40th Voorburg Group Meeting

Den Haag

September 21st - 25th, 2026

Cross cutting topic

How to use quarterly deflators to calculate monthly ISP:

Croatian experience and practical challenges

Josipa Kalčić Ivanić

Croatian Bureau of Statistics – Service Statistics Department

DRŽAVNI ZAVOD ZA STATISTIKU
CROATIAN BUREAU OF STATISTICS

Contents:

1. Introduction

In Croatia, the Index of Services Production (ISP) is compiled on a monthly basis, while some of the deflators used in the calculation are available only at quarterly frequency. This creates a methodological challenge related to the conversion or allocation of quarterly price information to individual months.

This paper focuses mainly on the methods currently applied in Croatia when producing the monthly ISP. It presents practical experience with the use of quarterly deflators, discusses the main challenges encountered in the production process, and illustrates their impact on the resulting monthly volume indices. Recommended approaches from methodological literature are also briefly discussed to provide a broader context and to assess possible improvements to the current practice.

2. Croatian ISP compilation framework

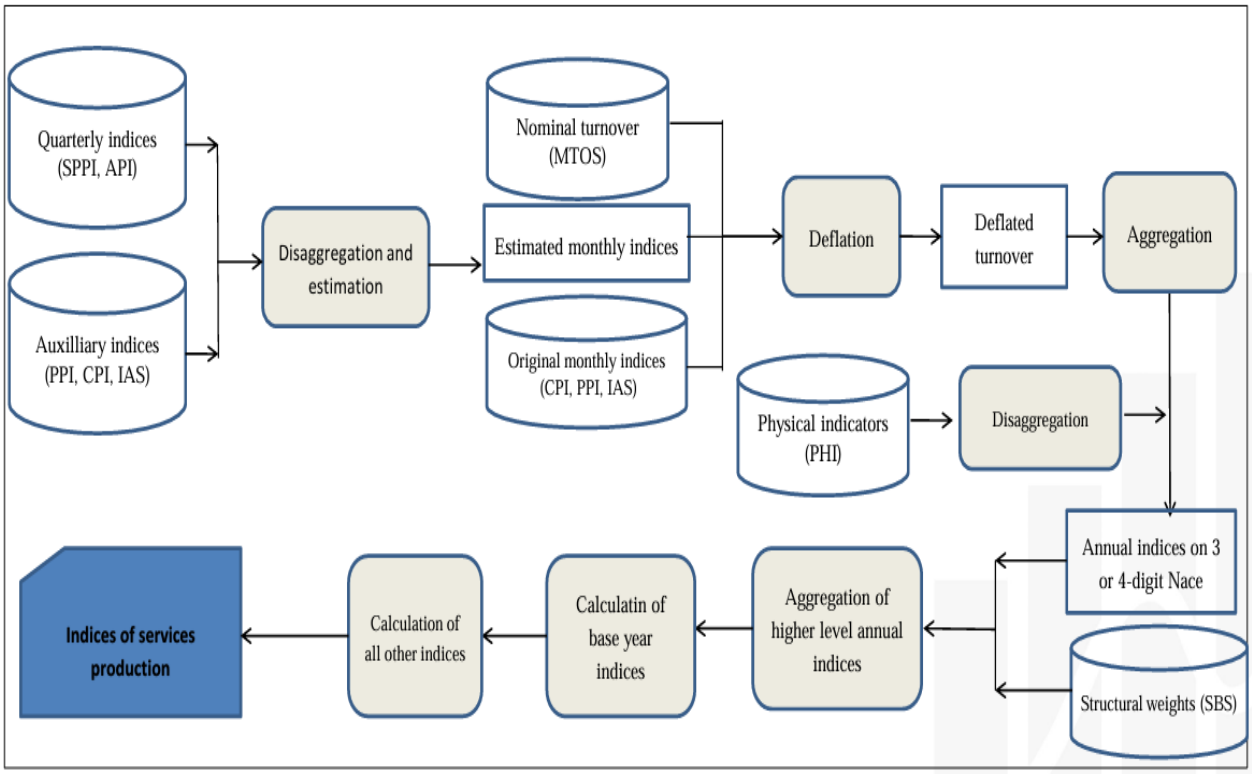
The Croatian Index of Services Production (ISP) is compiled as a monthly volume indicator whose main purpose is to measure short-term changes in services production. The preferred approach is the deflation of nominal turnover with an appropriate price index, while direct volume indicators are used only in selected cases where suitable price information is not available. The ISP covers the service activities required under the European Business Statistics framework and contributes to the broader system of short-term production indicators, as it can be combined with volume indicators for industry, construction and trade to generate an overall production volume indicator for the business economy, the Total Market Production Index (TMPI).

The Croatian ISP compilation process combines several statistical and administrative data sources. Nominal monthly turnover is obtained from the Monthly Report on Turnover Service Activities in combination with administrative VAT data. The main price indicators used as deflators are monthly and quarterly Service Producer Price Indices (SPPI), monthly Consumer Price Indices (CPI), monthly Producer Price Indices (PPI) and quarterly Agriculture Price Indices (API). Monthly Indices of Average Gross Salaries (IAS) and quarterly Physical Indicators (PHI), such as the transport of goods, are also used. Structural weights used for aggregation are obtained from Structural Business Statistics (SBS).

SPPIs are considered the most appropriate deflators for services. However, they are not available for all service activities and many of them are available only on a quarterly basis. In such cases, other price indicators are used either as the main deflator or as monthly auxiliary indicators for deriving monthly values from quarterly indices. CPI is the most frequently used auxiliary source, while PPI and indices of average gross salaries are used for selected activities.

The ISP compilation process is implemented through a web-based application. The entire process consists of gathering the required input data, estimating or disaggregating quarterly deflators into monthly indices, deflating nominal turnover at micro level, calculating real indices at the 3- or 4-digit NACE level, aggregating them to higher activity levels using structural weights, calculating base-year indices and deriving all other indices from the base-year time series.

Figure 1. Statistical process of ISP calculation in the Croatian Bureau of Statistics



Abbreviations: SPPI – Service Producer Price Indices; PPI – Producer Price Index; CPI – Consumer Price Index; API – Agriculture Price Index; IAS – Index of Average Gross Salaries; PHI – Physical Indicators – transport of goods (ton/km of reilway transport, ton/km of pipeline transport and ton/km in transport on inner waters); SBS – Structural Business Statistics.

3. The mixed-frequency challenge

A particular methodological challenge arises from the difference between the monthly frequency of turnover data and the quarterly frequency of some of the most appropriate price indices, particularly SPPIs. Monthly turnover has to be converted from nominal to volume terms, while many SPPIs and APIs are available only quarterly. The challenge therefore arises not only from the difference in data frequencies, but also from the timing of data availability.

Since the monthly ISP has to be produced at T+60, the corresponding quarterly price indices are not available for the first two months of the quarter at the time of the first estimate. For example, the January ISP has to be produced by the end of March and the February ISP by the end of April, while the preliminary first-quarter SPPI becomes available only around 20 May (T+50). Therefore, monthly deflators for January and February have to be estimated. However, when the March ISP is compiled at the end of May, the preliminary first-quarter SPPI is already available and can be used in the calculation. The final first-quarter SPPI becomes available around 15 June (T+75), after which the monthly deflators and ISP may be revised. Consequently, monthly deflators for the most recent periods have to be estimated before the observed quarterly price information becomes available.

Two methodological situations therefore have to be distinguished.

The first concerns real-time estimation. During current production, when the quarterly price index is not yet available, monthly deflators have to be estimated. Depending on the availability of suitable monthly information, the estimation is based either on the movement of an auxiliary monthly index or on historical price movements. This makes it possible to compile the monthly ISP within the required transmission deadline.

The second situation concerns temporal disaggregation. Once the observed quarterly price index becomes available, it is disaggregated into three monthly indices. The previously estimated monthly deflators are then replaced by values derived from the observed quarterly information, and the ISP is recalculated. Where a suitable monthly auxiliary indicator is available, the quarterly index is distributed according to its monthly pattern; otherwise, the linear method is used.

4. Current Croatian approach and alternative methods

The Croatian methodology follows a rule-based approach that is primarily determined by two factors: whether the quarterly source index is already available and whether a suitable monthly auxiliary indicator exists. Depending on the information available, the monthly deflator is either estimated during the current production process or derived through the temporal disaggregation of the observed quarterly price index once it becomes available.

For each activity, the choice of an appropriate estimation and disaggregation method is important because it can affect short-term month-to-month movements, growth rates, revision patterns, and the subsequent seasonal adjustment of the monthly ISP series. The objective is therefore not only to produce timely monthly deflators, but also to ensure realistic monthly dynamics and minimise subsequent revisions.

Table 1. Croatian decision rule for quarterly and monthly deflator inputs

Information available in current production	Auxiliary monthly series	Procedure	Result
Quarterly index not yet available	Yes	AUX (Auxiliary-indicator forecast using current auxiliary movement)	Preliminary monthly deflator
Quarterly index not yet available	No	Historical-movement forecast using previous-year monthly movement	Preliminary monthly deflator
Quarterly index available	Yes	AUX (Auxiliary Index Method for the disaggregation of an observed quarterly index using a monthly auxiliary indicator)	Observed quarterly index-consistent monthly deflator
Quarterly index available	No	LM (Linear Method): a method for disaggregating an observed quarterly index into monthly values by linear interpolation between quarterly observations.	Observed quarterly index - consistent monthly deflator
Monthly source index available	Not required	Use monthly source directly; combine sources if necessary	Monthly deflator

Once all relevant price series have been converted to monthly frequency, they can be combined into a single deflator. Where several price sources are used for the same NACE activity, the methodology applies a weighted arithmetic mean. The weights may reflect both the importance of different source types and the internal weights of indices within the same source. The final monthly deflator is then applied to nominal turnover to obtain deflated turnover, which is subsequently used for the calculation of the ISP.

4.1 Estimation methods

The two main approaches are the indirect and the direct approach. The direct approach may be particularly useful when reliable external monthly information exists, while the indirect approach can be appropriate for relatively stable quarterly price series.

Under the indirect approach, the quarterly SPPI is first forecast, and the estimated quarterly values are subsequently converted into monthly values. The main advantage of this approach is that forecasting is performed at the frequency at which the original price index is observed. Under the direct approach, monthly deflators are estimated directly using previously derived monthly values and, where available, external monthly indicators. The Eurostat Guide notes that this approach can

be particularly useful when suitable monthly auxiliary indicators exist or when the quarterly price series exhibits relatively high volatility.

The Croatian ISP methodology follows a direct approach. In Croatia, when the quarterly price index for the current quarter is not yet available, the monthly deflator must be estimated. The estimation procedure used in the Croatian production system depends on whether a suitable monthly auxiliary indicator is available. Thus, when the quarterly source index is unavailable, the choice of the estimation method is determined primarily by whether an appropriate monthly auxiliary indicator exists, allowing the monthly deflator to be produced in a timely manner while maintaining plausible monthly dynamics.

4.1.1 Auxiliary-indicator forecast

If a suitable monthly auxiliary index is available, the latest monthly deflator is extrapolated using the current month-to-month movement of that auxiliary series:

$$I_Q^M/\emptyset 2021 = (I_Q^{M-1}/\emptyset 2021) \cdot \frac{I_{AUX}^M/\emptyset 2021}{I_{AUX}^{M-1}/\emptyset 2021}$$

Where:
$I_Q^M/\emptyset 2021$ … deflator that is estimated
$I_Q^{M-1}/\emptyset 2021$ … deflator from the previous month (already calculated – estimated in the processing for the previous month)
$I_{AUX}^M/\emptyset 2021$ … monthly auxiliary index for the current month
$I_{AUX}^{M-1}/\emptyset 2021$ … monthly auxiliary index for the previous month

This procedure transfers the observed short-term movement of the auxiliary indicator to the target deflator. For example, for a quarterly SPPI for which CPI is used as the auxiliary source, the January deflator can be estimated by applying the December-to-January CPI movement to the December deflator.

The monthly movement of the selected CPI should be sufficiently similar to that of the corresponding SPPI. Since the CPI reflects B2C transactions, whereas the SPPI covers B2All transactions, larger differences may arise in activities with a significant B2B or B2G component. In such cases, the suitability of the auxiliary indicator should be reassessed and, where appropriate, adjusted to reduce revisions.

4.1.2 Historical movement forecast when no auxiliary indicator exists

If no suitable monthly auxiliary series is available, the current deflator is estimated using the month-to-month movement observed in the corresponding period of the previous year:

$$I_Q^M/\emptyset 2021 = (I_Q^{M-1}/\emptyset 2021) \cdot \frac{I^{M-12}/\emptyset 2021}{I^{M-13}/\emptyset 2021}$$

Where:
$I_Q^M/\emptyset 2021$ … deflator that is estimated
$I_Q^{M-1}/\emptyset 2021$ … deflator from the previous month (already calculated − estimated in the processing for the previous month)
$I^{M-12}/\emptyset 2021$ … deflator for the same month of the previous year
$I^{M-13}/\emptyset 2021$ … deflator for the month M-1 of the previous year

This means that the previous year's monthly pattern is carried forward to the current period. The method is operationally simple, but it assumes that the short-term price pattern is sufficiently stable from one year to the next.

4.2 Disaggregation methods

In Croatia, once the observed quarterly price index becomes available, the preliminary monthly estimates are replaced by monthly values that are fully consistent with the observed quarterly data. The choice of method again depends on the availability of a suitable monthly auxiliary indicator. When such an indicator exists, the auxiliary index method (AUX) is applied; otherwise, the Linear Interpolation Method (LM) is used.

The Eurostat Guide on Developing an Index of Services Production describes several methods for converting quarterly price series into monthly series. These methods range from simple mathematical interpolation techniques to more advanced temporal disaggregation procedures.

In addition to the auxiliary index method (AUX) and the Linear Interpolation Method (LM), which are currently applied in Croatia, cubic spline interpolation is of particular interest. Although it is not currently implemented in the Croatian methodology, its potential as an alternative to the LM method for selected activities is being investigated.

Other temporal disaggregation methods discussed in the Eurostat ISP Guide include discrete interpolation, the Denton method, and the Feibes, Bott and Lisman (FBL) smoothing method. Discrete interpolation is generally not recommended because it produces a stepwise pattern in the resulting monthly series. In contrast, the Denton and FBL methods are presented as alternative temporal disaggregation approaches available within the ECOTRIM framework.

4.2.1 Auxiliary index method (AUX)

When an auxiliary monthly indicator is available, the quarterly value is distributed across the three months according to the monthly pattern of that indicator. If several auxiliary indicators are used for one quarterly source, they are first combined using a weighted arithmetic mean.

$$I_Q^i = I_Q * \frac{M_A^i}{M_A^Q}$$

Where:

I_Q^i ($i\epsilon\{1,2,3\}$) are first, second and third month of the quarter

M_A^i are the respective auxiliary monthly base-year indices

$\overline{M_A^Q}$ is the average of the three auxiliary monthly base-year indices inside the quarter.

An important property of this formula is that the average of the three derived monthly indices equals the observed quarterly index. The quarterly level is therefore preserved, while the intra-quarter pattern is informed by observed monthly data.

Example: Assume that the observed quarterly price index is 105.0 and that a suitable monthly auxiliary index takes values 103.0, 104.0 and 106.0. The average auxiliary index for the quarter is 104.33. Applying the AUX formula produces the monthly deflators shown below.

Month	Auxiliary index	Derived monthly deflator	Illustrative nominal turnover	Deflated turnover
Month 1	103.0	103.66	100.0	96.47
Month 2	104.0	104.66	110.0	105.10
Month 3	106.0	106.68	120.0	112.49

The average of the three derived monthly deflators is 105.0, equal to the observed quarterly index. The example shows the main advantage of the AUX method: the observed quarterly index is preserved, but the monthly profile follows a related observed indicator rather than being mechanically flat or purely interpolated.

4.2.2 Linear interpolation method (LM)

If no suitable auxiliary monthly indicator exists, the Croatian methodology applies the linear interpolation method (LM). The method is based only on the quarterly price series and assumes a regular intra-quarter development. Monthly indices are derived so that the quarterly level is preserved while the movement between quarterly observations is distributed across the three months.

$$I_Q^1 = I_Q * \frac{3}{1+I_{Q/Q-1}+(I_{Q/Q-1})^2}$$

$$I_Q^2 = I_Q * \frac{3}{1+I_{Q/Q-1}+(I_{Q/Q-1})^2} * I_{Q/Q-1}$$

$$I_Q^3 = I_Q * \frac{3}{1+I_{Q/Q-1}+(I_{Q/Q-1})^2} * (I_{Q/Q-1})^2$$

Where:

I_Q^1, I_Q^2 and I_Q^3 are monthly indices for first, second and third month of the quarter respectively

I_Q is the (base-year) quarterly index

$I_{Q/Q-1}$ chain "quarter to previous quarter" index

The advantage of the linear interpolation method is that it can be used even when no monthly proxy is available. Its limitation is that the resulting monthly path is imposed by the interpolation rule rather than by observed monthly price information.

Croatian methodological work has identified significant differences between preliminary and final results for some activities where the linear method was applied.

4.2.3 Cubic spline interpolation

A potentially relevant alternative to the current linear interpolation method (LM) is cubic spline interpolation. Cubic spline uses cubic polynomial functions between successive quarterly observations.

Unlike linear interpolation, it does not constrain the movement between two quarterly observations to a straight line. The rate of change can vary gradually, which produces a smoother and more flexible monthly profile. The method can also be implemented with a constraint ensuring consistency between the derived monthly indices and the observed quarterly index.

However, greater flexibility does not necessarily imply greater accuracy. The resulting monthly profile is still mathematically derived rather than observed. Cubic spline is therefore likely to be more appropriate for series with relatively gradual price developments than for series characterised by abrupt or infrequent price changes.

4.2.4 Comparison of the main methods

The methods described above differ mainly in the way the intra-quarter monthly pattern is determined. Some approaches derive monthly movements only from the quarterly series, while others use additional observed monthly information. This distinction is important because different methods can produce substantially different month-to-month movements even when they are all consistent with the same observed quarterly index.

Table 2. Comparison of the main disaggregation methods

Criterion	**Linear interpolation / LM**	**Cubic spline interpolation**	**Interpolation using additional monthly information / AUX**
Basis / data used	Quarterly series only	Quarterly series only	Quarterly series plus a related monthly indicator, e.g. CPI/PPI
Shape between quarterly observations	Straight-line movement between adjacent quarterly observations	Smooth curved movement based on cubic polynomials between adjacent quarterly observations	Monthly profile follows the observed pattern of the related monthly indicator
Month-to-month rate of change	Determined by the linear path between quarterly observations	Can vary gradually between quarterly observations	Can vary month by month in line with movements in the auxiliary indicator
Flexibility	Lower	Higher	Depends on the auxiliary series; generally allows the monthly profile to reflect observed higher-frequency information
Complexity	Low	Higher than linear interpolation	Moderate; requires a suitable monthly auxiliary series and an adjustment to the quarterly level
Consistency with observed quarterly index	Yes, with re-scaling where required	Yes, if appropriately constrained	Yes, after adjustment to the observed quarterly index
Main advantage	Simple, transparent and easy to apply when no monthly auxiliary indicator is available	Produces a smoother and more flexible monthly profile than linear interpolation	Uses observed monthly information and is likely to provide the most realistic approximation where suitable data exist
Main risk / limitation	The imposed linear path may not reflect actual monthly price movements	Greater flexibility does not necessarily imply greater accuracy; standard disaggregation methods may perform poorly when price changes are abrupt or infrequent	Quality depends on how closely the auxiliary indicator reflects the target price series
When useful	When no suitable monthly auxiliary indicator is available and simplicity is important, particularly when monthly values are used as deflators for	When no suitable monthly auxiliary indicator is available and a more flexible intra-quarter profile is considered useful	When a relevant monthly indicator is available and shows a similar pattern to the quarterly SPPI

Criterion	**Linear interpolation / LM**	**Cubic spline interpolation**	**Interpolation using additional monthly information / AUX**
	monthly turnover		
Use in Croatia	Yes	No - possible alternative for testing	Yes

The Eurostat ISP Guide considers linear interpolation, cubic spline interpolation and interpolation using additional monthly information to be admissible approaches. Where a suitable monthly indicator is available, the use of additional information is likely to provide the most realistic approximation of monthly price movements. In the absence of such information, linear interpolation offers the advantage of simplicity, while cubic spline interpolation allows for a more flexible monthly profile.

For Croatia, this comparison supports the current distinction between the AUX method, applied when an appropriate monthly auxiliary indicator is available, and the LM method, applied when such monthly information is not available. The AUX approach incorporates observed monthly movements into the disaggregation, whereas LM provides an operationally simple solution based solely on the quarterly price series.

For the Croatian ISP, the choice of method should therefore not be based solely on mathematical smoothness. It should also take into account several practical criteria: the plausibility of month-to-month movements, consistency with the observed quarterly price index, feasibility within the T+60 production deadline, and the size of revisions once more complete quarterly price information becomes available.

5. Quality assessment

The Croatian production experience shows that the main methodological challenge is not the arithmetic of deflation itself, but the integration of lower-frequency price information into a monthly production indicator without distorting short-term movements. This issue is particularly relevant for activities using quarterly deflators, where the availability of price information does not always coincide with the T+60 production deadline for the monthly ISP.

For months for which the corresponding quarterly price index is not yet available, a preliminary monthly deflator has to be estimated. Once the quarterly price information becomes available, monthly deflators are recalculated using the appropriate disaggregation method and the ISP may consequently be revised. The ISP application therefore includes outputs that allow preliminary and revised results to be compared systematically.

The size and direction of revisions can be evaluated by activity, deflator source and estimation or disaggregation method. Persistently large revisions may indicate that the selected monthly proxy, forecasting rule or disaggregation method should be reconsidered.

Regular production also includes validation of both the calculated deflators and the resulting ISP indices. The Croatian procedure includes checks on the completeness of deflator calculation, the identification of extreme year-on-year index movements and comparisons between volume and nominal turnover indices. Quarterly comparisons are also useful for assessing whether the implied price movement is broadly consistent with the corresponding SPPI or other relevant price information. A substantial discrepancy may indicate an inappropriate deflator, an unsuitable auxiliary indicator, an unusual revision or another data-quality issue requiring further investigation.

Revision analysis provides an additional measure of the performance of the current approach. For total services production, the revision indicators for year-on-year growth rates of calendar/working-day adjusted data over the period January 2023–December 2025 are shown below.

Table 3. Revision indicators for total services production, January 2023–December 2025

Indicator	Value	Interpretation
MAR – Mean Absolute Revision	1.15 percentage points	Average absolute size of the difference between preliminary and revised growth rates
MR – Mean Revision	−0.38 percentage points	Average signed revision; revised growth rates were slightly lower on average

The Mean Absolute Revision is considerably larger than the absolute value of the Mean Revision. This indicates that revisions occur in both directions and partly offset each other. The average magnitude of revisions is not negligible, while the smaller negative MR suggests only a limited systematic downward revision. These results support the use of preliminary-to-final revision performance as an important quality criterion when assessing methods for quarterly deflators.

The effects of the selected deflator method may also extend to seasonal and calendar adjustment. The original monthly ISP series is used as input to the adjustment procedure, meaning that method-induced monthly patterns may affect month-to-month growth rates, outlier identification and the estimated seasonal pattern. This is particularly relevant when a disaggregation method creates pronounced movements around quarter boundaries or when preliminary monthly estimates are subsequently revised after quarterly price information becomes available.

In Croatia, seasonal and calendar adjustment is performed in JDemetra+ using the X-13 ARIMA approach. Revisions to the original series may therefore also lead to revisions of previously published adjusted series. A separate quantitative assessment of how much of these revisions is specifically attributable to quarterly-deflator methods has not yet been carried out and remains an area for further empirical work.

Overall, the key quality question is therefore not only how quarterly price information is converted into monthly deflators, but also whether the selected method produces plausible short-term movements and limits the difference between the first published estimate and the result obtained once more complete quarterly price information becomes available.

6. Assessment of the current approach and further methodological work

The current Croatian approach is operationally feasible and provides a practical solution for producing a monthly ISP within the T+60 deadline, even when the corresponding quarterly price indicators are not yet available. It avoids the need to introduce additional monthly price surveys specifically for ISP purposes and allows different price and non-price indicators to be selected according to the characteristics of individual activities. Once the observed quarterly price information becomes available, preliminary monthly estimates can be aligned with the quarterly index. The approach is also transparent and can be implemented through clearly defined production rules within the ISP application.

At the same time, several limitations remain. For activities using quarterly deflators, the first published ISP necessarily relies on estimated rather than observed monthly price developments. The quality of the AUX method depends on the strength and stability of the relationship between the auxiliary indicator and the target price series, while the historical-movement approach may reproduce an outdated monthly pattern when price-setting behaviour changes. In addition, different temporal disaggregation methods may produce different month-to-month paths even when they are all consistent with the same observed quarterly index. The subsequent replacement of preliminary estimates by monthly values derived from observed quarterly information therefore leads to regular revisions.

These considerations suggest that future methodological work should follow a differentiated approach by activity rather than assume that a single method is optimal for all services. Reliable monthly deflators should be used directly whenever appropriate monthly price information is available, while auxiliary indicators should be assessed empirically in terms of correlation, co-movement and revision performance. For activities in which the current LM method results in relatively large or persistent revisions, alternative interpolation methods, particularly cubic spline interpolation, could be tested and compared with the current approach.

The assessment of alternative methods should consider not only preliminary-to-final revisions, but also the plausibility of month-to-month movements and the impact of different deflator methods on both unadjusted and seasonally adjusted ISP series. Further improvements could also include greater automation of deflator updating and the regular production of diagnostic information by activity, deflator source and method.

7. Conclusions

The Croatian experience shows that quarterly deflators can be successfully used in the compilation of a monthly ISP, but the methodological challenge has two distinct dimensions: estimating monthly deflators in real time before the corresponding quarterly price information becomes available and deriving monthly values from the observed quarterly indices once they are available.

The current Croatian system addresses real-time estimation through auxiliary-indicator and historical-movement procedures, while temporal disaggregation of observed quarterly indices is carried out using the auxiliary index method (AUX) or the linear interpolation method (LM). The AUX method has the advantage of incorporating observed monthly information while remaining consistent with the observed quarterly index. When no suitable monthly auxiliary indicator is available, the LM method is currently used to derive the monthly profile from the quarterly series. Both approaches are operationally transparent, but they may produce different month-to-month patterns and consequently different revision behaviour.

The available Croatian revision indicators confirm that revisions are relevant. For total services production, the Mean Absolute Revision of year-on-year growth rates was 1.15 percentage points over the period January 2023–December 2025, while the Mean Revision was −0.38 percentage points. This suggests that the evaluation of methods for deriving monthly deflators should focus not only on the smoothness of the resulting series, but also on the plausibility of month-to-month movements and on the ability of the methods to produce stable preliminary estimates that remain close to the results obtained once the observed quarterly information becomes available.

The main conclusion is therefore that no single method is necessarily optimal for all service activities. The preferred approach should depend on the availability and quality of monthly information, the characteristics of price developments in each activity and the observed revision performance. A systematic activity-by-activity assessment of the current methods and possible alternatives, including cubic spline interpolation where appropriate, provides a practical basis for further methodological improvements to the Croatian monthly ISP.