Methodology of European labour force surveys: (3) Sample rotation patterns

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(3) Sample rotation patterns

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Abstract

This paper is the last of a set of three Working Papers the common objective of which is to provide a systematic and comparative exposition of various aspects of the methodology of labour force surveys in 27 countries of the European Union, plus the three EFTA and the two Candidate Countries. The present paper is concerned with various aspects of the temporal structure of labour force surveys over time, such as the reference period, the distribution of data collection over time, the pattern of sample rotation, and estimation procedures under a rotational design. The temporal structures of the European labour force surveys are quite diverse and not standardised. The paper documents and analyses this diversity.

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1 Introduction

As is well known, labour force surveys (LFSs) are among the most important social surveys on economic activity of the general population. Most countries in the world, all developed countries as well as many developing countries, undertake regular labour force surveys – annually, and increasingly on a quarterly or even monthly basis. In comparison with many other types of social surveys, labour force surveys tend to be quite standardised and comparable across countries. This, above all, is because these surveys follow the common and agreed international standards of the International Labour Organisation (ILO, 1982; also see technical elaboration in Hussmanns, Mehran and Verma, 1990). In EU countries, the national labour force surveys are further standardised on the basis of various framework and technical regulations laid down by the European Commission (European Commission 1998, 2000), which closely follow the ILO standards.

This paper is the last of a set of three Working Papers the common objective of which is to provide a systematic and comparative exposition of various aspects of the methodology of labour force surveys in 27 countries of the European Union, plus the three EFTA countries (Iceland, Norway, Switzerland) and the two Candidate Countries (Croatia, Turkey).[2]

The papers discuss in turn the following aspects of the methodology of European labour force surveys:

(1) Scope and sample size[3]

(2) Sample design and implementation[4]

(3) Sample rotation patterns

The present paper is concerned with various aspects of the structure of labour force survey over time. The two complementing Working Papers analyse the following aspects. The first paper describes the framework and basic characteristics of different types of household surveys of the labour force, the basic concepts and definitions used in the labour force surveys in European countries, and the choice of sample sizes in relation to the national population sizes. The second paper discusses the sampling designs, bringing out aspects of the sample structure including clustering and stratification; it also notes some important aspects of the data collection methodology of the EU national labour force surveys.

Most labour force surveys are conducted on a continuing basis, with samples and data linked over time. The objective of the present Working Paper is to complement the other two papers with discussion of various aspects of the structure of labour force survey over time. These include temporal structure of the survey such as the reference period, distribution of the sample over time, patterns of sample rotation, and estimation procedures under rotational designs.

The temporal aspects of the EU labour force surveys are less standardised across countries than are some other aspects of the surveys.

Section 2 discusses basic features defining the temporal structure of the survey, including the concept of fixed versus moving reference periods, reference periods used for the measurement of employment and unemployment, and the choices made in European labour force surveys.

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[2] Throughout this document, for simplicity the term 'EU countries' is used to cover 32 countries, including EU Member States (27), EFTA (3) and Candidate Countries (2).

[3] Ciampalini, Gagliardi and Verma (2008)

[4] Gagliardi, Verma and Ciampalini (2009)

The issue of the distribution of data collection over time, and the related concepts of survey rounds and subrounds are explained in Section 3.

Section 4 presents a detailed discussion of patterns of sample rotation in labour force surveys. Statistical considerations involved in the choice of the sample rotation schemes, in relation to various types of measures to be estimated from the survey, are discussed.

Section 5 analysis the sample rotation patterns adopted by EU countries in their labour force surveys. While the basic concepts defining the temporal structure of the survey such as the reference and reporting periods are standardised in EU labour force surveys, this does not apply to the sample rotation patterns adopted which generally remain country-specific.

Finally, Section 6 provides a technical exposition of procedures for the estimation of differences and average measures in labour force surveys involving rotational designs. Illustrations of variations in sample overlaps and correlations over time are provided to clarify the issues involved.

A major task involved in the research leading to this paper has been the compilation of information on LFS methodologies in European countries from a variety of sources, both from published material and from data and documentation accessible through the internet, and the analysis of this information in a comparative context. The paper contain some original discussion of the LFS sample rotation patterns.

We hope that the material presented in the paper can also serve as a resource for teaching purposes on the subject.

2 Temporal structure of the labour force survey

2.1 Reference period and related concepts

A basic aspect of the labour force survey is its *time dimension*.

Different types of “periods” are involved in defining the structure and content of a survey, perhaps the most fundamental being the *reference period*.

<u>Time periods in the survey structure</u>

(1) Reference period

This is the period with reference to which information for individual units in the survey is provided. The reference period may be fixed, i.e. defined in terms of specified calendar dates; or it may be a moving reference period, defined as a specified duration measured backwards from the time of interview.

(2) Survey period

This refers to the period over which field-work is carried out for data collection. A basic choice is whether we spread-out the field-work (up to the point of conducting it on a *continuous basis*), or concentrate it over a relatively short period.

(3) Recall period

This refers to the (maximum) duration over which the respondent has to recall retrospective information. This affects the quality of the responses obtained. With a moving reference period, the recall period is the same in length as the reference period; and therefore it is also uniform for all individual units in the survey. However, with a fixed reference period, the recall period varies from one unit to another depending on when the information with the given reference period is collected for the unit concerned. The difference between individual recall periods increases with increasing duration of field-work.

(4) Survey reference period

While the survey period refers to the time during which the information is collected, the *survey reference period* is the time to which the information collected in the survey as a whole relates. For example, in a survey with survey period of (i.e. field-work spread over) 12 months and a moving reference period of 6 months, the survey reference period is 18 months – the earliest information collected in the survey is 6 months before the start of field-work, and the most recent information collected is at the end of field-work. It may be noted that the question of the survey being “representative in time” relates, strictly speaking, to the survey reference period covered, rather than to the corresponding survey (or field-work) period (Verma and Gabilondo, 1993).

(5) ‘Inference’ period

This refers to the period in relation for which the survey results are used, i.e., the period to which the inferences from the survey may be taken to apply. The survey results can be useful for a longer period if the population conditions being studied are more stable over time. Usually this period cannot be defined with precise boundaries and remains dependent on the judgement of the analyst/user of the data. Also, the extant of the period for which the survey conclusion are relevant may vary according to the type of information being considered.

2.2 Fixed versus moving reference period

As noted above, the reference period can be fixed or moving.

<u>(a) Fixed reference period</u>

A reference period, whatever its length, may be demarcated in terms of fixed calendar dates or in terms of an interval of time preceding the interview date. When it is defined in terms of calendar dates, the reference period will be the same for all respondents. It is then referred to as a *fixed* reference period. The use of a fixed reference period provides information related to a definite time, which is the same for all units in the sample. This system can avoid different “period effects” (the influence of the weekend, the end of the month, etc.) for different respondents. A fixed reference period may also be more suitable for linking with data from other sources. Or its use may be necessary in view of some legal or conventional requirements to produce estimates for definite (calendar) periods.

On the other hand, the use of a fixed reference period tends to make the recall period not only longer, but also different for different respondents. This can be a serious problem if the field-work is spread out over a long period.

The disadvantages of a fixed reference period, for example the lengthening and unevenness of the recall period, are reduced when field-work is concentrated over a short duration. However this in turn causes uneven or irregular workloads for the field staff. Problems of uneven workloads tend to become less disruptive with the increasing frequency of surveys. Indeed, some monthly labour force surveys are periodic in nature (with field-work concentrated in one or two weeks during the month), and use the last calendar week or month as the fixed reference period. For a fuller discussion of these concepts, see Hussmanns, Mehran and Verma (1990).

<u>(b) Moving reference period</u>

Alternatively, the reference period may be defined in terms of a given length of time preceding the interview date; if respondents are not interviewed at the same time (or in the same week or in the same month), the exact calendar period for which the data are collected would vary from one respondent to another. The reference period in such situations is said to be a *moving* reference period.

With continuous field-work, a moving reference period is generally the appropriate one. The disadvantages of prolonged and unequal recall periods arising from the use of a fixed reference period become more serious with field-work extended over a long period such as a quarter or a year. The advantages of a moving reference period are (i) shorter recall and (ii) the evening-out of seasonal and other period effects over the sample as a whole. However, the resulting data with a moving reference period relate to a less well-defined point or period in time, and for individual respondents the results may be influenced by differing period effects.
The quarterly labour force surveys in European countries generally employ continuous field-work which, furthermore, tends to be very uniformly distributed over weeks of the year. (See Section 3.1 below.)

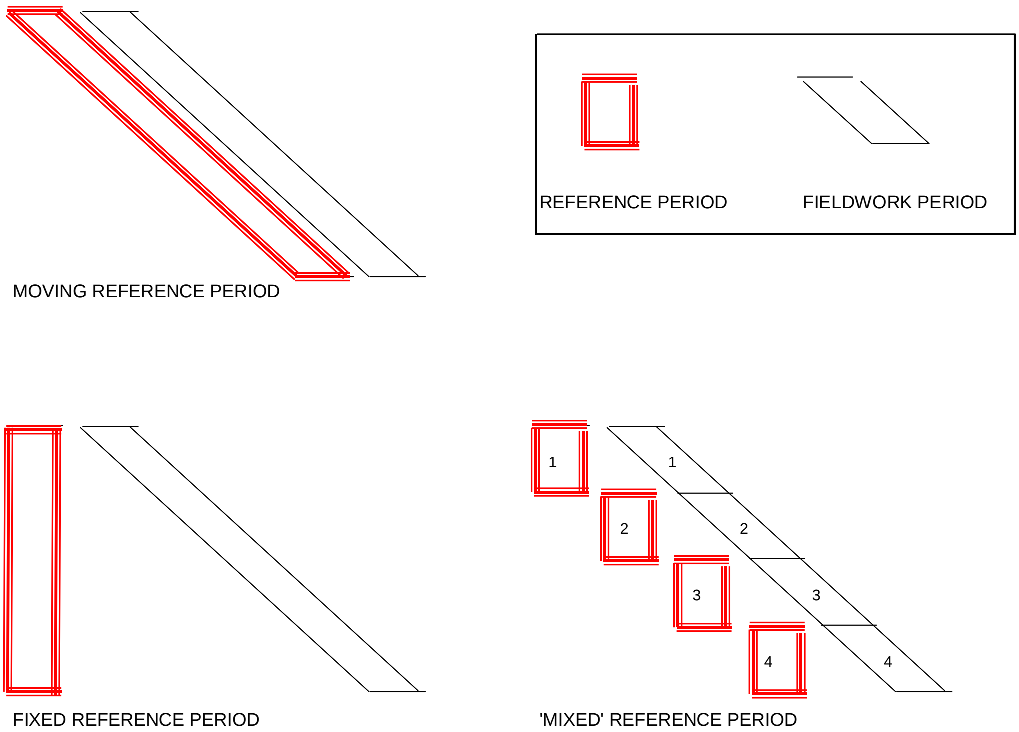
(c) 'Mixed' reference period

There is a third option for the reference period that can be seen as a mixture of the two previous concepts. For instance in a survey with quarterly rounds, the interviews may be conducted during (one or more weeks) each month, with each month having a fixed reference week immediately preceding the field-work for that month.

The following example may clarify the concept of a 'mixed' reference period. Suppose there is a continuous labour force survey, with one round conducted each quarter. The reference period for the measurement of employment is one week. With a moving reference period, this would mean seven days immediately preceding the day of interview for any particular respondent. A fixed reference period would mean a fixed week, for the whole sample enumerated during the quarter, a week which entirely precedes the quarter concerned. This last-mentioned schema can result in long recall periods for at least a part of the sample, and therefore is not generally used in labour force surveys. Instead, a common practice is to divide the field-work in the survey round into shorter time segments (say subrounds; see Section 3.1), with the reference period *fixed* separately for each subround, and *moving* systematically from one subround to the next. For example, the reference period may be the week immediately preceding each monthly subround of a survey with quarterly rounds. This gives a *mixed* type of reference period.

The three types of reference periods are illustrated in Figure 1.

Figure 1. Types of reference period



2.3 Reference periods for the measurement of employment and unemployment

Measurement of employment: short and long reference periods

The short reference period is normally appropriate for the continuing type of survey aimed primarily at generating current indicators. International standards give one day and one week as examples of the length of a short reference period (International Labour Office,1982). In EU – and most other – labour force surveys, a *one week reference period* is used for defining employment.

In less frequent surveys aimed at structural characteristics of longer-term interest, the use of both a long reference period (such as a whole year) and a short reference period (such as one week) in combination may be considered. The long reference period and 'usual status approach' (as distinct from the more commonly used 'current status approach') may be particularly appropriate for in-depth surveys where the objective is to investigate complex underlying relationships between economic activity and other variables.[5]

Measurement of unemployment

Job search period

According to the international standards defining unemployment, one or more specific steps for seeking work must have taken place within "a specific recent period". This period is normally not the same as the basic survey reference period (for measuring employment) of one week or one day, but may be longer, such as one month or four weeks covering and preceding the basic reference

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[5] In labour force surveys, the *usual activity status* is normally defined in terms of the activity carried out for a *majority of the time* during a long reference period such as a whole year.

period. An appropriate length of the search period may be determined in the light of national circumstances, taking into account prevailing time-lags in processing demands for employment, which may also be different between paid employment and self-employment. The periodicity of the survey should also be taken into consideration; for example, one could argue that a job search period of more than four weeks should not be used in a monthly survey.

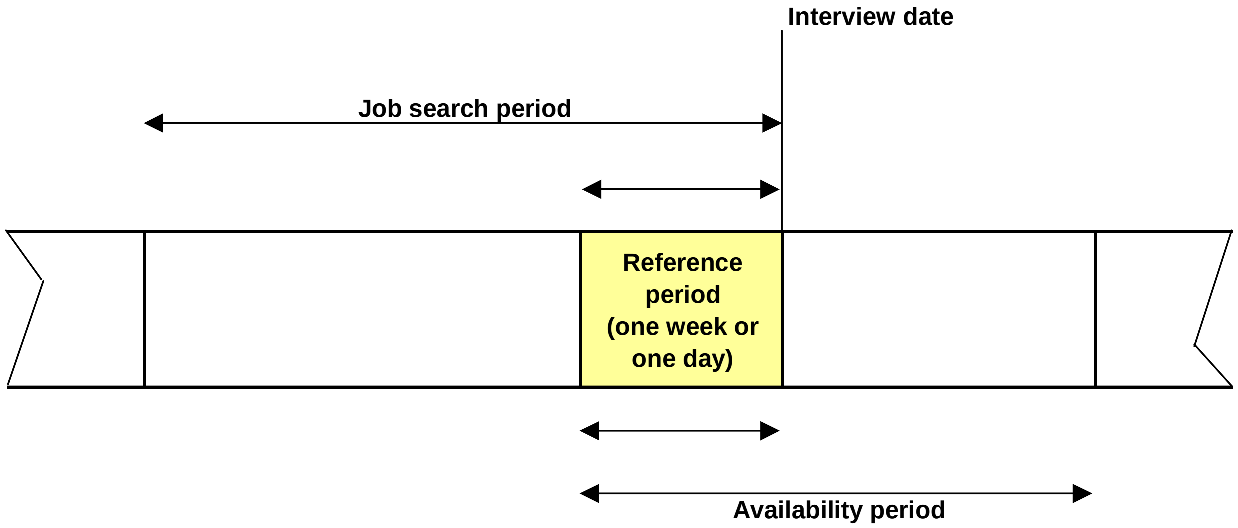
In European labour force surveys, most countries use a job search period of four weeks or one month.

Period of availability for work

Persons should be available for work during the reference period if they are to be considered as unemployed. In practice, however, many countries use a somewhat longer period, e.g. 15 days or two weeks including and following the basic reference period used for measuring employment. This is to account for the fact that not everyone who is seeking work can be expected to take up a job immediately one is offered.

The concept of different types of reference periods is illustrated in Figure 2.

Figure 2. Reference periods for defining employment and unemployment



(Source: Hussmanns, Mehran and Verma, 1990)

2.4 The choices made in EU labour force surveys

Table 1 shows the three main reference periods used in the European labour force surveys: the reference period for measuring employment, and the reference periods for the activities of seeking employment and being available for work for measuring unemployment. The information shown in Table 1 is summarised in Table 2.

The following is noted in Eurostat website about the general definition of the reference period used. In practice, the details may vary somewhat among the countries as shown in the tables and the accompanying commentary in this section.

> <u>Reference period</u>
>
> The EU-LFS measures the labour status and other characteristics during one reference week in each quarter of the calendar year (seasonal quarter in IE and UK until 2005). From 2003, the sample units are distributed uniformly over the quarter so that the quarterly estimates are equivalent to an average week in the quarter (except in IT, CY and AT: from 2004). The reference week starts on Monday and concludes on Sunday. The first week of the year/quarter is the week including the first Thursday of the year/quarter. Each quarter has 13 weeks. The first week in 2003 started on Monday 30 December 2002. For more information on the transition to a quarterly continuous survey, see the EU LFS webpage: Comparability of results.

Table 1. Reference period for the measurement of employment and unemployment

	Reference periods		
	Employment	Seeking work	Availability for work
Austria	One week (moving)	Four weeks (moving)	Two weeks (moving)
Belgium	One week (moving)	Four weeks (moving)	Two weeks (moving)
Bulgaria	One week (moving)	Four weeks (moving)	Two weeks (moving)
Cyprus	One week (moving)	Four weeks (moving)	Two weeks (moving)
Czech Republic	One week (moving)	Four weeks (moving)	Two weeks (moving)
Denmark	One week (fixed)	Four weeks (fixed)	Two weeks (fixed)
Estonia	One week (moving)	Four weeks (moving)	Two weeks (moving)
Finland	One week (moving)	Four weeks (moving)	Two weeks (moving)
France	One week (moving)	One month (moving)	Two weeks (moving)
Germany	One week (fixed)	Four weeks (moving)	Two weeks (moving)
Greece	One week (fixed)	Four weeks (moving)	Two weeks (moving)
Hungary	One week (moving)	Four weeks (moving)	Two weeks (moving)
Ireland	One week (fixed)	Four weeks (moving)	Four weeks (moving)
Italy	One week (fixed)	Four weeks (fixed)	Two weeks (fixed)
Latvia	One week (moving)	Four weeks (moving)	Two weeks (moving)
Lithuania	One week (fixed)	Four weeks (moving)	Two weeks (moving)
Luxembourg	No information provided		
Malta	One week (fixed)	Four weeks (moving)	Two weeks (moving)
Netherland	One week (moving)	When interviewed	When interviewed
Poland	One week (moving)	Four weeks (moving)	Two weeks (moving)
Portugal	One week (moving)	Four weeks (moving)	Two weeks (moving)
Romania	One week (moving)	Four weeks (moving)	Fifteen days (moving)
Slovakia	One week (moving)	Four weeks (moving)	Two weeks (moving)
Slovenia	One week (moving)	Four weeks (moving)	Two weeks (moving)
Spain	One week (moving)	Four weeks (moving)	Two weeks (moving)
Sweden	One week (moving)	One week (moving)	One week (moving)
United Kingdom	One week (moving)	Four weeks (moving)	Two weeks (moving)
Iceland	One week (moving)	Four weeks (moving)	Two weeks (moving)
Norway	One week (fixed)	Four weeks (moving)	Two weeks (moving)
Switzerland	One week (moving)	Four weeks (moving)	Two weeks (moving)
Croatia	One week (mixed: fixed for each month)	Four weeks (moving)	Two weeks (moving)
Turkey	One week (moving)	Three months (moving)	Fifteen days (moving)

Notes.

Luxembourg: no information is provided

Cyprus, Norway and Iceland: there is some uncertainty in the information available to us.

Switzerland: survey is conducted only during the second quarter of the year.

Main sources: www.ilo.org, Eurostat (2007).

Table 2. Grouping of EU countries by type of reference periods

Countries	Reference periods for measuring:		
	Employment	Seeking work	Availability for work
Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Estonia, Finland, Hungary, Iceland, Latvia, Poland, Portugal, Slovakia, Slovenia, Spain, Switzerland, United Kingdom	One week (moving)	Four weeks (moving)	Two weeks (moving)
Romania	One week (moving)	Four weeks (moving)	Fifteen days (moving)
Sweden	One week (moving)	One weeks (moving)	One weeks (moving)
France	One week (moving)	One month (moving)	Two weeks (moving)
Turkey	One week (moving)	Three months (moving)	Fifteen days (moving)
Netherlands	One week (moving)	When interviewed	When interviewed
Germany, Greece, Lithuania, Malta, Norway	One week (fixed)	Four weeks (moving)	Two weeks (moving)
Ireland	One week (fixed)	Four weeks (moving)	Four weeks (moving)
Croatia	One week (mixed: fixed for each month)	Four weeks (moving)	Two weeks (moving)
Denmark, Italy	One week (fixed)	Four weeks (fixed)	Two weeks (fixed)
Luxembourg	No information provided		

Source: website www.ilo.org

Concerning the *reference period for employment*, there is heterogeneity among countries concerning the type of reference period used. While the length of the reference period (one week) is the same in all EU, labour force surveys, some countries use a fixed week while others use a moving week (or a 'mixed type of period).

Concerning the *reference periods for the measurement of unemployment*, both the seeking work and availability for work periods are meant to overlap with the employment reference period, as shown in Figure 2. The reference periods for the measurement of unemployment in the EU standards for the LFS are defined in the following terms (Eurostat, 2004):

> "(1) In accordance with the ILO standards adopted by the 13th and 14th International Conference of Labour Statisticians (ICLS), for the purposes of the Community labour force sample survey, unemployed persons comprise persons aged 15 to 74 who were:
>
> (a) without work during the reference week, i.e. neither had a job nor were at work (for one hour or more) in paid employment or self-employment;
>
> (b) currently available for work, i.e. were available for paid employment or self-employment before the end of the two weeks following the reference week;
>
> (c) actively seeking work, i.e. had taken specific steps in the four week period ending with the reference week to seek paid employment or self-employment or who found a job to start later, i.e. within a period of at most three months.".

For the purposes of point 1(c), the regulation lists specific steps which may be accepted. Also provided are special considerations which apply to persons in education and training, lay-offs and seasonal workers.

Following these standards, the specification for the reference periods in, for example, the Polish LFS is as follows:[6]

Poland	**Reference periods**	
	Employment	one week (moving reference period)
	Seeking work	four weeks (the reference week being the 4th week)
	Availability for work	two weeks (the reference period plus the following week)

The above definitions are in line with Figure 2, *which applies irrespective of whether the reference period of one week for the measurement of employed is moving or fixed.* The definition implied in Figure 2 means that the reference period for the measurement of unemployment should be of the same type as that used for the measurement of employment – either both should be fixed, or both moving. Otherwise, the employment status of an individual is not defined consistently.

Nearly all the countries refer to a period of four weeks preceding the interview for job seeking, and two weeks following the interview for availability for work. Consequently, the reference period for measuring unemployment in all these cases - irrespective of whether the period for measuring employment is a fixed or a moving one - appears to be of the type of a *moving* reference period. Hence, Table 1 appears to contradict the consistency requirement in countries using a fixed reference period for employment - except in a couple of cases such as Denmark and Italy where the different reference periods are consistent, all being of the fixed type. Unfortunately this is how the information has been provided on survey characteristics (ILO website). For example, the following is stated in relation to the reference periods for some of the countries where the reference period for employment is apparently of the fixed type:

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[6] ILO website.

	Reference periods	
Lithuania	Employment	one week
	Seeking work	four weeks period prior to the interview week
	Availability for work	within two weeks after the interview week
Germany	Employment	one week, e.g. the last holiday-free week of April
	Seeking work	four weeks prior to the date of the interview
	Availability for work	two weeks following the date of the interview
Ireland	Employment	one week
	Seeking work	four weeks preceding the interview
	Availability for work	four weeks following the interview
Greece	Employment	one fixed week
	Seeking work	four weeks preceding the survey interview.
	Availability for work	within two weeks after the interview.

3 Distribution of field-work over time

3.1 The concepts of survey rounds and sub-rounds

<u>The concept of survey rounds</u>

As noted, labour force surveys in EU countries are conducted primarily to generate a time-series of data on current levels and trends. Continuing surveys are used to obtain indicators of changes in current rates of labour force participation, employment, unemployment and underemployment; and to measure trend, cyclic and seasonal variations in these rates. With appropriate design and data of sufficiently high quality, the survey may also provide estimates of gross changes and flows of individuals between different types of economic activity.

Typically, a survey with such aims consists of an ongoing series of survey ‘rounds’, each round being designed to produce and report separate estimates covering a specified period. A basic issue to be considered in a continuing survey is the degree to which samples for different rounds should be independent of each other, and the extent to which they should be correlated or overlapping. This is determined by the rotation pattern adopted for the survey.

EU labour force surveys are designed to be *quarterly surveys*, each quarter of the year constituting one round of the survey for which separate estimates are published.

<u>Distribution of field-work over time</u>

Among continuing surveys, two types of arrangement are commonly found. The first arrangement is to conduct the survey on a *continuous* basis, i.e. to carry out field-work uninterruptedly. The second arrangement is that of periodic surveys with *intermittent* field-work concentrated over relatively short intervals. During each round there may be one or more than one intervals of field-work.

There can be certain advantages in concentrating the field-work. Firstly, this can make it easier to control and implement field operations. Secondly, it becomes easier to obtain information with a fixed reference period, i.e. with the same reference period for all respondents in terms of fixed calendar dates. However, there can also be some disadvantages in concentrating field-work. Firstly, the average conditions over a period such as a quarter or a year may not be as well represented in periodic surveys as in continuous surveys with field-work evenly distributed throughout. Secondly, periodic field-work does not provide field enumerators with a continuous and evenly distributed workload. This can be a problem when full-time interviewers dedicated to the LFS are to be employed.

Most of the EU labour force surveys are conducted on a continuous basis throughout the year, every year. The year is divided into quarterly rounds. Each round has to be fully representative of the study population, since it must provide valid estimate for its quarter. Within the quarterly round, it is common to have three monthly subrounds (see below), often with non-overlapping samples so as to provide for efficient cumulation over subrounds in a quarter. It is often possible to go further with a continuous survey, for example to organise the field-work on a weekly basis.

As shown in Table 3, field-work distribution is remarkably uniform in a majority (75%) of the EU-27 labour force surveys. There are some exceptions to this uniformity as noted below. The comments apply to the 2005 survey; in some countries the pattern may have been made more regular subsequently.

Main exception to uniform distribution of field-work over weeks of the year (2005 EU-LFS):

Switzerland. Field-work was carried out only during one quarter, a quarterly labour force survey not having been established yet.

Croatia. 2005 field-work was carried out during only one week out of every four weeks. A survey round lasts for 6 months.

Turkey. Field-work was carried out during two weeks out of every four weeks. The survey is quarterly nevertheless.

Hungary. Field-work was carried out during three weeks out of every four weeks.

Belgium. Field-work was carried out during 12 (rather than 13) weeks each quarter.

There were very minor exceptions to continuity in Slovenia, Malta and Romania.

In Ireland and the UK, field-work was continuous, but the reporting year preceded the calendar year by 4 weeks. This has been adjusted to the calendar year since 2005 in both the countries.

One point should be clarified in relation to the figures in Table 3. Strictly speaking, these figures refer to the distribution of the sample in terms of the reference weeks used for the measurement of employment, rather than to the distribution of field-work (data collection). Often the two are not identical because of delays in completing the field-work following the reference period to which it relates.

Table 3. Distribution of LFS interviews by reference week 2005 (%)

Week	CH	HR	TR	HU	BG	SI	MT	RO	IE	UK	BE	CZ	DK	DE	EE	EL	ES	FR	IT	CY	LV	LT	LU	NL	AT	PL	PT	SK	FI	SE	IS	NO	Week
2004																																	2004
49	-								2.0	1.8																							49
50	-								1.8	1.8																							50
51	-								1.8	1.7																							51
52	-					-			1.7	1.8																							52
2005																																	2005
Q1																																	Q1
1	-	-	-	-	2.3	4.2	1.9	2.0	1.8	1.9	1.8	2.0	1.9	0.8	2.0	2.0	1.9	2.0	2.0	1.7	2.1	2.1	0.5	2.1	1.9	2.0	2.0	1.7	2.2	1.8	2.0	2.0	1
2	-	-	-	3.1	2.3	-	2.1	2.1	1.8	1.8	2.0	2.0	1.9	1.0	2.0	1.9	1.9	2.0	2.0	2.4	2.3	2.0	2.5	1.8	1.9	2.0	2.1	1.9	2.1	1.8	2.0	2.0	2
3	-	-	4	3.6	2.1	4.3	2.1	2.2	1.9	1.8	2.1	1.9	2.0	1.9	2.1	1.9	1.9	2.0	2.0	1.7	2.1	1.9	3.0	2.2	1.9	2.0	1.8	2.0	2.1	1.8	1.9	2.0	3
4	-	-	4	1.8	2.1	-	1.9	2.2	2.0	1.9	2.0	1.9	2.0	1.4	1.7	1.9	1.9	2.0	2.0	2.0	2.0	2.0	2.7	1.5	1.8	2.0	2.1	2.1	2.1	1.7	2.0	1.9	4
5	-	8.2	-	-	2.3	4.5	2.2	2.0	2.0	1.9	2.1	1.9	1.9	1.9	2.0	2.0	2.0	2.0	2.0	2.1	2.0	1.9	2.5	2.0	1.9	1.9	2.1	2.0	2.1	1.8	2.0	1.9	5
6	-	-	-	-	2.2	-	1.8	2.1	2.0	1.9	2.0	2.0	2.0	1.8	2.0	2.1	2.1	1.9	2.0	2.0	1.9	2.0	1.9	1.8	1.9	2.0	2.1	2.0	2.1	1.8	2.0	2.0	6
7	-	-	4	4.0	2.2	4.5	1.9	2.2	1.9	1.8	2.0	1.9	1.9	2.3	1.9	2.0	2.0	1.8	2.0	1.6	2.0	1.9	3.0	2.7	1.9	2.0	2.0	2.0	2.1	1.8	1.8	1.9	7
8	-	-	4	3.2	2.0	-	1.8	2.2	1.9	1.8	2.0	2.0	1.9	1.7	2.1	1.9	2.0	1.9	2.0	2.1	1.9	1.9	2.9	1.6	2.1	2.0	1.9	2.0	2.1	1.7	1.8	2.0	8
9	-	8.3	-	1.1	2.2	3.8	2.1	2.0	1.9	1.8	1.9	1.9	2.0	2.2	2.2	2.0	2.0	2.0	2.0	1.9	2.0	1.8	4.2	2.1	2.0	2.0	1.9	2.1	1.7	1.5	1.9	2.0	9
10	-	-	-	-	2.1	2.9	1.9	2.1	1.9	1.8	2.0	1.9	2.0	2.0	1.9	1.9	2.0	1.9	2.0	2.1	1.9	2.1	4.1	2.2	2.0	1.9	1.9	1.9	1.7	1.4	2.0	2.0	10
11	-	-	4	4.1	2.1	1.4	2.1	2.2	1.7	1.7	1.9	1.9	2.0	1.8	2.0	2.0	1.9	2.0	1.9	2.0	2.1	1.9	2.5	3.4	1.9	1.9	2.0	1.9	1.7	1.4	2.0	1.9	11
12	6.5	-	4	2.6	2.0	0.1	3.7	2.2	1.7	1.7	1.9	2.0	2.0	1.5	2.4	2.0	1.9	2.1	2.0	2.2	2.0	2.2	0.6	1.3	1.9	1.9	1.9	1.7	1.7	1.4	1.9	1.9	12
13	20.6	8.6	-	1.5	-	2.1	-	-	1.8	1.8	1.9	1.9	1.9	1.4	1.7	1.9	1.9	1.8	2.0	2.1	1.9	2.0	1.9	1.1	1.9	1.9	2.0	1.5	1.7	1.4	1.8	1.9	13

(cont.)

Week	CH	HR	TR	HU	BG	SI	MT	RO	IE	UK	BE	CZ	DK	DE	EE	EL	ES	FR	IT	CY	LV	LT	LU	NL	AT	PL	PT	SK	FI	SE	IS	NO	Week
Q2																																	**Q2**
14	9.2	-	4	-	2.2	1.9	1.9	2.0	1.9	1.8	1.9	1.9	1.9	2.0	1.9	2.0	2.0	2.1	2.0	1.5	1.8	2.0	1.9	1.9	1.9	1.9	2.0	1.8	2.0	2.0	1.8	2.0	**14**
15	17.0	-	-	3.0	2.2	2.3	2.0	2.2	2.0	1.7	1.9	1.9	2.0	1.7	2.0	1.9	1.9	2.0	2.0	2.0	1.7	2.1	2.2	2.3	1.9	1.9	2.1	1.9	2.1	1.9	1.9	2.0	**15**
16	16.8	-	4	3.2	2.0	1.6	1.9	2.2	2.0	1.8	2.0	1.9	2.0	2.3	2.0	1.9	1.9	2.0	2.0	1.7	2.0	2.0	2.2	2.3	1.9	2.0	1.8	2.0	2.1	2.0	2.0	1.9	**16**
17	9.0	8.5	4	2.1	2.0	2.0	1.9	2.0	2.0	1.9	2.1	1.9	1.9	1.4	1.8	1.8	1.9	1.9	2.0	1.9	2.0	2.0	2.1	0.6	1.8	1.9	2.0	2.0	2.1	1.9	1.9	1.9	**17**
18	5.2	-	-	-	2.2	2.0	2.1	2.1	2.1	1.9	1.8	1.9	1.9	2.3	2.0	2.0	2.0	2.0	2.0	2.0	2.1	2.0	2.1	1.8	1.8	1.9	2.0	2.1	2.1	2.0	1.9	1.9	**18**
19	4.2	-	-	2.7	2.1	2.4	2.0	2.1	2.0	1.8	2.0	2.0	2.0	1.6	2.0	2.0	2.1	1.9	1.9	1.7	1.9	2.0	1.7	2.4	1.9	1.9	2.0	2.0	2.1	2.0	1.9	1.9	**19**
20	**20**	1.9	4	3.4	2.1	2.2	1.6	2.2	2.1	1.8	2.0	1.9	1.9	2.0	1.9	2.0	1.9	1.8	1.9	1.8	1.8	1.8	2.0	1.7	2.0	1.9	2.0	2.1	2.1	1.9	1.9	3.5	
21	2.8	8.4	4	2.3	1.9	1.7	1.8	2.0	2.1	1.8	2.0	1.9	2.0	2.0	2.1	1.9	2.0	1.9	2.0	1.9	2.1	1.8	2.2	2.0	2.2	1.9	1.8	2.0	2.0	1.9	1.9	2.0	**21**
22	2.3	-	-	-	2.1	2.4	2.4	2.0	2.0	1.7	1.9	1.9	1.9	2.2	1.7	2.0	2.0	2.1	2.0	2.1	1.7	1.8	0.7	1.8	2.0	1.9	1.8	2.1	1.6	1.6	1.9	1.9	**22**
23	1.4	-	-	-	2.1	2.1	2.2	2.1	2.0	1.8	2.0	1.9	1.9	2.0	1.7	1.9	2.0	1.9	1.9	2.3	2.1	1.8	2.8	2.1	2.0	1.9	1.9	1.9	1.6	1.6	1.8	1.9	**23**
24	0.9	-	4	3.8	2.0	1.8	2.2	2.2	1.9	1.7	2.0	1.9	1.9	2.3	1.7	1.9	1.9	2.0	1.9	1.9	2.0	1.7	2.2	2.3	1.9	1.9	1.9	1.9	1.6	1.6	1.9	1.8	**24**
25	0.6	8.4	4	3.1	2.0	0.4	2.1	2.0	1.9	1.8	1.9	1.9	1.8	1.8	2.0	1.9	1.9	2.0	1.9	2.3	2.0	1.9	2.2	2.0	1.9	1.9	1.9	1.8	1.6	1.6	1.9	1.8	**25**
26	-	-	-	1.4	-	2.6	2.0	0.1	1.7	1.8	1.8	1.9	1.8	1.3	1.7	1.9	1.8	1.7	1.8	2.0	1.9	1.9	2.7	1.1	1.9	1.9	1.9	1.4	1.6	1.5	1.7	1.7	**26**
Q3																																	**Q3**
27	-	-	-	-	2.2	2.1	2.0	2.0	1.7	1.8	1.9	1.9	1.8	2.0	1.9	2.0	1.9	1.9	1.8	1.6	1.9	1.9	3.2	1.9	1.9	1.9	1.8	1.7	2.1	2.2	1.8	2.0	**27**
28	-	-	-	3.4	2.1	2.0	1.8	2.0	1.8	1.7	2.0	1.9	1.9	1.7	1.9	1.9	1.9	1.8	1.7	2.3	2.1	2.0	1.3	1.8	1.9	1.9	2.0	2.0	2.1	2.2	1.8	2.0	**28**
29	-	8.1	4	3.3	1.9	1.2	1.8	2.2	1.9	1.8	1.8	1.8	1.9	2.2	1.9	1.9	1.8	1.7	1.7	2.1	1.9	2.0	1.3	2.4	1.8	1.9	1.8	2.0	2.1	2.2	2.0	2.0	**29**
30	-	-	4	1.7	2.0	2.0	1.6	2.1	1.9	1.8	2.1	2.0	1.8	1.7	1.8	1.9	1.8	1.7	1.8	1.9	2.0	1.8	1.6	1.2	1.8	1.9	1.9	1.9	2.1	2.2	2.0	2.0	**30**
31	-	-	-	-	2.1	1.7	2.0	2.0	1.8	1.8	2.1	1.9	1.9	2.3	1.9	2.0	1.9	1.9	1.9	2.0	2.0	2.0	1.7	1.9	1.8	1.9	1.9	1.9	2.1	2.2	1.9	1.9	**31**
32	-	-	-	2.9	1.9	2.4	1.7	2.0	1.8	1.8	1.7	1.9	2.0	1.7	1.9	2.0	1.9	1.9	1.9	1.6	2.0	1.9	1.1	1.8	1.8	1.9	1.9	1.9	2.1	2.2	2.0	1.9	**32**
33	-	-	4	3.3	2.1	2.2	1.7	2.2	2.0	1.8	2.0	1.9	1.9	2.4	1.7	1.9	1.8	1.8	1.9	2.1	1.8	1.9	1.1	2.2	2.0	1.9	1.9	2.1	2.1	2.2	2.0	2.0	**33**
34	-	8.3	4	2.2	1.9	2.6	1.8	2.0	1.9	1.8	1.8	1.9	2.0	1.8	1.9	1.9	1.9	1.9	2.0	2.0	1.9	1.8	1.3	1.9	2.2	1.9	1.9	1.9	2.1	2.2	2.0	2.0	**34**
35	-	-	-	-	2.1	1.7	2.1	0.0	2.0	1.7	1.9	1.9	2.0	2.2	1.8	2.0	1.9	2.0	1.9	1.9	1.9	1.8	2.9	1.9	2.0	1.9	1.8	2.1	1.7	1.9	2.0	1.9	**35**
36	-	-	-	-	2.0	2.3	1.7	2.0	2.0	1.8	2.0	2.0	1.9	1.9	1.8	1.9	1.9	1.9	1.9	2.1	1.9	1.9	1.7	2.2	2.0	1.9	1.8	2.0	1.7	1.8	1.9	1.9	**36**
37	-	-	4	3.8	2.1	1.8	1.7	1.9	1.9	1.7	1.9	1.9	2.0	2.3	1.7	1.9	1.9	2.0	1.9	1.6	1.8	1.8	0.7	2.0	1.9	1.9	1.9	2.0	1.7	1.9	2.0	1.9	**37**
38	-	8.2	4	3.2	2.0	0.2	1.9	2.2	2.0	1.8	1.9	1.9	2.0	1.8	1.9	1.9	1.9	2.0	1.9	1.7	1.9	2.0	1.7	2.2	1.9	1.9	1.9	1.9	1.7	1.8	1.9	1.8	**38**
39	-	-	-	1.5	-	2.3	1.8	2.0	2.0	1.8	1.8	1.9	2.0	1.2	1.9	1.9	1.8	1.8	1.9	1.7	1.7	1.9	1.3	0.7	1.9	2.0	1.9	1.7	1.7	1.8	1.8	1.8	**39**

Table 3 (cont.). Distribution of LFS interviews by reference week 2005 (%)

Week	CH	HR	TR	HU	BG	SI	MT	RO	IE	UK	BE	CZ	DK	DE	EE	EL	ES	FR	IT	CY	LV	LT	LU	NL	AT	PL	PT	SK	FI	SE	IS	NO	Week
Q4																																	Q4
40	-	-	-	-	2.1	1.4	2.0	2.0	2.0	1.8	1.9	1.9	1.9	2.1	2.0	1.9	1.9	2.0	1.9	1.6	1.8	2.0	0.6	1.7	1.9	1.9	1.8	1.8	2.1	2.4	1.9	2.0	40
41	-	-	-	3.2	2.1	2.5	1.8	2.1	1.9	1.7	1.8	1.9	2.0	1.8	2.1	1.9	1.9	1.9	1.9	2.3	1.9	2.0	0.5	2.2	1.9	1.9	1.9	1.9	2.1	2.3	1.9	2.0	41
42	-	-	4	3.3	2.0	1.7	1.9	2.1	1.9	1.8	1.8	1.8	1.9	2.4	2.0	1.9	1.9	1.9	1.9	2.0	1.9	2.1	0.9	2.2	1.8	1.9	1.8	2.0	2.1	2.4	2.0	2.0	42
43	-	8.6	4	1.9	2.0	1.9	1.9	2.1	2.0	1.8	1.9	2.0	1.9	1.8	1.7	1.9	1.9	1.9	2.0	1.9	1.8	1.9	1.7	1.8	1.9	1.9	1.9	1.9	2.1	2.3	1.9	2.0	43
44	-	-	-	-	2.2	2.2	1.9	2.0	1.9	1.8	1.9	1.9	1.8	2.4	1.8	1.9	1.9	2.0	2.0	2.1	1.9	2.1	1.3	2.9	1.8	1.9	1.9	1.9	2.1	2.4	1.9	1.9	44
45	-	-	-	-	2.1	2.5	1.8	2.0	2.0	1.8	1.9	2.0	2.0	2.1	2.0	1.9	1.9	2.0	1.9	1.8	1.9	2.0	1.9	2.5	1.8	1.9	2.0	2.0	2.1	2.3	2.0	1.9	45
46	-	-	4	4.1	2.1	1.7	1.8	2.1	2.1	1.8	1.9	1.9	1.9	2.6	1.8	1.8	1.9	1.8	1.9	2.0	2.0	1.8	1.5	2.3	1.9	1.9	1.9	2.1	2.1	2.3	2.0	1.9	46
47	-	8.3	4	2.9	2.0	2.1	1.9	2.1	2.0	1.8	1.9	1.9	1.9	2.0	2.0	1.8	2.0	1.9	1.9	1.8	1.9	1.8	1.6	1.2	2.1	2.0	1.8	2.1	2.1	2.3	1.9	2.0	47
48	-	-	-	1.2	2.2	2.4	2.0	2.0	2.1	1.7	1.7	1.9	1.9	3.1	2.0	2.0	1.9	2.0	1.9	1.8	1.8	1.8	1.1	1.4	2.0	1.9	1.9	2.0	1.7	1.9	2.0	1.9	48
49	-	-	-	-	1.9	2.2	1.9	2.0	-	-	1.8	1.9	1.9	3.4	2.0	1.9	1.9	1.9	1.9	2.1	1.9	1.9	0.6	3.3	2.0	1.9	1.8	2.0	1.7	1.9	1.9	2.0	49
50	-	8.2	4	4.3	2.1	1.6	1.9	2.1	-	-	1.8	1.9	1.8	1.6	2.1	1.9	1.9	1.9	1.8	1.8	1.7	1.8	1.7	2.6	1.9	1.9	1.9	2.0	1.7	1.9	2.1	1.9	50
51	-	-	4	2.7	2.0	0.1	1.8	2.0	-	-	2.0	1.9	1.9	2.5	2.0	1.9	1.8	1.9	1.8	1.8	1.9	1.9	3.4	1.4	1.9	1.9	1.9	1.8	1.6	1.9	1.9	1.8	51
52	-	-	-	1.3	-	-	2.0	0.0	-	-	2.0	1.9	1.9	0.4	1.9	1.9	1.8	1.7	1.8	1.6	1.7	1.8	2.8	0.3	1.9	2.0	1.9	1.5	1.6	1.9	1.8	1.8	52

Notes:

The vertical bar means no fieldwork during the week

SI quarters used for the publication of the results begin one week earlier than the standard EU quarters

IE quarters used for the publication of the results begin 4 weeks earlier than the standard EU quarters

UK As IE in 2005 (shown above), but standardised starting from 2006.

TR The pattern shown is approximate: normally field work is carried out during the middle two weeks every month.

Sources: EUROSTAT (2007). Labour force survey in the EU, Candidate and EFTA Countries. Main characteristics of the national surveys 2005

The concept of sub-rounds

If the survey round is of a sufficiently long duration, it may be divided into *subrounds*. The characteristic feature of the concept of a 'subround' is that, like the full round, *each subround covers a representative sample of the entire target population*, in spite of its limited duration compared to the whole survey round. The difference is that, unlike the case for a full round, the subround need not be large enough to produce separate results.

Division of a survey round into subrounds permits better, in the sense of being more representative, coverage of the sample over shorter time segments during the round - such as over individual months during a quarter, or individual quarters during a year. Data from various subrounds can be aggregated to produce average results for the whole survey round; results of different subrounds can be compared to estimate seasonal variation and other trends (Hussmanns, Mehran and Verma, 1990).

Hence a subround is a distribution of the sample over time, each subround covering a representative subsample. Here is an example of a survey with quarterly rounds divided into monthly subrounds, taken from Salmi and Kiiski (1984), describing the situation for the Finnish LFS at that time:

> The labour force survey in Finland is conducted in quarterly rounds, each round being divided into monthly subrounds. Each month a new subsample is introduced and is enumerated five times over a 16-month period: during the first, fourth, seventh, 13^{th} and 16^{th} months after introduction. It can be seen that in any particular month, five such subsamples are enumerated (which is the same as the total number of times any subsample is enumerated). There is no overlap between subrounds from month to month: this implies the measurement of month-to-month (as distinct from quarterly) change was not a primary objective of the Finnish survey. However, from one quarter to the next the sample overlaps by 80 per cent and can estimate quarterly variations more accurately. The year-to-year overlap is 40 per cent.

There are a number of advantages of dividing the survey round into subrounds. Since each component enumerates a (spatially) representative sample, the total survey becomes better representative both in space and over time during the survey round. A second important advantage is that comparison between subrounds can provide additional information on seasonal changes and trends over the round. In addition, it may be possible to produce separate estimates, at least for the main variables, for each subround. Using moving averages over subrounds, the results can be issued more frequently (in principle, after every subround) than issuing them only once per round.[7] This is possible only because the sample for each subround is representative of the whole population. Finally, there are also operational advantages. For instance, the rate of field-work can be made more uniform and better controlled and regulated; and data processing and reporting can be arranged sequentially for one subround at a time.

The main disadvantage of the system is the higher cost involved in enumerating representative and dispersed samples in each subround. The additional cost will be smaller if each subround enumerates only a subset (but still a representative subsample) of primary or other higher-stage units in the sample. The additional cost will be higher if the full sample of primary (and other higher-stage) sampling units is to be covered in each subround.

The additional cost will be minimised if the samples for subrounds within the same round are independent (thus permitting the most efficient cumulation to produce results for the round

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[7] For instance, in a survey with quarterly rounds and monthly subrounds, moving averages over three most recent subrounds may be issued each month. These will have essentially the same precision as the full, quarterly, estimates. The UK labour force survey provides an example of this practice.

concerned). The per-unit cost for producing overall (say, quarterly) estimates will be greatly increased if the same set of ultimate units is repeatedly enumerated, such as once during each subround.

The above possibilities may be illustrated with the following simple example. Suppose that for a quarterly round of the LFS, the sample consists of '*n*' individuals, selected from '*a*' clusters, with '*b*' persons per cluster, giving $n=a*b$. Suppose the round is divided into three monthly subrounds. Each subround may be based on a random subsample of *(a/3)* distinct clusters, with all the *(b)* persons from each of these clusters enumerated during the concerned month. For any given statistic, the variance over a subround will be approximately 3 times larger than that over the whole round. An alternative design will be to take all the *(a)* clusters into the sample of each subround, but take *(b/3)* individuals from each clusters for enumeration during the month. This will make the subround sample more efficient (which can be useful in producing some main results by subround). But this feature also makes the field-work more expensive. The additional statistical efficiency of subround in this second scheme is lost when the data are cumulated over subrounds for producing estimates for the whole round. (That is, for estimates at the round level, the above two schemes have essentially the same efficiency.) This is because in the second scheme, the subround samples, while non-overlapping, are not independent of each other as they come from the same clusters: the subround samples are positively correlated, reducing the efficiency of cumulation.

With a continuous survey, it is often possible to divide the field-work into much smaller time segments than 'subrounds' in the above sense, such as into weekly samples in a continuous quarterly survey. In fact, nearly all the surveys in Table 3 with uniform weekly samples have this feature. Such division into time segments can be useful for organisation and control of survey implementation. However, conceptually such divisions are different from 'subrounds' in that, unlike the latter, normally each smaller division does not involve a representative sample of whole population but only of a part of it.

3.2 Sample rotation between rounds and sub-rounds: basic considerations

Sample rotation between rounds

For a given survey, samples for the rounds may be related in various ways. The choice of the pattern will depend upon the type of statistics to be produced from the survey and considerations of sampling efficiency and costs. Several options are possible.

1. One option is to have an independent sample for each round. In practice this usually means a design which is common to all rounds but ensures that samples for the various rounds are entirely distinct and non-overlapping at all stages. Each round enumerates a different set of primary sampling units, and hence different units at all lower stages, including the ultimate sampling units such as addresses, households or persons.

2. The other extreme is to have a panel, in which the sample originally selected is retained over time, except for sample updating through various means which may be necessary to keep the sample representative of changes in the target population.

3. Most commonly, labour force surveys use rotational designs. In this type of designs, a subset of sampling units is retained from one round to the next, and the remaining replaced by new units. A rotational design provides positive correlations between surveys from different rounds, which are lacking with independent samples. The correlation depends on the extent and pattern of rotation or overlap between the samples.

4. In a multistage sampling design, it is possible to use different patterns of rotation for different levels of units. For instance, higher units (such as areas) may be kept in the survey for a longer

period than lower units (such as households). Some illustrations from EU labour force surveys will be provided in Section 5.3.

Sample rotation between subrounds within a round

The basic difference between rounds and subrounds is that for each round separate statistical estimates need to be produced, but generally this is not required for each subround separately. Even though each subround normally provides a valid sample of the target population, the sample size generally is not large enough to produce useful separate estimates for individual subrounds. Typically, data from subrounds are cumulated to produce estimates for the whole round. For this purpose, subrounds within a round are normally based on *independent or non-overlapping samples* so as to permit maximum efficiency in cumulating the results over the round concerned.

Here is an example from the Swedish LFS (Eurostat 2007):

> "The sampling design is a stratified single-stage simple random sampling of individuals. The sampling frame is Statistics Sweden's Register of the Total Population.
>
> The sample is drawn at the end of the fourth quarter every year to cover the coming year's need of new sample persons. When the sample is drawn it is stratified according to county, sex, and age group (15, 16-64, 65-74). In this way 144 strata are constructed. The inclusion probabilities are in general proportional to the size of the strata, although some small counties have to be over-represented in the sample.
>
> The LFS sample consists of three separate samples [i.e. 3 monthly subrounds in each quarterly round], one for each month in the quarter. Every month about 20,000 persons are included in the sample. Every monthly sample consists of 8 rotation panels (waves), of which 7/8 recur after 3 months and 1/8 is replaced by new individuals. Persons in the sample are interviewed once a quarter with a total of eight interviews during a two-year period, after which they leave the sample. … However, nearly all the sample was renewed in April 2005."

4 Estimating diverse measures with overlapping samples

It is useful to keep in view that a labour force survey is required to provide estimates of measures of various types, each of which has its own statistical requirements. These include the following, among other types.

(1) estimates of current levels for individual periods separately, such as annual or (in the case of European labour force surveys) quarterly estimates;

(2) estimates of net differences or changes between periods, such as from one quarter to the next;

(3) overall aggregates over a number of periods, such as over quarters of a year, or even over more than one year, for example to provide more detailed geographical breakdown;

(4) geographical breakdown;

(5) moving averages;

(6) seasonal variation;

(7) estimates of gross differences, changes and flows over time at the individual (micro) level.

Below we discuss measures of types (1)-(3) in some detail. This is followed by a few remarks on the other types of measures (4)-(7).

4.1 Estimates of current levels

Estimates of type (1), i.e. ordinary cross-sectional estimates, are of interest in any survey. Essentially, these estimates are not affected by the degree of overlap between the samples from one period to another. That is, with P and Q indicating the overlapping and non-overlapping proportions of the sample, for an ordinary mean such as a weighted average of the means for the two parts

$$\bar{y} = Q \cdot \bar{y}_Q + P \cdot \bar{y}_P \,, \qquad [1]$$

the precision of the estimation of a current level is not affected by the degree of overlap.

However with a partial overlap, a modest improvement can be achieved by adjusting the estimate for the overlapping part from regression over the full earlier sample, and then appropriately reweighting the two components to produce a composite estimate of the current level.

The procedure in brief is as follows (Kish, 1965).

The current estimate for the overlapping part is adjusted from the results of the previous sample as

$$\tilde{y}_P = \bar{y}_P + R(\bar{x} - \bar{x}_P) \,. \qquad [2]$$

Here $\bar{x}$ is the estimate from the previous round for the whole sample of that round, and $\bar{x}_P$ the same for the part overlapping with the current round; R is the regression or correlation coefficient. The composite current estimate is computed as

$$\tilde{y} = W_Q \cdot \bar{y}_Q + W_P \cdot \tilde{y}_P \qquad [3]$$

with weights

$$W_Q = Q - p \cdot Q \,;\; W_P = P + p \cdot Q \,;\text{ where } p = PQ \cdot \frac{R^2}{1 - Q^2 R^2} \,. \qquad [4]$$

Variance of the composite estimate (3) relates to that of (1) as:

$$Var(\tilde{y}) = (1 - p) \cdot Var(\bar{y}) \,. \qquad [5]$$

It can be shown that minimum variance

$$Var(\tilde{y})_{opt} = (1 - p_{opt}) \cdot Var(\bar{y}) \qquad [6]$$

is obtained with

$$p_{opt} = \frac{1 - \sqrt{1 - R^2}}{2} \qquad [7]$$

corresponding to the overlap

$$P_{opt} = \frac{\sqrt{1 - R^2}}{1 + \sqrt{1 - R^2}} \,. \qquad [8]$$

The actual gain may be a little larger in a time series of survey rounds since the preceding rounds also benefit from the composite estimation.

Several variations of the basic procedure described above are possible. In some establishment surveys for example, information is obtained from each establishment in a round not just for the most recent period but for two or more periods preceding the survey, so that composite estimates can be produced even without an overlap between the rounds in terms of the actual establishments enumerated. Such possibilities hardly exist for household surveys based on personal interviews.

4.2 Estimates of net differences

Measures of type (2) are concerned with measuring net change.

Measures of changes from a previous period (say between consecutive quarters) are most efficiently estimated with *maximum overlap* between the two consecutive periods. The variance of estimates of differences between two overlapping samples is affected by covariance between the two samples. The covariance term arises from the overlap or other relationship between the samples. Generally, it is a positive quantity because of repeated measurement on the same units. Hence precision in estimating the change is increased with overlapping samples. In a multistage design the samples may be related though common higher stage units without necessarily involving overlaps in terms of the same ultimate stage units. The correlations are of course higher when the ultimate units overlap.

The following simplified formulation may be helpful in indicating the above ideas in quantitative terms. The formulation is based on Kish (1965).

The variance of the estimate of difference between two estimates $\bar{x}$ and $\bar{y}$ is given by:

$$Var(\bar{y}-\bar{x}) = Var(\bar{y}) + Var(\bar{x}) - 2 \cdot Cov(\bar{y},\bar{x}) . \qquad [9]$$

For two simple random samples each of size n and with proportion P of the samples overlapping, and for simplicity assuming that the element variances are the same in different samples, the above expression can be written as

$$Var(\bar{y}-\bar{x}) = Var_0 \cdot (1-PR) . \qquad [10]$$

Var_0 is the variance of the difference when there is no overlap (i.e. with independent samples). With a complete overlap (P=1) the variance is reduced by the factor (1-R), where R is the correlation coefficient.

With a 50% overlap for instance, variance of the difference is reduced by the factor (1-0.5*R).

The estimation of change can be made more precise by giving increased weight (W_P) to the overlapping part which contributes less to the variance, and giving a correspondingly smaller weight (W_Q) to the non-overlapping part. *This of course assumes that each of the two parts constitutes a representative sample in its own right.* This requirement is in fact satisfied in most rotational designs used in practice.

In general terms we can write

$$(\bar{y}-\bar{x})_W = W_P \cdot (\bar{y}-\bar{x})_P + W_Q \cdot (\bar{y}-\bar{x})_Q . \qquad [11]$$

Here on the left is a weighted estimate of the difference between estimates $\bar{x}$ and $\bar{y}$, say for two consecutive periods. On the right are two estimates produced, respectively, from the overlapping (P) and the non-overlapping (Q) parts of the sample.

This gives the variance of the weighted differences as

$$Var(\bar{y}-\bar{x})_W = Var_0 \cdot \left[\frac{(1-R) \cdot W_P^2}{P} + \frac{W_Q^2}{Q} \right] . \qquad [12]$$

The optimum solution for minimum variance of the difference is to weight the components in inverse proportion of their unit variances, i.e. reduce the relative weight of the non-overlapping component by the factor (1-R). This gives the normalised weights (meaning the weights scaled to add up to 1.0 for the two components) as

$$W_P = \frac{P}{(1-QR)}; \; W_Q = \frac{(1-R)\cdot Q}{(1-QR)}, \tag{13}$$

and hence

$$Var(\bar{y}-\bar{x})_W = Var_0 \cdot \left[\frac{(1-R)}{(1-QR)}\right]. \tag{14}$$

With reweighting as above, a modest overlap such as P=1/3 may give almost the full benefit (1-R) of complete overlap.

The above relationship should also approximately hold for more complex sample designs, though with clustering where the overlap is at the level of higher stage units rather than at the level of the ultimate units, the gain in precision will be underestimated (Kish, 1965). In such situations, the approach is improved by defining P as the proportion of units coming from the common PSUs, and R as the correlation between these units (which is likely to be much lower than that for actually overlapping ultimate units).

4.3 Aggregation or averaging

This concerns estimates of type (3), i.e. averages or aggregation of the sample over time in order to improve sampling precision. This type of estimates are required for small domains or classes for which the sample size from a single round is too small.

For aggregation, the variance of the sum of two sample estimates is:

$$Var(\bar{y}+\bar{x}) = Var(\bar{y}) + Var(\bar{x}) + 2\cdot Cov(\bar{y},\bar{x}) \tag{15}$$

so that the positive correlation due to the overlap increases the variance of the aggregate. With the same simplifying assumptions as those made above for net differences, variance of an aggregate may be written as follows:

$$Var(\bar{y}+\bar{x}) = Var_0 \cdot (1+PR) \tag{16}$$

The efficiency can be improved by weighting up the non-overlapping component (which contributes less to the variance of the aggregate) by the factor (1+R), i.e. by assigning the normalised weights

$$W_P = \frac{P}{(1+QR)}; \; W_Q = \frac{(1+R)\cdot Q}{(1+QR)} \tag{17}$$

giving

$$Var(\bar{y}+\bar{x})_w = Var_0 \cdot \left[\frac{(1+R)}{(1+QR)}\right]. \tag{18}$$

In comparison with the case of differences, the gain due to the reweighting is modest in estimating averages or totals. Aggregation is served best by having no overlap. When the primary concern is to aggregate data over a period of time, non-overlapping samples are the most appropriate.

4.4 Other types of estimates

The following are some other types of estimates encountered in labour force surveys.

(4) Geographical breakdown

EU labour force surveys are generally designed to provide sufficiently reliable estimates at the level of (at least large) regions; that is why their sample sizes tend to be much larger than other social surveys (such as EU-SILC). Nevertheless special methods may be required for producing estimate for smaller areas or other small domains. There are essentially three types of procedures available for the production of adequate estimates for small domains:

(a) increased sample size – but this is limited by practical and cost constraints;

(b) cumulation over survey rounds such as over quarters of a year, or even over several years – trading detail in time for detail in space and for subpopulations;

(c) small area or domain estimation using special procedures – by supplementing the survey data by auxiliary variables from other, usually large but substantively less details sources.

In the last mentioned methodology, a relatively more detailed but smaller-scale survey data provides direct labour-related information at the micro level; this information can be aggregated to areas such as NUTS regions where the survey contain some sample units and the area identifies are available in the microdata. On the other side, correlates of labour-related characteristics of the areas can come from aggregated statistics (such as Eurostat NewCronos data base for EU counties). The two sources can be combined to produce composite estimates, provided that (i) the survey data contain information for the identification of the area to which each unit belongs, and (ii) the aggregate data on the correlates are available for all the areas in the population of interest (Rao, 2003). For the estimation of measures at regional level via small area estimation techniques, we believe that a good procedure is to use the Empirical Best Linear Unbiased Predictor (EBLUP) estimator, with appropriate procedures to evaluate the robustness of such measures (Verma et al, 2005).

(5) Moving averages

Producing estimates in the form of moving averages permits cumulation of data over several survey *rounds* but, if desired, retaining the frequency of release of the estimates unchanged. This can permit more detailed breakdown of the results, such as for regions or other subpopulations. The resulting estimates of course represent average conditions over a longer time period.

In a similar way, using moving averages but over *subrounds*, the results at the total level can be issued more frequently (in principle, after every subround), compared to issuing them only once per round. As noted earlier, this is possible only when the sample for each subround is representative of the whole population. For instance, in a survey with quarterly rounds and monthly subrounds, moving averages over three most recent subrounds may be issued each month. These estimates will have essentially the same precision as the normal estimates for each round.

(6) Seasonal variation

Estimating seasonal variation over periods (such as quarters) of a year amounts to estimating changes between periods. This is similar to (2) of Section 4.2, and is served best by overlapping samples over the periods being compared. More precise estimates of seasonal variations such as over quarterly or monthly periods may be obtained by cumulating the pattern over more than one year. In this case the precision is improved by minimising year-to-year overlaps in the sample, i.e. independent samples for the same season (quarter) of successive years. This aspect is similar to (3) discussed in Section 4.3.

The situation is similar when the 'seasons' of interest are of shorter duration than the survey rounds – for example monthly variations in a survey with quarterly rounds. It is desirable to have large overlaps between seasonal (in this example, monthly) subsamples. Furthermore, the subsample for each season must be a proper 'subround', i.e. separately representative of the whole study population. These requirements can be in conflict with the usual preference for having independent samples for subrounds within a survey round as to permit efficient cumulation for estimating at the level of the round.

(7) Estimates of gross differences, changes and flows over time at the of individual (micro) level

This type of estimates requires a panel design in which the same units are followed up from one period to another.

Most EU labour force surveys use rotational designs (see Section 3.2 and Section 5). Overlaps between samples over time can permit longitudinal analysis. Such overlaps need to be at the level of individual persons who are the main units for longitudinal analysis. (More complex units such as households are less suited for longitudinal analysis, though some possibilities exist). Proper longitudinal analysis is limited by the manner in which most labour force surveys implement samples with households as the ultimate units and the temporal overlap between these units.

The common procedure in labour force surveys for dealing with a household which has moved to another location between the time of its selection into the sample and enumeration, is to take into the survey the new household (if any) which now lives at the address where the original household was selected. Hence the sample may be more appropriately described as a sample of 'occupied addresses' where the selected households lived at the time of selection, rather than as a sample of the specific households through the selection of which the 'occupied addresses' came into the sample (Gagliardi, Verma and Ciampalini, 2009). The same concept applies in relation to overlaps in the sample over time in a rotational design. The overlap in the sample from one survey round to another is in terms of occupied addresses, rather than in terms of following the particular households living at those addresses. The main consequence of such designs is that movers are not represented in the longitudinal sample (though of course, they are properly represented in the cross-sectional sample for each round).

The statistics published from labour force surveys tend mostly to be of the form of cross-sectional estimates of levels and their cumulations and net differences over time. Estimates of gross differences, changes and flows over time at the of individual (micro) level are limited by the above-mentioned sampling considerations. They are also more sensitive to response errors.

5 The LFS sample rotation patterns in EU countries

5.1 Existing rotational designs

In this and the next subsection, we discuss the rotation patterns for ultimate units (such as addresses, households or persons). In multi-stage designs, the pattern of rotation for higher stage units (such as sample areas) may be the same or different as illustrated in the examples given in Section 5.3.

In all labour force surveys, the pattern of rotation is "stable". This means that new sets of units are introduced into the sample at regular intervals, and once introduced, each set is retained or dropped from the sample following the same pattern as any other set. Once such a system is established, it provides a fixed degree of overlap from any one round to the next, and between any two rounds separated by a given time interval.

Linear pattern

It should be noted, however, that in practice, adjustments are often required to the rotational pattern in order to maintain or adjust the sample size. Many surveys use a straightforward pattern of rotation which may be called ‘linear’. The sample consists of *n* subsamples; at the beginning of each survey round, one new subsample is introduced and the oldest subsample is dropped. Each subsamples remains in the survey for *n* consecutive periods (rounds). The overlap between rounds decreases linearly as the interval separating them increases. For two sample introduced *i* rounds apart the overlap is $(n-i)/n$, up to $i=(n-1)$; after that $(i \geq n)$, the overlap becomes zero.

For example for a five consecutive period rotation pattern, we can construct the following schema in order to show the degree of overlap of the sample. In the schema, the sample at time t consist of 5 subsamples represented by the rows. One such subsample was introduced per year between (t-4) and t. Every sample remains in the survey for 5 years. The sample introduced at (t-4) will be dropped after survey year t, that introduced at (t-3) dropped after year (t+1), and so on. Note that, once the system has been established, in any cross-sectional sample the average number of times a unit has already been in the sample for this scheme is (4+3+2+1)/5 = 10/5 = 2.

Figure 3. Illustration: sample rotation pattern "5-consecutive"

	Survey round (t = current round)						
	t-5	t-4	t-3	t-2	t-1	t	k
		x	x	x	x	x	4
			x	x	x	x	3
				x	x	x	2
					x	x	1
						x	0
Overlap between t and ...	t-5	t-4	t-3	t-2	t-1		average k=
	0	1/5	2/5	3/5	4/5		10/5=2

k = number of times a unit has been previously included in the sample

In theory, the overlap between samples at t and (t-1) is (4/5), declining linearly to zero between samples at t and (t-5). In practice, the degree of sample overlap between rounds tends to be somewhat smaller than what is indicated in the illustration for the pattern concerned. Firstly, this is due to non-response which increases with the length of time a unit has already been in the sample (“panel attrition”). This means that a larger proportion of the overlapping compared to the non-overlapping part tends to get lost. Another reason for reduced overlap in practice results from the commonly used procedure in labour force surveys of dealing with household which have moved to another location between rounds. As noted earlier (Section 4.4), this procedure is to take into the survey the new household (if any) which now lives at the address from where the original household has moved away. Hence all mover households are lost from the overlapping part of the sample. The same is true of individual persons leaving the household between two rounds of the survey: normally the survey enumerates only current residents.

More complicated rotation patterns

Many surveys use rotation patterns more complicated than the linear pattern described above. More complicated patterns are used to vary the degree of sample overlap and how it changes over time.

A commonly used pattern is to move units in and out of the sample repeatedly. Once introduced, a unit may be retained into the sample for a certain length of time (say for n_1 rounds), then dropped from the sample for a certain length of time (say for m_1 rounds), reintroduced again (say for n_2 rounds), and so on until the unit is finally dropped from the sample.

In general, such a sequence may be represented by the notation

$$n_1\text{-}(m_1)\text{-}n_2\text{-}(m_2)\text{-}n_3 \ldots\ldots \text{ with } n = \sum n_i$$

Here n_i is the time for which the unit is in the sample for the i^{th} time; m_i represents the time the unit was out of the sample after its i^{th} time in the sample; n is the total number of rounds the unit is in the sample before being finally dropped from the survey. For instance, pattern 2-(3)-2 means that, once introduced, a unit remains in the sample for 2 rounds, then is taken out of the sample for 3 rounds, and then reintroduced for 2 more rounds, after which it is finally dropped.

With this notation, a linear rotation pattern will be represented as "n-consecutive".

Table 4 shows the different rotation schemes followed in European labour force surveys.

Another type of complexity in the rotation pattern in multi-stage sampling designs can be the application of different patterns to different levels of units. This complexity has been ignored in Table 4: what the table shows is the rotation pattern for the *ultimate sampling units*. In many surveys, the shown pattern also applies to the rotation of higher stage units, if any. This is not always the case, however; examples of European labour force surveys where a different pattern is followed for higher stage units are described in Section 5.3 below.

Table 4. Patterns of sample rotation (by quarters, Q)

Country	Pattern (by quarter)	Year 1 Q.1	Q.2	Q.3	Q.4	Year 2 Q.5	Q.6	Q.7	Q.8
Austria	5-consecutive	x	x	x	x	x			
Belgium*	2-consecutive	x	x						
Bulgaria	2-(2)-2	x	x	-	-	x	x		
Cyprus	6-consecutive	x	x	x	x	x	x		
Czech Republic	5-consecutive	x	x	x	x	x			
Denmark	2-(2)-1	x	x	-	-	x			
Estonia	2-(2)-2	x	x	-	-	x	x		
Finland	3-(1)-2	x	x	x	-	x	x		
France	6-consecutive	x	x	x	x	x	x		
Germany*	1-(3)-1-(3)-1-(3)-1	x	-	-	-	x	-	-	...
Greece	6-consecutive	x	x	x	x	x	x		
Hungary	6-consecutive	x	x	x	x	x	x		
Ireland*	5-consecutive	x	x	x	x	x			
Italy	2-(2)-2	x	x	-	-	x	x		
Latvia	1-(1)-1-(1)-1	x	-	x	-	x			
Lithuania	2-(1)-2	x	x	-	x	x			
Luxembourg*	2-consecutive	x	x						
Malta	2-consecutive	x	x						
Netherland	5-consecutive	x	x	x	x	x			
Poland	2-(2)-2	x	x	-	-	x	x		
Portugal	6-consecutive	x	x	x	x	x	x		
Romania	2-(2)-2	x	x	-	-	x	x		
Slovakia	5-consecutive	x	x	x	x	x			
Slovenia	3-(1)-2	x	x	x	-	x	x		
Spain	6-consecutive	x	x	x	x	x	x		
Sweden	8-consecutive	x	x	x	x	x	x	x	x
United Kingdom	5-consecutive	x	x	x	x	x			
Iceland	3-(2)-2	x	x	x	-	-	x	x	
Norway	8-consecutive	x	x	x	x	x	x	x	x
Switzerland*	1-(3)-1-(3)-1-(3)-1-(3)-1	x	-	-	-	x	-	-	...
Croatia*	independent samples	x							
Turkey	2-(2)-2	x	x	-	-	x	x		

*Notes:

BE Not all the sample of Q.1 is interviewed in Q.2; also, Q.2 uses a reduced questionnaire.

DE The sample may be described in terms of annual rotation as "4-consecutive (annual)";
note that the survey is still quarterly, with non-overlapping samples between quarters of a year.

IE The sample rotation consists simply of changing the (one out of five) cluster selected from each block (a larger area) in the sample; the sample of blocks itself remains fixed for a period of about 5 years.

LU Only half the sample of Q.1 is retained in Q.2.

CH The sample is best described as "5-consecutive (annual)";
the survey is annual, conducted during only one quarter of each year.

HR Each half year is covered with 6 indipendent monthly samples. The two 6-monthly samples of households used during one year in fact come from the same clusters; hence they are correlated.

The same information as Table 4 is displayed in Table 5 with EU countries rearranged according to the pattern of rotation followed, in particular according to the number of rounds any unit is included in the sample. This makes the different patterns clearer.

The least overlap between samples of survey rounds is in Croatia (completely non-overlapping samples of household), followed by Belgium (only a shorter interview repeated for the same household), Luxembourg (only half the sample repeated for a second time), and Malta (two repetitions of the sample). At the next level, a unit appears three times in the sample in Denmark and Latvia.

At the other extreme, a unit appears in the sample 8 times in Norway and Sweden.

In the remaining majority of the surveys, a unit appears in the sample 4-6 times before being finally dropped.

Within any group of countries with the same number of appearances of a unit in the sample, the actual rotation patterns can be quite different – for instance “5-consecutive” versus “3-(2)-2”.

Some special cases may be noted.

In Germany, there is no overlap between consecutive quarters. The only overlap is between samples a whole year apart. Nevertheless, because of continuous fieldwork, the survey is still designed to provide quarterly results. The rotation pattern in terms of quarters has been described in the table as “1-(3)-1-(3)-1-(3)-1”; more appropriately perhaps, it can also be described in annual terms as “4-consecutive (annual)”.

Similarly in Switzerland, the sample is best described as "5-consecutive (annual)". But the situation is quite different from that of the German survey. Switzerland LFS is the only case discussed here which is not a quarterly survey. The survey is still only annual, conducted during only one quarter of each year. The survey in Croatia may be viewed as a 6-monthly survey, though it can provide results for each quarter of the year.

Bulgaria, Croatia and Ireland are examples with different patterns of rotation for different level of units in the sample (i.e. for households/addresses and area units). These are described in Section 5.3.

Table 5 (Table 4 sorted). Grouping of countries by the pattern of sample rotation

Country	Pattern (by quarter)	Year 1 Q.1	Q.2	Q.3	Q.4	Year 2 Q.5	Q.6	Q.7	Q.8
Croatia	independent samples	x							
Belgium	2-consecutive	x	x						
Luxembourg	2-consecutive	x	x						
Malta	2-consecutive	x	x						
Denmark	2-(2)-1	x	x	-	-	x			
Latvia	1-(1)-1-(1)-1	x	-	x	-	x			
Lithuania	2-(1)-2	x	x	-	x	x			
Bulgaria	2-(2)-2	x	x	-	-	x	x		
Estonia	2-(2)-2	x	x	-	-	x	x		
Italy	2-(2)-2	x	x	-	-	x	x		
Poland	2-(2)-2	x	x	-	-	x	x		
Romania	2-(2)-2	x	x	-	-	x	x		
Turkey	2-(2)-2	x	x	-	-	x	x		
Germany	1-(3)-1-(3)-1-(3)-1	x	-	-	-	x	-	-	...
Austria	5-consecutive	x	x	x	x	x			
Czech Republic	5-consecutive	x	x	x	x	x			
Ireland	5-consecutive	x	x	x	x	x			
Netherland	5-consecutive	x	x	x	x	x			
Slovakia	5-consecutive	x	x	x	x	x			
United Kingdom	5-consecutive	x	x	x	x	x			
Finland	3-(1)-2	x	x	x	-	x	x		
Slovenia	3-(1)-2	x	x	x	-	x	x		
Iceland	3-(2)-2	x	x	x	-	-	x	x	
Switzerland	1-(3)-1-(3)-1-(3)-1-(3)-1	x	-	-	-	x	-	-	...
Cyprus	6-consecutive	x	x	x	x	x	x		
France	6-consecutive	x	x	x	x	x	x		
Greece	6-consecutive	x	x	x	x	x	x		
Hungary	6-consecutive	x	x	x	x	x	x		
Portugal	6-consecutive	x	x	x	x	x	x		
Spain	6-consecutive	x	x	x	x	x	x		
Norway	8-consecutive	x	x	x	x	x	x	x	x
Sweden	8-consecutive	x	x	x	x	x	x	x	x

5.2 Analysis of rotation patterns

Consider the rotation pattern

n_1-(m_1)-n_2-(m_2)-n_3- …… with $n = \sum n_i, \quad m = \sum m_i$.[8]

Recall that here n_i is the time (number of rounds) for which the unit is in the sample in its i^{th} appearance; m_i represents the time the unit was out of the sample after its i^{th} inclusion in the sample; n is the total number of rounds the unit is in the sample before being finally dropped from the survey; and m is the total number of rounds it was temporarily out of the survey between its first appearance and final exit.

This schema may be implemented as follows. At each round of the survey, one new subsample or 'rotation group' is introduced; thereafter that subsample follows the above-mentioned rotation pattern. It can be seen that, once the system has been fully established, exactly n subsamples will be active in any cross-sectional sample of the survey.

What is the average 'age' of a cross-sectional sample at any time and how does it depend on the rotation patterns? That is, what is the average number of times the units have already been in the survey on previous occasions? This question is of both methodological and substantive interest. The number of times the n subsamples currently present have been previously in the survey is given by the sequence k_i = 0 to (n-1). Assuming the subsamples to be of the same size (which is the usual design in rotational samples), the average number of times a unit in a cross-sectional sample has been in the survey equals

$\bar{k} = \frac{S(n-1)}{n}$, where $S(n-1)$ is the sum of (n-1) natural numbers, giving $\bar{k} = \frac{(n-1)}{2}$.

This means that the average number of times a unit at any cross-section has already been in the sample depends only on n, the total number of rounds the unit is in the sample before being finally dropped from the survey. It does not depends on the periods m_i for which any unit may be temporarily withdrawn from the survey. Hence for example, different rotation patterns with n=4 such as

2(2)2, 2(1)2, 1(3)1(3)1(3)1, or 4-consecutive

have the same distribution k_i = 0 to 3, and average $\bar{k} = 1.5$. Similarly patterns with n=5 such as

3(1)2, 3(2)2, or 5-consecutive

have the same distribution k_i = 0 to 4, and average $\bar{k} = 2.0$.

The various rotation patterns appearing in EU labour force surveys are illustrated in Figure 3. The above relationships can be clearly seen.

[8] Obviously, there is one less term in the m_i series compared with that for n_i, the relevant sequence ending when the unit is finally drop from the sample.

Figure 4. Illustration of rotation patterns

t= current period; t-1, t-2 etc. sequence of preceding periods (rounds)
n= total number of times any unit is included in the sample
k= number of times the unit has been prevoiusly included in sample (0 to n-1)

Pattern	**Time period or round (t = current period)**						
n = 2							
2-consecutive				t-2	t-1	t	k
					x	x	1
						x	0
Overlap between t and ...				t-2	t-1		average k=
				0	1/2		1/2=0.5
n = 3							
3-consecutive			t-3	t-2	t-1	t	k
				x	x	x	2
					x	x	1
						x	0
Overlap between t and ...			t-3	t-2	t-1		average k=
			0	1/3	2/3		3/3=1
2(2)1	t-5	t-4	t-3	t-2	t-1	t	k
		x	x	-	-	x	2
			x	x	-	-	
				x	x	-	
					x	x	1
						x	0
Overlap between t and ...	t-5	t-4	t-3	t-2	t-1		average k=
	0	1/3	1/3	0	1/3		3/3=1
1(1)1(1)1	t-5	t-4	t-3	t-2	t-1	t	k
		x	-	x	-	x	2
			x	-	x	-	
				x	-	x	1
					x	-	
						x	0
Overlap between t and ...	t-5	t-4	t-3	t-2	t-1		average k=
	0	1/3	0	2/3	0		3/3=1

Figure 4. Illustration of rotation patterns (cont.)

t= current period; t-1, t-2 etc. sequence of preceding periods (rounds)
n= total number of times any unit is included in the sample
k= number of times the unit has been prevoiusly included in sample (0 to n-1)

n = 4

4-consecutive

	t-4	t-3	t-2	t-1	t	k
		x	x	x	x	3
			x	x	x	2
				x	x	1
					x	0
Overlap between t and ...	t-4	t-3	t-2	t-1		average k=
	0	1/4	2/4	3/4		6/4=1.5

2(2)2

	t-6	t-5	t-4	t-3	t-2	t-1	t	k
		x	x	-	-	x	x	3
			x	x	-	-	x	2
				x	x	-	-	
					x	x	-	
						x	x	1
							x	0
Overlap between t and ...	t-6	t-5	t-4	t-3	t-2	t-1		average k=
	0	1/4	2/4	1/4	0	2/4		6/4=1.5

2(1)2

	t-5	t-4	t-3	t-2	t-1	t	k
		x	x	-	x	x	3
			x	x	-	x	2
				x	x	-	
					x	x	1
						x	0
Overlap between t and ...	t-5	t-4	t-3	t-2	t-1		average k=
	0	1/4	2/4	1/4	2/4		6/4=1.5

1(3)1(3)1(3)1

	t-13	t-12	t-11	t-10	t-9	t-8	t-7	t-6	t-5	t-4	t-3	t-2	t-1	t	k
		x	-	-	-	x	-	-	-	x	-	-	-	x	3
			x	-	-	-	x	-	-	-	x	-	-	-	
				x	-	-	-	x	-	-	-	x	-	-	
					x	-	-	-	x	-	-	-	x	-	
						x	-	-	-	x	-	-	-	x	2
							x	-	-	-	x	-	-	-	
								x	-	-	-	x	-	-	
									x	-	-	-	x	-	
										x	-	-	-	x	1
											x	-	-	-	
												x	-	-	
													x	-	
														x	0
Overlap between t and ...															
	t-13	t-12	t-11	t-10	t-9	t-8	t-7	t-6	t-5	t-4	t-3	t-2	t-1		average k=
	0	1/4	0	0	0	2/4	0	0	0	3/4	0	0	0		6/4=1.5

Figure 4. Illustration of rotation patterns (cont.)

t= current period; t-1, t-2 etc. sequence of preceding periods (rounds)
n= total number of times any unit is included in the sample
k= number of times the unit has been prevoiusly included in sample (0 to n-1)

5-consecutive				t-5	t-4	t-3	t-2	t-1	t	k
					x	x	x	x	x	4
						x	x	x	x	3
							x	x	x	2
								x	x	1
									x	0
Overlap between t and ...				t-5	t-4	t-3	t-2	t-1		average k=
				0	1/5	2/5	3/5	4/5		10/5=2
3(1)2			t-6	t-5	t-4	t-3	t-2	t-1	t	k
				x	x	x	-	x	x	4
					x	x	x	-	x	3
						x	x	x	-	
							x	x	x	2
								x	x	1
									x	0
Overlap between t and ...			t-6	t-5	t-4	t-3	t-2	t-1		average k=
			0	1/5	2/5	2/5	2/5	3/5		10/5=2
3(2)2										
		t-7	t-6	t-5	t-4	t-3	t-2	t-1	t	k
			x	x	x	-	-	x	x	4
				x	x	x	-	-	x	3
					x	x	x	-	-	
						x	x	x	-	
							x	x	x	2
								x	x	1
									x	0
Overlap between t and ...		t-7	t-6	t-5	t-4	t-3	t-2	t-1		average k=
		0	1/5	2/5	2/5	1/5	1/5	3/5		10/5=2
6-consecutive			t-6	t-5	t-4	t-3	t-2	t-1	t	k
				x	x	x	x	x	x	5
					x	x	x	x	x	4
						x	x	x	x	3
							x	x	x	2
								x	x	1
									x	0
Overlap between t and ...			t-6	t-5	t-4	t-3	t-2	t-1		average k=
			0	1/6	2/6	3/6	4/6	5/6		15/6=2.5
8-consecutive	t-8	t-7	t-6	t-5	t-4	t-3	t-2	t-1	t	k
		x	x	x	x	x	x	x	x	7
			x	x	x	x	x	x	x	6
				x	x	x	x	x	x	5
					x	x	x	x	x	4
						x	x	x	x	3
							x	x	x	2
								x	x	1
									x	0
Overlap between t and ..	t-8	t-7	t-6	t-5	t-4	t-3	t-2	t-1		average k=
	0	1/8	2/8	3/8	4/8	5/8	6/8	7/8		28/8=3.5

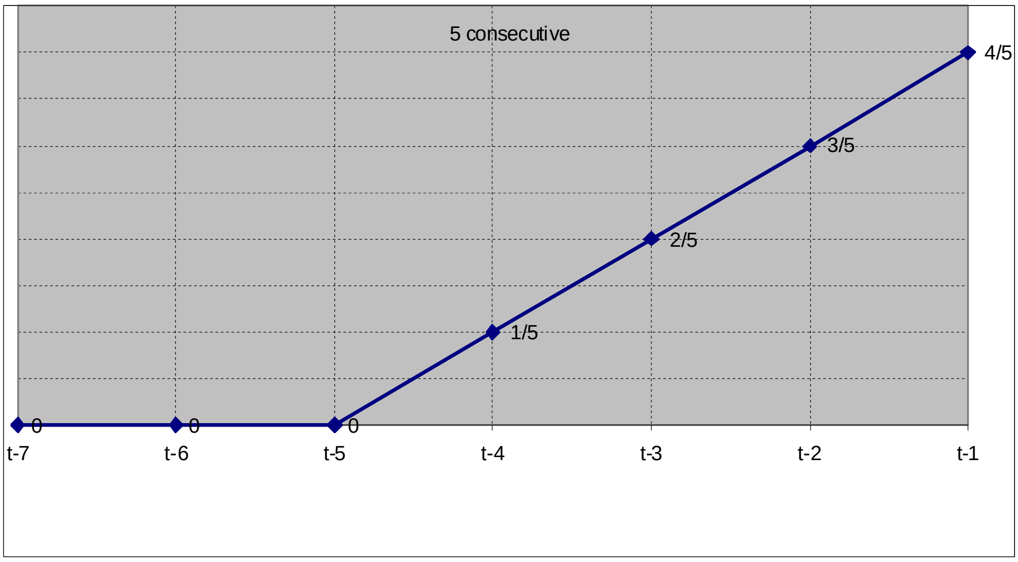
What is different between different patterns with same n but different sequences of n_i and m_i is the *distribution of the sample overlap* in time. The overlap no more declines in a straight line as in the 'linear' rotation pattern, but it can go up and down as the time interval between the surveys rounds being compared is increased. The *same amount* of overlap with preceding samples is stretched over a longer period - from (n-1) periods with a linear pattern to (n+m-1) periods in the more complex pattern[9]. This is illustrated in Figure 5, where three different patterns with n=5 are compared in terms of the temporal distribution of the sample overlap. Note that the 'total amount of overlap' (the area under the curves shown) is the same for all the patterns.

The three patterns illustrated in the figure are:

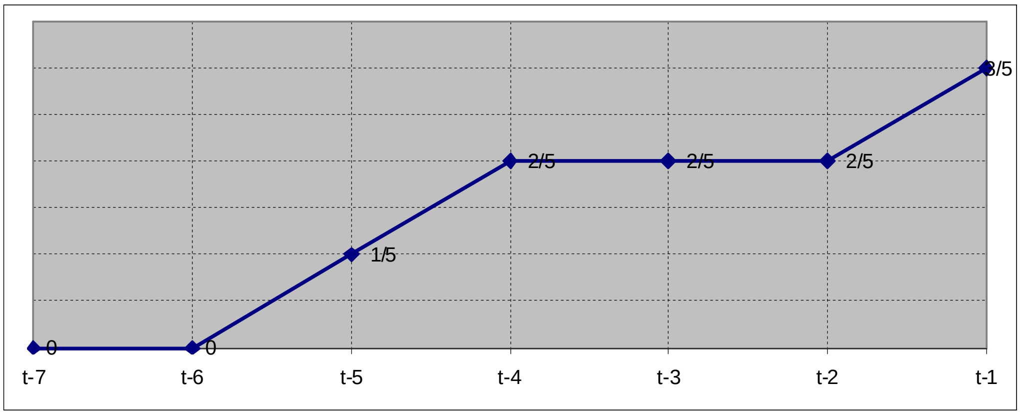
5-consecutive	(Austria, Czech Republic, Ireland, Netherlands, Slovakia, UK)
3(1)2	(Finland, Slovenia)
3(2)2	(Iceland)

[9] Note that in all examples shown in Figure 4, for a given n, (i) the distribution of the cross-sectional sample at t by the 'age' of its subsamples is the same independent of the m values; (ii) the average of the last column ('age' of subsamples), and the total of the last row (distribution of sample overlap by time) are the same; and (iii) the sample overlap becomes zero finally at time t-(n+m).

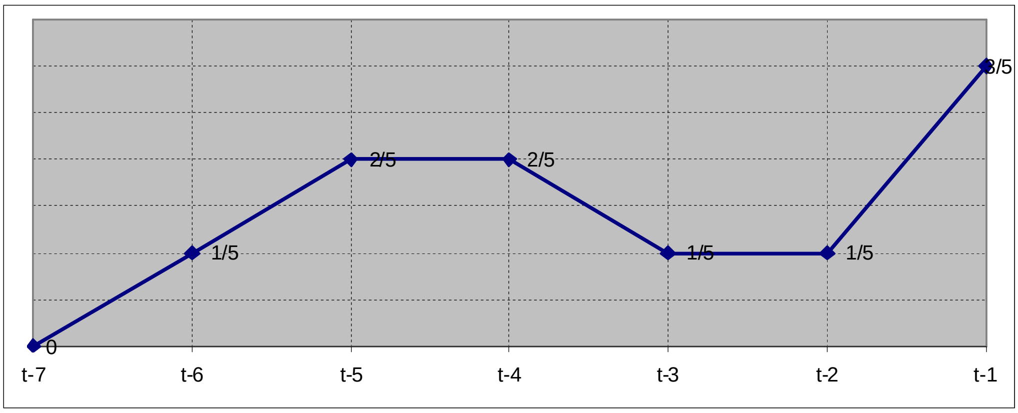
Figure 5. Illustrations of variation in sample overlap over time.
Three patterns with same average overlap: 5-consecutive, 3(1)2, and 3(2)2.



Pattern: 5 consecutive quarters
Austria, Czech Republic, Ireland, Netherlands, Slovakia, United Kingdom



Pattern: 3 (1) 2 (Finland, Slovenia)



Pattern: 3 (2) 2 (Iceland)

5.3 Rotation in multi-stage designs: some examples

As noted earlier, in a multi-stage sampling design, it is possible to use different patterns of rotation for different levels of units. Various possibilities exist in this connection. At the one extreme, we may keep the PSUs unchanged over time and rotate the sample of lower stage units only within fixed PSUs. At the other end, units at different levels may be rotated in the same way at the same rate.

More generally, different types of units may be kept in the survey for different lengths of time. In multi-stage samples, it is possible to retain higher stage units (such as areas) in the sample for a longer period, and subject lower stage units (such as households) to a faster rotation. This may be desirable for various reasons. For one thing, longer use of the same areas can be convenient and efficient from both practical and statistical point of view. The cost associated with changing the sample areas is reduced. Also, a greater overlap between areas in successive rounds provides positive correlations, thus increasing the precision of estimations of trends. Furthermore, by making the rotation of lower stage units faster, repeated enumeration of the same households and persons is avoided or reduced, thus limiting respondent burden.

Some illustrations of differential rotation in multi-stage designs from EU labour force surveys are provided below. These descriptions are summarised from Eurostat (2007, 2008).[10]

<u>Bulgaria</u>

The Labour force survey is based on a two-stage stratified cluster sample. Clusters at the first stage are the enumeration districts; the second (ultimate) stage unit is the household, all persons in a sample household being included in the survey. For each quarter, the sample consists of 2,250 clusters selected with probability proportional to the population in the districts; each of these clusters yields a sample of 8 households during the quarter, giving the total sample size as 18,000 households per quarter.

The quarterly sample is divided into three independent sub-samples of 750 clusters each, one for each month of a quarter. The households from each of these subsamples are evenly spread through the 4 weeks of the month the subsample is active.

Thus there is no overlap among units at any level between the 3 monthly subsamples in a quarter. However, there is overlap over time between quarterly samples, which is different for the two levels of units as follows.

Pattern of rotation (quarterly)	Cluster	8-consecutive
	Household	2-(2)-2

The rotation pattern for clusters is 'linear' – once selected, a cluster remains in the sample for 8 consecutive quarters, though for only one month during each quarter, as noted above. In principle, a stable pattern can be achieved by dividing the subsample into 8 'rotation groups', with one such new group introduced each quarter and retained for 8 successive quarters.

Within a sample cluster, the sample households are divided into four parts (say H1-H4) of 4 households each. Each part is subject to 2-(2)-2 rotation pattern as shown in the figure below. A respondent is interviewed in two consecutive quarters, then temporarily removed for the next two quarters, enumerated again for the following two quarters, and thereafter is finally removed from the survey. During the one month each quarter when the cluster is actively in the sample, two of

[10] The LFS in Turkey provides another example of differential rotation in a multi-stage design.

these sets of households are enumerated[11], giving a sample of 8 households per cluster per quarter as required.

Year-Quarter	1-1	1-2	1-3	1-4	2-1	2-2	2-3	2-4	
Cluster	C	C	C	C	C	C	C	C	
Household subsample (1)	H1	H1	-	-	H1	H1	-	-	
Household subsample (2)		H2	H2			H2	H2		
Household subsample (3)	-	-	H3	H3	-	-	H3	H3	
Household subsample (4)				H4	H4			H4	(H4)

Rotation pattern: Bulgaria

Croatia (2005 survey)

The sampling design is a two-stage stratified sample. First-stage sampling frame is a list of area units called segments, created from one or more neighbouring 2001 Population Census areas and not crossing borders of municipalities. Segments (a total of 720 for the 2005 survey) are selected by PPS systematic sampling, where measure of size of a segment is the number of private households in the segment according to Population Census 2001. The selected segments are used for whole year 2005. After selecting a sample of segments, six non-overlapping subsamples of segments are selected from it by systematic sampling. One subsample is in the survey each month of the year, any particular subsample being activated on two occasions 6 months apart.

Second stage sampling frame is a list of 2001 Population Census dwellings within selected segments. Dwellings in the sampling frame are dwelling in which one or more private households have been found in Population Census 2001. Within selected segments, dwellings are selected by simple random sampling. Different samples of 12 dwellings each are selected for the two occasions the segment is in the sample during the year. All members of all private households in selected dwellings are interviewed.

The pattern is shown below. Cx (x=1-6) refers to one of the clusters in the set of six used for the year. Hx-1 and Hx-2 are the two non-overlapping subsample of dwellings (segments) drawn from cluster Cx. Each cluster is used twice during the year, six months apart.

No sample unit is carried over from previous years. Presumably, a new set of clusters is drawn each year. For a particular year, there is no overlap at all between monthly samples at the household level, while at the cluster level there is complete overlap between any two months separate by six months.

Month	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Cluster	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**
Household subsample	**H1-1**	**H2-1**	**H3-1**	**H4-1**	**H5-1**	**H6-1**	**H1-2**	**H2-2**	**H3-2**	**H4-2**	**H5-2**	**H6-2**

Rotation pattern: Croatia

[11] For examples, sets H1+H2 at time “1-2”, sets H2+H3 at time “1-3”, etc., in this pattern shown for Bulgaria.

Ireland

The Irish LFS uses a two-stage sample design. The first stage units are blocks (or small areas), each block containing, on average, 75 dwellings. *The sample of blocks is fixed for a period of about five years.* In the second stage of sampling, each block is split into 5 subsample of 15 households each. From every block in the sample, one subsample is surveyed each quarter. A subsample remains in the sample for 5 consecutive quarters, after which it is replaced by another subsample from the same block.

For implementing this rotation pattern, the total sample of blocks may be divided systematically into five equivalent groups. Let a typical block in each of these be represented as Cx, x=1-5. All the blocks remain in the sample each quarter, but the subsamples within them are rotated differently, as shown in the figure below. The (non-overlapping and exhaustive) subsamples into which a block 'x' is divided are identified as Cx-y, y=1-5.

Quarter	←	1	2	3	4	5	1	→
Block	Subsample within the block							
C1	←	C1-5	(C1-1)	C1-1	C1-1	C1-1	C1-1	(C1-2)
C2	←	C2-4	C2-4	(C2-5)	C2-5	C2-5	C2-5	→
C3	←	C3-3	C3-3	C3-3	(C3-4)	C3-4	C3-4	→
C4	←	C4-2	C4-2	C4-2	C4-2	(C4-3)	C4-3	→
C5	(new)	(C5-1)	C5-1	C5-1	C5-1	C5-1	(C5-2)	→

Rotation pattern: Ireland

For example in quarter '1', the 1st subsample of block C5 (i.e. subsample identified as C5-1), the 2nd subsample of block C4 (that is, C4-2), …, and the 5th subsample of block C1 (that is, C1-5) are used. The first one in the above sequence has been newly introduced in this quarter, and the last one is appearing in the sample for the fifth and the last time – to be replaced by a new subsample '1' in the same block in the next quarter. After five quarters, the existing subsample of block C5 is replaced by subsample '2' from the same block, and so on.

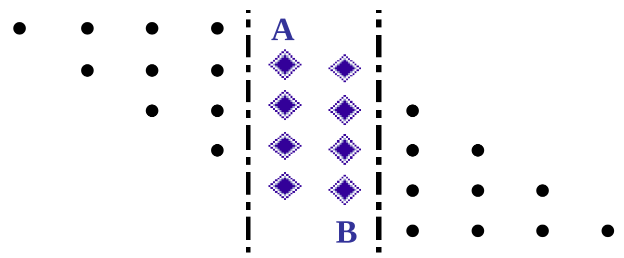
When all the five subsamples of a block have been used (over a period of 5x5=25 quarters), the block may be replaced by a new block. Thus the whole sample of blocks may be entirely replaced over a period of five consecutive quarters, this process being repeated once every 25 quarters. The sample of blocks remains entirely fixed during the intervening 20 quarters (5 years). By contrast, the rotation pattern for households is "5-consecutive".

6 Differences and averages under rotational design

6.1 Overlaps and correlation in rotational samples

Labour force survey are typically required to provide estimates of net change between two periods such as from one quarter to the next. Similarly, estimates are required of averages over a number of periods such as annual averages over consecutive quarters. With a rotational design, the total sample at any period (quarter) consists of a number of subsample introduced into the survey at different points in the past. The sample overlap between two periods generally differs from one subsample to another. For example, Figure 6 shows a sample with a 'linear' rotation pattern in which (1/5)th of the sample is replaced each quarter. (That is, any subsample remains in the survey for 5 consecutive quarters). Considering two consecutive quarters for instance, we see that the combined sample consists of 5 pairs, 4 of which are fully overlapping and 1 is made up of two entirely independent samples (indicated by A and B in the figure).

Figure 6. Estimating net differences in a rotating sample



Such differences between different subsamples in terms of the degree of sample overlap need to be taken into consideration in constructing measures of net change and averages over time under a rotational design. The objective of the present section is to clarify the procedure.

For simplicity of the illustrations, the following assumptions are made.

We will assume that the rotation pattern is 'linear', in which any unit once selected remains in the sample for *n* periods, thus giving a sample overlap equal to *(n-1)/n* between successive periods. For any given period, the total sample is divided into *n* subsamples, the total sample and each subsample being representative of the whole population. One of these subsamples is replaced by a different subsample in the following period. Next, we assume that variance of an estimate of interest from a single subsample at a given time has a constant value, say V^2, the same for all subsamples. The average correlation between estimates, from a given subsample, for two consecutive periods is also assumed to be a constant, say R. This means that the difference between and the average over two consecutive periods estimated from the same (i.e. fully overlapping) subsample have the following variances, respectively:

$$V_d^2 = V_1^2 + V_2^2 - 2RV_1V_2 = 2V^2 \cdot (1 - R)$$

$$V_m^2 = (V_1^2 + V_2^2 + 2RV_1V_2)/2^2 = \frac{1}{2}V^2 \cdot (1 + R)$$

6.2 Net change or difference between consecutive periods

The situation is illustrated in the Figure 6 already referred to. The total sample involved in the estimate consists of n pairs of subsamples, (n-1) of which are overlapping and 1 is a pair of independent subsamples. The resulting variances are as follows.

Type of pair	No. of such pairs	Variance of estimate from one pair
Fully overlapping	(n-1)	$2V^2(1\text{-}R)$
Independent	1	$2V^2$

Estimate of the difference form the whole sample may be obtained by simple average of the above estimates from individual pairs, i, of subsamples. Variance for such an estimate based on the whole sample may be written as:

$$V_d^2 = \sum V_i^2 / n = 2V^2\left[(n-1)(1-R)+1\right]/ n^2 = \frac{2V^2}{n}\left[1-\left(\frac{n-1}{n}\right)R\right]. \qquad [19]$$

The coefficient (n-1)/n for R appears because one of the n pairs has no sample overlap. With full overlap in all the samples, the expression would have been

$$V_d^2 = \frac{2V^2}{n}(1-R).$$

An alternative estimate with lower variance would be to take a weighted average, with the subsample estimates weighted inversely to their variance

$$V_d^2 = \sum W_i^2 V_i^2 \quad \text{with } \sum W = 1.$$

The appropriate weight for each of the overlapping pairs is:

$$W_i = 1/(n-R).$$

The non-overlapping pairs is less efficient in estimating the difference, and consequently has a lower weight:

$$W_i = (1-R)/(n-R).$$

Variance of the resulting estimate is somewhat smaller than [19]:

$$V_d^2 = 2V^2\left[(n-1)(1-R)+(1-R)\right]/(n-R)^2 = \frac{2V^2}{n}\cdot\frac{(1-R)}{\left(1-\frac{R}{n}\right)^2}. \qquad [20]$$

6.3 Averaging over quarters

Consider a rotational sample with n subsamples as before. Let the required estimate be the average over Q consecutive periods, such as Q=4 quarters for annual averages. The subsamples contributing to the average estimate are illustrated in Figure 7 for Q=4 and n values from 1 to 6.

The figure displays the subsamples contributing various number of observations during a fixed interval of Q rounds in a rotational design with a linear pattern with each unit staying in the sample for n consecutive periods. The illustrations are for a fixed value of Q=4 and a range of n values from 1 to 6.

The case n=1 corresponds simply to an independent subsample each quarter and, under the simplifying assumptions described in Section 6.2 above, the variance of the estimate of an average over Q period is:

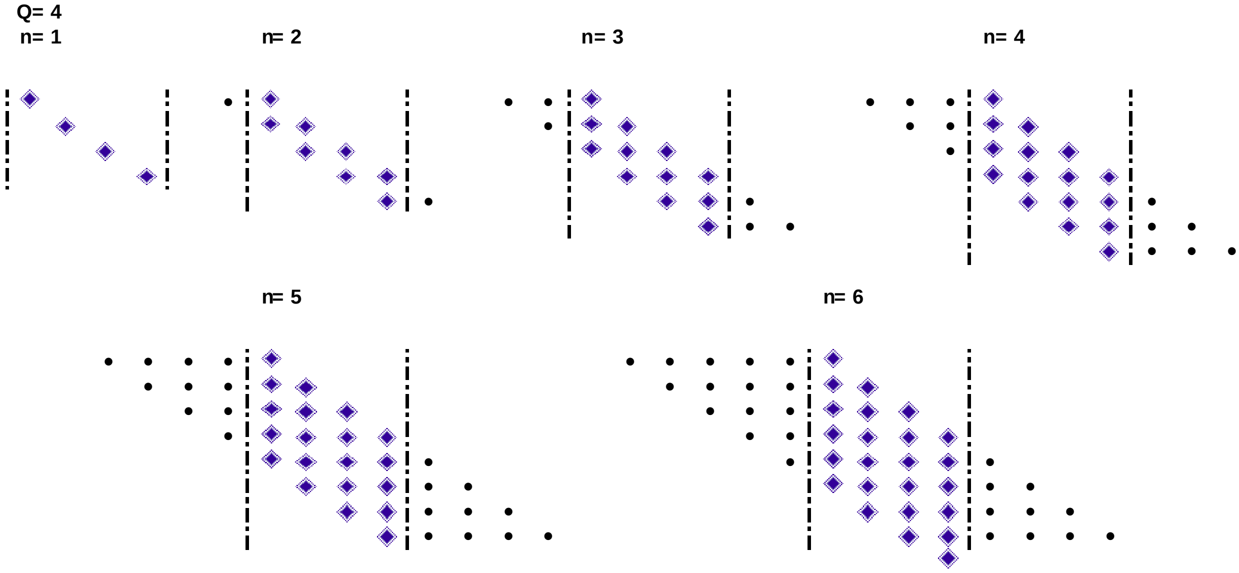
$$V_a^2 = \frac{V^2}{Q}.$$

In the general case, the total sample involved in the estimation of the average can be seen from the figure to consist of (n+Q-1) independent subsamples. Each subsample provides a number of 'observations' within the interval of interest (Q rounds). Obviously, by definition, these observation coming from the same subsample have a full sample overlap. For the linear rotation pattern assumed in the present illustration, the observations contributed by any given subsample are for consecutive periods. The distribution of the (n+Q-1) subsamples according to the number of observations (m) each provides during the given interval of interest (Q rounds) is as follows.

Defining m_1=min(n, Q) and m_2=max(n, Q), the following can be verified.

> For each value of index m = 1, 2, …, (m_1-1), there are 2 subsamples which provide exactly m observations during given interval Q.
>
> In addition, there are m_2 - (m_1-1) subsamples, each of which provides m_1 observations during given interval Q.

Figure 7. Averaging over time in a rotating sample
Illustration with Q = 4 and n = 1 to 6.



For illustration of the above formulae, consider Q=m_1=4, n=m_2=6. There are

> 2 subsamples contributing, respectively 1, 2 and (m_1-1)=3 observations; and
>
> m_2-(m_1-1)=3 subsamples, each contributing m_1=4 observations.

Similarly, for Q=m_2=4, n=m_1=3, we have

> 2 subsamples, one contributing 1 and the other contributing (m_1-1)=2 observations, and
>
> m_2-(m_1-1)=2 subsamples each contributing m_1=3 observations.

6.4 Effect of correlation on variance

In order to provide a simplified formulation of the effect of correlation arising from sample overlaps, we assume the following model. If R is the average correlation between estimates from overlapping samples in adjacent periods, then between periods one period apart (e.g. between the 1st and 3rd quarters), we assume that the average correlations is reduced to R^2, the correlation between period which are two periods apart (e.g. the 1st and the 4th quarters) is further reduced to R^3, and so on.

Consider a subsample contributing m observations during the interval (Q) of interest. By definition, these observations come from fully overlapping samples. Considering all the pairs of observations involved and the correlations between them under the model assumed above, variance of the average over the m observations is given by

$$V_m^2 = \frac{V^2}{m} \cdot \left(1 + f(m)\right), \qquad [21]$$

where

$$f(m) = \frac{2}{m} \cdot \left\{(m-1) \cdot R + (m-2) \cdot R^2 + \ldots + R^{m-1}\right\}. \qquad [22]$$

The term *f(m)* reflects the loss in efficiency in cumulation or averaging over overlapping samples. The following illustrates its values for various values of index m:

m =	***f(m)***
2	R
3	$\frac{2}{3}(2R + R^2)$
4	$\frac{2}{4}(3R + 2R^2 + R^3)$
5	$\frac{2}{5}(4R + 3R^2 + 2R^3 + R)$

We may view the above as variance "per-observation", say U_m^2, for the subsample concerned:[12]

$$U_m^2 = m \cdot V_m^2 = V^2 \cdot (1 + f(m)).$$

Repeated observations over the same sample are less efficient in the presence of positive correlations; this is summarised by the factor *[1+f(m)]* where m is the number of repetitions.

In estimating the average using the whole available sample of $(n \cdot Q)$ subsample observations[13], we may simply give each observation the same weight. Taking into account the number of observations and the variances involved, the resulting variance of the average becomes

[12] A subsample contributing a certain number m of observations during interval Q of interest has been identified here by subscript m.

[13] Obviously, we have n subsamples observed during each of Q periods in the rotational design assumed.

$$V_a^2 = \left(\frac{V^2}{n\cdot Q}\right)\cdot\left\{m_1\cdot\left[m_2-(m_1-1)\right]\cdot\left[1+f(m_1)\right]+2\sum_{m=1}^{m_1-1}m\cdot\left[1+f(m)\right]\right\}\Big/(n\cdot Q)=\left(\frac{V^2}{n\cdot Q}\right)\cdot F(R), \text{ say.}$$

The first factor is the variance to be expected from $(n\cdot Q)$ independent observations (with no sample overlaps or correlation), with V^2 as the assumed variance per observation. The other terms are the effect of correlation with sample overlaps. This effect, say F(R), disappears when *f(i)=0* for all *i=1 to m,* as can be verified in the above expression.

An alternative is to take a weighted average of the observations, with weights inversely proportional to their variance, i.e. to the corresponding factor *[1+f(m)]*. The effect on the resulting variance, though it may appear to be cumbersome in algebraic terms, can be easily worked out for any given rotation pattern and value of average correlation R. It has the form

$V_a^2 = \sum W_i^2\cdot V_i^2$, with $\sum W_i = 1$, where W_i is the weight of set i of observations.

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