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DOI: 10.17235/reed.2022.9094/2022
Link: PubMed (Epub ahead of print)

Please cite this article as:
Pinho Rolando, Veloso Ricardo, Estevinho Maria Manuela, Rodrigues Tânia, Lobo Bernardo Almada , Amorim-Lopes Mário, Freitas Teresa. Predicting the future: introducing business analytics to endoscopy units. Rev Esp Enferm Dig 2022. doi: 10.17235/reed.2022.9094/2022.

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# Predicting the future: introducing business analytics to endoscopy units

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**Data availability:** Data will be shared on reasonable request to the corresponding author.

**Disclosures:** The authors have no conflict of interests to disclose.

**Funding:** This study did not receive funding.

**Authors' contributions:** RP, RV, BAL and MAL were involved in study conception and design; RP, RV, MME and TF were involved in data analysis and interpretation; RP, RV and MME were involved in manuscript drafting; all the authors performed a critical revision and approved the final version of the manuscript.

**Abbreviations**

Esophagogastroduodenoscopy (EGD)

Percutaneous endoscopic gastrostomy (PEG)

endoscopic retrograde cholangiopancreatography (ERCP)

endoscopic ultrasound (EUS)

Full-time equivalent (FTE)

Vila Nova de Gaia Espinho Hospital Centre (CHVNGE)

Mean absolute percentage error (MAPE)

**Abstract**

Background and aims: Currently, most endoscopy software only provide limited statistics of past procedures, while none allows extrapolating patterns. To overcome this need, the authors applied business analytic models to predict future demand and need for endoscopists in a tertiary hospital endoscopy unit.

Methods: A query to the endoscopy database was done to retrieve demand from 2015 to 2021. The graphical inspection allowed inferring trend and seasonality, perceiving the impact of the COVID-19 pandemics, and selecting the best forecasting models. Considering COVID-19's impact in 2020's second quarter, data for esophagogastroduodenoscopy (EGD) and colonoscopy was estimated using linear regression of historical data. The actual demand in the first 2 quarters of 2022 was used to validate the models.

Results: During the study period 53886 procedures were requested. The best forecasting models were: i) simple seasonal exponential smoothing for EGD, colonoscopy, and percutaneous endoscopic gastrostomy (PEG); ii) double exponential smoothing for capsule endoscopy and deep enteroscopy and iii) simple exponential smoothing for endoscopic retrograde cholangiopancreatography (ERCP) and endoscopic ultrasound (EUS). The mean average percentage error ranged from 6.1% (EGD) to 33.5% (deep enteroscopy). Overall, 8788 procedures were predicted for 2022. The actual demand in the first 2 quarters of 2022 was within the predicted range. Considering the usual time allocation for each technique, 3.2 full-time equivalent endoscopists (40 hours-dedication to endoscopy) will be required to perform all procedures in 2022.

Conclusions: The incorporation of business analytics into the endoscopy software and clinical practice may enhance resource allocation, improving patient-focused decision-making and healthcare quality.

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**Keywords:** Endoscopy. Demand analysis. Health administration.

## Introduction

Endoscopic procedures play a key role in the diagnosis, surveillance, and treatment of a wide range of conditions and diseases. The demand for these procedures is projected to increase in the next years, mainly because of increasing uptakes of colorectal cancer screening programs[1,2]. In addition, the wide acceptance of open access endoscopy, in which endoscopic procedures requested by primary care physicians are performed without a previous clinic consultation, further boosts this demand[3,4]. Notwithstanding, the recent COVID-19 pandemic resulted in a substantial reduction in gastrointestinal endoscopies, creating a backlog of procedures and rearising the challenge of the waiting times[2]. Despite the projected increase in demand, the request for some endoscopic procedures may decrease, particularly in the case of ERCP as this technique is currently mainly reserved for therapeutic indications[5].

Furthermore, some endoscopic procedures may present seasonality in demand. Although seasonality is not expected for predominantly therapeutic procedures such as ERCP, in some elective procedures such as colonoscopy or gastroscopy a potential for seasonality is expected, such as a decrease in demand in the summer holidays. Consequently, the knowledge of the number of requested procedures (level of demand) and of the existence of trend or seasonality for the different endoscopic procedures, is of paramount importance to forecast demand.

Demand prediction of endoscopic procedures is critical to better plan capacity and resource allocation, improving productivity and efficiency. Some tools have already been developed to plan capacity according to historical demand such as the NHS Endoscopy Capacity and Demand Tool[6] although such tools do not take into account trend or seasonality. A recent study also evaluated discreet event simulation to forecast endoscopy demand using a hybrid approach for endoscopy services[7].

Therefore, the authors aimed to develop models to forecast the demand for endoscopic procedures (esophagogastroscopy, colonoscopy, capsule endoscopy, balloon-assisted enteroscopy, endoscopic retrograde cholangiopancreatography and endoscopic ultrasonography) in their tertiary endoscopic unit, based on historical demand per procedure and the presence or absence of trend and/or seasonality. Based on the forecasted demand, the number of full time equivalent

endoscopists to fulfil demand was calculated.

## Methods

### Analysis of historical data

A data query to the endoscopy software database used at the Department of Gastroenterology of the Vila Nova de Gaia Espinho Hospital Centre (CHVNGE) was performed to retrieve past demand for endoscopic procedures from January 2015 to December 2021. Time series modelling is widely used in the field of econometrics. In this study, data was decomposed in quarterly data, to account for the presence of seasonality in demand for certain endoscopic procedures. Visual inspection of data for each endoscopic procedure using trendlines generated in Microsoft Excel 365 ® was used to evaluate the existence of trend or seasonality in demand for the different endoscopic procedures offered in authors' unit. After the initial visual inspection, the best forecasting model for each endoscopic procedure was selected in accordance with the existence (or not) of trend and/or seasonality. The impact of the COVID-19 pandemic was also evaluated. When a significant impact in the request for a specific endoscopic procedure due to the COVID-19 pandemic was detected, the authors adjusted the demand in those quarters using extrapolated values from linear regression models using data from previous analogous quarters. This technique allowed to forecast future demand regardless of the effect of the COVID-19 pandemic.

### Forecast analysis

Forecast analysis was performed using the Statistical Package for the Social Sciences (SPSS®, version 28). According to the visual inspection of quarterly trendlines for demand, the best forecasting method (*linear regression*, *linear regression with seasonality*, *simple exponential smoothing*, *simple seasonal exponential smoothing*, *double exponential smoothing*, or *triple exponential smoothing*) was selected. Using these models, demand for the four quarters of 2022 was forecast. Exponential smoothing is a simple econometric method in which the more recent observations of the data series are given relatively more weight for the prediction, considering exponentially decreasing weights over time. Simple exponential smoothing does not consider trend nor seasonality for the forecast analysis. Conversely, simple seasonal exponential smoothing takes seasonality into account, whereas double exponential smoothing incorporates trend. On the other hand, triple exponential smoothing takes both seasonality and trend into consideration to make the

predictions. The mean absolute percentage error (MAPE), a measure of forecast accuracy based on the residues, was also calculated for each procedure. The data forecasted for the first 2 quarters of 2022 was compared with actual demand observed in these 2 quarters, to estimate the prospective fit of the models.

Using data predicted using the above-described forecast methods, the authors calculated the number of full-time endoscopists that should be allocated to perform all endoscopic procedures forecast to 2022 during that year. The authors considered the usual time allocation scheduled for each endoscopic procedure and a full-time endoscopist working 40 hours per week, 48 or 44 weeks per year. The number of FTE for each procedure was calculated multiplying the number of predicted procedures by the time allocated for each procedure (in minutes) divided by the total number of minutes available in the year (number of working weeks * number of hours worked per week * 60). The number of FTE required for each procedure was added to calculate the total number of FTE required.

**Results**

During the 2015-2021 study period, 53.886 procedures were requested (46.1% EGD, 40.8% colonoscopy, 4.1% ERCP, 3.5% EUS, 2.7% capsule enteroscopy, 2.2% PEG, 0.6% deep enteroscopy). The demand for each endoscopic procedure according to the years and quarters in which they were requested is detailed in Figure 1. Through visual inspection of historical quarterly data, the authors found a significant impact of the COVID-19 pandemic on demand for both esophagogastroscopy (EGD) and colonoscopy during the second quarter (Q2) of 2020. Demand for other endoscopic procedures was not severely affected. Therefore, data for demand for EGD and colonoscopy in the Q2 of 2020 was estimated using data from historical Q2 for each of these procedures, using a linear regression model, as depicted in Figure 1. Through visual inspection, the existence of seasonality without trend was observed for EGD, colonoscopy, and percutaneous endoscopic gastrostomy (PEG). A positive demand trend was found for capsule endoscopy, while for deep enteroscopy a slight negative trend was detected; no seasonality was observed for both procedures. Regarding endoscopic retrograde cholangiopancreatography (ERCP), no trend or seasonality were identified. For endoscopic ultrasonography (EUS), even though no seasonality was identified, an increase in demand during the last year was observed. This is probably explained by the acquisition of new echoendoscopes in 2021 to replace prior equipment that was unable to be used between late 2019

and 2020. Since this peak in demand in 2021 probably resulted from the availability of new echoendoscopes (a one-time external event), it was assumed that no trend existed.

Taking trend and seasonality into account: 1) *simple seasonal exponential smoothing* was selected to forecast demand for EGD, colonoscopy, and PEG, as seasonality without the presence of trend was observed; 2) *double exponential smoothing* was chosen for capsule endoscopy and deep enteroscopy, as trend without seasonality was detected; 3) or ERCP and EUS, the *simple exponential smoothing* model was applied, as nor trend or seasonality were found. The forecast curves for demand for each endoscopic procedure and forecast quarterly demand for 2022 are detailed in Figure 2 and Table 1. A total of 8788 endoscopic procedures are projected to be required during this year, mostly EGD (43.0%, n=3781) and colonoscopies (41.9%, n=3679). Based on the usual time slot allocated for each procedure at the authors' endoscopy unit (ranging from 30 minutes for EGD to 120 for deep enteroscopy) and considering a full time equivalent (FTE) of 40 hours weekly with 48 weeks per year, 3.2 FTE would be required to perform all endoscopic activities during 2022. In case the endoscopists worked 44 weeks per year, 3.5 FTE endoscopists would be required (Table 1). From a practical point of view, considering that each doctor usually performs other functions besides endoscopic procedures, more endoscopists may be needed (e.g., 8.5 endoscopists if each had 15 hours per week dedicated to endoscopy). The mean absolute percentage error (MAPE) for the predictions ranged from 6.1% for EGD to 35.5% (deep enteroscopy) – Table 2. As expected, predictions for procedures with higher demand, such as EGD and colonoscopy, had lower MAPE (6.1% and 7.7%, respectively). Forecasted demand for the first quarter of 2022 was compared with actual demand observed in these 2 quarters. As seen in Table 3, actual demand was within the expected 95% confidence intervals (95% CI) of the predictions, except for the forecasted demand of capsule endoscopy and enteroscopy in the first quarter of 2022. For capsule endoscopy, the actual demand in Q1 2022 was 136 whereas the 95% CI for the forecasted demand had ranged from 58 to 95. As for enteroscopy, actual demand in the first quarter of 2022 was 18, while the prediction had ranged from 0 to 15.

## Discussion

As expected, the COVID-19 pandemic had a significant impact on the demand for elective endoscopic procedures during the second quarter of 2020. According to the necessary measures that were undertaken to decrease the risk of infection to both patients and providers, several

restrictions on the indications for endoscopy procedures were implemented[8,9]. These measures were further adapted to gradually resume endoscopic activities during the post-lockdown phase[10] and the post-vaccination phase[11]. In the endoscopy unit of the Department of Gastroenterology of CHVNGE, the impact of the COVID-19 was only profound on the demand for colonoscopy and gastroscopy. This was already to be expected as these procedures are most commonly elective and were more frequently postponed according to the indications for elective endoscopic procedures during the COVID-19 pandemic[8,12]. Besides that, these procedures are frequently requested in office consultations which decreased dramatically during this period[13]. To avoid the impact of this unexpected context on the forecast of demand, data from the second quarter of 2020 was replaced by the values expected from the linear trend of historical Q2 data, as described in the methods section. In discrepancy from what has been described in the literature[14–17], an increasing trend in the demand for endoscopic procedures in the last years was not found in this unit, even after adjustment for the COVID-19 pandemic. This is probably because this is a tertiary referral endoscopy unit where most procedural demand comes from within the unit or from other hospital departments mostly to clarify symptoms, monitor previous conditions, or perform therapeutic procedures. Screening colonoscopies and routine gastroscopies are usually performed in an outpatient setting in other external units. Despite this, a positive trend in demand was observed for capsule endoscopy, which was also to be expected as this is a recent procedure with increasingly well-defined indications and expanding availability for medical providers[18–20].

Conversely, a slight negative trend in demand for deep enteroscopy was identified. Deep enteroscopy is also a relatively new procedure and although awareness of this procedure and its potential therapeutic capabilities are currently well known, its indications have been increasingly refined as scientific evidence of its efficacy and limitations accumulates[21–24], providing a possible explanation for the negative trend that was observed. Some seasonality in demand was observed for EGD, colonoscopy, and PEG. For EGD and colonoscopy, a slight increase in demand was apparent in the first quarters, while a slight increase in the first quarters and a decrease in the last quarters was observed for PEG. The decrease in demand for EGD and colonoscopy in the third and fourth quarters was also to be expected due to the usual reduction in office consultations during these periods. Also, prior studies[25] have suggested that the incidence of upper gastrointestinal bleeding follows a seasonal trend, being more frequent in winter and spring than in

summer and autumn. On the other hand, the seasonality identified for PEG was not expected by the authors regarding the usual indications for this specific endoscopic procedure.

As expected, no significant trend or seasonality were observed for ERCP and EUS demand, as these are procedures with particular indications and timings, less influenced by fluctuations in the offer of consultations or external factors such as the COVID-19 pandemic, although an increasing trend in the demand for EUS has been documented in other centers[26]. A large American cross-sectional study also reported a decrease in demand for ERCP, particularly with diagnostic intention[27].

The demand registered in the first 2 quarters of 2022 was within the forecasted predictions in 85.7% (12/14) of the cases. Of note, the actual demand only fell out of the predicted range for capsule endoscopy and deep enteroscopy in the first quarter of 2022. This mismatch may be due to the low demand for these endoscopic procedures between 2015 and 2021 in comparison to that registered for other techniques, which lowers the accuracy of the predictions. Despite this, the predictions for both capsule endoscopy and deep enteroscopy were accurate in the second quarter of 2022, as was the forecast of PEG demand.

The ability to forecast demand is of paramount importance to plan resource allocation. As is the case with the healthcare sector in general, endoscopy units also suffer from Baumol's cost disease[28,29]. Indeed, despite exponential technological advances in endoscopic equipment, endoscopy remains a heavily human resource-intensive activity with ever-increasing specialization[30]. This heavy reliance on skilled human resources impairs large gains in productivity and scalability that are seen in other sectors, thereby mandating careful planning of personnel allocation.

Even though several guidelines have addressed the need for structured endoscopic reports based on informatic reporting systems[31–33], this goal has remained elusive. Efforts to develop a comprehensive endoscopy reporting system, based on a structured terminology have already been described[34], although endoscopy platforms using the minimum standard terminology[35] remain scarce. Furthermore, integration with the hospital information system is often lacking and the use of interchangeable formats such as DICOM for endoscopic images is rare. Furthermore, the endoscopy software usually lacks business analytics capabilities, although some already provide limited dashboards with business intelligence data mainly related to production aspects of the endoscopy suite, such as the number of endoscopies performed by each user.

The addition of predictive analytics to the endoscopy reporting system, such as simple forecasting models of demand as the hereby described may generate dashboards populated with predictive data that may be used to better tailor endoscopic activity and resource allocation. Besides the level of demand, the presence of trend and seasonality may be institution specific. Therefore, these forecasting models need to be based on historical data from each institution to tailor prediction analytics accordingly. Nevertheless, it is important to consider that predictive models rely on the quality of the raw data and are not able to account for unexpected variations from external factors, as recently experienced due to the COVID-19 pandemic. Also, these models do not guarantee compliant waiting times so it is essential to have some redundant extra capacity available, sufficient to meet unforeseen extra demand and this should not be used as a replacement for adequate triage of patients according to their clinical priority.

In conclusion, the incorporation of business analytics capabilities into the endoscopy software and clinical practice may be useful to increase the level of understanding of the endoscopy units, supporting patient-tailored decision-making and improving healthcare services quality. Future studies may improve these models, by predicting the demand for other health-care professionals besides the endoscopists and adding more variables (external causes).

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**Table 1.** Projections for 2022 - demand for endoscopic procedures and corresponding full time equivalent (FTE) requirements.

| | EGD | Colonoscopy | PEG | Capsule enteroscopy | Deep enteroscopy | ERCP | EUS | Total |
|---|---|---|---|---|---|---|---|---|
| Q1 2022 (n) | 977 | 985 | 57 | 77 | 8 | 89 | 102 | 2295 |
| Q2 2022 (n) | 951 | 923 | 51 | 80 | 8 | 89 | 102 | 2204 |
| Q3 2022 (n) | 913 | 870 | 52 | 83 | 7 | 89 | 102 | 2116 |
| Q4 2022 (n) | 941 | 902 | 48 | 86 | 7 | 89 | 102 | 2174 |
| **Total for 2022 (n)** | 3781 | 3679 | 208 | 326 | 30 | 356 | 408 | 8788 |
| Allocated time (min) | 30 | 45 | 60 | 60 | 120 | 75 | 60 | - |
| **FTE 44w/y** | 1.07 | 1.57 | 0.12 | 0.19 | 0.03 | 0.25 | 0.23 | 3.46 |
| **FTE 48w/y** | 0.98 | 1.44 | 0.11 | 0.17 | 0.03 | 0.23 | 0.21 | 3.18 |

**Table 2.** Mean absolute percentage error (MAPE) for the different endoscopic procedures.

| Procedure | MAPE (%) |
|---|---|
| EGD (adjusted) | 6.1 |
| Colonoscopy (adjusted) | 7.7 |
| PEG | 15.7 |
| Capsule Enteroscopy | 12.5 |
| Deep Enteroscopy | 35.5 |
| ERCP | 12.6 |
| EUS | 21.4 |

**Table 3.** Comparison of actual and forecast demands for the first two quarters of 2022. The numbers within brackets in the forecast lines represent the 95% confidence interval of the forecast.

| | Demand | EGD | Colonoscopy | PEG | Capsule enteroscopy | Deep enteroscopy | ERCP | EUS |
|---|---|---|---|---|---|---|---|---|
| Q1 | Actual | 1000 | 998 | 72 | 136 | 18 | 103 | 132 |
| | Forecast | 977 (829-1124) | 985 (831-1139) | 57 (40-74) | 77 (58-95) | 8 (0-15) | 89 (64-113) | 102 (67-136) |
| Q2 | Actual | 850 | 830 | 39 | 90 | 11 | 97 | 102 |
| | Forecast | 951 (779-1122) | 923 (751-1095) | 51 (33-69) | 80 (61-99) | 8 (0-15) | 89 (62-116) | 102 (62-142) |

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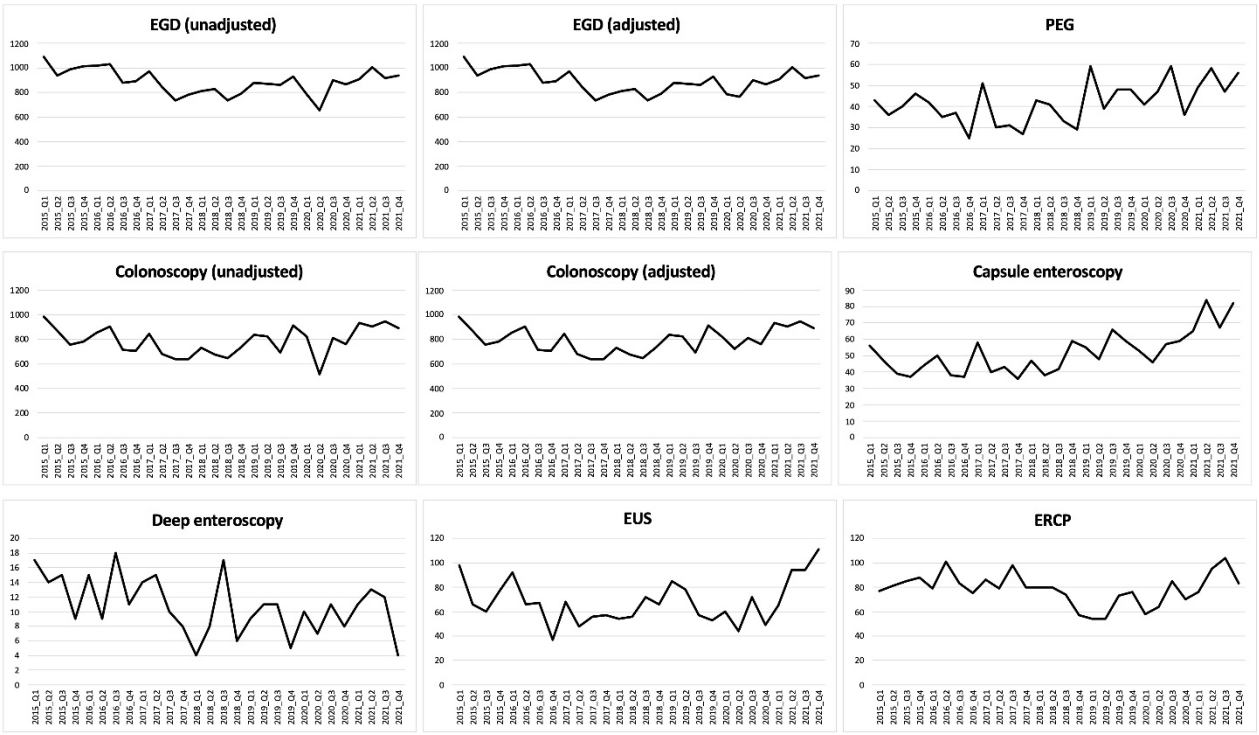


**Figure 1.** Demand for the different endoscopic procedures between January 2015 and December 2021 - esophagogastroscopy (EGD; non-adjusted and adjusted for the COVID-19 pandemic), percutaneous endoscopic gastrostomy (PEG), colonoscopy (non-adjusted and adjusted for the pandemic), capsule enteroscopy, deep enteroscopy, endoscopic ultrasonography (EUS) and endoscopic retrograde cholangiopancreatography (ERCP).

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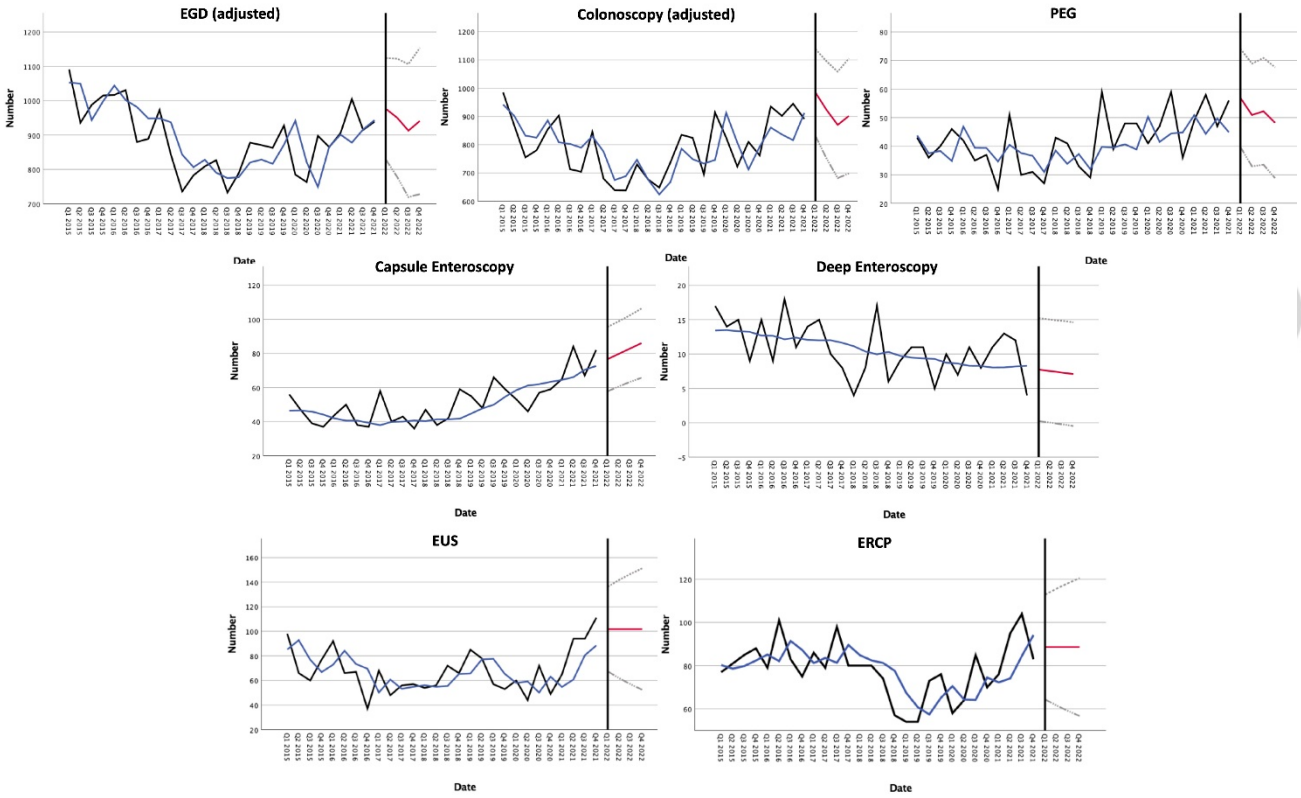


**Figure 2.** Demand for each endoscopic procedure during the study period and forecast demand for 2022 - esophagogastroscopy (EGD) and colonoscopy (both adjusted for the pandemic), percutaneous endoscopic gastrostomy (PEG), capsule enteroscopy, deep enteroscopy, endoscopic ultrasonography (EUS) and endoscopic retrograde cholangiopancreatography (ERCP).