**A reweighting method to adjust for enterprise changes: the Italian quarterly job vacancy rate and hours worked estimates**

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**Abstract**

*The Italian National Institute of Statistics produces quarterly estimates of the job vacancy rate and hours worked for EU Regulations and national dissemination through calibrated weights. Job vacancy and hours worked data are collected by two direct business surveys. The survey samples are drawn from the Italian statistical business register (ASIA), updated to two years before the reference quarter of the survey data, while the calibration constraints are derived from an administrative based source for the reference quarter.*

*The distance in time between the reference periods of sampling frame and source for calibration constraints implies that sample units may be classified as belonging to different strata depending on whether the information in the sample frame or in the source used for calibration constraints is used, due to changes in the enterprises’ economic activity and/or size between the two reference periods.*

*As a consequence, if the initial weights are based on the sample frame units classification, calibrated weights are found to show a high variability within some calibration strata. In particular, in a given calibration stratum, weights can be concentrated only on few sample units while the remaining ones can be near to zero.*

*To ensure a more homogeneous distribution of the calibration weights within strata, the initial weights have been recalculated, updating the sample units classification with the information used in the calibration strata construction and based on the source used for the calibration constraints.*

*Furthermore, the initial weights are calculated so as to correct also for non-response by the inverse of the response rate in the calibration stratum.*

*The first empirical results obtained applying this method have shown a reduction in the estimated sampling variance with respect to those obtained using initial weights based only on the not updated information of the sampling frame.*

**Keywords:** calibration, reweighting, short-term, business statistics

1. **Introduction**

This work is the result of the reweighting and calibration process used to obtain the quarterly hours worked and job vacancies indicators.

Istat disseminates hours worked and job vacancies indicators on a quarterly basis.

To produce these indicators, data on the target variables collected by two surveys are used together with those on jobs of an auxiliary administrative source (OROS) which are employed for editing and imputation and calibration. The first survey is the ISTAT quarterly survey on job vacancies and hours worked (VELA), based on a stratified random sample of about 26.000 enterprises with less than 500 employees in Nace Rev. 2 sections B to S. The sample is drawn from the Istat register of active enterprises (ASIA), updated to two years before the survey reference period. The stratification variables are economic activity, size and geographical area. The second survey is the ISTAT monthly survey on employment, hours worked, wages and labour costs in large enterprises (GI), which is a census survey of around 1,400 enterprises with at least 500 employees in sections B to S.

A calibration estimator is used to obtain the quarterly estimates, and the calibration constraints within each calibration domain are derived from OROS for the reference quarter. The calibration domains are obtained aggregating one or more sampling strata. The aggregation usually takes place for different geographical areas and size classes within the same economic activity, but it can involve also this third variable.

Due to the different reference periods of ASIA and OROS, enterprises may be classified in different calibration domains depending on whether we consider the information in ASIA or in OROS for the reference quarter, as a consequence of changes in size and/or economic activity over time. These movements across domains, if not properly handled, can result in high calibration weights variability within the calibration domains.

The purpose of this paper is to present and explain the methodology developed in order to handle these movements across domains, between the sampling design and calibration population, due to the different reference periods, reducing the weights variability within the calibration domains and standard errors of the estimates.

1. **The estimation procedure**

A calibration estimator (Deville & Särndal, 1992 and Särndal, 2007) is used to obtain Italian hours worked and job vacancies estimates. The general procedure is the following:

1. First, design weights $δ\_{j}$, are obtained as the inverse of the inclusion probabilities of any enterprise in the sample.
2. Then, correction factors $k\_{j}$, are worked out as the reciprocal of the response rates, in order to take into account enterprises non-response. Intermediate weights, corrected for non-response, are then computed multiplying design weights by these correction factors $d\_{j}=δ\_{j}\*k\_{j}$.
3. Then, starting from intermediate weights $d\_{j}$, final weights $w\_{j}$ are obtained solving a constrained minimization problem. The function to be minimized is a (logit, in this case) distance between final and intermediate weights. The constraints are based on the number of jobs in the calibration domains, as measured by OROS for the reference quarter.

The sampling design is simple random without replacement (srswo), so the design weights $δ\_{j}$ are given by the ratio between the number of units in the population and the number of units in the sample within each stratum h ($∀h=1, …, l$):

$$δ\_{j}= \frac{N\_{h}}{n\_{h}^{s}}$$

where $n\_{h}^{s}$ is strictly smaller than and equal to *Nh* respectively in VELA and GI*.*

Design weights are corrected with the reciprocal of the response rates in each calibration domain $H$ ($∀H=1, …, L where L\leq l$):

$$k\_{j}=\frac{1}{{n\_{H}^{r}}/{n\_{H}^{s}}}$$

where $n\_{H}^{r}$ is the number of respondents in the calibration domain $H$.

Hence, the intermediate weights are obtained as:

$d\_{j}=δ\_{j}\*k\_{j}=\frac{N\_{h}}{n\_{h}^{s}}\*\frac{1}{{n\_{H}^{r}}/{n\_{H}^{s}}}$*.*

Therefore, intermediate weights are the product between design weights depending on the sampling information (based on ASIA) and the reciprocal of the response rates in the calibration domains, depending on the more updated information from OROS.

Calibration domains are obtained aggregating one or more sampling strata, and a single stratum $h$ belongs to a single calibration domain $H$, as shown in Table 1.

**Table 1. Correspondence between strata and calibration domains, based on Asia only**

|  |  |  |
| --- | --- | --- |
| **Strata** | **Calibration Domains** | **Design Weights** |
| $$h\_{1}$$ | $$H\_{1}$$ | $${N\_{1}}/{n\_{1}}$$ |
| $$h\_{2}$$ | $${N\_{2}}/{n\_{2}}$$ |
| $$h\_{3}$$ | $${N\_{3}}/{n\_{3}}$$ |
| $$h\_{4}$$ | $$H\_{2}$$ | $${N\_{4}}/{n\_{4}}$$ |
| $$h\_{5}$$ | $${N\_{5}}/{n\_{5}}$$ |
| **…** | **…** | **…** |
| $$h\_{l-1}$$ | $$H\_{L}$$ | $${N\_{l-1}}/{n\_{l-1}}$$ |
| $$h\_{l}$$ | $${N\_{l}}/{n\_{l}}$$ |

The different sources used for sampling and calibration and the distance between the two sources reference periods imply that an enterprise can be classified differently according to the two sources, if its stratification variable values have changed over time. As a consequence, the original correspondence between a design stratum h and a calibration domain $H$ may be broken, because an enterprise can be assigned during the estimation phase to a calibration domain that is not obtained as an aggregation of strata including the one in which the enterprise was classified on the basis of Asia. In the example in Table 2, considering the OROS updated information for the enterprises’ stratification variables, some enterprises belonging to the $h\_{1}$ stratum according to ASIA can be classified within calibration domain $H\_{1}$, while others in $H\_{2}$. This increases the weights variability within calibration domains. In the example below the weights variability increases within the calibration domain $H\_{2}$.

**Table 2. Correspondence between strata and calibration domains, considering the updated information for the calibration domains**

|  |  |  |
| --- | --- | --- |
| **Strata** | **Calibration Domains** | **Design Weights** |
| $$h\_{1}$$ | $$H\_{1}$$ | $${N\_{1}}/{n\_{1}}$$ |
| $$h\_{2}$$ | $${N\_{2}}/{n\_{2}}$$ |
| $h\_{3}$ | $${N\_{3}}/{n\_{3}}$$ |
| $$h\_{1}$$ | $$H\_{2}$$ | $${N\_{1}}/{n\_{1}}$$ |
| $$h\_{4}$$ | $${N\_{4}}/{n\_{4}}$$ |
| $$h\_{5}$$ | $${N\_{5}}/{n\_{5}}$$ |
| **…** | **…** | **…** |
| $$h\_{l-1}$$ | $$H\_{L}$$ | $${N\_{l-1}}/{n\_{l-1}}$$ |
| $$h\_{l}$$ | $${N\_{l}}/{n\_{l}}$$ |

The problem mainly affects the enterprises that in the estimation phase are classified in census calibration domains, while in the sampling phase were classified in strata with inclusion probabilities strictly lower than one. The different classification implies that in some census calibration domains there can be most enterprises with design weight equal to one and a small number of enterprises coming from sample strata with larger design weights. In this situation, the final weights can be often near to zero for the enterprises that had design weight equal to one, while much larger weights are attributed to the enterprises with larger design weights.

1. **Design weights corrections to adjust for enterprise changes**
	1. *Old reweighting procedure*

Until the estimates for the fourth quarter 2017, to solve the problem of the different stratum classification over time, the design weights were calculated at the moment of the quarterly estimation, at the level of calibration domains rather than design strata and considering only the information contained in OROS (Bellisai et al. 2013). Thus, the design weights were:

$δ\_{j}= {N\_{H}}/{n\_{H}^{s}}$.

Design weights were corrected with the reciprocal of the response rates in each calibration domain H, with the following correction factors:

$k\_{j}=\frac{1}{{n\_{H}^{r}}/{n\_{H}^{s}}}$ ,

where $n\_{H}^{r}$ is the number of respondents in the calibration domain H.

Therefore, the intermediate weights were equal to:

$d\_{j}={δ\_{j}k\_{j}=N\_{H}}/{n\_{H}^{r}}$.

And no problem described at the end of Section 2 and related to the change in the variables stratification values over time did not occur. However, this procedure implies significant differences between the thus calculated design weights and the original inclusion probabilities within design strata. A revised procedure was therefore studied and implemented, which is closer to the one described in Section 2.

*3.2 A new reweighting procedure*

Starting from the estimates for the first quarter of 2018 and the revisions of the three previous years, the formula for the design weights has been revised. In particular, the formula described in Section 2 has been used, in which the weights are calculated within the sampling stratum *h*, but with the difference that the information on the stratification variables, concerning only the enterprises in the sample, are updated with OROS:

$δ\_{j}= \frac{N\_{h}^{updated}}{n\_{h}^{s\\_updated}}$.

Hence, the values of numerator and denominator are very similar to the $N\_{h}$ and $n\_{h}^{s}$ that would be calculated if only the sampling design and ASIA information were used. While the j-th enterprise in the sample is classified as belonging to a stratum, on the basis of the most recent information about the stratification variable values available in OROS.

As a consequence, the correspondence between strata and calibration domains is maintained as in Table 1.

1. **Empirical results: weights variability and standard error estimates**

The impact of the reclassification on the basis of OROS of only the enterprises in the sample, can be highlighted by a comparison of the final weights distributions obtained applying the procedures described in Section 2 and in Section 3.2.

In Table 3, the comparison is made on the estimates for the fourth quarter 2015. It can be observed that if the formula in Section 2 is applied, the final weights at the first percentiles are much lower than if the respondents enterprises are reclassified according to OROS. In fact, without correction of the design weights for the new information on the sample, the lowest final weights values are very near to zero, and between 5% and 10% are lower than one. With the new reweighting procedure, the minimum value of the final weights is 0.57 and already at the first percentile we have weights equals to one.

Although the constrained minimization problem is solved in both cases, the second case is preferable, because it allows the estimates to represent all the respondent enterprises. This is even more relevant in the light of the fact that the final weights with a value similar to zero are recorded in the largest dimensional class, corresponding to the census strata, with initial weights equal to 1.

**Table 3. Percentile distribution of the final weights – 4th quarter 2015 estimates**

|  |  |  |
| --- | --- | --- |
| **Level** | **No correction of the design weights** | **New reweighting procedure** |
| **100% Max** | 80.718 | 83.122 |
| **99%** | 60.351 | 58.588 |
| **95%** | 41.740 | 41.020 |
| **90%** | 31.979 | 32.348 |
| **75% Q3** | 21.152 | 20.378 |
| **50% Median** | 10.853 | 10.540 |
| **25% Q1** | 5.877 | 5.605 |
| **10%** | 1.046 | 1.122 |
| **5%** | 0.904 | 1.050 |
| **1%** | 0.466 | 1.000 |
| **0% Min** | 0.001 | 0.578 |

In Table 4, we have a real example of the weights distribution for all enterprises within a generic census calibration domain (DOM2).

**Table 4. A real example of the weights distribution within a census calibration domain**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  |  |  |  |  |  |  |
| **Calibration Domain** | **X** | **No correction of the design weights** | **Old reweighting procedure** | **New reweighting procedure** |
| Strata | Design weight | Final weight | Strata | Design weight | Final weight | Strata | Design weight | Final weight |
| DOM2 | 304 | A-1 | 8.325 | 4.981 | DOM2 | 1 | 1 | A-2 | 1 | 1 |
| DOM2 | 350 | A-1 | 8.325 | 4.561 | DOM2 | 1 | 1 | A-2 | 1 | 1 |
| DOM2 | 420 | A-1 | 8.325 | 3.992 | DOM2 | 1 | 1 | A-2 | 1 | 1 |
| DOM2 | 483 | A-1 | 8.325 | 3.524 | DOM2 | 1 | 1 | A-2 | 1 | 1 |
| DOM2 | 520 | **A-2** | **1** | **0.385** | DOM2 | 1 | 1 | A-2 | 1 | 1 |
| DOM2 | 527 | **A-2** | **1** | **0.38** | DOM2 | 1 | 1 | A-2 | 1 | 1 |
| DOM2 | 586 | **A-2** | **1** | **0.337** | DOM2 | 1 | 1 | A-2 | 1 | 1 |
| DOM2 | 633 | **A-2** | **1** | **0.307** | DOM2 | 1 | 1 | A-2 | 1 | 1 |
| DOM2 | 637 | **A-2** | **1** | **0.304** | DOM2 | 1 | 1 | A-2 | 1 | 1 |
| DOM2 | 707 | **A-2** | **1** | **0.264** | DOM2 | 1 | 1 | A-2 | 1 | 1 |
| DOM2 | 728 | **A-2** | **1** | **0.252** | DOM2 | 1 | 1 | A-2 | 1 | 1 |
| DOM2 | 760 | **A-1** | **8.325** | **0.236** | DOM2 | 1 | 1 | A-2 | 1 | 1 |
| DOM2 | 1445 | **A-2** | **1** | **0.053** | DOM2 | 1 | 1 | A-2 | 1 | 1 |
|  |  |  |  |  |  |  |  |  |  |  |

X is the calibration variable (jobs). Stratum is the aggregation of economic activity (A) and dimensional class (1 for sample class and 2 for census class). As we can see, in the basic method without correction of the design weights, we have some units that, with the updated information, are classified in the census domain, although they were classified in the sample stratum, at the time of the sampling. Hence, for these units we have an initial weight larger than one. This means that to meet the calibration constraints on the total of X while minimizing the distance between initial and final weights, the enterprises in the census stratum (A-2) will have a final weight much smaller than one. This can be a problem, for example when estimating job vacancies. In fact, on a given reference date, most respondent enterprises have no vacancies, and the probability of an enterprise having at least a vacancy and the number of vacancies increase with the enterprise size. In the example, larger enterprises, which are more likely to have job vacancies, are assigned a final weight near to zero if no correction of the design weights is implemented. Moreover, with the old reweighting procedure, for calibration purposes, the stratum is defined as equal to the calibration domain. Therefore, final weights are equal to one for all enterprises. The same weight distribution is generated by the new reweighting procedure. In the analysed case, in the calibration domain DOM2, with the new procedure all enterprises are classified in stratum A-2. However, usually each calibration domain is an aggregation of more than one stratum. This is the case represented in Table 5.

**Table 5. A real example of the weights distribution within a sample calibration domain**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Calibration Domain** | **X** | **No correction of the design weights** | **Old reweighting procedure** | **New reweighting procedure** |
| Stratum | Design weight | Final weight | Stratum | Design weight | Final weight | Stratum | Design weight | Final weight |
| DOM1 | 479 | A1-1 | 9,5 | 13,7 | DOM1 | 14,2 | 8,7 | A1-1 | 10,3 | 13,7 |
| DOM1 | 346 | A1-1 | 9,5 | 12,8 | DOM1 | 14,2 | 10,1 | A1-1 | 10,3 | 12,8 |
| DOM1 | 236 | A1-1 | 9,5 | 12,1 | DOM1 | 14,2 | 11,3 | A1-1 | 10,3 | 12 |
| DOM1 | 161 | A1-1 | 9,5 | 11,6 | DOM1 | 14,2 | 12,2 | A1-1 | 10,3 | 11,4 |
| DOM1 | 125 | A1-1 | 9,5 | 11,3 | DOM1 | 14,2 | 12,6 | A1-1 | 10,3 | 11,2 |
| DOM1 | 194 | **A2-1** | **7,3** | **8,3** | DOM1 | 14,2 | 11,8 | **A2-1** | **7,5** | **8,4** |
| DOM1 | 158 | **A2-1** | **7,3** | **8,2** | DOM1 | 14,2 | 12,2 | **A2-1** | **7,5** | **8,3** |
| DOM1 | 139 | **A2-1** | **7,3** | **8,1** | DOM1 | 14,2 | 12,5 | **A2-1** | **7,5** | **8,2** |
| DOM1 | 146 | **A3-1** | **3,1** | **3,3** | DOM1 | 14,2 | 12,4 | **A3-1** | **3,1** | **3,4** |

In this case, we have a sample calibration domain (DOM1), obtained aggregating strata across economic activity (A1, A2, A3). With the old reweighting procedure, design weights are very different from the inverse of the inclusion probabilities, because they were recalculated at the calibration domain level rather than at the design stratum one. On the other hand, with the new reweighting procedure, initial weights are similar to those obtained without updating the classification information for sample enterprises.

The coefficients of variation (CVs) of the estimates of the job vacancy rate and hours worked per capita obtained with the old and the new reweighting procedure for the four quarters 2016 are presented in Table 6. The CVs with the new method tend to be lower and more stable over time, in particular for the estimates of the job vacancy rate.

**Table 6. CVs for the total of the economic activities – Year 2016**

|  |  |  |
| --- | --- | --- |
| **Year 2016** | **Job vancancy rate** | **Hours worked per capita** |
| **Quarter** | **Old procedure** | **New procedure** | **Old procedure** | **New procedure** |
| 1 | 0.042 | 0.053 | 0.003 | 0.003 |
| 2 | 0.193 | 0.059 | 0.003 | 0.003 |
| 3 | 0.047 | 0.048 | 0.003 | 0.003 |
| 4 | 0.072 | 0.044 | 0.003 | 0.003 |

1. **Conclusions**

The new reweighting procedure used for the job vacancy and hours worked estimation takes into account changes in the size class and economic activity of the sample enterprises, between the sampling and estimation phases. The results show less variability of the final weights compared to the method that does not reclassify the sample enterprises with the information available at the time of the calibration and greater or similar accuracy of the estimates of the target variables, as measured by their standard errors.

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