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Cross-cutting topic
**Methods for adjusting the quarterly SPPI
to the needs of the monthly ISP**

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1. Introduction

The objective of this paper is to present the experiences of the Statistics Poland in disaggregation of the services producer price indices from quarter to monthly frequency.

The services producer price indices (SPPIs) are relatively new statistical products when comparing with other areas of producer price statistics. Among the first service activities covered by the statistical observation in the early 1990s were transport, warehousing, and communications, primarily due to the semi-material nature of these services and their connection to the production sphere. The works were conducted within the framework of *Survey of producer prices of goods and services in industry, transport and warehousing, telecommunications, forestry and fishing*. A dedicated survey covering the services sector was introduced by Statistics Poland in 2008 and has undergone continuous development ever since in order to meet both the information needs of data users and legal requirements resulted from the participation of Poland in the structure of the European Union.

Nowadays, the services producer price indices (SPPI) are compiled on a quarterly basis. Although these data are characterized by high reporting reliability, their low frequency constitutes a significant limitation in a dynamically changing economic environment. On the one hand, the regulatory framework of the European Business Statistics (EBS) Regulation came into force, prioritizing the timeliness and increased frequency of short-term statistics (STS). On the other hand, different groups of data users report a growing demand for monthly price data essential for conducting their analysis and constructing macroeconomics indicators, e.g the index of services production, the gross domestic product. The quarterly data is no longer sufficient. Therefore, it became necessary to develop a methodology for estimating monthly indices based on available quarterly aggregates.

As a first the Statistics Poland started to disaggregate SPPIs for transport activities (in 2018) just after changing the frequency of data collection for that activities from monthly to quarterly. Then, the necessity for estimating the monthly SPPIs for other services activities as a deflator for compiling the index of services production arose. The *ESS guidelines on temporal disaggregation, benchmarking and reconciliation* as well as the IMF's recommendations are the main source of information on the methods of disaggregation for SPPI. Furthermore, there are numerous research papers discussing both data disaggregation methodology and the software tools that enable to automate the of computational processes in this field.

In the consecutive chapters of paper there are presented: short background of SPPI survey, the methodology currently applied when the SPPI is being compiled, experimental disaggregation of SPPI using Denton-Cholette method.

2. Survey background

Since the *Services Producer Price Survey* had been introduced into official statistics it has been constantly updated to adapt to the information requirements expressed by different data user groups. The modifications cover both the scope of the surveyed services as well as changes in the methodology of compiling output information.

When the surveys was implemented into the official statistics it comprised: computer programming and information services, architectural and engineering services, technical testing and analysis, advertising, market research and public opinion polling, employment activities, security services, and cleaning activities. Subsequently, in the following years, the scope of this survey was expanded several times in order to observe further service activities. As a result, at present the scope of survey covers (by NACE Rev.2.1):

- 49 Land transport and transport via pipelines
- 50 Water transport
- 51 Air transport
- 52 Warehousing and support activities for transportation

- 53 *Postal and courier activities*
- 58 *Publishing activities*
- 59 *Motion picture, video and television programme production, sound recording and music publishing activities*
- 60 *Programming and broadcasting activities*
- 61 *Telecommunications*
- 62 *Computer programming, consultancy and related activities*
- 63 *Information service activities*
- 68 *Real estate activities*
- 69 *Legal and accounting activities*
- 70.2 *Management consultancy activities*
- 71 *Architectural and engineering activities; technical testing and analysis*
- 73 *Advertising and market research*
- 74 *Other professional, scientific and technical activities*
- 77 *Rental and leasing activities*
- 78 *Employment activities*
- 79 *Travel agency, tour operator and other reservation service and related activities*
- 80 *Security and investigation activities*
- 81 *Services to buildings and landscape activities*
- 82 *Office administrative, office support and other business support activities*

Moreover, as a result of modification of SPPI survey, which took place in 2018:

- 1) All services activities (including transport and telecommunication) are observed on quarterly basis within one *Services Producer Price Survey* (until 2016 data for transport, warehousing and telecommunication was collected monthly);
- 2) There are two harmonized questionnaires used for data collection: C-06 *Report on the producer prices in services activities* and C-09 *Report on the producer prices in transport, warehousing and telecommunication*;
- 3) Each questionnaire is divided into modules, each dedicated to a different type of service; each module consisted of sections dedicated to specific price survey methods for services. The representatives of the surveyed services (defined for specific 6-digit codes of CPA) are described by reporting units in details (selecting the most important parameters from the defined list).
- 4) The units are purposively selected for the survey from the population of enterprises with 10 or more persons employed conducting activities covered by the scope of the survey according to their principal as well secondary activity (consequently, reporting units, depending on the type of their principal and secondary activities, may be required to complete one or more modules of the form).
- 5) Large enterprises are obliged to report data for at least three representatives, while for medium-sized enterprises it will be recommended to report data for at least three representatives.

The first necessity for compiling a method of index disaggregation arose when the decision was made to change the frequency of the SPPI for transport, warehousing, and telecommunications activities from monthly to quarterly. The obligatory compilation of monthly ISP in compliance with EU law was the next challenge.

3. Method applied for disaggregation of SPPI in Poland

In order to perform the temporal disaggregation of quarterly services producer price indices (SPPIs) into monthly data, a two-step mid-point linear interpolation with flat additive benchmarking is currently applied. In European statistical practice (including the Eurostat guidelines on temporal disaggregation), this algorithm is referred to as a deterministic mathematical method without an indicator (a naïve/mathematical method).

The algorithm can be divided into three main operational phases:

Phase 1: Piecewise linear interpolation of mid-points

The procedure assumes that the value of the quarterly benchmark series, Q_k , is representative of the middle of the quarter. For two adjacent quarters Q_k and Q_{k+1} , the distance in time between their middle months is exactly 3 months.

The monthly increment (constant difference) is calculated as:

$$\Delta = \frac{Q_{k+1} - Q_k}{3}$$

As a result, the values assigned to the high frequency periods (months) form a straight line, eliminating the step problem (discrete jumps at the turn of the quarters).

Phase 2: Additive benchmarking

Price indices (e.g., SPPI) have the character of stock variables (time averaged stock). This means that a proper binding aggregation constraint requires the arithmetic mean of the three months of the quarter to be equal to the value of the quarterly index:

$$Q_k = \frac{M_{k,1} + M_{k,2} + M_{k,3}}{3}$$

Since the preliminary interpolation from the first phase does not automatically guarantee the fulfilment of this condition, an additive benchmarking (flat adjustment) is applied. A constant adjustment value C_k is added to each month in the quarter:

$$C_k = Q_k - \frac{\sum_{i=1}^3 M_{k,i}}{3}$$

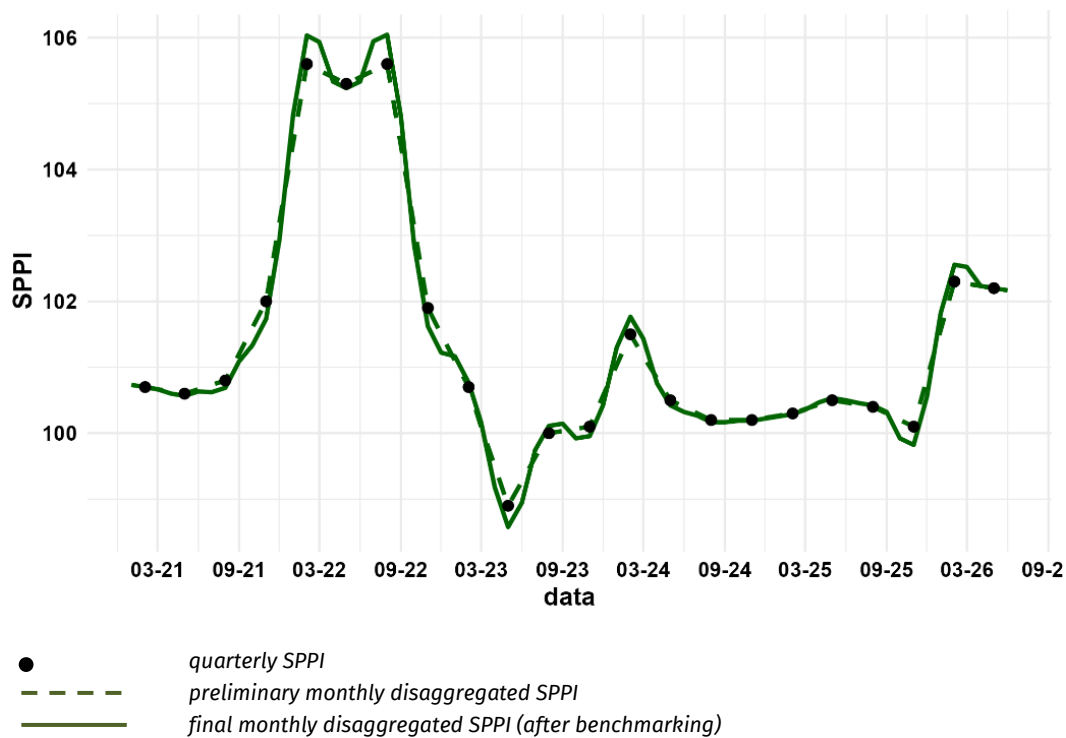
This adjustment ensures full temporal consistency of the resulting disaggregated high frequency series with the input low frequency benchmark series.

Phase 3: Extrapolation (estimation of boundary conditions)

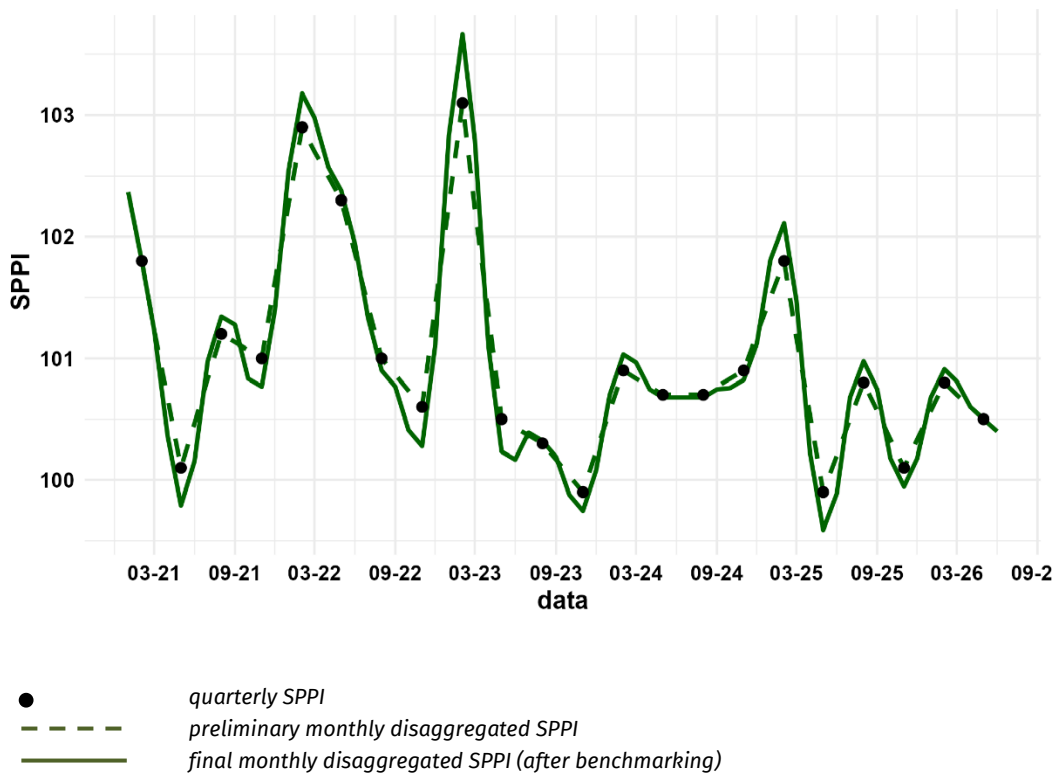
Since the adjacent quarters required to determine the Δ difference are missing for the first month of the first quarter and the last month of the last quarter, linear interpolation is not possible. The values for these extreme months are extrapolated residually via an algebraic transformation of the aggregation constraint (Phase 2), in order to preserve the base value of the aggregate.

The results of the above described algorithm for selected services activities are presented graphically below. The values of quarterly SPPIs and monthly disaggregated SPPIs for all services activities covered by survey can be found in Annex.

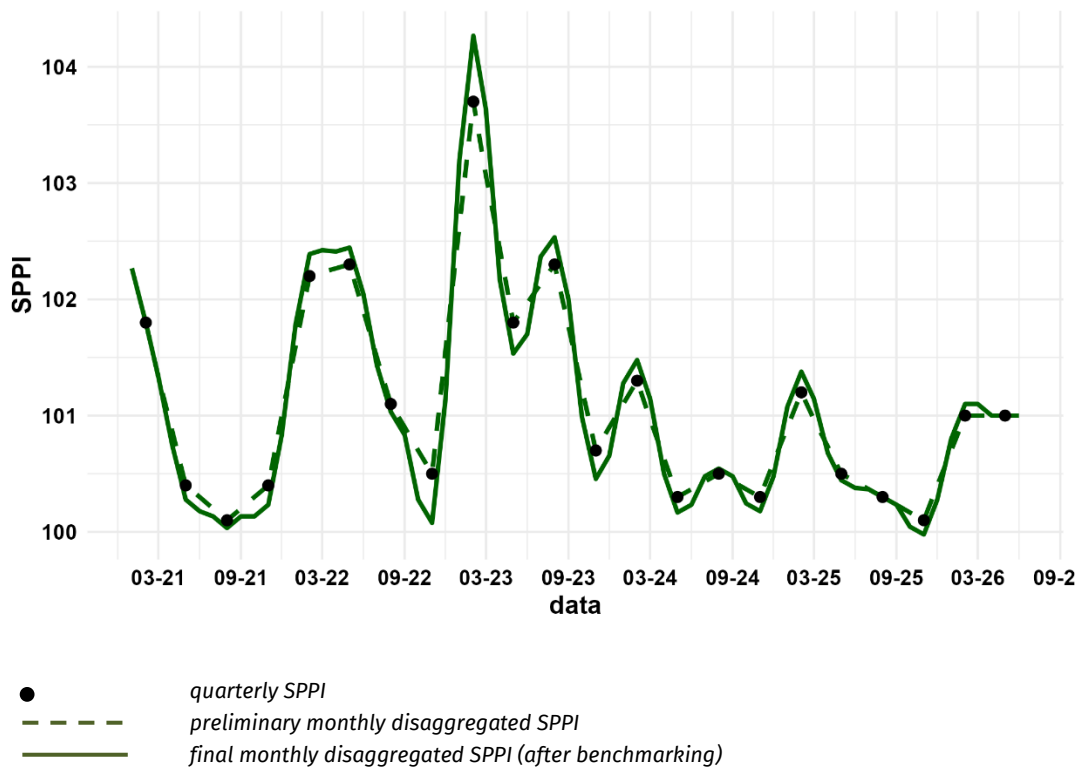
Graph 1 Quarterly SPPI and monthly disaggregated SPPI for Land transport and transport via pipelines (49 by NACE Rev. 2) - a two-step mid-point linear interpolation with flat additive benchmarking



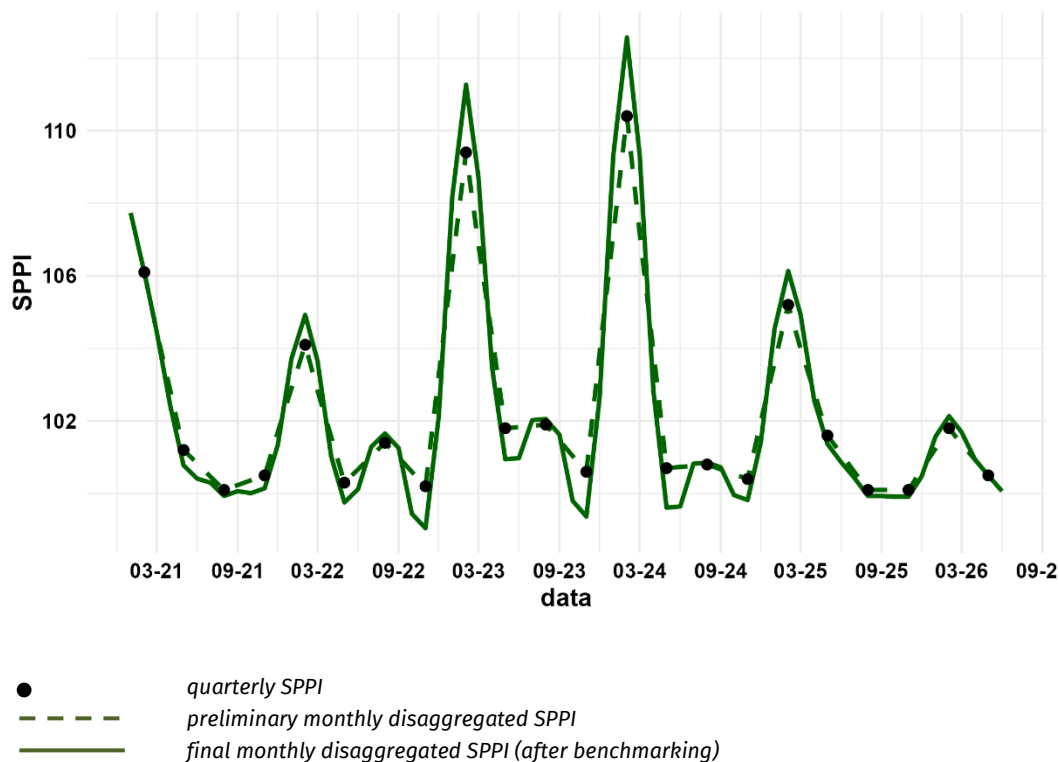
Graph 2 Quarterly SPPI and monthly disaggregated SPPI for Computer programming, consultancy and related activities (62 by NACE Rev. 2) - a two-step mid-point linear interpolation with flat additive benchmarking



Graph 3 Quarterly SPPI and monthly disaggregated SPPI for Architectural and engineering activities; technical testing and analysis (71 by NACE Rev.2) - a two-step mid-point linear interpolation with flat additive benchmarking



Graph 4 Quarterly SPPI and monthly disaggregated SPPI for Security and investigation activities (80 by NACE Rev.2) - a two-step mid-point linear interpolation with flat additive benchmarking



The method applied for temporal disaggregation of SPPI in Poland constitutes a solid computational compromise that can be implemented directly in spreadsheets without the need for specialized statistical software (e.g., R or Python). However, in the Statistics Poland the procedure is programmed in R. The advantages of method include clarity as the computational algorithm is fully transparent and easily replicable by analysts. Furthermore, unlike the simplest pro rata adjustment (where, for example, January, February, and March have an identical value equal to Q_1), this algorithm introduces a natural intra-quarter dynamic, minimizing the step problem.

One of the disadvantages (econometric limitations) of this method is the distortion of dynamics. Additive benchmarking introduces non-linear shifts. The discrete nature of the C_k adjustments between adjacent quarters means that the first derivative of the monthly series (the monthly growth rate) may undergo artificial fluctuations at the quarter boundaries. Moreover, the way of estimating indicators for the extreme months of the time series causes the data to be excessively burdened with an adjustment error. All fluctuations accumulate in January of the first year and in December of the last year (tail effects/endpoint instability).

Regarding the disadvantages of applied mathematical method (a two-step mid-point linear interpolation with flat additive benchmarking) as well as following the recommendations of Eurostat or International Monetary Fund (IMF) it was recognized that the more advanced, statistical methods should be analyzed.

4. Methods for temporal disaggregation of SPPI

Generally, in the case of flow series, which SPPIs are, the problem of temporal disaggregation boils down to finding an unknown high-frequency series whose sums, averages, or stock values are consistent with a known low-frequency series.

In the literature and the statistical practice an array of disaggregation methods are proposed to solve that problem, from the simple mathematic algorithms to the deeply developed regression-based methods. Regardless their complexity and econometric advance each of them consist of two-step procedure:

- 1) Determining the preliminary higher frequency data series;
- 2) Distributing the differences between the lower frequency values of preliminary higher frequency series and lower frequency of observed series among the preliminary data series;

As a result final estimation of disaggregated data is the sum of preliminary data series and the distributed residuals yields.

$$\widehat{SPPI}_m = p_m + Du_q$$

where:

$\widehat{SPPI}_m$ – final estimation of monthly SPPI

p_m – preliminary monthly data series

D – a $n_m \times n_q$ distribution matrix (n_m – number of monthly and n_q – number of quarterly observations)

u_q – vector containing the differences between the quarterlized values of p_m and the actual quarterly values of SPPI

$$u_q = SPPI_q - Cp_q$$

where:

$SPPI_q$ – quarterly actual values of SPPI

C – conversion matrix

However, the methods differ in the way the preliminary data series as well as the distribution matrix are

compiled¹. The solutions are divided into two main groups: mathematical movement-preserving methods (e.g. Denton, Denton-Cholette) and statistical regression-based methods (e.g. Chow-Lin, Fernandez, Litterman). In case of former the temporal disaggregation can be conducted with one or without any high frequency variable while the latter needs to utilize one or multiple related high frequency variables aggregated into an indicator matrix.

After analyzing the recommended methods and their methodological transparency, type of data series which are to be disaggregated (SPPI) as well as availability of high frequency data which could be used as the independent variable in the regression based methods the Denton-Cholette method (without auxiliary indicator)² has been selected for experimental temporal disaggregation of SPPI as a first.

The Denton methods use a single indicator for estimating their preliminary series. As a special case a constant can be used as an indicator which takes the value of 1. As a result this method allows for temporal disaggregation without high frequency indicator series. In order to compile the distribution matrix the Denton methods minimize the squared absolute or relative deviations from a (differenced) indicator series. For additive method there are different degree of differencing: the sum of the squared absolute deviations, first or second differences between the indicator and the final series. For the proportional Denton methods, deviations are measured in relative terms.

Denton-Cholette is a modification of the original approach and removes the spurious transient movement at the beginning of the resulting series. Cholette replaced the inverse of the penalty/differencing matrix enforcing movement preservation with an autocorrelation matrix to resolve boundary effect distortions ("start-up" errors in standard Denton formulations).³

5. Experimental temporal disaggregation of SPPI by the Denton-Chalotte method (without indicator)

The following parameters were selected when SPPIs are disaggregated with the Denton-Cholette method (without indicator) as:

- preliminary indicator - a constant (with value 1 for all months);
- conversion argument - averages (quarterly of SPPIs are the averages of monthly data);
- criterion of minimization – proportional (as the proportional deviations are minimized);

The procedure was conducted in the R software (tempdisagg package).

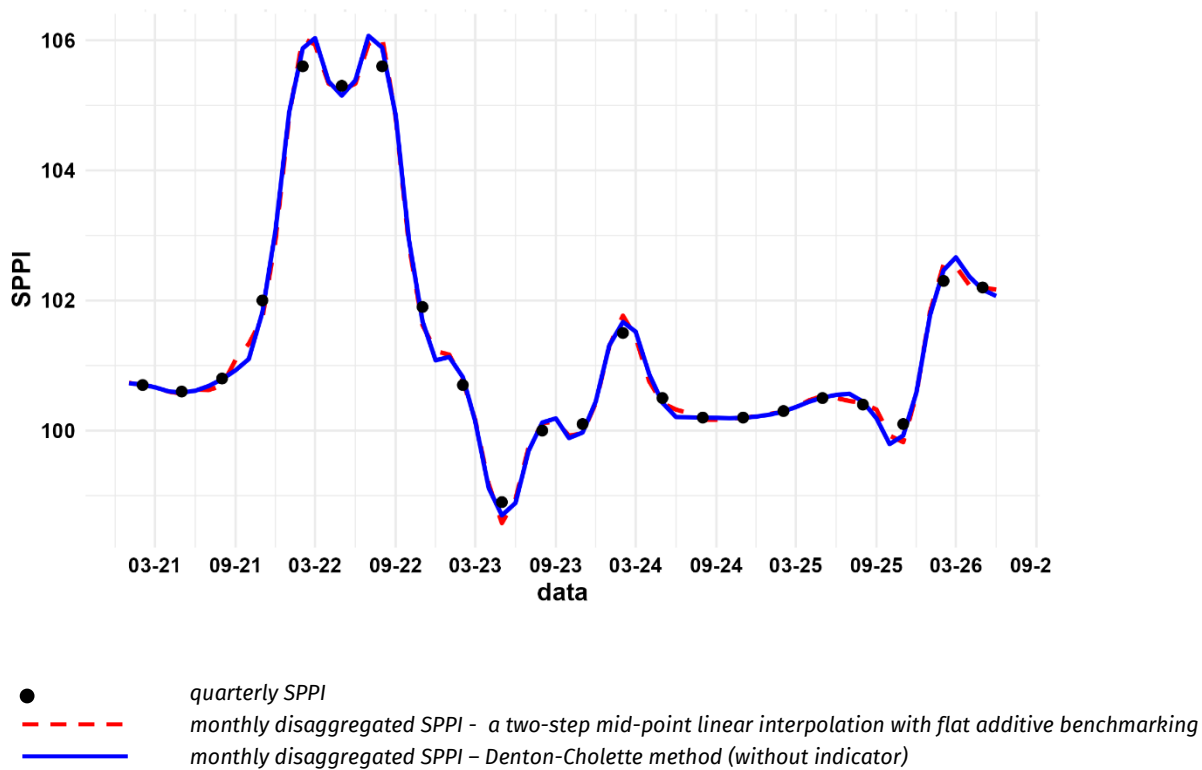
The monthly disaggregated SPPIs (for selected services activities) with the use of Denton-Chalotte's method (without any indicator) are presented graphically below. The values of quarterly SPPIs and monthly disaggregated SPPIs for all services activities covered by survey can be found in Annex.

¹ For details see: *Temporal Disaggregation of Time Series*, Ch. Sax, P. Steiner (2013)

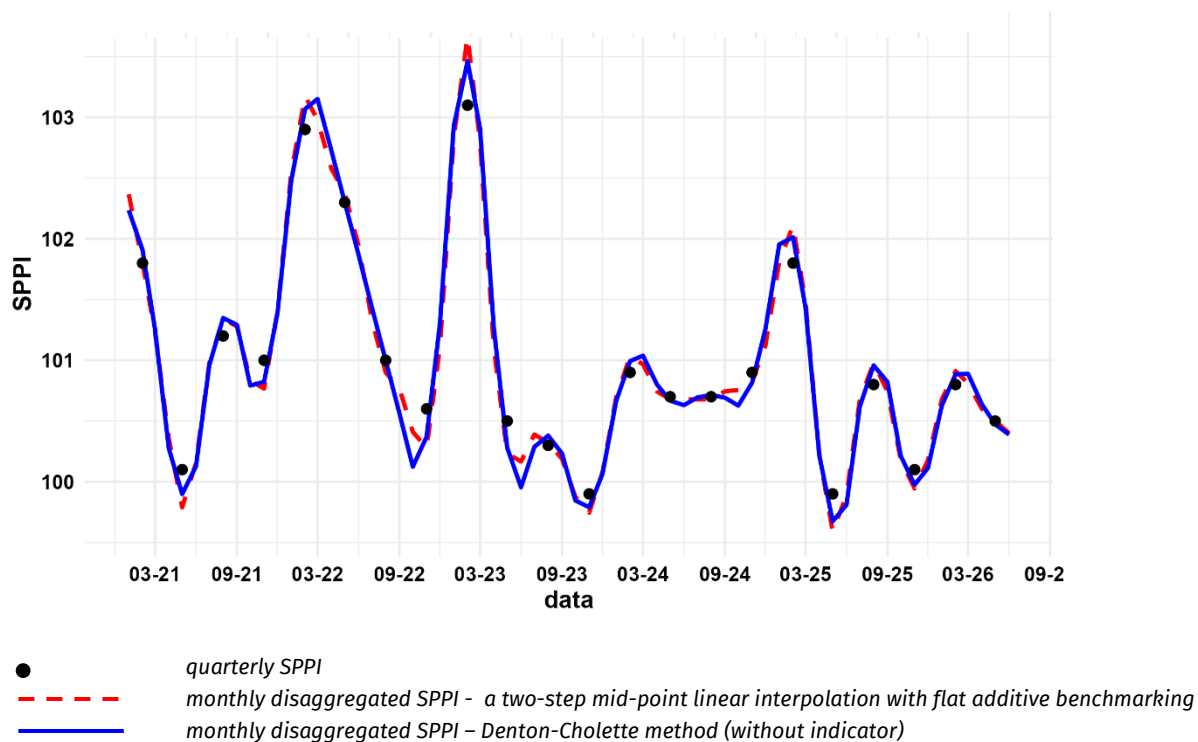
² The Denton-Cholette method without an indicator series (mathematically equivalent to the Boot-Feibes-Lisman approach)

³ See 1.

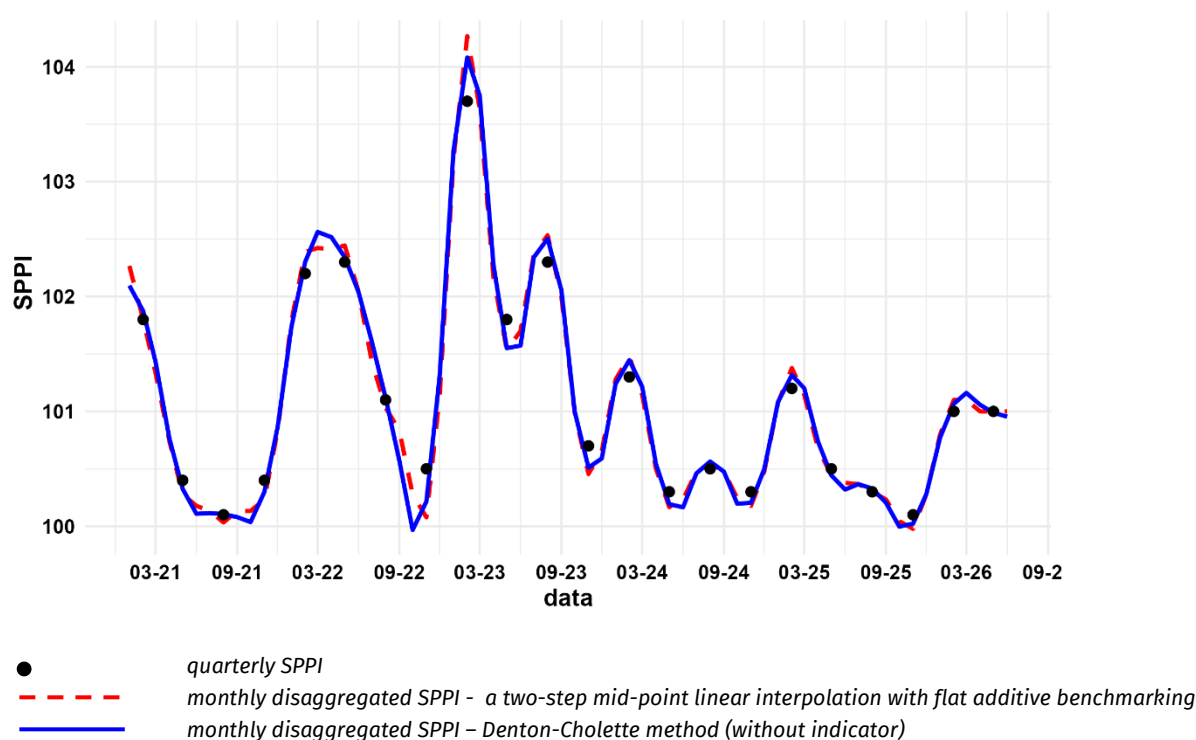
Graph 5 Quarterly SPPI and monthly disaggregated SPPI for Land transport and transport via pipelines (49 by NACE Rev.2) – Denton-Cholette method (without indicator)



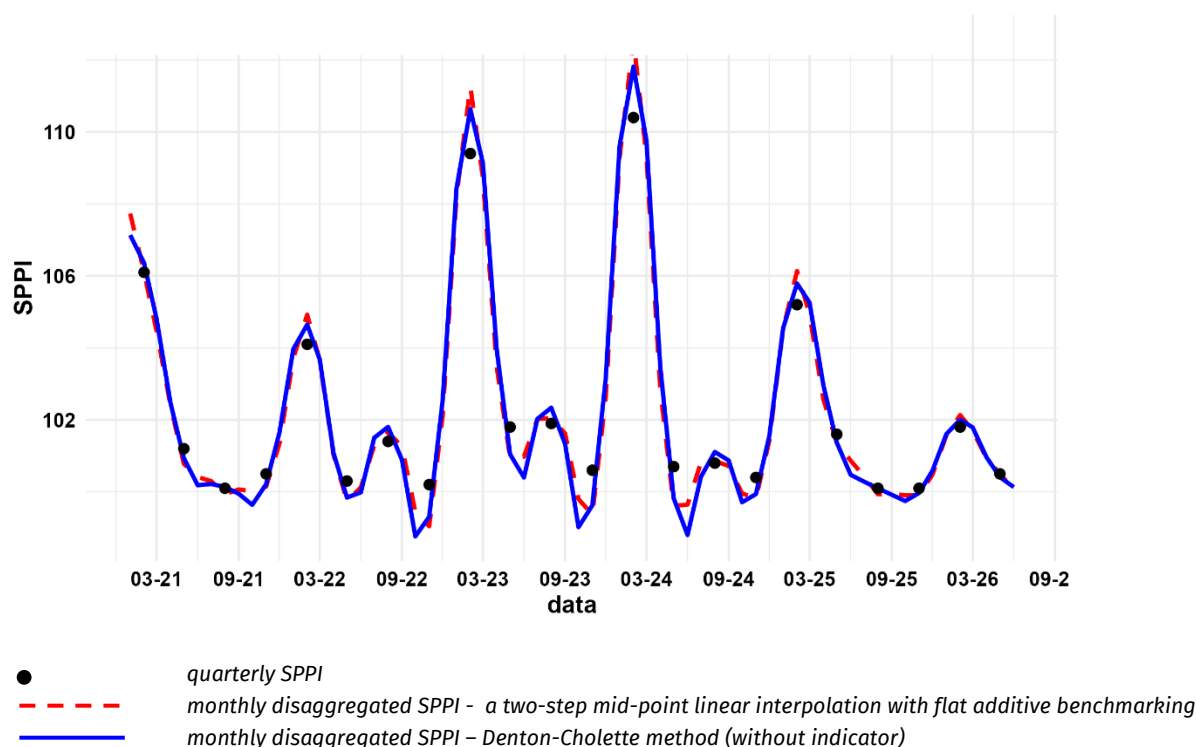
Graph 6 Quarterly SPPI and monthly disaggregated SPPI for Computer programming, consultancy and related activities (62 by NACE Rev.2) – Denton-Cholette method (without indicator)



Graph 7 Quarterly SPPI and monthly disaggregated SPPI for Architectural and engineering activities; technical testing and analysis (71 by NACE Rev.2) – Denton-Cholette method (without indicator)



Graph 8 Quarterly SPPI and monthly disaggregated SPPI for Security and investigation activities (80 by NACE Rev.2) – Denton-Cholette method (without indicator)



The graphical interpretation of the results indicates that the differences between the SPPI values disaggregated using a two-step mid-point linear interpolation with flat additive benchmarking and Denton-Cholette's method

(without indicator) are minor. Tables with quarterly SPPIs and monthly disaggregated SPPIs using both methods are presented in *Annex*.

6. Summing up

- Currently, a two-step mid-point linear interpolation with flat additive benchmarking is applied for the temporal disaggregation of the SPPI in Poland. In European statistical practice (including the Eurostat guidelines on temporal disaggregation), this procedure is referred to as a deterministic mathematical method without an indicator (a naïve/mathematical method). This method is relatively easy to implement without the need for specialized statistical software (e.g., R or Python). The algorithm is fully transparent and easily replicable by analysts.
- However, it should be noted that the additive benchmarking used in this method introduces non-linear shifts. Furthermore, the estimation approach for the endpoint months of the time series causes the data to be heavily burdened with adjustment errors. These errors tend to accumulate in January of the first year and December of the last year, leading to pronounced tail effects and endpoint instability.
- Therefore, taking into account the drawbacks of the applied method, as well as the guidelines of Eurostat and the International Monetary Fund (IMF), steps were taken to explore more advanced data disaggregation methods. After analyzing the methods proposed in the literature and the specific characteristics of SPPI series, it was decided to test the Denton-Cholette method without an indicator as a first priority (which is mathematically equivalent to the Boot-Feibes-Lisman approach).
- The Denton-Cholette method represents a movement-preserving mathematical approach. It allows for the elimination of the endpoint instability problem encountered when estimating indices for the first and last months of the time series. Moreover, the Denton-Cholette method without an indicator can be easily automated, as it does not require searching for additional high-frequency reference variables needed in regression-based methods.
- A comparison of the monthly SPPI series disaggregated using both methods indicates the consistency of the obtained results. However, the Denton-Cholette method provides a more precise estimation of index values for the extreme first and last months of the series. Furthermore, the implementation of this method in regular statistical production will not increase the burden on official statistics.
- As part of further activities, it is planned to analyze regression-based disaggregation methods. However, initial tests of methods such as the Chow-Lin and Litterman methods have shown that, in the case of the SPPI, it is difficult to identify high-frequency indicator series that are sufficiently cointegrated with services producer price indices. As a result, the implementation of regression-based methods for SPPI disaggregation involves an increased burden on statistical production and the necessity to justify the adopted solutions, particularly the auxiliary data applied.