

4th INTERNATIONAL CONFERENCE ON ECONOMIC STATISTICS

STATISTICAL MODELS FOR THE ECONOMIC TRANSITION: THE NEW CHALLENGE IN A DEVELOPING WORLD

Book of short papers

Editors:

Vittorio Nicolardi

Caterina Marini



**UNIVERSITÀ
DEGLI STUDI DI BARI
ALDO MORO**

DIEF

DIPARTIMENTO
DI **ECONOMIA
E FINANZA**



ICES 2026 - 4th International Conference on Economic Statistics

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Società
Italiana di
Statistica

Guest Editor Team of the Conference ICES 2026

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Preface

The global transformations that are reshaping the structural economic connections in the world markets are the core of the economic and social transition we have been living through over the last two decades. The inevitable changes, which are the result of the process in progress, have their consequences for all aspects of the human life, not only those strongly related to the economic developments, such as production and consumption, but also those connected to the socio-demographic equilibria. All scientific fields are being called upon to develop new statistical-economic methodologies and new interpretative approaches to better understand current and future scenarios underlying these phenomena. In this perspective, the effects of climate change and the implications of the ongoing transitions represent an essential part of the picture.

The volume collects a selection of short papers that were presented at *the 4th International Conference on Economic Statistics (ICES)*, held at the University of Bari Aldo Moro (Italy) on 5 - 6 February 2026.

Papers provide a wide overview of the most innovative analytical approaches, both methodological and applied, to better understand current and future scenarios underlying the socio-economic phenomena and their transition in a changing world, with a particular focus on the themes of sustainability and innovation.

The conference has explored the challenging opportunities of the ongoing transitions and the papers included in this volume reflect the multiplicity and diversity of the conference program that covered many topics such as labour market, time-dependent economic-financial data, sustainable growth and dynamics, regional competitiveness, digitalisation and technology in the framework of statistical models, input-output economic models, new indicators and data collection, time series and spatial analysis, environmental accounting, machine learning and artificial intelligence.

ICES is an annual event created to foster the scientific debate within the Italian community of the economic statisticians. This 4th ICES edition held in Bari opened up the scientific debate not only at the academic international level but also among institutional entities. In fact, it saw the participation of scholars from universities abroad and representatives of leading Italian research institutions.

Bari (Italy)
February 2026

Vittorio Nicolardi
Caterina Marini

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Local spatio-temporal Bayesian estimation of key agricultural economic indicators

Felicetta Carillo, Paolo Maranzano, Laura Marcis, Maria Chiara Pagliarella and Renato Salvatore

Abstract A Bayesian spatio-temporal extension of the Fay-Herriot small area estimation model is presented, integrating temporal dynamics via evolving random coefficients and spatial dependence through a distance-based structure. The model improves estimate reliability by borrowing strength across areas and time, capturing both overall trends and yearly increments. Its effectiveness is demonstrated using agricultural economic data characterized by spatial and temporal correlations.

Key words: agricultural economic indicators, hierarchical model, small area estimation, bayesian estimation

1 Introduction

Small Area Estimation (SAE) [3] aims at producing reliable estimates for domains or geographical areas where direct survey estimators suffer from high sampling variability due to small sample sizes. In such settings, direct estimates are often unstable and may lead to misleading inference, motivating the use of model-based approaches that borrow strength from auxiliary information and related areas. At the

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area level, the Fay-Herriot model represents the standard reference framework for SAE. This model combines direct estimators with area-level covariates through a mixed-effects specification and treats the sampling error variances as known quantities, typically obtained from design-based variance estimates of the direct estimators [2]. Consequently, inference does not focus on estimating the sampling error variances, which are assumed to be given, but rather on the latent random effects capturing unobserved area-specific heterogeneity. Building on this framework, this paper considers a Bayesian spatio-temporal small area model that extends the classical Fay-Herriot approach by incorporating both temporal and spatial dependence in the model. Temporal dynamics are captured through a random coefficients model evolving, while spatial dependence across areas is modelled using a distance-based structure. This model also allows for observing the overall evolution of the estimates and the variable yearly increments thereof [1]. The proposed methodology is illustrated through an empirical application based on data from the Farm Accountancy Data Network (FADN), a harmonized survey providing detailed economic information on agricultural holdings. The FADN collects a wide range of economic, structural, and financial variables describing agricultural activity, including production values, costs, inputs, and farm characteristics. The availability of repeated observations over multiple years and across small geographical units makes these data particularly suitable for small area estimation, especially in contexts where direct estimates at the area level are unreliable. Key economic variable such as the standard output, together with surface area variables, labor input, and livestock units, provides a measure of the performance of agricultural activity. Given the presence of both spatial proximity and temporal persistence in agricultural economic outcomes, the FADN data offer an appropriate setting for assessing the performance of a Bayesian spatial small area model.

2 Method and application

To estimate the mean of the local target response parameters based on the sampled area means provided by the direct estimates $y_{i,t}$, $i = 1, \dots, m$, we adopt an area-level model specified as a time-varying random coefficient model with fixed regressors. We define the multiple-stage model for the random process θ_t at time t :

$$\theta_{i,t} = \mathbf{x}'_{i,t}\beta + u_{i,t}, \quad \theta_{i,t} = \phi\theta_{i,t-1} + \alpha_{t-1}, \quad \mathbf{u}_t = \rho_s \mathbf{W}\mathbf{u}_t + \mathbf{v}_t,$$

with $\mathbf{X}_t$ the design matrix of the fixed effects of order $m \times p$, with m as the number of the areas, $\mathbf{W}$ a the spatial weight matrix for the $i = 1, \dots, m$ subjects, and a matrix $\mathbf{Z}$ as the design matrix of random-area effects for the corresponding m areas, ϕ is a fixed coefficient to be estimated, and α represents the increment in mean of the series. Thus, the simultaneous spatial error process formulation for $\theta_{i,t}$ gives the model:

$$\theta_t = \mathbf{X}_t\beta + \mathbf{Z}\mathbf{u}_t = \mathbf{X}_t\beta + \mathbf{Z}(\mathbf{I} - \rho_s \mathbf{W})^{-1}\mathbf{v}_t,$$

where $\mathbf{Z}(\mathbf{I} - \rho_s \mathbf{W})^{-1} \mathbf{v}_t$ is the random part of $\theta_{i,t}$, $\mathbf{Z} = \mathbf{I}_m$, and ρ_s is the spatial autocorrelation coefficient. In order to obtain more accurate estimates of the means at the province level, outperforming the efficiency direct sampling estimates, the model θ_t is considered as the linking regression model for the local area parameters (the small area means) when integrated with the sampling (observational) model $\mathbf{y}_t = \theta_t + \mathbf{e}_t$, $e_{it} \sim N(0, \sigma_{y,i,t}^2)$. Following the Fay-Herriot model and its extensions, the sampling error variances $\sigma_{y,i,t}^2$ are customarily considered to be known in the model introduced. The Hierarchical Bayes (HB) model considered in this study is designed to capture the temporal evolution of the variable of interest as well as its variation across small areas, and is specified as follows:

$y_{i,t} \sim \text{normal}(\theta_{i,t}, \sigma_{y,i,t}^2),$	Sampling (observational) model
$\theta_{i,t} \sim \text{normal}(\theta_{i,t-1} + \alpha_{t-1}, \sigma_\theta^2),$	Underlying trend
$\alpha_{t-1} \sim \text{normal}(\phi \alpha_{t-2}, \sigma_\alpha^2),$	Increments in mean
$\gamma \sim \text{normal}(x_i' \beta, \sigma_\gamma^2),$	Area parameters linking model
$v_t \sim \text{normal}(0, \sigma_v^2),$	Spatial random-area effect

This study focuses on key economic indicators from the FADN dataset that describe farm size and performance and are consistently available across areas and over time. Standard output is used as the main variable of interest, while labour, land, and livestock inputs are included as covariates, allowing for a parsimonious model specification that captures the main drivers of farm economic performance. The analysis considers the period from 2018 to 2022 and focuses on 47 provinces belonging to the North-East and North-West macro-areas of Italy, covering the regions of Alto Adige, Emilia-Romagna, Friuli Venezia Giulia, Lombardia, Piemonte, Trentino, Valle d'Aosta, and Veneto. The random coefficients $\theta_{i,t}$ and α_{t-1} are estimated, giving a representation of the time dependence in the years considered of the evolution of the general average of the standard output indicator in the Northern Italian farms, together with the dynamic small area estimates at the Province level (NUTS3). The Bayesian estimates reflect the spatial and temporal patterns of the sample-based estimates obtained with the direct estimator, while simultaneously providing a more reliable and accurate estimation, as is typical in classical small area estimation models. Therefore, the estimates are not affected by the variability induced by the small sample sizes that may characterize certain areas (see Figures 1 and 2 for a comparison). The proposed model represents a valuable tool for the dynamic assessment of economic policies at the local level and can be readily extended to finer spatial scales than provinces, such as municipalities or other domains not explicitly defined within the sampling design.

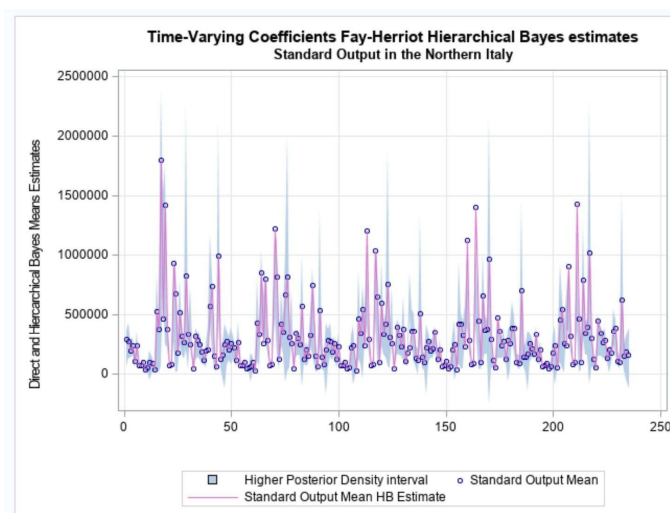
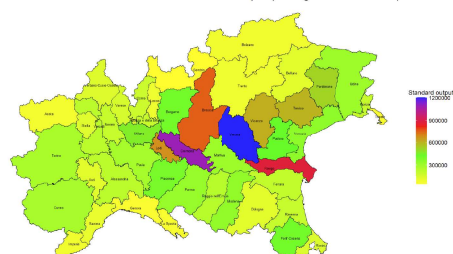


Fig. 1 The comparison between the estimates highlights that the direct estimates fall within the Higher Posterior Density Interval of the Bayesian estimates. On the x-axis, the 47 provinces considered over the five years are represented.

Direct estimates of the mean of the Standard Output (averaged in 2018–2022)



HB estimates of the mean of the Standard Output (averaged in 2018–2022)

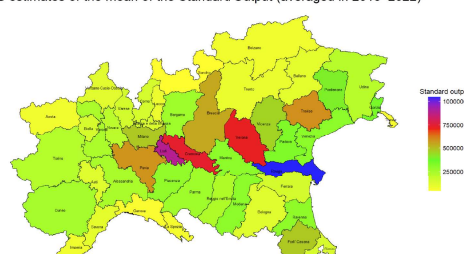


Fig. 2 On the left, the average of the direct estimates for the 47 provinces considered; on the right, the Bayesian estimate obtained with the model proposed in this work. For some provinces, the estimated value differs from the direct estimate, despite the overall trend being nearly identical.

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