THE ISBA BULLETIN

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A MESSAGE FROM THE PRESIDENT

- Raquel Prado -
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I am truly honored to serve as ISBA President. ISBA was the very first professional society I joined as PhD student a few years ago. I have been a member of several ISBA committees and have also served as an officer to the Board and the Program Council. I take this new role with a great sense of responsibility and huge enthusiasm.

I want to begin by thanking our former President Marina Vannucci for leading ISBA last year. We are very lucky to have her in the Executive Board for one more year serving as 2019 Past-President. I want to thank Kerrie Mengersen (2018 Past-President and Chair of SafeISBA) and Amy Herring (2016-2018 Executive Secretary) who recently retired from the Executive Board, for their incredible work and non-stop dedication to ISBA during the past three years. A very warm welcome to Sylvia Frühwirth-Schnatter and Feng Liang who are serving, respectively, as Secretary and President-Elect this year. Bobby Gramacy will continue to be our Treasurer this year. Thank you Bobby for keeping our finances in order! Many thanks also to our past ISBA board members David Banks, Abel Rodriguez, Marc Suchard and Luke Tierney, and all the retiring section and chapter officers for their service. I welcome the four new Board members Eduardo Gutiérrez-Peña, Beatrix Jones, Ioanna Manopoulou, Nancy Reid and James Scott, and also all the newly appointed officers of the Sections and Chapters. I really look forward to working with you to continue serving our society.

Clair Alston also ended her 3-year term in the Program Council. Thank you Clair for all the work you did in this committee along with current members David Rosell and Li Ma. We really had a wonderful ISBA World Meeting last year in Edinburgh. I also take this opportunity to thank all the members of the Scientific and Local Organizing Committees. Thanasis Kottas is joining David and Li this year as the new Vice-Chair of the Program Council. Welcome Thanasis!

The Program Council and the Scientific and Local Organizing Committees of the 2020 ISBA World Meeting are very actively working on the organization of this conference. As you know this meeting will take place in Kunming, Yunnan, China from June 29 to July 3rd 2020. You can read more about this meeting and other ISBA sponsored/endorsed events on page 3. Regarding the 2020 World Meeting please keep an eye for further announcements from the Program Council and the Scientific Committee later this year. We have also recently approved the venues of the next two ISBA World Meetings.

In this issue

I want to thank all the ISBA members who put together the outstanding proposals we received for future meetings. We can now formally announce that the 2022 World Meeting will take place in Montreal, Canada while the 2024 World Meeting will take place in Venice, Italy.

This is also a year of changes in the editorial team of ISBA. Bruno Sansó (past Editor-in-Chief of Bayesian Analysis), Beatrix Jones (past Editor of the ISBA Bulletin) and Kate Calder (Web Editor) have just ended their 3-year terms. I want to thank them for their outstanding work as ISBA Publication Editors. I welcome Michele Guindani as Editor-in-Chief of Bayesian Analysis, Maria DeYoreo as Editor of the ISBA Bulletin, and Daniel Williamson as ISBA Web Editor.

Finally, I want to say that I am specially grateful to the SafeISBA Task Team for leading the efforts that resulted in the ISBA Code of Conduct and Professional Ethics, Equal Opportunity, and Anti-Harrassment Policies, and also to all the members who provided feedback on these documents. These documents have been recently approved by the ISBA Board and will be available soon, in final form, on the ISBA website https://bayesian.org. I also want to announce that SafeISBA has just transitioned to the ISBA Professional Conduct Committee. Past-President Marina Vannucci and I will serve on this committee as ex-officio members. Marina will chair the committee this year and I will be the chair in 2020. Members of this committee will serve overlapping 5 year terms beginning every year on January 1st. The current members of the Professional Conduct Committee and their respective terms are: Amy Herring (1-year term), Clara Grazian (2-year term), Pierre Jacob (3-year term), Trevor Campbell (4-year term), and Herbie Lee (5-year term). Amy and Clara were part of the SafeISBA team. Welcome Pierre, Trevor and Herbie!

I look forward to working with all our current officers and our entire ISBA community around the world to support activities that will continue to make our society stronger. I also want to encourage each of you to get involved with ISBA this year if you are not already doing so. There are multiple ways of participating with different levels of time commitment and workload going from from renewing your membership or inviting research collaborator to join our society, to volunteering for one of our committees, or to run as an officer for one of the Sections or Chapters. If you have an idea about an event that can benefit ISBA or want to share your views about a particular topic please get in touch with an officer. Every effort counts!

– Raquel Prado

FROM THE EDITOR

- Maria DeYoreo -
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Dear fellow Bayesians, I am happy to serve as your *ISBA Bulletin* Editor! I would like to thank Beatrix Jones for the hard work she put into producing quality bulletins over the past couple of years (which I am now appreciating!), and for answering my countless questions as I put this issue together. I'd also like to introduce our new Associate Editors. Brenda Betancourt will be serving as AE for the *j-ISBA* section of the bulletin. Brenda is also the new treasure of j-ISBA section, taking over Clara Grazian's role. I would also like to welcome Gregor Kastner, who will be serving along with Anton Westveld to produce a *Features* section. This section will feature topics from different themes, one in each issue, such as a software highlight, Bayes in Action column, or an interview. This quarter's bulletin features an R package for stochastic volatility modeling. Please do not hesitate to contact these AEs if you have a great idea or some material for a feature they should include in future issues.

CALL FOR ASSOCIATE EDITORS

We are in need of an Associate Editor for a *News from the World* section to take over from Xinyi Xu who has previously served as AE. This AE would compile news from ISBA members, such as

announcements of important awards members have received, solicit conference reports and announce upcoming conferences or meetings of interest to members, or share interesting things happening in the Bayesian community. Please contact mdeyoreo@rand.org if you are interested in serving as an AE for the *Bulletin*! If you know someone who might be a great candidate for this position, please tell them to contact me to talk about this opportunity. This is a great opportunity to get more involved with ISBA by contributing to the society and staying up to date with what's happening in the community, and to meet more people within the Bayesian community.

FROM THE PROGRAM COUNCIL

- Li Ma-
program-council@bayesian.org

Welcome New Member: Athanasios Kottas has joined the Program Council as the new Vice-Chair. At the same time, we are very grateful to our departing member Clair Alston-Knox for her dedicated service in the past three years. Thank you Clair!

The 2020 ISBA World Meeting will be held June 29-July 3, 2020 at Kunming, China, hosted by Yunnan University. Information about the meeting will be added to the conference website http://www.isba2020worldmeeting.com as it becomes available. We encourage members to start thinking about potential contributions to the program. In April 2019, we will approach Sections to propose Special Topics Sessions of interest to their members, with contributed sessions from individuals being advertised at a later time. We will keep you updated with progress and due dates for contributions throughout the year.

Meeting Sponsorships and Co-sponsorships. If you are planning a meeting in 2020 and would like to request financial sponsorship (or co-sponsorship) or non-financial endorsement from ISBA, please submit your requests to the program council at program-council@bayesian.org. Detailed information on how to submit a request for either sponsorship or endorsement can be found at https://bayesian.org/events/request-sponsorshipendorsement/.

Upcoming ISBA-sponsored/endorsed events

1. Advances and Challenges in Machine Learning Languages, May 27 – 28 2019, Cambridge, UK.
2. Sixth Symposium on Games and Decisions in Reliability and Risk, May 29 – May 31, Washington DC, USA.
3. 11th International Workshop on Bayesian Inference in Stochastic Processes, June 12-14 2019, Madrid, Spain.
4. Statistics conference in honour of Aad van der Vaart's 60th birthday, June 17 – 21, 2019, Leiden, The Netherlands.
5. VI Latinamerican Bayesian Conference (COBAL VI), June 19 – 21, 2019, Lima, Peru.
6. 12th International Conference on Bayesian Nonparametrics (BNP12), June 24 – 28, 2019, Oxford, UK.
7. O'Bayes 2019: Objective Bayes Methodology Conference, June 29 – July 2 2019, Warwick, UK.
8. The 4th EAC-ISBA Conference, July 13 – 14, 2019, Kobe, Japan.
9. BayesComp 20. January 8 – 10, 2020. Gainesville, Florida, USA.

10. The 5th EAC–ISBA Conference: A Satellite Meeting of the 2020 ISBA World Meeting in Celebrating James O Berger's 70th Birthday, June 26 – 27 2020, Da Li, China.

11. BAYSM 2020, June 26 – 27 2020, Kunming, China.

UPDATES FROM BA

From the BA Editor

- Michele Guindani-
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This is my first column in the Bulletin as Editor-in-Chief of *Bayesian Analysis*. I am honored and humbled to take this position, following in the footsteps of many great Editors before me. In particular, I want to thank the previous Editor-in-Chief, Bruno Sansó, who has promoted multiple initiatives, which have increased the visibility of the journal and fulfilled its mission to be a beacon of Bayesian ideas. Back in 2005, the first EIC of the journal, Rob Kass, wrote in this column that *Bayesian Analysis* provides an "outward-looking" view of Bayesian statistics which can be of interest "not only to statisticians but to a very broad spectrum of quantitative researchers. Stephen E. Fienberg reiterated a similar philosophy in the first issue of the journal, by noting that "today, Bayesian methods are integrated into both the fabric of statistical thinking within the field of statistics and the methodology used in a broad array of applications." It is my opinion that this outward-looking perspective should remain the defining characteristic of the journal.

Of course, the success of the journal is the result of the work of the entire Editorial Board and of the authors who have decided to submit their best manuscripts to BA. The Editorial Board of BA comprises 10 co-Editors, 1 Managing Editor (Tony Pourmohamad), and 43 Associate Editors from all continents. I would like to thank the past co-Editors who have served many years of dedicated and efficient editorial commitment to the journal: Ming-Hui Chen (2010-2018), Murali Haran (2016-2018) and Mark Steel (2010-2018). I welcome Maria DeIorio (National University of Singapore), Petros DellaPortas (University College, London), Athanasios Kottas (University of California, Santa Cruz) and Alexandra Schmidt (McGill University) as new co-Editors. I would like also to thank all the Associate Editors, who have helped achieve a smooth and high-quality review process. You can learn more about the new Editorial Board on the BA website.

ISBA fully supports Bayesian Analysis as an open access journal and contributes to the payment of its publication fees. These fees are assessed per page, and cover all the aspects of the publishing pipeline: the IT management of the web-based submission platform, the production and editing of the accepted manuscripts, the fully accessible online website and storage of pdfs and code. Please, consider contributing to the publication charges, when you renew your ISBA membership or you have one of your papers accepted in the journal. This way, you will ensure the long-term economic viability of the journal and the dissemination of Bayesian ideas.

In addition to being an open access journal, BA promotes visibility via multiple initiatives: regular announcements on the ISBA mailing list and ISBA bulletin, invited sessions at the ISBA World Meeting and the JSM, Discussion papers, and the Lindley Prize, which is awarded for innovative research in Bayesian Statistics that is presented at an ISBA World Meeting and accepted for publication in BA. In coordination with Danny Williamson (ISBA Web Editor) and Lindsay Shand (ISBA Deputy Web Editor), we will also start promoting newly accepted and published manuscripts through social media.

The March issue of Bayesian Analysis is available on the BA website. The issue contains 11 manuscripts. There is a Discussion paper on "Dynamic Bayesian Influenza Forecasting in the United States with Hierarchical Discrepancy" by Dave Osthus, James Gattiker, Reid Priedhorsky, and Sara Y. Del Valle. The authors propose a dynamic Bayesian flu forecasting model that explicitly accounts for systematic deviations between mechanistic models of disease transmissions and the data that are unable to be explained by pure observational noise. The manuscript introduces and demonstrates

the importance of discrepancy modeling to the growing and consequential field of flu forecasting. In the proposed approach, discrepancy modeling is done hierarchically, allowing information to be shared across available flu seasons. The authors further demonstrate the superiority of the proposed approach relative to all models that competed in the CDC's 2015-2016 and 2016-2017 forecasting challenges. The manuscript is accompanied by thoughtful invited discussions, by Lance Waller, Leonhard Held and Johannes Bracher, and Vladimir N. Minin, Jonathan Fintzi, Luis J. Martinez Lomeli, and Jon Wakefield. A contributed discussion has been written by David Conesa, Ruben Amorós, Antonio López-Quílez, and Miguel-Angel Martinez-Beneito. I hope you enjoy the March issue of BA!

If you have suggestions about how to make Bayesian Analysis even more impactful, please feel free to reach out!

j-ISBA

- Brenda Betancourt -
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Dear ISBA community, 2018 was a great year for j-ISBA full of activities and strides to establish the section as a friendly space for young researches to interact. To start this year, I would like to introduce Trevor Campbell as the new Chair-Elect and myself as the new Treasurer. We are both excited to be more involved in all ISBA activities in a service capacity and really appreciate the community's participation in the voting process. We would like to thank Daniele Durante and Clara Grazian for their hard work in the past year. Their contributions as Chair and Treasurer have greatly strengthen the j-ISBA section. Let's present the board members of j-ISBA for 2019:

Federico Camerlenghi (Chair): Federico is an Assistant Professor at the Department of Economics, Management and Statistics of the University of Milan-Bicocca. He received his Ph.D. in Mathematics and Statistics from the University of Pavia in December 2015 under the supervision of Prof. A. Lijoi and Prof. I. Pruenster, with a thesis entitled "Hierarchical and Nested Random Probability Measures with Statistical Applications". His research interests encompass both computational and methodological aspects of Bayesian nonparametric statistics, including applications to species sampling problems, disclosure risk assessment and survival analysis.

Trevor Campbell (Chair-Elect): Trevor is an Assistant Professor in the Department of Statistics at the University of British Columbia. He received his Ph.D. working in the Laboratory for Information and Decision Systems (LIDS) at MIT. Prior to his graduate studies, he received his B.A.Sc. in Engineering Science from the University of Toronto. His research focuses on scalable, automated Bayesian inference with theoretical guarantees, and Bayesian modeling and inference for streaming data.

Brenda Betancourt (Treasurer): Brenda is an Assistant Professor in the Department of Statistics at the University of Florida. Previously, she was a Postdoctoral Associate in the Department of Statistical Science at Duke University, and obtained her Ph.D. in Statistics at the University of California, Santa Cruz where. She is originally from Bogotá, Colombia. Her research interests include Bayesian nonparametrics, models and algorithms for entity resolution, and network analysis.

Weixuan Zhu (Program Chair): Weixuan got his PhD in Statistics from Universidad Carlos III de Madrid. His thesis was entitled "Flexible Bayesian Nonparametric Priors and Bayesian Computational Methods". Then he went to the University of Sheffield as a postdoc research associate, working on the applications of ABC methods in Ecology population modelling. In 2017, he joined Xiamen University as an Assistant Professor. His research interests include Bayesian nonparametric models, Approximate Bayesian Computation, and MCMC algorithms.

Ilaria Bianchini (Secretary): Ilaria is about to conclude a PhD in "Mathematical models and methods for engineering" at Politecnico di Milano, where she graduated in Mathematical Engineering, with a specialisation in applied statistics. Her research has been focused on Bayesian nonparametric models, clustering and biomedical applications. She was member of the local organising committee of BAYSM, the Bayesian young statistician meeting, held in Florence in June 2016. Currently, she is

working as a research data scientist in a start-up, dealing with statistical models for natural language processing.

In the second half of 2018, j-ISBA had two sessions in conferences: one at JSM in Vancouver, Canada, and another at ERCIM WG (CMStatistics) in London. Both of them presented young researchers' work on Bayesian nonparametrics. To continue with this tradition, we are happy to announce that this year j-ISBA has an invited session at the VI Latin American Meeting on Bayesian Statistics (VI COBAL). The session organized by Isadora Antoniano (Bocconi, Italy) is titled "Junior Contributions to Bayesian Modeling and Inference" and includes talks by junior researchers from Latin America: Isabelle Beaudry (PUC, Chile), Kelly Cristina (UFRJ, Brazil), and Henrique Bolfarine (USP, Brazil). These young researchers are currently working on providing advances in Bayesian inference from different perspectives, covering sampling, regression and high-dimensional sparse models.

Stay tuned for more j-ISBA activities and join our Section! j-ISBA is an open community and we are always happy to hear from our members. Be part of the j-ISBA life through our Facebook group, our Twitter account or our blog (https://jisbablog.wordpress.com/)!

NEWS FROM THE WORLD

Members' News

Bayesian Demography course: Adrian Raftery and Hana Ševčíková will be giving a short course on Bayesian Demography on Lake Como in Northern Italy, June 24-28, 2019. The course outline and programme are available at http://www.mi.imati.cnr.it/conferences/abs19/index.html, where one can also register.

We will be covering core concepts of demography and Bayesian statistics. We will then discuss Bayesian methods for population estimation and projection, some of which have been developed in our group and are now being used by the UN for their official population projections for all countries.

Meetings and conferences

The 12th Bayesian nonparametrics (BNP) meeting will be held in Oxford from the 24th to the 28th of June 2019: http://www.stats.ox.ac.uk/bnp12/

The Bayesian nonparametrics conference is a bi-annual international meeting bringing together leading experts and talented young researchers working on applications and theory of nonparametric Bayesian statistics. It is an official section meeting of the Bayesian Nonparametrics section of the International Society for Bayesian Analysis (ISBA).

You can register and apply for a poster presentation at: http://www.stats.ox.ac.uk/bnp12/registration.html#registration. A poster for the conference is included below.

BayesComp20 will be held at the University of Florida in January of 2020. Deadline for submission of contributed proposals: April 1, 2019. http://users.stat.ufl.edu/~jhobert/BayesComp2020/Conf_Website/

Bayes Comp is a biennial conference sponsored by the ISBA section of the same name. The conference and the section both aim to promote original research into computational methods for inference and decision making and to encourage the use of frontier computational tools among practitioners, the development of adapted software, languages, platforms, and dedicated machines, and to translate and disseminate methods developed in other disciplines among statisticians.

4th EAC-ISBA Conference will be held in Kobe, Japan, July 13-14, 2019. Early registration deadline is March 31, 2019. https://eacisba2019.wordpress.com

The conference serves the Eastern Asia Chapter's purpose of promoting research and education in Bayesian statistics in the area as well as the countries nearby. The conference program includes keynote sessions, tutorial lectures, invited sessions and a poster session. The conference has confirmed the two keynote speakers, Siddhartha Chib (Washington University in St. Louis, USA) and Hedibert Freitas Lopes (INSPER, Brazil). The two tutorial lectures will be given by Dipak K. Dey (University of Connecticut, USA) and Igor Prünster (Bocconi University, Italy)

GEOMED 2019 will be held at the University of Glasgow on 27th - 29th August 2019. It is the XI international, interdisciplinary conference on spatial statistics, geographical epidemiology and geographical aspects of public health. https://www.gla.ac.uk/events/conferences/geomed/

The conference aims to bring together statisticians, geographers, epidemiologists, computer scientists, and public health professionals to discuss methods of spatial analysis, as well as present and debate the results of such analyses.

Bocconi Summer School in Statistics and Probability, July 8-19, 2019, Lake of Como, Italy. Deadline for applications is March 27, 2019. http://bocconi2019.lakecomoschool.org/

The 2019 edition of the Bocconi Summer School in Statistics and Probability, on "Random Graphs and Complex Networks: Structure and Function", will take place on July 8-19, 2019, at Villa del Grumello, Lake Como, Italy.

SOFTWARE HIGHLIGHT

STOCHVOL 2.0.0 – STOCHASTIC VOLATILITY MODELS WITH LEVERAGE IN R

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A key element of modern time series analysis is the dynamic modeling of variance, and capturing its empirical features has become a natural aim of theorists and practitioners alike. The time-variability of volatility has long been documented [16], and stochastic volatility models [SV, 24] are a class of approaches heavily used in finance and econometrics to take into account heteroskedasticity, i.e. the time-dependent structure of price variation. The basic SV model can be formulated as

$$\begin{aligned} y_t &= \exp(h_t/2)\varepsilon_t, \\ h_t &= \mu + \varphi(h_{t-1} - \mu) + \sigma\eta_{t-1}, \end{aligned} \tag{1}$$

for $t = 1, \ldots, T$, where $\vec{y} = (y_1, \ldots, y_T)'$ are observations, usually a log-return series, $\vec{h} = (h_1, \ldots, h_T)'$ is a latent vector, the log-variances, and μ, φ, and σ are the mean, persistence, and volatility of the latent AR(1) process. The increment series $(\varepsilon_t)_{t=1}^T$ and $(\eta_t)_{t=1}^{T-1}$ are serially and mutually independent standard normals. The two sources of randomness and the latent state space structure make SV a flexible and intuitive tool for variance modeling. However, despite SV's appeal [e.g., 19], GARCH [2, 6] models have historically become more popular among practitioners owing to the challenging estimation of SV compared to GARCH (especially in the frequentist setting [8]) and to the lack of standard software for the estimation of SV.

The `stochvol` [13] package is an attempt at addressing the need for user-friendly SV estimators. The package was first published through the Comprehensive R Archive Network (CRAN) in January 2013 and has since undergone dozens of refinements and updates. From its early stages on, it has featured several variants of the ancillarity-sufficiency interweaving strategy [ASIS, 14, 25] and joint sampling of the states "all without a loop" [17]. In addition, it resorts to computationally efficient C and C++ code which is interfaced to R via `Rcpp` [5]. As a result, `stochvol` has been providing a means to computationally fast and numerically stable inference for SV models for over six years now. The package can be used in a standalone fashion [12] or as a "plug-in" within more elaborated schemes such as vector autoregressions [10] or factor models [15]. In February 2019, `stochvol` received a major upgrade to support the modeling of asymmetric returns. The new functionality is not yet well documented, therefore the aim of this article is to briefly describe this new addition and to exemplify some usage possibilities.

The leverage effect

By definition, the leverage effect is the negative dependence between the rate of return and the change in volatility, and it is an extension to volatility models for capturing asymmetric returns. The phenomenon was first described by Black [1], who possibly also coined the term. Put simply, his explanation was based on firm leverage in the Modigliani-Miller firm structure model [18].

Out of a multitude of ways to incorporate the leverage effect [e.g., 3, 4, 7, 11, 20], `stochvol` implements the SV model with leverage [SVL, 11] that involves a correlation term between the log-returns and the increments of the log-volatility. More precisely, SVL extends (1) by

$$\operatorname{cor}(\varepsilon_t, \eta_t) = \rho, \tag{2}$$

for $t = 1, \ldots, T-1$, where ρ captures the leverage effect.

Bayesian inference

The non-linear relationship between the observations and the latent states makes statistical inference non-trivial. A carefully designed simulation algorithm is thus needed to obtain a practical and useful piece of software. From a bird's eye view, `stochvol` implements a Markov chain Monte Carlo (MCMC) method that iterates over two Metropolis-Hastings acceptance-rejection steps to sample from $p(\vec{h}, \mu, \varphi, \sigma, \rho \mid \vec{y})$:

1. Draw $\vec{h}$ from $p(\vec{h} \mid \mu, \varphi, \sigma, \rho, \vec{y})$ using an independence proposal generated via the auxiliary conditionally Gaussian state space sampler in [21].
2. Draw $(\mu, \varphi, \sigma, \rho)'$ from $p(\mu, \varphi, \sigma, \rho \mid \vec{h}, \vec{y})$ using a four-dimensional random walk proposal. The default setting in `stochvol` is to find a suitable proposal covariance matrix based on a pre-burnin estimation of the SV model without leverage. Moreover, this part's sampling efficiency is boosted by repeated ASIS steps [9, 25].

Prior distributions

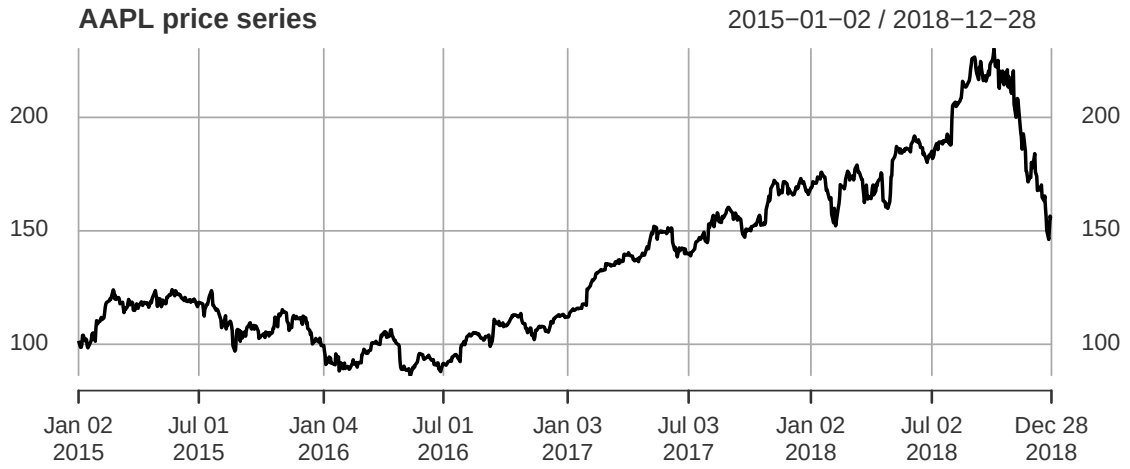
Prior elicitation is a crucial building block of Bayesian inference. The `stochvol` package implements standard (independent) priors [14, 21]: $\mu \sim \mathcal{N}(\mu_\mu, \sigma_\mu)$, $(\varphi+1)/2 \sim \text{Beta}(\alpha_\varphi, \beta_\varphi)$, $(\rho+1)/2 \sim \text{Beta}(\alpha_\rho, \beta_\rho)$, and $\sigma^2 \sim B_\sigma \chi^2_1$. Alternatively, σ^2 can be inverse Gamma distributed matching the first two moments of $B_\sigma \chi^2_1$. Using $\mu_\mu = 0$ and $\sigma_\mu = 100$ forms a quite uninformative setup for μ; $\alpha_\varphi = 5$ and $\beta_\varphi = 1.5$ constitutes a weak prior belief in persistence; $\alpha_\rho = 4$ and $\beta_\rho = 4$ imply a slightly informative prior for ρ; $B_\sigma = 1$ defaults to a vague prior that does not bound σ away from zero. These values can be set via the input parameters `priormu`, `priorphi`, `priorrho`, and `priorsigma`.

A case study on Apple

The core sampling function that estimates the SVL model is `svlsample`. It inherits the already established programming interface of `svsample` – the corresponding function without leverage – as much as possible. We use the daily adjusted closing stock prices of Apple Inc. (AAPL) in the period 2015–2018 to exemplify `stochvol`'s newest features. The data source is Yahoo! Finance which we access through the `quantmod` [23] package.

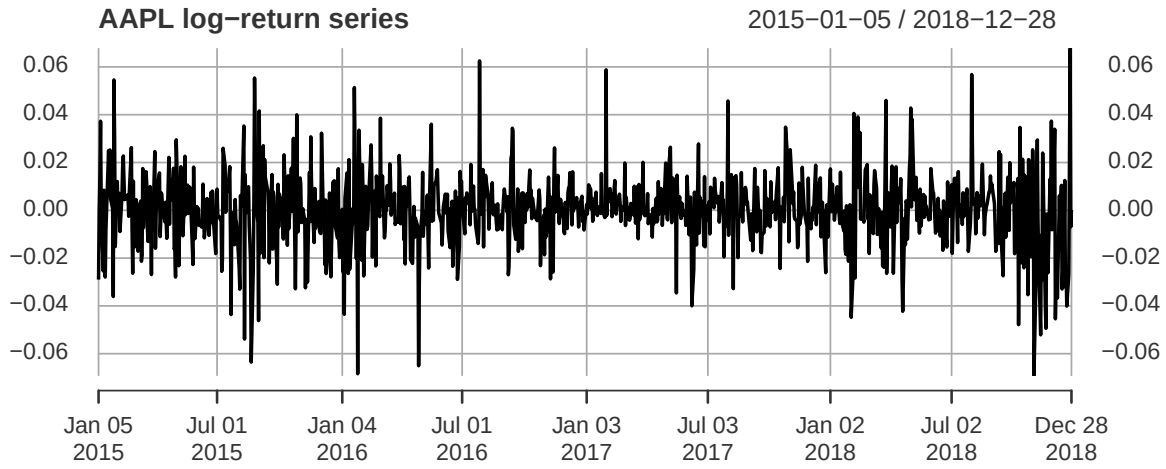
Below is an illustration of how to acquire and plot the price information. Note that `svlsample` expects a univariate numeric vector `y` without `NA`s.

```
library(quantmod)
getSymbols("AAPL", from = "2015-01-01", to = "2018-12-31")
price <- na.omit(AAPL$AAPL.Adjusted)
plot(price, main = "AAPL price series")
```



The `logret` function comes in handy to calculate de-meaned log-returns.

```
library(stochvol)
logreturn <- logret(price, demean = TRUE)
plot(logreturn, main = "AAPL log-return series")
```

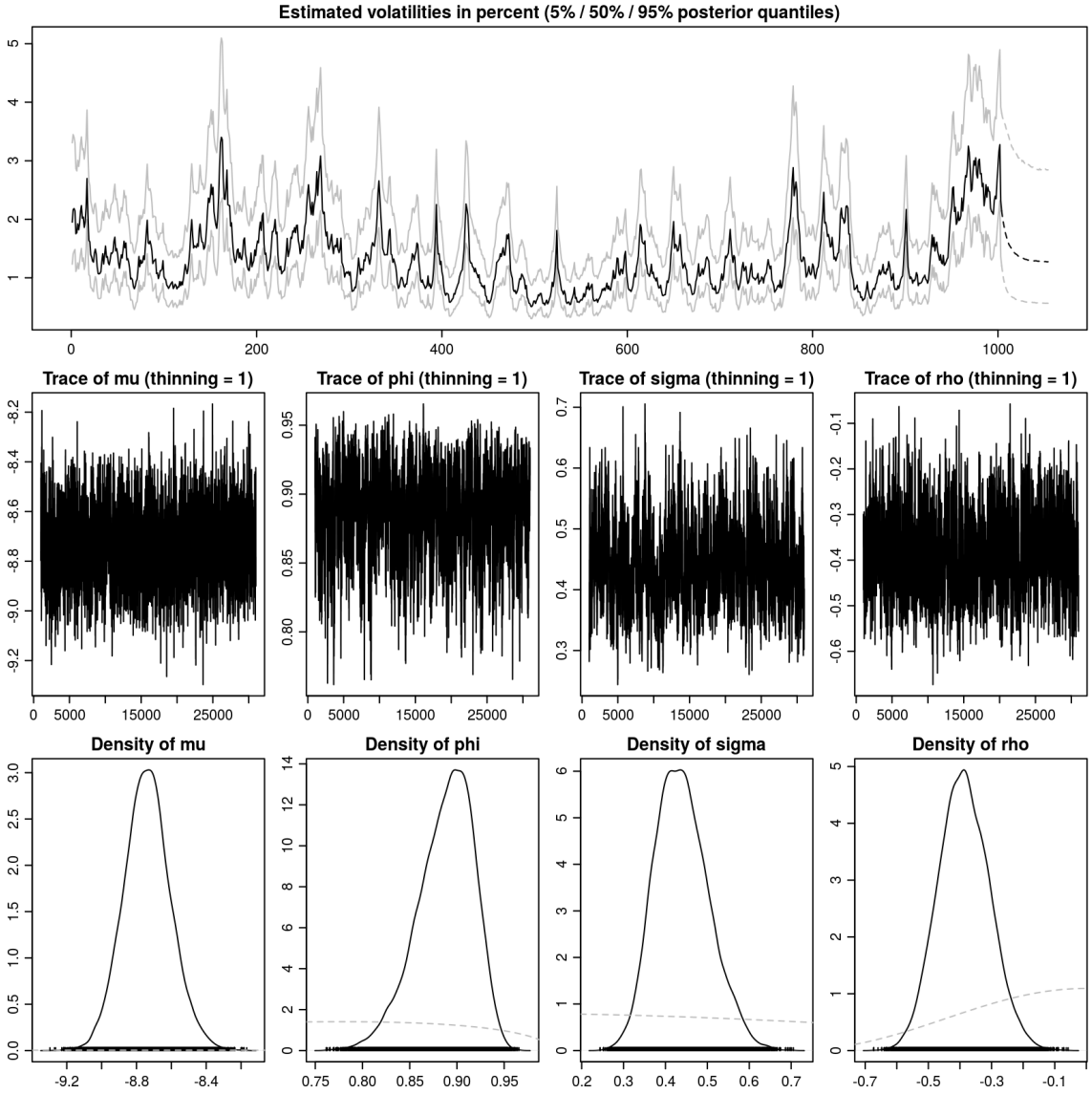


Running the sampler boils down to:

```
svlres <- svlsample(logreturn, draws = 30000)
```

The output object `svlres` contains posterior draws stored as `coda` [22] objects, priors, data, runtime information, and summary statistics, among other information. After the progress bar is full, we can plot a summary of the posterior distributions and a 50-step ahead forecast:

```
plot(svlres, forecast = 50)
```



The resulting graphic contains three rows. The top panel shows quantiles of the posterior volatility (in percent), alongside quantiles of the posterior predictive distribution thereof. The lower panels display trace plots of the Markov chain together with the prior (dashed lines) and the posterior (solid lines) distributions of μ, φ, σ, and ρ. We ascertain the validity of the results by looking at the trace plots to investigate whether the Markov chain is stable and mixes well. In our experience, if the parameters are sampled efficiently, then the entire MCMC estimation (including the latent states) is reliable.

In the case of Apple, this visual summary convinces us that the Markov chain is stable, so the densities are a good approximation of the marginal posteriors. Importantly, the substantial deviation of the posterior from the prior in all four plots indicates that the likelihood contains considerable information about the parameters. As practically all the mass of $p(\rho \mid \vec{y})$ lies below zero, we establish a significant leverage effect for Apple's closing prices in the period under investigation.

SV as a nested model

The class of SV models is essentially a specification capturing heteroskedasticity, therefore nesting SV in larger schemes and using it as the increment distribution is a rather natural idea. For instance,

by using the SVL formulation given in (1) and (2), we implicitly assume that the log-price is moving according to a random walk with SVL increments, i.e. the first equation in (1) can be rewritten as

$$\log(p_t) = 0 + 1 \cdot \log(p_{t-1}) + \exp(h_t/2)\varepsilon_t, \tag{3}$$

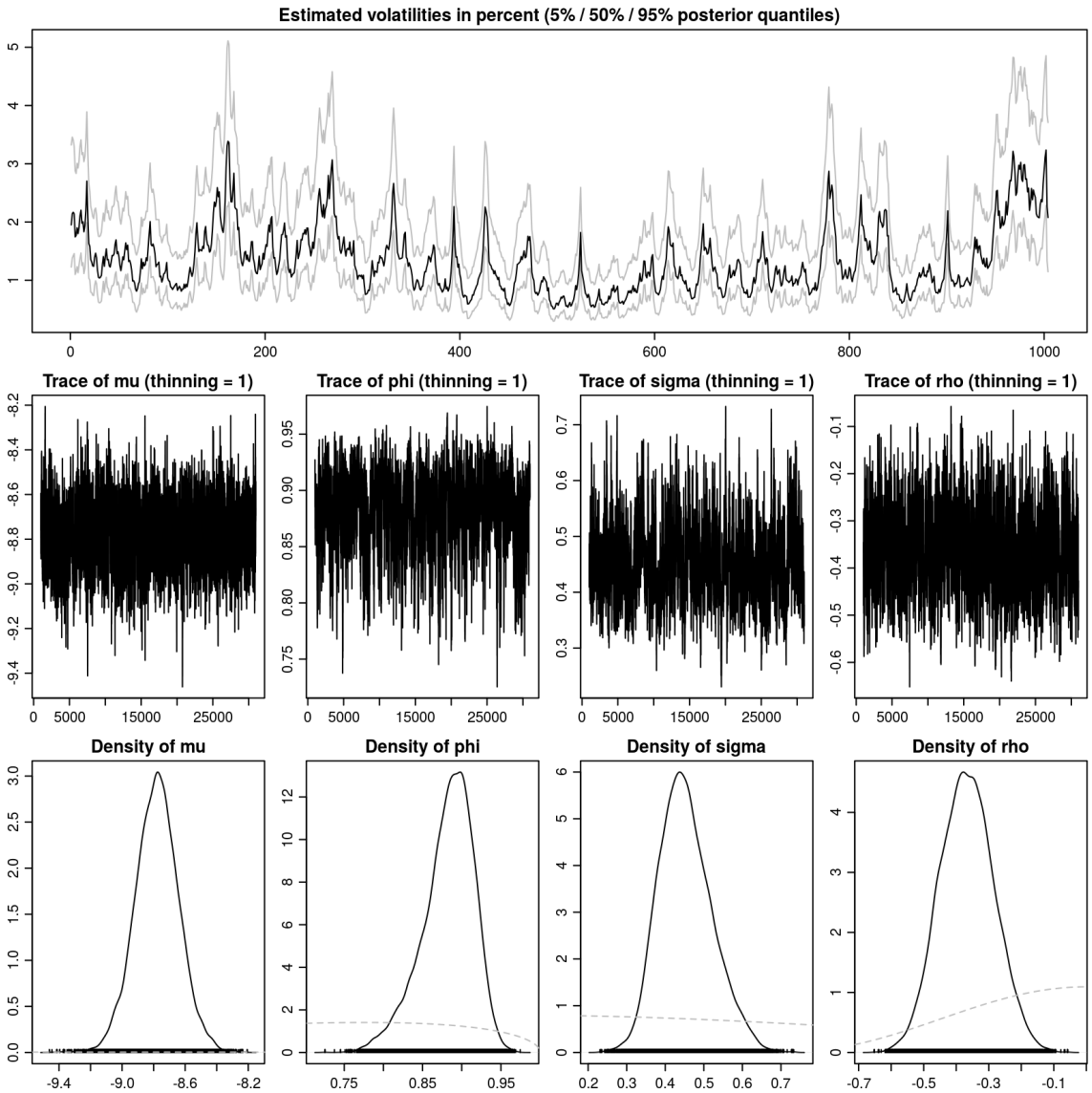
where p_t denotes the price at time t. Formulated that way, a natural extension of (3) is an AR(1) structure on the log-price with SVL increments:

$$\log(p_t) = \beta_0 + \beta_1 \log(p_{t-1}) + \exp(h_t/2)\varepsilon_t. \tag{4}$$

These Bayesian linear regression models, including AR(q), are natively implemented in `stochvol`. They are accessible through the input parameter `designmatrix` both in the case of `svsample` and `svlsample`. In the general case of linear regression, `designmatrix` accepts a matrix of regressors, but the string `"arq"` is sufficient for an AR(q) model, e.g. `"ar0"` for a constant mean model, `"ar2"` for an AR(2) model.

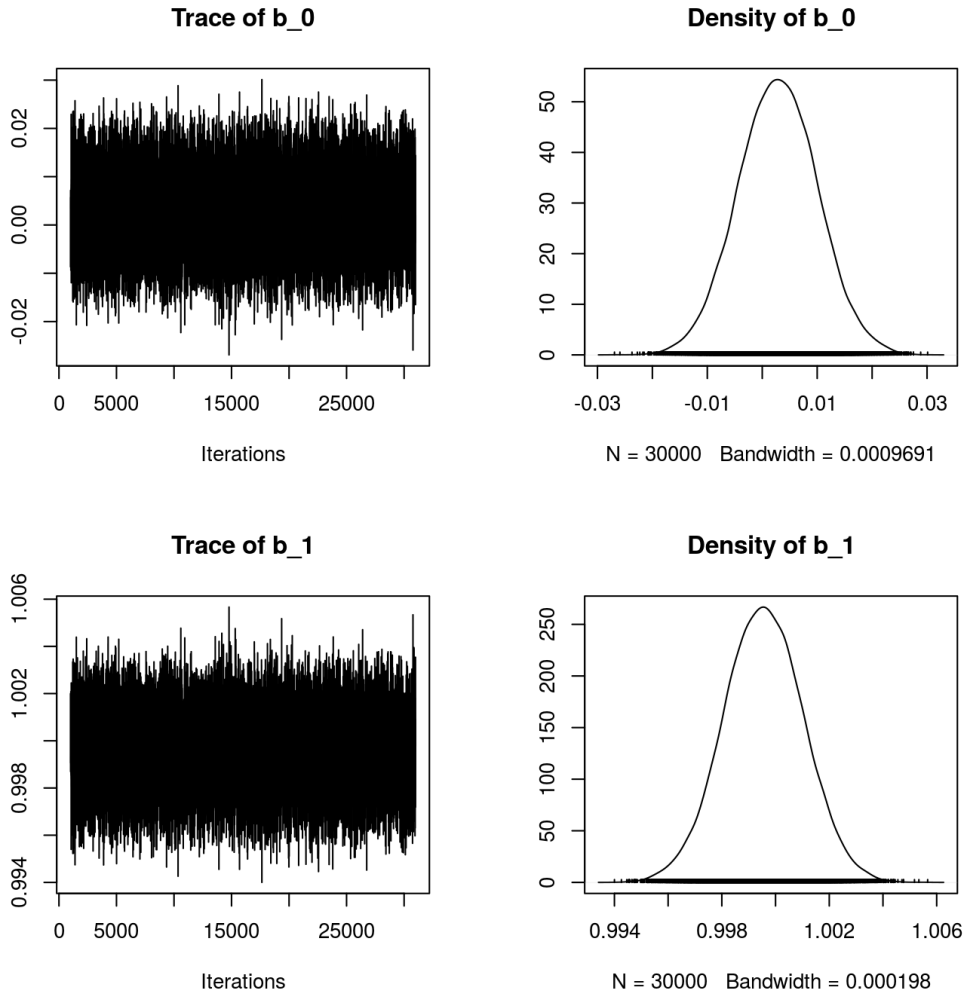
The code snippet below demonstrates how to estimate and plot (4) with SVL increments:

```
svlres2 <- svlsample(log(price), designmatrix = "ar1", draws = 30000)
plot(svlres2)
```



The estimates have not changed significantly. Now we check the marginal posteriors of the βs:

```
plot(svlres2$beta)
```



Based on these results, we do not find evidence against model (3). The AR(1) structure on the log-price seems superfluous.

For other models that nest SV(L), the functions `svsample2` and `svlsample2` may prove useful. They are faster and lighter variants of `svsample` and `svlsample`, respectively, by omitting any input validation. Moreover, R packages linking to `stochvol` can make use of the C++ functions `update_sv` and `update_svl`, the workhorse procedures under the hood. For an example package that calls low-level updates directly, see the `factorstochvol` [15] package on CRAN.

More information

The `stochvol` package is available on CRAN under https://CRAN.R-project.org/package=stochvol, and also on GitHub under https://github.com/gregorkastner/stochvol.

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