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The effect of card payments on VAT revenue in  
Greece

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# THE EFFECT OF CARD PAYMENTS ON VAT REVENUE IN GREECE

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## ABSTRACT

The effect of card payments on VAT revenue performance in Greece is investigated using quarterly observations on card transactions during 2002q1-2016q2. Time-varying-coefficient methods are employed, in order to study the role of increasing card payments after the imposition of cash restrictions in July 2015. We find that (i) a 1pp increase in the share of card payments in private consumption results in approximately 1% higher revenue through increased compliance; (ii) lowering the VAT rate can generate revenue gains; (iii) card transactions may facilitate tax buoyancy. It is argued that stronger incentives for using card payments in tax evading industries can help lock-in the recent strong revenue performance when cash restrictions are lifted.

*JEL classification:* E62, H21, H25, H26, K34

*Keywords:* VAT, card payments, time-varying-coefficients, Greece

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## 1. Introduction

The strong performance of VAT revenue in Greece since end-2015 has been without precedent during the crisis, despite the numerous and sizeable increases in tax rates in the context of the economic adjustment programmes. Identifying the drivers behind the recent pick-up has important policy implications, particularly as regards the fiscal requirements of the ESM financial assistance programme. Most crucially, the key question for policy makers is to what extent the recent revenue performance can be expected to continue, or whether it represents a temporary windfall.

The evolution of VAT revenue after 2015q3 has become difficult to reconcile with developments in the tax base and the tax rates. VAT revenue in 2015q4, 2016q1 and 2016q2 registered sizeable year-on-year (y-o-y) increases by 8.5%, 18.0% and 15.9%, respectively (Figure 1 top row), which stand in sharp contrast with the year-on-year shrinking of the tax base<sup>1</sup> by 0.3%, 2.9% and 1.1% in the respective quarters (Figure 1, second row). During the same period, the standard VAT rate remained unchanged at 23% until June 2016, when it was raised to 24%, while the average rate is estimated to have increased only moderately by 1 percentage point, as a result of the abolition of a number of exemptions from the standard rate in 2015q3 (Figure 1, bottom row). Also, the composition of the tax base, measured by the share of durables in households' consumption, does not record any major shifts on a yearly basis before 2016q3 (Figure 1, third row).

Hence, the recent pick-up in VAT revenue presents a puzzle and suggests that it is likely driven by factors other than the tax base and the tax rate. One such factor could be the increased intensity of card payments. Before July 2015, the share of private consumption spent using payment cards (Figure 1, fourth row) ranged from a low of 2.2% in 2002 to a peak of 5.4% in 2007, while during 2010-2014 it lingered close to the period average of 4.4%. The imposition of restrictions on cash withdrawals in July 2015, however, triggered a surge in the use of card payments. During the second half of 2015 the share of card payments in private consumption

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<sup>1</sup> Measured as nominal private consumption plus intermediate consumption of the general government. A detailed description of all variables is included in the data appendix.

more than doubled on a yearly basis, reaching 9.5%, rising further to 11.2% by 2016q2. The question that arises, therefore, is whether the strong revenue performance since end-2015 is associated with the surge in card payments.

To the extent that tax evasion is facilitated by cash transactions, the restrictions on cash withdrawals and the ensuing surge in card payments are likely to have increased the perceived probability of detection, leading to greater tax compliance. Rogoff (2014) argues that in most countries well over 50% of currency is used to hide transactions. While a positive relation between card payments and economic activity has been reported in Hasan et al. (2012) and in Zandi et al. (2013), the evidence on the effect of card payments on VAT revenue performance is scarce. Madzharova (2014) is, to the best of our knowledge, the only empirical study investigating the effect of card transactions on VAT revenue efficiency. Using annual observations in a panel of 26 EU countries during 2000-2010 she reports evidence that cash transactions impede revenue performance, although, card payments are not found to have a significantly positive influence. Regarding Greece, the available evidence is very limited and less formal. The National Bank of Greece (2016) estimate a positive effect of cashless transactions on real GDP growth and report an estimated 1.4pp contribution to real growth during the second half of 2015. The Foundation for Economic and Industrial Research (2015) report a positive relation between total tax revenue and various components of card transactions based on casual regressions during 2000-2013.

In this paper we investigate the effect of card payments on VAT revenue performance in Greece using quarterly observations on card transactions during 2002q1-2016q2. In order to study the recent episode of rising card payments since end-2015, we need to distinguish between the effects of different drivers at each point in time. To this end, the constant-parameter methods applied in the literature may not be particularly well suited. Instead, we employ continuously time-varying-coefficient methods (TVC) along the lines of Hall et al (2013), which to the best of our knowledge is the first such application in this area of research. We find that: (a) a 1pp increase in the share of card payments in private consumption results in approximately 1% higher VAT revenue through increased compliance; (b) lowering

the VAT rate can generate revenue gains; and (c) card transactions may facilitate tax buoyancy. Section 2 describes the empirical specification, section 3 discusses our baseline results, section 4 reports a series of robustness checks and section 5 concludes and provides policy recommendations. Detailed description of all variables is included in the data appendix.

## 2. Empirical specification<sup>2</sup>

We apply time-varying methods along the lines of Hall et al (2013), which allow us to distinguish between the effects of different drivers at each point in time. We model the yearly growth rate of VAT revenue using quarterly observations according to the following time-varying coefficient (TVC) model:

$$\Delta^4 \ln(VAT_t) = b_{0,t} + b_{1,t} \Delta^4 \ln(VATRATER_t) + b_{2,t} \Delta^4 \ln(VATBASE_t) \quad (1)$$

where  $\Delta^4$  denotes year-on-year difference (i.e.  $\Delta^4 x_t = x_t - x_{t-4}$ ),  $VAT_t$  is VAT revenue,  $VATRATER_t$  is the average VAT rate and  $VATBASE_t$  is the post-tax measure of the tax base, measured by the sum of nominal private consumption and general government intermediate consumption. The time-varying coefficients  $b_{1,t}$  and  $b_{2,t}$  are elasticities of revenue with respect to the tax rate and the tax base, respectively. Effects other than the base and the rate are captured by  $b_{0,t}$ , which may thus be interpreted as a proxy for tax compliance. We estimate  $b_{i,t}$ ,  $i = 0, 1, 2$  as functions of the share of card payments in private consumption,  $CARDSHAREP_t$  and of the share of durable goods in households' consumption,  $DUR_t$ . The general specification is given by:

$$b_{i,t} = c_{i0} + c_{i1} b_{i,t-1} + \mathbf{W}(L) \mathbf{x}_t + e_{it} \quad (2)$$

where

$\mathbf{x}_t = [\ln(DUR_t), \Delta^4 \ln(DUR_t), \ln(CARDSHAREP_t), \Delta^4 \ln(CARDSHAREP_t)]'$ ,  
 $\mathbf{W}(L) = w_{i0} + w_{i1}L + w_{i2}L^2 + \dots + w_{ip}L^p$ , with  $w_{ij}$  being  $1 \times n$  vectors,  $c_{i0}, c_{i1}$  and the elements of  $w_{ij}$  are estimated constant parameters. The residuals  $e_{it}$  are

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<sup>2</sup> A detailed description of all variables is included in the data appendix.

normally distributed with variance  $\sigma_{i,t}$  which is allowed to permanently shift in 2010q2, marking the adoption of the first economic adjustment programme.

$$e_{i,t} \sim N(0, \sigma_{i,t}^2), \sigma_{i,t} = \begin{cases} \sigma_{i,1}, & t < 2010q2 \\ \sigma_{i,2}, & t \geq 2010q2 \end{cases}$$

Based on the discussion above, we anticipate tax compliance, captured here by the time-varying coefficient  $b_{0,t}$ , to increase after 2015q3 and to be a positive function of  $CARDSHAREP_t$ . The revenue elasticity with respect to the tax base,  $b_{2,t}$ , can be expected to be positively related to the share of durable goods in households' consumption, as durables tend to be taxed at higher rates compared to necessities. We have no clear priors regarding the effects of  $CARDSHAREP_t$  and  $DUR_t$  on the revenue elasticity with respect to the tax rate,  $b_{1,t}$ .

### 3. Estimation results

Equations (1)-(2) define a state-space model which has been estimated using the Kalman filter during 2003q4-2016q2 under different specifications. We discuss explicitly the results obtained using the non-seasonally adjusted series, the average VAT rate and the post-tax measure of the tax base. In following sections we report robustness checks for different specifications using the standard rate, the pre-tax measure of the tax base and the seasonally adjusted series.

Figure 2 (top left panel) plots the decomposition of year-on-year revenue growth during 2015q1-2016q2 into the three components estimated in equation (1), namely, compliance, as proxied by  $b_{0,t}$ , and the time-varying contributions of changes in the tax rate,  $b_{1,t}\Delta^4\ln(VATRATER_t)$ , and the tax base,  $b_{2,t}\Delta^4\ln(VATBASE_t)$ . The recorded increases in revenue are explained fully by compliance, which has had increasing double-digit contributions to revenue growth after 2015q3, compensating for the negative contributions of both, the tax base and the tax rate. Recalling that  $VATRATER_t$  is the average VAT rate, its negative contribution to revenue growth indicates that the abolition of a number of exemptions from the standard rate in 2015q3, as well as the increase in the standard rate itself in June 2016, have both been counter-productive.

Figure 3 (left column) plots the estimated annualized time-varying coefficients  $b_{i,t}$ ,  $i = 0, 1, 2$ , (dark lines, right axis) along with changes in the coefficient drivers (bars, left axis) obtained through equation (2). The coefficient drivers “cards” and “durables” collect all terms on the right-hand-side of (2) involving  $CARDSHAREP_t$  and  $DUR_t$ , respectively. The top row reports the time-varying estimate of compliance,  $b_{0,t}$ . In line with our priors, the increases in 2015 and 2016 are positively affected by the rising share of card payments in private consumption and to a lesser extent by changes in the composition of consumption, as measured by the share of durables. The contribution of card payments amounts to 6% (sum of the bars labelled “cards” in 2015 and 2016), which corresponds approximately to 1% higher revenue for every 1pp increase in the share of card payments in private consumption. The elasticity with respect to the tax rate  $b_{1,t}$  (middle row) is estimated to have fallen into negative territory after 2009, affected by the declining share of durables in households’ consumption. Despite a partial recovery in 2015 and 2016, partly associated with the increase in card transactions, it remains significantly negative. This suggests that lowering the VAT rate can result in revenue gains, as the prevailing rate lies on the declining segment of the Laffer curve. The elasticity with respect to the tax base  $b_{2,t}$  (bottom row) is estimated to have declined during the crisis, on the back of the sizeable shift of households’ consumption away from high-tax durables towards lower-tax necessities, as unemployment rates increased and disposable incomes declined. A partial recovery close to unity is estimated by 2016, associated with the increased use of card payments. This suggests that the intensified use of card payments could facilitate buoyancy gains as economic activity recovers. The high value of  $b_{2,t}$  in excess of 2 at the outbreak of the crisis also suggests that the fiscal multiplier of indirect taxes may have been more sizeable than predicted by SVAR analyses at the time.<sup>3</sup>

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<sup>3</sup> Widely used estimates of the elasticity of indirect taxes with respect to economic activity were, at the time, in the region of unity for Greece. Caldara and Kamps (2012) illustrate that underestimation of the tax elasticity leads to less sizeable revenue multipliers in standard SVAR analyses.



#### 4. Robustness checks

The TVC model defined in equations (1)-(2) has been estimated under alternative specifications using: (a) the more widely available standard VAT rate,  $STVATRATER_t$ , instead of the average rate,  $VATRATER_t$ ; (b) seasonally adjusted series; and (c) the pre-tax measure of the tax base, computed as  $VATBASE_t - VAT_t$ . In total we have generated five additional sets of results under these alternative options. To the extent possible, results are reported alongside our baseline output in order to facilitate comparison. As a final check we carry out a forecast evaluation exercise.

We find consistent confirmation that the accelerated growth in VAT revenue since end-2015 is explained by compliance (blue bars in Figures 2 and 6), which has been positively affected by the increased intensity in card transactions (pink bars, top row in Figures 3, 4 and 7). The baseline estimate of 1% higher revenue for each 1pp increase in  $CARDSHAREP$  remains generally robust (in 5 out of 6 specifications) and is in line with first year responses generated by different constant-parameter models (Figure 8).<sup>4</sup> We also find consistent evidence that the recent increases in the average and standard VAT rate have had a negative effect on revenue growth, suggesting a declining Laffer curve (green bars in Figures 2 and 6). The negative contribution of the rate is found to be smaller in specifications using the standard rate and is concentrated in 2016q2, reflecting the fact that the standard rate remained unchanged until June 2016, when it was raised by 1pp. There is also consistent indication that the elasticity of revenue with respect to the rate is likely to have been in negative territory for several years (dark line, middle row in Figures 3, 4 and 7). The evidence is less clear regarding the effect of card payments on the elasticity with respect to the tax rate, with the majority (4 out of 6) of the specifications indicating no effect (pink bars, middle row in Figures 3, 4, and 7). Card payments are more consistently found (in 5 out of 6 specifications) to have positively affected the recovery in the elasticity with respect to the tax base (pink bars, bottom row in Figures 3, 4 and 7), suggesting that the intensified use of card payments could facilitate buoyancy gains as economic activity recovers.

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<sup>4</sup> Specification details in Annex 1.

As a final check we evaluate the role of card payments in predicting the recent revenue performance by forecasting out-of-sample the first two quarters of 2016. The baseline TVC model in equations (1)-(2) is estimated until 2015q4, covering the first observation of positive revenue growth since the imposition of capital controls in July 2015. Revenue is dynamically forecast until 2016q2, given the exogenous variables *VATBASE*, *VATRATE*, *DUR* and *CARDSHAREP*. The model is then re-specified dropping all terms involving *CARDSHAREP* from equation (2) and a second set of forecasts is generated, denoted “TVC no cards”. As benchmarks we report forecasts from a constant parameter VAR with and without *CARDSHAREP* as an exogenous regressor, as well as a trivial single-equation autoregressive process.<sup>5</sup> Figure 5 (left panel) reports the cumulative point forecasts for the first six months of 2016, while the right panel summarizes the descriptive statistics. Excluding card payments leads to underestimation of VAT revenue in both 2016q1 and 2016q2. The inclusion of *CARDSHAREP* is found to improve forecast performance and forecast errors change signs in the TVC model with cards, suggesting that there is no systematic under-prediction. Conditional on the exogenous variables, the baseline model is found to marginally underestimate cumulative VAT revenue during the first half of 2016 by 1.1%.

## 5. Conclusions and policy implications

The strong performance of VAT revenue since end-2015 presents a puzzle and is difficult to reconcile with developments in the tax base and the tax rates. Identifying the drivers behind the recent pick-up is key for policy makers to assess whether it can be expected to continue, or whether it represents a temporary windfall.

Using time-varying-coefficient methods we have found consistent evidence that the recent pick up in revenue growth is fully explained by influences other than the tax base and the tax rate, which we collectively summarize under the term “compliance”. We find that compliance has more than compensated for the negative

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<sup>5</sup> Specification details are reported in the notes of Figure 5.

contributions of the tax base and the tax rates and has been positively affected by the intensified use of card payments, following the imposition of restrictions on cash withdrawals in July 2015. Our estimates suggest that a 1pp increase in the share of card payments in private consumption results in approximately 1% higher revenue through increased compliance. We report this finding to be qualitatively and quantitatively robust to a number of different specifications.

We also find consistent evidence that the recent increases in the average and standard VAT rate have had a negative effect on revenue growth, suggesting a declining Laffer curve. In fact, the elasticity of revenue with respect to the rate is estimated to have been in negative territory for several years, suggesting that lower VAT rates can induce revenue gains. The effect of card payments on the elasticity of revenue with respect to the tax rate is less clear, with the majority of the specifications indicating no effect. Card payments are more consistently found to have positively affected the recovery in the elasticity with respect to the tax base, suggesting that the intensified use of card payments could facilitate buoyancy gains as economic activity recovers.

While card payments are unambiguously found to have contributed to the recent revenue growth, it remains an open question whether card penetration growth can be expected to continue going forward. If the observed surge in card payments reflects an act of necessity triggered by the restricted access to cash, rather than a genuine preference shift, there is a risk that card payments – and revenue – will recede when the cash restrictions are lifted. August 2018 marks the end of official sector financing under the existing ESM financial assistance programme, by which time Greece is envisaged to have regained access to the international capital markets. This effectively means that existing restrictions to capital movements, including to cash withdrawals, ought to be lifted well in advance.

The current juncture provides, therefore, policy makers with a narrow window of opportunity for locking-in the revenue gains realized since end-2015, by providing consumers with effective incentives for the use of card payments. Madzharova (2014) argues that deducting from consumers' PIT electronic payments made to high risk industries is a superior policy to the imposition of fines, as it aligns the incentives

of the final consumer and the tax authorities. Furthermore, the tax authorities become better equipped for spotting tax evading professionals, by comparing declared incomes and VAT receipts before and after the introduction of the policy. Recent legislation in Greece<sup>6</sup> provides consumers with PIT incentives for using electronic transactions. While this is a welcome first step, the legislation shies away from focusing on industries most prone to tax evasion, as consumers may qualify for the full benefits of the law without needing to pay electronically for any of the high-risk professional services identified by Artavanis et al. (2016). Stronger tax incentives, better focused on high risk industries can help sustain and further expand card usage, securing the recent revenue performance when cash restrictions are lifted.

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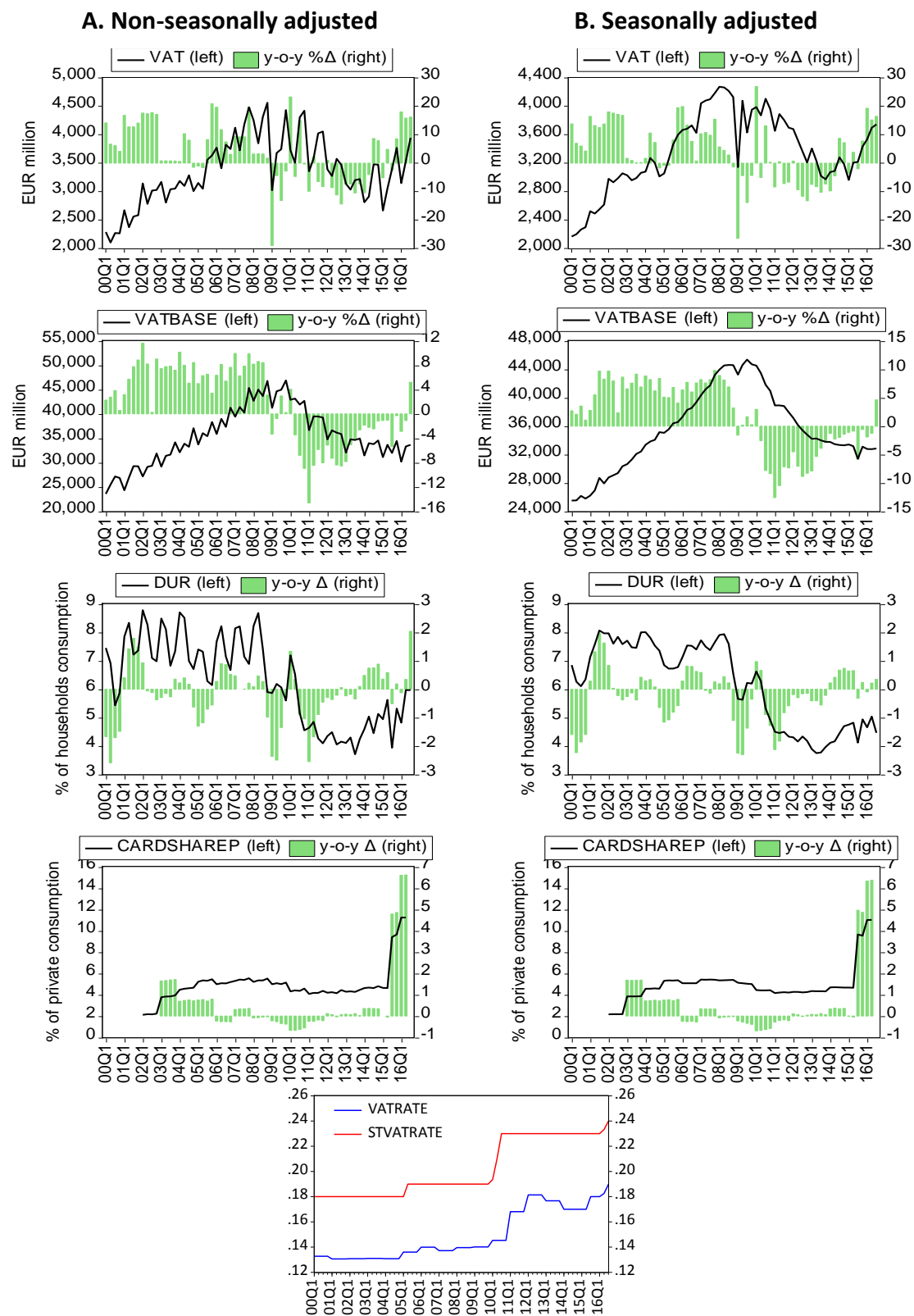
<sup>6</sup> Law 4446/2016.

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# Tables and Figures

Figure 1 – Data overview 2000q1-2016q3

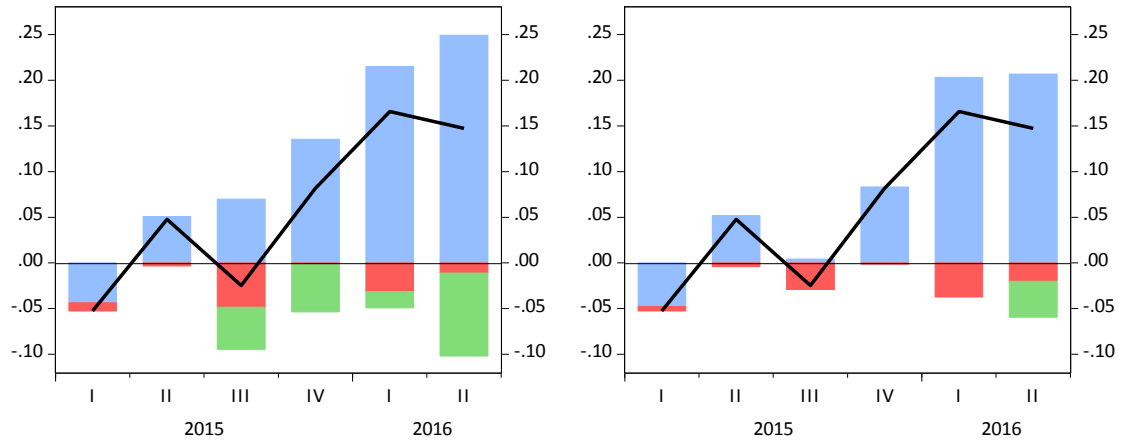


**Figure 2 – Decomposition of y-o-y growth in VAT revenue**

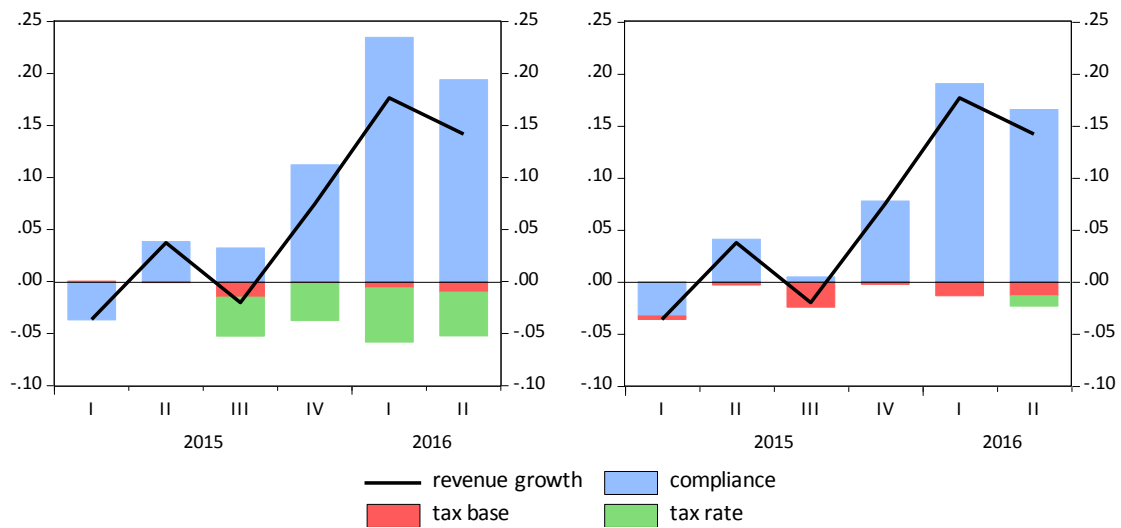
A. Using the average VAT rate

B. Using the standard VAT rate

Non-seasonally adjusted

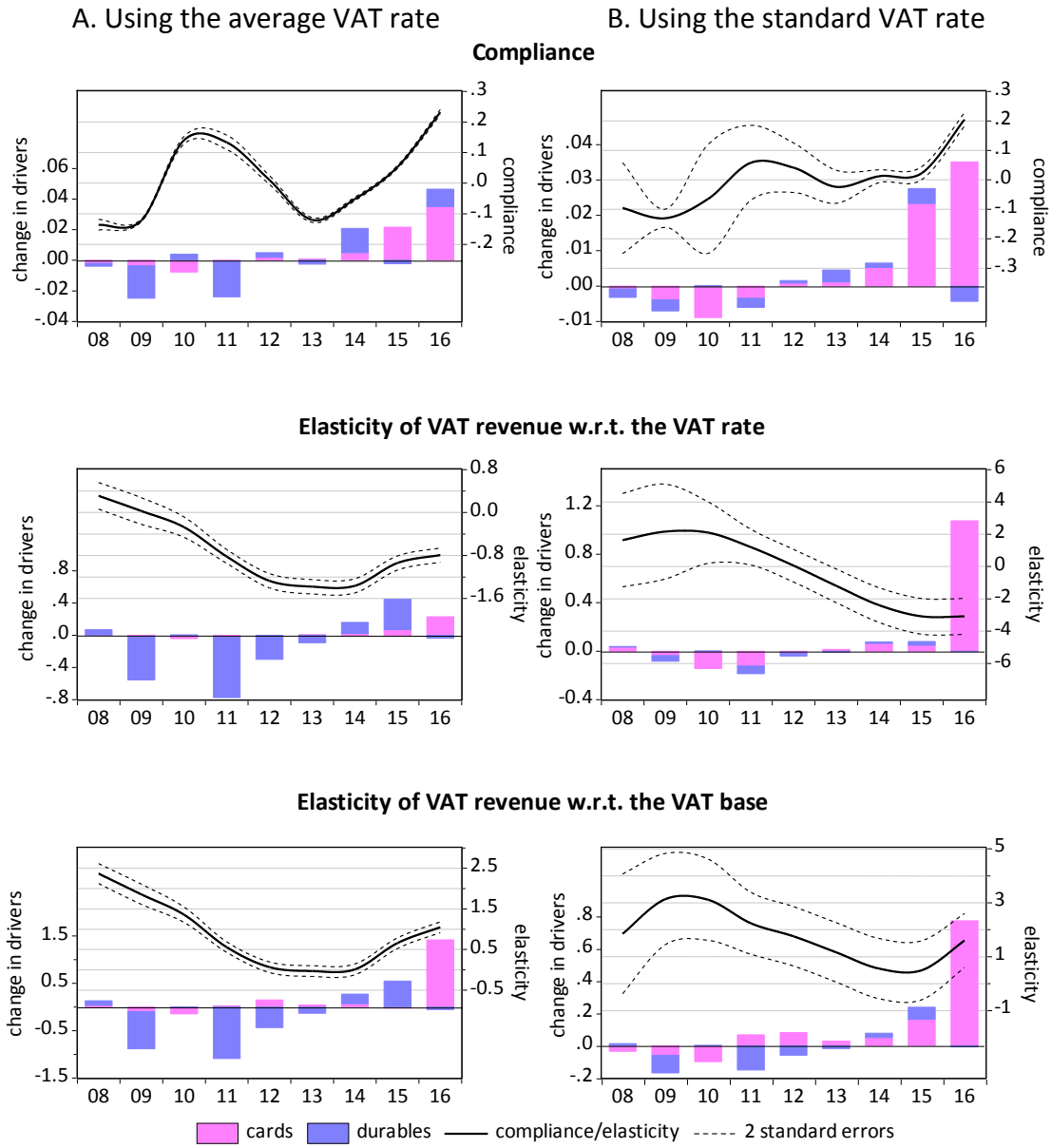


Seasonally adjusted



Notes: Using the post-tax measure of the tax base.

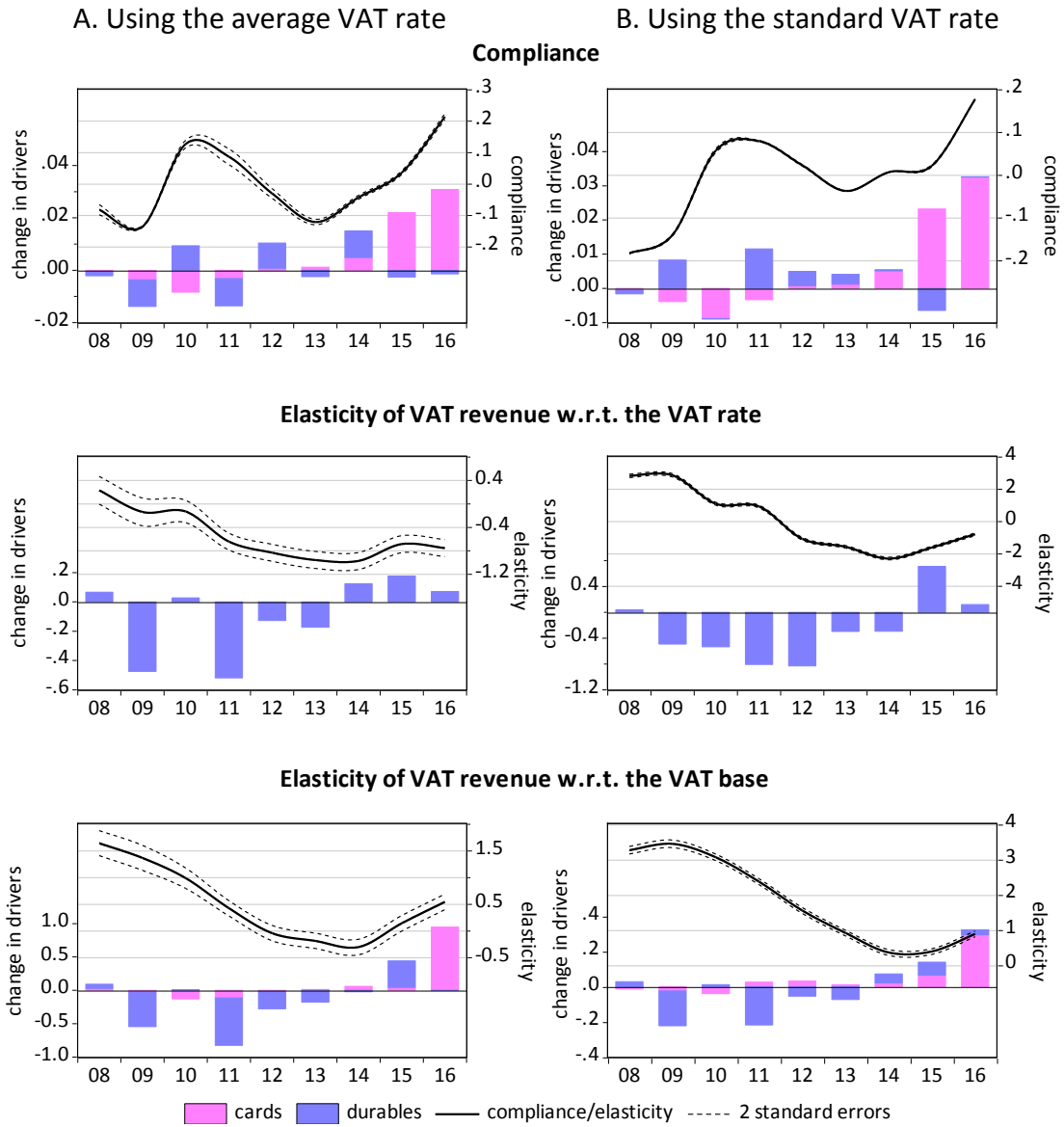
**Figure 3 – Time-varying coefficients and coefficient drivers  
Non-seasonally adjusted**



Notes: The year 2016 covers only the first two quarters. Using the post-tax measure of the tax base.



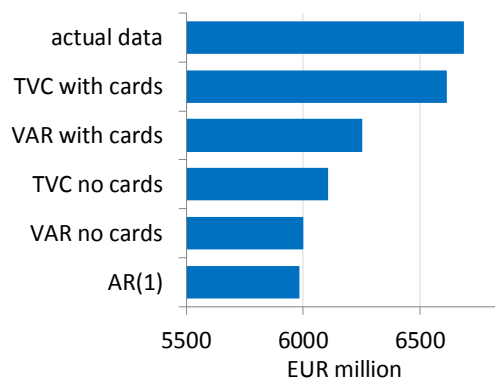
**Figure 4 – Time-varying coefficients and coefficient drivers  
Seasonally adjusted**



Notes: The year 2016 covers only the first two quarters. Using the post-tax measure of the tax base.

**Figure 5 – Two periods ahead out-of-sample forecasts 2016q1-2016q2**

**A. Cumulative forecast for 2016H1**

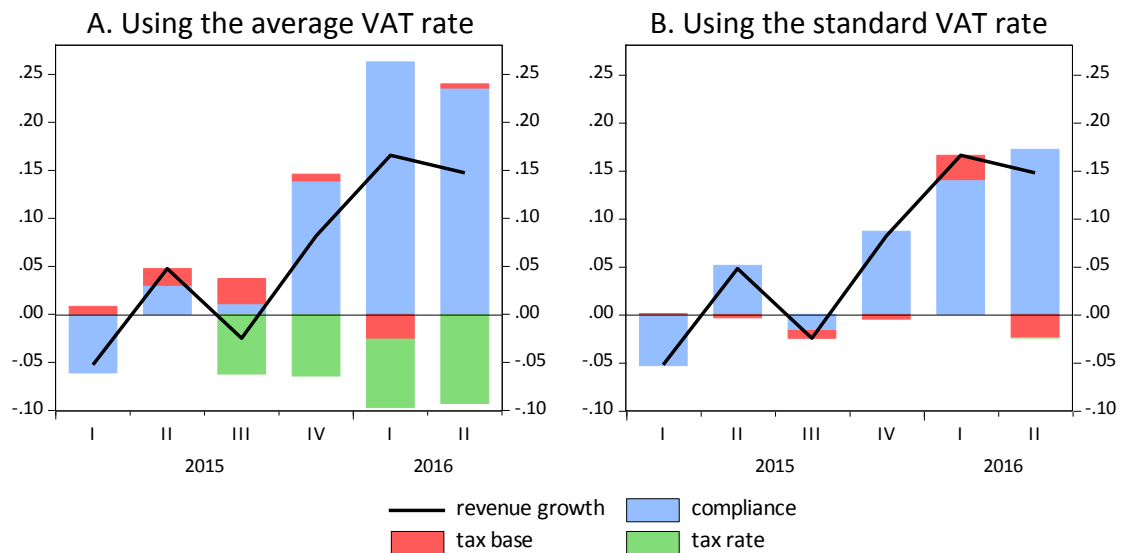


**B. Forecast performance**

	RMSE	MAE	MAPE	% error	
				16q1	16q2
<b>TVC with cards</b>	200	197	6.0	-7.4	4.5
<b>VAR with cards</b>	227	216	6.6	-9.1	-4.1
<b>TVC no cards</b>	300	290	8.8	-11.7	-6.0
<b>VAR no cards</b>	350	344	10.4	-13.0	-7.9
<b>AR(1)</b>	352	351	10.5	-10.7	-10.3

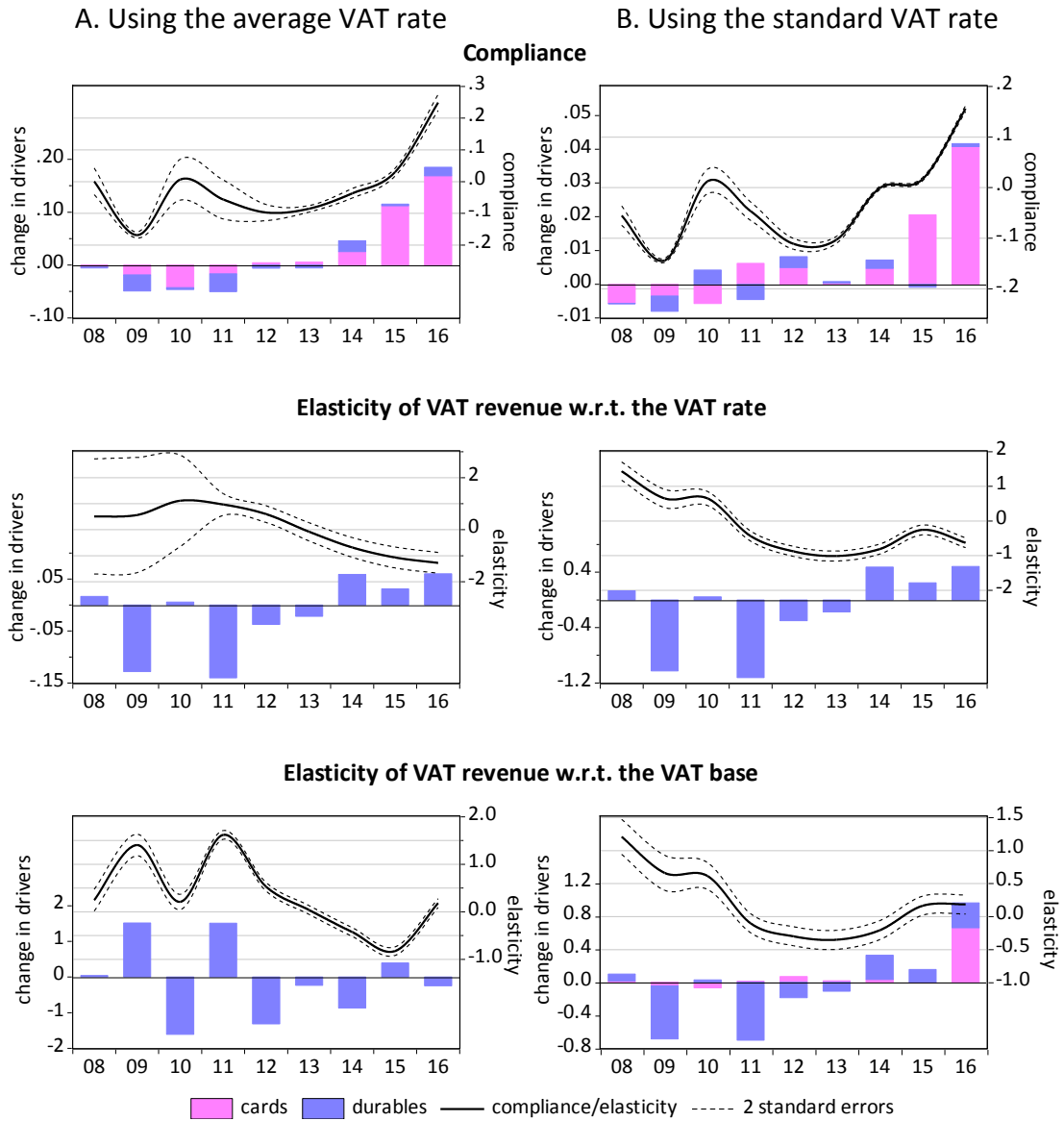
Notes: Estimation ends in 2015q4. “no cards” denotes that all terms involving *CARDSHAREP* are dropped prior to estimation. “TVC with cards” is the baseline TVC model given by eqs (1)-(2) in the text. “VAR with cards” is described in Annex 1 as “Model 1a”. Only *VAT* and *U* are treated endogenously in the forecast. “AR(1)” is a single-equation autoregression of the y-o-y log-difference of *VAT*.

**Figure 6 – Decomposition of y-o-y growth in VAT revenue  
Robustness to using the pre-tax measure of the tax base**



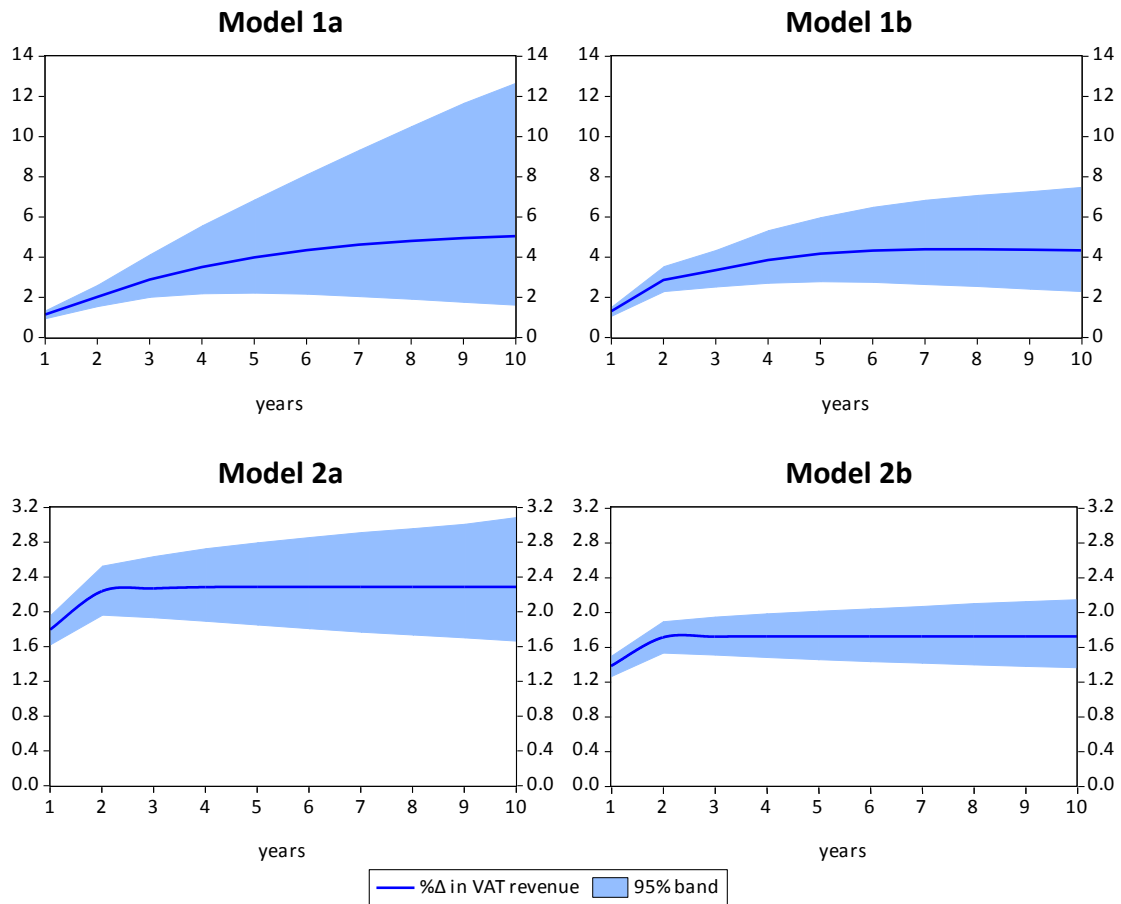
Notes: Based on the non-seasonally adjusted series.

**Figure 7 – Time-varying coefficients and coefficient drivers  
Robustness to using the pre-tax measure of the tax base**



Notes: The year 2016 covers only the first two quarters. Based on the non-seasonally adjusted series.

**Figure 8 – Percentage change of VAT revenue in response to a permanent increase in *CARDSHAREP* by 1pp**  
 (Based on constant parameter VAR and VECM)



Notes: Models 1 and 2 are constant parameter VAR and VECM, respectively, described in Annex 1. "a" denotes use of the average VAT rate and "b" denotes use of the standard VAT rate.

## Data Appendix

1.  $CARDS_t$  = Bank of Greece data on the value of payments with credit and debit cards issued by resident PSPs, available on an annual basis during 2002 – 2015 and for the first half of 2016. Transformed into quarterly frequency using the seasonal pattern of  $CONS_t$ .
2.  $CARDSHAREP_t = CARDS_t / CONSP_t$ .
3.  $CONS_t$  = Final consumption expenditure (nominal), National Accounts (ESA 2010), available during 1995q1- 2016q3.
4.  $CONSG_t$  = Final consumption expenditure of the general government (nominal), National Accounts (ESA 2010), available during 1995q1- 2016q3.
5.  $CONSH_t$  = Final consumption expenditure of households (nominal), National Accounts (ESA 2010), available during 1995q1- 2016q3.
6.  $CONSHD_t$  = Final consumption expenditure of households on durable goods (nominal), National Accounts (ESA 2010), available during 1995q1- 2016q3.
7.  $CONSP_t = CONS_t - CONSG_t$ .
8.  $DUR_t = CONSHD_t / CONSH_t$ .
9.  $INC_t$  = Intermediate consumption of the general government (nominal), National Accounts (ESA 2010), available during 1999q1- 2016q3.
10.  $U_t$  = Unemployment rate (ages 15 to 74), Labour Force Survey, available during 1998q1-2016q3.
11.  $VAT_t$  = VAT revenue (nominal), National Accounts (ESA 2010), available during 1999q1- 2016q3.
12.  $VATBASE_t = CONS_t - CONSG_t + INC_t$ .
13.  $VATRATE_t$  = Average (weighted) VAT rate (μεσοσταθμικός συντελεστής ΦΠΑ), Ministry of Finance, available on an annual basis during 2000-2015. Distributed equally across quarters. The reported increase during 2015 is applied during the second half of the year. Observations for the first 2 quarters of 2016 have been extrapolated using the growth rate of the standard rate.
14.  $STVATRATE_t$  = Standard VAT rate, European Commission (2016) until 1<sup>st</sup> January 2016 and Ministry of Finance until 31<sup>st</sup> December 2016. Quarterly

observations are adjusted for the days the rates have been in force within a given quarter.

Seasonally adjusted observations are readily available for series 3, 4, 5, 6. We apply the X12 seasonal adjustment to series 9, 10, 11. No adjustment is made to series 13 and 14. All remaining variables are constructed using the adjusted series based on the definitions above.

## Annex 1: Specification of constant-parameter models

### Model 1a (*not seasonally adjusted data*)

Model 1a is a 4-equation VAR given by:

$$\Delta^4 \mathbf{y}_t = \mathbf{a}_0 + \mathbf{\Gamma}(L)\Delta^4 \mathbf{y}_t + \mathbf{A}(L)\Delta^4 \mathbf{x}_t + \mathbf{e}_t \quad (1a)$$

, where  $\Delta^4$  denotes year-on-year difference (i.e.  $\Delta^4 \mathbf{z}_t = \mathbf{z}_t - \mathbf{z}_{t-4}$ )

$$\mathbf{y}_t = [\ln(VAT_t), \ln(VATBASE_t), DUR_t, \ln(U_t)]'$$

$$\mathbf{x}_t = [\ln(VATRATER_t), \ln(CARDSHAREP_t)]'$$

$$\mathbf{\Gamma}(L) = \Gamma_1 L + \Gamma_2 L^2 + \dots + \Gamma_p L^p$$

$$\mathbf{A}(L) = A_0 + A_1 L^1 + \dots + A_p L^p$$

The deterministic vector  $\mathbf{a}_0$  includes a constant and a dummy variable for 2009q1.

The model is estimated over the whole range of available data for lag-length  $p = 2$ . The treatment of  $CARDSHAREP_t$  as an exogenous variable reflects the view that the share of card transactions in consumption expenditure depends on exogenous factors, such as restrictions to cash withdrawals and technology penetration. A second version (denoted Model 1b) is estimated, using the standard VAT rate ( $STVATRATER_t$ ) instead of the effective VAT rate ( $VATRATER_t$ ).

### Model 2a (*seasonally adjusted data*)

Model 2a is a 2-equation VECM given by:

$$\Delta \mathbf{y}_t = \mathbf{a}_0 + \boldsymbol{\alpha} \boldsymbol{\beta}'_t \mathbf{z}_{t-1} + \mathbf{\Gamma}(L)\Delta \mathbf{y}_t + \mathbf{A}(L)\Delta \mathbf{x}_t + \mathbf{e}_t \quad (2a)$$

, where

$$\mathbf{y}_t = [\ln(VAT_t), \ln(VATBASE_t)]'$$

$$\mathbf{x}_t = [U_t, DUR_t, CARDSHAREP_t, VATRATE_t, VATRATE_t^2]'$$

$$\mathbf{z}_t = [\mathbf{y}_t, \mathbf{x}_t]'$$

$\beta_t' \mathbf{z}_{t-1}$  is a non-linear cointegrating vector normalized on  $\ln(VAT_t)$ , representing the Laffer curve. The non-linear cointegrating coefficients  $\beta_t$  are specified as follows:

$$\beta_t = \begin{cases} \beta_1, & t < 2009q1 \\ \beta_2, & t \geq 2009q1 \end{cases}$$

The lag polynomials  $\Gamma(L)$ ,  $\mathbf{A}(L)$  are as in Model 1. Model 2a is estimated for  $p = 2$  and a second version (denoted Model 2b) has been estimated using the standard VAT rate ( $STVATRATE_t$ ) instead of the effective VAT rate ( $VATRATE_t$ ).

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