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FISCAL STRUCTURAL REFORMS: THE EFFECT OF CARD PAYMENTS ON VAT REVENUE IN THE EURO AREA

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Abstract

The use of traceable payment methods presents an additional reform option for improving tax compliance. As regards consumption, card payments are the main alternative to cash in the euro area. Although the use of micro-data has provided clear evidence in favour of increasing information trails, time series evidence on the role of card payments in increasing compliance have been scarce and confined to the recent experience of Greece. The effect of card payments on VAT revenue is investigated using quarterly panel data for the 19 euro area economies covering the period 2003q1-2016q4. Time-varying coefficient methods are employed in order to estimate the country-specific contribution of compliance to revenue growth as a function of card payments. In line with the micro-data literature, the analysis indicates that increasing the share of card payments in private consumption expenditure improves VAT tax compliance. The gains are found to increase: (i) the lower the initial level of card use; (ii) the higher the share of self-employment and (iii) the lower the level of revenue efficiency. The highest benefits are estimated for Greece and Italy.

JEL classification: H21, H25, H26

Keywords: VAT, card payments, tax compliance, time-varying coefficients, Euro area

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1. Introduction

Absorbing cyclical fluctuations in euro area member states relies crucially on the capacity to accumulate fiscal buffers during economic good times. On the revenue side, structural reforms that improve tax compliance can play a role in increasing the capacity of governments to accumulate such fiscal buffers. Along with traditional administrative measures for curtailing tax evasion, payment methods may present additional opportunities for improving tax compliance.

The literature on tax evasion originally concentrated on the deterrence effects of the probability of being audited and the size of the penalty for under-reporting tax liabilities. However, it was soon appreciated that the observed audit frequencies and penalties are too low to account for the relatively high compliance levels in modern tax systems, suggesting that there are important missing dimensions.¹ Among the different avenues that have been explored, a growing strand of the literature emphasizes the role of information trails. Field experiments, *inter alia*, in the US (Slemrod et al. 2001), Denmark (Kleven et al. 2011) and Chile (Pomeranz, 2015), as well as recent administrative microdata from Brazil (Naritomi, 2016), provide evidence that tax compliance increases for transactions that are subject to third-party reporting. As regards direct taxation, incomes from self-employment provide greater opportunities for non-compliance compared to wages and salaries earned in dependent employment, as information on the latter is typically available from more than one source.²

The Value Added Tax (VAT) by design provides incentives for generating a paper trail between firms along the production chain. However, these incentives break down at the final consumer stage.³ The so-called “last-mile” problem of VAT arises due to the typically limited incentives for consumers to request a receipt, which creates scope for collusion with sellers to under-report the transaction. In Brazil, monetary rewards to consumers, including tax rebates and lottery prizes for reporting transactions are reported by Naritomi (2016) to have increased the retail revenue reported by firms by 22% over four years.

¹ See Andreoni et al. (1998) for a literature review.

² Threat-of-audit letters have been found by Slemrod et al. (2001) and Kleven et al. (2011) to trigger sizeable upward revisions in the declared amounts for self-reported incomes, but little or no changes in incomes subject to third-party reporting.

³ Pomeranz (2015) provides evidence from Chile that under threat-of-audit, VAT payments increase more strongly for final sales to consumers than for transactions between firms.

Increasing the information trail of consumption expenditure may therefore lead to higher VAT compliance. An interesting implication of this, is that tax compliance could be related to payment preferences, as information trails may vary sharply between cash and non-cash transactions. Rogoff (2014) argues that in most countries well over 50% of currency is used to hide transactions. In contrast, non-cash payments are typically traceable and generate third-party information, e.g. through the banking system. Structural reforms that promote the use of traceable, non-cash payments can, therefore, be expected to improve tax compliance by increasing the perceived probability of detection.

Despite the increasing role of online services, card payments remain the dominant alternative to cash in the euro area, as far as retail purchases are concerned. According to a recent survey by Esselink and Hernández (2017), card payments make up around 85 percent of the total value of non-cash purchases at points of sale.⁴ A higher share of card payments in consumption expenditure may therefore be expected to improve the efficiency of consumption taxes, such as VAT.

While a positive relation between card payments and economic activity has been reported in Hasan et al. (2012) and in Zandi et al. (2013), evidence on the effect of card payments on VAT revenue performance is scarce. Madzharova (2014) investigates 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. More recently, Hondroyiannis and Papaoikonomou (2017) (hereafter HP17) studying the VAT performance in Greece report a positive effect of card payments on VAT compliance, triggered by the imposition of cash restrictions in July 2015.⁵

This paper investigates the effect of card payments on VAT revenue using quarterly panel data for the 19 euro area economies covering the period 2003q1-2016q4. We focus on card payments in relation to VAT for two reasons: First, cards

⁴ Online payments are not included. The authors estimate online payments at €144 billion, excluding Germany. Based on the GDP share, online payments in Germany would amount to a further €59 billion, in which case cards would still make up 73% of total non-cash payments in the euro area.

⁵ Slemrod et al (2017) find evidence of a positive effect of credit card information reporting on direct tax declarations for small businesses in the US, although, the overall net effect on revenues is largely offset by increased reported expenses. The analysis, however, does not inform on the effect of substituting cash for card payments.

are the dominant alternative to cash for retail purchases in the euro area. Second, unlike other non-cash payments, such as bank transfers, cards can be safely assumed to be used primarily for consumption. As far as we are aware, official sources on payment statistics do not permit the identification of consumption expenditure across different payment methods. Time-varying coefficient methods are employed in order to estimate the country-specific contribution of compliance to revenue growth as a function of card payments. In line with the micro-data literature, the analysis indicates that increasing the share of card payments in private consumption expenditure improves VAT tax compliance. The gains are found to increase: (i) the lower the initial level of card use; (ii) the higher the share of self-employment and (iii) the lower the level of revenue efficiency. The highest benefits are estimated for Greece and Italy.

The contribution of the paper is twofold. First, to our knowledge it provides the first confirmation of the well-established literature on information trails using aggregate macroeconomic time series in a multi-country setting. Second, it has very timely policy implications, as low-hanging fruit are identified in euro-area economies with much to gain from strengthening the credibility of their fiscal performance, such as Greece.

The rest of the paper is organized as follows: Section 2 outlines the econometric framework and discusses data concepts and definitions. Section 3 reports the empirical results obtained from a benchmark model and an augmented specification. Section 4 reports additional robustness checks and section 5 concludes.

2. Econometric framework and data

2a. Sources and definition of variables

We use quarterly national accounts data available from Eurostat for the 19 member states of the euro area⁶ on the following variables: VAT revenue (VAT_t), total final consumption ($CONS_t$), final consumption of the general government ($CONSG_t$) and intermediate consumption of the general government (INC_t). All series are non-seasonally adjusted and are measured in nominal terms. The commonly available

⁶ Belgium, Germany, Estonia, Ireland, Greece, Spain, France, Italy, Cyprus, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Austria, Portugal, Slovenia, Slovakia and Finland.

sample covers the period 2002q1-2016q4. Card payments for all euro area members are available at annual frequency from the ECB. We use the nominal value of payments made through credit and debit cards issued by resident Payment Service Providers. The commonly available sample covers the period 2002-2016. A quarterly series of card payments ($CARDS_t$) is constructed by applying the seasonal pattern of total final consumption. The standard VAT rate for all euro area members is available from the European Commission until January 2017. A quarterly series ($RATE_t$) is constructed over the period 1999q3-2016q4, adjusting for the days the reported rates have been in force within a given quarter.

The tax base is defined by the sum of non-government final consumption plus government intermediate consumption $BASE_t = CONS_t - CONSG_t + INC_t$. This is a post-tax concept, which can be argued to be more appropriate when VAT covers a broad range of goods and services, as is the case in our sample. A pre-tax concept can be obtained by subtracting VAT revenue from our post-tax measure.⁷ All empirical analysis has been carried out using both definitions.

We construct the share of non-government consumption expenditure that was paid by cards as $CARDSHAREP_t = CARDS_t / (CONS_t - CONSG_t)$. This variable is intended as a measure of the intensity of card use, by expressing the payments actually made by cards as a share of all payments that could potentially have been made by cards. The choice not to scale card payments by broader measures of economic activity, like total consumption, or GDP, is guided by the view that cards are predominantly used for retail purchases and by non-government agents.⁸ Scaling card payments by total final consumption, for example, would introduce variation related to the size of government consumption, which is completely uninformative regarding agents' preferences of payment method.

We use quarterly data from the Labour Force Survey, commonly available during 2005q1-2016q4, on the number of self-employed persons ($SELF_t$) and the total number of employed persons (EMP_t) to calculate the share of self-employed out of total employment $SELFEMP_t = SELF_t / EMP_t$. Revenue efficiency is measured as the

⁷ The pre-tax concept is more appropriate when the VAT is targeted on goods and services with a low price elasticity of demand. A simple numerical example is included as an Annex.

⁸ Private consumption expenditure may still include payments, such as imputed rents, which are not made via cards. This caveat also applies to the tax base, as imputed rents do not generate VAT revenue.

share of actual VAT revenue out of the potential revenue a given tax base would yield under universal application of the standard rate: $EFFICIENCY_t = \frac{VAT_t}{(BASE_t)*(RATE_t)}$.

All empirical analysis is based on the variables *CARDSHAREP*, *VAT*, *BASE* (post-and-pre-tax definitions), *RATE*, *SELFEMP* and *EFFICIENCY*, which are plotted for the 19 euro area member states in charts 1a-1g. Descriptive statistics are reported in Table 1, while a summary of all variable definitions is provided in the data appendix.

2b. Benchmark model

The Time-Varying Coefficients (TVC) model in HP17 is reformulated as a panel for the 19 euro area economies with cross-section i given by:

$$\Delta_4 \ln(VAT_{i,t}) = b_{0i,t} + b_{1i,t} \Delta_4 \ln(RATE_{i,t}) + b_{2i,t} \Delta_4 \ln(BASE_{i,t}) \quad (1)$$

where Δ_4 denotes year-on-year difference (i.e. $\Delta_4 x_t = x_t - x_{t-4}$), $VAT_{i,t}$ is quarterly VAT revenue, $RATE_{i,t}$ is a measure of the policy rate and $BASE_{i,t}$ is a measure of the macroeconomic tax base. Details on variable definitions and sources, as well as the motivation for specific concepts are provided in section 2a and in the data appendix. Equation (1) holds exactly at all times and, hence, the time-varying coefficients $b_{0i,t}$, $b_{1i,t}$ and $b_{2i,t}$ collect the influences of all factors affecting VAT growth, in line with Hondroyannis et al. (2009), Swamy et al. (2010), and Hall et al. (2013). Such influences include, for example, the coverage and range of the various rates, changes in the composition of consumption due to tastes, fiscal policy or demographic factors, such as the age and geographical distribution of consumers, as well as tax enforcement policy, the quality of tax administration, cultural factors affecting tax-compliance and payment preferences. Identifying the distinct effects of individual factors requires the assignment of specific functional forms to the time-varying coefficients involving the variables of interest.

While $b_{1i,t}$ and $b_{2i,t}$ depict the time-varying elasticities with respect to the standard rate and the tax base, respectively, $b_{0i,t}$ is an overall scaling factor, similar to total factor productivity growth in a Cobb-Douglas production function. That is, $b_{0i,t}$ determines the overall effectiveness of the factors that influence VAT. As such, $b_{0i,t}$

may be interpreted as a proxy for tax compliance. Among the various factors affecting tax compliance, our interest lies in identifying the specific influence of card payments. To this end $b_{0i,t}$ is estimated as a function of changes in the share of card payments in private consumption, $CARDSHAREP_t$:

$$b_{0i,t} = c_0 + c_1 \Delta_4 \ln(CARDSHAREP_{i,t}) + c_2 \Delta_4 \ln(CARDSHAREP_{i,t})^2 + e_{0i,t} \quad (2)$$

where c_0, c_1, c_2 are estimated constant parameters, common across cross-sections and $e_{ki,t} \sim N(0, \sigma_i^2)$, assuming $E(e_{ki,t} e'_{kj,t}) = 0$, for $i \neq j$. The coefficients c_1 and c_2 isolate the effect of card use, while all other influences are – by definition – collected by c_0 and $e_{i,t}$. We allow for a quadratic functional form in line with Madzharova (2014), permitting for the possibility of decreasing returns to (increases in) card use. However, it is likely that such diminishing returns may not be easily detectable over the historical range of card use in the euro area. No economic structure is imposed on $b_{1i,t}$ and $b_{2i,t}$, which are modelled as driftless random walks:⁹

$$b_{1i,t} = b_{1i,t-1} + e_{1i,t} \quad (3a)$$

$$b_{2i,t} = b_{2i,t-1} + e_{2i,t} \quad (3b)$$

As discussed above, this does not suggest that other factors affecting VAT growth are not taken into account. By fitting the data perfectly, the model necessarily accounts for the full set of factors affecting VAT, even if it can only inform on the distinct effect of card use.

2c. Augmented model

In the benchmark model the marginal influence of card use on VAT compliance is captured by the common constant parameters c_1 and c_2 in equation (2). There are, however, good reasons to expect the effects of card use on tax compliance to vary through time and across countries.

Increasing third-party reporting has been shown to be more effective at improving tax compliance in those cases where there are greater opportunities for

⁹ HP17 impose a structure on all time-varying coefficients, which are estimated as functions of card use and the share of durable goods in households' consumption. Here we choose to remain agnostic regarding the economic drivers of $b_{1i,t}$ and $b_{2i,t}$ for the following reasons: First, quarterly national accounts data on households' consumption on durables are not available for Belgium, Ireland and Spain. Second, the number of model specification choices is kept down to a minimum. Third, adding estimated parameters comes at a high computational cost.

under-reporting transactions. Opportunities for non-compliance tend to be significantly greater for those in self-employment than for wage-earners.¹⁰ This suggests that the parameters c_1 and c_2 may vary across countries depending on the incidence of self-employment. According to quarterly data from the Labour Force Survey, the share of self-employment in total employment during 2016 ranged from as low as 9% in Luxembourg to 22% in Italy and 30% in Greece (Chart 2a). Other things being equal, one would expect, therefore, card payments to generate higher compliance gains in economies with higher levels of self-employment, such as Greece and Italy. Additionally, the scope for increasing further the use of cards could vary depending on the existing level of card use (Chart 2b). A higher prevalence of traceable payments could induce positive externalities on compliance along the VAT chain, such as reported by Pomeranz (2015). In the presence of such compliance spillovers, the incremental gains from higher card use captured by parameters c_1 and c_2 would decline as the level of card use increases. Also, at any given level of card use the opportunities to hide transactions may vary depending on the overall efficiency of tax administration (Chart 2c). For instance, despite similarly low levels of card use in Greece and Germany, a more efficient tax collection in Germany would suggest that the marginal benefit from increasing the use of cards can be much lower.

To account for these factors, equation (2) is re-formulated as follows:

$$b_{0i,t} = c_0 + (SELFEMP_{i,t}) * (1 - CARDSHAREP_{i,t}) * (EFFICIENCY_{i,t-1})^{-1} * (c_1 \Delta_4 \ln(CARDSHAREP_{i,t}) + c_2 \Delta_4 \ln(CARDSHAREP_{i,t})^2) + e_{i,t} \quad (2')$$

where $SELFEMP_{i,t}$ is the share of self-employment in total employment and $EFFICIENCY_{i,t} = \frac{VAT_{i,t}}{(BASE_{i,t}) * (RATE_{i,t})}$. Under this formulation the effect of changes in card use measured by the coefficients c_1 and c_2 becomes conditional on the country-specific incidence of self-employment, the prevailing level of card use and the past level of revenue efficiency. A positive c_1 would indicate that a given increase in card

¹⁰ Artavanis et al. (2016) estimate that in Greece around 45% of self-employed income goes unreported and thus untaxed. This compares with an estimated under-reporting of around 1/3 of self-employed income for the UK by Pissarides and Weber (1989) and 35% for the US according to Feldman and Slemrod (2007). Threat-of-audit letters have been found by Slemrod et al. (2001) and Kleven et al. (2011) to trigger sizeable upward revisions in the declared amounts for self-reported incomes, but little or no changes in incomes subject to third-party reporting.

use has a stronger positive impact on VAT revenue the higher the incidence of self-employment, the lower the current level of card use and the lower the existing level of revenue efficiency. The inclusion of revenue efficiency is intended as a proxy of the overall effectiveness of tax administration. It is included as an inverse, rather than as distance from unity, in order to avoid the sign reversal in Luxembourg, which has an efficiency level above unity. The lagged value is used in order to avoid endogeneity issues, as a *ceteris paribus* increase in VAT at time t necessarily increases efficiency at time t .

3. Empirical results

3a. Benchmark model

Equations (1)-(3b) define a state-space model which has been estimated using the Kalman filter for the panel of 19 euro area countries over the full set of commonly available observations covering 2003q1-2016q4. Table 2, column I reports the estimates obtained for the coefficients c_1 and c_2 in the equation for compliance in (2) using the post-tax and the pre-tax measure of the tax base. In both cases compliance, as measured by $b_{0i,t}$, is found to be a positive function of card use. The relationship is stronger and more statistically significant in the case of the pre-tax measure, while in both cases the quadratic term is strongly insignificant. Chart 3a plots the estimated gains in VAT revenue from an increase by one percentage point in the level of CARDSHAREP in 2016q4. As the coefficients c_1 and c_2 are common for all countries, the reported differences in revenue gains simply reflect differences in the level of card use in 2016q4. Hence, the most sizeable benefits arise for Greece,¹¹ followed by Germany and Italy and the least sizeable for Portugal, Luxembourg and Estonia.

3b. Augmented model

The estimates of equation (2') are reported in Table 2 under column IV using the post-and pre-tax definition of the tax base. Intermediate specifications are reported

¹¹ Point estimates range between 0.7% and 1.1% depending on the definition of the tax base. This is broadly in line with the estimated gain of 1% in VAT revenue for each percentage point increase in CARDSHAREP reported in HP17 for Greece during 2015q2-2016q2.

in columns II and III. The results confirm that compliance, as measured by $b_{0i,t}$, is a positive function of card use. Furthermore, in line with the literature and our priors, the estimated marginal effect varies through time and across countries, depending on the prevailing country-specific level of self-employment, the level of card use and the past level of revenue efficiency. Chart 3b plots the estimated gains in VAT revenue from an increase by one percentage point in the level of CARDSHAREP, conditionally on the 2016q4 levels of card use, self-employment and (lagged) revenue efficiency. The highest gains are estimated for Greece, followed by Italy and Spain. This is very much in line with our priors, as these countries combine low levels of card use, high levels of self-employment and low revenue efficiency. The conditional point estimates for these countries are higher compared to the estimates from the benchmark model, particularly in the case of Greece, for which a 1 percentage point increase in CARDSHAREP is found to generate approximately 2% additional VAT revenue through improved compliance. This is two times higher than the estimate of the benchmark model and the estimate reported in HP17. Furthermore, the comparatively high revenue gains estimated for Germany using the benchmark model now become considerably lower, as the positive influence from low card use is mitigated by the influence of low self-employment and around average revenue efficiency.

Charts 4a (post-tax base) and 4b (pre-tax base) plot the estimated relation between VAT growth (vertical axis) and the year-on-year changes in $\ln(\text{CARDSHAREP}_{i,t})$ (horizontal axis) for different levels of EFFICIENCY (rows), CARDSHAREP (columns) and SELFEMP (shades). The charts are organized in five rows, denoting efficiency levels from 40% to 80% and in six columns, denoting levels of card use from 10% to 60%. Each graph in the 5×6 grid measures VAT growth on the vertical axis and $\Delta_4 \ln(\text{CARDSHAREP}_{i,t})$ on the horizontal, evaluated for six different levels of self-employment between 5% (lighter shade) and 30% (darkest shade). The top left corner is representative of a country like Greece, with low revenue efficiency and card use. With a self-employment rate of 30%, the relationship for Greece is given by the darkest shade. Compliance gains from increasing card use decline the higher the existing level of card use (moving from left to right), the higher the level of revenue efficiency (moving from top to bottom) and the lower the incidence of self-employment (moving from dark to lighter shades within each graph).

4. Robustness checks

4a. Excluding individual cross-sections

In order to evaluate the extent to which the full-sample results are influenced by individual outlier countries, the augmented model has been re-estimated excluding one cross-section at a time. Chart 5a plots the estimated coefficients c_1 and c_2 (vertical) for each excluded cross-section (horizontal). In all cases deviations from the full-sample estimates are found to be marginal and not statistically significant, indicating that the full-sample results are not driven by any single country. The effects on the corresponding responses of VAT revenue to a 1 percentage point increase in CARDSHAREP are plotted in Chart 5b. Deviations from the full-sample responses are in some cases statistically significant, but remain very small in magnitude. Overall, the evidence indicates that the full-sample results are not driven by individual outliers.

4b. Panel VAR

The TVC estimates of the revenue gains from higher card use provide a measure of the *ceteris paribus* effect on impact, but do not inform on the evolution over longer horizons. We use a constant parameter panel VAR in order to quantify the effect over longer horizons. The estimate of compliance $\widehat{b_{0i,t}}$ obtained from (2') is included as an exogenous regressor in the following panel VAR, treating endogenously VAT revenue and the tax base:

$$\Delta_4 \mathbf{y}_{i,t} = \mathbf{a}_{0i} + \mathbf{\Gamma}(L)\Delta_4 \mathbf{y}_{i,t} + \mathbf{A}(L)\Delta_4 \mathbf{x}_{i,t} + \mathbf{B}(L)\widehat{b_{0i,t}} + \mathbf{e}_{i,t} \quad (4)$$

where $\mathbf{y}_{i,t} = [\ln(VAT_{i,t}), \ln(BASE_{i,t})]'$, $\mathbf{x}_{i,t} = [\ln(RATE_{i,t}), \ln(RATE_{i,t})^2]'$,

$\mathbf{\Gamma}(L) = \Gamma_1 L + \Gamma_2 L^2 + \dots + \Gamma_p L^p$, $\mathbf{A}(L) = A_0 + A_1 L^1 + \dots + A_p L^p$,

$\mathbf{B}(L) = B_0 + B_1 L^1 + \dots + B_p L^p$ and \mathbf{a}_{0i} is a cross-section fixed effect.

The VAR model given by (4) has been estimated by OLS for the panel of 19 euro area countries over the full set of commonly available observations, which under a lag length of 4 cover the period 2006q1-2016q4. The estimated model is used in order to trace the percentage changes of $EFFICIENCY_{i,t} = \frac{VAT_{i,t}}{(BASE_{i,t}) * (RATE_{i,t})}$, $VAT_{i,t}$ and

$BASE_{i,t}$ in response to a 1 percentage point increase in $CARDSHAREP_{i,t}$, propagated through $\widehat{b_{0,t}}$ according to the estimated relation (2').

Charts 6a-6c plot the annualized responses to a 1 percentage point increase in the share of card payments in private consumption. A higher share of card payments generates permanent gains in revenue efficiency, as higher VAT revenue dominates over smaller and delayed increases in the tax base. On impact, efficiency gains reflect almost exclusively the positive effect on VAT revenue, as the tax base remains largely unaffected, which lends support to the interpretation of $\widehat{b_{0,t}}$ as a proxy for compliance. The estimated revenue gains are qualitatively and quantitatively in line with the evidence obtained from the TVC model, with benefits being highest for Greece followed by Italy and Spain.

5. Conclusions

The use of traceable payment methods presents an additional reform option for improving tax compliance. As regards consumption, card payments remain by far the main alternative to cash in the euro area. Although the use of micro-data has provided clear evidence in favour of increasing information trails, time series evidence on the role of card payments in increasing compliance have been scarce and confined to the recent experience of Greece.

This paper revisits the effect of card payments on VAT revenue using quarterly panel data for the 19 euro area economies over the period 2003q1-2016q4. Time-varying coefficient methods have been employed in order to estimate the country-specific contribution of compliance to revenue growth as a function of card payments. The analysis indicated that increasing the share of card payments in private consumption expenditure improves VAT tax compliance. Furthermore, in line with the literature and our priors, the estimated marginal effect varies through time and across countries, depending on the prevailing country-specific level of self-employment, the level of card use and the past level of revenue efficiency. Compliance gains from higher card use are found to increase: (i) the lower the initial level of card use; (ii) the higher the share of self-employment and (iii) the lower the level of revenue efficiency. The highest benefits are estimated for Greece and Italy.

We find these results to be qualitatively and to a large extent also quantitatively robust to different specifications.

The significance of these results is twofold. First, to our knowledge they provide the first confirmation of the well-established literature on information trails using aggregate macroeconomic time series in a multi-country setting. Second, they have very timely policy implications, as low-hanging fruit are identified in euro-area economies with much to gain from strengthening the credibility of their fiscal performance, such as Greece.

Data Appendix

1. $CARDS_t$ = Value of payments with credit and debit cards issued by resident PSPs (except cards with an e-function only), available on an annual basis from the ECB SDW (common EA sample 2002-2016). 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), common EA sample 00q1-16q4.
4. $CONSG_t$ = Final consumption expenditure of the general government (nominal), National Accounts (ESA 2010), common EA sample 00q1-16q4.
5. $CONSP_t = CONS_t - CONSG_t$.
6. INC_t = Intermediate consumption of the general government (nominal), National Accounts (ESA 2010), common EA sample 02q1-16q4.
7. VAT_t = VAT revenue (nominal), National Accounts (ESA 2010), common EA sample 02q1-16q4.
8. $BASE_t = \begin{cases} CONS_t - CONSG_t + INC_t, & \text{post tax} \\ CONS_t - CONSG_t + INC_t - VAT_t, & \text{pre tax} \end{cases}$.
9. $RATE_t$ = Standard VAT rate, European Commission (January 2017). Adjusted for the days the reported rates have been in force within a given quarter.
10. $EFFICIENCY_t = \frac{VAT_t}{BASE_t * RATE_t}$.
11. $SELF_t$ = Labour Force Survey quarterly observations on self-employed persons aged 15-74. Common EA sample 05q1-16q4.

12. EMP_t = Labour Force Survey quarterly observations on total number of employed persons aged 15-74. Common EA sample 05q1-16q4.
13. $SELFEMP_t = SELF_t/EMP_t$.

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Annex – The post-and-pre-tax measures of the tax base in a static linear setting.

For linear demand and supply schedules given by $Q^D = d - xP$ and $Q^S = bP$, respectively, the market-clearing consumption expenditure before the introduction of taxation is given by:

$$C^* = \frac{bd^2}{(b+x)^2} \quad (\text{A.1})$$

C^* is the true base on which a per unit tax t is applied. Following a ceteris paribus introduction of the tax, the supply schedule becomes $Q^{St} = bP - bt$ and the new market clearing consumption expenditure is given by:

$$C^{post\ tax} = \frac{(d+bt)(bd-btx)}{(b+x)^2} \quad (\text{A.2})$$

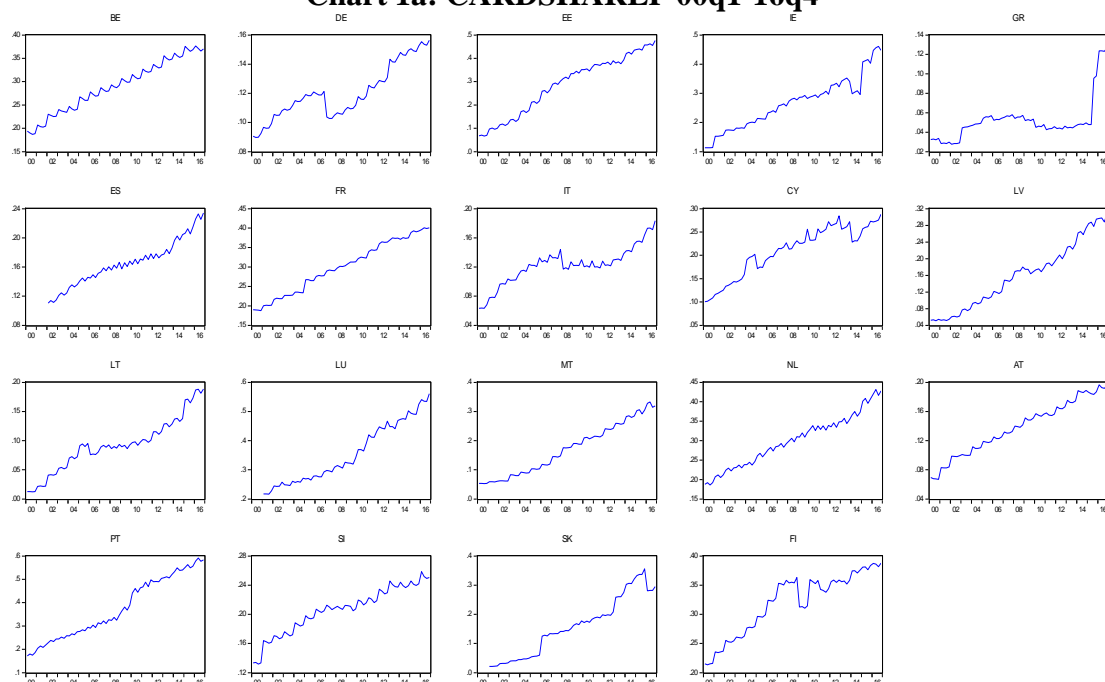
, which is the post-tax measure of the tax base. Tax revenue T amounts to $t(bd - btx)/(b + x)$ and the pre-tax measure of the tax base is given by:

$$C^{pre\ tax} = C^{post\ tax} - T \quad (\text{A.3})$$

Chart A plots the difference from the true tax base in (A.1) (expressed in % of T), of the post-tax measure in (A.2) (blue line), and of the pre-tax measure in (A.3) (pink line), for different values of (the absolute value of) the price elasticity of demand, evaluated under the following normalizations: $d = b = 1$, $t = 1\%$.

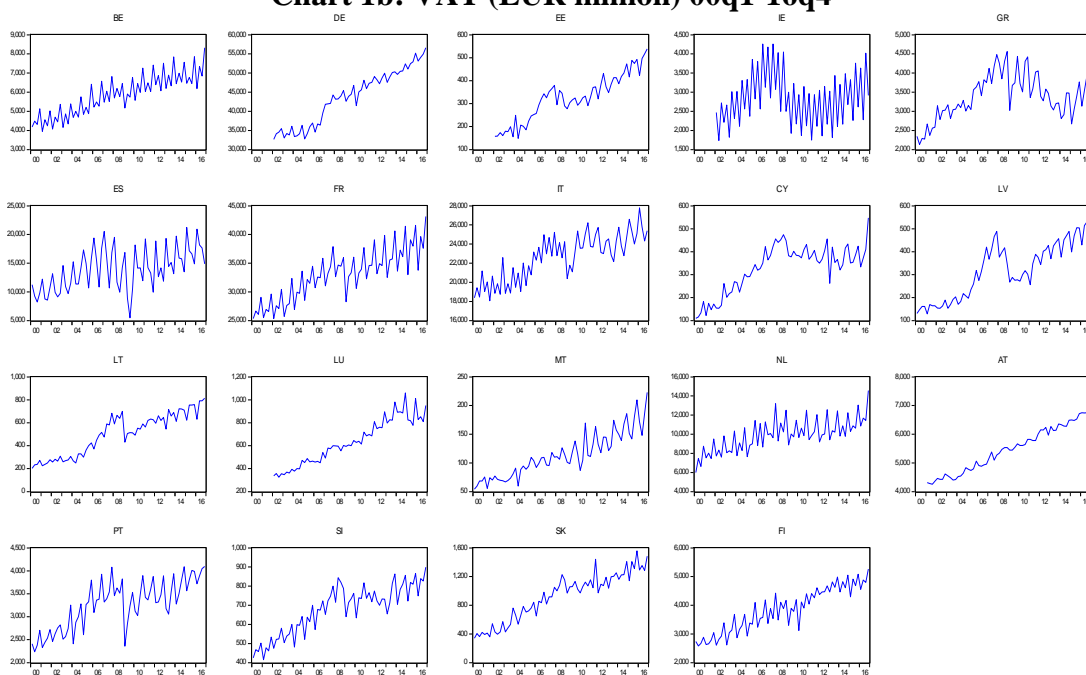
When demand is perfectly inelastic, the per-unit tax is fully borne by consumers, increasing the market clearing price by t with no change in quantity. As such, the post-tax final consumption over-estimates the true tax base by the full amount of the tax revenue, while the pre-tax measure is exactly equal to the true base. Conversely, when demand has a unitary elasticity, consumption expenditure remains unchanged by the introduction of the tax and hence, the post-tax measure is exactly equal to the true tax base, while the pre-tax measure under-estimates the base by the full amount of the tax revenue. The pre-tax measure is superior over the short range of elasticities between 0 and 0.33, whereas the post-tax measure dominates over all values greater than 0.33.

Chart 1a: CARDSHAREP 00q1-16q4



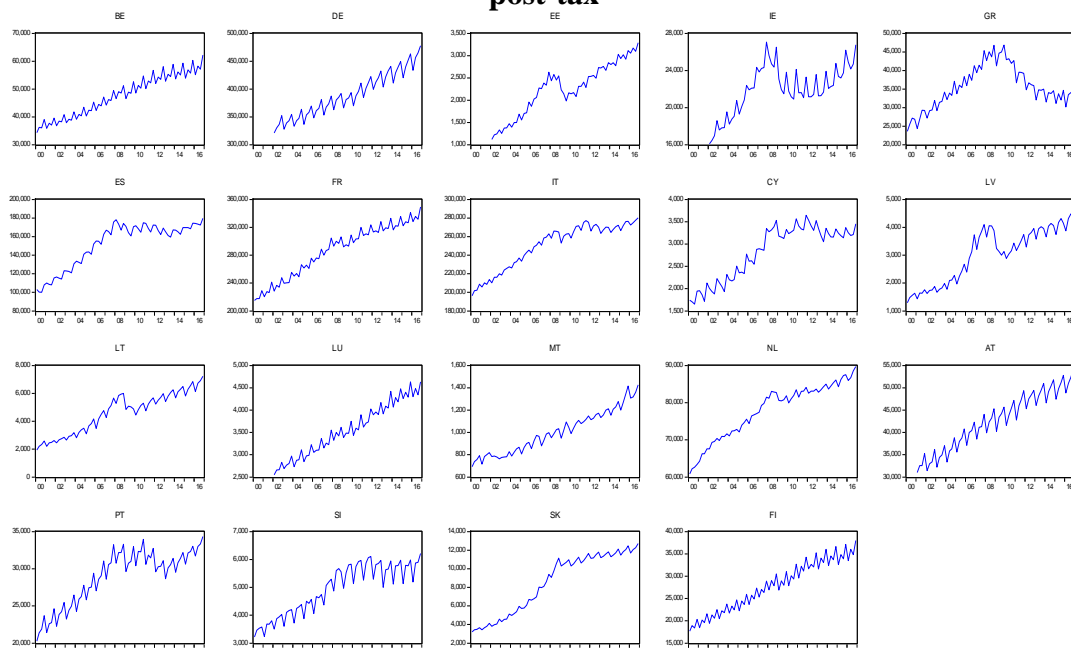
Notes: Value of card transactions as a share of private consumption.
Source: ECB Payment Statistics and Eurostat National Accounts ESA 2010.

Chart 1b: VAT (EUR million) 00q1-16q4



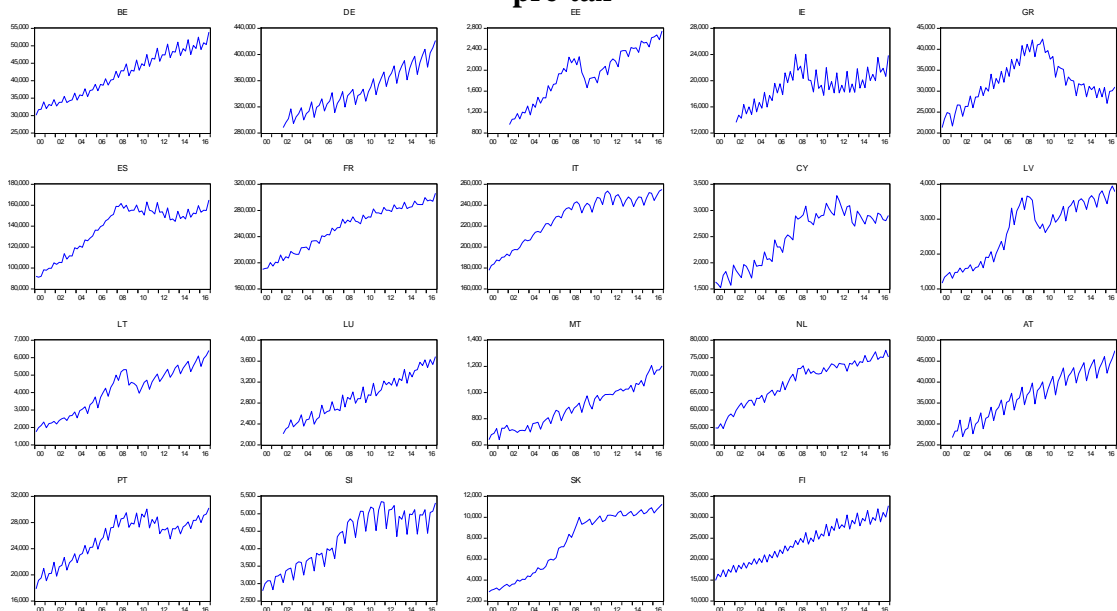
Source: Eurostat National Accounts ESA 2010.

Chart 1c: BASE (EUR million) 00q1-16q4
post-tax



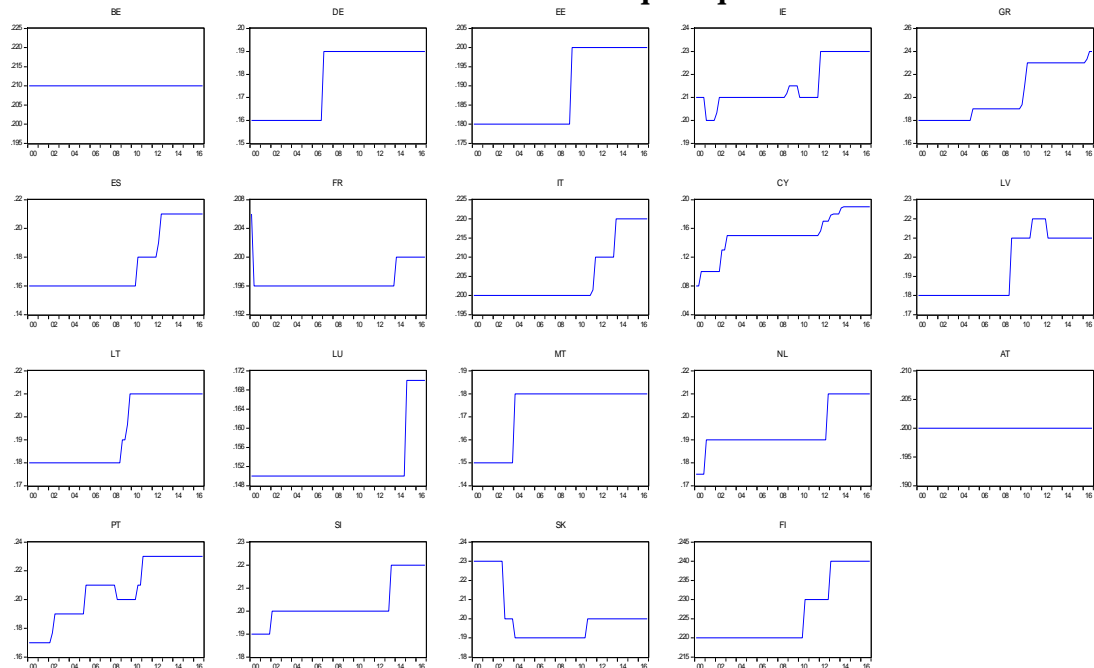
Notes: Sum of private consumption and government intermediate consumption.
Source: Eurostat National Accounts ESA 2010.

Chart 1d: BASE (EUR million) 00q1-16q4
pre-tax



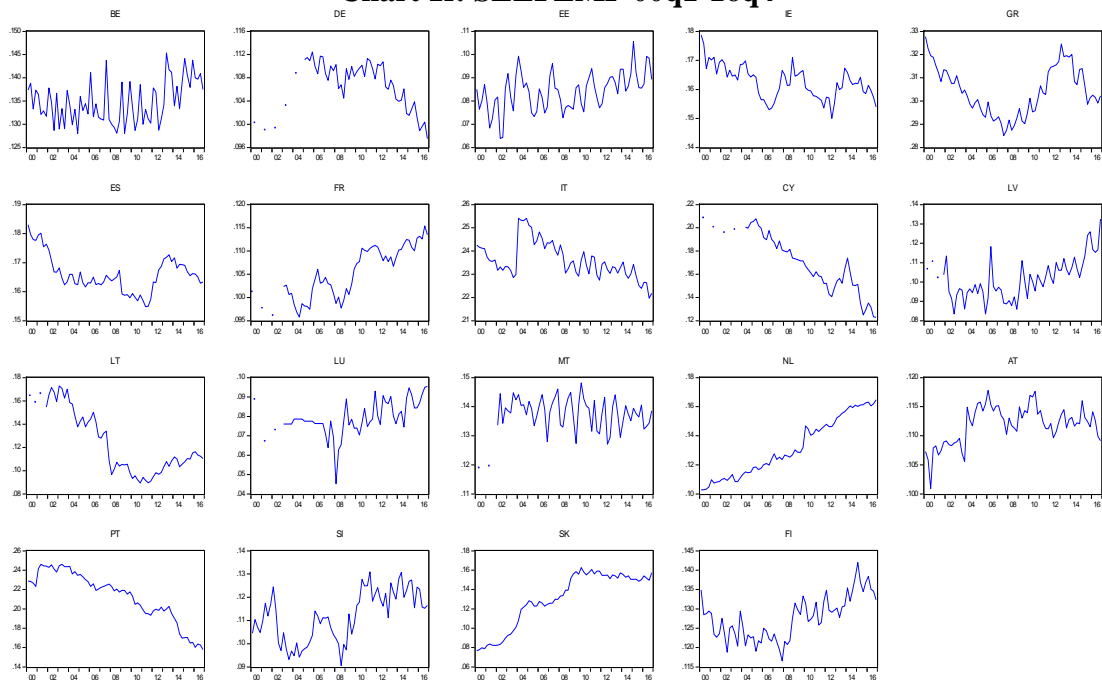
Notes: Sum of private consumption and government intermediate consumption less VAT revenue.
Source: Eurostat National Accounts ESA 2010.

Chart 1e: RATE 00q1-16q4



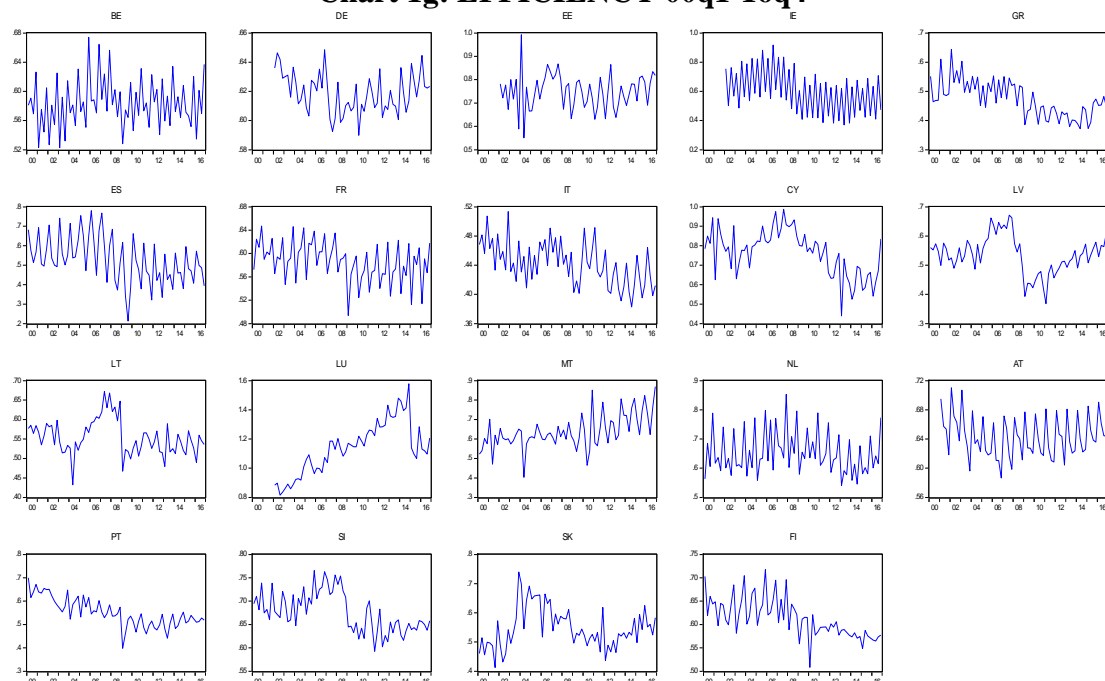
Source: European Commission.

Chart 1f: SELFEMP 00q1-16q4



Source: Eurostat, Labour Force Survey.

Chart 1g: EFFICIENCY 00q1-16q4



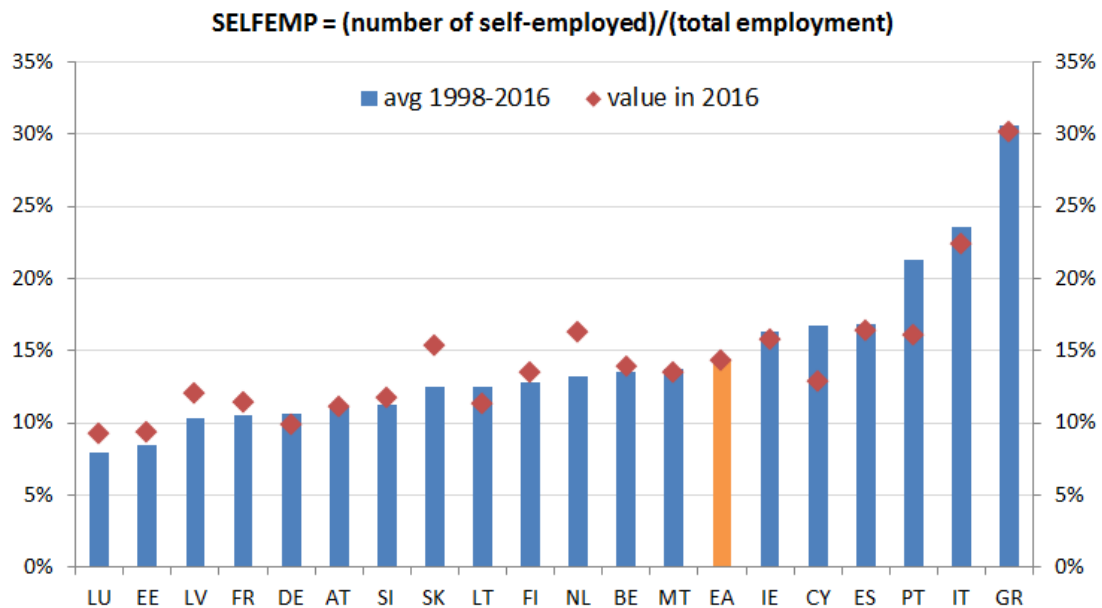
Notes: $VAT/(BASE \times RATE)$.

Table 1 – Descriptive statistics

	CARDSHAREP	VAT*	BASE* (post-tax)	BASE* (pre-tax)	RATE	SELFEMP	EFFICIENCY
Mean	0.22	7733	71025	63292	0.20	0.15	0.62
Median	0.21	3126	25933	23077	0.20	0.13	0.60
Maximum	0.59	56596	477845	421249	0.24	0.33	1.58
Minimum	0.01	55	738	678	0.08	0.05	0.21
Std. Dev.	0.12	11783	108331	96710	0.02	0.06	0.16
Observations	1196	1196	1196	1196	1196	1196	1196

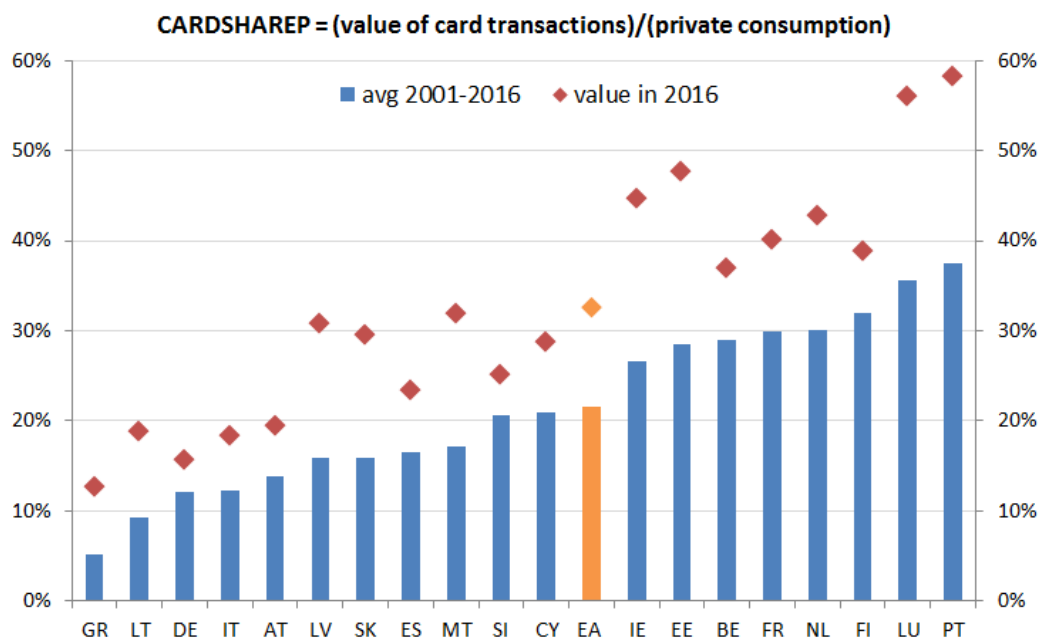
* EUR million.

Chart 2a: Self-employment as a share of total employment



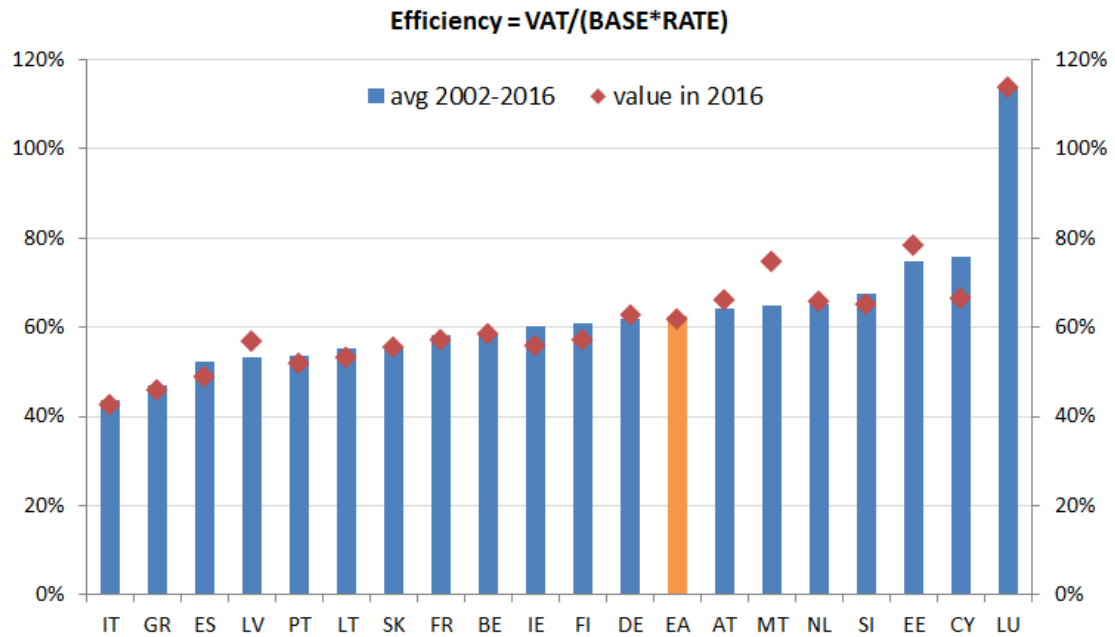
Source: Labour Force Survey

Chart 2b: Value of card transactions as a share of private consumption



Source: ECB Payment Statistics and Eurostat National Accounts ESA 2010. EA computed as the unweighted average of the 19 EA members.

Chart 2c: VAT revenue efficiency



Notes: Measured by the ratio of VAT revenue to the product of the tax base times the standard rate. The tax base is given by the sum of private consumption and government intermediate consumption. EA computed as the unweighted average of the 19 EA members.

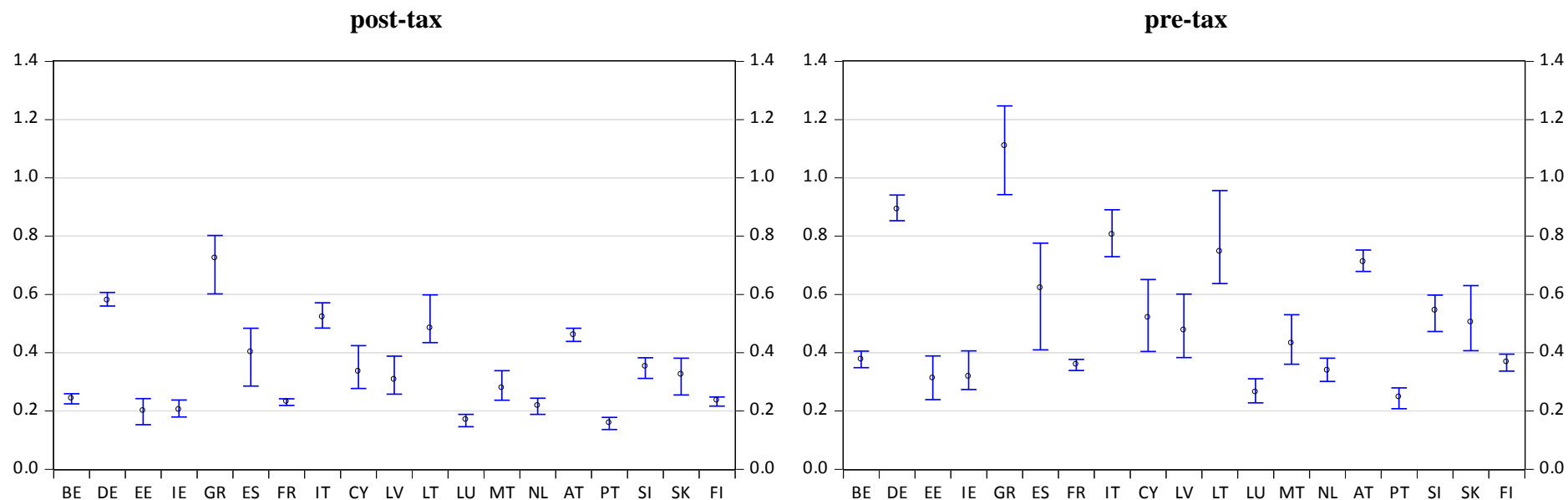
Source: Eurostat National Accounts ESA 2010 and European Commission.

Table 2: Marginal effect of card use on VAT tax compliance

Dependent variable: $b_{0i,t}$								
Sample: 2003q1-2016q4; Cross-sections: 19								
	post-tax				pre-tax			
	I	II	III	IV	I	II	III	IV
$\Delta_4 \ln(CARDSHAREP_{i,t})$	0.09*				0.15**			
	[1.67]				[2.41]			
$\Delta_4 \ln(CARDSHAREP_{i,t})^2$	0.0005				-0.04			
	[0.004]				[-0.31]			
$\Delta_4 \ln(CARDSHAREP_{i,t}) * SELFEMP_{i,t}$		0.77**				0.96**		
		[2.10]				[2.05]		
$\Delta_4 \ln(CARDSHAREP_{i,t})^2 * SELFEMP_{i,t}$		-0.33				-0.52		
		[-0.61]				[-0.74]		
$\Delta_4 \ln(CARDSHAREP_{i,t}) * SELFEMP_{i,t} * (1 - CARDSHAREP_{i,t})$			0.94**				1.16**	
			[2.08]				[2.05]	
$\Delta_4 \ln(CARDSHAREP_{i,t})^2 * SELFEMP_{i,t} * (1 - CARDSHAREP_{i,t})$			-0.45				-0.68	
			[-0.70]				[-0.81]	
$\Delta_4 \ln(CARDSHAREP_{i,t}) * SELFEMP_{i,t} * (1 - CARDSHAREP_{i,t}) * (EFFICIENCY_{i,t-1})^{-1}$				0.45**				0.58*
				[2.02]				[1.81]
$\Delta_4 \ln(CARDSHAREP_{i,t})^2 * SELFEMP_{i,t} * (1 - CARDSHAREP_{i,t}) * (EFFICIENCY_{i,t-1})^{-1}$				-0.24				-0.35
				[-0.76]				[-0.73]
periods	56	48	48	48	56	48	48	48

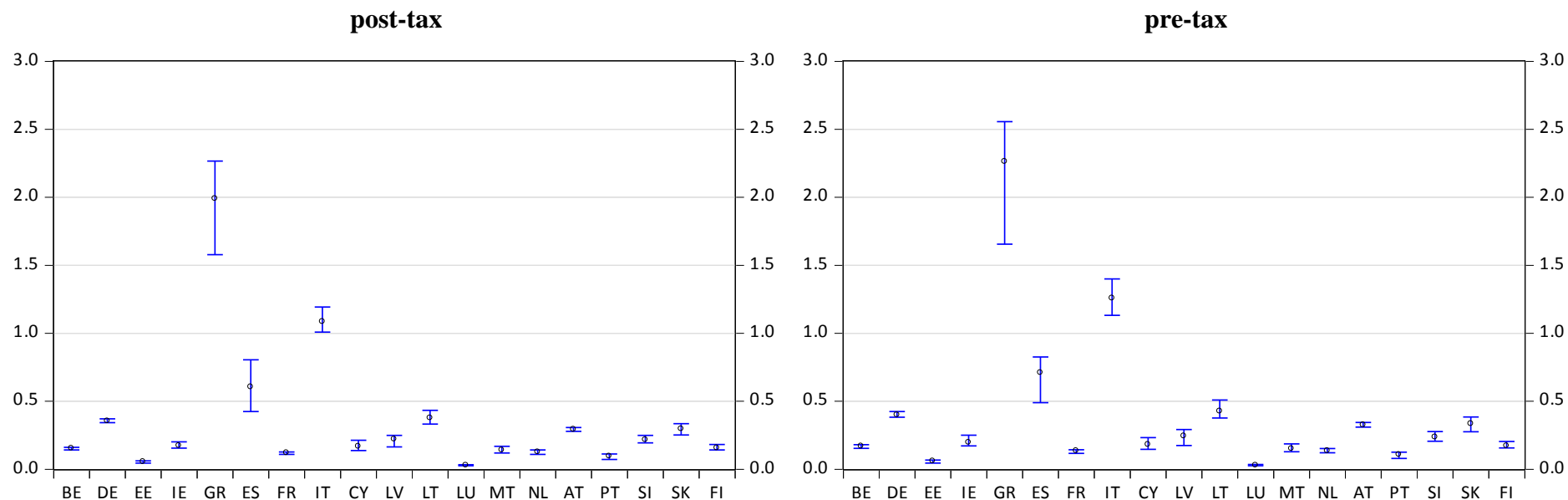
Notes: z-statistic in square brackets. “*” and “**” denote significance at the 10% and 5% levels, respectively. The post-tax definition of the tax base is given by the sum of private consumption and government intermediate consumption. The pre-tax definition subtracts VAT revenue from the post-tax measure. Columns I and IV denote the benchmark and augmented models, respectively.

Chart 3a: Percentage change of VAT revenue from a 1 percentage point increase in CARDSHAREP
Benchmark model



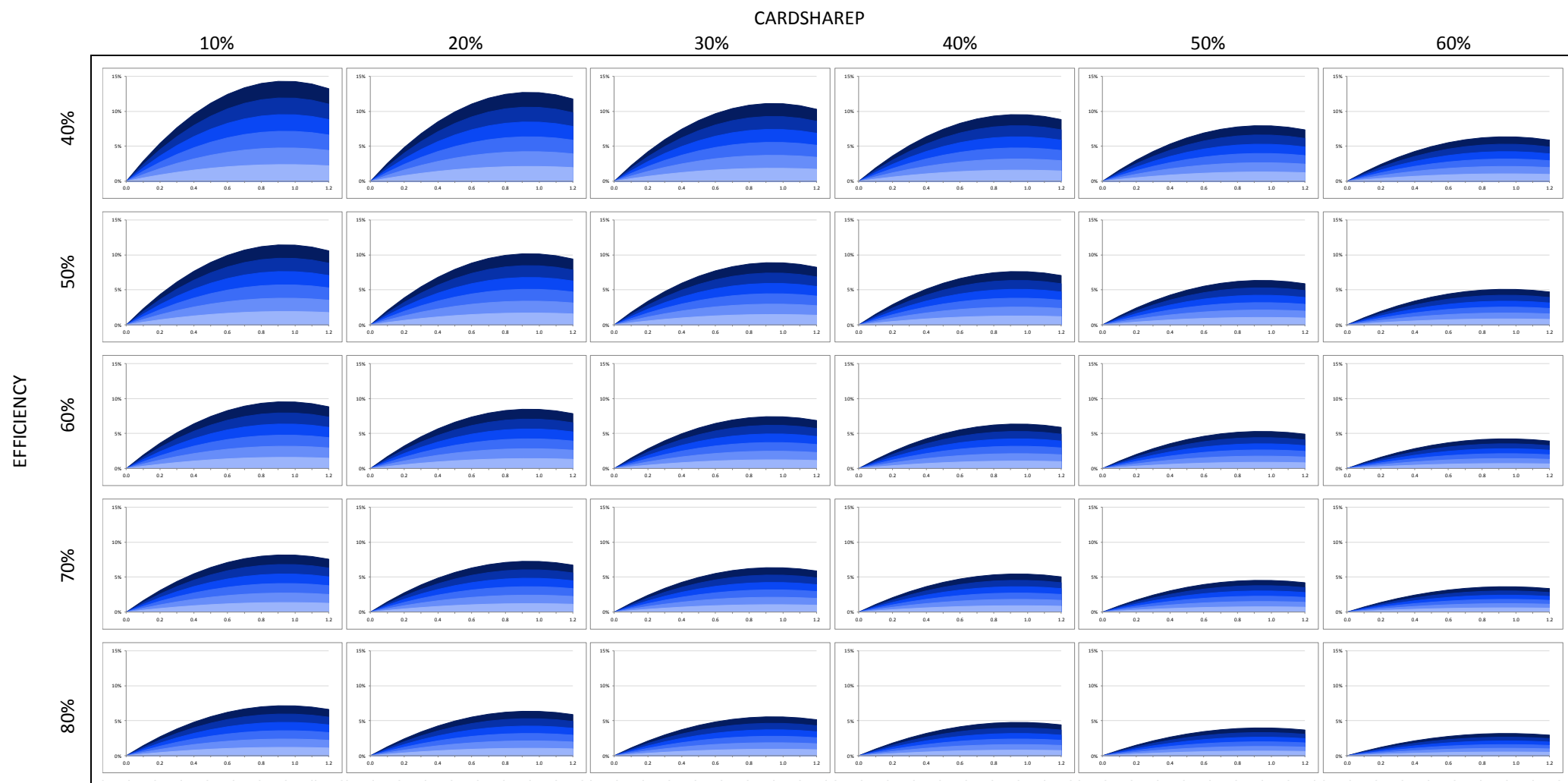
Notes: Point estimates (circles) and 95% bootstrapped error bands (vertical lines). The post-tax definition of the tax base is given by the sum of private consumption and government intermediate consumption. The pre-tax definition subtracts VAT revenue from the post-tax measure. The increase in CARDSHAREP is applied to the value in 2016q4.

Chart 3b: Percentage change of VAT revenue from a 1 percentage point increase in CARDSHAREP conditionally on the 2016q4 levels of CARDSHAREP, SELFEMP and lagged EFFICIENCY



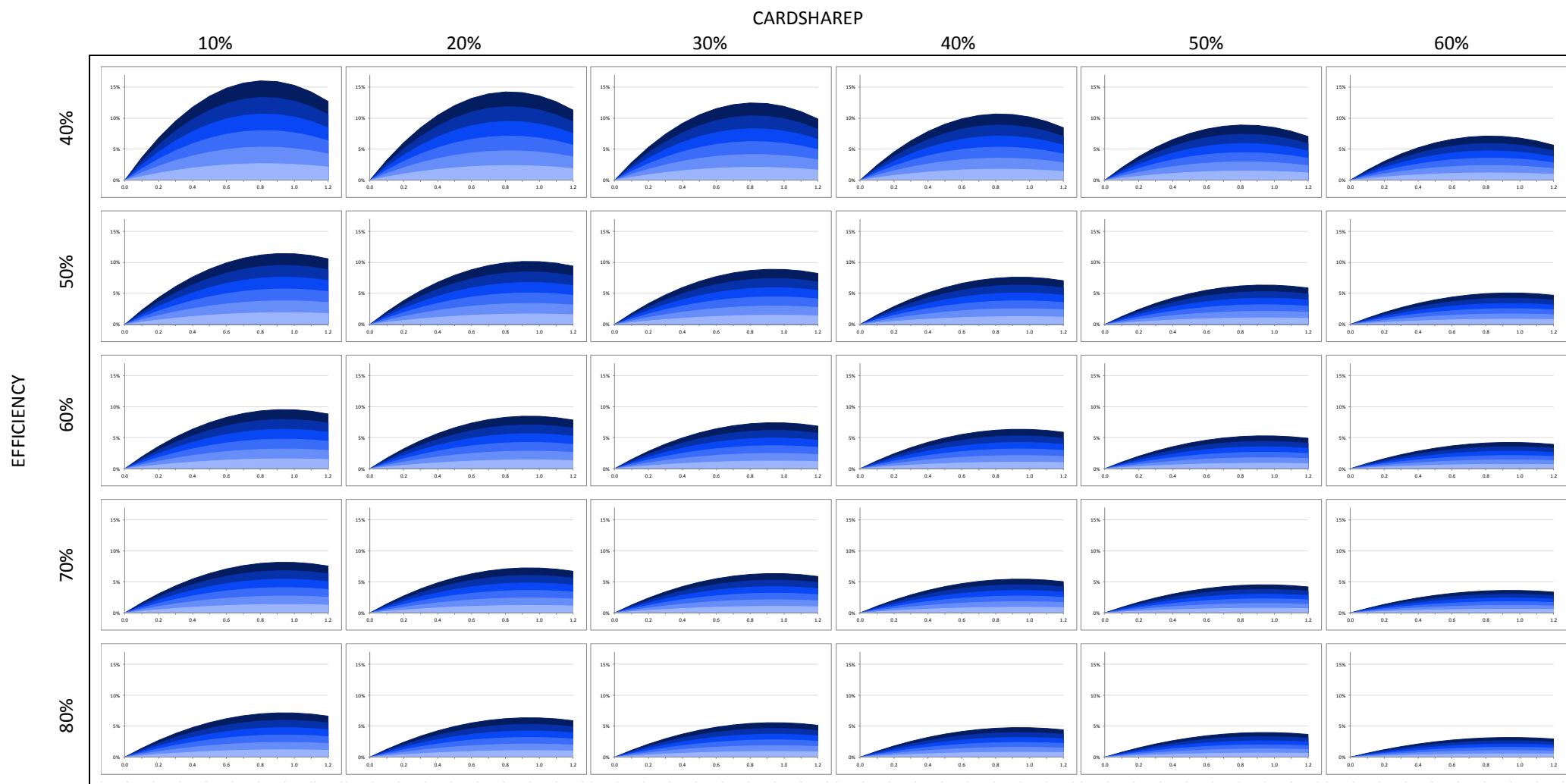
Notes: Point estimates (circles) and 95% bootstrapped error bands (vertical lines). The post-tax definition of the tax base is given by the sum of private consumption and government intermediate consumption. The pre-tax definition subtracts VAT revenue from the post-tax measure. The increase in CARDSHAREP is applied to the value in 2016q4.

**Chart 4a: Estimated relation between VAT growth (vertical axis) and y-o-y changes in $\ln(\text{CARDSHAREP})$ (horizontal axis)
for different levels of
EFFICIENCY (rows), CARDSHAREP (columns) and SELFEMP (■ 30% ■ 25% ■ 20% ■ 15% ■ 10% ■ 5%)**



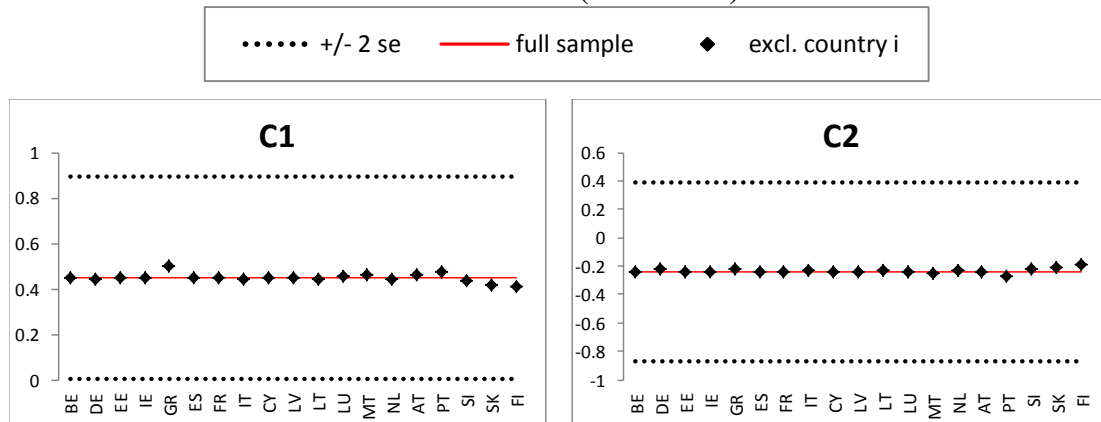
Notes: Based on the post-tax definition of the tax base, measured as the sum of private consumption and government intermediate consumption.

Chart 4b: Estimated relation between VAT growth (vertical axis) and y-o-y changes in $\ln(\text{CARDSHAREP})$ (horizontal axis) for different levels of
EFFICIENCY (rows), CARDSHAREP (columns) and SELFEMP (■ 30% ■ 25% ■ 20% ■ 15% ■ 10% ■ 5%)



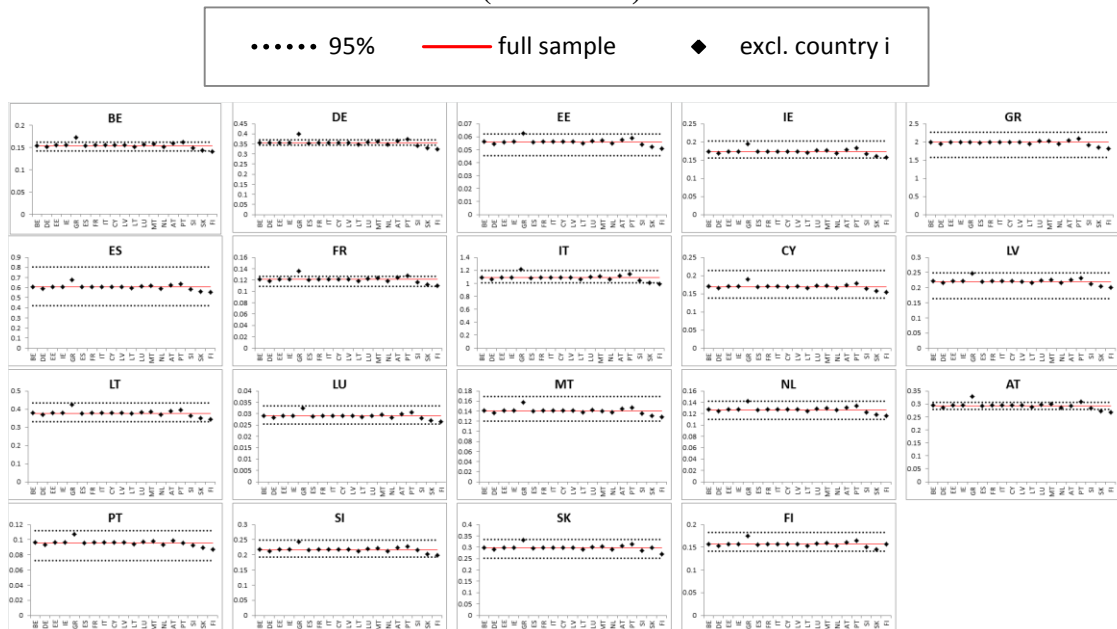
Notes: Based on the pre-tax definition of the tax base, measured as the sum of private consumption and government intermediate consumption less VAT revenue.

Chart 5a: Coefficients c_1 and c_2 (vertical). Robustness to exclusion of individual cross-sections (horizontal)



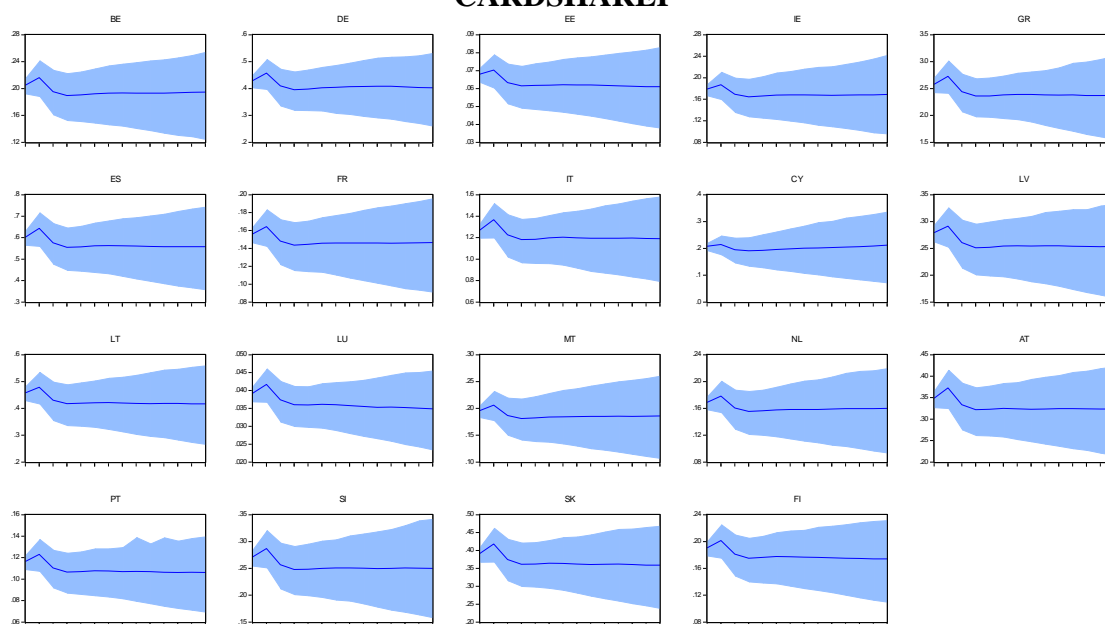
Notes: Using the post-tax measure of the tax base. Estimates are conditional on the 2016q4 levels of CARDSHAREP, SELFEMP and lagged EFFICIENCY.

Chart 5b: Percentage change of VAT revenue from a 1 percentage point increase in CARDSHAREP (vertical). Robustness to exclusion of individual cross-sections (horizontal)



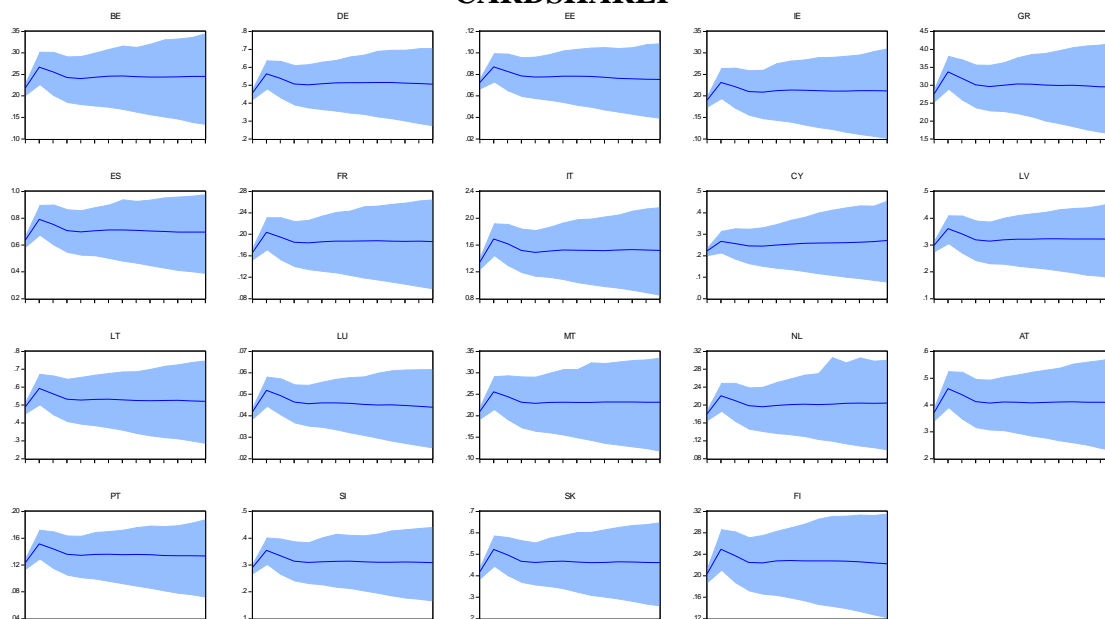
Notes: Using the post-tax measure of the tax base. Estimates are conditional on the 2016q4 levels of CARDSHAREP, SELFEMP and lagged EFFICIENCY.

Chart 6a: Percentage change of EFFICIENCY in response to a 1pp increase in CARDSHAREP



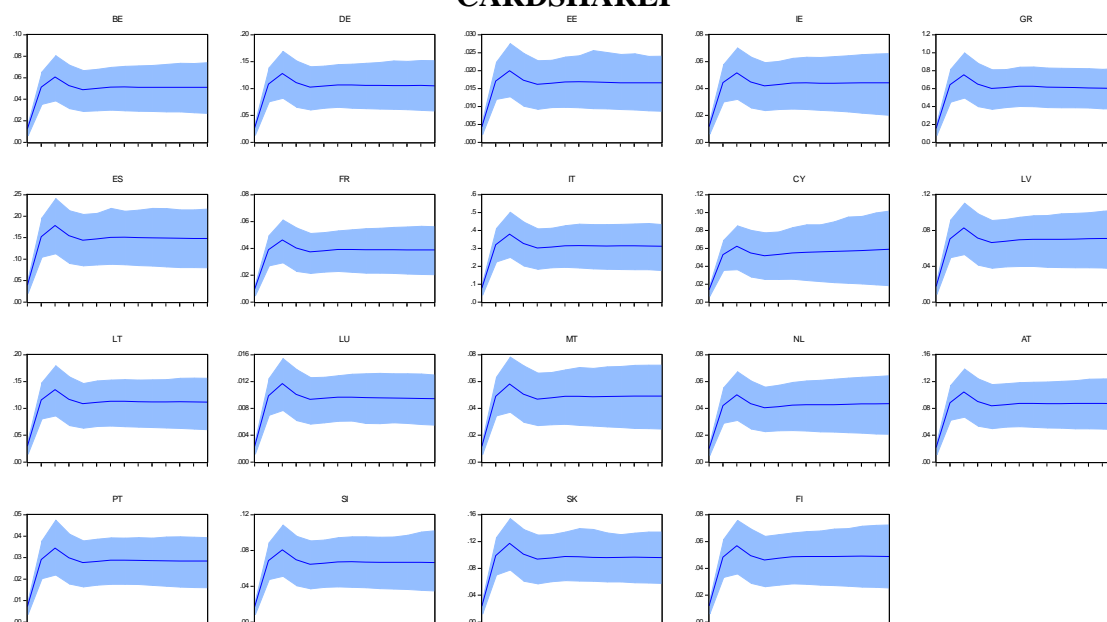
Notes: Annualized responses (solid lines) and 68% bootstrap bands (shaded areas) obtained using the post-tax measure of the tax base. Based on the panel VAR defined in section 4b.

Chart 6b: Percentage change of VAT in response to a 1pp increase in CARDSHAREP



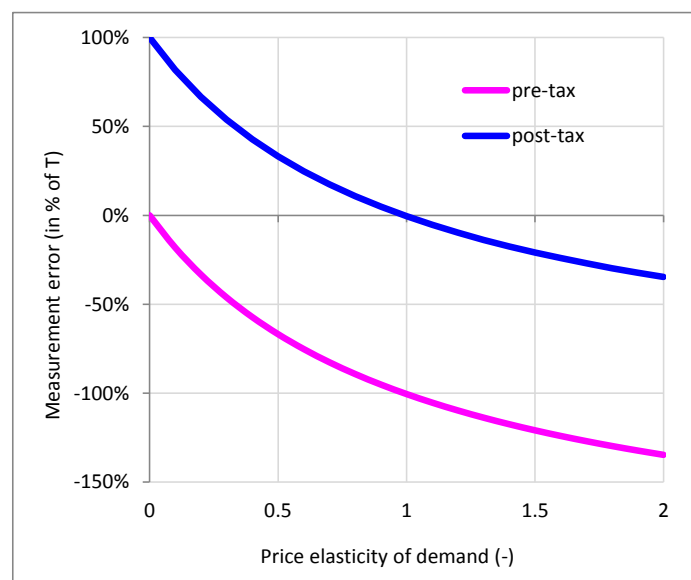
Notes: Annualized responses (solid lines) and 68% bootstrap bands (shaded areas) obtained using the post-tax measure of the tax base. Based on the panel VAR defined in section 4b.

Chart 6c: Percentage change of BASE in response to a 1pp increase in CARDSHAREP



Notes: Annualized responses (solid lines) and 68% bootstrap bands (shaded areas) obtained using the post-tax measure of the tax base. Based on the panel VAR defined in section 4b.

Chart A: Measurement error of the pre-and post-tax measures of the base for different values of the price elasticity of demand



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