



Digital capacity conversion in uzbekistan's sanatorium-resort sector: a methodological framework for analysing hybrid wellness service systems

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ABSTRACT

This paper presents a methodological framework for analysing how fixed institutional capacity converts into service output in hybrid wellness-tourism systems, using Uzbekistan's sanatorium-resort sector as an illustrative application. The framework combines a log-linear capacity model with a structured diagnostic and robustness protocol - variance inflation, residual autocorrelation, structural-break sensitivity and leave-one-out stability checks - designed for short official annual series that are common in transition-economy sector statistics. Applying the framework to Uzbekistan's 2010–2024 official sector data, the number of institutions and bed capacity show a positive association with nominal service output in the full-sample model ($R^2 = 0.727$), and the diagnostic protocol identifies the 2020 pandemic year as the principal source of residual autocorrelation. At the same time, the individual elasticity estimates prove unstable: the coefficients on institutions and bed capacity reverse sign when 2020 is excluded. The paper argues that the value of the framework lies in making such instability visible: explicit model specification, pre-specified diagnostic steps and transparent reporting of what the resulting estimates can and cannot support offer a replicable template for sector-level capacity research in data-constrained post-Soviet and transition-economy settings.

Keywords:

methodological framework; capacity conversion; log-linear modelling; robustness diagnostics; sanatorium-resort sector; wellness tourism; transition economies.

Преобразование цифрового потенциала в санаторно-курортном секторе Узбекистана: методологическая основа анализа гибридных систем оздоровительных услуг

АННОТАЦИЯ

В статье представлена методологическая основа для анализа преобразования фиксированного институционального потенциала в объём услуг в гибридных оздоровительно-туристических системах на примере санаторно-курортного сектора Узбекистана. Методологическая основа объединяет лог-линейную модель потенциала со структурированным протоколом диагностики и проверки устойчивости - анализом фактора инфляции дисперсии, автокорреляции остатков, чувствительности к структурным сдвигам и устойчивости по методу leave-one-out, - разработанным для

Ключевые слова:

методологическая основа; преобразование потенциала; лог-линейное моделирование; диагностика устойчивости; санаторно-курортный



коротких официальных годовых рядов, характерных для отраслевой статистики переходных экономик. Применение основы к официальным данным Узбекистана за 2010–2024 годы показывает положительную связь числа учреждений и коечного фонда с номинальным объемом услуг в модели на полной выборке ($R^2 = 0,727$); диагностический протокол определяет пандемийный 2020 год как основной источник автокорреляции остатков. Вместе с тем оценки отдельных эластичностей оказываются неустойчивыми: при исключении 2020 года знаки коэффициентов при числе учреждений и коечном фонде меняются на противоположные. В статье обосновывается, что ценность предлагаемой основы состоит в том, что она делает такую неустойчивость видимой: явная спецификация модели, заранее заданные диагностические этапы и прозрачное представление того, что полученные оценки могут и не могут подтверждать, образуют воспроизводимый шаблон для исследований отраслевого потенциала в условиях ограниченности данных в постсоветских странах и странах с переходной экономикой.

сектор;
оздоровительный
туризм; переходные
экономики.

O'zbekiston sanatoriy-kurort sektorida raqamli salohiyatni konvertatsiya qilish: gibridd sog'lomlashtirish xizmatlari tizimlarini tahlil qilishning metodologik asoslari

ANNOTATSIYA

Maqolada O'zbekiston sanatoriy-kurort sektori misolida gibridd sog'lomlashtirish-turizm tizimlarida mavjud institutsional salohiyatning xizmatlar hajmiga aylanishini tahlil qilish uchun metodologik asos taklif etiladi. Ushbu asos log-chiziqli salohiyat modelini qisqa rasmiy yillik qatorlar uchun mo'ljallangan tizimli diagnostika va barqarorlikni tekshirish protokoli - dispersiya inflyatsiyasi omili, qoldiqlar avtokorrelyatsiyasi, tarkibiy uzilishlarga sezgirlik va leave-one-out barqarorlik tekshiruvlari - bilan birlashtiradi; bunday qisqa qatorlar o'tish iqtisodiyoti mamlakatlarining tarmoq statistikasida keng uchraydi. Metodologik asosni O'zbekistonning 2010–2024 yillardagi rasmiy tarmoq ma'lumotlariga qo'llash natijasida to'liq tanlanma modelida muassasalar soni va o'rinlar sig'iminining nominal xizmatlar hajmi bilan musbat bog'liqligi aniqlanadi ($R^2 = 0,727$), diagnostika protokoli esa 2020 yil pandemiya davrini qoldiqlar avtokorrelyatsiyasining asosiy manbai sifatida ko'rsatadi. Shu bilan birga, alohida elastiklik baholari barqaror emas: 2020 yil chiqarib tashlanganda muassasalar soni va o'rinlar sig'imi bo'yicha koeffitsiyentlar ishorasi teskarisiga o'zgaradi. Maqolada taklif etilgan asosning qimmatli shunday beqarorlikni ko'rinadigan qilishida ekanligi asoslanadi: modelni aniq spetsifikatsiya qilish, oldindan belgilangan diagnostika bosqichlari hamda olingan baholar nimalarni tasdiqlashi va nimalarni tasdiqlay olmasligini shaffof ko'rsatish ma'lumotlar cheklangan postsovet va o'tish iqtisodiyoti sharoitlarida tarmoq salohiyatini tadqiq etish uchun takror qo'llash mumkin bo'lgan andozani tashkil etadi.

Kalit so'zlar:

metodologik asos;
salohiyatni
konvertatsiya qilish;
log-chiziqli
modellashtrish;
barqarorlik
diagnostikasi;
sanatoriy-kurort
sektori;
sog'lomlashtirish
turizmi; o'tish
iqtisodiyoti



Introduction. Sector-level research on service and tourism infrastructure in transition economies is frequently constrained by short official annual time series, inherited institutional categories that do not map cleanly onto modern constructs such as “digital adoption,” and the absence of established estimation templates tailored to these conditions. The sanatorium-resort sector is a characteristic case: it is a legacy system of institutions that is now being repositioned within the wider wellness and health-tourism market [1–3]. Research on this market has expanded rapidly [4], and the literature distinguishes between medical, spa and wellness offerings [5, 6]. Evidence on how the productive capacity of such institutions converts into service output nevertheless remains thin. This paper addresses that gap directly: rather than treating methodology as a supporting section of a substantive study, it presents the estimation and diagnostic framework itself as the primary contribution, using Uzbekistan's sanatorium-resort sector as a worked application.

Two strands of the literature motivate a capacity-centred approach. Studies of destination competitiveness treat the stock of resources and facilities as a core determinant of tourism performance [7–9], while research on information technology shows that digital investment yields returns mainly in combination with complementary organisational assets [10–12]. Service-dominant logic, in turn, frames service output as the result of resource integration rather than of capacity alone [13, 14], and organisations that combine several institutional logics, as state-affiliated sanatoria do, add a further layer of complexity [15]. The framework is organised around three methodological commitments. First, the functional form of the capacity model is specified and justified explicitly before estimation, rather than selected post hoc. Second, every reported estimate is accompanied by a structured diagnostic protocol - multicollinearity, residual autocorrelation, structural-break sensitivity and leave-one-out stability - so that the stability of the estimates, not only their point values, is reported. Third, the scope of inference is bounded explicitly: the framework is designed to characterise associations between fixed capacity and nominal output, and it is not presented as a causal-identification strategy. Section 2 sets out the general framework - data structure, model specification and diagnostic protocol - in terms that generalise beyond the Uzbek case. Section 3 applies the framework to the sanatorium-resort sector. Section 4 reports the resulting estimates and diagnostics. Section 5 discusses how the framework can be adapted to related hybrid service settings, Section 6 states the limitations, and Section 7 concludes.

2. Methodological Framework

2.1 Analytical approach. The framework treats sector-level service output as a function of fixed institutional capacity, estimated in logarithms so that coefficients are interpretable as elasticities. This choice is appropriate when, as is typical in sector statistics, output and capacity indicators grow multiplicatively rather than additively over the observation window, and when the relationship between capacity and output is expected to exhibit diminishing returns at high capacity levels.

2.2 Data structure and variables. The framework requires an annual panel of sector-level indicators comprising one output measure and a small set of capacity and demand indicators, denoted generically as:

$$Y_t, X_{1,t}, \dots, X_{k,t} \quad (1)$$

In the applied case (Section 3), the output measure is nominal health and social service output, and the explanatory set comprises the number of institutions, bed capacity, accommodated persons and foreign treatment visitors, observed annually over the period 2010–2024.

2.3 Model specification. The core estimating equation is a log-linear specification of the form:

$$\ln(Y_t) = \beta_0 + \beta_1 \ln(X_{1,t}) + \beta_2 \ln(X_{2,t}) + \beta_3 \ln(X_{3,t}) + \beta_4 \ln(X_{4,t}) + \varepsilon_t \quad (2)$$

where each β_k is interpreted as the elasticity of output with respect to indicator k , and ε_t is assumed i.i.d. conditional on the diagnostic checks in Section 2.4 being satisfied. Parameters are estimated by ordinary least squares, with goodness of fit assessed via the coefficient of determination:



$$R^2 = 1 - \frac{SS_{res}}{SS_{tot}} \quad (3)$$

Because the framework is intended for small samples, inference is based on conventional OLS standard errors; heteroskedasticity-consistent covariance estimators [16] are a natural extension but are not applied here.

2.4 Diagnostic and robustness protocol.

Four diagnostic steps are applied as a standard protocol, independent of the substantive case.

(i) Multicollinearity is assessed via the variance inflation factor for each regressor k [17–19]; values well below the common rule-of-thumb threshold of 10 are read as indicating that multicollinearity does not materially distort the estimates:

$$VIF_k = \frac{1}{1 - R^2_k} \quad (4)$$

(ii) Residual autocorrelation is assessed via the Durbin-Watson statistic [20]:

$$d = \frac{\sum_{t=2}^T (e_t - e_{t-1})^2}{\sum_{t=1}^T e_t^2} \quad (5)$$

(iii) Structural-break sensitivity is assessed by re-estimating equation (2) with the candidate break year excluded, and separately with a dummy variable for that year included [21], comparing the resulting R^2 , Durbin-Watson statistic and coefficient stability against the baseline.

(iv) Small-sample stability is assessed via leave-one-out cross-validation [22], re-estimating the model T times with one observation withheld each time and reporting the resulting coefficient range and the root-mean-squared error (in log units):

$$RMSE_{LOO} = \sqrt{\frac{1}{T} \sum_{t=1}^T (y_t - \hat{y}_{t,-t})^2} \quad (6)$$

The protocol is deliberately ordered: specification first, estimation second, and diagnostics applied as a fixed sequence rather than selectively reported, so that the bounds of what the resulting estimates support are established independently of the substantive findings.

3. Applied Case: Uzbekistan's Sanatorium-Resort Sector. The framework is applied to official annual sector statistics for Uzbekistan's sanatorium-resort sector, 2010–2024, published by the national Statistics Agency [23]. The output variable is nominal health and social service output (billion UZS); the capacity and demand indicators are the number of sanatorium-resort institutions, bed capacity (thousand places), accommodated persons (thousand) and foreign treatment visitors (thousand). The resulting panel spans fifteen annual observations, which the diagnostic protocol in Section 2.4 is specifically designed to accommodate. Table 1 below reports the full annual panel underlying the application, so that the worked example in Sections 3–4 is fully reproducible from the figures reported here.

Table 1. Official annual sector dataset underlying the applied case (source: national Statistics Agency)

Year	Y (bn UZS)	X1 Institutions	X2 Beds (k)	X3 Accommodated (k)	X4 Foreign (k)
2010	258.0	278	34.7	383.0	15.0
2011	354.4	323	53.1	446.9	24.0
2012	498.8	351	52.5	491.4	35.0
2013	671.9	370	52.4	517.6	52.0
2014	869.9	387	56.8	556.2	85.4
2015	1100.4	392	58.2	575.2	55.7
2016	1416.3	434	57.3	623.1	27.1
2017	1701.5	460	57.1	632.8	28.7
2018	2220.0	484	59.2	631.1	52.5
2019	3104.3	509	61.6	807.1	55.5
2020	3386.7	494	57.6	285.6	15.0
2021	5105.9	328	99.5	671.7	32.4
2022	6613.1	405	52.2	651.1	70.0
2023	8621.7	591	57.8	887.4	61.3
2024	6733.9	523	70.7	751.6	54.6

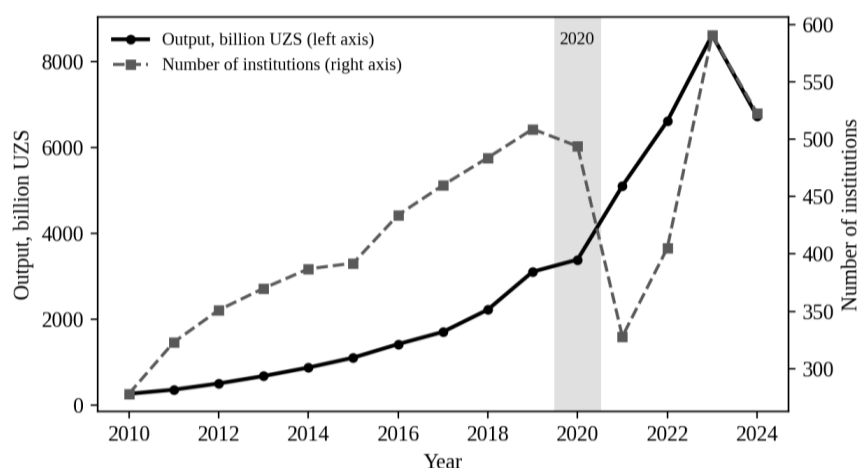


Figure 1. Sector output and institutional capacity, 2010–2024. The 2020 pandemic year is shaded; residual instability associated with this year is formally assessed in Section 4.2 and Section 4.3.

3.1 Reporting checklist

Table 2 operationalises the framework as a reporting checklist, so that the applied case in Sections 3–4 can be audited step by step against the general protocol set out in Section 2.

Table 2. Reporting checklist derived from the four-step diagnostic protocol (Section 2.4)

Step	Framework requirement	Applied in this case
Specification	Functional form stated and justified before estimation	Log-linear form; Section 2.1
Estimation	OLS with full coefficient table reported	Table 3
Multicollinearity	VIF reported for every regressor	Section 4.2
Autocorrelation	Durbin-Watson reported for baseline and adjusted models	Table 4
Structural breaks	Candidate break years tested by exclusion and dummy	Table 4 (2020)
Small-sample stability	Leave-one-out coefficient range and RMSE reported	Table 4; Appendix A
Scope of inference	Explicit statement of what estimates do and do not support	Sections 4.3, 6

4. Results

4.1 Parameter estimates

Table 3 reports the estimated coefficients for equation (2). In the full-sample model the coefficients on institutions and bed capacity are positive ($t = 2.92$ and $t = 2.14$, significant at the 5% and 10% levels respectively), while the coefficients on accommodated persons and foreign visitors are not distinguishable from zero.

Table 3. OLS estimates for the log-linear capacity model ($R^2 = 0.727$; $F = 6.65$; $n = 15$)

Variable	Coefficient	Std. error	t-stat
Constant	−22.127	6.210	−3.56
$\ln(X_1)$ Institutions	2.971	1.017	2.92
$\ln(X_2)$ Bed capacity	2.117	0.988	2.14
$\ln(X_3)$ Accommodated persons	0.527	1.021	0.52
$\ln(X_4)$ Foreign visitors	−0.068	0.493	−0.14

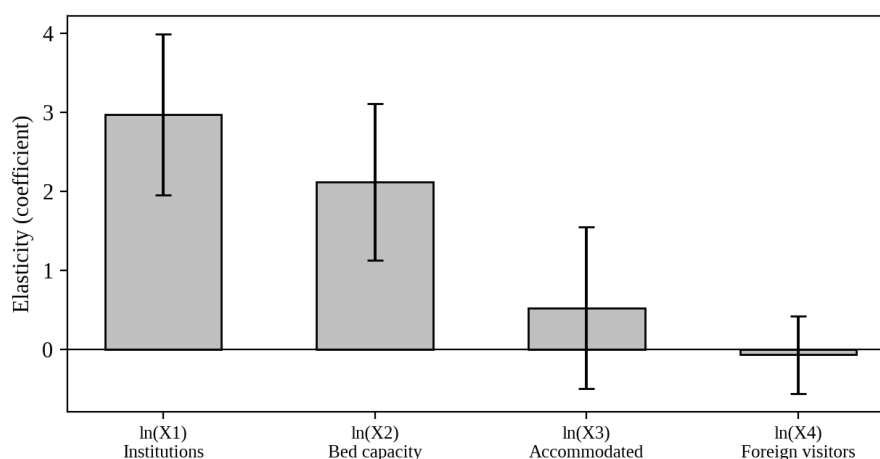


Figure 2. Estimated elasticities with ± 1 standard-error bars (full sample). The coefficients on institutions and bed capacity are the dominant terms in the full-sample model.

4.2 Diagnostic protocol applied

Variance inflation factors for all four regressors (1.30 to 2.60) remain well within conventional tolerance, indicating that multicollinearity does not materially distort the estimates in Table 3. The baseline Durbin-Watson statistic ($d = 0.95$) indicates residual autocorrelation; applying step (iii) of the protocol - re-estimating with 2020 excluded - raises the statistic to $d = 2.00$ and R^2 to 0.883, identifying the pandemic year as the principal source of the baseline autocorrelation rather than a general specification failure. The same exclusion, however, changes the coefficient pattern (Table 4 and Section 4.3).

Table 4. Diagnostic protocol results (framework steps i–iv applied to the sanatorium-resort case)

Diagnostic step	Result	Methodological reading
Baseline model	$R^2 = 0.727$; $d = 0.95$	Residual autocorrelation present
Excl. 2020 (break year)	$R^2 = 0.883$; $d = 2.00$; $\beta_1 = -2.40$; $\beta_2 = -0.32$	Autocorrelation resolves, so 2020 is its source; but the signs of the institution and bed-capacity coefficients reverse
2020 dummy included	$R^2 = 0.886$; $d = 1.93$; dummy coefficient 6.24 ($t = 3.55$)	Slope coefficients identical to the exclusion model; not retained in the final specification (over-parameterised)
Leave-one-out	RMSE = 2.036 (log units)	Coefficient ranges widen and signs are not stable (Appendix A); supports exploratory framing

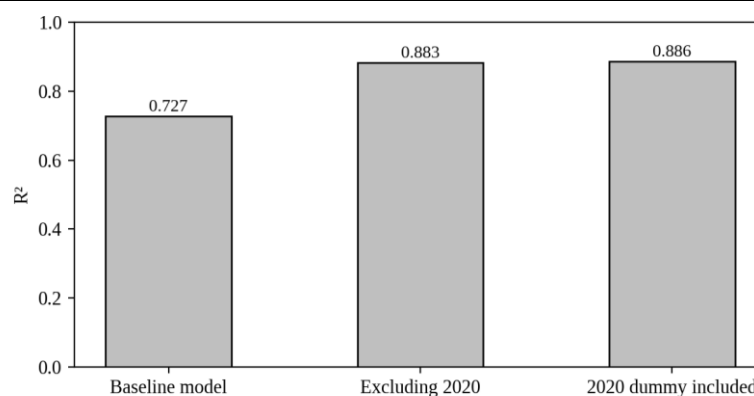


Figure 3. Model fit across diagnostic specifications. The gap between the baseline and break-adjusted R^2 isolates the contribution of the pandemic year to unexplained variation.



4.3 Interpretation

Read jointly, Table 3 and Table 4 show that the 2020 observation has a decisive influence on the estimates. Excluding 2020 removes the residual autocorrelation and raises R^2 to 0.883, but it also changes the coefficient pattern: the elasticities of institutions and bed capacity become negative and statistically indistinguishable from zero (-2.40 and -0.32), while the elasticity of accommodated persons rises to 6.64 ($t = 3.58$). This pattern is consistent with the sharp fall in the number of accommodated persons in 2020 (from 807.1 to 285.6 thousand) while institutions and beds hardly changed, so that the 2020 observation is what separates the capacity indicators from the utilisation indicator in the full-sample model.

The positive full-sample association between capacity indicators and nominal output should therefore be read as a descriptive association conditioned by the pandemic years, not as a stable structural elasticity. The leave-one-out diagnostic in Appendix A confirms this: none of the four slope coefficients keeps its sign across all re-estimations. The framework treats this finding as an expected property of a short annual series, and as a result in itself, rather than as a defect to be concealed.

4.4 Capacity-based projection

As a methodological extension, the framework supports a simple capacity-based projection of output, obtained by applying the average annual growth rate implied by the fitted values of equation (2) over the observed window to the most recent observed value:

$$\hat{Y}_{t+h} = Y_t \times (1 + \bar{g})^h \quad (7)$$

where $\bar{g}$ is the average compound annual growth rate of output implied by the fitted series, $\bar{g} = (\hat{Y}_{2024} / \hat{Y}_{2010})^{1/14} - 1 = 29.8\%$, and h is the projection horizon in years. This is reported as an illustrative extrapolation under constant capacity-conversion conditions, not as a forecast that accounts for future capacity investment, policy change or demand shocks. Because the series is nominal and observed output fell between 2023 and 2024, the path in Table 5 should be read only as an arithmetic illustration of equation (7).

Table 5. Illustrative capacity-based projection, equation (7) applied to the fitted 2010–2024 series

Year	Horizon h (years)	Output (UZS trillion)
2024 (observed)	-	6.73
2025	1	8.74
2026	2	11.35
2027	3	14.73
2028	4	19.12
2029	5	24.81
2030	6	32.21

5. Discussion: Generalising the Framework

The three-part structure - explicit specification, fixed diagnostic sequence, bounded inference - is not specific to sanatorium-resort statistics. It applies directly to other hybrid service sectors in transition economies that combine inherited fixed capacity with limited annual reporting: regional hospital networks, state-run spa and balneological systems, and vocational-training infrastructures share the same short-panel, capacity-centred data structure. Applying the same four-step diagnostic protocol in these settings would allow researchers to report comparable stability bounds across sectors, rather than each study developing an ad hoc robustness strategy.

Table 6 contrasts the framework's reporting requirements with two common alternative practices in short-panel sector research: reporting a single specification without diagnostics, and reporting diagnostics only when a reviewer requests them.



Table 6. Reporting practices compared

Practice	Typical reporting	Consequence for short annual panels
Single specification, no diagnostics	Coefficients and R^2 only	Instability from small T or outlier years is invisible
Diagnostics on reviewer request	Added post hoc, often selectively	Risk of reporting only diagnostics that favour the preferred result
This framework	Fixed four-step protocol reported in full, ex ante	Stability bounds are visible regardless of outcome

The applied case illustrates the point: a coefficient table and an R^2 of 0.727 alone would have suggested a clear capacity–output relationship, whereas the fixed diagnostic sequence shows that the signs of the capacity coefficients depend on two atypical years. A further implication concerns comparability across studies. When different sector-level studies in transition-economy settings adopt the same specification-and-diagnostic sequence, their reported stability bounds - rather than only their point coefficients - become directly comparable, which is rarely possible when robustness checks are applied inconsistently across the literature.

6. Limitations

The applied case in Sections 3–4 is based on a short annual series ($T = 15$ observations), and the diagnostic protocol in Section 2.4 is explicitly designed to make the resulting stability bounds, rather than the point estimates alone, the basis for interpretation. Three further limitations should be noted. First, the output variable is nominal, so the estimated elasticities partly reflect price growth rather than a real expansion of services; deflating the series and testing for common trends are not feasible with fifteen observations, and the low baseline Durbin-Watson statistic is consistent with trending behaviour in nominal series. Second, the results are strongly conditioned by two atypical years, 2020 and 2021, as the leave-one-out ranges in Appendix A show. Third, the capacity indicators are purely quantitative and do not capture qualitative attributes of facilities, such as their accessibility [24]. Extending the underlying panel to quarterly or facility-level observations would allow tighter identification and is noted as a direction for future methodological refinement rather than a defect of the framework as specified.

7. Conclusion

This paper has set out a reusable methodological framework — log-linear capacity specification paired with a four-step diagnostic protocol — for sector-level research on fixed-capacity hybrid service systems, and applied it to Uzbekistan's sanatorium-resort sector. The framework's contribution lies less in any single coefficient than in making the diagnostic sequence explicit and portable: specification, estimation and bounded interpretation applied in a fixed order, reported in full rather than selectively, and designed from the outset for the short official annual series that characterise much of transition-economy sector statistics. In the applied case the protocol shows that the positive full-sample association between capacity indicators and nominal output is conditioned by the pandemic years and should be read as descriptive rather than structural.

Appendix A. Leave-One-Out Coefficient Stability

Table A1 reports the range of each coefficient estimate across the 15 leave-one-out re-estimations described in Section 2.4(iv), alongside the baseline full-sample estimate from Table 3. Wide ranges relative to the baseline estimate indicate that a coefficient's magnitude, and here also its sign, is sensitive to individual annual observations, which is the reason the framework reports ranges rather than point estimates alone.

Table A1. Leave-one-out coefficient ranges (derived from the protocol in Section 2.4)

Variable	Baseline estimate	LOO minimum (omitted year)	LOO maximum (omitted year)	Sign preserved
$\ln(X_1)$ Institutions	2.971	-2.40 (2020)	5.61 (2021)	No
$\ln(X_2)$ Bed capacity	2.117	-1.76 (2021)	3.30 (2010)	No
$\ln(X_3)$ Accommodated persons	0.527	-0.29 (2021)	6.64 (2020)	No
$\ln(X_4)$ Foreign visitors	-0.068	-0.46 (2022)	0.47 (2021)	No

None of the four slope coefficients keeps its sign across all leave-one-out re-estimations. The elasticity of institutions is lowest (-2.40) when 2020 is omitted and highest (5.61) when 2021 is omitted; the elasticity of bed capacity turns negative when 2021 (-1.76) or 2020 (-0.32) is omitted. The framework therefore classifies the full-sample capacity elasticities as unstable and restricts the interpretation of Table 3 to a descriptive association (Section 4.3).

Appendix B. Notation Summary

Table B1. Notation used throughout Sections 2–4

Symbol	Meaning
Y_t	Sector output in year t
$X_{1,t} - X_{4,t}$	Capacity and demand indicators in year t
β_k	Elasticity of output with respect to indicator k
ε_t	Residual (error) term in year t
e_t	Regression residual in year t
VIF_k	Variance inflation factor for regressor k
d	Durbin-Watson statistic
$RMSE_{LOO}$	Leave-one-out root-mean-squared error (log units)
T	Number of annual observations in the panel
h	Projection horizon in years
$\bar{g}$	Average compound annual growth rate implied by the fitted series

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