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

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Abstract

Fiscal structural reforms aimed at increasing tax compliance and improving the efficiency of revenue collection, have typically concentrated on improving the institutional and operational aspects of tax administration. Promoting the use of card payments presents an additional reform option for improving tax compliance and, unlike administrative reforms, it is readily quantifiable. 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. 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. The analysis indicates that increasing the share of card payments in private consumption expenditure may (*i*) improve tax compliance and collection efficiency; (*ii*) increase VAT revenue; (*iii*) contain efficiency losses after rate hikes. The estimated gains are highest for Greece, Germany and Italy and smallest for Portugal, Luxembourg and Estonia.

JEL classification: H21, H25, H26

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1. Introduction

Given the delegation of monetary policy to a central monetary authority, absorbing cyclical fluctuations at the national level in euro area member states relies crucially on fiscal policy. The absorbing capacity of fiscal policy, however, depends on the ability to accumulate fiscal buffers during economic good times, which has had a less than perfect track record. Fiscal structural reforms can play a role in improving the capacity of governments to accumulate fiscal buffers. On the revenue side, structural reforms can increase the efficiency of tax collection, for example, by curtailing tax evasion and improving compliance.

To the extent that tax evasion is facilitated by cash transactions, structural reforms that promote the use of traceable non-cash payments are likely to increase 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. Despite the increasing role of online services and the emergence of technological innovations, such as crypto-currencies, card payments remain the dominant alternative to cash in the euro area, as far as retail purchases are concerned. A recent survey by Esselink and Hernández (2017) reports that - at points of sail - card payments remain the dominant form of non-cash payment in the euro area, making up around 85 percent of the total value of non-cash purchases.[1]

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

[1] 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.

Papaoikonomou (2017) (hereafter HP17) studying the VAT performance in Greece, report a positive effect of card payments on VAT compliance.[2]

This paper investigates the effect of card payments[3] on VAT revenue using quarterly panel data for the 19 euro area economies covering the period 2003q1-2016q4. As a first step we use a Time-Varying Coefficients (TVC) model in order to obtain a measure of compliance as a function of card payments. In a second step, we include our estimate of compliance as an exogenous regressor in a VAR model and evaluate the dynamic response of revenue efficiency, VAT revenue and the tax base to increases in card use, where the latter is propagated through the TVC measure of compliance. The analysis indicates that increasing the share of card payments in private consumption expenditure may (*i*) improve tax compliance and collection efficiency; (*ii*) increase VAT revenue; (*iii*) contain efficiency losses after rate hikes. The estimated gains are highest for Greece, Germany and Italy and smallest for Portugal, Luxembourg and Estonia.

2. Data and preliminary analysis

2a. Sources and definition of variables

We use quarterly national accounts data available from Eurostat for the 19 member states of the euro area[4] 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 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 PSPs. 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

[2] Slemrod et al (2017) report evidence of a positive effect of credit card information reporting on direct tax declarations for small businesses in the US. However, the overall net effect on revenues is largely offset by increased reported expenses.

[3] One additional reason for focusing on card payments in relation to VAT, rather than non-cash payments in general , is that cards can be safely assumed to be used for consumption, while other non-cash transactions may also include financial transactions.

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

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.[5] 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.[6] 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.

Chart 1 reveals that there has been considerable variation across euro area countries in the intensity of car use, as measured by $CARDSHAREP_t$. In 2016 card use was lowest in Greece[7], followed by Germany and Italy, while it was highest in Portugal, Luxembourg and Estonia. The euro area average is 33%, which is in line with the survey-based evidence provided in Esselink and Hernández (2017).[8]

[5] 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.
[6] Private consumption expenditure may still include payments, such as imputed rents, which are not made via cards. Such items are generally negligible, but can be more sizeable in some Baltic states. This is a caveat that also applies to the tax base, as imputed rents do not generate VAT revenue.
[7] In spite of the sizeable increase in card use since end-2015, triggered by the imposition of restrictions to cash withdrawals in July 2015, card payments in Greece during 2016 accounted for only 12.4% of private consumption expenditure.
[8] Based on a survey of payments made in the 19 euro area countries in 2016, card transactions are reported to account for 37% of the value of total payments, excluding online payments. Accounting for online payments, the share of cards is 35%.

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

2b. Preliminary analysis

The results of a preliminary analysis are reported in order to illustrate some key properties of the data and to motivate the approach taken in the main part of the analysis in the following section. Table 1 reports panel OLS estimates over the full available sample for the following naïve model of revenue efficiency:

$$\Delta_4 ln(EFFICIENCY_{i,t}) = a_i + a_t + a_1 \Delta_4 ln(CARDSHAREP_{i,t}) + \\ + a_2 \Delta_4 ln(CARDSHAREP_{i,t})^2 + e_{i,t} \qquad (1)$$

, where Δ_4 denotes year-on-year difference (i.e. $\Delta_4 x_t = x_t - x_{t-4}$) and a_i, a_t are cross-section and period fixed effects, respectively. The coefficients on card use are very small, wrongly signed and strongly insignificant. This comes as no surprise and is in line with the lack of empirical support for the anticipated positive effect of card use on revenue efficiency reported in Madzharova (2014).

Recalling that efficiency is measured by the ratio of actual over potential revenue, a natural question to ask is what are the distinct contributions of the numerator and the denominator in the overall insignificance of card payments as an explanatory factor of revenue efficiency? To investigate further, we model VAT revenue and the tax base according to the following panel VAR:

$$\Delta_4 \boldsymbol{y}_{i,t} = \boldsymbol{a}_{0i} + \boldsymbol{\Gamma}(L)\Delta_4 \boldsymbol{y}_{i,t} + \boldsymbol{A}(L)\Delta_4 \boldsymbol{x}_{i,t} + \boldsymbol{e}_{i,t} \qquad (2)$$

where $\boldsymbol{y}_{i,t} = [ln\,(VAT_{i,t}), ln\,(BASE_{i,t})]'$,

$\boldsymbol{x}_{i,t} = \left[ln\,(RATE_{i,t}), ln\,(RATE_{i,t})^2, ln\,(CARDSHAREP_{i,t})\right]'$,

$\boldsymbol{\Gamma}(L) = \Gamma_1 L + \Gamma_2 L^2 + \cdots + \Gamma_p L^p$, $\boldsymbol{A}(L) = A_0 + A_1 L^1 + \cdots + A_p L^p$, and $\boldsymbol{a}_{0i}$ is a cross-section fixed effect. Unlike single-equation methods, the use of a VAR escapes endogeneity concerns between tax revenue and tax base. The treatment of $CARDSHAREP_t$ as exogenous reflects the view that it is driven by influences that are not related to macroeconomic or fiscal conditions, such as payment culture, the penetration of cards-related technology and administrative restrictions to cash withdrawals, as in the case of Greece since July 2015.

The model has been estimated under 18 different specifications, using OLS estimates for lag-lengths 1 through 8 and Bayesian estimates for lag-length 4, in all cases using both measures of the tax base. In each case we compute the percentage change of $EFFICIENCY_t$, VAT_t and $BASE_t$ in response to a 1 percentage point increase in $CARDSHAREP_t$. As a baseline we take the OLS estimates with 4 lags using the post-tax definition of the tax base. Charts 2a-2c plot the annualized responses across all 18 specifications (shaded areas), along with the baseline specification (solid lines) with 68% bootstrapped error bands (dotted lines). The responses confirm the absence of any lasting significantly positive influence of card use on revenue efficiency, as has been documented in the literature using single-equation methods. Furthermore the VAR responses reveal that, while a higher share of card payments in private consumption leads to significantly higher VAT revenue, its effect on revenue efficiency is neutralized by an equivalent significant increase in the tax base.

The positive influence of card use on the tax base reflects the strong positive correlation between these variables in our sample (Chart 3), which could arise, for example, if the technological advances facilitating card use also have positive macroeconomic effects. This suggests that the effects of card use on revenue efficiency cannot be studied within a naïve model that cannot isolate the compliance effects of card use. Armed with this insight, the main part of the empirical analysis derives precisely such a measure of tax compliance as a function of card payments, which permits the study of the effects of card use on revenue efficiency.

3. Main empirical analysis

We study the effect of card payments on revenue efficiency using a two-step procedure. In the first step we use a Time-Varying Coefficients (TVC) model in order to obtain a measure of compliance as a function of card payments. In the second step, we include our estimate of compliance as an exogenous regressor in a VAR model and evaluate the dynamic response of the endogenous variables to increases in card use, where the latter is propagated through the TVC measure of compliance. In effect, the TVC estimates are used in order to identify the compliance shocks associated with increased card use. All results have been generated using both, the post-and pre-tax

concepts of the tax base. To the extent possible, both sets of results are reported and discussed jointly. In following sections we report robustness checks for different model specifications and/or assumptions.

3a. Time-Varying Coefficients 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:

$$\Delta_4 ln(VAT_{i,t}) = b_{0i,t} + b_{1i,t}\Delta_4 ln(RATE_{i,t}) + b_{2i,t}\Delta_4 ln(BASE_{i,t}) \quad (3)$$

The time-varying coefficients $b_{1i,t}$ and $b_{2i,t}$ are country-specific elasticities of revenue with respect to the tax rate and the tax base, respectively. Effects other than the tax base and the tax rate are captured by $b_{0i,t}$, which may thus be interpreted as a proxy for tax compliance. It is estimated as a function of the share of card payments in private consumption, $CARDSHAREP_t$:

$$b_{0i,t} = c_0 + c_1\Delta_4 ln(CARDSHAREP_{i,t}) + c_2\Delta_4 ln(CARDSHAREP_{i,t})^2 + e_{i,t} \quad (4)$$

where c_0, c_1, c_2 are estimated constant parameters, common across cross-sections and $e_{i,t} \sim N(0, \sigma_i^2)$, assuming $E(e_{i,t}e'_{j,t}) = 0$, for $i \neq j$. No economic structure is imposed on $b_{1i,t}$ and $b_{2i,t}$, which are modelled as driftless random walks[9]:

$$b_{1i,t} = b_{1i,t-1} + e_{i,t} \quad (5a)$$

$$b_{2i,t} = b_{2i,t-1} + e_{i,t} \quad (5b)$$

Equations (3)-(5b) 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. Chart 4 plots the country-specific decomposition of y-o-y revenue growth into the three components estimated in equation (3), namely, compliance, as proxied by $b_{0i,t}$, and the time-varying contributions of changes in the tax rate, $b_{1i,t}\Delta_4 ln(RATE_{i,t})$, and the tax base, $b_{2i,t}\Delta_4 ln(BASE_{i,t})$. Despite differences in model specification, the panel estimates under both definitions of the tax base confirm the general finding for Greece in HP17,

[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.

namely that the sizeable pick-up in VAT revenue since end-2015 is driven by increased compliance. One additional observation is that, in some cases, increases in the tax rate are followed by declines in compliance. This is the case, for example, in the increases of the standard rate in Germany in 2007 and in Spain in 2010 and 2012. While in the case of Germany the positive effect of the higher rate clearly outweighs the loss through lower compliance, in the case of Spain, compliance losses negate a considerable part of the rate hikes.

Table 2 reports the estimates obtained for the coefficients c_1 and c_2 in the equation for compliance (4) 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 5 plots the estimated gains in VAT revenue through increased compliance (red line) as a function of changes in card use (blue circles) the relationship is close to linear, with diminishing returns suggested in the case of the pre-tax base by the insignificant quadratic term.[10] As illustrated in Charts 6 and 6', the estimated measure of compliance $\widehat{b_{0i,t}}$ is strongly positively correlated with the observed changes in efficiency in the full sample and in each country individually. Overall, $\widehat{b_{0i,t}}$ is a strongly significant determinant of year-on-year changes in efficiency, explaining between 55% and 59% of the observed variation.

3b. Panel VAR

Having obtained an estimate of compliance $\widehat{b_{0i,t}}$ from (4), we include it as an exogenous regressor[11] in the following panel VAR:

$$\Delta_4 \boldsymbol{y}_{i,t} = \boldsymbol{a}_{0i} + \boldsymbol{\Gamma}(L)\Delta_4 \boldsymbol{y}_{i,t} + \boldsymbol{A}(L)\Delta_4 \boldsymbol{x}_{i,t} + \boldsymbol{B}(L)\widehat{b_{0i,t}} + \boldsymbol{e}_{i,t} \qquad (6)$$

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

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

[10] The estimates suggest that a year-on-year increase in ln(CARDSHAREP) by 1 unit leads to a year-on-year increase in VAT revenue by approximately 10%. 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.

[11] This is exactly equivalent to replacing $\Delta_4 ln(CARDSHAREP_{i,t})$ with $\widehat{b_{0i,t}}$ in the VAR model given by equation (2).

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

The VAR model given by (6) has been estimated by OLS for the panel of 19 euro area countries over the full set of commonly available observations, which under the benchmark lag length of 4 cover the period 2004q1-2016q4.

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 the following two shocks: (*i*) a 1 percentage point increase in $CARDSHAREP_{i,t}$, propagated through $\widehat{b_{0i,t}}$ according to the estimated relation (4) and (*ii*) a 1 percentage point increase in $RATE_{i,t}$. The latter is motivated by the earlier observation with reference to Chart 4, that increases in the tax rate may be associated with reduced compliance.

Charts 7a-7c plot the annualized responses to a 1 percentage point increase in the share of card payments in private consumption. Revenue efficiency is found to increase significantly, with permanent gains ranging between 0.2% and 1.0%. The gains are more sizeable in countries with low use of card payments (GR, DE, IT) and with reference to the pre-tax measure of the tax base. The higher point estimates obtained using the pre-tax measure of the tax base reflect the more sizeable estimate of $c_1$in equation (4), reported in Table 2. The difference between the pre-and-post-tax measures becomes statistically irrelevant after approximately 3 years. The efficiency gains arise due to permanent increases in VAT revenue[12] (Chart 7b) outweighing smaller, yet statistically significant, increases in the tax base (Chart 7c).[13]

The annualized responses to a 1 percentage point increase in the standard rate are plotted in Charts 8a-8c. Efficiency losses are significant and take effect within the first year, with reference to both measures of the tax base (Chart 8a). While VAT revenue is not significantly reduced during the first year (Chart 8b), in subsequent periods it is affected by the significantly negative effect on the tax base (Chart 8c). Although revenue as a share of the tax base is not significantly reduced, the higher tax rate inflates the denominator of efficiency, resulting in the reported efficiency loss. In other words, the change in actual revenue falls short of the change in potential revenue. This lends support to the observation made with reference to Chart 4,

[12] The reported first year increase in VAT revenue for Greece is in the region of 1%, which is in line with the findings reported in HP17.
[13] The significant increase in the tax base may be spurious, reflecting an important missing variable. We return to this issue in the robustness checks.

namely, that the positive influence of rate hikes on VAT revenue is undermined by losses in compliance.

4. Robustness checks

In addition to generating estimates using both concepts of the tax base in the main analysis, we check the robustness of the results to (i) allowing for heterogeneity between countries with above and below average card use; (ii) excluding individual cross-sections; (iii) the inclusion of per capita GDP as an additional explanatory variable in the VAR model; and (iv) estimating the panel VAR using Bayesian methods and by applying dynamic panel bias correction. We find the results from the main analysis to be qualitatively and to a large extent also quantitatively robust.

4i. Distinguishing between countries with high and low card use

We allow for different effects of *CARDSHAREP* on compliance ($b_{0i,t}$) between economies with above and below-average card use, by reformulating equation (4) in the TVC model as follows:

$$b_{0i,t} = high * [c_0^h + c_1^h \Delta_4 \ln(CARDSHAREP_{i,t}) + c_2^h \Delta_4 \ln(CARDSHAREP_{i,t})^2] + low * [c_0^l + c_1^l \Delta_4 ln(CARDSHAREP_{i,t}) + c_2^l \Delta_4 ln(CARDSHAREP_{i,t})^2] + e_{i,t} \quad (4')$$

$$high = \begin{cases} 1, & for\ countries\ with\ above\ average\ CARDSHAREP \\ 0, & otherwise \end{cases}$$

$$low = 1 - high.$$

We additionally allow for heterogeneous dynamic behaviour between countries with above and below average card use. To this end, the VAR model given by (6) is reformulated as follows:

$$\Delta_4 \boldsymbol{y}_{i,t} = high * [\boldsymbol{a}_{0i}^h + \boldsymbol{\Gamma}^h(L)\Delta_4 \boldsymbol{y}_{i,t} + \boldsymbol{A}^h(L)\Delta_4 \boldsymbol{x}_{i,t} + \boldsymbol{B}^h(L)\widehat{b_{0i,t}}] + low * [\boldsymbol{a}_{0i}^l + \boldsymbol{\Gamma}^l(L)\Delta_4 \boldsymbol{y}_{i,t} + \boldsymbol{A}^l(L)\Delta_4 \boldsymbol{x}_{i,t} + \boldsymbol{B}^l(L)\widehat{b_{0i,t}}] + \boldsymbol{e}_{i,t} \quad (6')$$

where $\widehat{b_{0i,t}}$ is taken from (4') and *high* and *low* are defined in eq.(4). Countries with high card use are BE, EE, IE, FR, LU, NL, PT and FI.

The reformulated TVC and VAR models have been used in order to generate the full set of results reported in the main analysis, using both measures of the tax base. Chart 12 plots the decomposition of VAT growth obtained using the reformulated TVC

model. The observations noted in the main analysis remain valid. Namely, the recent revenue growth in Greece is largely due to improved compliance and rate hikes are associated with compliance losses in the case of DE and ES. Chart 13 plots the estimated relations between compliance and card use with the estimates reported in Table 3. As can be expected, compliance gains from higher card use are found to be more statistically significant and more sizeable in the group of countries with below average use of card payments. In contrast, the gains from increasing further the use of cards in countries in which card payments represent an above average share of private consumption, are estimated to be smaller and more uncertain. This is suggestive of intuitive diminishing returns to card use and is confirmed using both measures of the tax base.

Charts 14a-14c plot the responses from the reformulated VAR to a 1 percentage point increase in CARDSHAREP, allowing for dynamic heterogeneity between countries with high and low card use. In line with the results in the main analysis, efficiency gains are largest in countries with low card use, as revenue increases outweigh smaller, yet, statistically significant increases in the tax base. An additional insight is provided by the responses to a 1 percentage point increase in the standard rate, reported in Charts 15a-15c. Countries with high card use are found to suffer smaller losses in efficiency, which in some cases are borderline significant during the first year. This appears to be driven by short-lived increases in revenue, turning into insignificant reductions after approximately three years. In contrast, countries with low card use tend to experience more severe efficiency losses and do not display revenue increases.

4ii. Excluding individual cross-sections

Chart 9 illustrates the sensitivity of the baseline responses of efficiency to a 1 percentage point increase in CARDSHAREP to the exclusion of individual countries. The vertical axis measures the long-run response (60 quarters) obtained using the baseline TVC and VAR models using the post-tax measure of the tax base. The point estimate after 60 quarters is given by the red line. The dark diamonds denote the same response obtained after re-estimating the TVC and VAR models without the country indicated on the horizontal axis. In each case, 68% bootstrapped error bands are reported by dots. We do not find evidence that the baseline responses are significantly affected by the exclusion of any individual country.

4iii. Including per capita GDP in the VAR

The efficiency gains reported in the baseline results following an increase in card use were shown to arise due to permanent increases in VAT revenue outweighing smaller, yet statistically significant, increases in the tax base. The significant increase in the tax base could spurious, reflecting an important missing variable. Indeed, adding per capita GDP as an exogenous variable in the VAR model in equation (6) is found to eliminate any significant increase in the tax base in response to an increase in card use (Chart 10c). Yet, the baseline effect on efficiency remains unaffected (Chart 10a). As regards the responses to an increase in the standard rate (Charts 11a-11c), the efficiency loss reported in the baseline model is confirmed, although in this case the long-run decline in VAT revenue and in the tax base becomes statistically insignificant.

4iv. Bayesian estimates and bias correction

The panel OLS estimator used in the baseline VAR has been reported to be subject to substantial bias, even when the time dimension, *T*, is large, as in this case. Juessen and Linnemann (2010) provide a comparison of different estimation techniques and suggest the use of a simple bias-adjustment to the OLS estimator, originally proposed by Hahn and Kuesteiner (2002) for single equations. The bias corrected estimator is given by $\hat{\hat{\theta}} = \frac{T+1}{T}\hat{\theta} + \frac{1}{T}$, where $\hat{\theta}$ is the OLS estimate. Additionally, we have applied also Bayesian estimation with standard Minnesota priors. Chart 16 reports the responses of efficiency to a 1 percentage point increase in CARDSHAREP (top panel) and in the standard rate (lower panel). In both cases the baseline OLS responses (solid blue lines) are reported along with 68% bootstrap bands (blue shade), together with the responses obtained using the Bayesian estimator (red line with solid dots) and the bias-adjusted estimator (green line with empty circles). In all cases we find no qualitative differences and the quantitative differences are not statistically insignificant.

5. Conclusions [to be completed]

The analysis indicates that increasing the share of card payments in private consumption expenditure may (*i*) improve tax compliance and collection efficiency; (*ii*) increase VAT revenue; (*iii*) contain efficiency losses after rate hikes. The

estimated gains are highest for Greece, Germany and Italy and smallest for Portugal, Luxembourg and Estonia.

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. $BASE_t = CONS_t - CONSG_t + INC_t$.
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. $EFFICIENCY_t = \frac{VAT_t}{BASE_t * RATE_t}$

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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:

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

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:

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

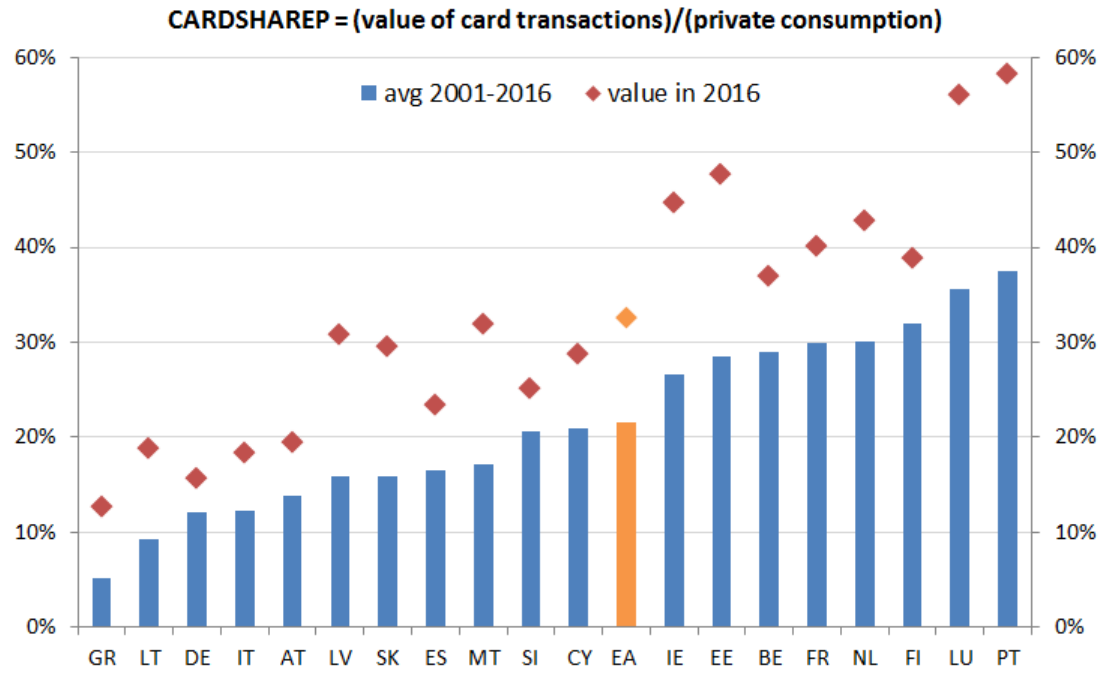
, which is the post-tax measure of the tax base. Tax revenue *T* amounts to $t(bd - btx)/(b + x)$ and the pre-tax measure of the tax base is given by:

$$C^{pre\ tax} = C^{post\ tax} - T \tag{A.3}$$

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 1: Value of card transactions as a share of private consumption



Source: ECB Statistical Data Warehouse. EA computed as the unweighted average of the 19 EA members.

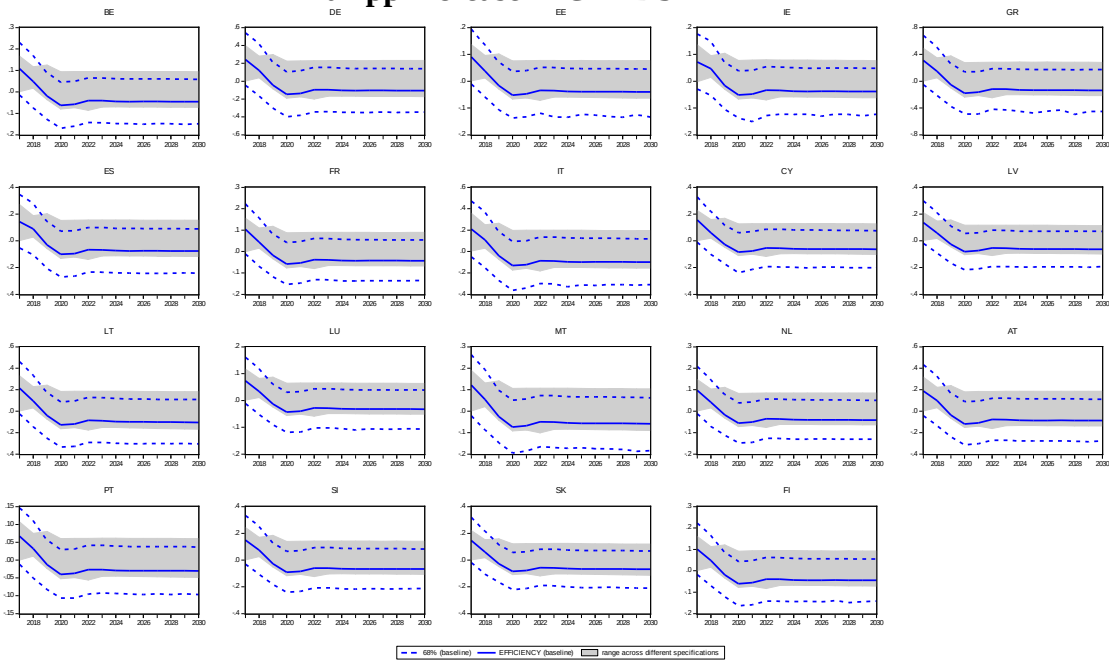
Table 1: Preliminary panel OLS regression of efficiency on card use

Dependent variable: $\Delta_4 ln(EFFICIENCY_{i,t})$
Sample: 2001q1-2016q4; Periods: 64; Cross-sections: 19; Observations: 1168
Cross-section and period fixed effects

	post-tax	**pre-tax**
$\Delta_4 ln(CARDSHAREP_{i,t})$	-0.01 [-0.29]	-0.02 [-0.50]
$\Delta_4 ln(CARDSHAREP_{i,t})^2$	0.04 [0.59]	0.06 [0.73]
Adjusted R-squared	0.11	0.11

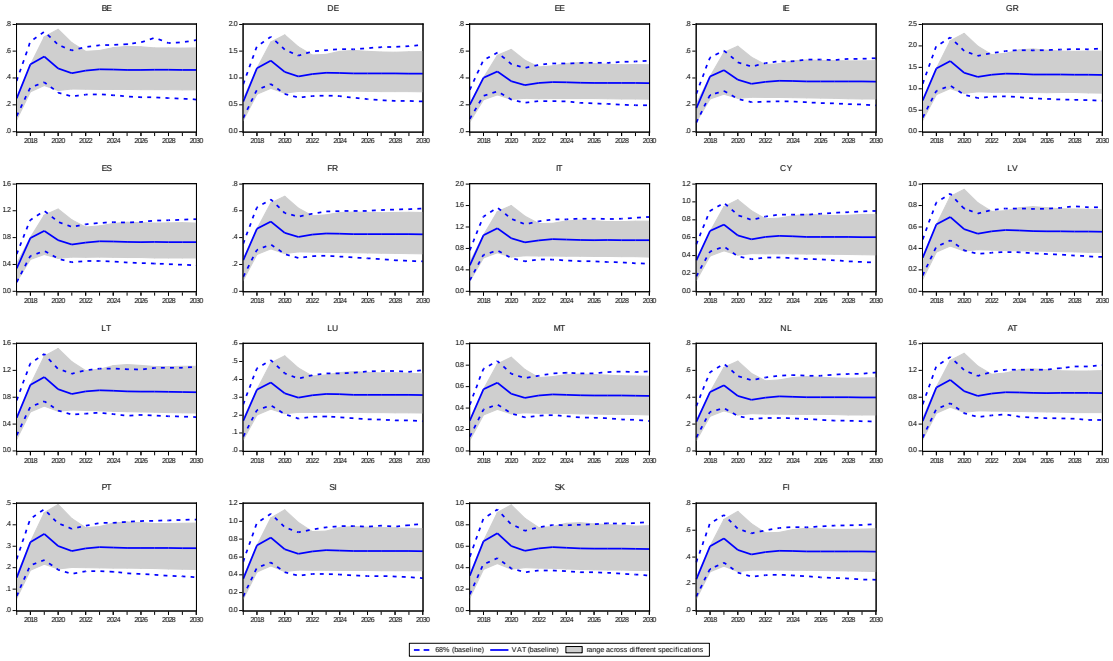
Notes: *t*-ratios in square brackets. The post-tax definition of the tax base is given by the sum of private consumption and government intermediate consumption. The pre-tax definition subtracts VAT revenue from the post-tax measure.

Chart 2a: Preliminary VAR - Percentage change of EFFICIENCY in response to a 1pp increase in CARDSHAREP



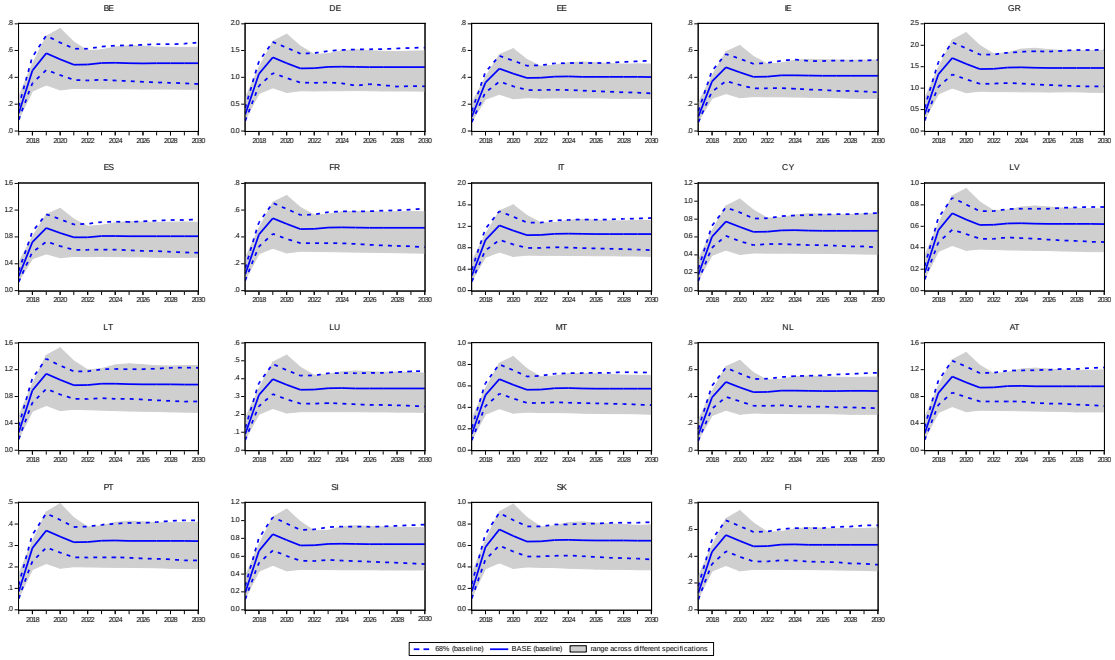
Notes: The solid line denotes the response obtained from the baseline specification (OLS, lag 4). Dotted lines are 68% bootstrap bands around the baseline. The shaded area indicates the range of the responses obtained under 18 alternative VAR specifications using OLS estimates for lags 1-8, Bayesian estimates under lag 4 and in all cases the post-tax and pre-tax definition of the tax base.

Chart 2b: Preliminary VAR - Percentage change of VAT in response to a 1pp increase in CARDSHAREP



Notes: The solid line denotes the response obtained from the baseline specification (OLS, lag 4). Dotted lines are 68% bootstrap bands around the baseline. The shaded area indicates the range of the responses obtained under 18 alternative VAR specifications using OLS estimates for lags 1-8, Bayesian estimates under lag 4 and in all cases the post-tax and pre-tax definition of the tax base.

Chart 2c: Preliminary VAR - Percentage change of BASE in response to a 1pp increase in CARDSHAREP



Notes: The solid line denotes the response obtained from the baseline specification (OLS, lag 4). Dotted lines are 68% bootstrap bands around the baseline. The shaded area indicates the range of the responses obtained under 18 alternative VAR specifications using OLS estimates for lags 1-8, Bayesian estimates under lag 4 and in all cases the post-tax and pre-tax definition of the tax base.

Chart 3: Correlation between CARDSHAREP and BASE

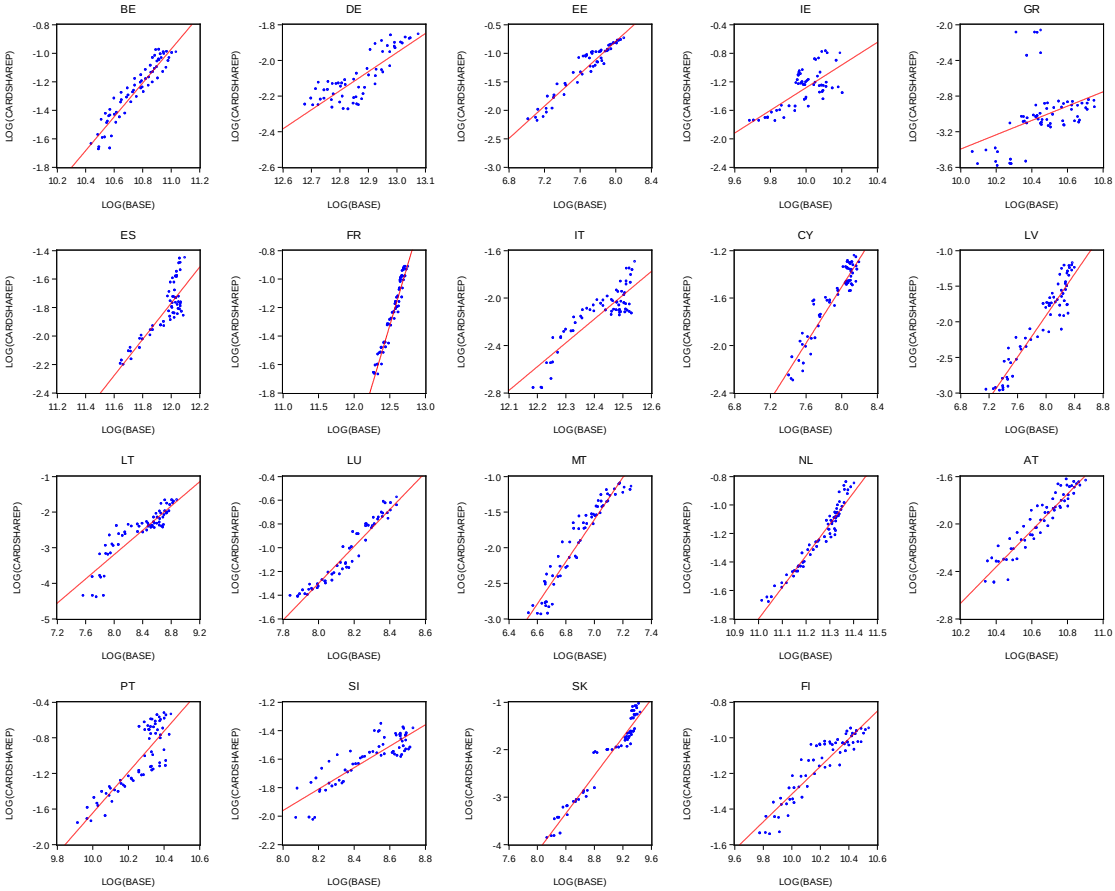
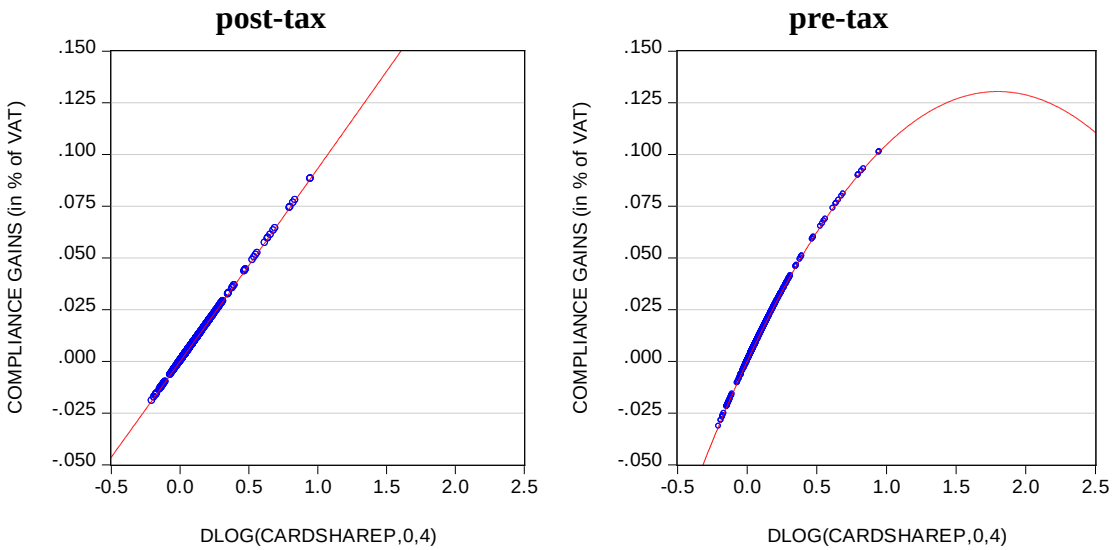


Chart 4 - Decomposition of VAT growth according to the baseline TVC model

Notes: 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.

Chart 5: Tax compliance and card use according to the baseline TVC model



Notes: 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.

Table 2: Tax compliance and card use according to the baseline TVC model

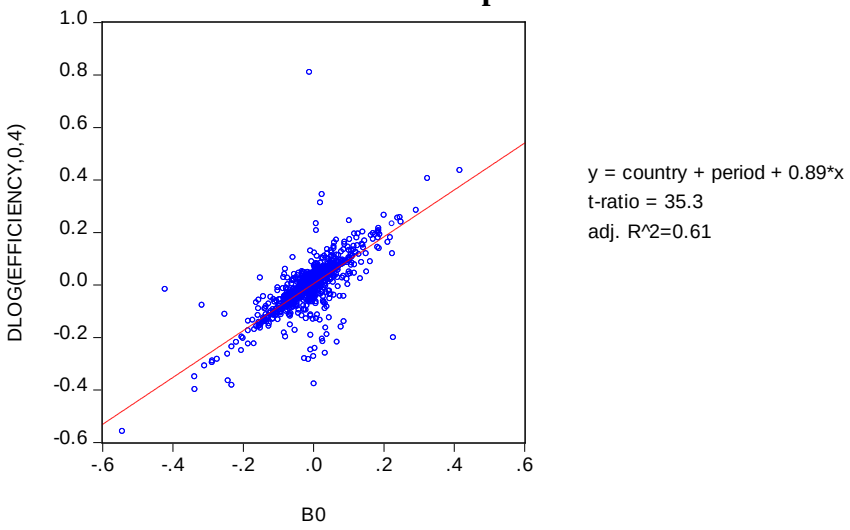
Dependent variable: $b_{0i,t}$
Sample: 2003q1-2016q4; Periods: 56; Cross-sections: 19

	post-tax	**pre-tax**
$\Delta_4 ln(CARDSHAREP_{i,t})$	0.09*	0.15**
	[1.67]	[2.41]
$\Delta_4 ln(CARDSHAREP_{i,t})^2$	0.0005	-0.04
	[0.004]	[-0.31]

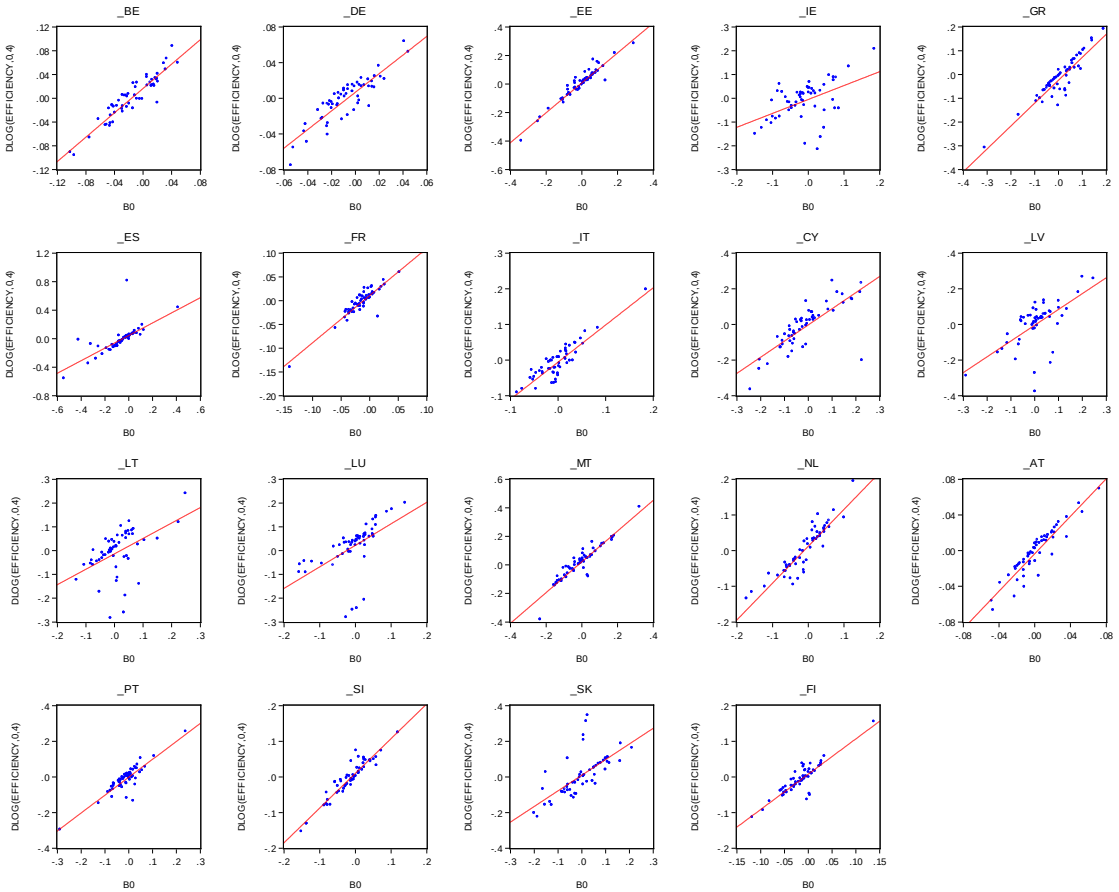
Notes: z-statistic in square brackets. "*" and "**" denote significance at the 10% and 5% levels, respectively. The post-tax definition of the tax base is given by the sum of private consumption and government intermediate consumption. The pre-tax definition subtracts VAT revenue from the post-tax measure.

Chart 6 – Correlation between Efficiency and Compliance* for the post-tax base

A. Full sample



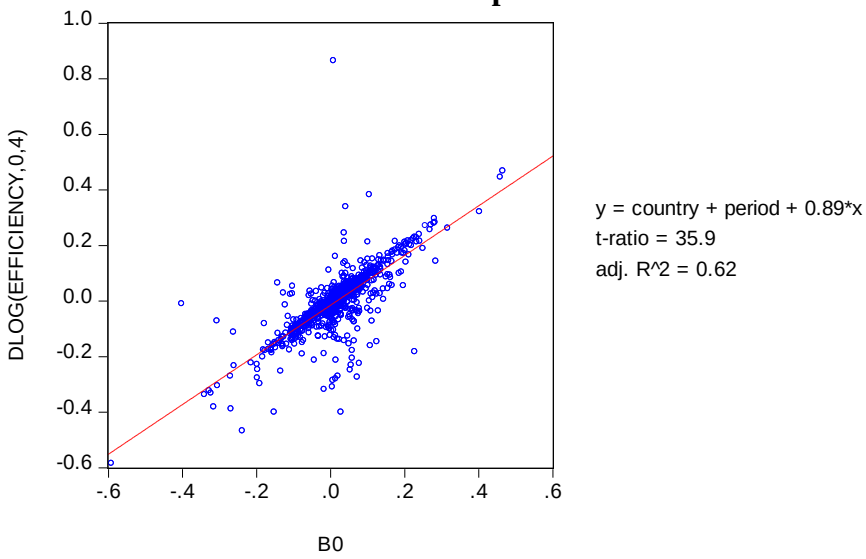
B. Individual cross-sections



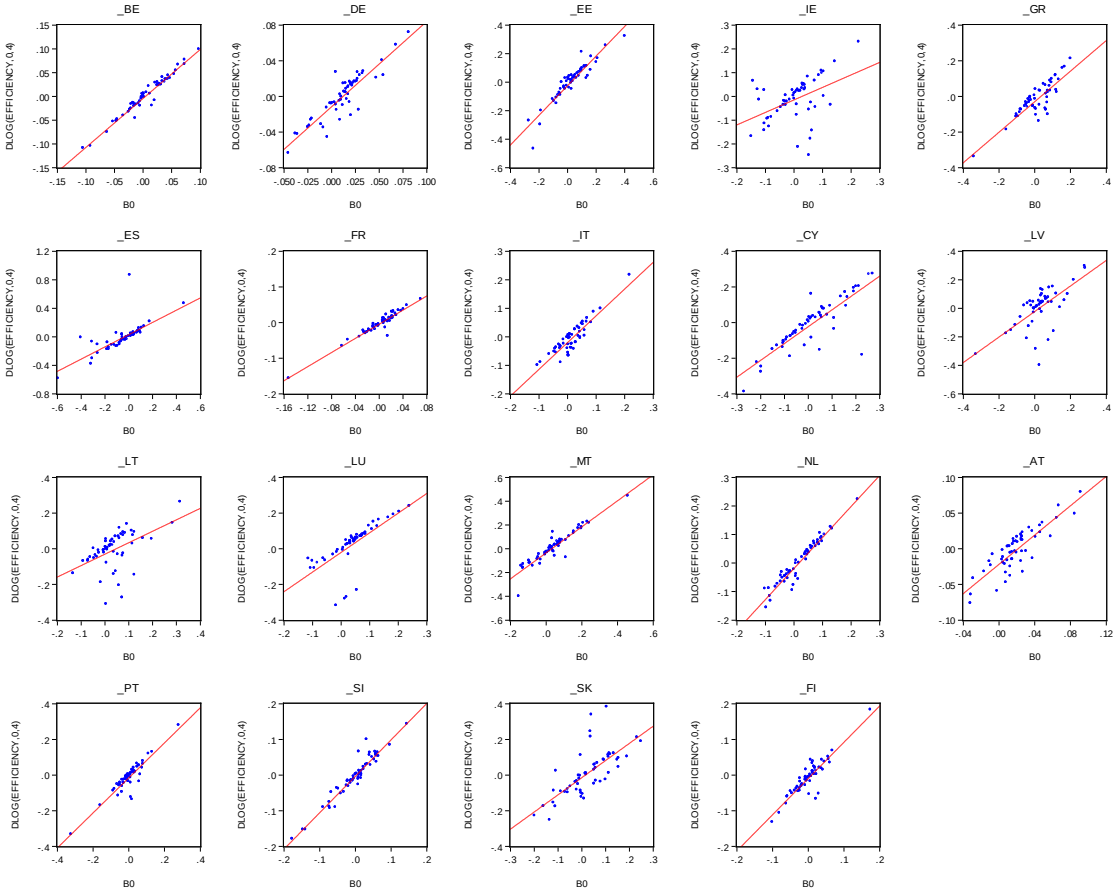
*Given by the estimate of $b_{0i,t}$ in the baseline TVC model. The post-tax definition of the tax base is given by the sum of private consumption and government intermediate consumption. The pre-tax definition subtracts VAT revenue from the post-tax measure.

Chart 6' – Correlation between Efficiency and Compliance* for the pre-tax base

A. Full sample

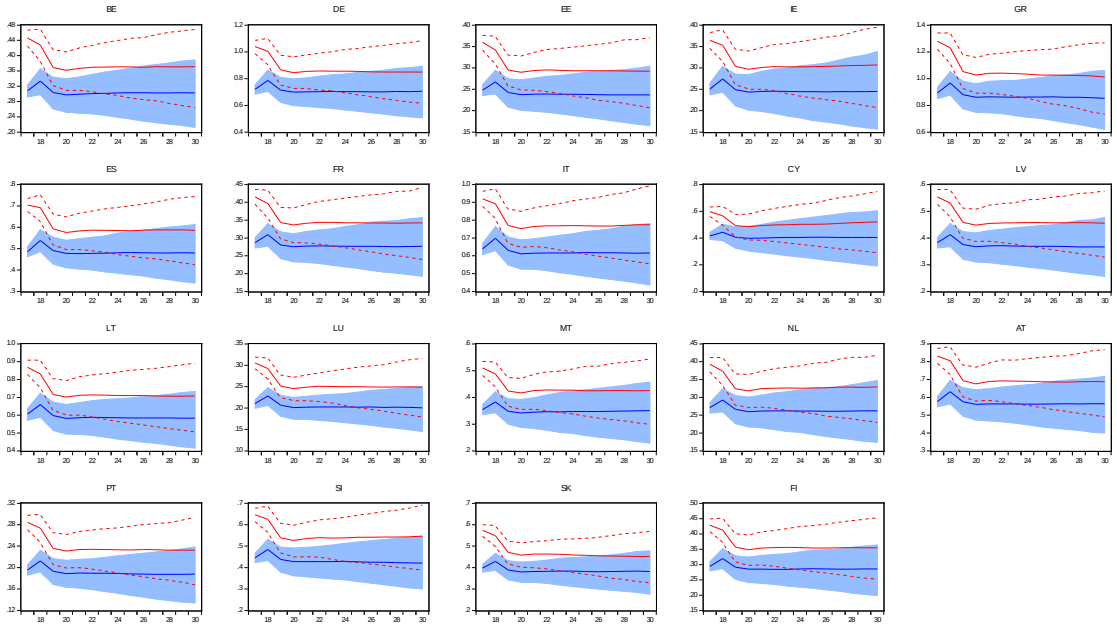


B. Individual cross-sections



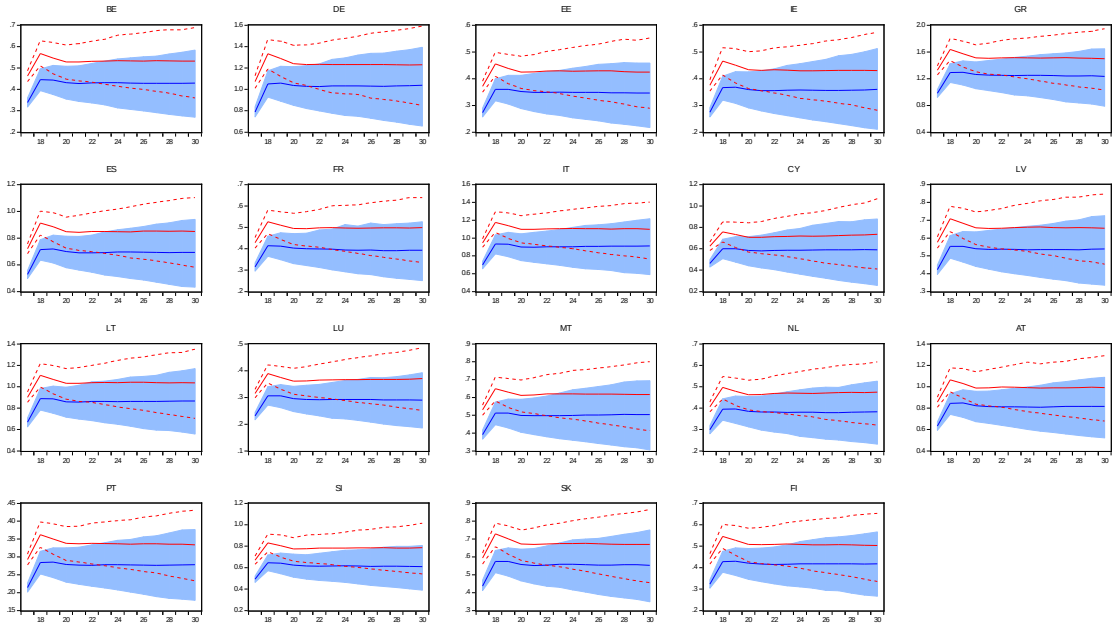
*Given by the estimate of $b_{0i,t}$ in the baseline TVC model. The post-tax definition of the tax base is given by the sum of private consumption and government intermediate consumption. The pre-tax definition subtracts VAT revenue from the post-tax measure.

Chart 7a: Percentage change of EFFICIENCY in response to a 1pp increase in CARDSHAREP



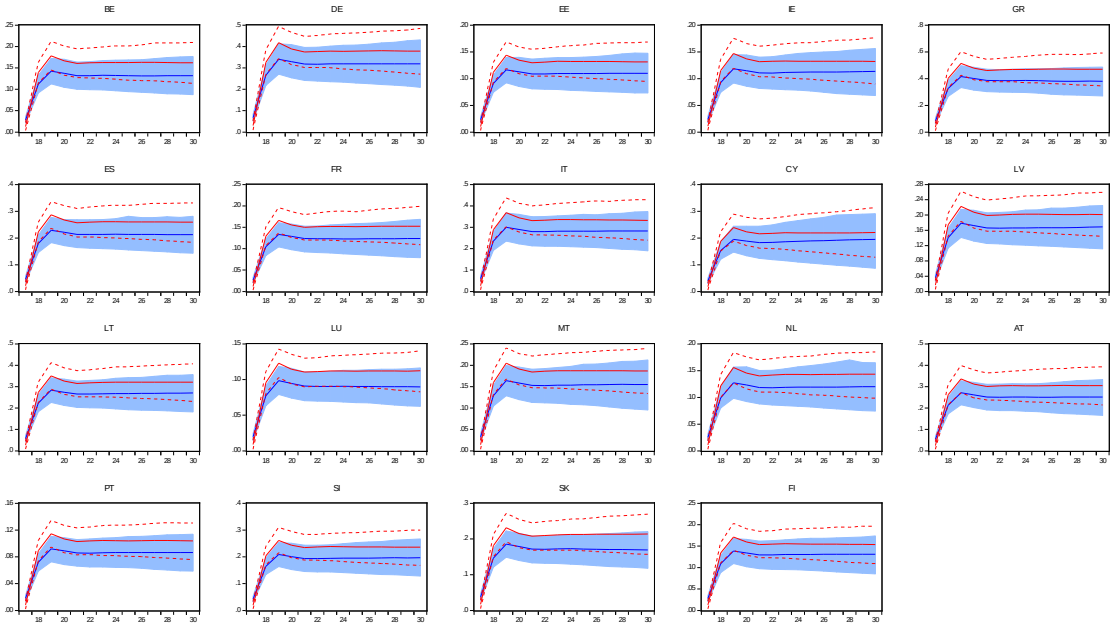
Notes: Annualized responses (solid lines) and 68% bootstrap bands (shaded areas and dotted lines) obtained using the post-tax (blue) and the pre-tax (red) measure of the tax base.

Chart 7b: Percentage change of VAT in response to a 1pp increase in CARDSHAREP



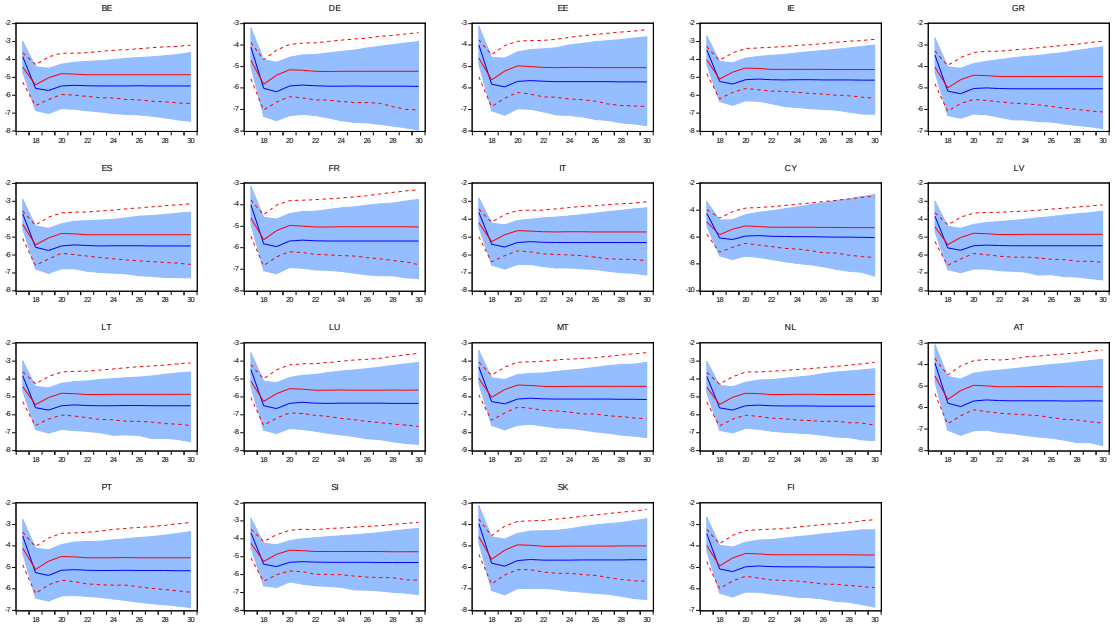
Notes: Annualized responses (solid lines) and 68% bootstrap bands (shaded areas and dotted lines) obtained using the post-tax (blue) and the pre-tax (red) measure of the tax base.

Chart 7c: Percentage change of BASE in response to a 1pp increase in CARDSHAREP



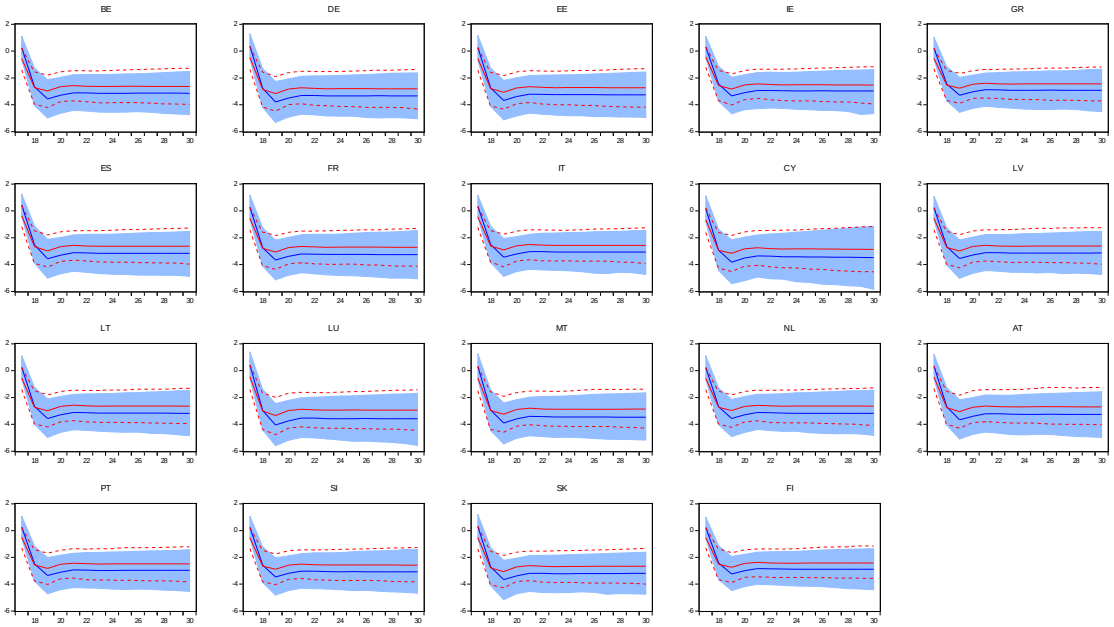
Notes: Annualized responses (solid lines) and 68% bootstrap bands (shaded areas and dotted lines) obtained using the post-tax (blue) and the pre-tax (red) measure of the tax base.

Chart 8a: Percentage change of EFFICIENCY in response to a 1pp increase in RATE



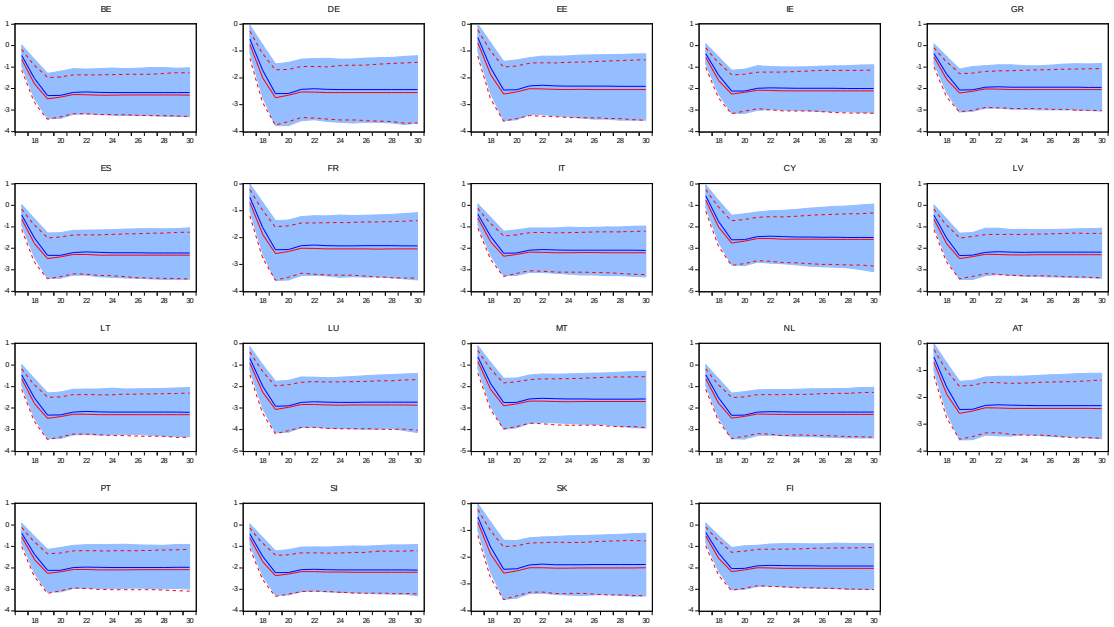
Notes: Annualized responses (solid lines) and 68% bootstrap bands (shaded areas and dotted lines) obtained using the post-tax (blue) and the pre-tax (red) measure of the tax base.

Chart 8b: Percentage change of VAT in response to a 1pp increase in RATE



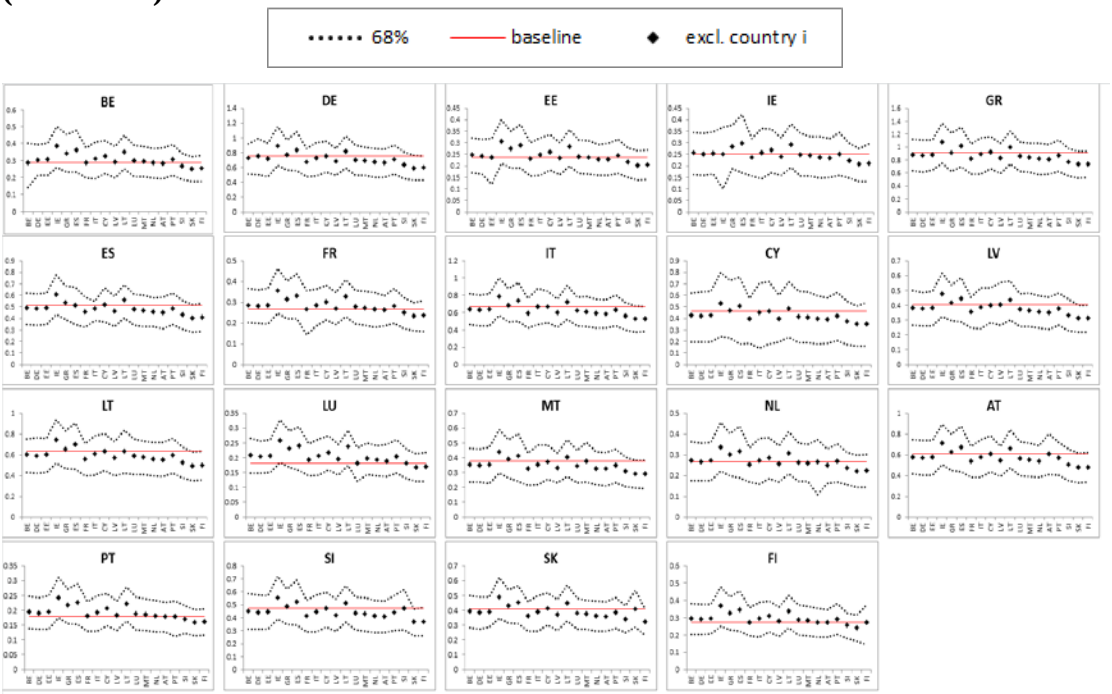
Notes: Annualized responses (solid lines) and 68% bootstrap bands (shaded areas and dotted lines) obtained using the post-tax (blue) and the pre-tax (red) measure of the tax base.

Chart 8c: Percentage change of BASE in response to a 1pp increase in RATE



Notes: Annualized responses (solid lines) and 68% bootstrap bands (shaded areas and dotted lines) obtained using the post-tax (blue) and the pre-tax (red) measure of the tax base.

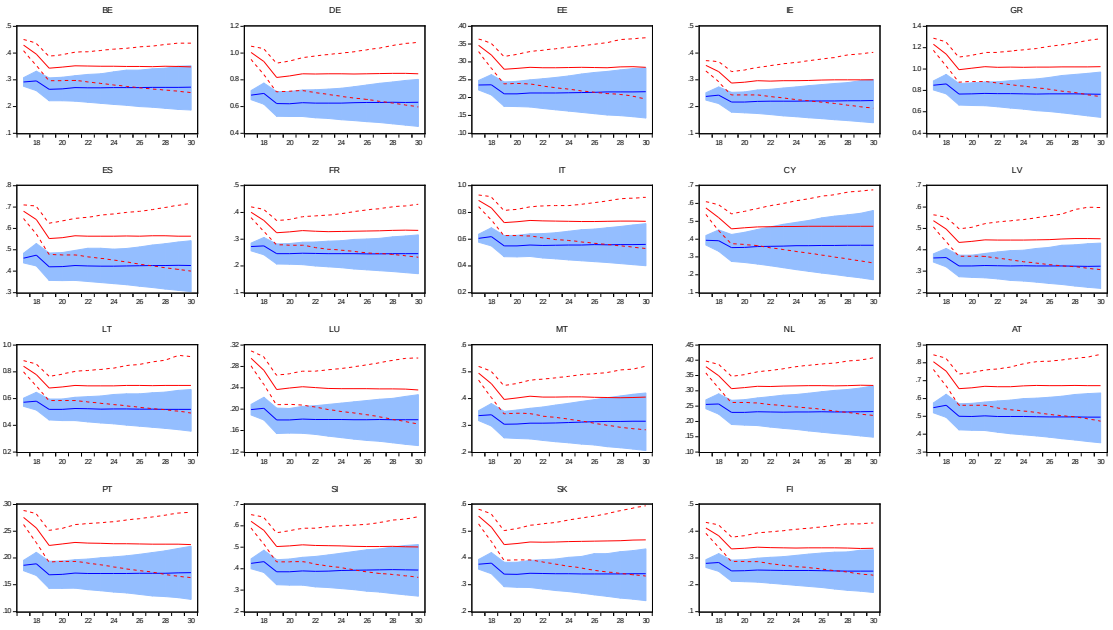
Chart 9: Long-term (60qrts) response of EFFICIENCY to a 1pp increase in CARDSHAREP (vertical). Robustness to exclusion of individual cross-sections (horizontal)



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

Chart 10a: Percentage change of EFFICIENCY in response to a 1pp increase in CARDSHAREP

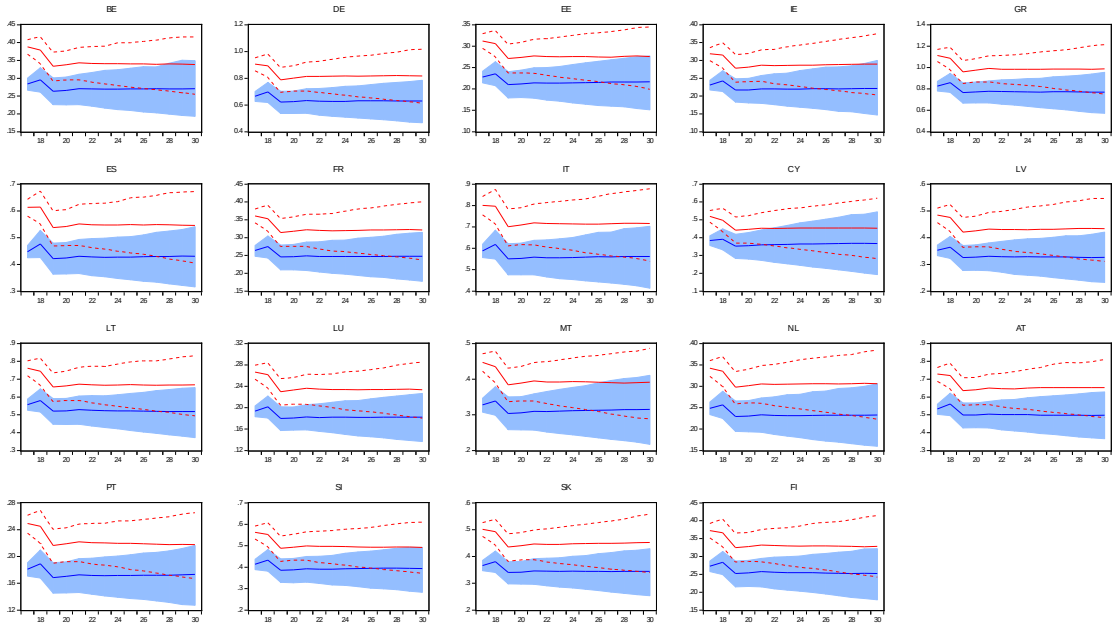
Robustness to the inclusion of per capita GDP in VAR



Notes: Annualized responses (solid lines) and 68% bootstrap bands (shaded areas and dotted lines) obtained using the post-tax (blue) and the pre-tax (red) measure of the tax base.

Chart 10b: Percentage change of VAT in response to a 1pp increase in CARDSHAREP

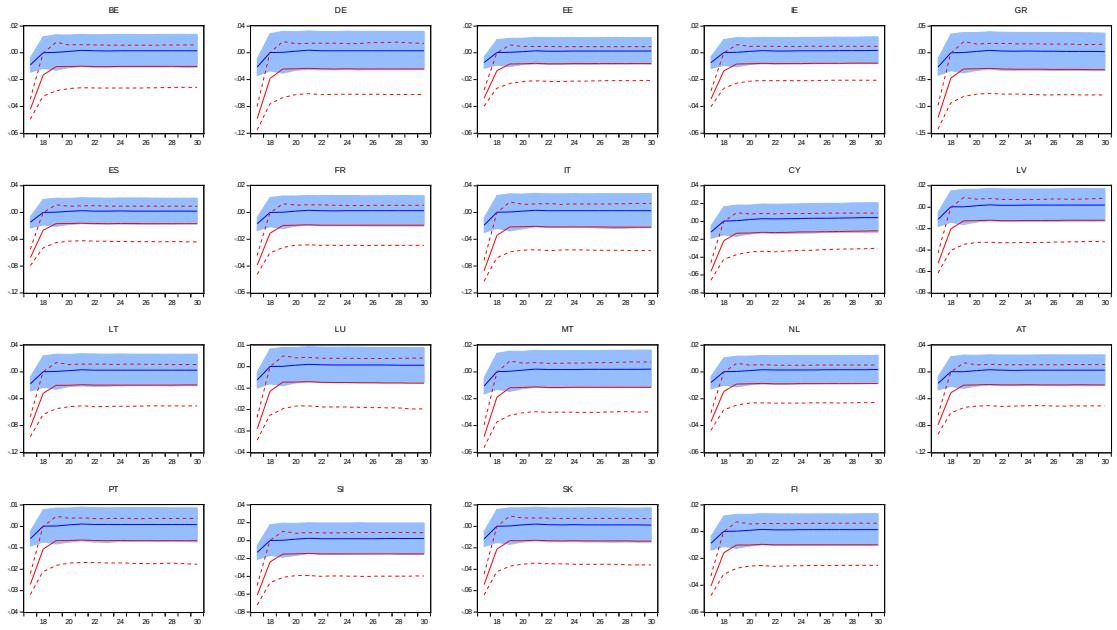
Robustness to the inclusion of per capita GDP in VAR



Notes: Annualized responses (solid lines) and 68% bootstrap bands (shaded areas and dotted lines) obtained using the post-tax (blue) and the pre-tax (red) measure of the tax base.

Chart 10c: Percentage change of BASE in response to a 1pp increase in CARDSHAREP

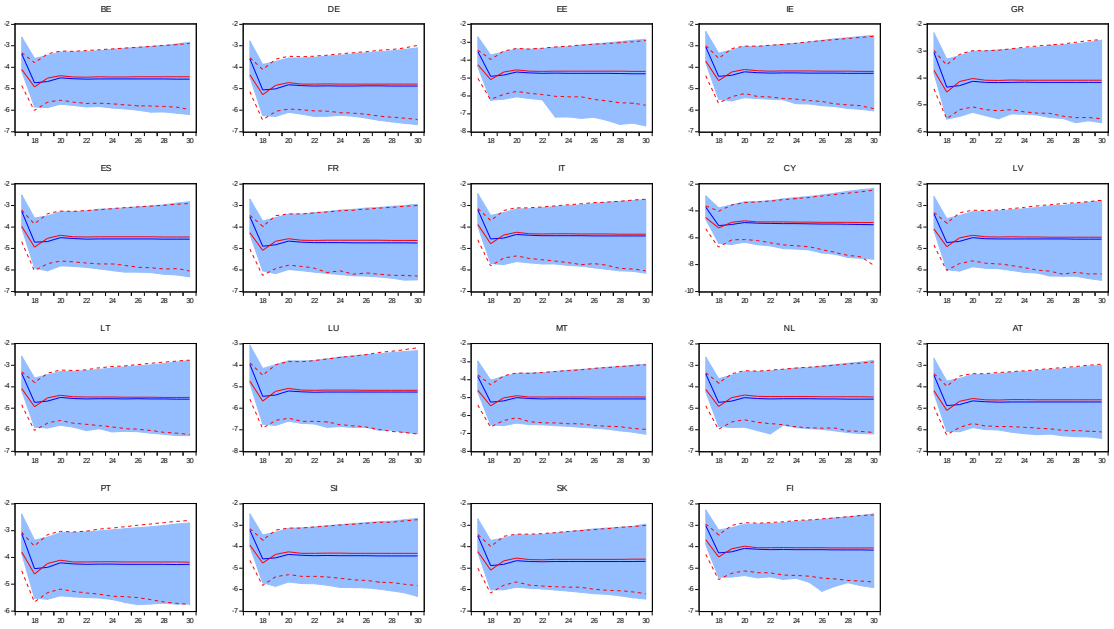
Robustness to the inclusion of per capita GDP in VAR



Notes: Annualized responses (solid lines) and 68% bootstrap bands (shaded areas and dotted lines) obtained using the post-tax (blue) and the pre-tax (red) measure of the tax base.

Chart 11a: Percentage change of EFFICIENCY in response to a 1pp increase in RATE

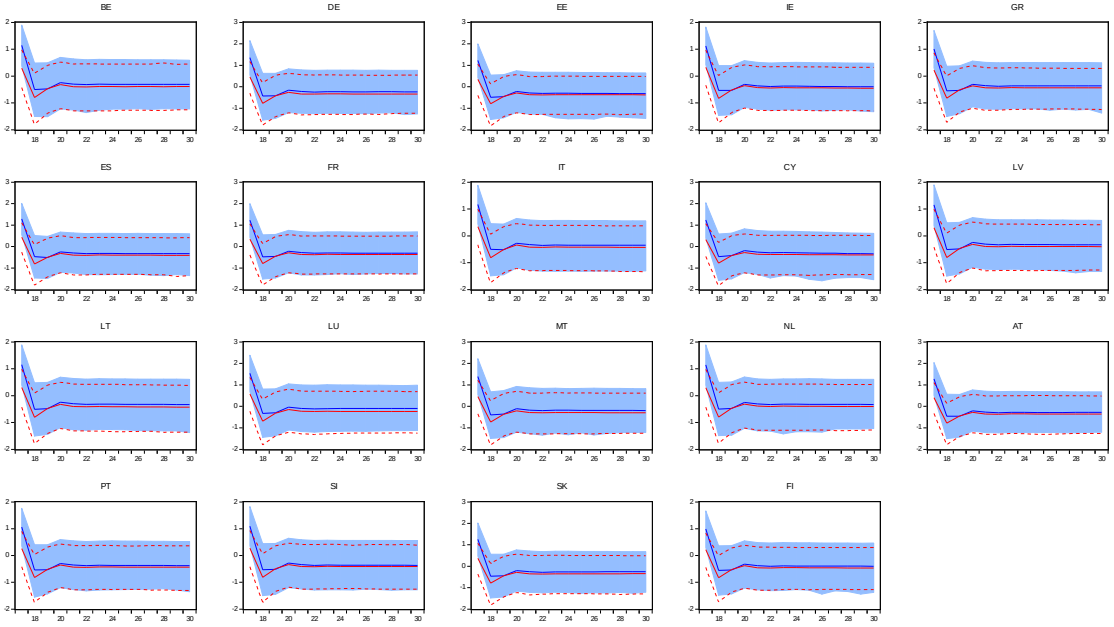
Robustness to the inclusion of per capita GDP in VAR



Notes: Annualized responses (solid lines) and 68% bootstrap bands (shaded areas and dotted lines) obtained using the post-tax (blue) and the pre-tax (red) measure of the tax base.

Chart 11b: Percentage change of VAT in response to a 1pp increase in RATE

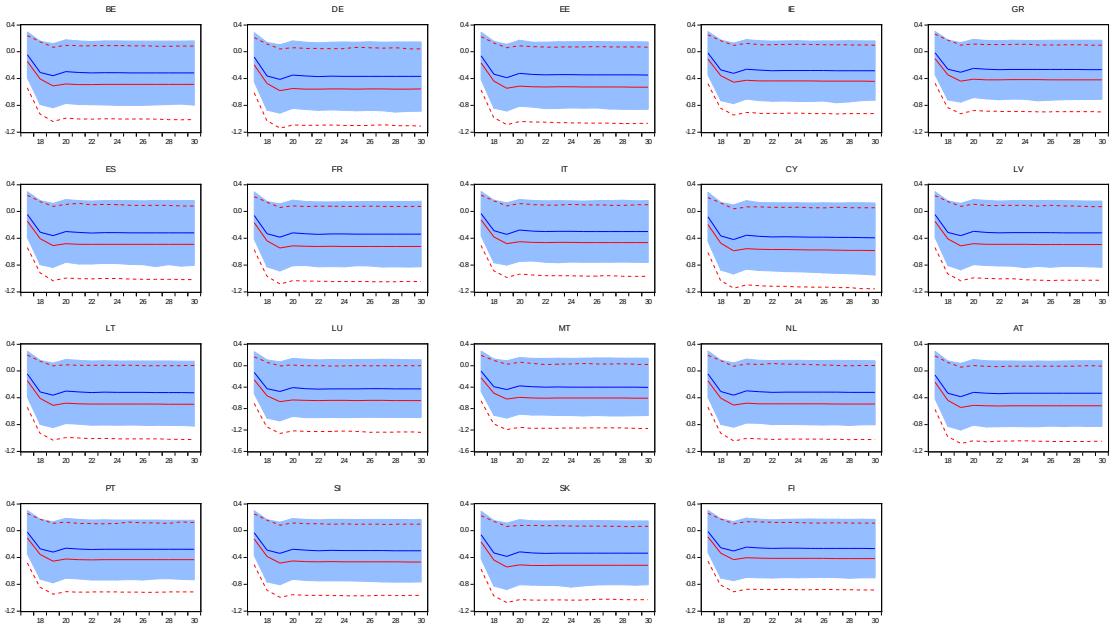
Robustness to the inclusion of per capita GDP in VAR



Notes: Annualized responses (solid lines) and 68% bootstrap bands (shaded areas and dotted lines) obtained using the post-tax (blue) and the pre-tax (red) measure of the tax base.

Chart 11c: Percentage change of BASE in response to a 1pp increase in RATE

Robustness to the inclusion of per capita GDP in VAR

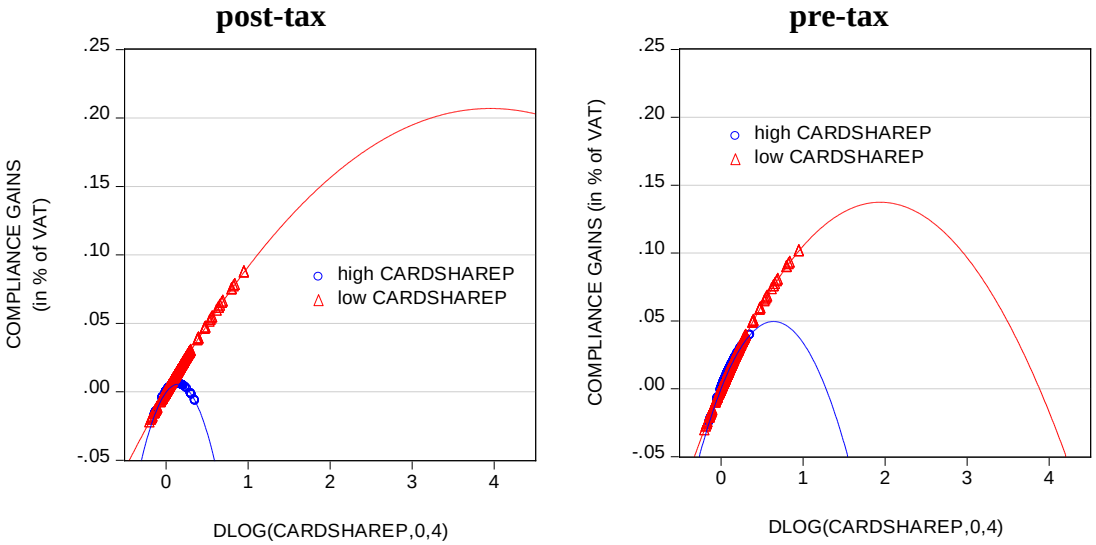


Notes: Annualized responses (solid lines) and 68% bootstrap bands (shaded areas and dotted lines) obtained using the post-tax (blue) and the pre-tax (red) measure of the tax base.

Chart 12 - Decomposition of VAT growth in TVC model differentiating between countries with high and low card use*

Notes: High/low card use is defined as above/below average CARDSHAREP during 2000q1-2016q4. Countries with high card use are BE, EE, IE, FR, LU, NL, PT and FI. 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.

Chart 13: Tax compliance and card use in TVC model differentiating between countries with high and low card use



Notes: High/low card use is defined as above/below average CARDSHAREP during 2000q1-2016q4. Countries with high card use are BE, EE, IE, FR, LU, NL, PT and FI. 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.

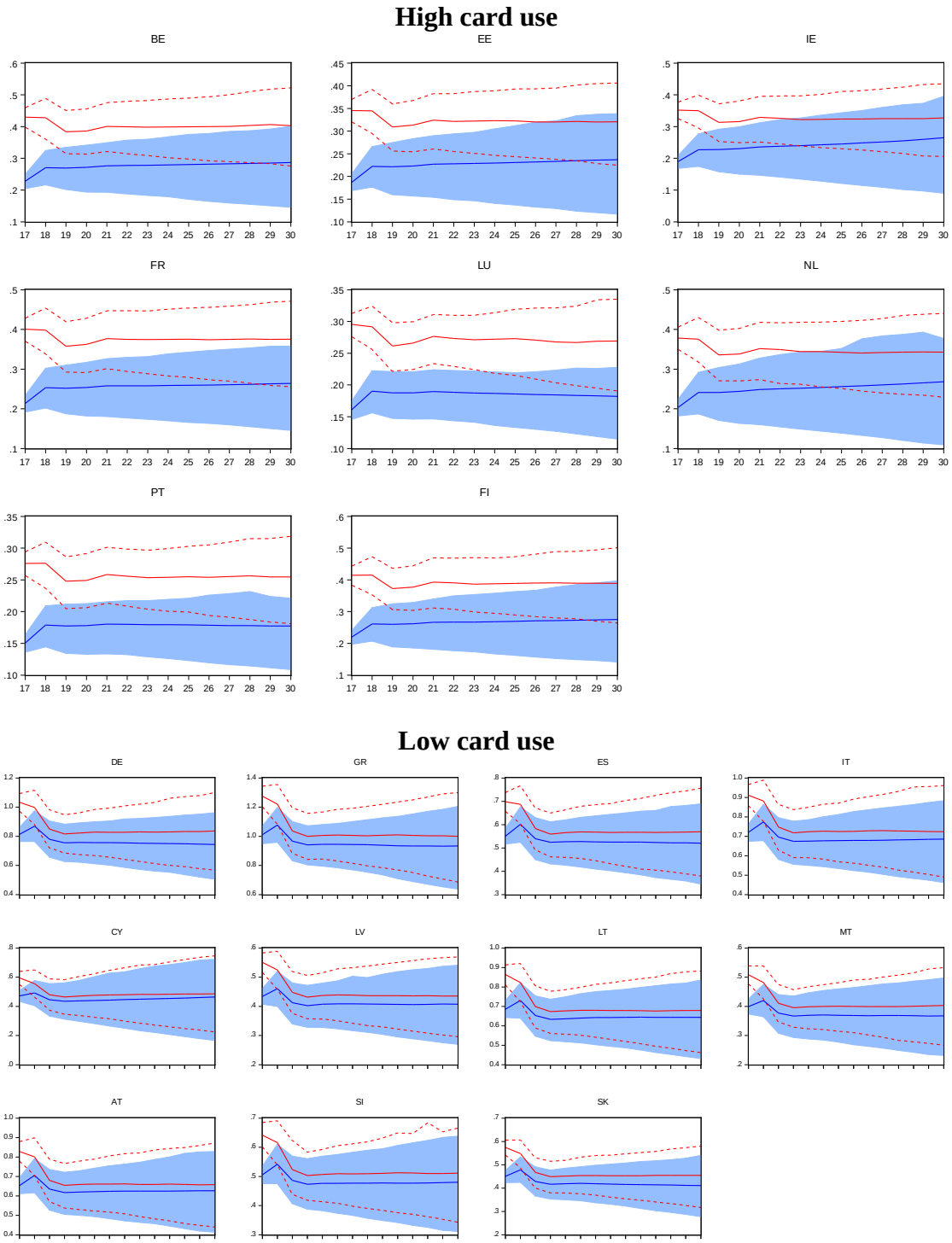
Table 3: Tax compliance and card use in TVC model differentiating between countries with high and low card use

Dependent variable: $b_{0i,t}$
Sample: 2003q1-2016q4; Periods: 56

	post-tax	**pre-tax**
High card use		
$\Delta_4 ln(CARDSHAREP_{i,t})$	0.08 [0.96]	0.15 [1.60]
$\Delta_4 ln(CARDSHAREP_{i,t})^2$	-0.28 [-0.44]	-0.12 [-0.17]
Low card use		
$\Delta_4 ln(CARDSHAREP_{i,t})$	0.10* [1.87]	0.14** [2.55]
$\Delta_4 ln(CARDSHAREP_{i,t})^2$	-0.01 [-0.13]	-0.04 [-0.30]

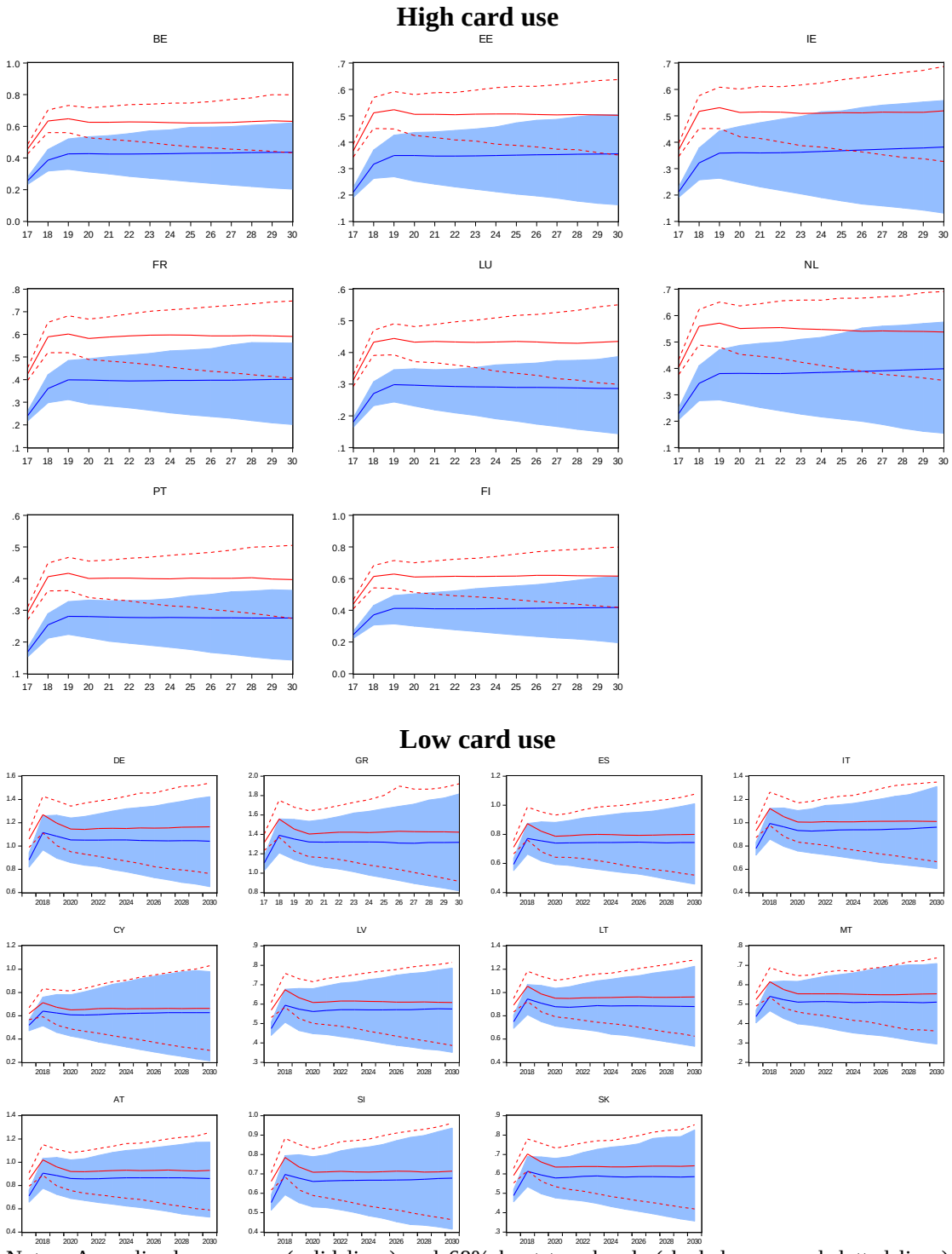
Notes: *z*-statistic in square brackets. "*" and "**" denote significance at the 10% and 5% levels, respectively. High/low card use is defined as above/below average CARDSHAREP during 2000q1-2016q4. Countries with high card use are BE, EE, IE, FR, LU, NL, PT and FI. The post-tax definition of the tax 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.

Chart 14a: Percentage change of EFFICIENCY in response to a 1pp increase in CARDSHAREP



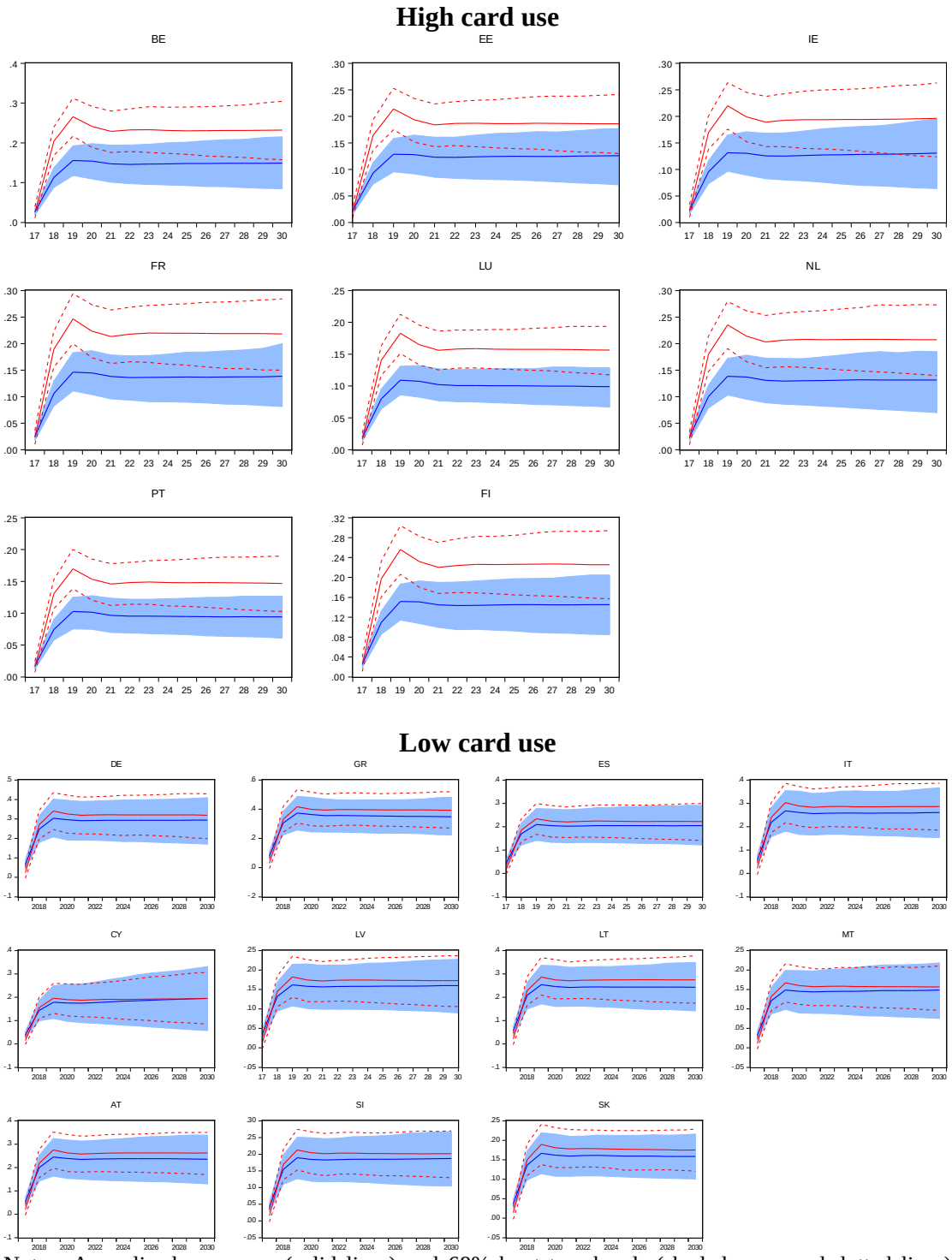
Notes: Annualized responses (solid lines) and 68% bootstrap bands (shaded areas and dotted lines) obtained using the post-tax (blue) and the pre-tax (red) measure of the tax base. The post-tax definition of the tax base is given by the sum of private consumption and government intermediate consumption. The pre-tax definition subtracts VAT revenue from the post-tax measure. High/low card use is defined as above/below average CARDSHAREP during 2000q1-2016q4.

Chart 14b: Percentage change of VAT in response to a 1pp increase in CARDSHAREP



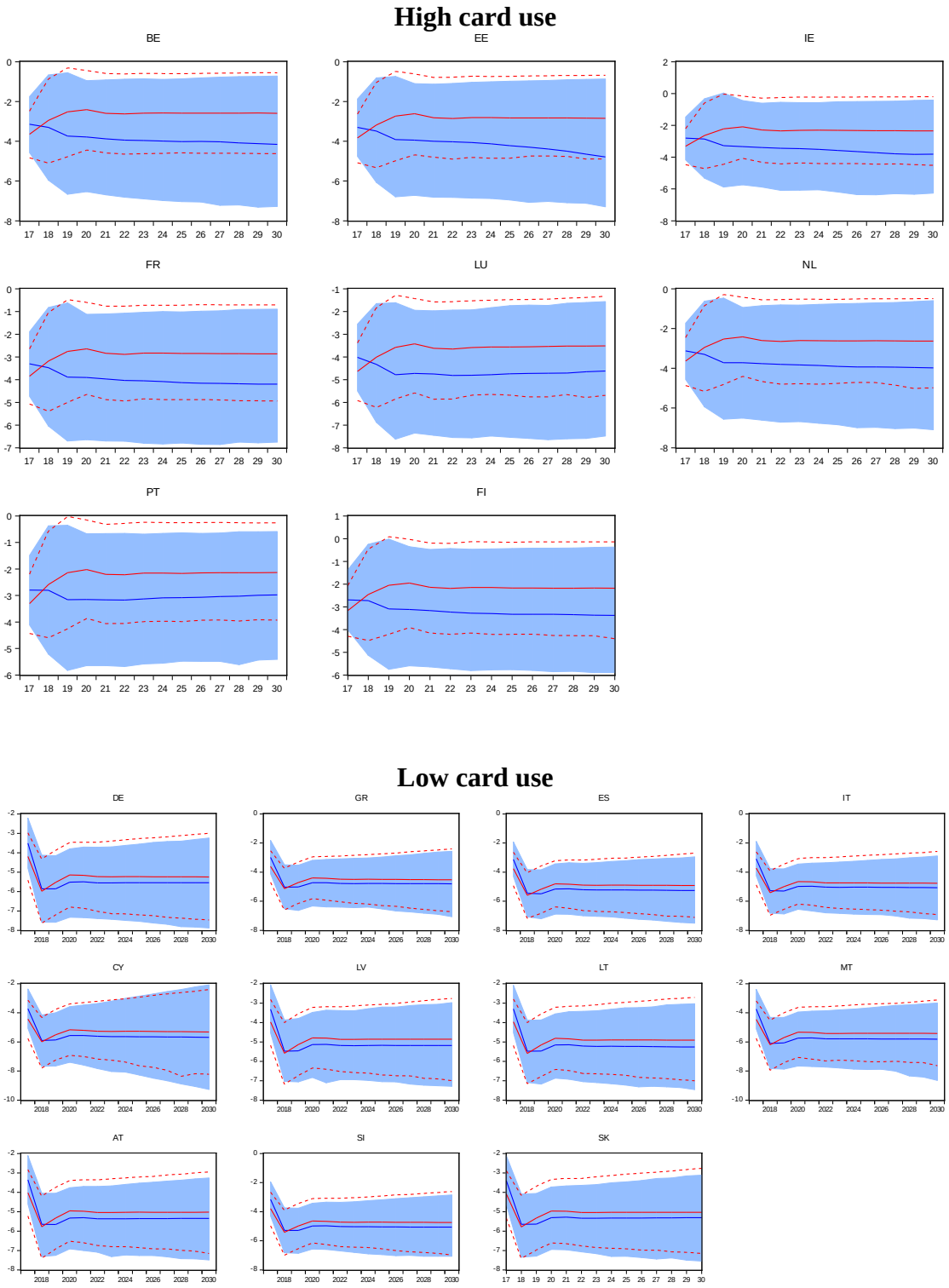
Notes: Annualized responses (solid lines) and 68% bootstrap bands (shaded areas and dotted lines) obtained using the post-tax (blue) and the pre-tax (red) measure of the tax base. The post-tax definition of the tax base is given by the sum of private consumption and government intermediate consumption. The pre-tax definition subtracts VAT revenue from the post-tax measure. High/low card use is defined as above/below average CARDSHAREP during 2000q1-2016q4.

Chart 14c: Percentage change of BASE in response to a 1pp increase in CARDSHAREP



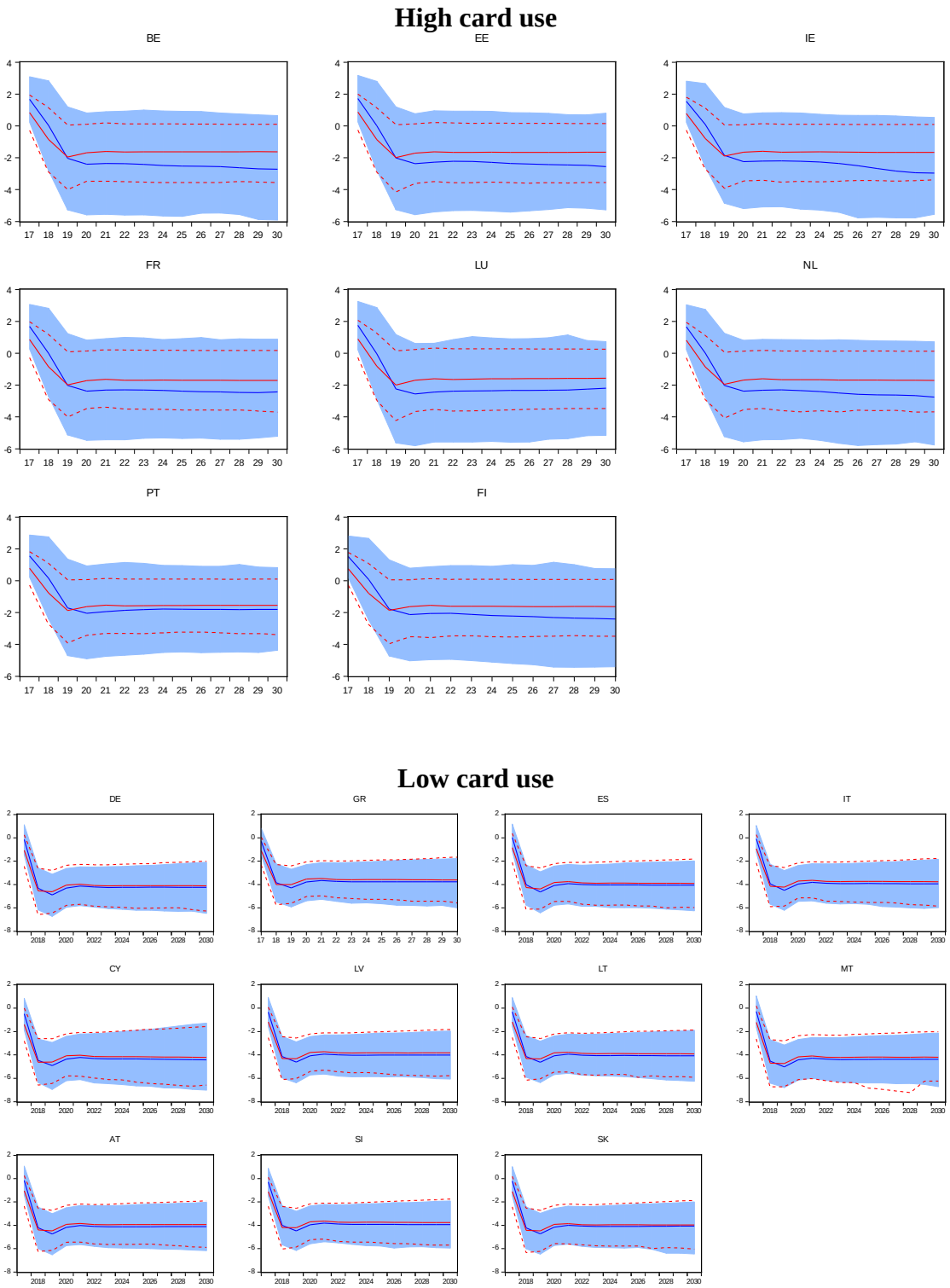
Notes: Annualized responses (solid lines) and 68% bootstrap bands (shaded areas and dotted lines) obtained using the post-tax (blue) and the pre-tax (red) measure of the tax base. The post-tax definition of the tax base is given by the sum of private consumption and government intermediate consumption. The pre-tax definition subtracts VAT revenue from the post-tax measure. High/low card use is defined as above/below average CARDSHAREP during 2000q1-2016q4.

Chart 15a: Percentage change of EFFICIENCY in response to a 1pp increase in RATE



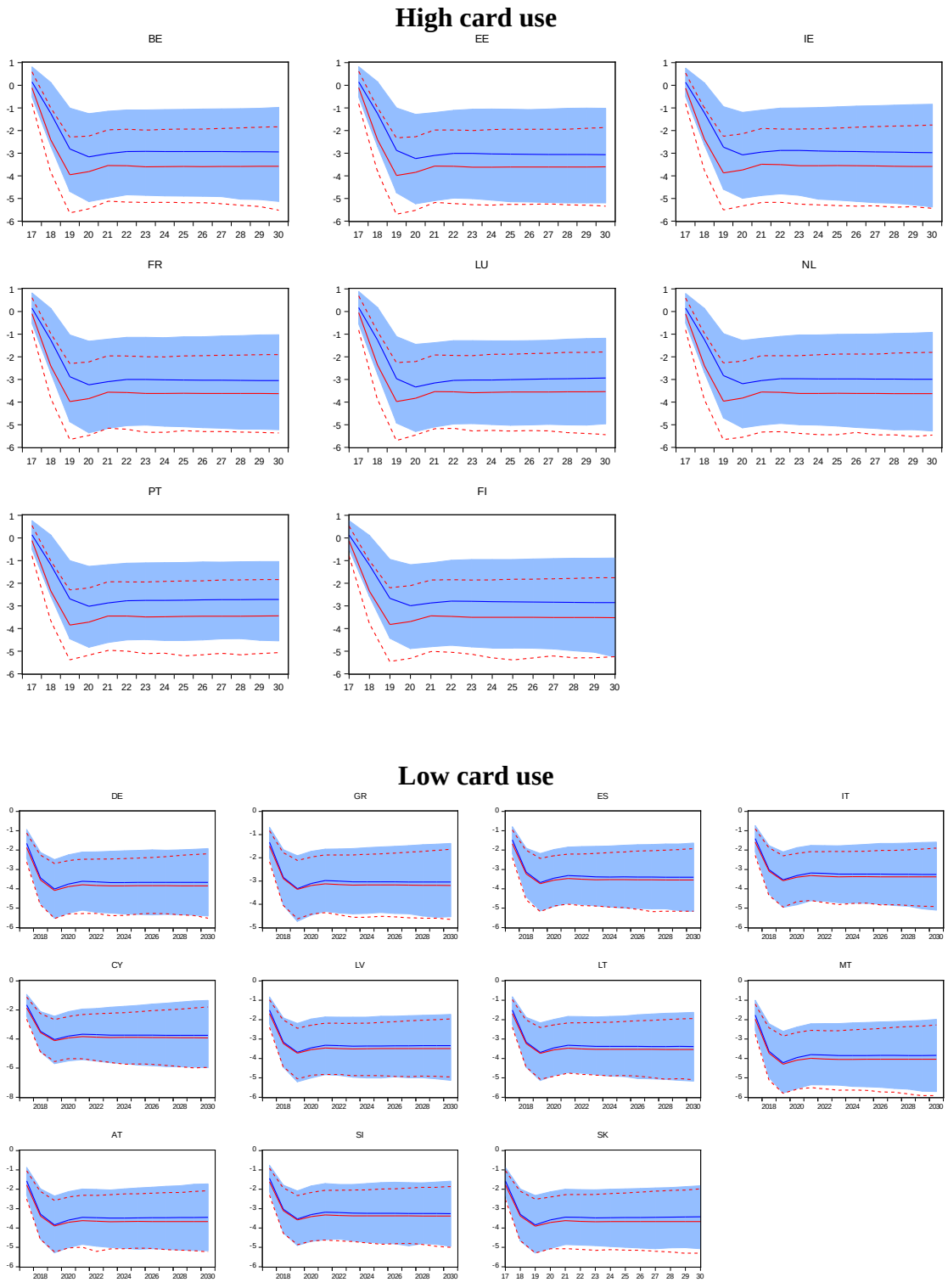
Notes: Annualized responses (solid lines) and 68% bootstrap bands (shaded areas and dotted lines) obtained using the post-tax (blue) and the pre-tax (red) measure of the tax base. The post-tax definition of the tax base is given by the sum of private consumption and government intermediate consumption. The pre-tax definition subtracts VAT revenue from the post-tax measure. High/low card use is defined as above/below average CARDSHAREP during 2000q1-2016q4.

Chart 15b: Percentage change of VAT in response to a 1pp increase in RATE



Notes: Annualized responses (solid lines) and 68% bootstrap bands (shaded areas and dotted lines) obtained using the post-tax (blue) and the pre-tax (red) measure of the tax base. 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. High/low card use is defined as above/below average CARDSHAREP during 2000q1-2016q4.

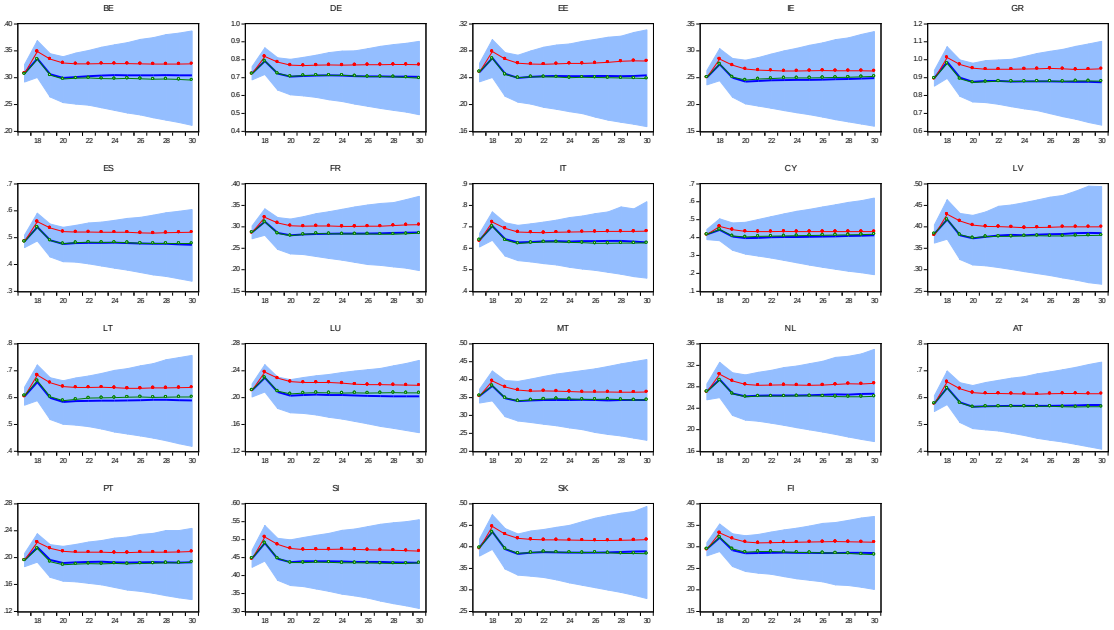
Chart 15c: Percentage change of BASE in response to a 1pp increase in RATE



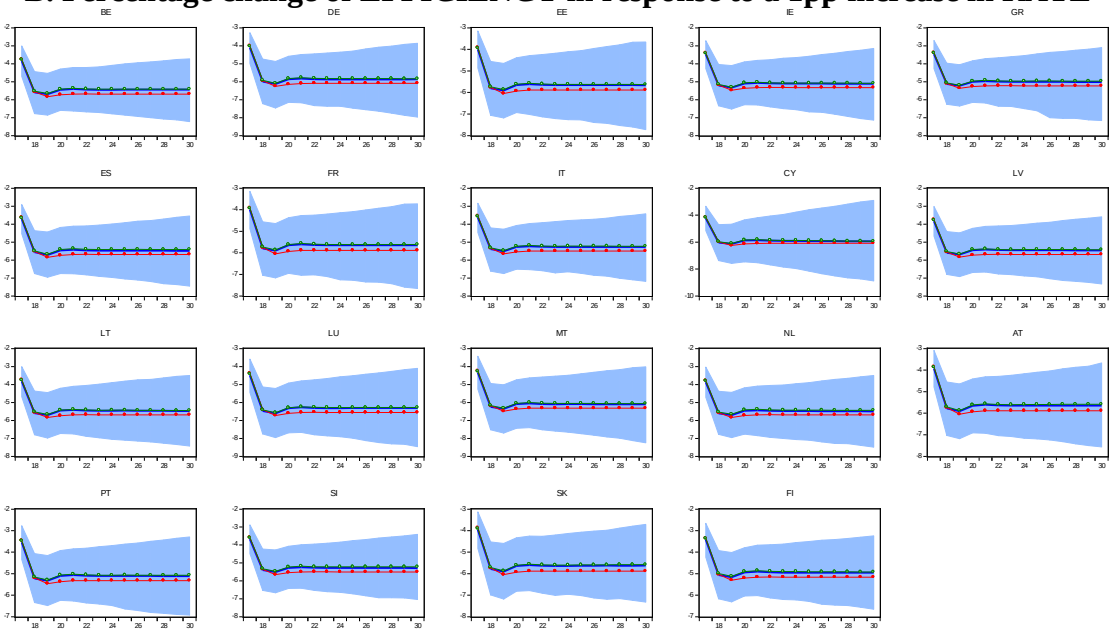
Notes: Annualized responses (solid lines) and 68% bootstrap bands (shaded areas and dotted lines) obtained using the post-tax (blue) and the pre-tax (red) measure of the tax base. The post-tax definition of the tax base is given by the sum of private consumption and government intermediate consumption. The pre-tax definition subtracts VAT revenue from the post-tax measure. High/low card use is defined as above/below average CARDSHAREP during 2000q1-2016q4.

Chart 16: Robustness to alternative estimators

A. Percentage change of EFFICIENCY in response to a 1pp increase in CARDSHAREP



B. Percentage change of EFFICIENCY in response to a 1pp increase in RATE



Notes: Annualized responses. Based on the post-tax measure of the tax base.

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