

AN APPLICATION OF DYNAMIC FACTOR MODELS TO NOWCAST REGIONAL ECONOMIC ACTIVITY IN SPAIN **2019**

María Gil, Danilo Leiva-Leon, Javier J. Pérez
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Documentos Ocasionales
N.º 1904

BANCO DE ESPAÑA
Eurosistema



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ISSN: 1696-2230 (on-line edition)

Abstract

The goal of this paper is to propose a model to produce nowcasts of GDP growth of Spanish regions, by means of dynamic factor models. This framework is capable to incorporate in a parsimonious way the relevant information available at the time that each forecast is made. We employ a Bayesian perspective to provide robust estimation of all the ingredients involved in the model. Accordingly, we introduce the Bayesian Factor model for Regions (BayFaR), which allows for the inclusion of missing data and combines quarterly data on regional real output growth (taken from the database of the AIReF and from the individual regional statistics institutes, when available) and monthly information associated to indicators of regional real activity. We apply the BayFaR to nowcast the GDP growth of the four largest regions of Spain, and illustrate the real-time nowcasting performance of the proposed framework for each case. We also apply the model to nowcast Spanish GDP in order to be able to assess the relative growth of each region.

Keywords: regional activity, nowcasting, dynamic factor model.

JEL classification: C32, E37, R13.

Resumen

El objetivo de este trabajo es el desarrollo de modelos de factores dinámicos para generar estimaciones de crecimiento del PIB a corto plazo (*nowcast*) a escala regional. El uso de esta metodología permite incorporar, de una manera parsimoniosa, la información relevante disponible en el momento de realizar las estimaciones. Se utiliza una perspectiva bayesiana para conseguir estimaciones robustas de todos los ingredientes del modelo. Así, se introduce el modelo de factores bayesiano para las regiones (BayFaR, denominación en inglés), que permite incluir indicadores con observaciones no disponibles, así como combinar distintas frecuencias: tasas de crecimiento del PIB para las diferentes regiones en frecuencia trimestral (obtenidas tanto de AIREF como de los institutos de estadística regionales) e información mensual procedente de los indicadores de actividad regional. Aplicamos el modelo de factores bayesiano con el propósito de obtener estimaciones de crecimiento del PIB a corto plazo para las cuatro mayores regiones de España, y se ilustra la evolución de las estimaciones en tiempo real en cada uno de los casos. También se aplica el mismo modelo para realizar el *nowcast* del PIB del conjunto de la economía a fin de poder valorar la evolución relativa de cada una de las regiones.

Palabras clave: actividad regional, *nowcasting*, modelo de factores dinámicos.

Códigos JEL: C32, E37, R13.

INDEX

Abstract 5

Resumen 6

1 Introduction 8

2 Data sources 11

3 Nowcasting Regional Economic Activity 15

3.1 Methodology 15

3.2 Illustration on the real-time performance of the models 16

References 20

ANNEX I 21

ANNEX II. Bayesian estimation algorithm 22

ANNEX III. Short-term regional indicators dynamics 24

1 Introduction

During recent years, there has been an increasing interest in studying how economic shocks propagate through the regions of a given country.¹ This information could help policy makers to identify the underlying sources of aggregate fluctuations, which in turn, would contribute to design policies that promote macroeconomic stability. Nonetheless, despite the existence of an active field of study of regional economics, the macroeconomic analysis of short term developments at the subnational level tends to be restricted in many countries due to data limitations.

In Spain, while first figures of national quarterly Gross Domestic Product (GDP) are released just one month after the corresponding quarter ends by the National Statistical Institute (INE, henceforth), its distribution among regions is not available from the same, official source. Indeed, INE publishes homogeneous and complete regional GDP accounts only at the annual frequency. The so called Spanish Regional Accounts (SRA) are elaborated by the INE with the main objective of providing a quantified, systematic and complete description of the regional economic activity in Spain (Autonomous Communities and provinces). Among other variables, these accounts provide a homogeneous and consistent measure of GDP, consistent with the SNA. In addition, though, the statistical agencies of eleven regions (Comunidades Autónomas, CCAA henceforth) compile their own quarterly GDP figures. Seven of these eleven CCAA produce their own annual “national” accounts, which do not necessarily coincide with the annual figures of the SRA. It is worth mentioning that, according to the Spanish legislation, absent national statistics those produced by the CCAA are to be considered the official ones, to be taken as the reference when needed for policy or other purposes.

This implies that when policy makers need to assess, in real-time, regional developments of the economy, they need to rely either on out-of-date (annual) information or on non-homogeneous (quarterly) figures. This feature poses a significant limitation when they are interested in inferring relative potential changes in economic trends of a given region, or set of regions, triggered by specific events or policies.

Under this context, an alternative is to rely on high frequency indicators. As it is shown in Artola et al. (2018), the lack of homogeneous and official quarterly measures of aggregate regional activity (in particular, real GDP) for the Spanish economy is somehow compensated by the availability of a large set of regional economic indicators at the monthly frequency. As it is emphasized in Stock (2005), a way to deal with the limitations that policy makers face when inferring short-term regional GDP developments is to combine different sources of information in order to provide timely and accurate inferences. This is the line that Cuevas and Quilis (2015) follow when computing estimates of quarterly real GDP for all the Spanish regions.²

1 Some recent examples are Leiva-Leon (2017) and Gadea-Rivas et al. (2019), who analyze the propagation of business cycle shocks among regions of the United States and the European Union, respectively.

2 The estimates of quarterly regional GDP are obtained by combining annual, quarterly and monthly information at the regional level, and the corresponding data is regularly published at the Independent Authority of Fiscal Responsibility's (AIReF henceforth) webpage.

Although the use of econometric methodologies to mix data from different frequencies has been widely used to predict national output growth, there is only few works that have focused on using them to provide very-short-term forecasts, also called as “nowcasts”, of GDP growth at the regional level. In particular, Henzel et al. (2016) focus on nowcasting the GDP growth of the German region of Saxony by feeding regional, national and international information into bridge equations. Also, Lehmann and Wohlrabe (2013) pursue a similar goal, but in addition, they provide forecasts for the state of Baden-Wuttemberg. More sophisticated techniques for mixing data frequencies, such as MIDAS regressions, have been used by Grant et al. (2015) to nowcast the GDP growth of the Scottish region of the United Kingdom. Another type of tools that has been proven to be successful in tracking GDP growth dynamics in real-time is factorial analysis. This type of analysis is typically used to extract the common dynamics from a set of real activity indicators and then use that information to predict a target variable, for example, aggregate output. A recent example is Bok et al. (2017) who produce nowcasts of GDP growth for the U.S. economy, published by the Federal Reserve Bank of New York, by relying on a dynamic factor framework.³ At the regional level, Chernis et al. (2017) also employ factor models for nowcasting Canadian provincial GDP, which is released by Statistics Canada on an annual basis, with a lag of eleven months.

It is important to notice that most of previous studies focused on regional nowcasting rely on models that are estimated with classical methods. Nonetheless, when dealing with data at the regional level, due to its higher degree of disaggregation, some undesired features are more present than when working with data at the national level. In particular, regional data tend to exhibit much noisier dynamics, outliers are more frequent, and the sample length availability is usually shorter than for the case of national data. The data on indicators of regional activity of Spain is not the exception, and it is subject to all these features. The combination of these undesired characteristics in the data may generate problems when estimating forecasting models to nowcast regional developments. Specifically, when using a dynamic factor model to perform real-time forecasts, the model needs to be re-estimated as new information arrives. Consequently, the inclusion of newly arrived data that may not be well behaved could potentially induce large variations in the path of the nowcasts of a given quarterly GDP figure, and in worst cases, abrupt changes in the direction of the nowcasting path trend, delivering mixed signals to the policy maker.

An alternative that provides robust results in recursive estimations of large models and tends to be less sensitive to the undesired features in the data described above, is the Bayesian estimation method. This is because, unlike classical methods, when using a Bayesian framework there is no need of a maximization procedure to compute estimates of the parameters of interest, instead, the posterior densities of all the elements in the model are simulated based on the notion of Monte Carlo Markov Chains. A couple of additional advantages of Bayesian methods in comparison with classical ones is the ability, first, to provide a full description of the entire distribution of the forecasts, and consequently to perform robust inference, and second, to handle

³ Dynamic factor models have been also used to nowcast output growth of a given country, e.g. U.S., in nominal terms (Barnett et al. (2016)) and in real terms (Mariano and Murasawa (2003)), or the output growth of a union of countries, e.g. the euro area, (Camacho and Pérez-Quirós (2010)).

easily with a model that contains a potentially large number of predictive indicators. Bayesian methods are neither free of shortcomings, since under certain conditions the final estimation results might be highly sensitive to the prior information induced in the framework. However, when the models are linear, this sensitivity to the prior tends to be relatively small, providing robustness to the final estimates. In recent work, Koop et al. (2018) propose a Mixed-frequency VAR model, estimated with Bayesian methods, to nowcast regional output growth for the regions of the United Kingdom, showing successful results under large dataset environments.

The goal of this paper is to propose a model to produce nowcasts of GDP growth of Spanish regions. In doing so, we rely on dynamic factor models due to its ability to synthesize diverse information contained in several indicators into a single index, which turns out to be useful to produce accurate forecasts of a target variable. Moreover, this framework is capable to incorporate in a parsimonious way the relevant information available at the time that each forecast is made. In particular, the proposed model would be able to produce real-time inferences of real GDP growth for different regions of Spain. By taking into account the above discussion about the estimation methods, we employ a Bayesian perspective to provide robust estimation of all the ingredients involved in the model. Accordingly, we introduce the Bayesian Factor model for Regions (BayFaR), which allows for the inclusion of missing data and combines quarterly data on regional real output growth (taken from the database of the AIReF and from the individual regional statistics institutes) and monthly information associated to indicators of regional real activity. We apply the BayFaR to nowcast the GDP growth of four of the largest regions of Spain, which are, Andalusia, Catalonia, Madrid and Valencian Community, and illustrate the real-time nowcasting performance of the proposed framework for each case. We also apply the model to nowcast Spanish GDP in order to be able to assess the relative growth of each region.

Overall, the proposed BayFaR proves to be a versatile and reliable tool to provide timely assessments of GDP growth at the regional level. This is due to its robustness to the irregularities inherent in the regional data on real activity. Moreover, the framework is able to produce accurate nowcasts of national GDP growth. Therefore, it can be also used as a complementary tool in the suite of short-term forecasting models employed by the Banco de España to track national activity.

The rest of the paper is organized as follows. Section 2 provides a description of the data used in the empirical framework. Section 3 describes the nowcasting model and shows its real-time forecasting ability.

2 Data sources

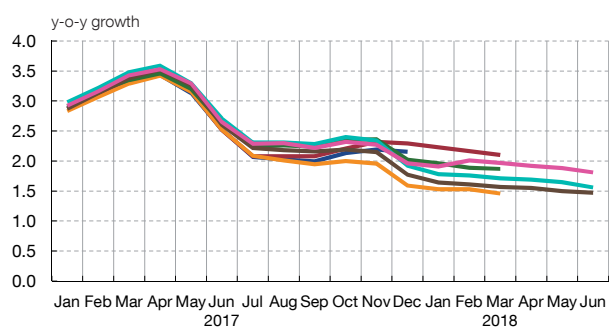
As mentioned above, the INE elaborates the so called Spanish Regional Accounts (SRA). The data published under this statistical operation are annual, and cover the sample period that starts in 1980. Nonetheless, the INE does not elaborate neither by itself nor in cooperation with regional statistical institutes a companion set of quarterly regional accounts.

In this regard, as discussed in Artola et al. (2018), the statistical agencies of eleven regions (Andalusia, Aragon, Canary Islands, Cantabria, Castilla Leon, Catalonia, Extremadura, Galicia, Madrid, Navarre and the Basque Country) compile their own quarterly GDP figures, including some demand and/or supply side breakdown. Interestingly, seven of these eleven CCAA produce their own annual “national” accounts, which do not necessarily coincide with the annual figures of the SRA. Although all of them share the general principles contained in the European System of National Accounts, they are not fully homogeneous in their methodology, selection of sources, operational procedures and time coverage. The comparison between real GDP annual growth rates according to INE’s SRA and the regional statistics institutes, for those regions, is depicted in Annex I, Chart A.1.1. The differences between the two sources are generally limited, with some exceptions, though, in some specific periods of time and regions. As regards quarterly GDP figures produced by the regional statistics institutes, they are consistent in this seven cases with their own annual GDP figures. In the other cases their estimated quarterly GDP is either fully consistent with INE’s SRA (Canary Islands and Extremadura), or based on economic indicators. This information is summarized in Table 1.

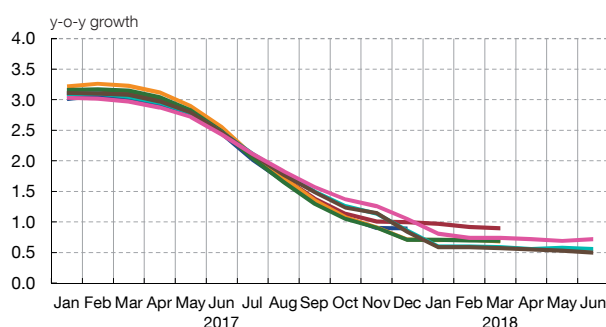
Instead, the availability of standard economic indicators at the regional level is significant in the case of Spain, and a fair subset of them is available in a homogeneous fashion for all (or most of) the CCAA, see Artola et al. (2018) for a detailed description of all available regional economic indicators. For the purposes of short-term economic analysis performed in real-time, though, a number of indicators pose some technical difficulties which had to be tackled before the time series are in shape for the analyst. First, and unlike data pertaining to the country as a whole, in many cases the published time series are not adjusted for calendar and seasonal effects (a prominent example being the Industrial Production Index), so it is necessary to resort to methodologies, like TRAMO-SEATS, to adjust the raw, original data. Second, the time coverage of some statistics is shorter than the available for the national indexes. Finally, some series present breaks or missing observations over the available time span for which they are published, typically following methodological changes or changes in the scope of the statistic.

The lack of homogeneous quarterly national accounts’ data for all the Spanish regions, in a situation in which there is a relatively fair number of short-term economic indicators, from comparable sources, has led some economic institutions and researchers in Spain to engage in the hurdle of producing their own datasets. Of particular note is the dataset of Cuevas and Quilis (2015), given its methodological soundness and the fact that it is freely available from AIReF’s webpage. The authors obtain quarterly estimates of real GDP for all the Spanish regions, derived in a consistent way with the official data provided by the National Accounts, both SRA

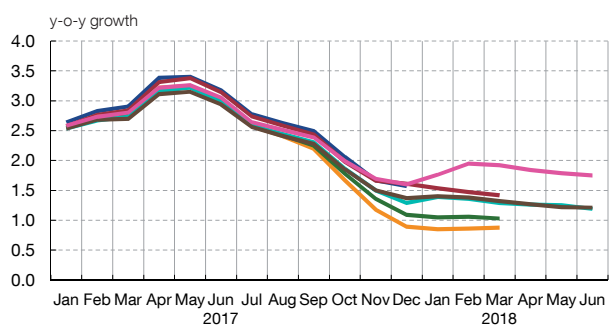
1 ANDALUSIA



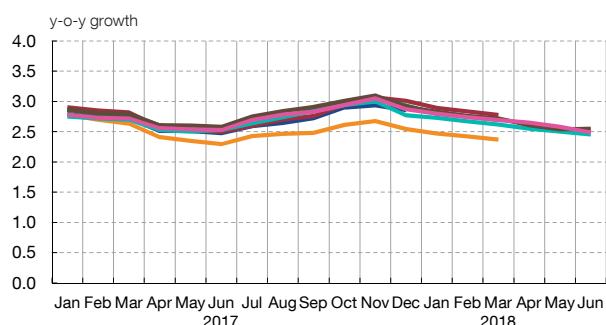
2 CATALONIA



3 VALENCIAN COMMUNITY



4 MADRID



13 DEC. 2017 27 DEC. 2017 11 JAN. 2018 29 JAN. 2018 08 FEB. 2018 21 FEB. 2018 02 MAR. 2018

SOURCE: Own elaboration.

QUARTERLY REGIONAL ACCOUNTS PUBLISHED BY REGIONAL STATISTICS INSTITUTES

TABLE 1

	Regional Statistics Institute (link to web page)	Availability	Consistency with INE Annual Accounts (a)
Andalusia	IECA	Yes	No
Aragon	IAEST	Yes	No
Asturias	SADEI	No	—
Balearic Islands	IBESTAT	No	—
Canary Islands	ISTAC	Yes	Yes
Cantabria	ICANE	Yes	No
Castilla Leon	ECL	Yes	No
Castilla La Mancha	IES	No	—
Catalonia	IDESCAT	Yes	No
Valencian Community	PEGV	No	—
Extremadura	IEEX	Yes	Yes
Galicia	IGE	Yes	No
Madrid	IEM	Yes	No
Murcia	CREM	No	—
Navarre	NASTAT	Yes	No
Basque country	EUSTAT	Yes	No
La Rioja	IER	No	—

SOURCE: Regional Statistics Institutes.

a Consistency measured at the cut-off date of this document (15th July, 2018).

SHORT-TERM INDICATORS OF REGIONAL ECONOMIC ACTIVITY AND CORRELATION WITH GDP GROWTH **TABLE 2**

	Social Security registrations	Industrial production index	Retail trade index	Services sector activity index	Commercial motor vehicles registrations
Quarterly growth rates and AIReF data for GDP					
Andalusia	0.89	0.64	0.64	0.78	0.36
Catalonia	0.90	0.52	0.67	0.80	0.51
Valencian Community	0.91	0.54	0.68	0.81	0.23
Madrid	0.90	0.48	0.65	0.67	0.31
Quarterly growth rates and Regional Institutes data for GDP					
Andalusia	0.86	0.64	0.63	0.78	0.41
Catalonia	0.87	0.60	0.56	0.85	0.54
Valencian Community	—	—	—	—	—
Madrid	0.91	0.41	0.63	0.69	0.36
Annual growth rates and AIReF data for GDP					
Andalusia	0.96	0.80	0.83	0.89	0.47
Catalonia	0.95	0.60	0.83	0.89	0.56
Valencian Community	0.95	0.65	0.84	0.92	0.53
Madrid	0.95	0.78	0.80	0.86	0.45
Annual growth rates and Regional Institutes data for GDP					
Andalusia	0.95	0.80	0.85	0.90	0.52
Catalonia	0.94	0.71	0.83	0.95	0.65
Valencian Community	—	—	—	—	—
Madrid	0.96	0.82	0.80	0.89	0.52

SOURCES: INE, AIReF, Regional Statistics Institutes and own elaboration.

and Quarterly National Accounts. Following this methodology, the AIReF is able to release early (or flash) estimates of quarterly regional GDP almost synchronized with the publication by the INE of the quarterly national GDP. Quite importantly, the methodology ensures that transversal consistency is compliant with the chain linking procedures, circumventing its non-additive features in the balancing step. Differences among the quarterly real GDP series produced by the AIReF and those of the regional statistical institutes are not major, but are not negligible either, particularly when considered as tools to assess macro-regional developments in real-time.

Thus, we approach the problem at hand by benchmarking both regional quarterly GDP datasets: the AIReF one, as described above, and the one compiled from the regional statistical institutes, when available (from its individual web sites).

Given the available set of information on regional activity, we select some indicators at the monthly frequency to use them in our nowcasting model, which is described below. In particular, we use (i) Social Security Registrations, (ii) Industrial Production Index, (iii) Retail Trade Index, (iv) Services Sector Activity Index, and (v) Commercial Motor Vehicles Registrations. The reasoning for this selection relies on the work by Camacho and Pérez Quirós (2011), who also proposed a dynamic factor model to nowcast Spanish GDP growth, but at the national level. The authors showed that the combination of information contained in the selected indicators delivers a useful signal to produce accurate predictions of national GDP. Moreover, as it is shown in Table 2,

the correlation between the selected activity indicators and the GDP associated to a particular region is substantially high, especially for Social Security Registrations and Services Sector Activity Index. This pattern of high correlation persists independently on (i) whether we use the GDP published by the AIReF or by the Regional Institutes of Statistics, or (ii) if we use quarterly or annual frequency. These statistics provide additional empirical evidence about the reliability of the selected indicators to produce accurate forecast of regional activity.⁴

⁴ The dynamics of both GDP growth and real activity indicators, at the regional level, are plotted in Chart A3.1 of the Annex III, showing that despite some heterogeneity, all the variables tend to display a considerable degree of comovement.

3 Nowcasting Regional Economic Activity

In this section, we describe the proposed framework to construct short-term forecasts of regional output, denoted as the BayFaR. Next, we turn to illustrate the performance of the model by applying it to produce nowcasts of the output growth of four Spanish regions, which are, Andalusia, Catalonia, Valencian Community and Madrid and at the national level. The motivation for choosing those regions rely on the large economic weight that they have on the national aggregate output. However, the framework can be easily applied to generate nowcasts of any other region of interest.

3.1 Methodology

To combine information at the quarterly and monthly frequencies, we rely on the approximation proposed by Mariano and Murasawa (2003). Let y_t^* and y_t be the quarterly and monthly growth rates of GDP, respectively. Next, the quarterly growth rates can be expressed as a weighted sum of monthly growth rates,

$$y_t^* = \frac{1}{3} y_t + \frac{2}{3} y_{t-1} + y_{t-2} + \frac{2}{3} y_{t-3} + \frac{1}{3} y_{t-4}$$

Moreover, to reduce the detrimental effects of the noisy signals that characterize the monthly growth rates of regional real activity indicators, we express such data in annual growth rates.⁵

We assume that there is a single common factor, f_t , underlying the dynamics of the observed quarterly output growth, y_t^* , and the monthly activity indicators, $x_{i,t}$, along with corresponding idiosyncratic terms for output, $u_{y,t}$, and for each monthly indicator, $u_{i,t}$, which are cross-sectionally independent, for $i = 1, 2, \dots, n$. Therefore, quarterly regional output growth can be expressed as,

$$y_t^* = \lambda_y \left(\frac{1}{3} f_t + \frac{2}{3} f_{t-1} + f_{t-2} + \frac{2}{3} f_{t-3} + \frac{1}{3} f_{t-4} \right) + \left(\frac{1}{3} u_{y,t} + \frac{2}{3} u_{y,t-1} + u_{y,t-2} + \frac{2}{3} u_{y,t-3} + \frac{1}{3} u_{y,t-4} \right)$$

while monthly growth rates of regional real activity indicators are expressed as follows,

$$x_{i,t} = \lambda_i \sum_{j=0}^{11} f_{t-j} + u_{i,t}$$

The common factor is assumed to evolve according to an autoregressive process of second order,

$$f_t = \phi_1 f_{t-1} + \phi_2 f_{t-2} + v_t$$

with $v_t \sim N(0, 1)$. Similarly, the idiosyncratic terms associated to the monthly indicators are assumed to follow second order autoregressive processes,

⁵ This strategy is also employed in Camacho and García-Serrador (2014) to nowcast output growth of the euro by including financial activity indicators.

$$u_{i,t} = \psi_{i,1} u_{i,t-1} + \psi_{i,2} u_{i,t-2} + \varepsilon_{i,t}$$

with $\varepsilon_{i,t} \sim N(0, \sigma_i^2)$, while the idiosyncratic term of output growth is assumed to be a white noise, that is, $u_{y,t} \sim N(0, \sigma_y^2)$.⁶

The model is estimated by using the Gibbs sampler, which consists on, first, generating draws of the parameters of the model from appropriate posterior distributions, conditional on the factor. Second, generating draws of the factor by using the Carter and Kohn (1994) algorithm, conditional on the parameters of the model. Third, repeat the previous two steps a large number of time to simulate an empirical posterior distribution of both factor and parameters. More details about the estimation algorithm can be found in the Appendix II.

3.2 Illustration on the real-time performance of the models

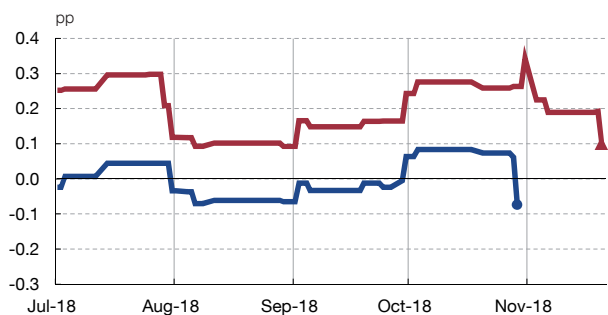
The BayFaR receives as input the information about monthly indicators and quarterly GDP growth of a given region, and returns two important outputs. The first one corresponds to the underlying common factor, which can be interpreted as an index that summarizes all the economic activity developments taking place in that region. The second output makes reference to the short-term predictions of the current GDP growth associated to that region. While both types of output provide valuable information about the stance of real activity in a given region, their interpretations are somewhat different. On the one hand, the index of economic activity measures the strength of the economic performance associated to that region during a specific month, and therefore, this information is useful to make comparisons, at the monthly frequency, between current with past strengths of regional real activity. On the other hand, the nowcasts derived from the model are updated inferences about the rate at which the GDP of a given region is expected to grow during the present quarter.

Every time that new information about the inputs of the model is published by the corresponding statistical institutes (or AIReF), the BayFaR is re-estimated to produce updated values for both the index of regional activity and the nowcasts of GDP growth. Therefore, it is important to assess the changes in both outputs as new information arrives.

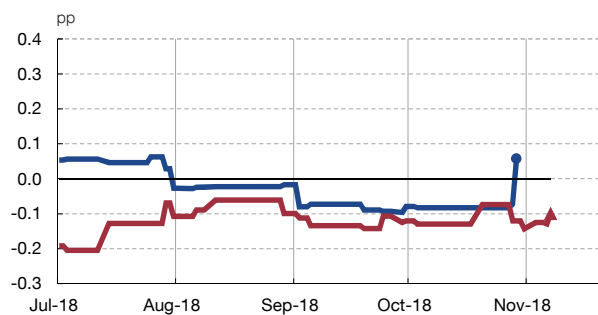
Chart 1 plots the economic activity indexes estimated with different vintages of data, associated to each Spanish region under consideration (using AIReF's quarterly GDP figures). This figure shows how the values of the indexes are updated as new information is incorporated to the nowcasting model. In particular, there are several updates of the indexes obtained with samples that include information until the end of 2017:Q4, 2018:Q1 and 2018:Q2. A couple of features deserve to be commented. First, during the period 2017-2018, the estimated indexes were describing a deceleration of the economic activity in Andalusia, Catalonia and Valencian Community. However, this was not the case for Madrid, where the corresponding index pointed to a relatively steady performance over the last two years. Second, the uncertainty associated

⁶ This feature is assumed in order to facilitate the Bayesian estimation of the model, since the information on GDP is only observed one month every quarter.

1 ANDALUSIA

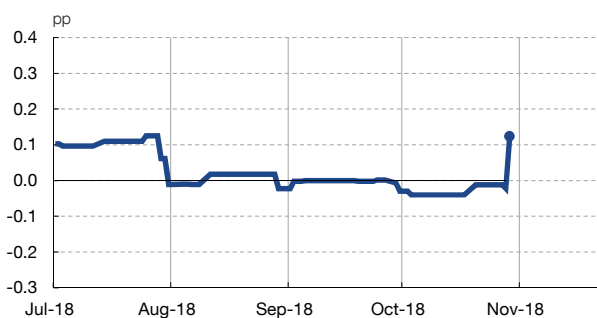


2 CATALONIA



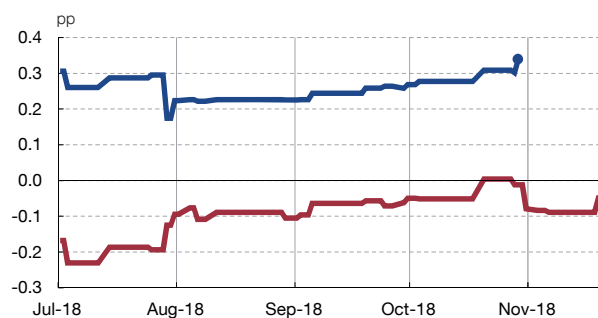
— AIReF — REGIONAL STATISTICS INSTITUTES

3 VALENCIAN COMMUNITY



— AIReF

4 MADRID



— AIReF — REGIONAL STATISTICS INSTITUTES

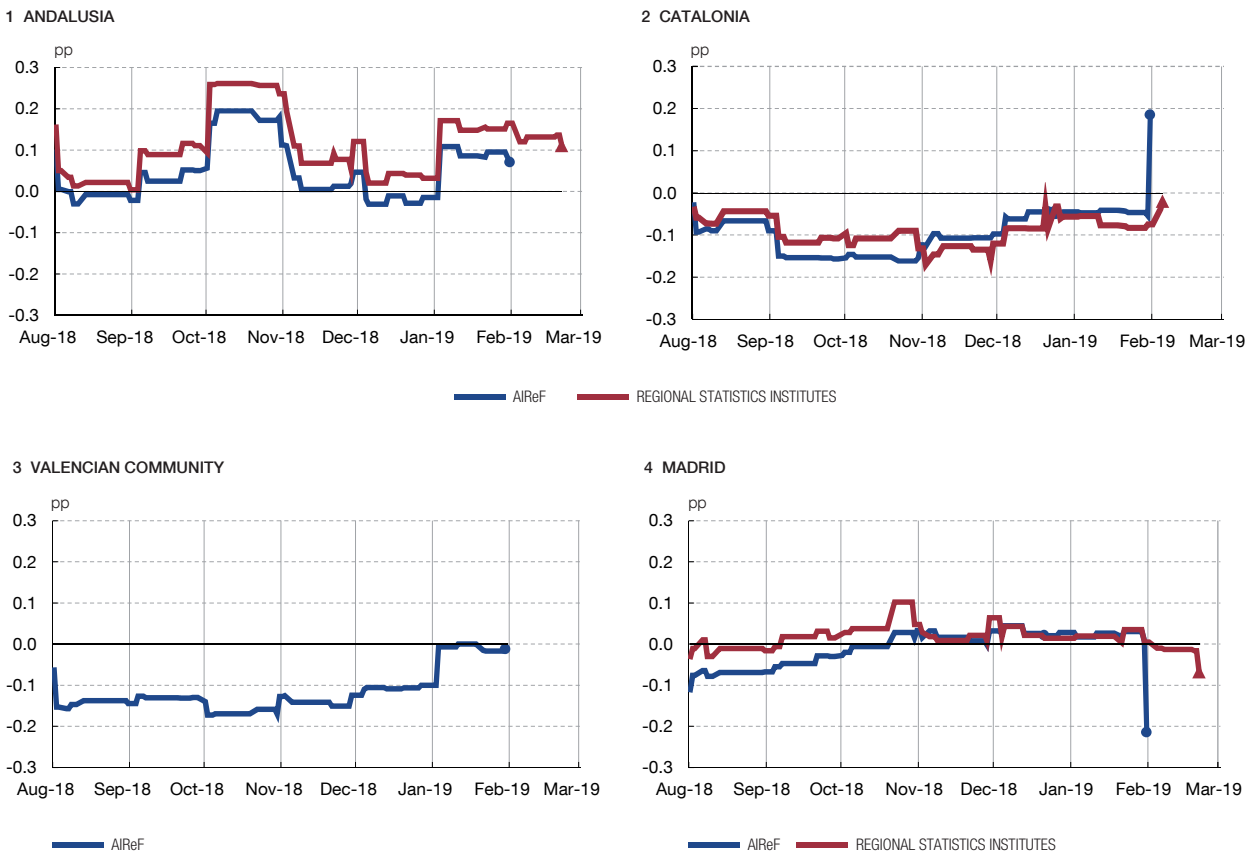
SOURCES: AIReF, Regional Statistics Institutes and own elaboration.

a Computed as the difference between the point real-time nowcast for 2018Q3 and the 2018Q2 estimate. The red line represents the estimates using data from regional statistics institutes and the blue line represents the estimates using data from AIReF.

to the economic performance of the regions, measured by the dispersion between the revisions of the estimates, present some differences. While in Andalusia, Madrid and Valencian Community, there was a considerable amount of uncertainty about their economic performance during 2018, in Catalonia there was little uncertainty that its economy was going to exhibit a slack in activity. Therefore, the information provided by the proposed indexes of regional economic activity is useful for policy makers to detect, on a timely basis, potential changes in economic trends across regions, and also to provide a measure of uncertainty about the expected developments.

Next, we turn to illustrate the predictive performance of the proposed framework. In doing so, we report the real-time nowcasts of the quarters 2018:Q3 and 2018:Q4, for the four regions of interest. In addition, for comparison purposes, we apply the model to nowcast the same two quarters but for the national GDP growth rate.

For each region under study, Chart 2 shows the acceleration/deceleration of real GDP growth foreseen for 2018:Q3, published by both the AIReF and Regional Institutes of Statistics in real-time, i.e., when such data is made available by each institution. The forecasts are computed, on a daily basis, five months before the first release of GDP growth



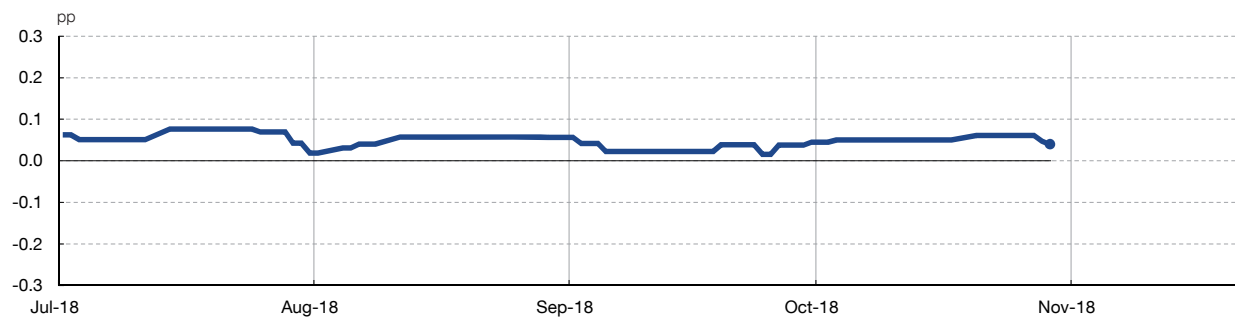
SOURCES: AIReF, Regional Statistics Institutes and own elaboration.

a Computed as the difference between the point real-time nowcast for 2018Q4 and the 2018Q3 estimate. The red line represents the estimates using data from regional statistics institutes and the blue line represents the estimates using data from AIReF.

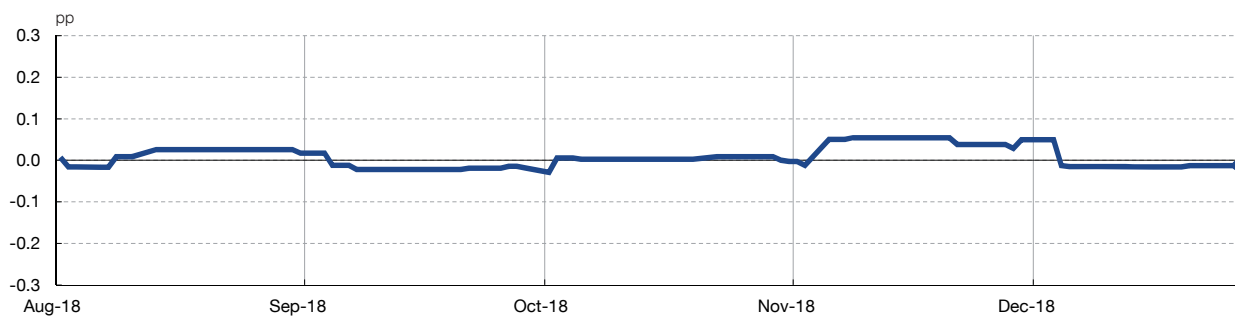
is publicly announced. Notice that the predictions, in general, are more accurate and stable as the release date of the advanced GDP figure becomes closer. This is the case for the GDP published by the two different institutions, showing the flexibility of the model when it targets output growth from both different regions and sources. Next, we perform the same exercise but focusing on nowcasting the 2018:Q4 regional output growth. The results are plotted in Chart 3, showing that the performance of the BayFaR keeps being relatively similar, in that it fairly tracks the GDP growth of Spanish regions.

Finally, we employ the proposed nowcasting model to also produce short-term forecasts of the national GDP growth. In particular, we use the same type of monthly indicators included in the regional models but at the national level, along with the national real GDP published by the National Institute of Statistics. Chart 4 reports the performance of the model for the quarters 2018:Q3 and 2018:Q4 showing significant accuracy in monitoring the activity at the national level, as in the case of regional output. Moreover, notice that for the case of the Spanish GDP growth, at the national level, the real time nowcasts tend to be slightly smoother and more accurate than at the regional level. This can be associated to the fact

1 ESTIMATES FOR 2018-Q3



2 ESTIMATES FOR 2018-Q4



SOURCES: INE and own elaboration.

a Computed as the difference between the point real-time nowcast for 2018Q3 and the 2018Q2 estimate (upper chart) and for 2018-Q4 and the 2018-Q3 estimate (lower chart).

that forecasting GDP at the regional level tends to be a more challenging task than at the national level, due to the all the undesired features imbedded in data on real activity at a higher level of disaggregation.

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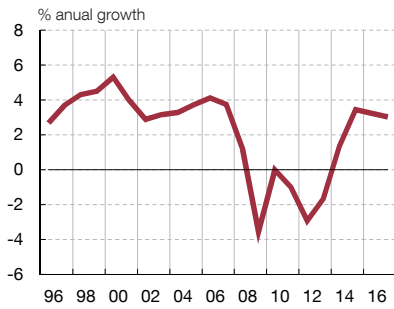
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ANNEX I

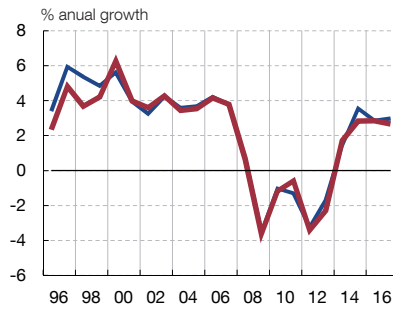
EVOLUTION OF ANNUAL REGIONAL REAL GDP ACCORDING TO THE NATIONAL AND THE REGIONAL STATISTICS INSTITUTES

CHART A1.1

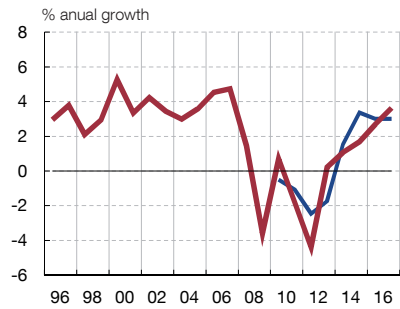
1 SPAIN



2 ANDALUSIA



3 ARAGON



4 CANARY ISLANDS



5 CANTABRIA



6 CASTILLA LEON



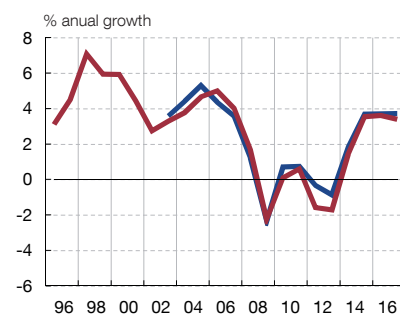
7 CATALONIA



8 EXTREMADURA



9 MADRID



10 GALICIA



11 NAVARRE



12 BASQUE COUNTRY



— REGIONAL STATISTICS — NATIONAL STATISTICS

SOURCES: National and regional statistics institutes.

ANNEX II. Bayesian estimation algorithm

The estimation of the BayFaR is carried out through Bayesian methods. In particular, let the vector collecting the parameters of the model be

$$\Theta = (\lambda_y, \lambda_1, \dots, \lambda_n, \phi_1, \phi_2, \psi_{1,1}, \psi_{1,2}, \dots, \psi_{n,1}, \psi_{n,2}, \sigma_y^2, \sigma_1^2, \dots, \sigma_n^2),$$

and the vector collecting the latent variables, i.e. the factor and idiosyncratic terms, be defined as β_t . In simple terms, the Gibbs sampling procedure consists of two main steps. First, conditional on the parameters Θ , generate draws of the latent vector, β_t . Second, conditional on the latent vector, β_t , generate draws of the parameters Θ .

First Step: To generate the draws from the posterior distribution of the latent vector, which includes the factor, conditional on the parameters, the Carter and Kohn (1994) algorithm is applied to the state-space representation of the nowcasting model. It is important to notice that in order to apply this algorithm, the covariance matrix of the innovations associated to the transition equation of the state-space needs to be partitioned into an invertible and a, potentially, non-invertible block. Therefore, the corresponding state-space representation is given by the following, measurement and transition equations, respectively.

$$\begin{bmatrix} y_t \\ x_{1,t} \\ x_{2,t} \\ x_{3,t} \\ x_{4,t} \\ x_{5,t} \end{bmatrix} = \begin{bmatrix} \frac{\lambda_y}{3} & \frac{1}{3} & 0 & \dots & 0 & \frac{2\lambda_y}{3} & \dots & 0 & \frac{2}{3} & \dots & \frac{1}{3} & 0 & \dots & 0 \\ \lambda_1 & 0 & 1 & \dots & 0 & \lambda_1 & \dots & \lambda_1 & 0 & \dots & 0 & 0 & \dots & 0 \\ \lambda_2 & 0 & 0 & \dots & 0 & \lambda_2 & \dots & \lambda_2 & 0 & \dots & 0 & 0 & \dots & 0 \\ \lambda_3 & 0 & 0 & \dots & 0 & \lambda_3 & \dots & \lambda_3 & 0 & \dots & 0 & 0 & \dots & 0 \\ \lambda_4 & 0 & 0 & \dots & 0 & \lambda_4 & \dots & \lambda_4 & 0 & \dots & 0 & 0 & \dots & 0 \\ \lambda_5 & 0 & 0 & \dots & 1 & \lambda_5 & \dots & \lambda_5 & 0 & \dots & 0 & 0 & \dots & 0 \end{bmatrix} \begin{bmatrix} f_t \\ u_{y,t} \\ u_{1,t} \\ \vdots \\ u_{5,t} \\ f_{t-1} \\ \vdots \\ f_{t-11} \\ u_{y,t-1} \\ \vdots \\ u_{y,t-4} \\ u_{1,t-1} \\ \vdots \\ u_{5,t-1} \end{bmatrix}$$

$$\begin{bmatrix} f_t \\ u_{y,t} \\ u_{1,t} \\ \vdots \\ u_{5,t} \\ f_{t-1} \\ \vdots \\ f_{t-11} \\ u_{y,t-1} \\ \vdots \\ u_{y,t-4} \\ u_{1,t-1} \\ \vdots \\ u_{5,t-1} \end{bmatrix} = \begin{bmatrix} \phi_1 & 0 & 0 & \dots & 0 & \phi_2 & \dots & 0 & 0 & 0 & \dots & 0 & \dots & 0 \\ 0 & 0 & 0 & \dots & 0 & 0 & \dots & 0 & 0 & 0 & \dots & 0 & \dots & 0 \\ 0 & 0 & \psi_{11} & \dots & 0 & 0 & \dots & 0 & 0 & 0 & \dots & \psi_{12} & \dots & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ 0 & 0 & 0 & \dots & \psi_{51} & 0 & \dots & 0 & 0 & 0 & \dots & 0 & \dots & \psi_{52} \\ 1 & 0 & 0 & \dots & 0 & 0 & \dots & 0 & 0 & 0 & \dots & 0 & \dots & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ 0 & 0 & 0 & \dots & 0 & 0 & \dots & 0 & 0 & 0 & \dots & 0 & \dots & 0 \\ 0 & 1 & 0 & \dots & 0 & 0 & \dots & 0 & 0 & 0 & \dots & 0 & \dots & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ 0 & 0 & 0 & \dots & 0 & 0 & \dots & 0 & 0 & 0 & \dots & 0 & \dots & 0 \\ 0 & 0 & 1 & \dots & 0 & 0 & \dots & 0 & 0 & 0 & \dots & 0 & \dots & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ 0 & 0 & 0 & \dots & 1 & 0 & \dots & 0 & 0 & 0 & \dots & 0 & \dots & 0 \end{bmatrix} \begin{bmatrix} f_{t-1} \\ u_{y,t-1} \\ u_{1,t-1} \\ \vdots \\ u_{5,t-1} \\ f_{t-2} \\ \vdots \\ f_{t-12} \\ u_{y,t-2} \\ \vdots \\ u_{y,t-5} \\ u_{1,t-2} \\ \vdots \\ u_{5,t-2} \end{bmatrix} + \begin{bmatrix} v_t \\ u_{y,t} \\ \varepsilon_{1,t} \\ \vdots \\ \varepsilon_{5,t} \\ 0 \\ \vdots \\ 0 \\ 0 \\ \vdots \\ 0 \\ 0 \\ \vdots \\ 0 \end{bmatrix}$$

Second Step: Conditional on the factor and idiosyncratic terms, the sampling of the parameters of the model from their corresponding posterior distribution can be performed by using standard Bayesian econometrics steps for linear regressions. In particular, to sample draws associated to the slope coefficients of the regressions, that is, for factor loadings and autoregressive coefficients, we assume a normal prior distribution, $\alpha : N(0, 1)$, for $\alpha = \lambda_y, \lambda_1, \dots, \lambda_n, \phi_1, \phi_2, \psi_{1,1}, \psi_{1,2}, \dots, \psi_{n,1}, \psi_{n,2}$, and where instead, to sample the variance of the innovations associated to both the idiosyncratic terms and the factor we rely on an inverse-Gamma prior distribution, $\zeta : IG(0, 0)$, for $\zeta = \sigma_y^2, \sigma_1^2, \dots, \sigma_n^2$. Notice that to generate draws of the factor loadings, only the share of the sample associated to observed data of the corresponding variable should be used in the sampling.

ANNEX III. Short-term regional indicators dynamics

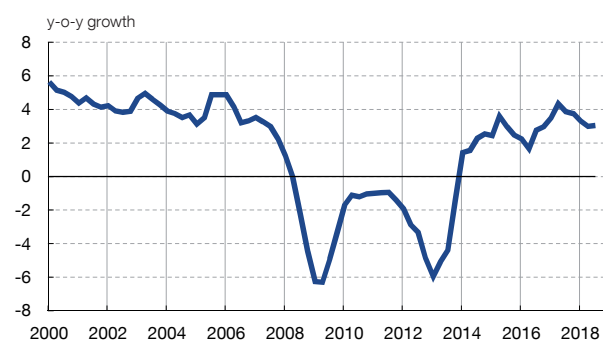
GDP AND INDICATORS. ANDALUSIA

CHART A3.1

1 GDP



2 SOCIAL SECURITY REGISTRATIONS



3 INDUSTRIAL PRODUCTION INDEX



4 RETAIL TRADE INDEX



5 SERVICES SECTOR ACTIVITY INDEX

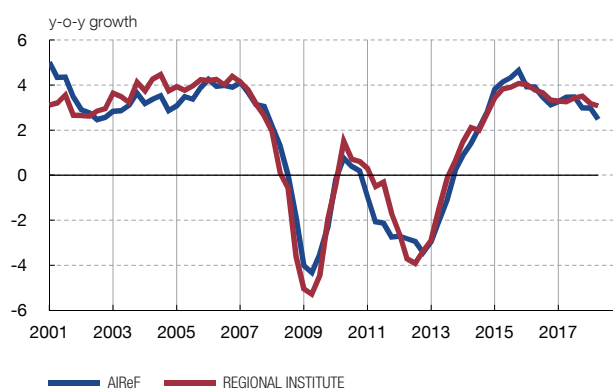


6 COMMERCIAL MOTOR VEHICLES REGISTRATIONS

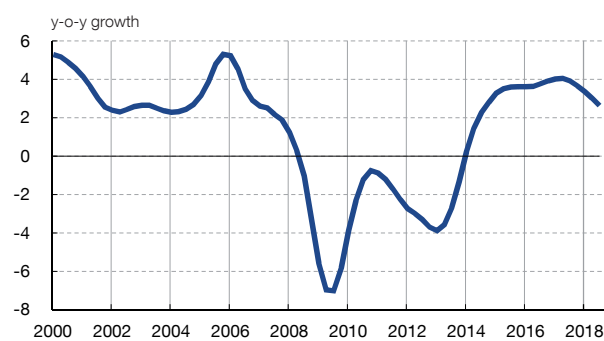


SOURCES: INE, AIReF, Regional Statistics Institutes and own elaboration.

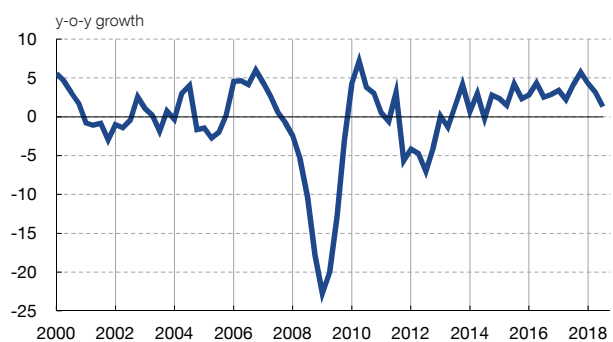
1 GDP



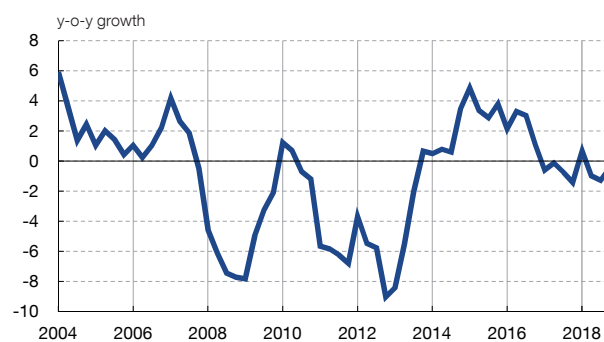
2 SOCIAL SECURITY REGISTRATIONS



3 INDUSTRIAL PRODUCTION INDEX



4 RETAIL TRADE INDEX



5 SERVICES SECTOR ACTIVITY INDEX



6 COMMERCIAL MOTOR VEHICLES REGISTRATIONS

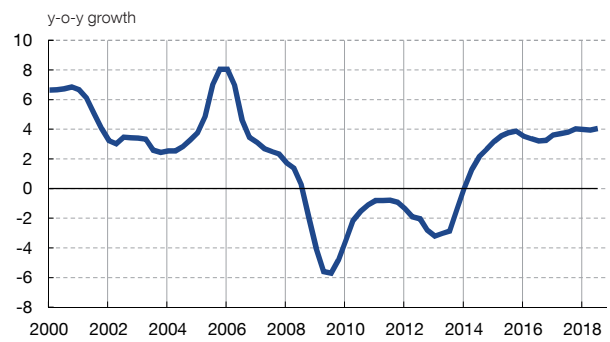


SOURCES: INE, AIReF, Regional Statistics Institutes and own elaboration.

1 GDP



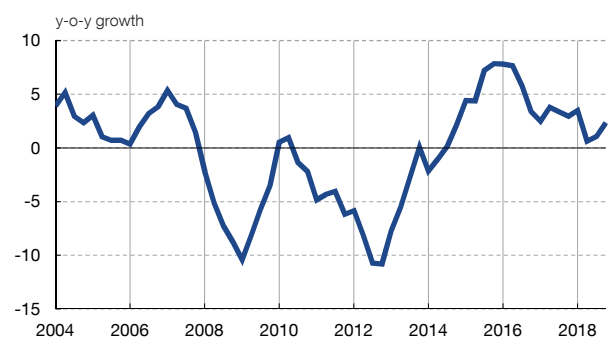
2 SOCIAL SECURITY REGISTRATIONS



3 INDUSTRIAL PRODUCTION INDEX



4 RETAIL TRADE INDEX



5 SERVICES SECTOR ACTIVITY INDEX



6 COMMERCIAL MOTOR VEHICLES REGISTRATIONS



SOURCES: INE, AIReF, Regional Statistics Institutes and own elaboration.

1 GDP (a)



2 SOCIAL SECURITY REGISTRATIONS



3 INDUSTRIAL PRODUCTION INDEX



4 RETAIL TRADE INDEX



5 SERVICES SECTOR ACTIVITY INDEX



6 COMMERCIAL MOTOR VEHICLES REGISTRATIONS



SOURCES: INE, Independent Authority for Fiscal Responsibility and own elaboration.

a. The underlying quarterly GDP figures are the ones estimated by the AIReF.

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