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**TRACKING ECONOMIC GROWTH BY  
EVOLVING EXPECTATIONS VIA GENETIC  
PROGRAMMING: A TWO-STEP APPROACH**

Oscar Claveria (AQR, XREAP)  
Enric Monte  
Salvador Torra (RISKCENTER, XREAP)

## 1. Introduction

Evolutionary computation can be regarded as a subfield of artificial intelligence and soft computing centred around a family of algorithms for global optimization inspired by biological evolution, as they adopt principles of the theory of natural selection to problem solving (Fogel, 2006). These algorithms are known as evolutionary algorithms (EAs). Evolutionary computation is increasingly used in economic research (Acosta-González and Fernández-Rodríguez, 2014; Claveria et al. 2018a,b; Ramos-Herrera and Acosta-González, 2017).

There are different types of EAs. The most commonly used EA in optimization problems is the genetic algorithm (GA) developed by Holland (1975). A generalization of GAs that expresses the solution in the form of computer programs was proposed by Cramer (1985) and is known as genetic programming (GP). This more general representation scheme allows the model structure to vary during the evolution. Whereas GAs code potential solutions by means of fixed length binary string representations, GP uses tree-structured, variable length representations suitable for non-linear empirical modelling.

Empirical modelling is based on the development of mathematical models from experimental data, which implies finding both the structure and the parameters of the model simultaneously. Koza (1992) proposed a novel approach to empirical modelling based on symbolic regression (SR) via GP. This modelling technique is based on the specification of any regression model (linear regression, radial basis functions, support vector machines, kriging, etc.) and then searching the space of mathematical expressions that best fit a given dataset. This search process is usually characterised by a trade-off between accuracy and simplicity. Koza (1992) proposed using GP to find the best single computer program that solves a given SR problem. This approach is especially useful to find patterns in large data sets, where little or no information is known about the system.

In this study we implement a SR via GP approach to find the relationship between a wide range of expectational variables and economic growth. We follow a two-step methodology proposed by Claveria et al. (2016b, 2017a) to derive mathematical functional forms that optimally combine survey variables to best fit the actual evolution of the economic activity in 28 countries of the OECD. We make use of survey expectations from the World Economic Survey (WES) carried out by the CESifo Institute for Economic Research.

Expectations about the state of the economy are a key factor in economic modelling. Agents' expectations are collected through tendency surveys. Business and consumer tendency surveys ask respondents whether they expect a variable to rise, to remain constant, or to fall. The relationship between quantitative data and agents' expectations was first formalised by Anderson (1952) and Theil (1952), who regressed the actual average percentage change of an aggregate variable on the percentage of respondents expecting a variable to rise and to fall. The theoretical framework designed for the quantification of these percentages was initially based on the existence of an interval around zero within which respondents perceive that there are no significant changes in the variable. Thus, they answer that they expect a certain variable to go up (or down) to the extent that the mean of their subjective probability distribution lies beyond a threshold level, known as the limit of the indifference interval. Carlson and Parkin (1975) developed this approach by using a normal distribution, and by assuming unbiasedness over the sample period to estimate the difference limen. This approach was later extended by Pesaran (1984, 1985), who allowed the model for an asymmetrical relationship between the actual average percentage change and the agents' changes in periods of growth.

By matching individual responses with realisations, several authors have further explored this relationship at the micro level (Białowolski, 2016; Lui et al., 2011a, 2011b; Mitchell et al., 2002, 2005a, 2005b; Mokinski et al., 2015). Müller (2010) proposed a variant of the Carlson-Parkin method with asymmetric and time invariant thresholds. Breitung and Schmeling (2013) found that the introduction of asymmetric and time-varying thresholds was key in order to improve the forecast accuracy of quantified survey expectations, while the individual heterogeneity across forecasters played a minor role. Using household-level data from the University of Michigan, Lahiri and Zhao (2015) found strong evidence against the threshold constancy, symmetry, homogeneity, and overall unbiasedness assumptions of the Carlson-Parkin method.

Experimental expectations generated by Monte Carlo simulations have also been used to delve into the relationship between individual expectations and their quantitative equivalent. Common (1985) generated simulated expectations to test the rational expectations hypothesis. Simulation experiments have also been used to assess the forecasting performance of different quantification methods of survey expectations. By means of individual computer-generated expectations, Claveria (2010) compared the forecasting performance of the main quantification methods, while Löffler (1999) and Terai (2009) estimated the measurement error introduced by the Carlson-Parkin method.

The link between survey expectations and quantitative data at the aggregate level has been widely investigated (Abberger, 2007; Batchelor and Dua, 1998, 1992; Bergström, 1995; Berk, 1999; Bovi, 2013; Bruestle and Crain, 2015, Bruno, 2014; Claveria et al., 2007; Claveria et al., 2016a, 2017b; Dees and Brinca, 2013; Driver and Urga, 2004; Graff, 2010; Hansson et al., 2005; Jean-Baptiste, 2012; Kauppi et al., 1996; Leduc and Sill, 2013; Lee, 1994; Lehmann and Wohlrabe, 2017; Mittnik and Zadrozny, 2005; Nardo, 2003; Nolte and Pohlmeier, 2007; Pesaran and Weale, 2006; Qiao et al., 2009, Rahiala and Teräsvirta, 1993; Robinzonov et al., 2012; Smith and McAleer, 1995; Sorić et al., 2013; Vermeulen, 2014; Wilms et al., 2016). Since survey data are approximations of unobservable expectations, they inevitably entail a measurement error. As a result, in spite of the great body of research in this field, there is no consensus in the literature about the usefulness of the information content of survey expectations.

On the one hand, Klein and Özmucur (2010) analysed the role of survey expectations in 26 European countries, and found that they improved the forecasting performance of autoregressive time series models. In a similar sense, Schmeling and Schrimpf (2011) found that survey-based measures of expected inflation were significant predictors of future aggregate stock returns in France, Germany, Italy, the UK, the US and Japan, both in-sample and out-of-sample. Making use of survey expectations of 12 European countries, Ghonghadze and Lux (2012) obtained a superior out-of-sample forecasting performance with a canonical opinion dynamics model than with univariate time series models. Jonsson and Österholm (2012) analysed the inflation expectations formation process in Sweden using survey expectations, obtaining a poor forecasting performance that could be partly attributable to a mismeasurement of expectations. However, Österholm (2014) found that survey-based expectations improved the out-of-sample forecasting performance of GDP growth predictions in Sweden.

Martinsen et al. (2014) constructed factor models based on disaggregate survey data to forecast inflation, unemployment and GDP in Norway. The authors obtained the most accurate results for GDP growth. Girardi (2014) found that survey expectations contained relevant information about business cycle developments in the Euro Area (EA), especially around periods of extreme cyclical swings. Guizzardi and Stacchini (2015) showed that the inclusion of business survey indicators in time series models increased the forecasting accuracy of the baseline models. In a recent study, Altug and Çakmakli (2016) generated inflation forecasts by combining data on survey expectations with the inflation target set by central banks, finding the former to increase the predictive power of the models.

Although these studies use a wide range of econometric techniques, none of them assesses the relationship between both official quantitative data and qualitative survey expectations by means of evolutionary methods. In this research we design a SR experiment and use evolutionary computation to find the optimal combinations of survey expectations that best fit the actual evolution of year-on-year growth rates of GDP. In a recent study, Lahiri and Zhao (2015) found a significant improvement in agents' expectations accuracy during periods of uncertainty. This finding has also led us to assess the impact of the 2008 financial crisis on agents' ability to forecast the evolution of economic activity. Hence, we use the estimates of GDP in 28 OECD economies and compare them to a baseline model by means of the mean absolute scaled error (MASE) proposed by Hyndman and Koehler (2006).

The rest of the paper is organized as follows. The next section reviews the existing literature and describes the methodological approach and the experimental set up. In Section 3 we describe the data and present the empirical results. Finally, Section 4 provides some concluding remarks.

## **2. Methodology**

GP is a soft computing search technique for problem-solving. GP's tree-structured programs are evolved by means of genetic operators for model approximation. In this study we design a SR experiment in order to derive a set of functional forms that link survey expectations to economic growth. This data-driven regression approach assumes no a priori model. Using EAs that apply Darwinian principles that imitate aspects of biological evolution, such as the principle of survival and reproduction of the fittest, an initial population of computer programs are bred through generations to find a set of analytical functions that best fit the data.

Koza (1992) proposed using GP for implementing SR. In his seminal paper, Koza (1995) applied GP to assess the non-linear "exchange equation", finding the empirical relationships between the price level, and gross national product, money supply, and the velocity of money. The versatility of this empirical modelling approach has attracted researchers from different areas (Álvarez-Díaz et al., 2009; Barmpalexis et al., 2011; Cai et al., 2006; Can and Heavey, 2011; Ceperic et al., 2014; Sarradj and Geyer, 2014; Wu et al., 2008; Yao and Lin, 2009).

Most of the applications of evolutionary computing to economics have been in finance (Goldberg, 1989). For a review of the applications of GAs for financial forecasting see Drake and Marks (2002). Acosta-González et al. (2012) used a GA to select the best econometric model for explaining the 2008 financial crisis, and found that the main determinant was the percentage of bank claims on private sector over deposits in the year 2006. By means of a computational search methodology based on GAs, Acosta-González and Fernández-Rodríguez (2014) selected the optimal financial ratios employed in a logit model to forecast bankruptcy in the Spanish building industry using annual public accounting information. Álvarez-Díaz and Álvarez (2005) used GP to forecast exchange rates of the yen and the pound to the US dollar. Based upon its performance in eight stock markets and eight foreign exchange markets during three consecutive test periods, Chen et al. (2008) thoroughly analysed the application of GP to financial trading, shedding some light on how GP performance could be connected to the trending and cyclical properties of financial data. Huang et al. (2015) presented a novel methodology for pairs trading using GAs.

Larkin and Ryan (2008) applied GP to nowcast stock prices using ordinal news sentiment data generated in real time by classifying financial news into positive, negative and neutral. The authors found that GP effectively predicted large intraday price jumps on the Standard & Poor 500 return index (S&P 500) up to an hour before they occurred without using current market prices information. Sheta et al. (2015) modelled the S&P 500 using multi-gene SR. Multi-gene SR is a special variation of the classic GP algorithms where each symbolic model is represented by a number of GP trees weighted by a linear combination. The method was used to evolve linear combinations of non-linear functions of 27 input variables, obtaining robust results when tracking the S&P 500 index in a weekly basis. Ramos-Herrera and Acosta-González (2017) evaluated the factors explaining exchange rate stability in 17 economies of the European Union (EU) making use of GAs. Among the higher impact factors, the authors found that variables measuring competitiveness, including agents' expectations, clearly stood out due to their repeated presence in the different models. Vasilakis et al. (2013) presented a GP-based technique to predict returns in the trading of the euro/dollar exchange rate based on historical data and assessed its forecasting performance relative to four different approaches, obtaining the highest trading performance with the proposed method. Wilson and Banzhaf (2009) compared a developmental co-evolutionary GP approach to standard linear GP for interday stock prices prediction.

Applications of evolutionary computation in economics are more recent and scarce. See Chen and Kuo (2002) for a classification of the literature on the application of evolutionary computation to economics and finance. By means of GAs, Acosta-González et al. (2014) selected the best econometric model for explaining the determinants of the size of the shadow economy using data from 38 economies. The authors found that the main determinants of the shadow economy were: taxes on capital gains of individuals, corporate taxes on income, profits and capital gains, domestic credit, bank secrecy, ethnic fractionalization, urban population, globalization, corruption and the socialist legal origin of country. Chen et al. (2010) introduced GP in a vector error correction model for macroeconomic forecasting. By means of SR via Pareto GP, Kotanchek et al. (2010) provided some insight into GDP forecasting. Duda and Szydło (2011) applied an improved version of GP known as gene expression programming (GEP) (Ferreria, 2011) to develop a set of economic forecasting models.

Kapetanios et al. (2016) assessed the forecasting performance of GAs and two other heuristic optimisation algorithms to forecast quarterly GDP growth and monthly inflation in the EA based on a large set of 195 monthly indicators. The authors found that variable selection based on heuristic optimisation outperformed variable reduction methods (principal components, partial least squares, and Bayesian shrinkage regression). See Milutinović et al. (2017) and Petković (2015) for alternative heuristic optimisation strategies. Klůčik (2012) used SR via GP in the estimation of total exports and imports to Slovakia. Krömer et al. (2013) presented an application of GP to the evolution of fuzzy rules based on the concept of extended Boolean queries. In their approach, fuzzy rules are used as symbolic classifiers learned from data and used to label data records and to predict the value of an output variable. The authors used GP to find fuzzy rules labelling faulty products in a steel processing plant. Kronberger et al. (2011) made use of SR to identify variable interactions between 33 economic indicators in order to estimate the evolution of prices in the US. In a recent study, Marković et al. (2017) assessed the role of ten science and technology factors as inputs for GDP growth prediction in 28 EU countries. The authors compared the predictive accuracy of GP and other soft computing methods to that of extreme learning machines (ELMs) (Huang et al., 2006), and obtained the highest accuracy with ELMs were initially proposed as learning algorithms for single-hidden layer feedforward neural networks characterised by fast training time. Yang et al. (2015) applied a data-driven approach based on SR to predict oil production in the US, using data from the 48 lower states since 1859.

Among recent developments in evolutionary computation, Zelinka (2005) introduced analytical programming, and showed its ability to synthesize suitable solutions (programs) in SR. Maschek (2010) developed a two-level learning (or self-adaptation) mechanism and evaluated how it affected an economic application of GAs. Vladislavleva et al. (2010) evaluated different ways of improving SR by incorporating weights into the fitness function. Waltman et al. (2011) examined to what extent the use of binary encoding strategies influence the results produced by GAs. Peng et al. (2014) proposed an improved GEP algorithm especially suitable for dealing with SR problems. Gandomi and Roke (2015) compared the forecasting performance of ANN models to that of GEP techniques. See Dabhi and Chaudhary (2015) and Poli et al. (2010) for a review of the main issues related to GP.

GP allows to find patterns in large data sets. This feature is particularly indicated when little or no information is known about the system. While in evolutionary programming (Fogel, 1966) the structure of the program to be evolved remains fixed, GP simultaneously evolves the structure and the parameters of the models. In this study we use GP to formalise the interactions between a set of indicators of survey expectations that best fit the evolution of economic activity. As there is an arbitrary functional relationship between this set of survey variables (Table 1), we link all of them to the actual percentage growth rate of GDP by means of a SR model:

$$y_{it} = f(x_{1it}, x_{2it}, x_{3it}, x_{4it}, x_{5it}, x_{6it}, x_{7it}, x_{8it}, x_{9it}, x_{10it}, x_{11it}, x_{12it}) \quad (1)$$

where  $x_{1it}, \dots, x_{12it}$  are the different survey variables, and  $y_{it}$  is a scalar referring to the year-on-year growth rate of quarterly GDP for country  $i$  at time  $t$ . We divide the set of survey variables into three types: judgements about the present economic situation ( $x_{1it}, x_{2it}, x_{3it}$ ), perceptions about the present economic situation compared to last year ( $x_{4it}, x_{5it}, x_{6it}$ ), and expectations for the next six months about the economic situation ( $x_{7it}, x_{8it}, x_{9it}$ ) and the foreign trade volume ( $x_{10it}, x_{11it}, x_{12it}$ ). See Table 1.

**Table 1.** Explanatory variables (WES expectational indicators)

<b>Judgements</b>	Overall economy	$x1_{it}$
Present	Capital expenditures	$x2_{it}$
Economic situation	Private consumption	$x3_{it}$
<b>Perceptions</b>	Overall economy	$x4_{it}$
Compared to last year	Capital expenditures	$x5_{it}$
Economic situation	Private consumption	$x6_{it}$
<b>Expectations</b>	Overall economy	$x7_{it}$
For the next 6 months	Capital expenditures	$x8_{it}$
Economic situation	Private consumption	$x9_{it}$
Foreign trade volume	Volume of exports	$x10_{it}$
	Volume of imports	$x11_{it}$
	Trade balance	$x12_{it}$

By means of GP we evolve the resulting symbolic mathematical expressions until a stopping criterion is reached, be it a predetermined value of the fitness function or a given number of generations. We want to note that there is a trade-off between fitness and complexity. To deal with the growth in the complexity of the SR function we introduce a term that penalizes the functions that exceed a given number of terms. In this study we have chosen a maximum number of 150 generations as as stopping criterion. In Table 2 we summarize the steps for implementing GP.

**Table 2.** GP implementation – Steps

1. Creation of an initial population of programs	1,000
2. Evaluation of fitness for each program	Root mean square error (RMSE)
3. Selection of a reproduction strategy	Tournament method (size 3)
4. Application of genetic operators	Mutation probability 0.1
5. Determination of constants	Automatically generated
6. Creation of a new population	Max. generations 150

(1) Creation of an initial population of programs – First, in order to start the process we create an initial population of 1000 programs.

(2) Evaluation of fitness for each program – An error metric is calculated for each member of the population. We use the Root Mean Square Error (RMSE) as a fitness function.

(3) Selection of a reproduction strategy – From the existing strategies for the selection of parents for replacement, which are the programs used to create offspring programs, we

use the tournament method so as to guarantee diversity in the population. This method is based on the selection of the fittest individual in each tournament among a group of individuals chosen at random from the population. One of the main advantages over other alternative methods is that the selection pressure can be easily adjusted and it is code-efficient.

(4) Application of genetic operators – Genetic operators (crossover and mutation) are applied to the parents selected on the basis of the fitness function. Crossover consists on the recombination of randomly chosen parts of parents, while mutation on randomly altering a part of a parent.

(5) Determination of constants – We include the automatic generation of constants provided by the GA. This set of constants is optimised after a number of generations to avoid the search path to deviate from the optimum.

(6) Creation of a new population – Generation after generation, the fitness of the population increases, as steps three and four are repeated until the creation of a new population when a required minimal fitness is achieved. In this experiment we have chosen a maximum number of 150 generations as a stopping criterion.

The output of this process is a set with the best individual functions from all generations. In this study we have used the open source Distributed Evolutionary Algorithms Package (DEAP) framework implemented in Python (Fortin et al. 2012; Gong et al. 2015).

### **3. Results**

In this section we present the results of the experiment. The SR has been estimated using survey data from the CESifo WES for 28 countries of the OECD, and GDP data retrieved from the OECD web (<https://data.oecd.org/gdp/quarterly-gdp.htm#indicator-chart>). The sample period goes from the second quarter of 2000 to the first quarter of 2014. The WES is carried out by the CESifo Institute for Economic Research. The questionnaire asks respondents whether they expect their country's general economic situation to get better, worse, or to remain unchanged.

Qualitative responses are transformed by means of a grading procedure consisting in giving a rank of 9 to positive replies, of 5 to indifferent replies, and of 1 to negative replies (CESifo World Economic Survey, 2011). Survey results are published as aggregated data

by country, weighting the results according to the country's share of trade worldwide. See Henzel and Wollmershäuser (2005), Stangl (2007, 2008), and Hutson et al. (2014) for a detailed analysis of WES data. The Ifo makes use of these data to construct the Economic Climate Index (ECI). The ECI is an aggregate indicator obtained as the arithmetic mean of assessments of the general economic situation and the expectations for the economic situation in the next six months. The trend in the ECI tends to correlate closely with the actual business-cycle trend measured in annual growth rates of real GDP (Garnitz et al., 2015). In Table 3 we present a descriptive analysis of the ECI for the 28 economies analysed in this study.

**Table 3.** Descriptive statistics – ECI (2000:Q2– 2014:Q1)

Country	Mean	Standard Deviation	Variation Coefficient (%)	Skewness	Kurtosis
Austria	5.30	1.07	20.2	-0.03	0.36
Belgium	5.14	1.09	21.1	-0.24	0.15
Bulgaria	5.45	1.09	19.9	-0.17	-0.22
Croatia	4.41	1.11	25.1	-0.21	-0.71
Czechia	5.75	1.11	19.3	-0.13	-0.89
Denmark	5.73	1.14	20.0	-0.09	-1.02
Estonia	6.05	1.33	21.9	-1.22	1.46
Finland	5.94	1.22	20.5	-0.49	-0.59
France	4.70	1.10	23.4	0.04	-0.07
Germany	5.49	1.09	19.9	-0.03	-0.93
Greece	4.56	1.57	34.5	0.67	0.25
Hungary	4.83	1.11	23.0	0.46	0.41
Ireland	5.34	1.77	33.2	-0.36	-0.64
Italy	4.44	0.93	21.0	-0.09	-0.61
Japan	4.57	1.38	30.1	-0.19	-0.87
Latvia	5.48	1.33	24.3	-0.79	-0.12
Lithuania	6.15	1.40	22.7	-1.38	2.07
Netherlands	5.33	1.12	21.0	0.26	-0.30
Norway	6.71	0.99	14.7	-1.20	0.97
Poland	5.67	1.23	21.6	-0.25	-1.10
Portugal	3.84	1.22	31.7	-0.17	-0.50
Romania	4.85	1.38	28.4	-0.46	-0.71
Slovakia	5.76	1.14	19.9	-0.36	-0.57
Slovenia	5.25	1.24	23.6	-0.60	-0.35
Spain	4.39	1.34	30.4	-0.35	-1.01
Sweden	5.71	1.28	22.3	-0.58	-0.07
UK	4.99	1.13	22.6	-0.77	0.74
US	5.25	0.94	17.8	-0.53	0.26

After 150 generations, and using as a selection criterion the capacity of the elements of the population to track the dependent variables (year-on-year growth rates of quarterly GDP for each country), we have selected the top 20 functions returned by the GP algorithm (Table 4).

**Table 4.** SR-generated indicators (building blocks)

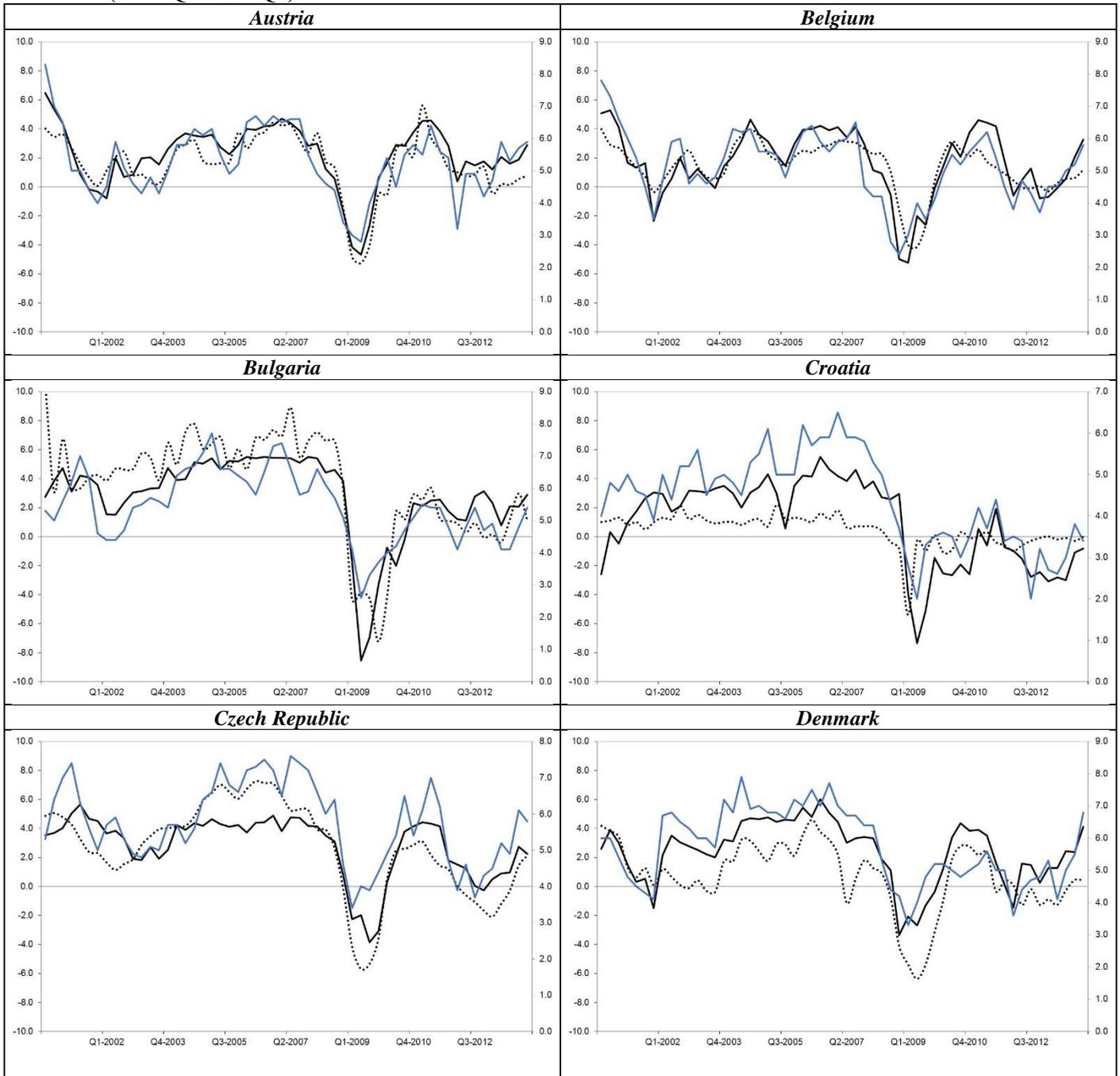
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$\text{Log}(x4_{it})$
$\text{Log}(x5_{it})$
$\text{Log}(x12_{it})$
$\text{Log}(x10_{it})$
$x2_{it} / x5_{it}$
$x3_{it} / x6_{it}$
$x1_{it} / x7_{it}$
$x12_{it} / x11_{it}$
$(x10_{it} / x11_{it}) - x12_{it}$
$\text{Log}(\text{Max}(x10_{it} / x3_{it}, x10_{it} / x1_{it}, x10_{it} / x2_{it}))$
$\text{Log}((x1_{it} + x3_{it})/2)$
$\text{Log}((x4_{it} + x5_{it} + x6_{it})/3)$
$\text{Log}((x7_{it} + x8_{it} + x9_{it})/3)$

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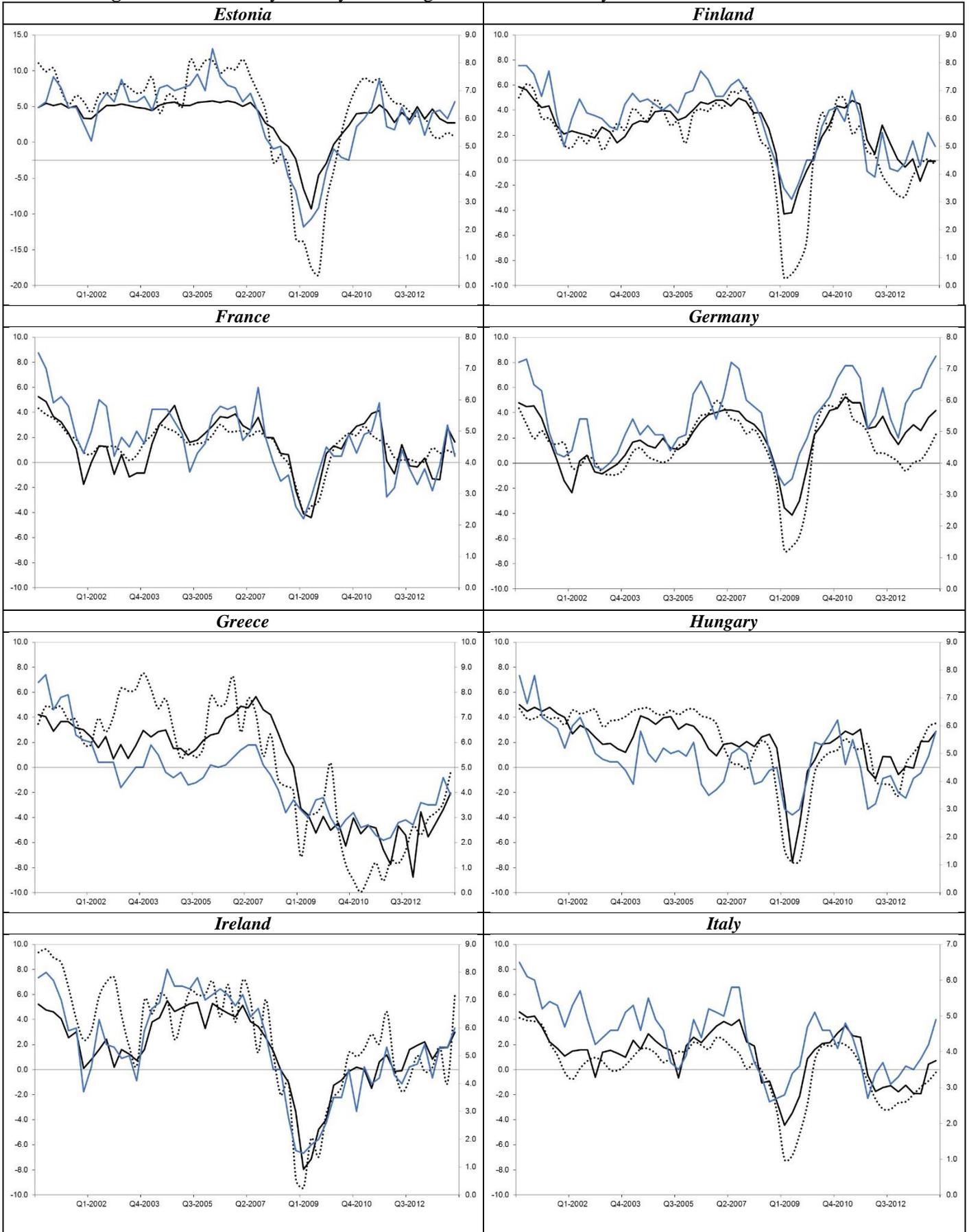
The GP-generated functions in Table 4 can be regarded as building blocks, which are then introduced as regressors of GDP growth so as to obtain the coefficients used to generate the optimal linear combination to estimate the evolution of economic growth. In order to assess the accuracy of the forecasts of GDP, we first compare the evolution of the obtained estimations of economic growth to that of the ECI. Fig. 1 compares the evolution of the GR-based estimates to that of the year-on-year growth rates of GDP and the ECI. We can observe that the estimates seem to correlate closely with the actual oscillations of GDP. In most economies agents' expectations seem to advance turning points, especially regarding the 2008 financial crisis. The severity of the crisis varies across countries, being Estonia, Latvia, and Lithuania the economies showing the highest percentages of decrease in the activity. At the opposite end, Norway and Poland show the lowest decline in terms of GDP growth, being the countries in which the GR-generated forecasts from agents' expectations more clearly overestimate the extent of the crisis.

**Fig. 1a.** Evolution of year-on-year GDP growth rates vs. survey-based economic indicators (2000:Q2-2014:Q1)



1. Note: The black dotted line represents the year-on-year growth rate of GDP in each country. The grey line represents the evolution of the scaled ECI (secondary axis). The black line represents the evolution of the proposed indicator.

**Fig. 1b.** Evolution of year-on-year GDP growth rates vs. survey-based economic indicators



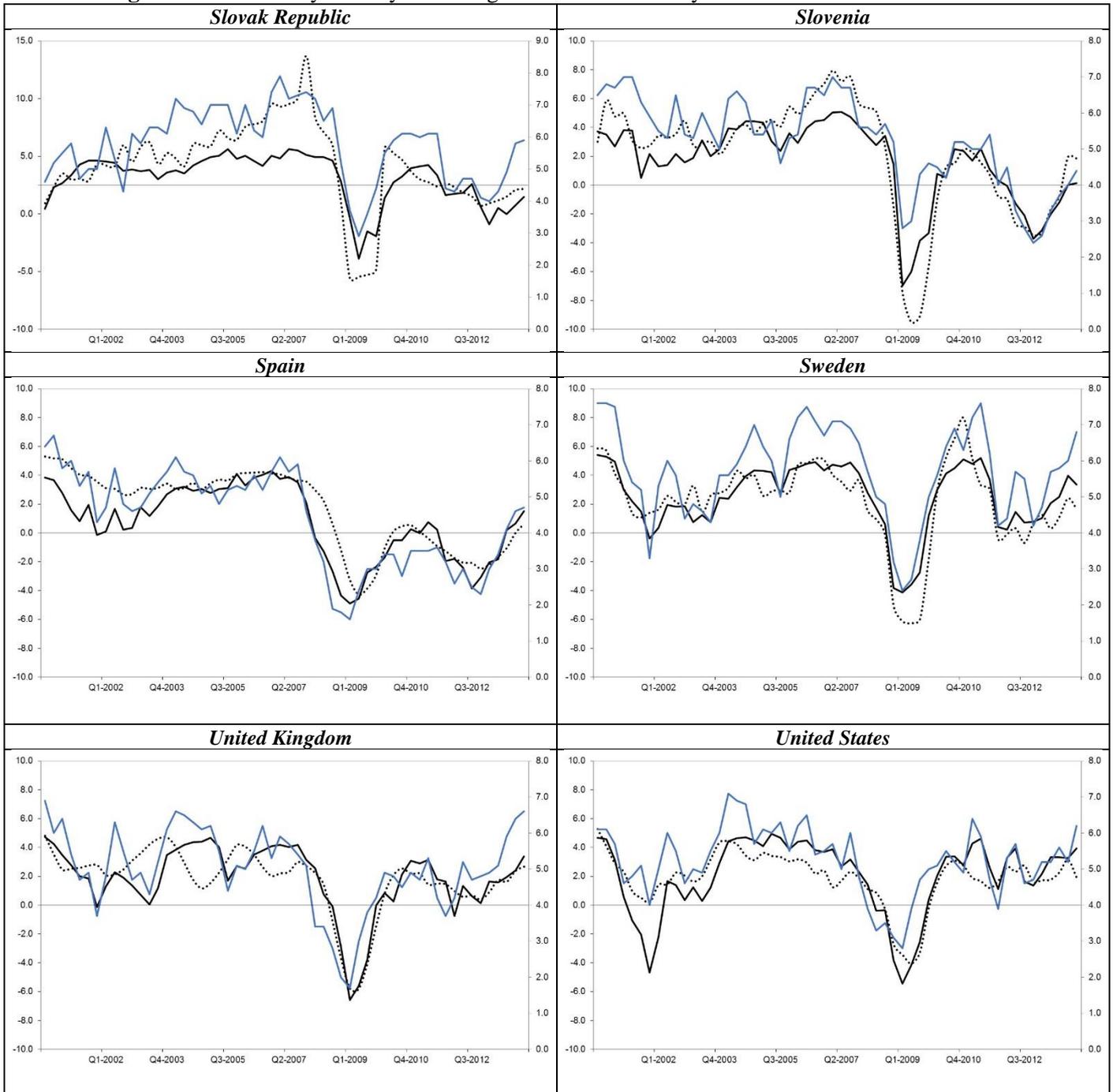
2. Note: See Note of Fig. 1a.

**Fig. 1c. Evolution of year-on-year GDP growth rates vs. survey-based economic indicators**



3. Note: See Note of Fig. 1a.

**Fig. 1d.** Evolution of year-on-year GDP growth rates vs. survey-based economic indicators



4. Note: See Note of Fig. 1a..

After the graphical analysis, we evaluate the in-sample forecasting performance of the quantified expectations by comparing them to a benchmark model in order to compute the MASE. This measure of forecast accuracy was developed by Hyndman and Koehler (2006), who proposed scaling the forecast errors by the in-sample mean absolute error

(MAE) obtained with a random walk. As official data are published with a delay of more than a quarter with respect to survey data, we use two-step ahead naïve forecasts as a baseline. The MASE statistic presents several advantages over other forecast accuracy measures. First, it is independent of the scale of the data. Second, it does not suffer from some of the problems presented by other relative measures of forecast accuracy such as the relative MAE. Finally, it is easy to interpret: values larger than one are indicative that the GP-based forecasts are worse than the average prediction computed in-sample with the baseline model.

If we denote the forecast error obtained by means of GP as  $e_t = Y_t - \hat{Y}_t$ , the scale error is defined as:

$$q_t = \frac{e_t}{\frac{1}{n-1} \sum_{i=3}^n |Y_i - Y_{i-2}|} \quad (2)$$

Hence, the MASE is obtained as the mean of  $q_t$ ,  $MASE = \text{mean}(q_t)$ .

With the aim of assessing the potential influence of the 2008 financial crisis on the forecasting accuracy of GP-generated estimates of GDP, we re-compute the MASE differentiating between the pre-crisis subperiod (2000-2007), the crisis (2007-2010), and the post-crisis subperiod (Table 5).

The results in Table 5 show that the most remarkable improvement of the survey-based estimates relative to the benchmark model are obtained in Sweden, Austria, and Finland, as opposed to Croatia and Lithuania. When splitting the results in sub-periods, we find that the accuracy of the estimates of GDP significantly worsens during the crisis in most countries, with the exception of Austria, Czechia, France, Ireland, Portugal, the UK and the US. When comparing the accuracy of agents' expectations between the post-crisis and the pre-crisis years, we obtain mixed results. This mixed evidence is in line with previous research. While Lahiri and Zhao (2015) found a significant improvement in agents' expectations accuracy during periods of uncertainty and Łyziak and Mackiewicz-Łyziak (2014) showed that the 2008 financial crisis period led to a decrease in expectational errors in transition economies, Erjavec et al. (2015) found that consumers' expectational bias regarding inflation in Croatia diminished in times of lower price volatility.

**Table 5.** Forecast accuracy by country (in-sample)

Country	MASE	Pre-crisis	Crisis	Post-crisis
Austria	0.652	0.660	0.489	0.835
Belgium	0.837	0.701	0.879	<b>1.067</b>
Bulgaria	<b>1.060</b>	<b>1.032</b>	<b>1.354</b>	0.757
Croatia	<b>3.590</b>	<b>3.273</b>	<b>4.931</b>	<b>2.596</b>
Czechia	0.991	<b>1.124</b>	0.736	<b>1.029</b>
Denmark	<b>1.250</b>	<b>1.074</b>	<b>1.509</b>	<b>1.298</b>
Estonia	<b>1.068</b>	0.933	<b>1.550</b>	0.758
Finland	0.682	0.368	<b>1.091</b>	0.831
France	0.904	0.906	0.567	<b>1.315</b>
Germany	0.737	0.542	0.725	<b>1.156</b>
Greece	<b>1.068</b>	0.997	<b>1.146</b>	<b>1.120</b>
Hungary	0.913	0.869	<b>1.092</b>	0.782
Ireland	0.821	0.959	0.641	0.757
Italy	0.837	0.645	<b>1.180</b>	0.813
Japan	0.825	0.799	0.926	0.753
Latvia	<b>1.230</b>	<b>1.338</b>	<b>1.548</b>	0.617
Lithuania	<b>2.221</b>	<b>1.885</b>	<b>2.668</b>	<b>2.371</b>
Netherlands	0.829	0.676	0.958	0.988
Norway	<b>1.321</b>	<b>1.024</b>	<b>1.622</b>	<b>1.570</b>
Poland	<b>1.130</b>	0.885	<b>1.604</b>	<b>1.056</b>
Portugal	0.845	0.808	0.773	<b>1.011</b>
Romania	<b>1.065</b>	<b>1.093</b>	<b>1.231</b>	0.802
Slovakia	<b>1.019</b>	0.815	<b>1.773</b>	0.513
Slovenia	0.741	0.693	<b>1.063</b>	0.443
Spain	<b>1.389</b>	<b>1.562</b>	<b>1.564</b>	0.814
Sweden	0.586	0.422	0.876	0.572
UK	0.880	<b>1.197</b>	0.688	0.457
US	<b>1.054</b>	<b>1.241</b>	0.693	<b>1.109</b>

Notes: \* MASE stands for the Mean Absolute Scaled Error. In this study we propose scaling the errors by the in-sample MAE obtained with the Naïve method for two-step ahead forecasts (as official data are published with a delay of more than a quarter with respect to survey data). Values larger than one (in bold) indicate worse predictions than the average forecast computed in-sample with the Naïve method.

#### **4. Concluding remarks and future work**

Evolutionary computation is increasingly being used for economic applications. In this study we implement GP to find the most fitted mathematical functional forms linking survey expectations to economic growth. By linearly combining the output of this GP-generated set of models, we estimate the evolution of GDP in 28 OECD economies. The proposed approach demonstrates the potential of survey expectations for economic forecasting and circumvents the issue of quantifying qualitative expectations on the direction of change. Thus, this data-driven method for modelling survey-based agents' expectations avoids making assumptions about the subjective probability distribution of respondents.

SR via GP allows selecting the fittest models of interaction between agents' expectations and the official quantitative series they refer to. As a result, the evolution of the GP-generated forecasts correlates closely with the actual oscillations of the economic activity and with other official economic indicators such as the ECI. This result suggests that this empirical approach to model survey expectations on the direction of change may provide gains in forecast accuracy.

We have also analysed the impact of the 2008 financial crisis on the accuracy of agents' expectations by assessing the capacity of GP-generated estimates of GDP to anticipate future economic growth. We have found that the crisis period has led to a deterioration in the forecasting performance of agents' expectations in most economies.

Despite the versatility of the proposed GP approach for modelling survey-based expectations to estimate economic growth, some aspects have been left for further research. We have not evaluated to what extent the forecasting performance of GP predictions could have been improved by increasing the maximum number of generations. There is also the question of whether the implementation of improved adaptive algorithms, such as Ferreira's gene expression programming or Zelinka's analytical programming, may improve the forecasting performance of computationally generated economic forecasts. Finally, another issue left for future research is the use of GP-based expectations to assess empirically observed economic relationships such as the Phillips curve, or to test the rational expectations hypothesis.

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"Productivity growth and competition in spanish manufacturing firms:  
What has happened in recent years?"  
(Desembre 2006)

**CREAP2006-10**

**Andonova, V.;** **Díaz-Serrano, Luis.** (CREB)

"Political institutions and the development of telecommunications"  
(Desembre 2006)

**CREAP2006-11**

**Raymond, J.L.**(GEAP); **Roig, J.L.** (GEAP)

"Capital humano: un análisis comparativo Catalunya-España"  
(Desembre 2006)

**CREAP2006-12**

**Rodríguez, M.**(CREB); **Stoyanova, A.** (CREB)

"Changes in the demand for private medical insurance following a shift in tax incentives"  
(Desembre 2006)

**CREAP2006-13**

**Royuela, V.** (AQR-IREA); **Lambiri, D.;** **Biagi, B.**

"Economía urbana y calidad de vida. Una revisión del estado del conocimiento en España"  
(Desembre 2006)

**CREAP2006-14**



**Camarero, M.; Carrion-i-Silvestre, J.LL. (AQR-IREA); Tamarit, C.**

"New evidence of the real interest rate parity for OECD countries using panel unit root tests with breaks"  
(Desembre 2006)

### **CREAP2006-15**

**Karanassou, M.; Sala, H. (GEAP); Snower, D. J.**

"The macroeconomics of the labor market: Three fundamental views"  
(Desembre 2006)

## **2007**

### **XREAP2007-01**

**Castany, L. (AQR-IREA); López-Bazo, E. (AQR-IREA); Moreno, R. (AQR-IREA)**

"Decomposing differences in total factor productivity across firm size"  
(Març 2007)

### **XREAP2007-02**

**Raymond, J. Ll. (GEAP); Roig, J. Ll. (GEAP)**

"Una propuesta de evaluación de las externalidades de capital humano en la empresa"  
(Abril 2007)

### **XREAP2007-03**

**Durán, J. M. (IEB); Esteller, A. (IEB)**

"An empirical analysis of wealth taxation: Equity vs. Tax compliance"  
(Juny 2007)

### **XREAP2007-04**

**Matas, A. (GEAP); Raymond, J.Ll. (GEAP)**

"Cross-section data, disequilibrium situations and estimated coefficients: evidence from car ownership demand"  
(Juny 2007)

### **XREAP2007-05**

**Jofre-Montseny, J. (IEB); Solé-Ollé, A. (IEB)**

"Tax differentials and agglomeration economies in intraregional firm location"  
(Juny 2007)

### **XREAP2007-06**

**Álvarez-Albelo, C. (CREB); Hernández-Martín, R.**

"Explaining high economic growth in small tourism countries with a dynamic general equilibrium model"  
(Juliol 2007)

### **XREAP2007-07**

**Duch, N. (IEB); Montolio, D. (IEB); Mediavilla, M.**

"Evaluating the impact of public subsidies on a firm's performance: a quasi-experimental approach"  
(Juliol 2007)

### **XREAP2007-08**

**Segarra-Blasco, A. (GRIT)**

"Innovation sources and productivity: a quantile regression analysis"  
(Octubre 2007)

### **XREAP2007-09**

**Albalade, D. (PPRE-IREA)**

"Shifting death to their Alternatives: The case of Toll Motorways"  
(Octubre 2007)

### **XREAP2007-10**

**Segarra-Blasco, A. (GRIT); Garcia-Quevedo, J. (IEB); Teruel-Carrizosa, M. (GRIT)**

"Barriers to innovation and public policy in catalonia"  
(Novembre 2007)

### **XREAP2007-11**

**Bel, G. (PPRE-IREA); Foote, J.**

"Comparison of recent toll road concession transactions in the United States and France"  
(Novembre 2007)

### **XREAP2007-12**

**Segarra-Blasco, A. (GRIT);**

"Innovation, R&D spillovers and productivity: the role of knowledge-intensive services"  
(Novembre 2007)



**XREAP2007-13**

**Bermúdez Morata, Ll.** (RFA-IREA); **Guillén Estany, M.** (RFA-IREA), **Solé Auró, A.** (RFA-IREA)

“Impacto de la inmigración sobre la esperanza de vida en salud y en discapacidad de la población española”  
(Novembre 2007)

**XREAP2007-14**

**Calaeys, P.** (AQR-IREA); **Ramos, R.** (AQR-IREA), **Suriñach, J.** (AQR-IREA)

“Fiscal sustainability across government tiers”  
(Desembre 2007)

**XREAP2007-15**

**Sánchez Hugalbe, A.** (IEB)

“Influencia de la inmigración en la elección escolar”  
(Desembre 2007)

**2008**

**XREAP2008-01**

**Durán Weitkamp, C.** (GRIT); **Martín Bofarull, M.** (GRIT) ; **Pablo Martí, F.**

“Economic effects of road accessibility in the Pyrenees: User perspective”  
(Gener 2008)

**XREAP2008-02**

**Díaz-Serrano, L.;** **Stoyanova, A. P.** (CREB)

“The Causal Relationship between Individual’s Choice Behavior and Self-Reported Satisfaction: the Case of Residential Mobility in the EU”  
(Març 2008)

**XREAP2008-03**

**Matas, A.** (GEAP); **Raymond, J. L.** (GEAP); **Roig, J. L.** (GEAP)

“Car ownership and access to jobs in Spain”  
(Abril 2008)

**XREAP2008-04**

**Bel, G.** (PPRE-IREA) ; **Fageda, X.** (PPRE-IREA)

“Privatization and competition in the delivery of local services: An empirical examination of the dual market hypothesis”  
(Abril 2008)

**XREAP2008-05**

**Matas, A.** (GEAP); **Raymond, J. L.** (GEAP); **Roig, J. L.** (GEAP)

“Job accessibility and employment probability”  
(Maig 2008)

**XREAP2008-06**

**Basher, S. A.;** **Carrión, J. Ll.** (AQR-IREA)

Deconstructing Shocks and Persistence in OECD Real Exchange Rates  
(Juny 2008)

**XREAP2008-07**

**Sanromá, E.** (IEB); **Ramos, R.** (AQR-IREA); **Simón, H.**

Portabilidad del capital humano y asimilación de los inmigrantes. Evidencia para España  
(Juliol 2008)

**XREAP2008-08**

**Basher, S. A.;** **Carrión, J. Ll.** (AQR-IREA)

Price level convergence, purchasing power parity and multiple structural breaks: An application to US cities  
(Juliol 2008)

**XREAP2008-09**

**Bermúdez, Ll.** (RFA-IREA)

A priori ratemaking using bivariate poisson regression models  
(Juliol 2008)



**XREAP2008-10**

**Solé-Ollé, A. (IEB), Hortas Rico, M. (IEB)**

Does urban sprawl increase the costs of providing local public services? Evidence from Spanish municipalities  
(Novembre 2008)

**XREAP2008-11**

**Teruel-Carrizosa, M. (GRIT), Segarra-Blasco, A. (GRIT)**

Immigration and Firm Growth: Evidence from Spanish cities  
(Novembre 2008)

**XREAP2008-12**

**Duch-Brown, N. (IEB), García-Quevedo, J. (IEB), Montolio, D. (IEB)**

Assessing the assignation of public subsidies: Do the experts choose the most efficient R&D projects?  
(Novembre 2008)

**XREAP2008-13**

**Bilotkach, V., Fageda, X. (PPRE-IREA), Flores-Fillol, R.**

Scheduled service versus personal transportation: the role of distance  
(Desembre 2008)

**XREAP2008-14**

**Albalate, D. (PPRE-IREA), Gel, G. (PPRE-IREA)**

Tourism and urban transport: Holding demand pressure under supply constraints  
(Desembre 2008)

**2009**

**XREAP2009-01**

**Calonge, S. (CREB); Tejada, O.**

“A theoretical and practical study on linear reforms of dual taxes”  
(Febrer 2009)

**XREAP2009-02**

**Albalate, D. (PPRE-IREA); Fernández-Villadangos, L. (PPRE-IREA)**

“Exploring Determinants of Urban Motorcycle Accident Severity: The Case of Barcelona”  
(Març 2009)

**XREAP2009-03**

**Borrell, J. R. (PPRE-IREA); Fernández-Villadangos, L. (PPRE-IREA)**

“Assessing excess profits from different entry regulations”  
(Abril 2009)

**XREAP2009-04**

**Sanromá, E. (IEB); Ramos, R. (AQR-IREA), Simon, H.**

“Los salarios de los inmigrantes en el mercado de trabajo español. ¿Importa el origen del capital humano?”  
(Abril 2009)

**XREAP2009-05**

**Jiménez, J. L.; Perdiguero, J. (PPRE-IREA)**

“(No)competition in the Spanish retailing gasoline market: a variance filter approach”  
(Maig 2009)

**XREAP2009-06**

**Álvarez-Albelo, C. D. (CREB), Manresa, A. (CREB), Pigem-Vigo, M. (CREB)**

“International trade as the sole engine of growth for an economy”  
(Juny 2009)

**XREAP2009-07**

**Callejón, M. (PPRE-IREA), Ortún V, M.**

“The Black Box of Business Dynamics”  
(Setembre 2009)

**XREAP2009-08**

**Lucena, A. (CREB)**

“The antecedents and innovation consequences of organizational search: empirical evidence for Spain”  
(Octubre 2009)



**XREAP2009-09**

**Domènech Campmajó, L.** (PPRE-IREA)

“Competition between TV Platforms”

(Octubre 2009)

**XREAP2009-10**

**Solé-Auró, A.** (RFA-IREA), **Guillén, M.** (RFA-IREA), **Crimmins, E. M.**

“Health care utilization among immigrants and native-born populations in 11 European countries. Results from the Survey of Health, Ageing and Retirement in Europe”

(Octubre 2009)

**XREAP2009-11**

**Segarra, A.** (GRIT), **Teruel, M.** (GRIT)

“Small firms, growth and financial constraints”

(Octubre 2009)

**XREAP2009-12**

**Matas, A.** (GEAP), **Raymond, J.Ll.** (GEAP), **Ruiz, A.** (GEAP)

“Traffic forecasts under uncertainty and capacity constraints”

(Novembre 2009)

**XREAP2009-13**

**Sole-Ollé, A.** (IEB)

“Inter-regional redistribution through infrastructure investment: tactical or programmatic?”

(Novembre 2009)

**XREAP2009-14**

**Del Barrio-Castro, T.**, **García-Quevedo, J.** (IEB)

“The determinants of university patenting: Do incentives matter?”

(Novembre 2009)

**XREAP2009-15**

**Ramos, R.** (AQR-IREA), **Suriñach, J.** (AQR-IREA), **Artís, M.** (AQR-IREA)

“Human capital spillovers, productivity and regional convergence in Spain”

(Novembre 2009)

**XREAP2009-16**

**Álvarez-Albelo, C. D.** (CREB), **Hernández-Martín, R.**

“The commons and anti-commons problems in the tourism economy”

(Desembre 2009)

**2010**

**XREAP2010-01**

**García-López, M. A.** (GEAP)

“The Accessibility City. When Transport Infrastructure Matters in Urban Spatial Structure”

(Febrer 2010)

**XREAP2010-02**

**García-Quevedo, J.** (IEB), **Mas-Verdú, F.** (IEB), **Polo-Otero, J.** (IEB)

“Which firms want PhDs? The effect of the university-industry relationship on the PhD labour market”

(Març 2010)

**XREAP2010-03**

**Pitt, D.**, **Guillén, M.** (RFA-IREA)

“An introduction to parametric and non-parametric models for bivariate positive insurance claim severity distributions”

(Març 2010)

**XREAP2010-04**

**Bermúdez, Ll.** (RFA-IREA), **Karlis, D.**

“Modelling dependence in a ratemaking procedure with multivariate Poisson regression models”

(Abril 2010)

**XREAP2010-05**

**Di Paolo, A.** (IEB)

“Parental education and family characteristics: educational opportunities across cohorts in Italy and Spain”

(Maig 2010)

**XREAP2010-06**

**Simón, H.** (IEB), **Ramos, R.** (AQR-IREA), **Sanromá, E.** (IEB)



“Movilidad ocupacional de los inmigrantes en una economía de bajas cualificaciones. El caso de España”  
(Juny 2010)

**XREAP2010-07**

**Di Paolo, A.** (GEAP & IEB), **Raymond, J. Ll.** (GEAP & IEB)  
“Language knowledge and earnings in Catalonia”  
(Juliol 2010)

**XREAP2010-08**

**Bolancé, C.** (RFA-IREA), **Alemaný, R.** (RFA-IREA), **Guillén, M.** (RFA-IREA)  
“Prediction of the economic cost of individual long-term care in the Spanish population”  
(Setembre 2010)

**XREAP2010-09**

**Di Paolo, A.** (GEAP & IEB)  
“Knowledge of catalan, public/private sector choice and earnings: Evidence from a double sample selection model”  
(Setembre 2010)

**XREAP2010-10**

**Coad, A., Segarra, A.** (GRIT), **Teruel, M.** (GRIT)  
“Like milk or wine: Does firm performance improve with age?”  
(Setembre 2010)

**XREAP2010-11**

**Di Paolo, A.** (GEAP & IEB), **Raymond, J. Ll.** (GEAP & IEB), **Calero, J.** (IEB)  
“Exploring educational mobility in Europe”  
(Octubre 2010)

**XREAP2010-12**

**Borrell, A.** (GiM-IREA), **Fernández-Villadangos, L.** (GiM-IREA)  
“Clustering or scattering: the underlying reason for regulating distance among retail outlets”  
(Desembre 2010)

**XREAP2010-13**

**Di Paolo, A.** (GEAP & IEB)  
“School composition effects in Spain”  
(Desembre 2010)

**XREAP2010-14**

**Fageda, X.** (GiM-IREA), **Flores-Fillol, R.**  
“Technology, Business Models and Network Structure in the Airline Industry”  
(Desembre 2010)

**XREAP2010-15**

**Albalate, D.** (GiM-IREA), **Bel, G.** (GiM-IREA), **Fageda, X.** (GiM-IREA)  
“Is it Redistribution or Centralization? On the Determinants of Government Investment in Infrastructure”  
(Desembre 2010)

**XREAP2010-16**

**Oppedisano, V., Turati, G.**  
“What are the causes of educational inequalities and of their evolution over time in Europe? Evidence from PISA”  
(Desembre 2010)

**XREAP2010-17**

**Canova, L., Vaglio, A.**  
“Why do educated mothers matter? A model of parental help”  
(Desembre 2010)

**2011**

**XREAP2011-01**

**Fageda, X.** (GiM-IREA), **Perdiguero, J.** (GiM-IREA)  
“An empirical analysis of a merger between a network and low-cost airlines”  
(Maig 2011)



**XREAP2011-02**

**Moreno-Torres, I.** (ACCO, CRES & GiM-IREA)

“What if there was a stronger pharmaceutical price competition in Spain? When regulation has a similar effect to collusion”  
(Maig 2011)

**XREAP2011-03**

**Miguélez, E.** (AQR-IREA); **Gómez-Miguélez, I.**

“Singling out individual inventors from patent data”  
(Maig 2011)

**XREAP2011-04**

**Moreno-Torres, I.** (ACCO, CRES & GiM-IREA)

“Generic drugs in Spain: price competition vs. moral hazard”  
(Maig 2011)

**XREAP2011-05**

**Nieto, S.** (AQR-IREA), **Ramos, R.** (AQR-IREA)

“¿Afecta la sobreeducación de los padres al rendimiento académico de sus hijos?”  
(Maig 2011)

**XREAP2011-06**

**Pitt, D., Guillén, M.** (RFA-IREA), **Bolancé, C.** (RFA-IREA)

“Estimation of Parametric and Nonparametric Models for Univariate Claim Severity Distributions - an approach using R”  
(Juny 2011)

**XREAP2011-07**

**Guillén, M.** (RFA-IREA), **Comas-Herrera, A.**

“How much risk is mitigated by LTC Insurance? A case study of the public system in Spain”  
(Juny 2011)

**XREAP2011-08**

**Ayuso, M.** (RFA-IREA), **Guillén, M.** (RFA-IREA), **Bolancé, C.** (RFA-IREA)

“Loss risk through fraud in car insurance”  
(Juny 2011)

**XREAP2011-09**

**Duch-Brown, N.** (IEB), **García-Quevedo, J.** (IEB), **Montolio, D.** (IEB)

“The link between public support and private R&D effort: What is the optimal subsidy?”  
(Juny 2011)

**XREAP2011-10**

**Bermúdez, Ll.** (RFA-IREA), **Karlis, D.**

“Mixture of bivariate Poisson regression models with an application to insurance”  
(Juliol 2011)

**XREAP2011-11**

**Varela-Irimia, X-L.** (GRIT)

“Age effects, unobserved characteristics and hedonic price indexes: The Spanish car market in the 1990s”  
(Agost 2011)

**XREAP2011-12**

**Bermúdez, Ll.** (RFA-IREA), **Ferri, A.** (RFA-IREA), **Guillén, M.** (RFA-IREA)

“A correlation sensitivity analysis of non-life underwriting risk in solvency capital requirement estimation”  
(Setembre 2011)

**XREAP2011-13**

**Guillén, M.** (RFA-IREA), **Pérez-Marín, A.** (RFA-IREA), **Alcañiz, M.** (RFA-IREA)

“A logistic regression approach to estimating customer profit loss due to lapses in insurance”  
(Octubre 2011)

**XREAP2011-14**

**Jiménez, J. L., Perdiguero, J.** (GiM-IREA), **García, C.**

“Evaluation of subsidies programs to sell green cars: Impact on prices, quantities and efficiency”  
(Octubre 2011)



**XREAP2011-15**

**Arespa, M.** (CREB)

“A New Open Economy Macroeconomic Model with Endogenous Portfolio Diversification and Firms Entry”  
(Octubre 2011)

**XREAP2011-16**

**Matas, A.** (GEAP), **Raymond, J. L.** (GEAP), **Roig, J.L.** (GEAP)

“The impact of agglomeration effects and accessibility on wages”  
(Novembre 2011)

**XREAP2011-17**

**Segarra, A.** (GRIT)

“R&D cooperation between Spanish firms and scientific partners: what is the role of tertiary education?”  
(Novembre 2011)

**XREAP2011-18**

**García-Pérez, J. I.; Hidalgo-Hidalgo, M.; Robles-Zurita, J. A.**

“Does grade retention affect achievement? Some evidence from PISA”  
(Novembre 2011)

**XREAP2011-19**

**Arespa, M.** (CREB)

“Macroeconomics of extensive margins: a simple model”  
(Novembre 2011)

**XREAP2011-20**

**García-Quevedo, J.** (IEB), **Pellegrino, G.** (IEB), **Vivarelli, M.**

“The determinants of YICs’ R&D activity”  
(Desembre 2011)

**XREAP2011-21**

**González-Val, R.** (IEB), **Olmo, J.**

“Growth in a Cross-Section of Cities: Location, Increasing Returns or Random Growth?”  
(Desembre 2011)

**XREAP2011-22**

**Gombau, V.** (GRIT), **Segarra, A.** (GRIT)

“The Innovation and Imitation Dichotomy in Spanish firms: do absorptive capacity and the technological frontier matter?”  
(Desembre 2011)

**2012**

**XREAP2012-01**

**Borrell, J. R.** (GiM-IREA), **Jiménez, J. L.,** **García, C.**

“Evaluating Antitrust Leniency Programs”  
(Gener 2012)

**XREAP2012-02**

**Ferri, A.** (RFA-IREA), **Guillén, M.** (RFA-IREA), **Bermúdez, Ll.** (RFA-IREA)

“Solvency capital estimation and risk measures”  
(Gener 2012)

**XREAP2012-03**

**Ferri, A.** (RFA-IREA), **Bermúdez, Ll.** (RFA-IREA), **Guillén, M.** (RFA-IREA)

“How to use the standard model with own data”  
(Febrer 2012)

**XREAP2012-04**

**Perdiguero, J.** (GiM-IREA), **Borrell, J.R.** (GiM-IREA)

“Driving competition in local gasoline markets”  
(Març 2012)

**XREAP2012-05**

D’Amico, G., **Guillen, M.** (RFA-IREA), Manca, R.

“Discrete time Non-homogeneous Semi-Markov Processes applied to Models for Disability Insurance”  
(Març 2012)



**XREAP2012-06**

**Bové-Sans, M. A.** (GRIT), Laguardo-Ramírez, R.  
“Quantitative analysis of image factors in a cultural heritage tourist destination”  
(Abril 2012)

**XREAP2012-07**

**Tello, C.** (AQR-IREA), **Ramos, R.** (AQR-IREA), **Artís, M.** (AQR-IREA)  
“Changes in wage structure in Mexico going beyond the mean: An analysis of differences in distribution, 1987-2008”  
(Maig 2012)

**XREAP2012-08**

**Jofre-Monseny, J.** (IEB), **Marín-López, R.** (IEB), **Viladecans-Marsal, E.** (IEB)  
“What underlies localization and urbanization economies? Evidence from the location of new firms”  
(Maig 2012)

**XREAP2012-09**

**Muñiz, I.** (GEAP), **Calatayud, D.**, **Dobaño, R.**  
“Los límites de la compacidad urbana como instrumento a favor de la sostenibilidad. La hipótesis de la compensación en Barcelona medida a través de la huella ecológica de la movilidad y la vivienda”  
(Maig 2012)

**XREAP2012-10**

**Arqué-Castells, P.** (GEAP), **Mohnen, P.**  
“Sunk costs, extensive R&D subsidies and permanent inducement effects”  
(Maig 2012)

**XREAP2012-11**

**Boj, E.** (CREB), **Delicado, P.**, **Fortiana, J.**, **Esteve, A.**, **Caballé, A.**  
“Local Distance-Based Generalized Linear Models using the dbstats package for R”  
(Maig 2012)

**XREAP2012-12**

**Royuela, V.** (AQR-IREA)  
“What about people in European Regional Science?”  
(Maig 2012)

**XREAP2012-13**

**Osorio A. M.** (RFA-IREA), **Bolancé, C.** (RFA-IREA), **Madise, N.**  
“Intermediary and structural determinants of early childhood health in Colombia: exploring the role of communities”  
(Juny 2012)

**XREAP2012-14**

**Miguelé, E.** (AQR-IREA), **Moreno, R.** (AQR-IREA)  
“Do labour mobility and networks foster geographical knowledge diffusion? The case of European regions”  
(Juliol 2012)

**XREAP2012-15**

**Teixidó-Figueras, J.** (GRIT), **Duró, J. A.** (GRIT)  
“Ecological Footprint Inequality: A methodological review and some results”  
(Setembre 2012)

**XREAP2012-16**

**Varela-Irimia, X-L.** (GRIT)  
“Profitability, uncertainty and multi-product firm product proliferation: The Spanish car industry”  
(Setembre 2012)

**XREAP2012-17**

**Duró, J. A.** (GRIT), **Teixidó-Figueras, J.** (GRIT)  
“Ecological Footprint Inequality across countries: the role of environment intensity, income and interaction effects”  
(Octubre 2012)

**XREAP2012-18**

**Manresa, A.** (CREB), **Sancho, F.**  
“Leontief versus Ghosh: two faces of the same coin”  
(Octubre 2012)



**XREAP2012-19**

**Alemany, R.** (RFA-IREA), **Bolancé, C.** (RFA-IREA), **Guillén, M.** (RFA-IREA)

“Nonparametric estimation of Value-at-Risk”

(Octubre 2012)

**XREAP2012-20**

**Herrera-Idárraga, P.** (AQR-IREA), **López-Bazo, E.** (AQR-IREA), **Motellón, E.** (AQR-IREA)

“Informality and overeducation in the labor market of a developing country”

(Novembre 2012)

**XREAP2012-21**

**Di Paolo, A.** (AQR-IREA)

“(Endogenous) occupational choices and job satisfaction among recent PhD recipients: evidence from Catalonia”

(Desembre 2012)

**2013**

**XREAP2013-01**

**Segarra, A.** (GRIT), **García-Quevedo, J.** (IEB), **Teruel, M.** (GRIT)

“Financial constraints and the failure of innovation projects”

(Març 2013)

**XREAP2013-02**

**Osorio, A. M.** (RFA-IREA), **Bolancé, C.** (RFA-IREA), **Madise, N.**, **Rathmann, K.**

“Social Determinants of Child Health in Colombia: Can Community Education Moderate the Effect of Family Characteristics?”

(Març 2013)

**XREAP2013-03**

**Teixidó-Figueras, J.** (GRIT), **Duró, J. A.** (GRIT)

“The building blocks of international ecological footprint inequality: a regression-based decomposition”

(Abril 2013)

**XREAP2013-04**

**Salcedo-Sanz, S.**, **Carro-Calvo, L.**, **Claramunt, M.** (CREB), **Castañer, A.** (CREB), **Marmol, M.** (CREB)

“An Analysis of Black-box Optimization Problems in Reinsurance: Evolutionary-based Approaches”

(Maig 2013)

**XREAP2013-05**

**Alcañiz, M.** (RFA), **Guillén, M.** (RFA), **Sánchez-Moscona, D.** (RFA), **Santolino, M.** (RFA), **Llatje, O.**, **Ramon, Ll.**

“Prevalence of alcohol-impaired drivers based on random breath tests in a roadside survey”

(Juliol 2013)

**XREAP2013-06**

**Matas, A.** (GEAP & IEB), **Raymond, J. Ll.** (GEAP & IEB), **Roig, J. L.** (GEAP)

“How market access shapes human capital investment in a peripheral country”

(Octubre 2013)

**XREAP2013-07**

**Di Paolo, A.** (AQR-IREA), **Tansel, A.**

“Returns to Foreign Language Skills in a Developing Country: The Case of Turkey”

(Novembre 2013)

**XREAP2013-08**

**Fernández Gual, V.** (GRIT), **Segarra, A.** (GRIT)

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[xarxa.xreap@gmail.com](mailto:xarxa.xreap@gmail.com)