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Greek GDP NOWcasting for Q2, Q3 & Q4, 2015; preliminary estimates of the impact of the new austerity measures

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Based on a range of macro data releases up to July 24th, this note provides a preliminary estimate of Greece's Q2 GDP as well as forecasts for the third and the fourth quarter of this year. It also presents a preliminary estimate of the recessionary impact of the new package of fiscal measures agreed at the July 13th Euro Summit.

GDP Nowcasting model estimate for Q2 and forecasts for Q3&Q4 2015

Our Nowcasting model produces high frequency, real-time estimates of Greece's gross domestic product by applying an econometric methodology that can properly handle data reporting lags, revisions and other important aspects characterizing the daily flow of macroeconomic information. In the particular exercise presented herein, we provide a preliminary estimate of Greece's Q2 GDP as well as forecasts for the third and the fourth quarter of this year. As a note of caution, we emphasize that due to reporting lags, the flow of macro data pertaining to Q2 2015 will continue in the following couple of months and thus, our GDP estimate for that quarter should be considered as strictly preliminary and subject to revisions. The same applies for our GDP forecasts for Q3 & Q4 GDP. That is, especially taking into consideration the unusually high degree of uncertainty characterizing the current economic and political trajectory. *A technical description of the model and its output can be found in Appendix at the end of this document.* In ESA2010 accounting terms, our estimate and forecasts for the second, third and fourth quarters of this year are as follows:

GDP in 2010 prices (mid-point estimate/forecast)

In EUR bn: Q2: €46.3bn; Q3: €45.bn; Q4: €44.4bn vs. €46.5bn in Q1 2015

QoQ s.a. growth: Q2: -0.6%; Q3: -2.3%; Q4: -1.7% vs. -0.16% in Q1 2015

YoY s.a. growth: Q2: -0.5%; Q3: -3.4%; Q4: -4.6% vs. +0.35% in Q1 2015

Full-year real GDP growth: -2.05% in 2015 vs. +0.77% in 2014

As things stand at this point, there is little doubt that the positive momentum that was experienced in the greater part of last year has been lost, with the domestic economy having already entered a new recessionary phase. For the year 2015 as a whole, we expect real GDP to contract by around 2%, with the economic downturn being more pronounced in the second semester of the year. The new fiscal austerity package agreed at the July 12 Euro Summit, the disruptions created by the recent bank holiday and the imposition of capital controls are expected to be among the key drivers of GDP dynamics in the months and quarters ahead. On the other hand, a swift resolution of uncertainty as regards the outlook of negotiations with official creditors on a new bailout programme and, eventually, the stabilization of the domestic banking system and the mobilization of EU funding to support domestic investment and job creation would be instrumental to allow a stabilization of the domestic environment and a resumption of positive economic growth.

In what follows, we present a preliminary analysis of the recessionary impact of the new package of fiscal austerity measures agreed at the July 13th Euro Summit.

Estimating the macroeconomic impact of the new package of austerity measures

Table A1 below shows the estimated macroeconomic effects of the austerity measures to be part of conditionality underlying Greece's 3rd bailout programme. The table assumes that fiscal multipliers follow the convex, autoregressive decay path analyzed below (see *Impact multipliers, multiplier persistence & hysteresis assumptions*).[1] The *impact* multipliers assumed herein are broadly similar with these estimated in a number of recent empirical studies on fiscal multipliers in Greece.[2] Furthermore, the parameter values (α, β) are similar to these assumed in European Commission (2013)[3]. The estimates presented below are based on the set of measures portrayed in Table A2. They should be considered as strictly preliminary and subject to revisions once the exact size and the implementation profile of the full set of new measures is publicly known.

Table A1 – Estimated impact of measures (EUR million)

Baseline Scenario - Impact multiplier values as in *Note* below / peristence (α=0.3) / no hysteresis (β = 0.0)	2015	2016	2017	2018	2019	2020	2015-2020
A . Revenue measures - permanent increase in VAT & other taxes	-1068	-1277	-383	-115	-34	-10	-2889
B. Other permanent revenue measures	-630	-744	-372	-186	-93	-47	-2072
C. Expenditure measures (permanent cuts in social transfers)	-460	-791	-476	-365	-320	-96	-2509
D. Defense spending cuts	-60	-78	-23	-7	-2	-1	-171
Total impact	-2218	-2891	-1255	-673	-450	-154	-7640

Source: Eurobank Research

Note

Assumed *impact* multiplier values

A: -0.6; B: -0.6; C: -1.0; D: - 0.6

[1] The decay function assumed herein reproduces relatively well the shape of the impulse-response function by typical DSGE models for most of permanent fiscal shocks.

[2] See e.g. Monokroussos P. and D. Thomakos, "Fiscal multipliers in deep economic recessions and the case for a 2-year extension in Greece's austerity programme", Eurobank Research, Economy & Markets Vol. VIII |Issue 4 |October 2012 http://www.eurobank.gr/Uploads/Reports/ECONOMY%20AND%20MARKETSfiscal%20multipliers.pdf
See also, Monokroussos P. and D. Thomakos, "Greek fiscal multipliers revisited. Government spending cuts vs tax hikes and the role of public investment expenditure", Eurobank Research, Economy & Markets Vol. VIII |Issue 3 |March 2013 http://www.eurobank.gr/Uploads/Reports/Economy%20and%20Markets%20march%2020123.pdf

[3] See "Effects of fiscal consolidation envisaged in the 2013 Stability and Convergence Programmes on public debt dynamics in EU Member States", European Commission, Economic Papers 504 / September 2013 http://ec.europa.eu/economy_finance/publications/economic_paper/2013/pdf/ecp504_en.pdf

Table B2 – New measures (in EUR million)

	2015	2016	2017	2018	2019
	Revenue measures (permanent increase in VAT and other taxes)				
VAT reform	795	2390	2390	2390	2390
Tax on insurance contracts	75.6	75.6	75.6	75.6	75.6
Increase in corporate income tax (to 29% from 26%)	410	410	410	410	410
Increase in luxury tax (to 13% from 10%)	48.5	48.5	48.5	48.5	48.5
Increase in solidarity tax (for incomes >30k/annum)	251	251	251	251	251
Increase in income tax rate for rents to 15% for incomes <€12k/annum and to 35% for incomes >€12k	200	200	200	200	200
Special levy on incomes > € 500k/annum	*n.a.*	*n.a.*	*n.a.*	*n.a.*	*n.a.*
Increase in the tonnage tax rate; abolishment of special tax treatments of the shipping industry	*n.a.*	*n.a.*	*n.a.*	*n.a.*	*n.a.*
	Other permanent revenue measures				
TV advertisment tax	100	100	100	100	100
E-gaming-VLTs (to be installed in H2 2015 & 2016)	35	225	225	225	225
Pharmaceutical rebates	140	140	140	140	140
Installment scheme	500	500	500	500	500
Fuel smuggling	75	300	300	300	300
Audits on bank accounts	200	500	500	500	500
Increase in the tonnage tax rate; abolishment of special tax treatements of the shipping industry	*n.a*	*n.a*	*n.a*	*n.a*	*n.a*
	Other revenue measures (one off and/or with temporary impact)				
Licenses to 4G and 5G		350			
Fees and licences for TV channels		340			
Increase in advance tax payment for corporate income	445				
	Expenditure measures (permanent cuts in social transfers)				
Gradual abolishment of early retirement scheme; adjustement of early retirement penalities (effective from 01/07/2015)	25.6	117.6	239.2	344.7	455.3
Provision of the basic, guaranteed contributory and means tested pension for those retiring after 30/06/2015 until they reach the statutory normal retirement age of 67 years	4.2	25.7	42.87	60	60
Increase for health contribution for main & supplementary pensions	422	854	854	854	854
Integration of supplementary funds into ETEA	8	16	16	16	16
Gradual abolishment of the solidary grant (EKAS) by end-2019 (or equivalent measures)	0	100	200	300	400
Abolishment of subsidies for excise on diesel oil for farmers (in FY-2016 Budget)	*n.a*	*n.a*	*n.a*	*n.a*	*n.a*
Abolishment of special tax treatement for agriculture income by 2017	*n.a*	*n.a*	*n.a*	*n.a*	*n.a*
	Expenditure measures (permanent cuts in defense expenditure)				
Cuts in defense spending	100	200	200	200	200
Source: official data and author's estimates					
n.a. denotes data not available					

Impact multipliers, multiplier persistence & hysteresis assumptions

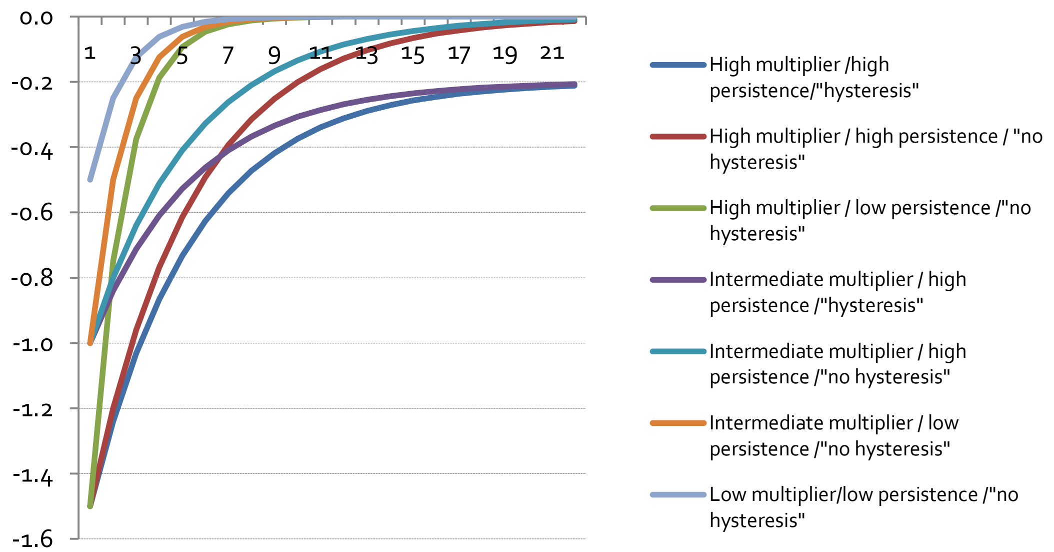
In order to incorporate multiplier persistence in our simulation exercise we follow Boussard et al. (2012) and European Commission (2013)[4] and assume that fiscal multipliers follow the following convex, autoregressive decay path:

$$m_{t,i} = (m_1 - \beta)\alpha^{i-t} + \beta$$

where, m_1 is the impact (*i.e.*, first year) multiplier, $m_{t,I}$ is the fiscal multiplier applying in year *i* following a permanent fiscal shock in year *t*, $0 < \alpha < 1$; and β *is* the long-run impulse response of GDP to fiscal consolidation. A negative value of β indicates that "hysteresis" effects are present (see *e.g.* de Long and Summers, 2012). A positive one represents a situation in which a consolidation today boosts long term growth by *e.g.* reducing the interest rate and by lessening the crowding out on private investment.

For illustration purposes, the following figure depicts a hypothetical decaying path of fiscal multipliers. In more detail, the initial value of the (impact) multiplier is assumed to take one of the following three values: **-1.5** "high multiplier"; **-1.0** "intermediate multiplier" and **-0.5** "low multiplier". Moreover, "high persistence" corresponds to the following parameter value: α=0.8 and "low persistence" corresponds to α=0.5. Finally, for the presence of "hysteresis" effects we assume β=-0.2, while the case of β=0 corresponds to "no hysteresis" effects.

Figure: Response of GDP to one-off cyclical adjustment



Source: EC (September 2013); Eurobank Global Markets Research

Note: Response of GDP in years t=1,...,21 per one unit cut in cyclically adjusted primary balance in year t=1. Assuming that the same logic applies, then a unit increase in the cyclically adjusted primary balance in year t=1, would lead to a GDP response that could be portrayed by inverting the above figure.

[4] See "Effects of fiscal consolidation envisaged in the 2013 Stability and Convergence Programmes on public debt dynamics in EU Member States", European Commission, Economic Papers 504 / September 2013 http://ec.europa.eu/economy_finance/publications/economic_paper/2013/pdf/ecp504_en.pdf

Appendix - Nowcasting model for Greek GDP: *an outline*

Information about the current state of the real economy is widely dispersed across consumers, firms and policy makers. Individual economic agents may know the recent history of their saving and investment decisions, but they are generally unaware of the contemporaneous decisions of others. Similarly, policymakers do not have access to accurate contemporaneous information concerning private sector activity. Information about the state of the economy is regularly collected, aggregated and disseminated to the general public by a number of official-sector entities such as national statistic agencies, ministries, employment offices and central banks. Yet, it is generally the case that the collection and aggregation of macroeconomic data takes time and thus, its dissemination (e.g. in the form of economic data announcements) occurs with considerable time lags. The implication of this is twofold; first, it inhibits the ability of the monetary and/or the fiscal authority to take timely policy decisions that fully incorporate the most recent information on the state of the macroeconomy; and second, it prevents a more accurate understanding of the behavior of private-sector agents and the evolution of asset prices[5]. In what follows, we provide a brief description of an econometric model we have developed to derive real-time estimates of Greek GDP, based on the information provided by a broad range of indicators of domestic economic and market activity.

Data reporting lags and other aspects characterizing the flow of macroeconomic information

The Nowcasting model presented in this paper aims to produce high frequency, real-time estimates of Greek GDP by applying an econometric methodology than can properly handle data reporting lags, revisions and other important aspects characterizing the daily flow of macroeconomic information. Our model is broadly similar to that initially presented in Evans (2005)[6], with certain modifications being made so as to meet our estimation and forecasting objectives. In the remaining part of this section we provide a non-technical description of the model and its output[7]. As a first step in understanding the structure of this paper it is crucial to highlight and discuss some of the peculiarities characterizing the flow of information that is relevant to the macroeconomy. For this purpose, a distinction needs to be made between the arrival of information and the data collection period. Information relevant to the evolution of real economic activity can generally arrive via data releases on any working day (except e.g. national holidays), while GDP data is collected on a quarterly basis. In Greece, the national stats agency, EL.STAT., releases GDP data for any given quarter τ in a sequence of two announcements. These announcements take the form of a *flash* estimate and a *provisional* data release that usually take place in the second and the third month of quarter τ+1, respectively. Yet, these releases do not actually represent the last official verdict on Gross Domestic Product in quarter τ, as every 1 year or so EL.STAT conducts a comprehensive review of its earlier estimates, an exercise that usually leads to certain revisions in past GDP data. Furthermore, a more comprehensive assessment (and a change of the base year) is conducted every five years.

Real-time inferences

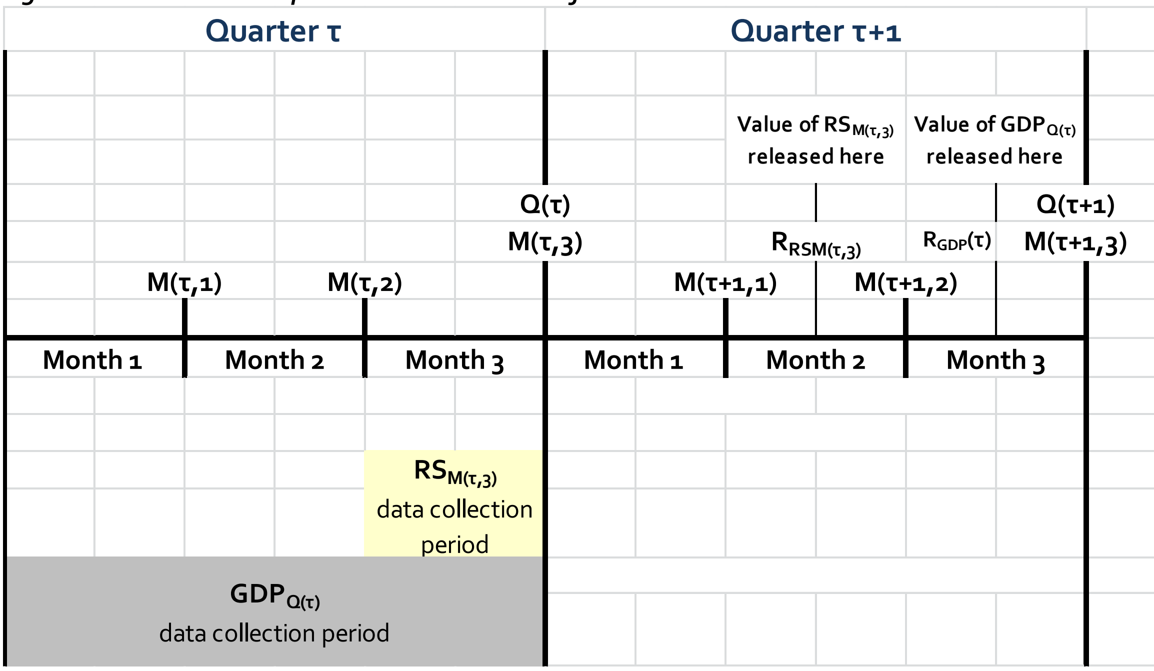
Following the relevant notation presented in Evans (2005), we index quarters by τ, with Q(τ) signifying the last day of quarter τ and M(τ, 1), M(τ, 2) and M(τ, 3) denoting the last days of the first, second and third months of quarter τ, respectively. The day on which a certain data release is taking place is then signified by $R_x(\tau)$ for a quarterly-frequency variable x collected over quarter τ, and by $R_x(\tau,i)$ with i=1,2,3 for a monthly-frequency variable collected over month i of quarter τ. In a similar vein, the value of a quarterly variable x released on day $R_x(\tau)$ is denoted by $x_R(\tau)$, while that of a monthly variable released on day $R_x(\tau,i)$ by $x_R(\tau,i)$. Figure 1 below helps to clarify the aforementioned points, offering a visual depiction of the relationship between data collection periods and reporting lags. The figure portrays the typical data collection periods and release times for Greek Gross Domestic Product and Retail Sales (RS), with $GDP_{Q(\tau)}$ representing real GDP growth in quarter τ and $RS_{M(\tau,3)}$ denoting the value of Greece's retail sales index for the 3rd month of quarter τ.

[5] For instance, Evans and Lyons (2004a) demonstrate that the lack of timely information concerning the state of the macroeconomy can significantly influence the dynamics of exchange and interest rates by altering the trading-based process of information aggregation.

[6] Evans. M., "Where Are We Now? Real-Time Estimates of the Macro Economy", NBER Working Paper No. 11064, January 2005.

[7] A more detailed prescription of our Nowcasting model and its output can be found in Greece Macro Monitor, *"Eurobank GDP NOWcasting model"*, Eurobank Global Markets Research, November 18, 2013.

Figure 1 – Data collection periods & released times for Greek GDP and Retail Sales



Source: Eurobank Global Markets Research

The reporting lags for the initial retail sales and the provisions GDP data depicted in the figure above are $R_{RSM(τ,3)}$ -M(τ,3) and $R_{GDP(τ)}$ - Q(τ) , respectively. Our analysis of the data series in hand shows that the reporting lag of the retail sales index has been 2 months for the majority of *initial* retail sales data releases. More specifically, in 76 out of a total of 80 such releases, the publication of the retail sales index for a given month (say the 3rd month of quarter τ) has taken place in the second month after the end of the reference quarter (i.e., following the notation presented in Figure 1, in the second month of quarter τ+1). Again, sticking to the notation presented in Evans (2005), let us denote by $X_Q(τ)$ the log of real GDP of quarter τ ending on day Q(τ) and $Y_R(τ)$ the provisional real GDP growth data released on day $R_Y(τ)$, which, as we have said earlier, usually falls in the 3rd month of quarter τ.

The relation between the provisional GDP growth data and the actual GDP is given by

$$Y_R(τ) = Δ^Q X_Q(τ) + U_R(τ) \quad (1)$$

Where $Δ^Q X_Q(τ) = X_Q(τ) - X_Q(τ-1)$ and $U_R(τ)$ represents the effect of future data revisions i.e., the revision to GDP growth made after $R_Y(τ)$. As implied by equation (1) the reporting lag for the provisional quarterly GDP data (i.e., the second report EL.STAT releases on GDP growth of quarter τ) is $R_Y(τ)$ - Q(τ). Similarly, the reporting lag for the data series x collected during month i of quarter τ is $R_x(τ,i)$-M(τ,i). Reporting lags vary from quarter to quarter as data is collected on a calendar basis, while announcements are not made on holidays and weekends.

Data used in our Nowcasting exercise

The sources of the data series used to derive real-time estimates of Greek GDP growth include: the Greek statistics agency, EL.STAT, Bank of Greece, the Ministry of Labor, Social Security and Welfare, the Foundation for Economic and Industrial Research (IOBE), ECB and Bloomberg. Data collection and reporting of all series used takes place in monthly frequency, except of real GDP and the retail trade turnover index for which data collection is quarterly. The model is estimating using one quarterly GDP release, which is taken from EL.STAT's Quarterly National Accounts report (provisional data). In our full data sample, the latter report is invariably released in the 3rd month of quarter τ+1 and provides a provisional estimate of real GDP in quarter τ. The other time series used in the model correspond to 24 indicators, which have been selected from an initial set of more than 60 indicators, on the basis of their economic significance and statistical properties.

The data samples used herein vary across indicators depending on data availability, with the longest one covering the period from March 2005 to March 2015. For some days there was only one data release and for a much smaller number of days there was more than one release. Table A1 at the end of this section provides an overview of the data series used to derive real-time estimates of Greek GDP, including relevant information about full-sample periods, data collection periods and reporting frequencies as well as the total number of observations for each series with reporting lags of 0,1,2,3 and 4 months.

We note that the data series for the macro indicators used to estimate our model correspond to *initial* data releases *e.g.* before any revisions to past data are made by the corresponding data source/provider. The only exception here concerns the GDP data, for which, as we explained earlier, we use the second release (provisional data) for any given quarter, as there is currently no availability of the time series of initial GDP releases (*flash* estimates). For the market indicators utilized in our study we use end-of-month closing prices/values taken from Bloomberg. We seasonally-adjust the data series used to estimate our model when appropriate (*e.g.* no seasonal adjustment is applied to our market indicators). In line with Evans (2005), we also apply the following data transformation for each of the monthly indicators and the quarterly retail trade turnover index.

Let $z^i_{R(\tau,j)}$ denote the raw value for series i released on day t = R (τ,j), where τ denotes the quarter and j the corresponding month to which the data refers to. The transformed series entering the model has the following semi-differencing form: $z^i_{R(\tau,j)} = (z^i_{R(\tau,j)} - z^i_{mean}) - \alpha_i\,(z^i_{R(\tau,j-1)} - z^i_{mean})$, where z^i_{mean} is the sample mean of z^i. As noted in Evans (2005), quasi-differencing in this way allows each of the raw-data series to have a differing degree of persistence than the monthly contribution to GDP growth without including serial correlation in the corresponding projection errors. The degree of quasi-differencing depends on the α_i parameters which are jointly estimated with the other model parameters. As a robustness check, we also estimated model specifications which did not incorporate semi-differencing of monthly series in the form described above, but, instead, first differencing of the corresponding series. The results of this exercise are qualitatively similar with the estimates provided by the initial semi-differencing.

The Model

The real-time estimates of GDP in quarter τ presented in this paper is based on the *provisional* data of Greece's quarterly national accounts (which are regularly reported in the 3rd month of quarter τ+1) and the monthly releases of a range of other macroeconomic and market indicators. For that purpose, we first decompose quarterly GDP growth into a sequence of daily increments as follows:

$$\Delta^Q X_{Q(\tau)} = \sum_{i=1}^{D(\tau)} \Delta^Q X_{Q(\tau-1)+i} \qquad (2.1)$$

where D(τ) = Q(τ) - Q(τ-1) is the duration of quarter τ and the daily increment ΔX_t represents the contribution on day t to the growth of GDP in quarter τ. To incorporate then the information contained in the i^th^ macro variable z^i, we project $z^i_{R(\tau,j)}$ on a portion of GDP growth

$$z^i_{R(\tau,j)} = \beta_i \Delta^M X_{M(\tau,j)} + u^i_{M(\tau,j)} \qquad (2.2)$$

Where $\Delta^M X_{M(\tau,j)}$ is the contribution to GDP growth in month j of quarter τ, ($\Delta^M X_{M(\tau,j)} = \sum_{i=M(\tau,j-1)+1}^{M(\tau,j)} \Delta X_i$), β_i is a projection coefficient and $u^i_{M(\tau,j)}$ is a projection error that is orthogonal to $\Delta^M X_{M(\tau,j)}$.

The end-of-quarter real time GDP estimates presented in this paper are then contracted as follows:

$E[\Delta^Q X_{Q(\tau)} / \Omega_{Q(\tau)}]$

where $\Omega_t = \Omega^z_t \cup \Omega^y_t$, with Ω^z_t representing the information set comprising of data on the macroeconomic and market indicators used in this study that have been released on or before day t.

The dynamics of the model are characterized by the evolution of the following two partial sums:

$$s^Q_t = \sum_{i=Q(\tau-1)+1}^{\min\{Q(\tau),t\}} \Delta X_i \qquad (3.1)$$

$s^M \sum_{i=M(\tau,j-1)+1}^{\min\{M(\tau,j),t\}} {}_t\, \Delta X_i$ (3.2)

Equation (3.1) represents the cumulative daily contribution to GDP growth in quarter τ, ending on day t ≤ Q(τ). Similarly, equation (3.2) depicts the cumulative daily contribution to GDP growth between the start of month j in quarter τ and day t, where t ≤ M(t,j).

To define the daily dynamics of the two partial sums described above, the following dummy variables are introduced:
$\lambda^M_t = 1$ *if* $t = M(\tau,j)+1$, from j = 1,2,3 and zero (0) otherwise.
$\lambda^Q_t = 1$ *if* $t = Q(\tau)+1$, and zero (0) otherwise.
In others words, λ^M_t and λ^Q_t take the value of one if day t is the first day of the month or quarter respectively.

Based on the above definitions, the daily dynamics of s^Q_t and s^M_t can be described by the following equations:
$s^Q_t = (1-\lambda^Q_t)\, s^Q_{t-1} + \Delta X_t,$ (4.1)

$s^M_t = (1-\lambda^M_t)\, s^M_t + \Delta X_t.$ (4.2)

The next portion of the model accommodates the reporting lags. Let $\Delta^{Q(j)}X_t$ denote the quarterly growth in GDP ending on day Q(τ-j) where Q(τ) represents the last day of the most recently completed quarter and t ≥ Q(τ).

Quarterly GDP growth in the last (completed) quarter is given by
$\Delta^{Q(1)}X_t = (1-\lambda^Q_t)\, \Delta^{Q(1)}X_{t-1} + \lambda^Q_t\, s^Q_{t-1}$ (5.1)

When t is the first day of a new quarter, $\lambda^Q_t = 1$ and $\Delta^{Q(1)}X_{Q(\tau)+1} = s^Q_{Q(t)} = \Delta^Q X_{Q(\tau)}$. On all other days, $\Delta^{Q(1)}X_t = \Delta^{Q(1)}X_{t-1}$.

Equations (4.1) and (5.1) provide the link between the daily contribution to GDP growth, ΔX_t, and the provisional GDP release, Y_t as follows:
$Y_t = \Delta^{Q(1)}X_t + U_{R(\tau)}$ (5.2)

The link between the daily contributions to GDP growth and the monthly macro variables in derived in a similar manner. In more detail, let $\Delta^{M(i)}X_t$ denote the monthly contribution to quarterly GDP growth ending on day M(τ, j-i), where M(τ, j) represents the last day of the most recently completed month and t ≥ M(τ,j). The contribution το GDP growth in the last (completed) month is the given by
$\Delta^{M(i)}X_t = (1-\lambda^M_t)\, \Delta^{M(i)}X_t + \lambda^M_t \Delta^{M(i-1)}X_{t-1}.$ (5.3)

Similarly to the case above, if t is the first day of a new month, $\lambda^M_t = 1$, then $\Delta^{M(1)}X_{M(\tau,j)+1} = s^Q_{M(\tau,j)} = \Delta^M X_{M(\tau,j)}$ and $\Delta^{M(i)}X_{M(\tau,j)+1} = \Delta^{M(i-1)}X_{M(\tau,j)+1}$ for J = 1,2,3. On all other days, $\Delta^{M(i)}X_t = \Delta^{M(i)}X_{t-1}$.
The $\Delta^{M(i)}X_t$ variables link the monthly data releases, z^i, to quarterly GDP growth as follows:
If the reporting lag for macro series i is less than one month, the value released on day t can be written as
$z_t^i = \beta_i \Delta^{M(1)}X_t + u_i^t.$ (6.1)

If now the reporting lag for the variable z^i is two months, the value released on day t can be written
$z_t^i = \beta_i \Delta^{M(2)}X_t + u_i^t.$ (6.2)

The same concept applies to data releases with reporting lags of three or more months, while for macro series with reporting lags of zero months (i.e., release takes place before the end of reference month), equations (6.1) and (6.2) take the following form:
$z_t^i = \beta_i s_M^t + u_i^t.$ (6.3)

To complete the model we next specify the dynamics for the daily contributions, ΔX_t as follows:
$\Delta X_t = \sum_{i=1}^{k} \phi_i \Delta^{M(1)}X_t + e_t,$ (6.4)

where e_t is an i.i.d., zero mean normally-distributed shock with variable σ^2_e

Note that the last equation expresses the growth contribution on day t as a weighted average of the monthly contributions over the last k (completed) months, plus an error term.

Finding the real time estimates of GDP and GDP growth boils down to computing $E[X_{Q(\tau)} / \Omega_t]$ and $E[\Delta^Q X_{Q(\tau)} / \Omega_t]$ using the quarterly signaling equation (5.2), the monthly signaling equations (6.1)-(6.3) and the ΔX_t process specified in equation (6.4) given the values of all estimated parameters in these equations. This estimation process is complicated by the fact that individual data releases are irregularly spaced, and arrive in a non-synchronized manner: On some days there may be only one release, on others there are several, and on some there are none at all. In short, the temporal pattern of data releases is quite unlike that found in standard time-series applications. The Kalman Filtering algorithm provides a solution to both problems. In particular, given a set of parameter values, the algorithm provides the means to compute the real-time estimates $E[X_{Q(\tau)} / \Omega_t]$ and $E[\Delta^Q X_{Q(\tau)} / \Omega_t]$. The algorithm also allows us to construct a sample likelihood function from the data series, so that the model parameters can be computed by maximum likelihood. Although the Kalman Filtering algorithm has been used extensively in the applied time-series literature, its application in the current context has several novel aspects that are properly dealt with in the framework provided in Evans (2005).

In what follows, we provide a brief description of the state-space form we use to write the model so as to generate the aforementioned calculations.
Starting with the state equation, this can be represented as follows:

$$Z_t = A_t Z_{t-1} + V_t \quad (7)$$

where, in our case, Z_t is the following 9x1 vector

$Z_t = [s^Q_t, \Delta^{Q(1)}X_t, s^M_t, \Delta^{M(1)}X_t, \Delta^{M(2)}X_t, \Delta^{M(3)}X_t, \Delta^{M(4)}X_t, \Delta^{M(5)}X_t, \Delta X_t]'$ and

A_t is a 9x9 coefficient matrix constructed by equations (4.1), (5.1) and (6.1)-(6.4).
We note here that the dimension (and the elements) of state vector Z_t in our model are determined by the release lags of the quarterly and monthly data we use. These are: 1 quarter for GDP (and a couple of other quarterly-frequency indicators we use); and 0 to 5 months for the monthly indicators. Finally, for the autoregressive parameter ϕ_i used to describe the dynamics of the daily contribution, ΔX_t, in equation (6.4), we estimate (as a test for robustness) different specifications with k = 0,1,2 & 3. Furthermore, unlike to traditional state space specifications, the state transition matrix A_t is not constant but depends on the values of quarterly and monthly dummies λ^M_t an λ^Q_t and thus , it is time-varying.
We next turn to the observation equation, which has the following form:

$$X_t = C_t Z_t + U_t \quad (8)$$

where X_t is the vector of *potential* data releases for day t, Z_t is the state vector and C_t the corresponding coefficient matrix.
Here, $X_t = [Y_t, z^1_t, z^2_t, \ldots z^j_t]'$ is a λx1 vector, where, as we noted earlier, Y_t represents the provisional GDP and $z^1_t, z^2_t, \ldots z^j_t$ are the monthly indicators utilized in our study. C_t is a λx9 matrix, with its first row having the following form:
[0, 1, 0, 0, 0, 0, 0, 0, 0]', since in our data sample provisional GDP data for quarter τ is always released before the end of quarter τ+1,
and its following λ-1 rows being represented as follows:
$[0, 0, \beta_J ML^o_t (z^j), \beta_J ML^1_t (z^j), \beta_J ML^2_t (z^j), \beta_J ML^3_t (z^j), \beta_J ML^4_t (z_j), \beta_J ML^5_t (z_j), 0]'$, for row J of matrix C_t,
where $ML^m_t (z^j)$, is a dummy variable that takes the value of 1 when the z^j macro/market indicators for a certain month of quarter τ is released with a time lag of m months (in our data sample, m=0,1,2,3,4 &5).

Again, equation (8) links the vector of potential data releases for day t, X_t, to the elements of the state vector, Z_t. The elements of X_t identify the value that would have been released for each series given the current state, Z_t; if day t was in fact the release day. Of course, on a typical day, we would only observe the elements in X_t that correspond to the actual releases that day. For example, if data on provisional GDP and monthly series i = 2 & 3 were released on day t, we would only observe the values in the 1st, 3rd, and 4th rows of X_t. On the other hand, on days when there are no releases, none of the elements of X_t are observed.

The vector of actual data releases for day t, Y_t, is related to the vector of potential releases by the following equation:
$Y_t = B_t X_t$ (8.1)

where B_t is a nx9 selection matrix that "picks out" .the n ≥1 data releases for day t.
Combining equations (8) and (8.1) gives the observation equation:
$Y_t = B_t C_t Z_t + B_t U_t$ (8.2)

Equation (82) differs in several respects from the observation equation specification found in standard time-series applications. First, the equation only applies on days for which at least one data release takes place. Second, the link between the observed data releases and the state vector varies through time via C_t as $QL^i_t(z)$ and $ML^i_t(z)$ change. These variations arise because the reporting lag associated with a given data series change from release to release. Third, the number and nature of the data releases varies from day to day (i.e., the dimension of Y_t can vary across consecutive data-release days) via the B_t matrix.

Equations (7) and (8) describe a state space form which can be used to derive real-time estimates of GDP. The estimation takes place in two steps. First, the maximum likelihood estimates of the model parameters are derived. Second, real-time estimates of GDP are calculated using the maximum likelihood parameter estimates from the first step. A more thorough analysis of these steps is provided in Evans (2005).

Derivation of Real-Time estimates of GDP
Upon deriving the maximum likelihood estimates of the model parameters, the Kalman Filtering equations can be used to derive real-time estimates of Greek GDP. These are given by the following formulas:
Real-time estimates of quarterly GDP growth in quarter τ
For **t = Q(τ)** *i.e.,* the last day of the reference quarter, real GDP growth of quarter τ estimated based on the information (i.e., values of the data series used) available at day t is given by
$\Delta^Q X_{Q(\tau)/Q(\tau)} = E[s^Q_{Q(\tau)} / \Omega_{Q(\tau)}] = h_1 Z^{est}_{Q(\tau)/Q(\tau)}$
where h_1 is a selection indicator that selects the first row of the 9x1 vector estimate Z at time t= Q(τ)
For **Q(τ) < t ≤ Q(τ+1)** *i.e.,* for days falling in quarter τ+1, real GDP growth of quarter τ estimated based on the information (i.e., values of the data series used) available at day t is given by
$\Delta^Q X_{Q(\tau)/t} = h_2 Z^{est}_{t/t}$
where h_2 a the selection indicator that selects the second row of the 9x1 vector estimate Z at time t
For **Q(τ-1) < t < Q(τ)** *i.e.,* for days after the first (and before the last) day of quarter τ, real GDP growth of quarter τ estimated based on the information (i.e., values of the data series used) available at day t is given by
$\Delta^Q X_{Q(\tau)/t} = [h_1 + h_4 \phi^{est} (Q(\tau)-t)\} Z^{est}_{t/t}$
when there is only one autoregressive parameter (k=1) in the specification of the dynamics for the daily contributions, ΔX_t, (i.e., the last element of the state vector Z). Here h_1 and h_4 are selection indicators that select the first and fourth elements of the 9x1 vector estimate Z at time t.

The main essence of our model can be summarized as follows. Each of the macro and market indicators used in our study is first transformed in such as way so as to allow us to account for its degree of relative persistence as regards its contribution in explaining economic growth. Then, each indicator is linked to both its own high-frequency (monthly) releases and to the lower-frequency (quarterly) releases of GDP growth. The latter is assumed to be driven by the combined effect of its own contributions (daily, monthly, and quarterly) and explained by the evolution of various indicators. All component equations of our models are stochastic and contain error terms whose corresponding variances are estimated and reported as log-variance estimates with negative signs. The variance estimates are all significant across models, thus validating the stochastic nature of the equations used. Finally, to model the daily contributions to GDP growth we consider the lagged effects of the monthly announcements and we find that their effect is either very small or statistically insignificant; this means that, during the period of examination, there is little persistence generated at the daily level by the releases and announcements of macroeconomic variables and thus the impact of news dies out rather quickly.

Table A1. Data series used in our empirical study (*)

Data series	Source	Full-sample period	Data collection period/ reporting frequency	Number of observations with reporting lag of zero (0) months or quarters	Number of observations with reporting lag of 1 month or quarter	Number of observations with reporting lag of 2 months	Number of observations with reporting lag of 3 months	Number of observations with reporting lag of 4 months
GDP (constant prices)	ELSTAT	3Q 2005-3Q2013	Quarterly	0	35	0	0	0
Retail sales index (volume)	ELSTAT	Mar 2005-Oct 2013	Monhtly	0	0	89	13	0
Road motor vehicles put into circulation for the 1st time	ELSTAT	Mar 2005-Oct 2013	Monhtly	0	98	2	2	0
Unemployment rate	ELSTAT	Apr 2007-Oct 2013	Monhtly	0	0	0	78	0
Number of employeed	ELSTAT	Apr 2007-Oct 2014	Monhtly	0	0	0	78	0
New Primate Sector Hirings	Ministry of Labour, Social Security & Welfare	Jan 2006-Oct 2013	Monhtly	0	92	0	0	0
CPI	ELSTAT	Mar 2005-Oct 2013	Monhtly	0	103	0	0	0
Building permits	ELSTAT	Jan 2008-Oct 2013	Monhtly	0	0	0	67	11
Industrial production index	ELSTAT	Mar 2005-Oct 2013	Monhtly	0	0	102	0	0
Manufacturing production index	ELSTAT	Mar 2005-Oct 2013	Monhtly	0	0	102	0	0
Current account balance	BoG	Mar 2005-Oct 2013	Monhtly	0	0	102	0	0
Turnover index in retail trade	ELSTAT	Jul 2007-Oct 2013	Quarterly	0	0	0	28	1
Index of new orders in industry	ELSTAT	Mar 2006-Oct 2013	Monhtly	0	0	83	2	9
Turnover index in industry	ELSTAT	Oct 2006-Oct 2013	Monhtly	0	0	83	1	0
MFI credit to domestic businesses and households	BoG	Oct 2008-Oct 2013	Monhtly	0	46	13	0	0
Domestic private sector bank deposits	BoG	Mar 2005-Oct 2013	Monhtly	0	101	1	0	0
CPI-based REER	ECB	Mar 2005-Oct 2013	Monhtly	0	102	0	0	0
ULC-based REER	ECB	Mar 2005-Oct 2013	Quarterly	0	0	0	0	35
Central gvnt revenue	FinMin	Mar 2005-Oct 2013	Monhtly	0	102	0	0	0
Central gvnt expenditure	FinMin	Mar 2005-Oct 2015	Monhtly	0	102	0	0	0
Economic Climate Index	IOBE	Mar 2005-Oct 2013	Monhtly	102	0	0	0	0
Athens Stock Exchange (ASE) index	Bloomberg	Mar 2005-Oct 2013	Monhtly	103	0	0	0	0
ASE Volatility	Bloomberg	Mar 2005-Oct 2013	Monhtly	103	0	0	0	0
EONIA	Bloomberg	Mar 2005-Oct 2013	Monhtly	103	0	0	0	0
VIX	Bloomberg	Mar 2005-Oct 2015	Monhtly	103	0	0	0	0

Source: ECB, ELSTAT, EC, Bloomberg, Ministry of Labour, Social Security & Welfare, Eurobank Global Markets Research

(*) Our data base has been properly updated to include all respective data releases up to July 24, 2015

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