in questions on attitudes, actual behavior, or expectations concerning the future. For three out of four knowledge questions we studied, we found a significant panel conditioning effect under either of the additional assumptions guaranteeing point identification. In one case, the bounding interval analysis showed that the effect remained significant even without making such an assumption. In all cases the panel conditioning effect was positive, suggesting that some people who have had the question once, are triggered to increase their knowledge about the phenomenon in the question before taking part in the next survey.

The conclusion that for most types of questions no evidence of panel conditioning is found seems reassuring. One reason may be that interviewer effects are excluded, since our panel is an Internet panel. This is in line with the finding of Van der Zouwen and Van Tilburg (2001) who find that panel conditioning is mainly caused by interviewer behavior. Of course this needs to checked further, with more examples than the ones we have analyzed here, before a general conclusion can be drawn. For questions concerning knowledge, panel conditioning seems an issue that researchers need to be aware of. Refreshment samples are a useful tool to do this. Even without concerns about panel conditioning, refreshment samples were already shown to be useful tools to analyze selective attrition (Hirano et al., 2001). Thus this paper supports the conclusion that for survey designers, a solid and sizable refreshment sample may be as important as reducing attrition by another fraction of a percentage point.

Appendix A

This appendix presents five numerical examples in which we demonstrate the use of interval and point estimates for measuring panel conditioning and attrition bias in two-wave data sets. Results for assumption 1a and 1b are not presented, since for these assumptions the attrition bias is zero (by definition) and the panel conditioning effect is equal to the total bias (for decomposition 1 and 2). Results for assumption 2b (decomposition 2) can be found in the row for assumption 2a (decomposition 1) since these are identical. Standard errors for the estimates were calculated using the Central Limit Theorem and the Delta-method.

Example A

-Fieldwork: November 2003 and November 2005

-N_1=1510 (Sample 1), N_P=1226 (Panel Sample), N_A=284 (Attrition Sample), N_R=891 (Refreshment Sample)

-Variable 1: Do you know what "Campylobacter" is (Yes/No); 19.3% answered 'Yes' at time 1 (N_1) and 25.5% at time 2 (N_P+N_R).

-Variable 2: Do you know what "Salmonella" is (Yes/No); 96.8% answered 'yes' at time 1 and 95.1% at time 2.

-Variable 3: Do you know what "Cross-infection" is (Yes/No); 55.7% answered 'yes' at time 1 and 67.1% at time 2.

Table 2: Total bias, panel conditioning and attrition bias for three knowledge questions in a questionnaire about hygiene (in %)

	knowledge Campylobacter		knowledge Salmonella		knowledge Cross-infection	
Total Bias						
Estimate	6.17*		-1.61		6.71*	
Decomposition 1						
	PC_1	AB_1	PC_1	AB_1	PC_1	AB_1
Interval estimate	$[1.10, 24.27]$	$[-18.10, 5.07]$	$[-5.55, -0.71]$	$[-0.91, 3.93]$	$[-7.92, 15.24]$	$[-8.53, 14.64]$
Ass. 2a	5.85* (1.86)	0.32 (0.48)	-1.76 (1.93)	0.15 (0.23)	5.88* (2.08)	0.83 (0.62)
Decomposition 2						
	PC_2	AB_2	PC_2	AB_2	PC_2	AB_2
Interval estimate	$[0.90, 19.70]$	$[-13.53, 5.28]$	$[-19.38, -0.58]$	$[-1.04, 17.77]$	$[-6.43, 12.38]$	$[-5.66.15, 13]$
Ass. 1d	5.96* (1.86)	0.21 (0.32)	-1.69 (0.92)	0.07 (0.11)	6.31* (2.06)	0.40 (0.30)

*=null hypothesis bias=0 is rejected at 5%-level, standard errors are reported between parentheses

Example B

-Fieldwork: November 2005 and January 2006

-N_1=1954, N_P=1888, N_A=66, N_R=481

-Variable 1: How much meat do you eat in a regular week (less than 5 times/5 or more); 44.6% answered 'less than 5 times' at time 1 (N_1) and 43.4% at time 2 (N_P+N_R).

-Variable 2: How much bird do you eat in a regular week (less than 1 time/1 or more); 12.6% answered 'less than 1 time' at time 1 and 13.1% at time 2.

Table 3: Total bias, panel conditioning and attrition bias for two behavior questions in a questionnaire about the bird flue (in %)

	number of meals with meat		number of meals with poultry	
Total Bias				
Estimate	-1.69		1.86	
Decomposition 1				
	PC_1	AB_1	PC_1	AB_1
Interval estimate	$[-3.25, 0.24]$	$[-1.93, 1.56]$	$[1.46, 4.95]$	$[-3.09, 0.41]$
Ass. 2a	-1.40 (2.54)	-0.29 (0.21)	1.79 (1.66)	0.07 (0.13)
Decomposition 2				
	PC_2	AB_2	PC_2	AB_2
Interval estimate	$[-3.14, 0.23]$	$[-1.93, 1.45]$	$[1.41, 4.79]$	$[-2.92, 0.46]$
Ass. 1d	-1.51 (2.53)	-0.18 (0.13)	1.81 (1.66)	0.50 (0.09)

null hypothesis bias=0 is never rejected at 5%-level, standard errors are reported between parentheses

Example C

-Fieldwork: February 2004 and February 2005.

-N_1=1322, N_P=1170, N_A=152, N_R=598 for variable 1 and 2

-N_1=1734, N_P=1548, N_A=186, N_R=701 for variable 3 (due to routing sample sizes are different for variable 3)

-Variable 1: Have you thought about your pension last year (Yes/No); 40.6% answered 'yes' at time 1 (N_1) and 35.0% at time 2 (N_P+N_R).

-Variable 2: Have you received a working disability pension (Yes/No); 9.8% answered 'yes' at time 1 and 9.6% at time 2.

-Variable 3: Have you ever heard of a foundation named "Stichting Pensioenkijker (a foundation about pensions)" (Yes/No); 7.6% answered 'yes' at time 1 and 14.9% at time 2.

Table 4: Total bias, panel conditioning and attrition bias for a behavior, fact, and knowledge question in a questionnaire about pensions (in %)

	think about pension		receive a disability pension		heard of StPensioenkijker	
Total Bias						
Estimate	3.88		-0.42		5.20*	
Decomposition 1						
	PC_1	AB_1	PC_1	AB_1	PC_1	AB_1
Interval estimate	$[0.31, 12.68]$	$[-8.80, 4.19]$	$[-1.71, 9.44]$	$[-9.87, 1.29]$	$[3.85^{**}, 15.87]$	$[-10.66, 1.35]$
Ass. 2a	3.33 (2.38)	0.58 (0.48)	-0.34 (1.47)	-0.86 (0.30)	5.20* (1.53)	0.00 (0.22)
Decomposition 2						
	PC_2	AB_2	PC_2	AB_2	PC_2	AB_2
Interval estimate	$[0.28, 11.22]$	$[-7.34, 4.16]$	$[-1.51, 10.03]$	$[-10.45, 1.09]$	$[3.44^{**}, 14.16]$	$[-8.96, 1.77]$
Ass. 1d	3.63 (2.36)	0.25 (0.21)	-0.35 (1.47)	0.07 (0.26)	5.20* (1.52)	0.00 (0.06)

*=null hypothesis bias=0 is rejected at 5%-level, standard errors are reported between parentheses
**=null hypothesis 'left bound PC interval'=0 is rejected at 5%-level

Example D

-Fieldwork: May 2006 and June 2006

-N_1=1033, N_P=938, N_A=95, N_R=449 for variable 1

-N_1=1040, N_P=943, N_A=97, N_R=451 for variable 2

-N_1=468, N_P=433, N_A=35, N_R=244 for variable 3 (due to item non-response sample sizes are different for each variable)

-Variable 1: Do you expect that pensions will be less in the future (Yes/No); 62.0% answered 'yes' at time 1 (N_1) and 60.6% at time 2 (N_P+N_R).

-Variable 2: Are you satisfied with your (future) pension (Yes/No); 28.9% answered 'yes' at time 1 and 30.4% at time 2.

-Variable 3: Do you have the possibility of a part-time pension (Yes/No); 47.0% answered 'yes' at time 1 and 43.8% at time 2.

Table 5: Total bias, panel conditioning and attrition bias for an expectation, attitude, and fact question in a questionnaire about pensions (in %)

	pensions will be less		satisfaction pension		possibility part-time pension	
Total Bias						
Estimate	-3.76		-2.24		-1.72	
Decomposition 1						
	PC_1	AB_1	PC_1	AB_1	PC_1	AB_1
Interval estimate	$[-10.17, 0.04]$	$[-3.72, 6.41]$	$[-5.52, 4.77]$	$[-7.00, 3.28]$	$[-5.33, 2.76]$	$[-4.47, 3.61]$
Ass. 2a	-3.00 (2.79)	-0.76 (0.46)	-2.56 (2.65)	0.33 (0.44)	-1.82 (3.98)	0.10 (0.66)
Decomposition 2						
	PC_2	AB_2	PC_2	AB_2	PC_2	AB_2
Interval estimate	$[-9.23, 0.04]$	$[-3.73, 5.47]$	$[-5.01, 4.32]$	$[-6.56, 2.77]$	$[-4.93, 2.55]$	$[-4.27, 3.21]$
Ass. 1d	-3.47 (2.78)	-0.29 (0.18)	-2.41 (2.64)	0.18 (0.24)	-1.76 (3.96)	0.04 (0.28)

null hypothesis bias=0 is never rejected at 5%-level, standard errors are reported between parentheses

Example E

-Fieldwork: November 2004 and December 2004.

-N_1=1435, N_P=1400, N_A=35, N_R=688

-Variable 1: What is your attitude towards Turkey joining the EU (Positive/Negative); 58.5% answered 'positive' at time 1 (N_1) and 63.7% at time 2 (N_P+N_R).

-Variable 2: When do you think Turkey will join the EU (Less than 10 years/10 years or more); 44.9% answered 'less than 10 years' at time 1 and 38.1% at time 2.

-Variable 3: Do you think immigration ia an important issue associated with Turkey joining the EU (Yes/No); 45.8% answered 'yes' at time 1 and 44.1% at time 2.

Table 6: Total bias, panel conditioning and attrition bias for an expectation and two attitude questions in a questionnaire about Turkey joining the EU (in %)

	attitude Turkey joins EU		period Turkey will join EU		importance immigration	
Total Bias						
Estimate	1.79		-4.35		1.21	
Decomposition 1						
	PC_1	AB_1	PC_1	AB_1	PC_1	AB_1
Interval estimate	$[0.22, 2.72]$	$[-0.94, 1.56]$	$[-5.37, -2.87]$	$[-1.48, 1.02]$	$[-2.33, 0.17]$	$[-1.38, 1.12]$
Ass. 2a	1.82 (2.25)	0.04 (0.20)	-4.18 (2.27)	-0.16 (0.21)	-1.14 (2.32)	-0.07 (0.21)
Decomposition 2						
	PC_2	AB_2	PC_2	AB_2	PC_2	AB_2
Interval estimate	$[0.22, 2.66]$	$[-0.87, 1.57]$	$[-5.24, -2.80]$	$[-1.55, 0.89]$	$[-2.28, 0.17]$	$[-1.38, 1.07]$
Ass. 1d	1.81 (2.24)	0.02 (0.11)	-4.26 (2.27)	0.08 (0.11)	-1.18 (2.31)	0.02 (0.07)

null hypothesis bias=0 is never rejected at 5%-level, standard errors are reported between parentheses

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