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11

# Standard Error on a Difference

Introduction.....	150
Statistical issues and computing standard errors on differences.....	150
The standard error on a difference without plausible values.....	152
The standard error on a difference with plausible values.....	157
Multiple comparisons.....	161
Conclusion.....	162



## INTRODUCTION

This chapter will discuss the computation of standard errors on differences. Following a description of the statistical issues for such estimates, the different steps for computing such standard errors will be presented. Finally, the correction of the critical value for multiple comparisons will be discussed.

## STATISTICAL ISSUES AND COMPUTING STANDARD ERRORS ON DIFFERENCES

Suppose that  $X$  represents the student score for a mathematics test and  $Y$  the student score for a science test for the same sample of students. To summarise the score distribution for both tests, one can compute:

- $\mu_{(X)}, \mu_{(Y)}$ , representing respectively the mean of  $X$  and the mean of  $Y$ ,
- $\sigma_{(X)}^2, \sigma_{(Y)}^2$ , representing respectively the variance of  $X$  and the variance of  $Y$ .

It can be shown that:

$$\mu_{(X+Y)} = \mu_{(X)} + \mu_{(Y)} \text{ and}$$

$$\sigma_{(X+Y)}^2 = \sigma_{(X)}^2 + \sigma_{(Y)}^2 + 2 \text{cov}(X, Y)$$

If a total score is computed by just adding the mathematics and science scores, then according to these two formulae, the mean of this total score will be the sum of the two initial means, and the variance of the total score will be equal to the sum of the variance of the two initial variables  $X$  and  $Y$  plus two times the covariance between  $X$  and  $Y$ . This covariance represents the relationship between  $X$  and  $Y$ . Usually, high performers in mathematics are also high performers in science; thus, one should expect a positive and high covariance in this particular example.

Similarly,

$$\mu_{(X-Y)} = \mu_{(X)} - \mu_{(Y)} \text{ and}$$

$$\sigma_{(X-Y)}^2 = \sigma_{(X)}^2 + \sigma_{(Y)}^2 - 2 \text{cov}(X, Y)$$

In other words, the variance of a difference is equal to the sum of the variances of the two initial variables minus two times the covariance between the two initial variables.

As described in Chapter 4, a sampling distribution has the same characteristics as any distribution, except that units consist of sample estimates and not observations. Therefore,

$$\sigma_{(\hat{\mu}_X - \hat{\mu}_Y)}^2 = \sigma_{(\hat{\mu}_X)}^2 + \sigma_{(\hat{\mu}_Y)}^2 - 2 \text{cov}(\hat{\mu}_X, \hat{\mu}_Y)$$

The sampling variance of a difference is equal to the sum of the two initial sampling variances minus two times the covariance between the two sampling distributions on the estimates.

Suppose that one wants to determine whether female performance is on average higher than male performance. As for all statistical analyses, the null hypothesis has to be tested. In this particular example, it will consist of computing the difference between the male performance mean and the female performance mean, or the inverse. The null hypothesis will be:

$$H_0 : \hat{\mu}_{(males)} - \hat{\mu}_{(females)} = 0$$

To test this null hypothesis, the standard error on this difference has to be computed and then compared to the observed difference. The respective standard errors on the mean estimate for males and for females ( $\sigma_{(\hat{\mu}_{males})}, \sigma_{(\hat{\mu}_{females})}$ ) can be easily computed.



What does the covariance between the two variables, *i.e.*  $\hat{\mu}_{(males)} \cdot \hat{\mu}_{(females)}$ , tell us? A positive covariance means that if  $\hat{\mu}_{(males)}$  increases, then  $\hat{\mu}_{(females)}$  will also increase. A covariance equal or close to 0 means that  $\hat{\mu}_{(males)}$  can increase or decrease with  $\hat{\mu}_{(females)}$  remaining unchanged. Finally, a negative covariance means that if  $\hat{\mu}_{(males)}$  increases, then  $\hat{\mu}_{(females)}$  will decrease, and inversely.

How are  $\hat{\mu}_{(males)}$  and  $\hat{\mu}_{(females)}$  correlated? Suppose that in the school sample, a coeducational school attended by low performers is replaced by a coeducational school attended by high performers. The country mean will increase slightly, as well as the means for males and females. If the replacement process is continued,  $\hat{\mu}_{(males)}$  and  $\hat{\mu}_{(females)}$  will likely increase in a similar pattern. Indeed, a coeducational school attended by high-performing males is usually also attended by high-performing females. Therefore, the covariance between  $\hat{\mu}_{(males)}$  and  $\hat{\mu}_{(females)}$  will be positive.

Let us now suppose that all schools are single gender. A boys' school can replace a girls' school in the sample and therefore  $\hat{\mu}_{(males)}$  and  $\hat{\mu}_{(females)}$  will change. If gender is used as a stratification variable, *i.e.* all girls' schools are allocated to an explicit stratum and all boys' schools are allocated to another explicit stratum, then a girls' school can only be replaced by another girls' school. In this case, only  $\hat{\mu}_{(females)}$  will change. As  $\hat{\mu}_{(females)}$  might change without affecting  $\hat{\mu}_{(males)}$ , the expected value of the covariance between  $\hat{\mu}_{(males)}$  and  $\hat{\mu}_{(females)}$  is 0.

Finally, a negative covariance means that if a school is attended by high-performing males, then that school is also attended by low-performing females or the inverse. This situation is not likely.

In summary, the expected value of the covariance will be equal to 0 if the two subsamples are independent. If the two subsamples are not independent, then the expected value of the covariance might differ from 0.

In PISA, country samples are independent. Therefore, for any comparison between two countries, the expected value of the covariance will be equal to 0. The standard error on the estimate is:

$$\sigma_{(\hat{\theta}_i - \hat{\theta}_j)} = \sqrt{\sigma_{(\hat{\theta}_i)}^2 + \sigma_{(\hat{\theta}_j)}^2}, \text{ with } \theta \text{ being any statistic.}$$

For instance, in PISA 2003, the mean score in mathematics is equal to 503 with a standard error of 3.3 in Germany, and the mean is equal to 529 with a standard error of 2.3 in Belgium. Therefore, the difference between Germany and Belgium is  $529 - 503 = 26$  and the standard error on this difference is:

$$\sigma_{(\hat{\theta}_i - \hat{\theta}_j)} = \sqrt{\sigma_{(\hat{\theta}_i)}^2 + \sigma_{(\hat{\theta}_j)}^2} = \sqrt{(3.3)^2 + (2.3)^2} = \sqrt{10.89 + 5.29} = \sqrt{16.18} = 4.02$$

The difference divided by its standard error, *i.e.*  $\frac{26}{4.02} = 6.46$ , is greater than 1.96, which is significant. This means that the performance in Belgium is greater than the performance in Germany.

Similarly, the percentage of students below Level 1 in mathematics is equal to 9.2% in Germany (with a standard error of 0.8) and to 7.2% in Belgium (with a standard error of 0.6). The difference is equal to  $9.2 - 7.2 = 2$  and the standard error on this difference is equal to:

$$\sigma_{(\hat{\theta}_i - \hat{\theta}_j)} = \sqrt{\sigma_{(\hat{\theta}_i)}^2 + \sigma_{(\hat{\theta}_j)}^2} = \sqrt{(0.8)^2 + (0.6)^2} = \sqrt{0.64 + 0.36} = \sqrt{1} = 1$$

The standardised difference is equal to 2 (*i.e.*  $\frac{2}{1}$ ), which is significant. Thus the percentage of students below Level 1 is greater in Germany than in Belgium.

Finally, the regression coefficient of student socio-economic background index on the science performance in PISA 2006 is equal to 47.71 for Germany (with a standard error equal to 1.89), and 46.45 for Belgium



(with a standard error equal to 2.08). These two regression coefficients do not statistically differ as the standardised difference is equal to 0.44:

$$\frac{\hat{\beta}_1 - \hat{\beta}_2}{\sqrt{\sigma_{(\hat{\beta}_1)}^2 + \sigma_{(\hat{\beta}_2)}^2}} = \frac{47.71 - 46.45}{\sqrt{(1.89)^2 + (2.08)^2}} = 0.44$$

While the covariance between two country estimates for any statistical parameter is expected to be 0, it differs from 0 between an OECD country and the OECD average or total, as any OECD country contributes to the computation of the OECD average or total parameter estimate. Chapter 12 will describe how the standard error on the difference between an OECD country and the OECD average can be computed.

Within a particular country, any subsamples will be considered as independent if the categorical variable used to define the subsamples was used as an explicit stratification variable. For instance, since Canada used the provinces as an explicit stratification variable, these subsamples are independent and any comparison between two provinces does not require the estimation of the covariance between the sampling distributions.

As a general rule, any comparison between countries does not require the estimation of the covariance, but it is strongly advised to estimate the covariance between the sampling distributions for within-country comparisons.

As described earlier in this section, the estimation of the covariance between, for instance,  $\hat{\mu}_{(males)}$  and  $\hat{\mu}_{(females)}$  would require the selection of several samples and then the analysis of the variation of  $\hat{\mu}_{(males)}$  in conjunction with  $\hat{\mu}_{(females)}$ . Such procedure is, of course, unrealistic. Therefore, as for any computation of a standard error in PISA, replication methods using the supplied replicate weights will be used to estimate the standard error on a difference.

## THE STANDARD ERROR ON A DIFFERENCE WITHOUT PLAUSIBLE VALUES

Let's suppose that a researcher wants to test whether females have higher job expectations than males in Germany.

As described in Chapter 7, the SPSS® macro MCR\_SE\_UNIV can be used to estimate the average job expectation for males and females respectively.

### Box 11.1 SPSS® syntax for computing the mean of job expectations by gender (e.g. PISA 2003)

```
GET FILE="C:\PISA\2003\DATA\INT_STUI_2003.SAV" .
SELECT IF (CNT="DEU") .
SAVE OUTFILE="C:\TEMP\DEU1.SAV" .

INSERT FILE="C:\PISA\MACRO\MCR_SE_UNIV.SPS" .

UNIVAR STAT=MEAN /
      DEP=BSMJ /
      GRP=CNT ST03Q01/
      INFILE="C:\TEMP\DEU1.SAV" / .
```



Box 11.1 presents the SPSS® syntax for the computation of the mean for job expectations at the age of 30 (BSMJ) by gender. Table 11.1 presents the structure of the output data file as well as the results by gender.

**Table 11.1**  
Output data file from Box 11.1

CNT	ST03Q01	Statistic	BSMJ	se_BSMJ
DEU	1	MEAN	53.05	0.57
DEU	2	MEAN	50.58	0.69

On average, job expectation is 53.05 for females and 50.58 for males. As German schools are usually coeducational and as gender is not used as an explicit stratification variable, the expected value of the covariance might differ from 0.

To compute the standard error by gender, it is necessary to compute the mean estimate for each of the 80 replicate weights. Table 11.2 presents the mean estimates by gender for 80 replicate weights.

**Table 11.2**  
Mean estimates for the final and 80 replicate weights by gender (PISA 2003)

Weight	Mean estimate		Weight	Mean estimate	
	Females	Males		Females	Males
<b>Final weight</b>	<b>53.05</b>	<b>50.58</b>			
Replicate 1	53.29	50.69	Replicate 41	52.69	50.55
Replicate 2	53.16	50.53	Replicate 42	53.28	51.23
Replicate 3	53.16	50.45	Replicate 43	53.07	50.39
Replicate 4	53.30	50.70	Replicate 44	52.95	49.72
Replicate 5	52.79	50.28	Replicate 45	53.31	51.04
Replicate 6	53.14	50.76	Replicate 46	53.72	50.80
Replicate 7	53.04	50.36	Replicate 47	52.91	51.03
Replicate 8	52.97	50.11	Replicate 48	53.10	50.53
Replicate 9	53.28	51.37	Replicate 49	53.05	50.81
Replicate 10	53.01	50.55	Replicate 50	53.79	50.90
Replicate 11	53.26	50.70	Replicate 51	52.65	50.15
Replicate 12	53.16	49.86	Replicate 52	53.30	50.45
Replicate 13	52.81	50.94	Replicate 53	52.68	50.12
Replicate 14	53.21	50.71	Replicate 54	52.74	50.01
Replicate 15	53.39	50.23	Replicate 55	53.50	50.11
Replicate 16	53.06	50.46	Replicate 56	52.54	50.58
Replicate 17	53.34	50.48	Replicate 57	53.31	51.03
Replicate 18	52.71	50.42	Replicate 58	53.13	50.34
Replicate 19	53.18	50.87	Replicate 59	52.72	50.37
Replicate 20	52.82	50.44	Replicate 60	53.49	51.43
Replicate 21	53.36	50.74	Replicate 61	53.13	50.71
Replicate 22	53.15	50.72	Replicate 62	53.61	51.27
Replicate 23	53.24	50.65	Replicate 63	52.74	50.15
Replicate 24	52.68	50.51	Replicate 64	53.19	50.25
Replicate 25	52.76	50.44	Replicate 65	53.28	51.04
Replicate 26	52.79	50.43	Replicate 66	52.91	50.94
Replicate 27	53.01	50.58	Replicate 67	53.25	50.85
Replicate 28	53.24	50.12	Replicate 68	53.12	50.74
Replicate 29	52.86	50.68	Replicate 69	53.08	50.31
Replicate 30	52.85	50.02	Replicate 70	52.92	50.44
Replicate 31	52.90	50.85	Replicate 71	53.35	50.63
Replicate 32	53.25	50.60	Replicate 72	53.25	50.75
Replicate 33	53.32	50.54	Replicate 73	52.54	50.42
Replicate 34	52.42	50.55	Replicate 74	52.58	50.20
Replicate 35	52.91	50.72	Replicate 75	52.49	49.75
Replicate 36	53.06	50.36	Replicate 76	52.98	50.96
Replicate 37	52.67	50.73	Replicate 77	53.04	50.24
Replicate 38	53.36	50.16	Replicate 78	53.30	50.44
Replicate 39	52.57	50.36	Replicate 79	52.93	50.36
Replicate 40	53.07	50.58	Replicate 80	52.98	50.76



The final difference estimate will be the difference between the two final estimates, *i.e.*  $53.05 - 50.58 = 2.47$ .

The procedure to estimate the final standard error is straightforward. It is similar to the procedure described in Chapter 7, except that  $\theta$  is now a difference, and not a mean or a regression coefficient. The different steps are:

- The difference in the means between females and males is computed for each of the 80 replicates.
- Each of the 80 difference estimates is compared with the final difference estimate, then squared.
- The sum of the square is computed then divided by 20 to obtain the sampling variance on the difference.
- The standard error is the square root of the sampling variance.

These different steps can be summarised as:

$$\sigma_{\hat{\theta}} = \sqrt{\frac{1}{20} \sum_{i=1}^{80} (\hat{\theta}_{(i)} - \hat{\theta})^2} \text{ with } \theta \text{ being a difference.}$$

Concretely:

- For the first replicate, the difference between the female mean estimate and the male mean estimate is equal to  $(53.29 - 50.69) = 2.60$ . For the second replicate, the difference estimate will be equal to  $(53.16 - 50.53) = 2.63$  and so on for the 80 replicates. All these difference estimates are presented in Table 11.3.
- Each of the 80 replicate difference estimates is compared with the final difference estimate and this difference is squared. For the first replicate, it will be  $(2.60 - 2.47)^2 = 0.0164$ . For the second replicate, it will be  $(2.63 - 2.47)^2 = 0.0258$ . These squared differences are also presented in Table 11.3.
- These squared differences are summed. This sum is equal to  $(0.0164 + 0.0258 + \dots + 0.0641) = 9.7360$ . The sampling variance on the difference is therefore equal to  $\frac{9.7360}{20} = 0.4868$ .
- The standard error is equal to the square root of 0.4868, *i.e.* 0.6977.

As  $\frac{2.47}{0.6977}$  is greater than 1.96, job expectations for females are statistically greater than job expectations for males in Germany.

If the researcher had considered these two German subsamples as independent, then s/he would have obtained the following for the standard error on this difference

$$\sigma_{(\hat{\theta}_i - \hat{\theta}_j)} = \sqrt{\sigma_{(\hat{\theta}_i)}^2 + \sigma_{(\hat{\theta}_j)}^2} = \sqrt{(0.57)^2 + (0.69)^2} = 0.895$$

In this particular case, the difference between the unbiased estimate of the standard error (*i.e.* 0.698) and the biased estimate of the standard error (*i.e.* 0.895) is quite small. The difference between the biased and unbiased estimates of the standard error, however, can be substantial, as shown later in this chapter.

A SPSS® macro of MCR\_SE\_DIFF has been developed for the computation of standard errors on differences. Box 11.2 presents the SPSS® syntax for running this macro. Table 11.4 presents the structure of the output data file.



**Table 11.3**  
Difference in estimates for the final weight and 80 replicate weights between females and males (PISA 2003)

Weight	Difference between females and males (females – males)	Squared difference between the replicate and the final estimates	Weight	Difference between females and males (females – males)	Squared difference between the replicate and the final estimates
<b>Final weight</b>	<b>2.47</b>				
Replicate 1	2.60	0.0164	Replicate 41	2.14	0.1079
Replicate 2	2.63	0.0258	Replicate 42	2.05	0.1789
Replicate 3	2.72	0.0599	Replicate 43	2.68	0.0440
Replicate 4	2.61	0.0180	Replicate 44	3.23	0.5727
Replicate 5	2.51	0.0011	Replicate 45	2.28	0.0373
Replicate 6	2.39	0.0067	Replicate 46	2.92	0.2038
Replicate 7	2.68	0.0450	Replicate 47	1.88	0.3488
Replicate 8	2.86	0.1483	Replicate 48	2.56	0.0084
Replicate 9	1.92	0.3085	Replicate 49	2.23	0.0567
Replicate 10	2.46	0.0002	Replicate 50	2.89	0.1768
Replicate 11	2.57	0.0089	Replicate 51	2.49	0.0004
Replicate 12	3.30	0.6832	Replicate 52	2.85	0.1440
Replicate 13	1.87	0.3620	Replicate 53	2.56	0.0072
Replicate 14	2.50	0.0009	Replicate 54	2.73	0.0667
Replicate 15	3.16	0.4756	Replicate 55	3.39	0.8520
Replicate 16	2.60	0.0173	Replicate 56	1.96	0.2631
Replicate 17	2.87	0.1577	Replicate 57	2.28	0.0351
Replicate 18	2.29	0.0327	Replicate 58	2.79	0.1017
Replicate 19	2.31	0.0269	Replicate 59	2.35	0.0158
Replicate 20	2.38	0.0078	Replicate 60	2.05	0.1749
Replicate 21	2.62	0.0221	Replicate 61	2.42	0.0027
Replicate 22	2.43	0.0014	Replicate 62	2.34	0.0164
Replicate 23	2.59	0.0142	Replicate 63	2.59	0.0137
Replicate 24	2.17	0.0901	Replicate 64	2.94	0.2230
Replicate 25	2.32	0.0227	Replicate 65	2.24	0.0539
Replicate 26	2.36	0.0132	Replicate 66	1.97	0.2524
Replicate 27	2.43	0.0015	Replicate 67	2.40	0.0050
Replicate 28	3.12	0.4225	Replicate 68	2.38	0.0089
Replicate 29	2.18	0.0844	Replicate 69	2.76	0.0848
Replicate 30	2.84	0.1333	Replicate 70	2.48	0.0002
Replicate 31	2.06	0.1709	Replicate 71	2.72	0.0609
Replicate 32	2.65	0.0312	Replicate 72	2.50	0.0006
Replicate 33	2.78	0.0970	Replicate 73	2.12	0.1217
Replicate 34	1.87	0.3611	Replicate 74	2.39	0.0073
Replicate 35	2.19	0.0809	Replicate 75	2.73	0.0693
Replicate 36	2.69	0.0490	Replicate 76	2.02	0.2031
Replicate 37	1.94	0.2825	Replicate 77	2.80	0.1058
Replicate 38	3.20	0.5355	Replicate 78	2.86	0.1519
Replicate 39	2.21	0.0683	Replicate 79	2.57	0.0091
Replicate 40	2.48	0.0001	Replicate 80	2.22	0.0641
			<b>Sum of squared differences</b>		<b>9.736</b>

Box 11.2 **SPSS® macro for computing standard errors on differences (e.g. PISA 2003)**

```

INSERT FILE="C:\PISA\MACRO\MCR_SE_DIFF.SPS" .
SET MPRINT=YES.
DIFnoPV DEP=BSMJ /
  STAT=MEAN /
  COMPARE=ST03Q01 /
  CATEG=1 2/
  INFILE="C:\TEMP\DEU1.SAV" /
  WITHIN=CNT/                               /*default=NOWITHIN*/
  WGT=W_FSTUWT/                             /*default=W_FSTUWT*/
  RWGT=W_FSTR/                              /*default=W_FSTR */
  CONS=0.05/                                 /*default=0.05 */
  NREP=80/.                                  /*default=80 */

```



Beside the arguments common to most SPSS® macros, four other arguments have to be specified:

1. The DEP argument informs the macro of the numerical variable on which a mean or a standard deviation will be computed per value of a categorical variable. In this example, VAR equals BSMJ.
2. The COMPARE argument specifies the categorical variables on which the contrasts will be based.
3. The CATEG argument specifies the values of the categorical variables for which contrasts are required. As gender has only two categories, denoted 1 and 2, CATEG is set as "1 2". If a categorical variable has four categories and if these four categories are specified in CATEG statement, then the macro will compute the standard error on the difference between:
  - category 1 and category 2;
  - category 1 and category 3;
  - category 1 and category 4;
  - category 2 and category 3;
  - category 2 and category 4;
  - category 3 and category 4.

If only categories 1 and 2 are specified, then only the contrast between 1 and 2 will be computed, regardless of the number of categories for this categorical variable.

4. The STAT argument specifies the required statistic. See Chapter 7 for available statistics.

**Table 11.4**  
**Output data file from Box 11.2**

CNT	CONTRAST	STAT	SESTAT
DEU	ST03Q01.1_2	2.47	0.6977
Total	ST03Q01.1_2	2.47	0.6977

The row denoted "Total" in Table 11.4 presents the statistic on the whole dataset regardless of the grouping variables.

For dichotomous variables, the standard error on the difference can also be computed by a regression model. Box 11.3 presents the SPSS® syntax to compute a gender difference in BSMJ and its standard error by using the MCR\_SE\_REG macro. Before running the syntax in Box 11.3, the gender variable of ST03Q01 needs to be recoded into a new variable denoted GENDER, with females being 1 and males being 0. Table 11.5 presents the structure of the output data file.

**Box 11.3 Alternative SPSS® macro for computing the standard error on a difference for a dichotomous variable (e.g. PISA 2003)**

```
GET FILE="C:\PISA\2003\DATA\INT_STUI_2003.SAV" .
SELECT IF (CNT="DEU") .
SELECT IF NOT (ST03Q01=8) .
RECODE ST03Q01 (1=1) (2=0) INTO GENDER.
SAVE OUTFILE="C:\TEMP\DEU2.SAV" .

INSERT FILE="C:\PISA\MACRO\MCR_SE_REG.SPS" .

SET MPRINT=YES.
REGnopV IND=GENDER/
  DEP=BSMJ/
  GRP=CNT/                               /* is default */
  INFILE="C:\TEMP\DEU2.SAV" /.
```





**Table 11.5**  
Output data file from Box 11.3

CNT	Ind	STAT	SE
DEU	INTERCEPT	50.58	0.69
DEU	GENDER	2.47	0.70
DEU	R_SQUARE	0.01	0.00

The difference estimate and its respective standard error are equal to the regression coefficient estimate and its standard error. For polytomous categorical variables, the use of the regression macro would require the recoding of the categorical variables into  $h-1$  dichotomous variables, with  $h$  being equal to the number of categories. Further, the regression macro will compare each category with the reference category, while the macro MCR\_SE\_DIFF will provide all contrasts.

### THE STANDARD ERROR ON A DIFFERENCE WITH PLAUSIBLE VALUES

The procedure for computing the standard error on a difference that involves plausible values consists of:

- Using each plausible value and for the final and 80 replicate weights, the requested statistic (e.g. a mean) has to be computed per value of the categorical variable.
- Computing, per contrast, per plausible value and per replicate weight, the difference between the two categories. There will be 405 difference estimates. Table 11.6 presents the structure of these 405 differences.
- A final difference estimate equal to the average of the five difference estimates.
- Computing, per plausible value, the sampling variance by comparing the final difference estimate with the 80 replicate estimates.
- A final sampling variance being equal to the average of the five sampling variances.
- Computing imputation variance, also denoted measurement error variance.
- Combining the sampling variance and the imputation variance to obtain the final error variance.
- A standard error being equal to the square root of the error variance.

**Table 11.6**  
Gender difference estimates and their respective sampling variances on the mathematics scale (PISA 2003)

Weight	PV1	PV2	PV3	PV4	PV5
<b>Final</b>	<b>-8.94</b>	<b>-9.40</b>	<b>-8.96</b>	<b>-7.46</b>	<b>-10.12</b>
Replicate 1	-9.64	-10.05	-10.29	-8.74	-11.45
.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....
Replicate 80	-8.56	-8.52	-8.85	-7.70	-9.84
<b>Sampling variance</b>	<b>(4.11)<sup>2</sup></b>	<b>(4.36)<sup>2</sup></b>	<b>(4.10)<sup>2</sup></b>	<b>(4.31)<sup>2</sup></b>	<b>(4.28)<sup>2</sup></b>

Note: PV = plausible value.

A SPSS® macro has been developed to compute standard errors on differences that involve plausible values. Box 11.4 provides the SPSS® syntax. In this example, the standard error on the difference in performance in mathematics between males and females is computed. Table 11.7 presents the structure of the output data file.



### Box 11.4 SPSS® syntax for computing standard errors on differences which involve PVs (e.g. PISA 2003)

```

INSERT FILE="C:\PISA\MACRO\MCR_SE_DIFF_PV.SPS" .

SET MPRINT=YES.

DIF_PV DEP=PV1MATH PV2MATH PV3MATH PV4MATH PV5MATH/
  STAT=MEAN/
  COMPARE=ST03Q01/
  CATEG= 1 2/
  INFILE="C:\TEMP\DEU1.SAV" /
  WITHIN = CNT/                               /*default=NOWITHIN*/
  WGT=W_FSTUWT/                               /*default=W_FSTUWT*/
  RWGT=W_FSTR/                                /*default=W_FSTR */
  CONS=0.05/                                  /*default=0.05 */
  NREP=80/.                                   /*default=80 */

```

As the absolute value of the ratio between the difference estimate and its respective standard error is greater than 1.96, the null hypothesis is rejected. Thus females perform on average lower than males in Germany in mathematics. These results might also be obtained through the regression macro for plausible values.

**Table 11.7**  
Output data file from Box 11.4

CNT	ST03Q01	STAT	SE
DEU	1-2	-8.98	4.37
Total	1-2	-8.98	4.37

Table 11.8 presents the gender difference in mean performance in mathematics for all OECD countries in PISA 2003, as well as the unbiased standard errors and the biased standard errors.

In nearly all countries, the unbiased standard error is smaller than the biased standard error, reflecting a positive covariance between the two sampling distributions. In a few countries, the difference between the two standard errors is small, but it is substantial for some other countries, such as Greece and Turkey.

These two SPSS® macros can also be used for other statistical parameters, such as variances or standard deviations. Table 11.9 presents the gender difference in the mean science performance and in the standard deviation for science performance in PISA 2006.

Surprisingly, males and females perform differently in only 8 countries out of 30. In two countries, *i.e.* Turkey and Greece, females outperform males while in Denmark, Luxembourg, Mexico, Netherlands, Switzerland and the United Kingdom, males outperforms females. On the other hand, in 23 countries, the standard deviation of the science performance for females is significantly smaller than the standard deviation of the science performance for males.



**Table 11.8**  
Gender differences on the mathematics scale, unbiased standard errors  
and biased standard errors (PISA 2003)

Country	Mean difference (females – males)	Unbiased standard error	Biased standard error
AUS	-5.34	3.75	4.04
AUT	-7.57	4.40	5.59
BEL	-7.51	4.81	4.69
CAN	-11.17	2.13	2.78
CHE	-16.63	4.87	5.98
CZE	-14.97	5.08	6.11
DEU	-8.98	4.37	5.59
DNK	-16.58	3.20	4.50
ESP	-8.86	2.98	4.02
FIN	-7.41	2.67	3.24
FRA	-8.51	4.15	4.60
GBR	-6.66	4.90	4.84
GRC	-19.40	3.63	6.11
HUN	-7.79	3.54	4.69
IRL	-14.81	4.19	4.54
ISL	15.41	3.46	3.15
ITA	-17.83	5.89	5.96
JPN	-8.42	5.89	7.04
KOR	-23.41	6.77	6.90
LUX	-17.17	2.81	2.40
MEX	-10.90	3.94	5.91
NLD	-5.12	4.29	5.36
NOR	-6.22	3.21	4.04
NZL	-14.48	3.90	4.23
POL	-5.59	3.14	4.18
PRT	-12.25	3.31	5.41
SVK	-18.66	3.65	5.30
SWE	-6.53	3.27	4.30
TUR	-15.13	6.16	10.33
USA	-6.25	2.89	4.65

**Table 11.9**  
Gender differences in mean science performance and in standard deviation  
for science performance (PISA 2006)

	Difference in mean (females – males)		Difference in standard deviation (females – males)	
	Difference	S.E.	Difference	S.E.
AUS	-0.05	3.76	-7.29	1.85
AUT	-7.53	4.91	0.40	3.56
BEL	-0.75	4.13	-6.81	2.54
CAN	-4.07	2.19	-5.90	1.62
CHE	-5.56	2.67	-0.67	1.67
CZE	-4.82	5.64	4.09	2.79
DEU	-7.14	3.71	-5.92	2.22
DNK	-8.93	3.24	-2.89	2.04
ESP	-4.36	2.36	-6.13	1.66
FIN	3.10	2.88	-7.87	1.93
FRA	-2.64	4.03	-8.87	2.72
GBR	-10.06	3.44	-9.45	2.19
GRC	11.41	4.68	-12.93	2.92
HUN	-6.48	4.17	-8.45	2.88
IRL	0.40	4.31	-7.07	2.12
ISL	6.17	3.44	-7.46	2.24
ITA	-3.05	3.53	-9.00	2.11
JPN	-3.26	7.40	-8.74	3.26
KOR	1.86	5.55	-7.43	2.67
LUX	-9.34	2.93	-8.71	2.15
MEX	-6.66	2.19	-3.14	1.76
NLD	-7.20	3.03	-2.80	2.35
NOR	4.37	3.39	-9.31	2.36
NZL	3.75	5.22	-8.57	2.42
POL	-3.38	2.48	-7.00	1.77
PRT	-5.04	3.33	-4.89	2.06
SVK	-6.23	4.73	-6.07	2.87
SWE	-1.28	2.97	-4.93	2.86
TUR	11.93	4.12	-4.64	2.25
USA	-0.58	3.51	-7.13	2.44



Comparisons of regression coefficients might also interest researchers or policy makers. For instance, does the influence of a student's socio-economic background on his/her performance depend on a student's gender? A regression model on the male subsample and another one on the female subsample will provide the regression coefficients but it will be impossible to compute the significance level of their difference, as the two samples are not independent. This test can, however, be easily implemented by modelling an interaction. Box 11.5 presents the SPSS® syntax for testing this interaction.

Question ST04Q01 is recoded into a new variable denoted MALE, with males being 1 and females being 0. A second variable, denoted INTER, is computed by multiplying MALE with HISEI. The INTER variable will be equal to 0 for all females and to HISEI for all males.

Box 11.5 **SPSS® syntax for computing standard errors on differences that involve PVs (e.g. PISA 2006)**

```
GET FILE="C:\PISA\2006\DATA\INT_STU06_DEC07.SAV" .
SELECT IF (CNT="BEL") .
SELECT IF NOT (ST04Q01=8) .
RECODE ST04Q01 (1=0) (2=1) INTO MALES .
COMPUTE INTER=MALES*HISEI .
SAVE OUTFILE="C:\TEMP\BEL.SAV" .

INSERT FILE="C:\PISA\MACRO\MCR_SE_REG_PV.SPS" .

SET MPRINT=YES .

*** MODEL 1 *** .

REG_PV INFILE="C:\TEMP\BEL.SAV" /
      IND=HISEI /
      DEP=PV1SCIE PV2SCIE PV3SCIE PV4SCIE PV5SCIE /
      GRP=CNT MALES / .

*** MODEL 2 *** .

REG_PV INFILE="C:\TEMP\BEL.SAV" /
      IND=HISEI MALES INTER /
      DEP=PV1SCIE PV2SCIE PV3SCIE PV4SCIE PV5SCIE /
      GRP=CNT / .
```

Table 11.10 presents the regression coefficients for the male subsample regression and the female subsample regression (e.g. Model 1) as well as the regression coefficients for the model including males and females altogether with the interaction (e.g. Model 2). Standard errors are also provided.

**Table 11.10**

**Regression coefficient of HISEI on the science performance for different models (PISA 2006)**

Models	Sample	Variables	Estimates	S.E.
Model 1	Females	Intercept	405.13	7.32
		HISEI	2.21	0.13
	Males	Intercept	401.90	5.89
		HISEI	2.27	0.12
Model 2	All	Intercept	405.13	7.32
		MALE	-3.23	7.46
		HISEI	2.21	0.13
		INTER	0.06	0.15



The model with the interaction returns values for the intercept and for the HISEI regression coefficient that are identical to the corresponding estimates on the subsample of females. The regression coefficient of INTER is equal to the difference between the two HISEI regression coefficients computed on both subsamples. The standard error for the INTER regression coefficient indicates that the null hypothesis cannot be rejected. Therefore, the influence of a student's social background on his/her performance does not depend on student gender.

## MULTIPLE COMPARISONS

In Chapter 4, it was noted that every statistical inference is associated with what is usually called a type I error. This error represents the risk of rejecting a null hypothesis that is true.

Let's suppose that at the population level, there is no difference in the mathematics performance between males and females. A sample is drawn and the gender difference in mathematics performance is computed. As this difference is based on a sample, a standard error on the difference has to be computed. If the standardised difference (*i.e.* the gender difference divided by its standard error) is less than  $-1.96$  or greater than  $1.96$ , that difference would be reported as significant. In fact, there are 5 chances out of 100 to observe a standardised difference lower than  $-1.96$  or higher than  $1.96$  and still have the null hypothesis true. In other words, there are 5 chances out of 100 to reject the null hypothesis, when there is no true gender difference in the population.

If 100 countries are participating in the international survey and if the gender difference is computed for each of them, then it is statistically expected to report 5 of the 100 gender differences as significant, when there are no true differences at the population level.

For every country, the type I error is set at 0.05. For two countries, as countries are independent samples, the probability of not making a type I error, *i.e.* accepting both null hypotheses, is equal to 0.9025 (0.95 times 0.95) (Table 11.11).

**Table 11.11**  
Cross tabulation of the different probabilities

		Country A	
		0.05	0.95
Country B	0.05	0.0025	0.0475
	0.95	0.0475	0.9025

This statistical issue is even more amplified for tables of multiple comparisons of achievement. Suppose that the means of three countries need to be compared. This will involve three tests: Country A versus Country B; Country A versus Country C; and Country B versus Country C. The probability of not making a type I error is therefore equal to:

$$(1 - \alpha)(1 - \alpha)(1 - \alpha) = (1 - \alpha)^3$$

Broadly speaking, if  $X$  comparisons are tested, then the probability of not making a type I error is equal to  $(1 - \alpha)^X$

Dunn (1961) developed a general procedure that is appropriate for testing a set of *a priori* hypotheses, while controlling the probability of making a type I error. It consists of adjusting the value  $\alpha$ . Precisely, the value  $\alpha$  is divided by the number of comparisons and then its respective critical value is used.



In the case of three comparisons, the critical value for an  $\alpha = 0.05$  will therefore be equal to 2.24 instead of 1.96. Indeed,

$$\frac{0.05}{3} = 0.01666$$

As the risk is shared by both tails of the sampling distribution, one has to find the z score that corresponds to the cumulative proportion of 0.008333. Consulting the cumulative function of the standardised normal distribution will return the value  $-2.24$ .

Nevertheless, the researcher still has to decide how many comparisons are involved. In PISA, it was decided that no correction of the critical value would be applied, except on multiple comparison tables.<sup>1</sup> Indeed, in many cases, readers are primarily interested in finding out whether a given value in a particular country is different from a second value in the same or another country, e.g. whether females in a country perform better than males in the same country. Therefore, as only one test is performed at a time, then no adjustment is required.

On the other hand, with multiple comparison tables, if the reader is interested in comparing the performance of one country with all other countries, the adjustment is required. For example, if one wants to compare the performance of Country 1 with all other countries, we will have the following comparisons: Country 1 versus Country 2; Country 1 versus Country 3; and Country 1 versus Country L. Therefore, the adjustment will be based on L-1 comparisons.

## CONCLUSION

This chapter was devoted to the computation of standard errors on differences. After a description of the statistical issues for such estimates, the different steps for computing such standard errors were presented. The SPSS® macros to facilitate such computations were also described.

It was clearly stated that any comparison between countries does not require the estimation of the covariance. However, it is strongly advised that the covariance between the sampling distributions for any within-country comparisons should be estimated.

The two SPSS® macros can however be used for between-country comparisons. As the expected value of the covariance is equal to 0, in a particular case, one might get a small positive or negative estimated covariance. Therefore, the standard error returned by the SPSS® macro might be slightly different from the standard errors based only on the initial standard errors.

Finally, the correction of the critical value for multiple comparisons was discussed.

## Note

1. The Bonferroni adjustment was not presented in the PISA 2006 multiple comparison tables (OECD, 2007).



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# Table of contents

<b>FOREWORD</b> .....	<b>3</b>
<b>USER'S GUIDE</b> .....	<b>17</b>
<b>CHAPTER 1 THE USEFULNESS OF PISA DATA FOR POLICY MAKERS, RESEARCHERS AND EXPERTS ON METHODOLOGY</b> .....	<b>19</b>
<b>PISA – an overview</b> .....	<b>20</b>
▪ The PISA surveys.....	20
<b>How can PISA contribute to educational policy, practice and research?</b> .....	<b>22</b>
▪ Key results from PISA 2000, PISA 2003 and PISA 2006.....	23
<b>Further analyses of PISA datasets</b> .....	<b>25</b>
▪ Contextual framework of PISA 2006.....	28
▪ Influence of the methodology on outcomes.....	31
<b>CHAPTER 2 EXPLORATORY ANALYSIS PROCEDURES</b> .....	<b>35</b>
<b>Introduction</b> .....	<b>36</b>
<b>Weights</b> .....	<b>36</b>
<b>Replicates for computing the standard error</b> .....	<b>39</b>
<b>Plausible values</b> .....	<b>43</b>
<b>Conclusion</b> .....	<b>45</b>
<b>CHAPTER 3 SAMPLE WEIGHTS</b> .....	<b>47</b>
<b>Introduction</b> .....	<b>48</b>
<b>Weights for simple random samples</b> .....	<b>49</b>
<b>Sampling designs for education surveys</b> .....	<b>51</b>
<b>Why do the PISA weights vary?</b> .....	<b>55</b>
<b>Conclusion</b> .....	<b>56</b>
<b>CHAPTER 4 REPLICATE WEIGHTS</b> .....	<b>57</b>
<b>Introduction</b> .....	<b>58</b>
<b>Sampling variance for simple random sampling</b> .....	<b>58</b>
<b>Sampling variance for two-stage sampling</b> .....	<b>63</b>
<b>Replication methods for simple random samples</b> .....	<b>68</b>
<b>Replication methods for two-stage samples</b> .....	<b>70</b>
▪ The Jackknife for unstratified two-stage sample designs.....	70
▪ The Jackknife for stratified two-stage sample designs.....	71
▪ The Balanced Repeated Replication method.....	72
<b>Other procedures for accounting for clustered samples</b> .....	<b>74</b>
<b>Conclusion</b> .....	<b>74</b>

<b>CHAPTER 5 THE RASCH MODEL</b> .....	<b>77</b>
<b>Introduction</b> .....	78
<b>How can the information be summarised?</b> .....	78
<b>The Rasch Model for dichotomous items</b> .....	79
▪ Introduction to the Rasch Model.....	79
▪ Item calibration.....	83
▪ Computation of a student's score.....	85
▪ Computation of a student's score for incomplete designs.....	89
▪ Optimal conditions for linking items.....	90
▪ Extension of the Rasch Model.....	91
<b>Other item response theory models</b> .....	92
<b>Conclusion</b> .....	92
 <b>CHAPTER 6 PLAUSIBLE VALUES</b> .....	 <b>93</b>
<b>Individual estimates versus population estimates</b> .....	94
<b>The meaning of plausible values (PVs)</b> .....	94
<b>Comparison of the efficiency of WLEs, EAP estimates and PVs for the estimation of some population statistics</b> .....	97
<b>How to perform analyses with plausible values</b> .....	100
<b>Conclusion</b> .....	101
 <b>CHAPTER 7 COMPUTATION OF STANDARD ERRORS</b> .....	 <b>103</b>
<b>Introduction</b> .....	104
<b>The standard error on univariate statistics for numerical variables</b> .....	104
<b>The SPSS® macro for computing the standard error on a mean</b> .....	107
<b>The standard error on percentages</b> .....	110
<b>The standard error on regression coefficients</b> .....	112
<b>The standard error on correlation coefficients</b> .....	114
<b>Conclusion</b> .....	115
 <b>CHAPTER 8 ANALYSES WITH PLAUSIBLE VALUES</b> .....	 <b>117</b>
<b>Introduction</b> .....	118
<b>Univariate statistics on plausible values</b> .....	118
<b>The standard error on percentages with PVs</b> .....	121
<b>The standard error on regression coefficients with PVs</b> .....	121
<b>The standard error on correlation coefficients with PVs</b> .....	124
<b>Correlation between two sets of plausible values</b> .....	124
<b>A fatal error shortcut</b> .....	128
<b>An unbiased shortcut</b> .....	129
<b>Conclusion</b> .....	130
 <b>CHAPTER 9 USE OF PROFICIENCY LEVELS</b> .....	 <b>133</b>
<b>Introduction</b> .....	134
<b>Generation of the proficiency levels</b> .....	134
<b>Other analyses with proficiency levels</b> .....	139
<b>Conclusion</b> .....	141



<b>CHAPTER 10 ANALYSES WITH SCHOOL-LEVEL VARIABLES</b> .....	<b>143</b>
<b>Introduction</b> .....	144
<b>Limits of the PISA school samples</b> .....	145
<b>Merging the school and student data files</b> .....	146
<b>Analyses of the school variables</b> .....	146
<b>Conclusion</b> .....	148
<b>CHAPTER 11 STANDARD ERROR ON A DIFFERENCE</b> .....	<b>149</b>
<b>Introduction</b> .....	150
<b>Statistical issues and computing standard errors on differences</b> .....	150
<b>The standard error on a difference without plausible values</b> .....	152
<b>The standard error on a difference with plausible values</b> .....	157
<b>Multiple comparisons</b> .....	161
<b>Conclusion</b> .....	162
<b>CHAPTER 12 OECD TOTAL AND OECD AVERAGE</b> .....	<b>163</b>
<b>Introduction</b> .....	164
<b>Recoding of the database to estimate the pooled OECD total and the pooled OECD average</b> .....	166
<b>Duplication of the data to avoid running the procedure three times</b> .....	168
<b>Comparisons between the pooled OECD total or pooled OECD average estimates and a country estimate</b> .....	169
<b>Comparisons between the arithmetic OECD total or arithmetic OECD average estimates and a country estimate</b> .....	171
<b>Conclusion</b> .....	171
<b>CHAPTER 13 TRENDS</b> .....	<b>173</b>
<b>Introduction</b> .....	174
<b>The computation of the standard error for trend indicators on variables other than performance</b> .....	175
<b>The computation of the standard error for trend indicators on performance variables</b> .....	177
<b>Conclusion</b> .....	181
<b>CHAPTER 14 STUDYING THE RELATIONSHIP BETWEEN STUDENT PERFORMANCE AND INDICES DERIVED FROM CONTEXTUAL QUESTIONNAIRES</b> .....	<b>183</b>
<b>Introduction</b> .....	184
<b>Analyses by quarters</b> .....	184
<b>The concept of relative risk</b> .....	186
▪ <b>Instability of the relative risk</b> .....	187
▪ <b>Computation of the relative risk</b> .....	188
<b>Effect size</b> .....	191
<b>Linear regression and residual analysis</b> .....	193
▪ <b>Independence of errors</b> .....	193
<b>Statistical procedure</b> .....	196
<b>Conclusion</b> .....	197



<b>CHAPTER 15 MULTILEVEL ANALYSES</b> .....	<b>199</b>
<b>Introduction</b> .....	200
<b>Two-level modelling with SPSS®</b> .....	202
▪ Decomposition of the variance in the empty model.....	202
▪ Models with only random intercepts.....	205
▪ Shrinkage factor.....	207
▪ Models with random intercepts and fixed slopes.....	207
▪ Models with random intercepts and random slopes.....	209
▪ Models with Level 2 independent variables.....	214
▪ Computation of final estimates and their respective standard errors.....	217
<b>Three-level modelling</b> .....	219
<b>Limitations of the multilevel model in the PISA context</b> .....	221
<b>Conclusion</b> .....	222
<b>CHAPTER 16 PISA AND POLICY RELEVANCE – THREE EXAMPLES OF ANALYSES</b> .....	<b>223</b>
<b>Introduction</b> .....	224
<b>Example 1: Gender differences in performance</b> .....	224
<b>Example 2: Promoting socio-economic diversity within school?</b> .....	228
<b>Example 3: The influence of an educational system on the expected occupational status of students at age 30</b> .....	234
<b>Conclusion</b> .....	237
<b>CHAPTER 17 SPSS® MACRO</b> .....	<b>239</b>
<b>Introduction</b> .....	240
<b>Structure of the SPSS® Macro</b> .....	240
<b>REFERENCES</b> .....	<b>321</b>
<b>APPENDICES</b> .....	<b>323</b>
<b>Appendix 1</b> Three-level regression analysis.....	324
<b>Appendix 2</b> PISA 2006 International database.....	332
<b>Appendix 3</b> PISA 2006 Student questionnaire.....	341
<b>Appendix 4</b> PISA 2006 Information communication technology (ICT) Questionnaire.....	350
<b>Appendix 5</b> PISA 2006 School questionnaire.....	352
<b>Appendix 6</b> PISA 2006 Parent questionnaire.....	359
<b>Appendix 7</b> Codebook for PISA 2006 student questionnaire data file.....	363
<b>Appendix 8</b> Codebook for PISA 2006 non-scored cognitive and embedded attitude items.....	407
<b>Appendix 9</b> Codebook for PISA 2006 scored cognitive and embedded attitude items.....	427
<b>Appendix 10</b> Codebook for PISA 2006 school questionnaire data file.....	439
<b>Appendix 11</b> Codebook for PISA 2006 parents questionnaire data file.....	450
<b>Appendix 12</b> PISA 2006 questionnaire indices.....	456



## LIST OF BOXES

Box 2.1	WEIGHT statement in SPSS®.....	37
<hr/>		
Box 7.1	SPSS® syntax for computing 81 means (e.g. PISA 2003).....	104
Box 7.2	SPSS® syntax for computing the mean of HISEI and its standard error (e.g. PISA 2003).....	107
Box 7.3	SPSS® syntax for computing the standard deviation of HISEI and its standard error by gender (e.g. PISA 2003).....	109
Box 7.4	SPSS® syntax for computing the percentages and their standard errors for gender (e.g. PISA 2003).....	110
Box 7.5	SPSS® syntax for computing the percentages and its standard errors for grades by gender (e.g. PISA 2003).....	112
Box 7.6	SPSS® syntax for computing regression coefficients, $R^2$ and its respective standard errors: Model 1 (e.g. PISA 2003).....	113
Box 7.7	SPSS® syntax for computing regression coefficients, $R^2$ and its respective standard errors: Model 2 (e.g. PISA 2003).....	114
Box 7.8	SPSS® syntax for computing correlation coefficients and its standard errors (e.g. PISA 2003).....	114
<hr/>		
Box 8.1	SPSS® syntax for computing the mean on the science scale by using the MCR_SE_UNIV macro (e.g. PISA 2006).....	119
Box 8.2	SPSS® syntax for computing the mean and its standard error on PVs (e.g. PISA 2006).....	120
Box 8.3	SPSS® syntax for computing the standard deviation and its standard error on PVs by gender (e.g. PISA 2006).....	131
Box 8.4	SPSS® syntax for computing regression coefficients and their standard errors on PVs by using the MCR_SE_REG macro (e.g. PISA 2006).....	122
Box 8.5	SPSS® syntax for running the simple linear regression macro with PVs (e.g. PISA 2006).....	123
Box 8.6	SPSS® syntax for running the correlation macro with PVs (e.g. PISA 2006).....	124
Box 8.7	SPSS® syntax for the computation of the correlation between mathematics/quantity and mathematics/space and shape by using the MCR_SE_COR_2PV macro (e.g. PISA 2003).....	126
<hr/>		
Box 9.1	SPSS® syntax for generating the proficiency levels in science (e.g. PISA 2006).....	135
Box 9.2	SPSS® syntax for computing the percentages of students by proficiency level in science and its standard errors (e.g. PISA 2006).....	136
Box 9.3	SPSS® syntax for computing the percentage of students by proficiency level in science and its standard errors (e.g. PISA 2006).....	138
Box 9.4	SPSS® syntax for computing the percentage of students by proficiency level and its standard errors by gender (e.g. PISA 2006).....	138
Box 9.5	SPSS® syntax for generating the proficiency levels in mathematics (e.g. PISA 2003).....	139
Box 9.6	SPSS® syntax for computing the mean of self-efficacy in mathematics and its standard errors by proficiency level (e.g. PISA 2003).....	140
<hr/>		
Box 10.1	SPSS® syntax for merging the student and school data files (e.g. PISA 2006).....	146
Box 10.2	Question on school location in PISA 2006.....	147
Box 10.3	SPSS® syntax for computing the percentage of students and the average performance in science, by school location (e.g. PISA 2006).....	147
<hr/>		
Box 11.1	SPSS® syntax for computing the mean of job expectations by gender (e.g. PISA 2003).....	152
Box 11.2	SPSS® macro for computing standard errors on differences (e.g. PISA 2003).....	155



Box 11.3	Alternative SPSS® macro for computing the standard error on a difference for a dichotomous variable (e.g. PISA 2003).....	156
Box 11.4	SPSS® syntax for computing standard errors on differences which involve PVs (e.g. PISA 2003).....	158
Box 11.5	SPSS® syntax for computing standard errors on differences that involve PVs (e.g. PISA 2006).....	160
<hr/>		
Box 12.1	SPSS® syntax for computing the pooled OECD total for the mathematics performance by gender (e.g. PISA 2003).....	166
Box 12.2	SPSS® syntax for the pooled OECD average for the mathematics performance by gender (e.g. PISA 2003).....	167
Box 12.3	SPSS® syntax for the creation of a larger dataset that will allow the computation of the pooled OECD total and the pooled OECD average in one run (e.g. PISA 2003).....	168
<hr/>		
Box 14.1	SPSS® syntax for the quarter analysis (e.g. PISA 2006).....	185
Box 14.2	SPSS® syntax for computing the relative risk with five antecedent variables and five outcome variables (e.g. PISA 2006).....	189
Box 14.3	SPSS® syntax for computing the relative risk with one antecedent variable and one outcome variable (e.g. PISA 2006).....	190
Box 14.4	SPSS® syntax for computing the relative risk with one antecedent variable and five outcome variables (e.g. PISA 2006).....	190
Box 14.5	SPSS® syntax for computing effect size (e.g. PISA 2006).....	192
Box 14.6	SPSS® syntax for residual analyses (e.g. PISA 2003).....	196
<hr/>		
Box 15.1	Normalisation of the final student weights (e.g. PISA 2006).....	203
Box 15.2	SPSS® syntax for the decomposition of the variance in student performance in science (e.g. PISA 2006).....	203
Box 15.3	SPSS® syntax for normalising PISA 2006 final student weights with deletion of cases with missing values and syntax for variance decomposition (e.g. PISA 2006).....	206
Box 15.4	SPSS® syntax for a multilevel regression model with random intercepts and fixed slopes (e.g. PISA 2006).....	208
Box 15.5	Results for the multilevel model in Box 15.4.....	208
Box 15.6	SPSS® syntax for a multilevel regression model (e.g. PISA 2006).....	210
Box 15.7	Results for the multilevel model in Box 15.6.....	211
Box 15.8	Results for the multilevel model with covariance between random parameters.....	212
Box 15.9	Interpretation of the within-school regression coefficient.....	214
Box 15.10	SPSS® syntax for a multilevel regression model with a school-level variable (e.g. PISA 2006).....	214
Box 15.11	SPSS® syntax for a multilevel regression model with interaction (e.g. PISA 2006).....	215
Box 15.12	Results for the multilevel model in Box 15.11.....	216
Box 15.13	SPSS® syntax for using the multilevel regression macro (e.g. PISA 2006).....	217
Box 15.14	SPSS® syntax for normalising the weights for a three-level model (e.g. PISA 2006).....	219
<hr/>		
Box 16.1	SPSS® syntax for testing the gender difference in standard deviations of reading performance (e.g. PISA 2000).....	225
Box 16.2	SPSS® syntax for computing the 5th percentile of the reading performance by gender (e.g. PISA 2000).....	227
Box 16.3	SPSS® syntax for preparing a data file for the multilevel analysis.....	230



Box 16.4	SPSS® syntax for running a preliminary multilevel analysis with one PV .....	231
Box 16.5	Estimates of fixed parameters in the multilevel model.....	231
Box 16.6	SPSS® syntax for running preliminary analysis with the MCR_ML_PV macro.....	233
Box 17.1	SPSS® macro of MCR_SE_UNI.sps.....	243
Box 17.2	SPSS® macro of MCR_SE_PV.sps.....	247
Box 17.3	SPSS® macro of MCR_SE_PERCENTILES_PV.sps .....	251
Box 17.4	SPSS® macro of MCR_SE_GrpPct.sps.....	254
Box 17.5	SPSS® macro of MCR_SE_PctLev.sps.....	257
Box 17.6	SPSS® macro of MCR_SE_REG.sps .....	261
Box 17.7	SPSS® macro of MCR_SE_REG_PV.sps.....	265
Box 17.8	SPSS® macro of MCR_SE_COR.sps.....	270
Box 17.9	SPSS® macro of MCR_SE_COR_1PV.sps.....	273
Box 17.10	SPSS® macro of MCR_SE_COR_2PV.sps.....	277
Box 17.11	SPSS® macro of MCR_SE_DIFF.sps.....	281
Box 17.12	SPSS® macro of MCR_SE_DIFF_PV.sps.....	285
Box 17.13	SPSS® macro of MCR_SE_PV_WLEQRT.sps.....	290
Box 17.14	SPSS® macro of MCR_SE_RR.sps.....	295
Box 17.15	SPSS® macro of MCR_SE_RR_PV.sps.....	298
Box 17.16	SPSS® macro of MCR_SE_EFFECT.sps.....	302
Box 17.17	SPSS® macro of MCR_SE_EFFECT_PV.sps .....	306
Box 17.18	SPSS® macro of MCR_ML.sps.....	311
Box 17.19	SPSS® macro of MCR_ML_PV.sps .....	315
Box A1.1	Descriptive statistics of background and explanatory variables.....	326
Box A1.2	Background model for student performance.....	327
Box A1.3	Final net combined model for student performance.....	328
Box A1.4	Background model for the impact of socio-economic background.....	329
Box A1.5	Model of the impact of socio-economic background: “school resources” module.....	330
Box A1.6	Model of the impact of socio-economic background: “accountability practices” module .....	331
Box A1.7	Final combined model for the impact of socio-economic background.....	331

## LIST OF FIGURES

Figure 1.1	Relationship between social and academic segregations.....	27
Figure 1.2	Relationship between social segregation and the correlation between science performance and student HISEI .....	27
Figure 1.3	Conceptual grid of variable types.....	29
Figure 1.4	Two-dimensional matrix with examples of variables collected or available from other sources .....	30
Figure 2.1	Science mean performance in OECD countries (PISA 2006).....	37
Figure 2.2	Gender differences in reading in OECD countries (PISA 2000).....	38
Figure 2.3	Regression coefficient of ESCS on mathematic performance in OECD countries (PISA 2003).....	38
Figure 2.4	Design effect on the country mean estimates for science performance and for ESCS in OECD countries (PISA 2006) .....	41
Figure 2.5	Simple random sample and unbiased standard errors of ESCS on science performance in OECD countries (PISA 2006) .....	42



Figure 4.1	Distribution of the results of 36 students.....	58
Figure 4.2	Sampling variance distribution of the mean.....	60
Figure 5.1	Probability of success for two high jumpers by height (dichotomous).....	80
Figure 5.2	Probability of success for two high jumpers by height (continuous).....	81
Figure 5.3	Probability of success to an item of difficulty zero as a function of student ability.....	81
Figure 5.4	Student score and item difficulty distributions on a Rasch continuum.....	84
Figure 5.5	Response pattern probabilities for the response pattern (1, 1, 0, 0).....	86
Figure 5.6	Response pattern probabilities for a raw score of 1.....	87
Figure 5.7	Response pattern probabilities for a raw score of 2.....	88
Figure 5.8	Response pattern probabilities for a raw score of 3.....	88
Figure 5.9	Response pattern likelihood for an easy test and a difficult test.....	89
Figure 5.10	Rasch item anchoring.....	90
Figure 6.1	Living room length expressed in integers.....	94
Figure 6.2	Real length per reported length.....	95
Figure 6.3	A posterior distribution on a test of six items.....	96
Figure 6.4	EAP estimators.....	97
Figure 8.1	A two-dimensional distribution.....	125
Figure 8.2	Axes for two-dimensional normal distributions.....	125
Figure 13.1	Trend indicators in PISA 2000, PISA 2003 and PISA 2006.....	175
Figure 14.1	Percentage of schools by three school groups (PISA 2003).....	194
Figure 15.1	Simple linear regression analysis versus multilevel regression analysis.....	201
Figure 15.2	Graphical representation of the between-school variance reduction.....	209
Figure 15.3	A random multilevel model.....	210
Figure 15.4	Change in the between-school residual variance for a fixed and a random model.....	212
Figure 16.1	Relationship between the segregation index of students' expected occupational status and the segregation index of student performance in reading (PISA 2000).....	236
Figure 16.2	Relationship between the segregation index of students' expected occupational status and the correlation between HISEI and students' expected occupational status.....	236

**LIST OF TABLES**

Table 1.1	Participating countries/economies in PISA 2000, PISA 2003, PISA 2006 and PISA 2009.....	21
Table 1.2	Assessment domains covered by PISA 2000, PISA 2003 and PISA 2006.....	22
Table 1.3	Correlation between social inequities and segregations at schools for OECD countries.....	28
Table 1.4	Distribution of students per grade and per ISCED level in OECD countries (PISA 2006).....	31
Table 2.1	Design effect and type I errors.....	40
Table 2.2	Mean estimates and standard errors.....	44





Table 2.3	Standard deviation estimates and standard errors.....	44
Table 2.4	Correlation estimates and standard errors.....	45
Table 2.5	ESCS regression coefficient estimates and standard errors.....	45
<hr/>		
Table 3.1	Height and weight of ten persons .....	50
Table 3.2	Weighted and unweighted standard deviation estimate .....	50
Table 3.3	School, within-school, and final probability of selection and corresponding weights for a two-stage, simple random sample with the first-stage units being schools of equal size.....	52
Table 3.4	School, within-school, and final probability of selection and corresponding weights for a two-stage, simple random sample with the first-stage units being schools of unequal size .....	52
Table 3.5	School, within-school, and final probability of selection and corresponding weights for a simple and random sample of schools of unequal size (smaller schools) .....	53
Table 3.6	School, within-school, and final probability of selection and corresponding weights for a simple and random sample of schools of unequal size (larger schools) .....	53
Table 3.7	School, within-school, and final probability of selection and corresponding weights for PPS sample of schools of unequal size .....	54
Table 3.8	Selection of schools according to a PPS and systematic procedure.....	55
<hr/>		
Table 4.1	Description of the 630 possible samples of 2 students selected from 36 students, according to their mean.....	59
Table 4.2	Distribution of all possible samples with a mean between 8.32 and 11.68.....	61
Table 4.3	Distribution of the mean of all possible samples of 4 students out of a population of 36 students.....	62
Table 4.4	Between-school and within-school variances on the mathematics scale in PISA 2003.....	65
Table 4.5	Current status of sampling errors.....	65
Table 4.6	Between-school and within-school variances, number of participating schools and students in Denmark and Germany in PISA 2003 .....	66
Table 4.7	The Jackknifes replicates and sample means.....	68
Table 4.8	Values on variables X and Y for a sample of ten students.....	69
Table 4.9	Regression coefficients for each replicate sample.....	69
Table 4.10	The Jackknife replicates for unstratified two-stage sample designs.....	70
Table 4.11	The Jackknife replicates for stratified two-stage sample designs.....	71
Table 4.12	Replicates with the Balanced Repeated Replication method.....	72
Table 4.13	The Fay replicates .....	73
<hr/>		
Table 5.1	Probability of success when student ability equals item difficulty.....	82
Table 5.2	Probability of success when student ability is less than the item difficulty by 1 unit.....	82
Table 5.3	Probability of success when student ability is greater than the item difficulty by 1 unit .....	82
Table 5.4	Probability of success when student ability is less than the item difficulty by 2 units .....	83
Table 5.5	Probability of success when student ability is greater than the item difficulty by 2 units.....	83
Table 5.6	Possible response pattern for a test of four items.....	85
Table 5.7	Probability for the response pattern (1, 1, 0, 0) for three student abilities.....	85
Table 5.8	Probability for the response pattern (1, 0) for two students of different ability in an incomplete test design.....	89
Table 5.9	PISA 2003 test design .....	91



Table 6.1	Structure of the simulated data.....	98
Table 6.2	Means and variances for the latent variables and the different student ability estimators.....	98
Table 6.3	Percentiles for the latent variables and the different student ability estimators.....	99
Table 6.4	Correlation between HISEI, gender and the latent variable, the different student ability estimators.....	99
Table 6.5	Between- and within-school variances.....	100
<hr/>		
Table 7.1	HISEI mean estimates .....	105
Table 7.2	Squared differences between replicate estimates and the final estimate.....	106
Table 7.3	Output data file from Box 7.2.....	108
Table 7.4	Available statistics with the UNIVAR macro .....	109
Table 7.5	Output data file from Box 7.3.....	109
Table 7.6	Output data file from Box 7.4.....	110
Table 7.7	Percentage of girls for the final and replicate weights and squared differences.....	111
Table 7.8	Output data file from Box 7.5.....	112
Table 7.9	Output data file from Box 7.6.....	113
Table 7.10	Output data file from Box 7.7.....	114
Table 7.11	Output data file from Box 7.8.....	114
<hr/>		
Table 8.1	The 405 mean estimates.....	118
Table 8.2	Mean estimates and their respective sampling variances on the science scale for Belgium (PISA 2006).....	119
Table 8.3	Output data file from Box 8.2.....	121
Table 8.4	Output data file from Box 8.3.....	121
Table 8.5	The 450 regression coefficient estimates.....	123
Table 8.6	HISEI regression coefficient estimates and their respective sampling variance on the science scale in Belgium after accounting for gender (PISA 2006).....	123
Table 8.7	Output data file from Box 8.5.....	123
Table 8.8	Output data file from Box 8.6.....	124
Table 8.9	Correlation between the five plausible values for each domain, mathematics/quantity and mathematics/space and shape.....	126
Table 8.10	The five correlation estimates between mathematics/quantity and mathematics/space and shape and their respective sampling variance.....	127
Table 8.11	Standard deviations for mathematics scale using the correct method (plausible values) and by averaging the plausible values at the student level (pseudo-EAP) (PISA 2003).....	128
Table 8.12	Unbiased shortcut for a population estimate and its standard error .....	129
Table 8.13	Standard errors from the full and shortcut computation (PISA 2006).....	130
<hr/>		
Table 9.1	The 405 percentage estimates for a particular proficiency level .....	136
Table 9.2	Estimates and sampling variances per proficiency level in science for Germany (PISA 2006) .....	137
Table 9.3	Final estimates of the percentage of students, per proficiency level, in science and its standard errors for Germany (PISA 2006).....	137
Table 9.4	Output data file from Box 9.3.....	138
Table 9.5	Output data file from Box 9.4.....	138
Table 9.6	Mean estimates and standard errors for self-efficacy in mathematics per proficiency level (PISA 2003).....	141
Table 9.7	Output data file from Box 9.6.....	141



Table 10.1	Percentage of students per grade and ISCED level, by country (PISA 2006).....	144
Table 10.2	Output data file from the first model in Box 10.3.....	148
Table 10.3	Output data file from the second model in Box 10.3.....	148
Table 11.1	Output data file from Box 11.1.....	153
Table 11.2	Mean estimates for the final and 80 replicate weights by gender (PISA 2003).....	153
Table 11.3	Difference in estimates for the final weight and 80 replicate weights between females and males (PISA 2003).....	155
Table 11.4	Output data file from Box 11.2.....	156
Table 11.5	Output data file from Box 11.3.....	157
Table 11.6	Gender difference estimates and their respective sampling variances on the mathematics scale (PISA 2003).....	157
Table 11.7	Output data file from Box 11.4.....	158
Table 11.8	Gender differences on the mathematics scale, unbiased standard errors and biased standard errors (PISA 2003).....	159
Table 11.9	Gender differences in mean science performance and in standard deviation for science performance (PISA 2006).....	159
Table 11.10	Regression coefficient of HISEI on the science performance for different models (PISA 2006).....	160
Table 11.11	Cross tabulation of the different probabilities.....	161
Table 12.1	Regression coefficients of the index of instrumental motivation in mathematics on mathematic performance in OECD countries (PISA 2003).....	165
Table 12.2	Output data file from Box 12.1.....	166
Table 12.3	Output data file from Box 12.2.....	167
Table 12.4	Difference between the country mean scores in mathematics and the OECD total and average (PISA 2003).....	170
Table 13.1	Trend indicators between PISA 2000 and PISA 2003 for HISEI, by country.....	176
Table 13.2	Linking error estimates.....	178
Table 13.3	Mean performance in reading by gender in Germany.....	180
Table 14.1	Distribution of the questionnaire index of cultural possession at home in Luxembourg (PISA 2006).....	184
Table 14.2	Output data file from Box 14.1.....	186
Table 14.3	Labels used in a two-way table.....	186
Table 14.4	Distribution of 100 students by parents' marital status and grade repetition.....	187
Table 14.5	Probabilities by parents' marital status and grade repetition.....	187
Table 14.6	Relative risk for different cutpoints.....	187
Table 14.7	Output data file from Box 14.2.....	189
Table 14.8	Mean and standard deviation for the student performance in reading by gender, gender difference and effect size (PISA 2006).....	191
Table 14.9	Output data file from the first model in Box 14.5.....	197
Table 14.10	Output data file from the second model in Box 14.5.....	197
Table 14.11	Mean of the residuals in mathematics performance for the bottom and top quarters of the PISA index of economic, social and cultural status, by school group (PISA 2003).....	195

Table 15.1	Between- and within-school variance estimates and intraclass correlation (PISA 2006).....	204
Table 15.2	Fixed parameter estimates .....	211
Table 15.3	Variance/covariance estimates before and after centering.....	213
Table 15.4	Output data file of the fixed parameters file.....	215
Table 15.5	Average performance and percentage of students by student immigrant status and by type of school.....	216
Table 15.6	Variables for the four groups of students .....	216
Table 15.7	Comparison of the regression coefficient estimates and their standard errors in Belgium (PISA 2006).....	218
Table 15.8	Comparison of the variance estimates and their respective standard errors in Belgium (PISA 2006) .....	218
Table 15.9	Three-level regression analyses.....	220
Table 16.1	Differences between males and females in the standard deviation of student performance (PISA 2000).....	226
Table 16.2	Distribution of the gender differences (males – females) in the standard deviation of the student performance .....	226
Table 16.3	Gender difference on the PISA combined reading scale for the 5 <sup>th</sup> , 10 <sup>th</sup> , 90 <sup>th</sup> and 95 <sup>th</sup> percentiles (PISA 2000) .....	227
Table 16.4	Gender difference in the standard deviation for the two different item format scales in reading (PISA 2000) .....	228
Table 16.5	Random and fixed parameters in the multilevel model with student and school socio-economic background.....	229
Table 16.6	Random and fixed parameters in the multilevel model with socio-economic background and grade retention at the student and school levels .....	233
Table 16.7	Segregation indices and correlation coefficients by country (PISA 2000).....	234
Table 16.8	Segregation indices and correlation coefficients by country (PISA 2006).....	235
Table 16.9	Country correlations (PISA 2000).....	237
Table 16.10	Country correlations (PISA 2006).....	237
Table 17.1	Synthesis of the 19 SPSS® macros.....	241
Table A2.1	Cluster rotation design used to form test booklets for PISA 2006 .....	332
Table A12.1	Mapping of ISCED to accumulated years of education .....	457
Table A12.2	ISCO major group white-collar/blue-collar classification .....	459
Table A12.3	ISCO occupation categories classified as science-related occupations .....	459
Table A12.4	Household possessions and home background indices.....	463
Table A12.5	Factor loadings and internal consistency of ESCS 2006 in OECD countries.....	473
Table A12.6	Factor loadings and internal consistency of ESCS 2006 in partner countries/economies.....	474



# User's Guide

## Preparation of data files

All data files (in text format) and the SPSS® control files are available on the PISA website ([www.pisa.oecd.org](http://www.pisa.oecd.org)).

## SPSS® users

By running the SPSS® control files, the PISA data files are created in the SPSS® format. Before starting analysis in the following chapters, save the PISA 2000 data files in the folder of "c:\pisa2000\data\", the PISA 2003 data files in "c:\pisa2003\data\", and the PISA 2006 data files in "c:\pisa2006\data\".

## SPSS® syntax and macros

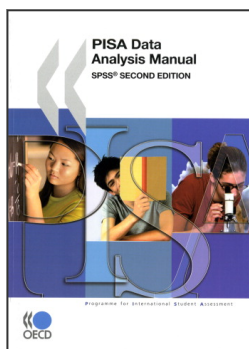
All syntaxes and macros in this manual can be copied from the PISA website ([www.pisa.oecd.org](http://www.pisa.oecd.org)). These macros were developed for SPSS 17.0. The 19 SPSS® macros presented in Chapter 17 need to be saved under "c:\pisa\macro\", before starting analysis. Each chapter of the manual contains a complete set of syntaxes, which must be done sequentially, for all of them to run correctly, within the chapter.

## Rounding of figures

In the tables and formulas, figures were rounded to a convenient number of decimal places, although calculations were always made with the full number of decimal places.

## Country abbreviations used in this manual

AUS	Australia	FRA	France	MEX	Mexico
AUT	Austria	GBR	United Kingdom	NLD	Netherlands
BEL	Belgium	GRC	Greece	NOR	Norway
CAN	Canada	HUN	Hungary	NZL	New Zealand
CHE	Switzerland	IRL	Ireland	POL	Poland
CZE	Czech Republic	ISL	Iceland	PRT	Portugal
DEU	Germany	ITA	Italy	SVK	Slovak Republic
DNK	Denmark	JPN	Japan	SWE	Sweden
ESP	Spain	KOR	Korea	TUR	Turkey
FIN	Finland	LUX	Luxembourg	USA	United States



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