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THE EFFECTS OF PERSISTENCE AND NON-RESPONSE IN SHORT-TERM STATISTICS

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Abstract. *Short-term business statistics are usually based on surveys with a rotating panel design in order to reduce the statistical burden for respondent. The partial overlapping of two periods allow for two different estimators for the year on year growth rate: (i) one that is based on the estimated population totals and (ii) one that is solely based on firms respondent in both periods. Indicators related to short-term statistics, such as the quarterly turnover for service sector, are a clear example on this way. Moreover these indicators are characterized by an high level of persistence which could have an effect on the performance of the two estimators. This paper aims to provide evidences on the two estimators in framework characterized by different degrees of persistence and non- response both modeled at a micro level. First the differences are shown by means of a simulation exercise. Secondly we provide an application based on the quarterly index of italian turnover for the Warehousing and Support Activities for Transportation. The results suggest that the estimator based on population totals outperforms the one based on firms respondent when the persistence and non-response are high as the one observed in the empirical case.*

Keywords: *Shor-term Statistics, Sampling methods, Warehousing and Support Activities for Transportation.*

1. INTRODUCTION

Economic variables are characterized by an high degree of persistence as observations at a certain point in time are closely related to previous values. The simple time series model that provides this behavior is the so called autoregressive model (AR) of order 1, where different values of the persistence are associated with the value of the parameter ϕ (positive values of the parameter around 1 imply an high degree of persistence)[2].

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2 For an introduction to AR and ARIMA model we refer to Brockwell and Davis (2016)

For estimating this economic behavior across the time, short-term business statistics, such as turnover or industrial production, use a sample design based on a rotating panel that implies a partially overlapping population between two periods. Differences in the panel units could be attributed to the rotating hypothesis in the sample design as well as to births and deaths in the population. According to the sample design different methods for estimating the (relative) change between two periods are available.

This paper considers two different estimators to provide an estimate of the growth rate for the quarterly index of italian turnover. The first estimator is based on the quarterly estimated population totals (STN) and the second one based solely on firms which respond in the overlap sample in two periods (quarter) (OLP)[3].

Inside this framework, several authors have already provided significant results both on the variance-covariance estimation and on the specific estimators that have minimum variance. For example, Valliant (1991) derives the estimator for the target indices in the context of two-stage sampling with an application to price indices, meanwhile Wood (2008), Qualité and Tillé (2008), Nordberg (2000) and Knottnerus and van Delden (2006) examine various estimators for the growth rate in different situations and Knottnerus (2011) derives estimators for relative change together with the corresponding population totals that have the property of minimum variance.

Extending the results provided by Qualité and Tillé (2008), our main contribution is to investigate the performance of the two estimators according to different degrees of non-response and persistence in the domain of short-term statistics. STN and OLP are both utilized to compile the short-term indices at the Italian National Statistical Institute (Istat), particularly in the monthly survey on retail trade (Istat (2018b)) and in the quarterly survey on turnover in the services sector (Istat (2018a)), where OLP is adopted for the economic sectors surveyed since 2000 and STN for those sectors analyzed starting from 2010.

We illustrate the performance of the two estimators by means of a simulation exercise able to reproduce the main characteristics of the quarterly survey on turnover. At the same time, we support our simulation exercise by means of an application based on the quarterly index of italian turnover for the Warehousing and Support Activities for Transportation.

We hope that our contribution could inform the debate about the standardization of the estimators currently adopted in Istat in the Short-Term Statistics

[3] The notation is the same provided in Knottnerus (2011)

(STS) domain, supporting, at least for the quarterly survey on turnover services, the complete adoption of the STN approach.

The paper is structured as follows. Section 2 describes the main characteristics of the sample design and the estimation methodology adopted in the European Countries and in Istat for the the quarterly turnover for services. Section 3 focuses on the main characteristics of the two estimators and section 4 shows the simulation results, while section 5 contains the empirical application. Our conclusion are reported in section 6.

2. THE INDEX OF TURNOVER FOR SERVICES SECTOR

The STS-Regulation requires turnover to be transmitted to Eurostat either as an index or as absolute figures. The turnover index is a simple value index (price multiplied by quantity/volume) and is a direct index in that it compares the value in the current period with the base year Eurostat (2006). In order to compile turnover indices at higher levels of economic classification (NACE), the indices at the lowest level have to be aggregated by using weights based on the turnover share of each activity in the base year provided by Structural Business Statistics. According to the Eurostat report (Eurostat (2009)) thirteen countries compile a Laspeyres or a fixed base index while four countries do not produce an index but a time series of the value of turnover.

As for the main methodological characteristics for European Countries, eleven of these use administrative data. The main source for the administrative data across countries if the value-added tax (VAT) that is a general tax that applies, in principle, to all commercial activities involving the production and distribution of goods and the provision of services. Usually information on this tax is related to that one on turnover. Among these eleven, six of them use administrative data in conjunction with statistical surveys. For example in Germany, the administrative data are used only for smaller firms, whereas in the case of Norway the administrative source is the main source, with surveys conducted for activities that are exempt from the administrative requirements (see Table 2 in Eurostat (2009)).

In Italy, the main administrative source for VAT is represented by a Governmnent Agency (called 'Agenzia delle Entrate'). The firms are required to report to the Agenzia delle Entrate on either a quarterly or monthly basis, depending on enterprise size, only the VAT difference between the credit and debt position. There is no evidence on the total turnover.

Assuming no space for the use of administrative data, in 2010 Istat launched new surveys to increase the coverage of the Italian Index of Turnover for ser-

vices sector and in particular for *Wholesale and retail trade of motor vehicles and motorcycles*, *Land transport and transport via pipelines*, *Warehousing and support activities for transportation*, *Accommodation* and *Food and beverage service activities*. The sample design is based on a stratified random sampling strategy for well-known statistical advantages because businesses are extremely heterogeneous in terms of size and type of economic activity and the use of stratified sample without replacement (SRS) increases the accuracy of parameters estimation. For these sectors the estimator adopted is based on the estimate of the total population (STN).

These indices have been released together with the information on the sectors already surveyed since 2000 (Bacchini et al. (2012)) that are elaborated by means of an OLP estimator. The need for fulfillment the set of indices required by STS regulation has postponed the relevant research for a homogeneity in the choice of the estimator for the different sectors[4].

The aim of our study is to provide evidences that could be useful to the choice of a standard estimator, at least for the quarterly survey on turnovers for service.

3. TWO ESTIMATORS FOR THE INDEX OF TURNOVER

Looking at the Italian quarterly turnover in services our attention concentrates on the performance of two different estimators for the quarterly growth rate of the turnover: one that is based on the quarterly estimated population totals (STN) and one that is based solely on firms respondent on both occasions in the overlap of the corresponding samples (OLP). We share this comparison with the work of Knottnerus (2011) and Knottnerus (2012).

Consider a population of N firms $U = \{1, 2, \ldots, N\}$ and suppose there are no births and deaths in the population. Let $y_{i,t}$ denote the value of the turnover for the i-th enterprise for a specific quarter t. Then suppose that the population is divided into H strata and for each stratum a sample random sample (SRS) of s_h firms is selected.

4 More generally, the sample design and the estimation methodology used in Istat for the compilation of short term indicators are quite heterogenous, depending on the different domains. For example, a cut-off sample is used for the index of industrial production and turnover and a census is used for the survey on employment in large firms. Administrative data are used for building permits, for the survey on gross wages, other labour costs and total labour costs and index of production in construction. Sampling surveys are used for job vacancies (Baldi et al. (2005)), retail trade (Istat (2018b)) and turnover for service sectors (Bacchini et al. (2012)) and (Bacchini et al. (2015)). For job vacancies an Horvitz-Thompson estimator (Cochran (1977)) is used, for retail trade the index is calculated by the OLP estimator.

If $y_{is_j,t}$ is the turnover for unit i belonging to the stratum s_j at time t,

$$\hat{y}_{.s_j,t} = \sum_{i \in s_j} y_{is_j,t} \tag{1}$$

is the sum of turnover for all sampling units in the stratum s_j and

$$\hat{y}_t = \sum_{s_j=1}^{H} \sum_{i \in s_j} y_{is_j,t} \tag{2}$$

is the sum for all the units in the sample where H is the number of strata. If we consider an Horvitz-Thompson estimator at time t_1 data for a sample of units are available and in the case of a stratified sampling design we can calculate the index number at time t_1 comparing the total turnover of the quarter with the turnover average at the reference base t_0 as[5]:

$$I_{t_1,t_0} = \frac{\hat{y}_{t_1}}{\hat{y}_{t_0}} 100 = \frac{\sum_{s_j=1}^{H} \sum_{i \in s_j} y_{is_j,t_1}}{\sum_{s_j=1}^{H} \sum_{i \in s_j} y_{is_j,t_0}} \tag{3}$$

Supposing there are only 2 strata in the population s_1 and s_2. The Horvitz-Thompson estimator for the time t_1 is:

$$\hat{y}_{t_1}^{HT} = \sum_{i \in s_1} y_{is_1,t} \frac{N_{s_1,t_1}}{n_{s_1,t_1}} + \sum_{i \in s_2} y_{is_2,t} \frac{N_{s_2,t_1}}{n_{s_2,t_1}} \tag{4}$$

where $\frac{N_{s_1,t_1}}{n_{s_1,t_1}}$ represents the sample fraction for the stratum s_1 at time t_1.

Along this framework, Knottnerus (2011) proposes a clear comparison between the performance of the standard estimator (STN) based on the estimated totals and the one based on firms respondent on both occasions in the overlap (OLP)[6]. In particular, Knottnerus (2011) argues that the STN estimator 'for estimating growth rates may lead to unnecessarily large confidence intervals around a misleading estimate of the growth rate'.

However, the comparison proposed by Knottnerus (2011) does not take explicitly into account the level of persistence that is one of the main characteristics of the economic variables. As we show both in the simulation experiment and in the empirical example, the degree of persistence at unit level interacts with the rate and process of total non-response.

5 We do not explicity specify the weights that are the same both at the numerator and at the denominator and are equals to the turnover derived from the annual survey at the base year

6 Between the two periods the total number of units and its allocation in the stratum does not change but the rotating design introduce a difference in the units selected in the sample

4. THE SIMULATION EXPERIMENT

Our main contribution is to analyze the implication of different degrees of non-response and persistence on the performance of the two estimators, the so called STN and OLP, that are currently used in short-term statistics at Istat. Although the unit non-response characteristics have been already considered (Qualité and Tillé (2008)), we introduce unit non-response together with a specific growth pattern for each enterprise in such a way that different degree of persistence could be addressed.

To investigate this comparison we build a simulation framework composed by 4 steps:

1. simulation of the population of N firms at time $t = 0$
2. simulation of the dynamic evolution for each firm of the population for time $t = 1, 2, \ldots, 240$
3. determining the sample size and select the unit in the sample
4. select the number of missing unit according to binomial distribution

With regards at the first step, the turnover of firms is characterised by a strong asymmetric distribution assuming only positive values. In the first period, the value of turnover for each firms has been generated according to a lognormal distribution with different values of the mean and the variance for each stratum[7]. A population of 1,900 units has been generated to approximate the sample size actually implemented for the sector of Warehousing and support activities for transportation (code 52 of Nace classification, see Bacchini et al. 2014). We suppose to have only 4 strata in the population associated to different classes of employees size (1,000 units in the stratum 1, 400, 400 and 100 respectively in the stratum 2, 3 and 4).

Figure 1 shows an example of the simulated population while table 1 illustrates the distribution of units and percentage turnover for each stratum on the total of the population. Both figure and table are in line with the real case.

Concerning the evolution of the turnover along time, we have done the hypothesis that each firm evolves according to an autoregressive pattern. To explore

[7] To reproduce a simulation nearest to the real one we have used the following values for the vector of the mean (20,290 72,900 129,000 549,000) and for that one of the variance (1 0.7 0.7 1) where the lowest variance is associated to the intermediate strata (2 and 3).

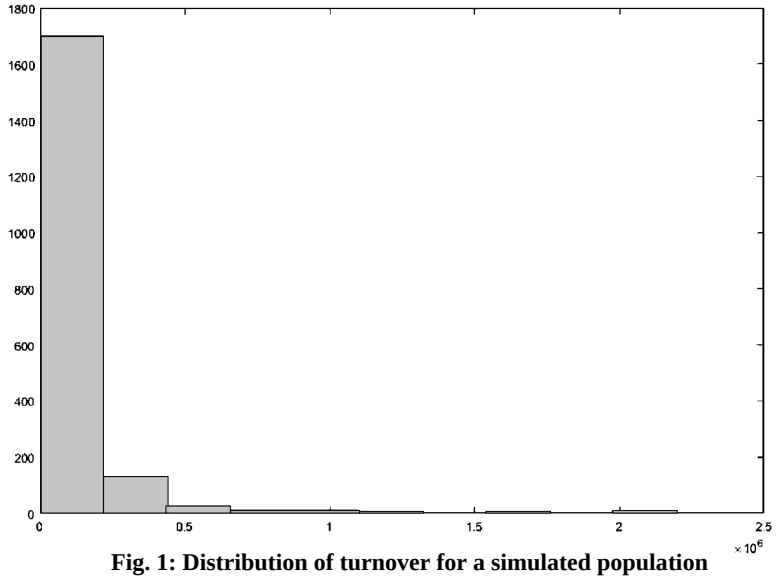


Fig. 1: Distribution of turnover for a simulated population

Tab. 1: Example of the distribution of units and turnover for stratum

Stratum	**N. of units**	**Percentage of turnover**
Stratum 1	1,000	4.5
Stratum 2	400	5.1
Stratum 3	400	34.4
Stratum 4	100	56.0
Total	1,900	100.0

the effects of different degree of persistence on the performance of the two estimators we consider two regimes, one with low persistence (parameter ϕ in the range $0.1 - 0.3$) and the other with higher persistence (parameter ϕ in the range $0.5 - 0.8$).

With regards to the sample design, a random stratified sample is selected. The sample size is determined by means of the generalized Bethel algorithms (Bethel (1989)) implemented in Mauss-R (Barcaroli et al. (2010))[8]. The algorithm allows to calculate the sample allocation for stratified sampling designs with the overall sample size and the allocation among the different strata determined starting as imposed by the accuracy of the estimates of interest. In the simulation the sample size are set to 22, 23 40 e 55 units for the 4 strata.

[8] Mauss-R is a tool developed at Istat for defining the sampling design for sample surveys on finite populations. It guarantees optimality criteria, flexibility and easy management for those who have the responsibility to design and conduct such surveys. It has been developed in R language.

Concerning the generation of the non-response, all surveys are characterised by either item and/or unit no response. For the survey on turnover we have only unit non-response. For each quarter the firm have only two states: respondent, providing information on turnover, or non respondent.

For a better control of the results of the simulation exercise we introduce a missing at random non-response mechanism (MAR) in the stratum instead of one completely at random on the overall population (MCAR). For each stratum, the missing pattern in the simulation it has been implemented generating a matrix of 1 and 0 for the sampling units according to a binomial distribution. The per- centage of non respondent units is controlled by the probability for the binomial distribution. This mechanism implies a missing at random hypothesis for non re- spondents for each stratum. We consider two different regimes for the probability of the binomial distribution: $P = 0.1$ and $P = 0.4$.

The simulation process consists in 1,000 replications of the steps 3 and 4 making the hypothesis of the two regimes both for persistence and probability of missingness. Considering the time, we generate 340 observations discarding the first 100 for a total of 240 periods.

For each replication the indexes are calculated using the two different estimators. The results are presented as an average for the 1,000 replications. Particu- larly we present the mean error (hereafter, ME), the mean absolute error (hereafter MAE) and the mean square error (hereafter, MSE) between the true index number and the index number obtained with the two estimators.

The performance of the two estimators depends both on the persistence and on the missing value rate. With a moderate persistence scheme ($\phi = 0.1 – 0.3$) and a low level of missing values ($P = 0.1$), the two estimators provide similar results in terms of ME, MAE and MSE. This result is expected because the effi- ciency of the considered estimator depends also on the amount of the unavailable information and on the hypothesis on the non-response mechanism that is MAR in the stratum.

The performance of the 2 estimators starts to diverge when probability of missingness and persistence increasing. In all these cases STN estimator performs better than the OLP according to all the measures (ME, MAE, MSE).

These results are straighforward comparing the plot of the averages for the replications (Figure 2 and 3) where the bias for the OLP estimatos clearly emerge.

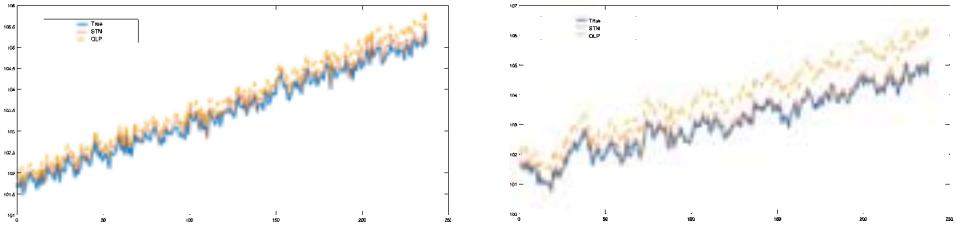
5. THE EMPIRICAL EXAMPLE

Our simulation experiment suggests that the estimator STN performs better than the estimator OLS in presemce of an high degree of persistence and missing- ness.

To illustrate how our results are compatible with the empirical experience, we

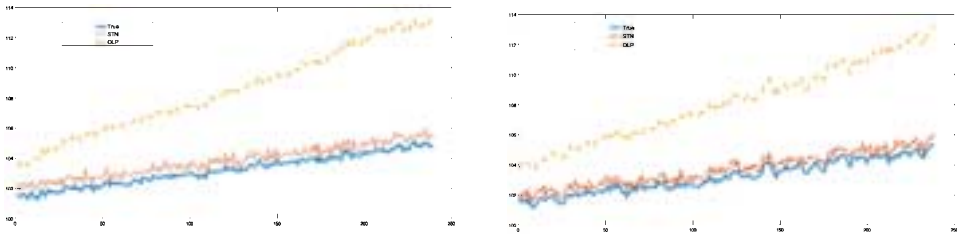
Tab. 2: Mean error, mean absolute error and mean square error for differ- ent autoregressive parameters and probability missing values

		P=0.1		P=0.4	
		AR ϕ = 0.1 – 0.3	AR ϕ = 0.5 = 0.8	AR ϕ = 0.1 – 0.3	AR ϕ = 0.5 – 0.8
ME	STN	0.12	0.18	0.61	0.53
	OLP	0.36	0.89	5.26	6.03
	STN	2.87	2.92	6.81	7.30
	OLP	3.38	4.55	12.04	12.24
	STN	12.72	13.59	73.96	84.45
	OLP	18.79	34.89	250.15	287.71



(a) AR (ϕ = 0.1 – 0.3) (b) AR (ϕ = 0.5 – 0.8)

Fig. 2: Number index obtained with estimators STN and OLP with P = 0.1, **1,000 simulation**



(a) AR (ϕ = 0.1 – 0.3) (b) AR (ϕ = 0.5 – 0.8)

Fig. 3: Number index obtained with estimators STN and OLP with P = 0.4**, 1,000 simulation**

have analysed the behavior of the two estimators with the quarterly italian data on turnover for the sector of Warehousing and Support Activities for Transportation (code 52 of Nace classification), for the period I.2011-I.2014. For this sector the sample design provides 12 strata (4 different economic activity and 3 different class for employees size).

For each quarter we have derived the growth rate according to STN and OLP estimators. The OLP estimator does not make use of all units available in each period but only of that ones available in both quarters involved in the computation

of the specific growth rate. On average 28% of the units available in each quarter are not elaborated using OLP estimator. These characteristics relates the real data close to the simulation experiment: presence of an high degree of persistence (Figure 4) together with a medium-high degree of non-response.

The two indices elaborated by STN and OLP illustrate a similar behavior in the period I-2011, 1-2014 except all the quarters of 2012 when STN provides a different picture (Figure 4). This result is in line with the simulation experiment. The time series of the growth rate exhibits a clearly persistent dynamic[9] and the OLP estimator does not reproduce completely this pattern.

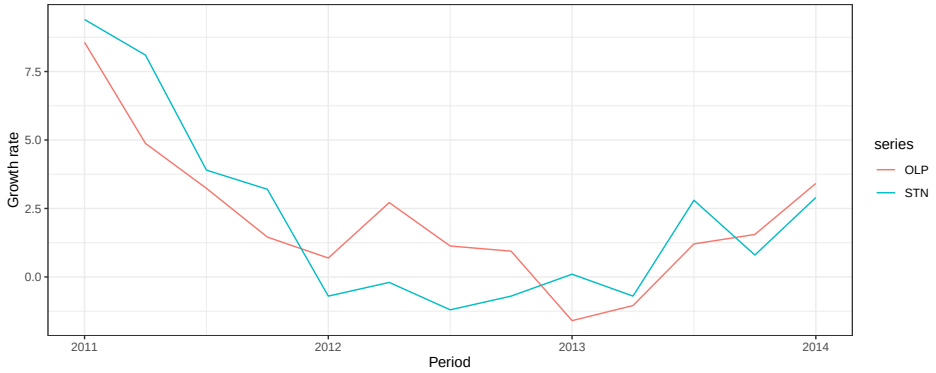


Fig. 4: Index of turnover for division 52, OLP and STN estimators - I-2011, 1-2014 growth rate

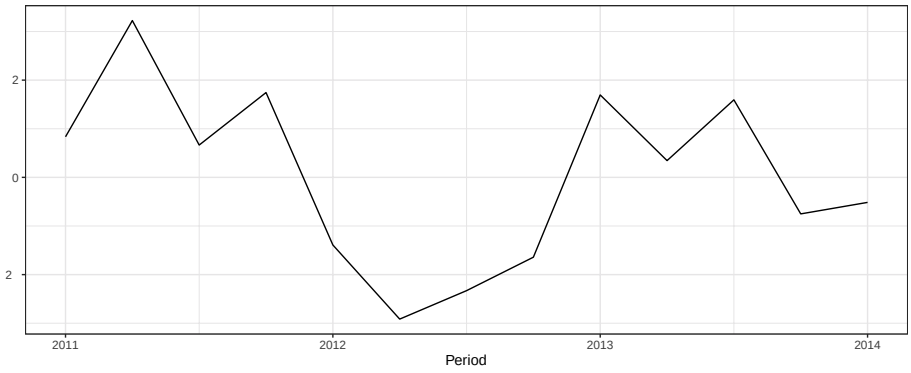


Fig. 5: Index of turnover for division 52, differences between OLP and STN estimators - I-2011, 1-2014 growth rate

[9] The AR(1) model with the best fit to the growth rate estimated by STN has a Δparameter equal to 0.92.

The characteristics of the two estimators are even more clear looking at the differences in the growth rate (figure 5). This series presents an autoregressive behaviour that is coherent with the hypothesis that OLP estimator has some difficulties to capture persistence.

6. CONCLUSION

Currently the principal short-term indices elaborated by Istat does not share an omogenous approach for the sample desing. This is partly due to some histori- cal differences in their implementation phase (quarterly indicators on services are youngest compared to the ones related to the manifacturing sector) as well as to the main topic of the survey (production vs turnover).

Conseguently different strategy are put in place for the sample design mainly related to two estimators: one based on the estimation of the total for the population in a period and the one solely based on the firms respondent on both occasions in the overlap of the corresponding samples.

This work has provided some interesting results on the comparison between the two estimators illustrating that both estimators perform in an optimal in presence of a low degree of persistence and missingness.

When the number of nonrespondents increases and the economy is running according to a phase characterised by a high degree of persistence, the STN estimator outperforms the OLP estimator.

These results are supported both by simulation investigation as well as by an empirical example related to the quarterly index of turnover in services.

We hope that these results will be further improved by a research activity on the standardisation program for the STS surveys in Istat, both on the sample design and on the use of estimators. We think that more effort should be necessary to reach a better degree of harmonisation.

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