

CARD PAYMENTS AND VALUE-ADDED TAX (VAT) COMPLIANCE

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AUTHOR'S DECLARATION

I, the undersigned, **Márton Vida**, candidate for the BA degree in Philosophy, Politics and Economics, declare herewith that the present thesis titled 'Card Payments and Value-Added Tax (VAT) Compliance' is exclusively my own work, based on my research and only such external information as properly credited in notes and bibliography. I declare that no unidentified and illegitimate use was made of the work of others, and no part of the thesis infringes on any person's or institution's copyright.

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Vienna, 22 May 2025

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ABSTRACT

While cash is known to be a complement of the shadow economy, the impact of card payments on Value-Added Tax (VAT) compliance has rarely been studied. This thesis aims to fill this gap by empirically investigating whether the rise of card payments whitened VAT revenue across Europe. Firstly, using quarterly time-series data from Hungary and constructing a simple indicator of VAT compliance (C-efficiency), I show that card payments positively impacted compliance. Secondly, employing a panel of 21 European countries, as well as the EU's VAT Compliance Gap indicator, it is found that the increase in the share of card transactions lower VAT non-compliance. I estimate that a one percentage point *ceteris paribus* increase in the share of card transactions in all transactions reduces VAT evaded by approximately 0.05-0.06 percentage points on average. While both tests suffer from limitations, they contribute to a small but growing body of evidence in the field. Two policy implications emerge: firstly, as electronic payments spread, the VAT will become a more effective tax than it used to be; and secondly, by discouraging the use of cash, governments can decrease VAT non-compliance.

TABLE OF CONTENTS

COPYRIGHT NOTICE.....	i
AUTHOR’S DECLARATION.....	ii
ABSTRACT	iii
TABLE OF CONTENTS	iv
LIST OF FIGURES	v
LIST OF TABLES	v
LIST OF EQUATIONS.....	v
CHAPTER ONE: INTRODUCTION	1
CHAPTER TWO: LITERATURE REVIEW	5
2.1. Indicators of VAT Compliance	5
2.1.1. C-efficiency	5
2.1.2. VAT Gap	7
2.2. VAT Adoption and Tax Compliance	7
2.3. Drivers of VAT Compliance	8
2.4. Cashless Payments and VAT Compliance	9
CHAPTER THREE: THEORY.....	11
CHAPTER FOUR: HUNGARIAN TIME-SERIES ESTIMATES.....	13
4.1. Regression Model.....	13
4.2. Data	14
4.2.1. Data Sources	14
4.2.2. Descriptive Statistics	16
4.3. Results	18
4.4. Discussion and Limitations	18
CHAPTER FIVE: EUROPEAN PANEL ESTIMATES	20
5.1. Regression Model.....	20
5.2. Data	21
5.2.1. Data Sources	21
5.2.2. Descriptive Statistics	22
5.3. Results	25
5.4. Discussion and Limitations	29
CHAPTER SIX: CONCLUSION	30
BIBLIOGRAPHY	32
ANNEX 1: UNIT-ROOT TESTS FOR HUNGARIAN DATA	35
ANNEX 2: HUNGARIAN TIME-SERIES REGRESSION OUTPUTS.....	36
ANNEX 3: EUROPEAN PANEL REGRESSION OUTPUTS (HETEROSKEDASTICITY-ROBUST STANDARD ERRORS).....	39
ANNEX 4: EUROPEAN PANEL REGRESSION OUTPUTS (CLUSTERED STANDARD ERRORS)	46

LIST OF FIGURES

Figure 1. VAT revenue as % of tax revenue for European regions. Data source: OECD, 2025.	1
Figure 2. VAT Compliance Gap over time in European regions. Data source: European Commission et. al., 2024.....	2
Figure 3. Share of card transactions in all transactions by European region, over time. Data source: European Central Bank, 2024.....	2
Figure 4: Quarterly time-series of VAT compliance (C-efficiency) and share of card payments in consumption in Hungary.	16
Figure 5. Components of the C-efficiency. Consumption and VAT Revenue over time in Hungary.....	17
Figure 6. Scatter plot of Card Share and VAT Gap, demeaned by year and country. Shaded areas show 95% confidence intervals.	23

LIST OF TABLES

Table 1. Time-series estimates for Hungary. Standard errors are computed using HAC standard errors with 4 lags, significance levels are computed using t-statistics. ***: $p < 0.01$, **: $p < 0.05$, *: $p < 0.1$	18
Table 2. Descriptive statistics for a panel of European countries.	22
Table 3. Panel OLS estimates for a European panel of countries. Standard errors are computed using heteroskedasticity-robust standard errors. ***: $p < 0.01$, **: $p < 0.05$, *: $p < 0.1$	25
Table 4. Panel OLS estimates for a panel of European countries. Standard errors are computed using two-way clustered standard errors (by time and entity). ***: $p < 0.01$, **: $p < 0.05$, *: $p < 0.1$	26

LIST OF EQUATIONS

Equation 1: Definition of C-Efficiency.....	5
Equation 2: Definition of C-Efficiency.....	6
Equation 3: Definition of the VAT Gap.....	7
Equation 4: Definition of the VAT Gap.....	7
Equation 5: Theory.....	11
Equation 6: Theory.....	11
Equation 7: Theory.....	11
Equation 8: Theory.....	11
Equation 9: Theory.....	12
Equation 10: Hungary Time-series Model.....	13
Equation 11: Hungary Time-series Model.....	13
Equation 12. European Panel Model.....	20
Equation 13: VAT Laffer Curve.....	27

CHAPTER ONE: INTRODUCTION

The value-added tax (VAT) is levied on sales at each production stage, with a mechanism to offset taxes already paid on inputs. While definitions of the VAT vary, its first implementation is often dated to post-WWII France, spreading rapidly in the 1960s throughout Western Europe and across the world. Besides the general will to broaden the tax base during the post-WWII period via a tax levied on all consumption, the VAT was largely preferred to earlier forms of taxation due to its low distortionary effects. Earlier sales taxes, which lacked a credit mechanism for taxes on inputs, distorted production chains; tariffs distorted gains from trade; whereas taxes on the consumption of specific products distorted industry competition (Ebrill, Keen, and Perry 2001, 1-6).

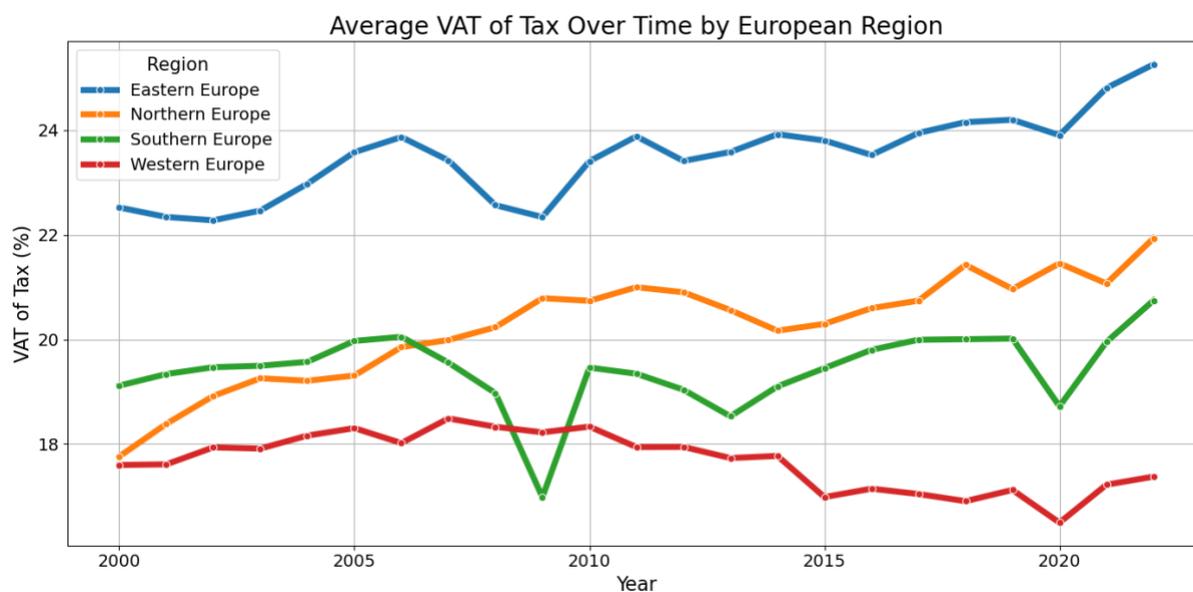


Figure 1. VAT revenue as % of tax revenue for European regions. Data source: OECD, 2025.

Today, VAT is an essential part of European tax systems, as EU countries collect 15-25% of their taxes through VAT. Moreover, over the last 20 years, EU periphery countries have gradually increased their reliance on VAT (see Figure 1). These increases have also been accompanied by a convergence towards their more economically advanced European peers in

terms of VAT compliance, measured by the EU’s VAT Gap indicator (see Figure 2). Meanwhile, as shown in Figure 3, card payments have been gradually replacing cash payments in all regions of Europe.

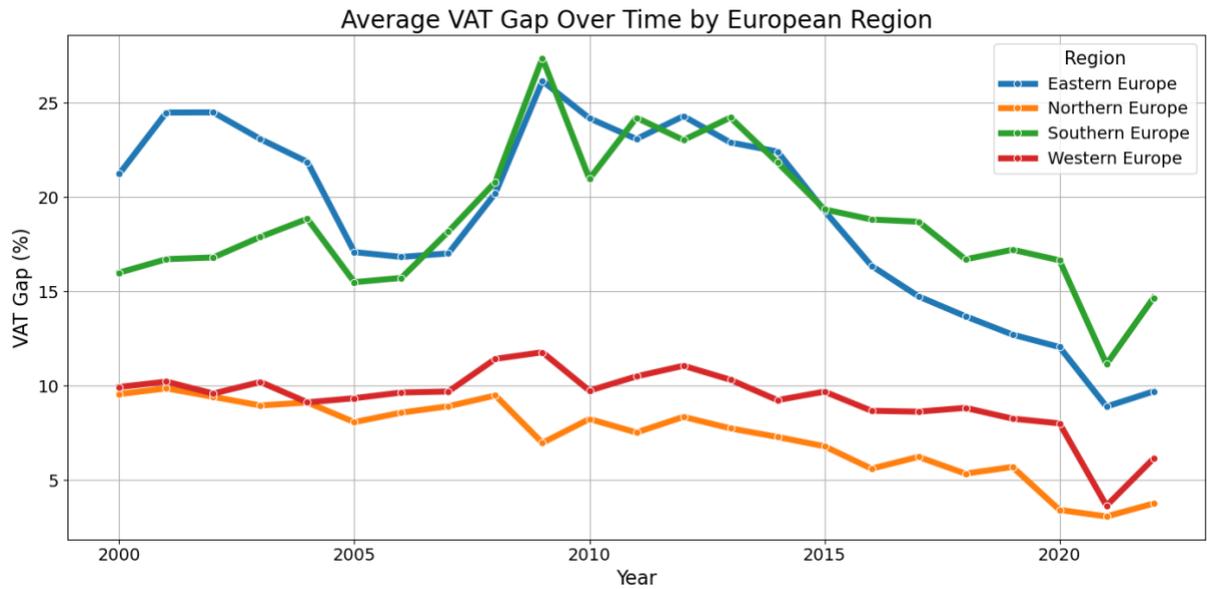


Figure 2. VAT Compliance Gap over time in European regions. Data source: European Commission et. al., 2024.

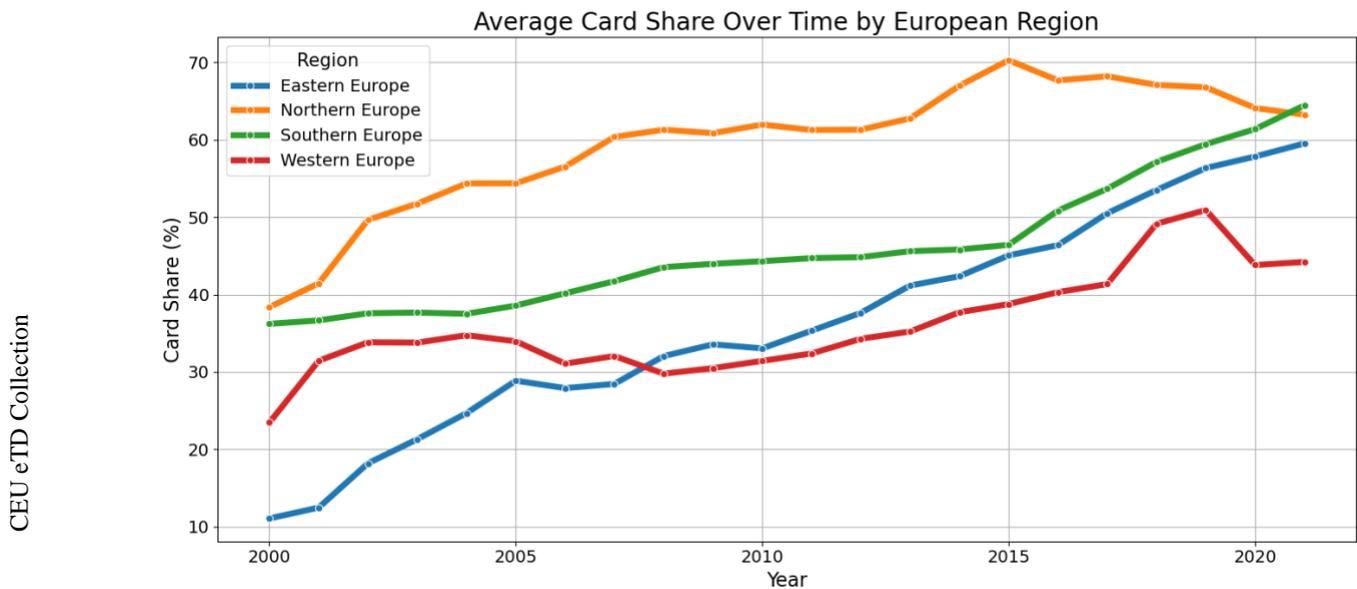


Figure 3. Share of card transactions in all transactions by European region, over time. Data source: European Central Bank, 2024.

Since VAT in some parts is preferred to other forms of taxation because of its supposed effectiveness, it is worth asking what has been driving VAT compliance in Europe. The

empirical literature is rich on certain aspects of VAT compliance: most notably, that since producers can claim credit for VAT paid on their inputs, there is an incentive for informal firms to formalise in long production chains (Hoseini and Briand 2020; Keen 2008; Jenkins and Kuo 2000; de Paula and Scheinkman 2010; Pomeranz 2015; Waseem 2022). However, the literature largely neglects the promise of electronic payments to enhance compliance, with a few exceptions (Hondroyiannis and Papaoikonomou 2017; 2020; Holá, Arltová, and Zídková 2022; Madzharova 2020). This is surprising given the fact that cash is known to be a driver of the shadow economy (Shy 2023).

Card payments may enhance VAT revenue via two channels: given their traceability, they may increase the perceived probability of punishment in the eyes of retailers; and given the possibility that electronic payments could be automatically transmitted to tax authorities, the administrative costs of compliance may also be lowered. The former channel may materialise even without significant government intervention. Hence, understanding if card payments impact VAT compliance is essential to ground policies aiming to whiten VAT revenue via this channel.

This thesis aims to fill this gap by empirically analysing the effect of card payments on VAT compliance in European economies. It does so in two ways. Firstly, employing a simple but crude indicator of VAT compliance (the C-efficiency), I show in the case of Hungary that widely available quarterly macro-data can be used to show the positive impact of the share of card payments in consumption on VAT compliance. Secondly, by employing the VAT Gap, the European Commission's more robust VAT compliance indicator, I show in a panel of European countries that the share of card transactions in all transactions is negatively associated with VAT non-compliance. Both results come with caveats and have certain limitations. Nevertheless, my findings suggests that the rise of card payments has positively contributed to

VAT compliance across Europe, contributing to the growing but narrow body of literature in the field (Hondroyannis and Papoikonomou 2017; 2020; Holá, Arltová, and Zídková 2022; Madzharova 2020).

The thesis is structured in the following way. In Chapter 2, I review the empirical literature on VAT compliance. After discussing two key quantitative indicators of VAT compliance that I will later use in my analysis (the C-efficiency and the VAT Gap), I review the empirical literature on drivers of VAT compliance, as well as focusing on the few papers that have specifically analysed the impact of card payments on VAT compliance. In Chapter 3, I briefly sketch a theory that predicts a linear relationship between the share of card transaction value in all transactions and VAT compliance, thereby giving an intuitive interpretation of the linear regression models I will use afterwards. Chapters 4 and 5 then test this prediction in two ways. In Chapter 4, I present an empirical test that relies on the C-efficiency and quarterly time-series data from Hungary. I find that the share of card transaction value in consumption had a positive impact on C-efficiency. However, these findings suffer from the limitations of C-efficiency as an indicator for VAT compliance, which lumps together legal VAT exemptions and reductions with VAT non-compliance. In Chapter 5, I use a more robust indicator of VAT compliance, the EU's VAT Gap indicator, and regress that on the share of card transactions in a panel of 21 European economies. These results hold under numerous alternative specifications of the model, but fail once I use two-way clustered standard errors (instead of heteroskedasticity-robust ones). Chapter 6 concludes and briefly discusses possible policy implications. Overall, while my results suffer from limitations, they are among the first empirical tests that indicate a positive association between the rise of card payments and VAT compliance across European economies.

CHAPTER TWO: LITERATURE REVIEW

This chapter reviews the empirical literature on VAT compliance, and more specifically, on the impact of card payments on VAT compliance. Section 2.1. reviews two quantitative indicators of VAT compliance that I will later use in my analysis. Section 2.2. and 2.3. review the empirical literature on VAT compliance in general. Lastly, Section 2.4. discusses the related literature on the impact of cashless payments on VAT compliance.

2.1. Indicators of VAT Compliance

To study VAT compliance empirically, the first step is to construct its indicator. The empirical literature often approaches this problem with micro-level data, such as surveys (Hoseini and Briand 2020; de Paula and Scheinkman 2010). Here, I discuss two general quantitative indicators of VAT compliance that rely on macroeconomic data: the C-efficiency and the VAT gap. I will also employ these two indicators in my analysis.

2.1.1. C-efficiency

The C-efficiency is the simplest indicator of VAT compliance, and it is easily computable from widely available macroeconomic data. While it relies on strong assumptions, given its simplicity, similar indicators are often used in the empirical literature (Hondroyannis and Papaioikonomou 2017; Aizenman and Jinjark 2009; Engel, Galetovic, and Raddatz 2001).

C-efficiency can be defined as (Keen 2013, 6):

$$C - efficiency = \frac{VAT\ Revenue}{VAT\ Rate \times Consumption}$$

Equation 1: Definition of C-Efficiency

The definition of C-efficiency in Equation 1, rests on the assumption that VAT revenue is a product of consumption, a standard VAT rate, and compliance. Hence, it is derived directly from Equation 2:

$$VAT\ Revenue = Compliance \times VAT\ Rate \times Consumption$$

Equation 2: Definition of C-Efficiency

There are numerous reasons why C-efficiency is crude. Firstly, while consumption data that is reported regularly by statistical agencies tries to predict unrecorded consumption, the consistency with which they estimate consumption overlooked by VAT authorities is by no means clear (Keen 2013, 14). Secondly, while there is a standard VAT rate in countries, it is usually accompanied by exemptions and reduced VAT rates. Sometimes authors justify using C-efficiency despite this, with the argument that a uniform VAT rate is the most efficient (Keen 2013, 11), but then C-efficiency further loses its interpretation as a proxy for compliance only. A common way to correct for the first shortcoming of C-efficiency is to control for multiple characteristics of VAT systems when C-efficiency is used as a dependent variable (Madzharova 2020).

A recent paper used C-efficiency in a creative way so that it better tracks VAT compliance (Morrow, Smart, and Swistak 2022). It has been observed that the share of imports in consumption correlates strongly with C-efficiency in some countries, but not in others. A probable cause is that imports are easier to monitor than domestic consumption; hence, in countries with low domestic VAT compliance, imports and C-efficiency correlate. The authors then used the strength of correlation between the share of imports in consumption and C-efficiency in different countries to rank countries based on their VAT compliance.

2.1.2. VAT Gap

As I explained at above, C-efficiency measures two kinds of deviations from a theoretical tax revenue levied on all consumption at a uniform rate: reduced rates and exemptions, as well as VAT compliance. So, one way to refine our indicator of VAT compliance is to say that we define an ideal VAT revenue such that we account for differentiated VAT rates on different commodities (Keen 2013, 18):

$$Ideal\ VAT\ Revenue = \sum Consumption\ of\ Commodity_i \times VAT\ Rate_i$$

Equation 3: Definition of the VAT Gap

One can now use Equation 3 to construct a more precise indicator of VAT non-compliance:

$$VAT\ Gap = \frac{Ideal\ VAT\ Revenue - Actual\ VAT\ Revenue}{Ideal\ VAT\ Revenue}$$

Equation 4: Definition of the VAT Gap

The VAT Gap has the interpretation of the share of the theoretical VAT revenue under full compliance that we cannot account for from the actual observed VAT revenue. It has more stringent data requirements, but the European Commission estimates it on an annual basis for member states (European Commission et al. 2024). The limitation on statistical agencies predicting unrecorded consumption still holds in the case of the VAT Gap (Keen 2013, 18).

2.2. VAT Adoption and Tax Compliance

Some studies suggest that VAT adoption contributed positively both to overall tax compliance (Keen and Lockwood 2010) and to economic growth (Chan and and Karim 2017) in most countries. The most widely studied mechanism accounting for higher compliance under VAT systems is the so-called self-enforcement of VAT. Unlike earlier forms of taxation, such as sales taxes, producers can claim credit for VAT paid on earlier stages of production via their inputs. This means that whenever non-compliant companies want to join production chains with at least

some formal actors, they have an incentive to become formal and be able to issue invoices to each other and claim back tax credits. Many empirical papers have verified that this mechanism is present in VAT systems (Hoseini and Briand 2020; Keen 2008; Jenkins and Kuo 2000; de Paula and Scheinkman 2010; Pomeranz 2015; Waseem 2022), thereby leading to higher compliance than alternative forms of taxation.

2.3. Drivers of VAT Compliance

Multiple authors investigated the specificities of VAT systems that improve compliance. In terms of the efficient VAT design, studies have found that increasing VAT rates leads to lower compliance, implying the existence of a Laffer curve and a revenue-maximising VAT rate (Agha and Haughton 1996; Hondroyiannis and Papaoikonomou 2017). Another paper argues that the higher number of tax rates also reduces compliance (Agha and Haughton 1996), arguably because of increased tax complexity.

Another studied aspect of VAT systems relevant for compliance is VAT thresholds. In most countries, companies with revenue below a certain threshold are not required to register for VAT. It is argued that there is an optimal threshold, as too low threshold implies excessive enforcement costs, whereas too high threshold implies a loss in tax revenue (Keen and Mintz 2004). Evidence was also found that there is a tendency for larger firms to masquerade as several smaller ones to take advantage of VAT thresholds (Onji 2009).

In terms of VAT enforcement, E-invoicing (Bellon et al. 2022) and VAT listings (Holá, Arltová, and Zídková 2022) have also been found to enhance VAT compliance, as well as higher spending on VAT administration (Agha and Haughton 1996; Engel, Galetovic, and Raddatz 2001). Interestingly, one paper found that the impact of audits on VAT compliance is ambiguous, as they have a non-trivial impact on the perceived probability of punishment (Bergman and Nevarez 2006).

Some papers also looked at the motivations of actors in evading VAT. A paper warns that for small companies, non-compliance is often driven more by administrative compliance costs rather than the actual cost of the VAT tax (Harju, Matikka, and Rauhanen 2019). Another paper found that customers' decisions to ask for a receipt often drives VAT compliance, rather than the decisions of sellers (Fjeldstad et al. 2020), pointing to the importance of educating the average customer about the risks of non-compliance.

2.4. Cashless Payments and VAT Compliance

Even though cash is known to be a complement of illicit activity and the shadow economy given its anonymity (Shy 2023), the effect of cashless payments for increased VAT compliance has rarely been studied. Electronic payments could enhance VAT compliance via two channels: increasing perceived probability of punishment given the traceability of cashless payments, and decreasing compliance costs should an automatic transfer of e-payment information be in place between sellers and tax authorities (Madzharova 2020). Knowing whether the economy uses less cash translates to lower VAT evasion has important implications both for optimal tax structures (Gordon and Li 2009) as well as for policies aiming to whiten tax revenues (Immordino and Russo 2018; Alvarez et al. 2022).

During recent years, some authors tried to fill this gap in the empirical literature. Analyzing Greece and the Eurozone area, two papers found that the share of card payments is positively associated with versions of the C-efficiency (Hondroyannis and Papaoikonomou 2017; 2020). Another paper also finds a positive association between card payments and compliance in a panel of European countries (Madzharova 2020). It uses C-efficiency as an indicator, and include controls regarding the specificities of each VAT system. This thesis corroborates these findings, regressing C-efficiency on the share of card payments in consumption using Hungarian time-series data.

A group of authors used the European Commission's VAT Gap to measure VAT non-compliance, and regressed it on the share of card payments in a panel of European countries (Holá, Arltová, and Zídková 2022). In my second empirical test, I use the same data source and arrive at a similarly positive result, but with some limitations. Beyond replication, this part of the thesis adds to the aforementioned work in two ways. Firstly, Holá, Arltová, and Zídková 2022 conducted their analysis before the European Commission published a revised panel dataset of VAT Gap in EU countries, in which they made ex-post corrections. Secondly, my findings do not hold up to certain robustness checks, which may suggest that more research is needed to ground the conclusions in Holá, Arltová, and Zídková 2022. The key takeaway is that this thesis both replicates and corroborates recent but rare findings on cashless payments and VAT compliance.

CHAPTER THREE: THEORY

I present a simple theory that predicts a linear relationship between the share of card transaction value in all transactions and the VAT Gap (see Section 2.1.2 above). Let the value of all transactions be numeraire, the share of card transactions be C , and the share of VAT evaded on card payments be S_d and on cash payments be S_h . Lastly, let the VAT rate be τ . Now I can write down the actual and ideal VAT revenue on which the VAT Gap depends (see Equations 3 and 4), as a function of VAT evaded on card and cash payments.

Ideal VAT revenue = τ

Equation 5: Theory

Actual VAT revenue = $\tau[C(1 - S_d) + (1 - C)(1 - S_h)]$

Equation 6: Theory

Using Equations 4, 5 and 6 I can express the VAT Gap as:

$$VAT\ GAP = \frac{\tau - \tau[C(1 - S_d) + (1 - C)(1 - S_h)]}{\tau} = S_h + C(S_d - S_h)$$

Equation 7: Theory

I can use Equation 7 to estimate a linear relationship between VAT Gap and the share of card payments in all transactions.

$$VAT\ Gap = \beta_0 + \beta_1 C + u, \text{ where: } \beta_0 = S_h, \beta_1 = S_d - S_h$$

Equation 8: Theory

Estimating Equation 8 gives a convenient interpretation of β_1 : it is the difference between the share of VAT evaded on card payments and cash payments. Since I hypothesize that VAT is more likely to be evaded on cash payments than on card payments (given the higher anonymity of cash), the expectation is that β_1 will be negative.

I also define an equation for Compliance, which is merely $1 - VAT\ Gap$.

Compliance = $\beta_0 + \beta_1 C + u$, where: $\beta_0 = 1 - S_h$, $\beta_1 = S_h - S_d$

Equation 9: Theory

In Equation 9 β_1 has a similar interpretation, but now we expect it to be positive, as we expect that the share of VAT evaded on card payments is lower than on cash payments. In what follows, I estimate robust variants of Equations 8 and 9 using two different datasets with different indicators of VAT compliance.

CHAPTER FOUR: HUNGARIAN TIME-SERIES ESTIMATES

This chapter presents estimates of Equation 9 developed in the previous chapter using time-series data from Hungary. Section 4.1. introduces a regression model. Section 4.2. presents descriptive statistics of the two key indicators used. Section 4.3. presents the results, which are then discussed in Section 4.4.

4.1. Regression Model

I present a simple model to estimate the impact of the share of card transactions on consumption in Hungary. The model makes use of the idea behind C-efficiency (Keen 2013), which has modest data requirements but rests on strong assumptions. See a short discussion of its limitations above, in Section 2.1.1. In particular, as an extension of Equation 9, I start with Equation 10:

$$\begin{aligned} Compliance_t &= \beta_0 + \beta_1 Card Share_t + \beta_2 GDP Per Capita_t + \beta_3 Year_t \\ &+ \sum_{i=1}^3 \alpha_i Quarter_i_t + u_t \end{aligned}$$

Equation 10: Hungary Time-series Model

Since compliance is unobserved, I use Equation 1 to estimate Equation 10:

$$\begin{aligned} C - efficiency_t &= \frac{VAT Revenue_t}{Consumption_t \times VAT Rate_t} \\ &= \beta_0 + \beta_1 Card Share_t + \beta_2 GDP Per Capita_t + \beta_3 Year_t \\ &+ \sum_{i=1}^3 \alpha_i Quarter_i_t + u_t \end{aligned}$$

Equation 11: Hungary Time-series Model

The key coefficient of interest will be β_1 , and it is expected to have a positive and significant impact on the dependent variable, indicating that the higher the share of card payments in consumption, the higher the VAT compliance. I include GDP per capita as a control because it

can be expected that economic development correlates both with VAT compliance (higher GDP is often associated with lower levels of informality) and with the share of card payments in consumption. I control for year to filter out a common time trend expected in both variables, and included dummies for each quarter to account for seasonality (since I will use quarterly data). I dropped the dummy for the fourth quarter to make it the reference quarter and avoid perfect multicollinearity with the intercept.

4.2. Data

4.2.1. Data Sources

I acquired quarterly data on the discussed indicators between 2014 and 2024 from Hungarian state agencies.

Quarterly data on consumption and GDP per capita come from the freely available dataset of the Hungarian Central Statistical Office (Központi Statisztikai Hivatal 2024). Since data on VAT revenues is reported in nominal terms, I use nominal final consumption (not seasonally adjusted), and since I use GDP per capita as an indicator for economic development, I use real GDP per capita.

Quarterly data on the value of card payments is taken from the dataset on money circulation of the Hungarian Central Bank (Magyar Nemzeti Bank 2025). The data covers the value of card payments made in Hungary with credit cards issued in Hungary, hence, some transactions are excluded. I divide this by nominal consumption to get the indicator for the share of card payments in consumption.

Monthly data on VAT revenues of Hungary is published by the Hungarian State Treasury (Magyar Államkincstár 2025). The original data is published on a monthly basis, to fit my analysis, I aggregated it by quarters.

Lastly, the standard VAT rate did not change in Hungary in the studied period; it was consistently at 27%, however, several reduced rates existed. As discussed in section 2.1.1, one of the limitations of the C-efficiency indicator is that it fails to account for these tax reductions; for that, one would need detailed data not only about the reduced rates and exemptions but also about the specific commodities consumed. One way I correct for this limitation is that instead of using the standard rate of 27%, I take for each year the average VAT rate on domestic consumption as reported by the Hungarian Tax Authority yearly in its yearbooks (Nemzeti Adó- és Vámhivatal 2024). One limitation is that these averages are reported every year, so I had to distribute them among quarters.

4.2.2. Descriptive Statistics

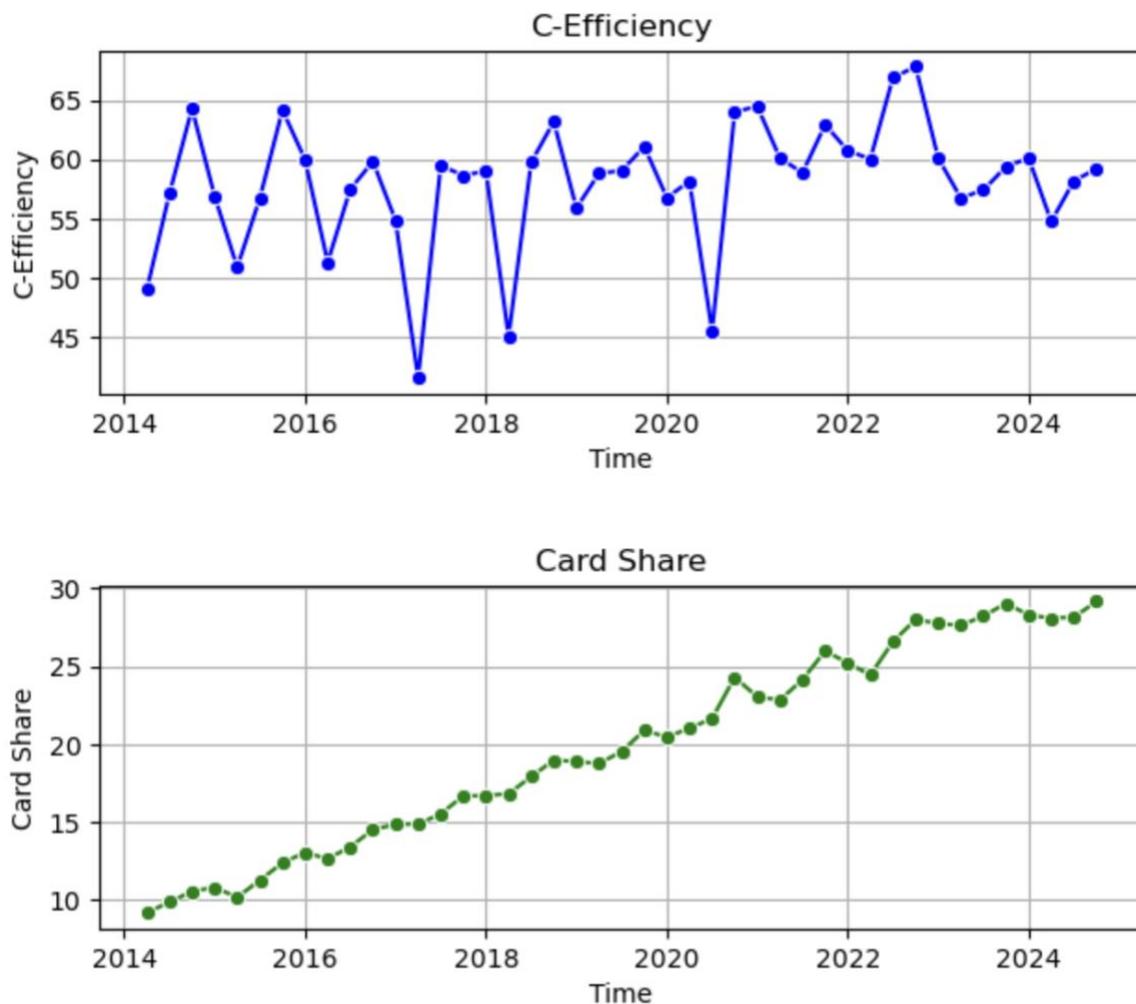


Figure 4: Quarterly time-series of VAT compliance (C-efficiency) and share of card payments in consumption in Hungary.

As we can see in the Figure 4, both VAT compliance and share of card payments in consumption have been trending upwards during the studied period. One worry is that, together with GDP, the variables have unit roots – the inclusion of which in time-series regressions risks spurious results. I test for the presence of such a unit root in the case of all three variables (C-efficiency, GDP, Card Share) using an Augmented Dickey-Fuller test, and fail to reject the null hypothesis for all of them that they have no unit root. See Annex 1 for the results of these unit-root tests. To correct for this, in my analysis, I will use first-differenced versions of all three variables. Should they be I(1) processes, this should ensure their stationarity (Wooldridge 2013, 395-399).

One may be surprised by the strength of cyclicality in C-efficiency as plotted in Figure 4. I show in Figure 5 that this variation is mainly driven by VAT revenue in the numerator of C-efficiency (recall the definition of C-efficiency from Equation 1). VAT revenue may exhibit such behaviour independently of consumption; for instance in certain quarters some industries may boom that are more prone to VAT non-compliance, such as tourism (European Commission et al. 2024, 16-21). In such cases, C-efficiency correctly tracks a cyclical trend in VAT compliance. However, it is likely that some of this cyclicality is coming from reporting practices of the Hungarian State Treasury. I try to mitigate this shortcoming by the inclusion of the quarterly dummies.

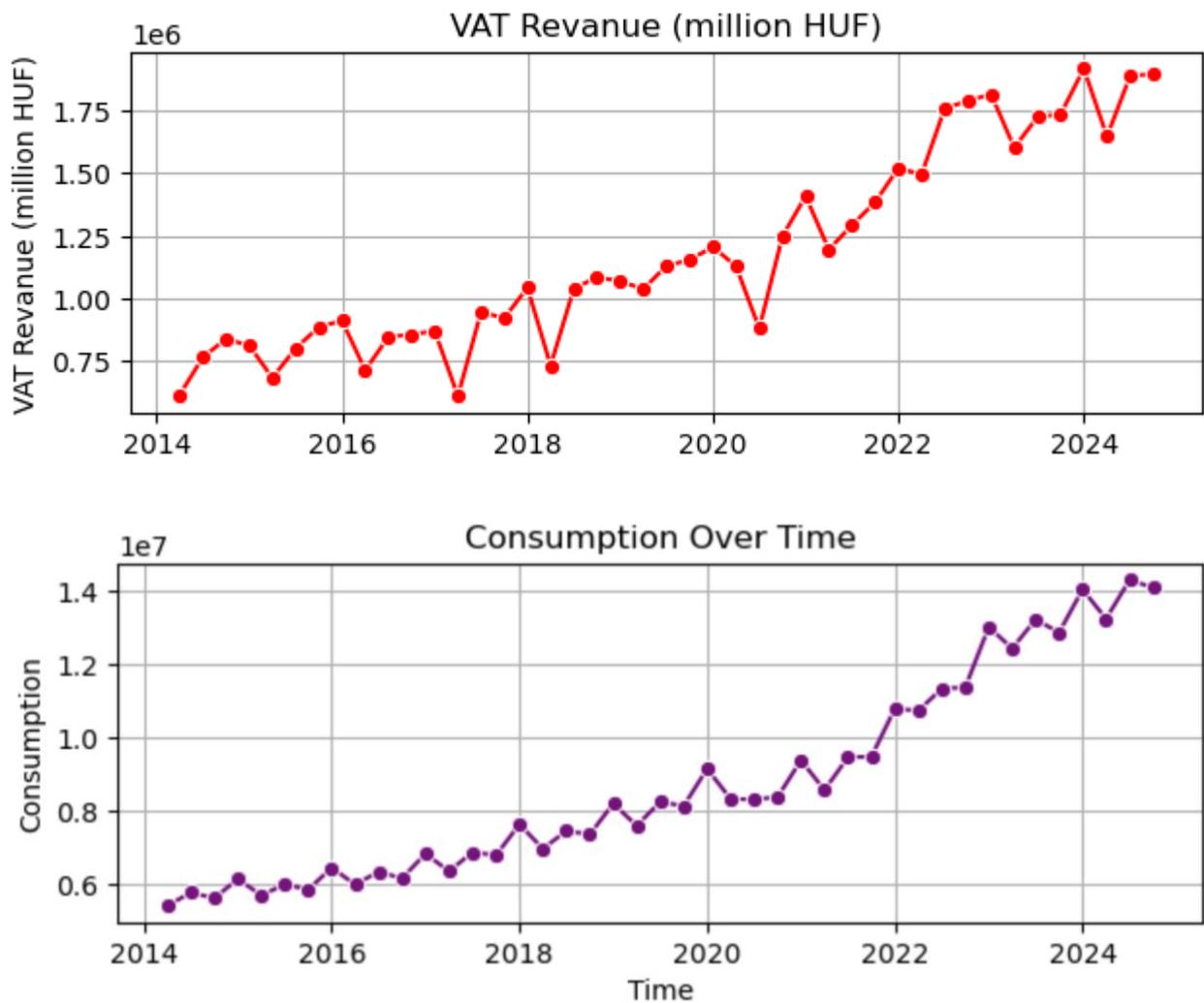


Figure 5. Components of the C-efficiency. Consumption and VAT Revenue over time in Hungary.

4.3. Results

	<i>Model 11.1.</i>	<i>Model 11.2.</i>	<i>Model 11.3.</i>
<i>Dependent Variable</i>	Δ C-efficiency	Δ C-efficiency	Δ C-efficiency
<i>ΔCard Share</i>	1.4370 (2.112)	3.5884*** (1.127)	-
<i>ΔGDP p.c.</i>	8.817e-07 (2.36e-06)	1.091e-06* (5.75e-07)	1.608e-06** (6.43e-07)
<i>Year</i>	-0.1254 (0.170)	-0.0677 (0.159)	-0.1412 (0.145)
<i>Quarter 1</i>	1.5393 (9.131)	-	-
<i>Quarter 2</i>	6.2482 (5.900)	-	-
<i>Quarter 3</i>	6.3912** (2.557)	1.2170 (2.165)	5.0044** (1.894)
<i>R squared</i>	0.401	0.346	0.250
<i>n</i>	42	42	42

Table 1. Time-series estimates for Hungary. Standard errors are computed using HAC standard errors with 4 lags, significance levels are computed using t-statistics. ***: $p < 0.01$, **: $p < 0.05$, *: $p < 0.1$

In Table 1. I present first-differenced estimates of Equation 11. I use heteroskedasticity- and autocorrelation-robust (HAC) standard errors (4-lags) and t-statistics to compute confidence levels. See Annex 2 for full regression outputs. I first estimate the full equation (Model 11.1.), and fail to show statistical significance. However, this may be driven by model overfitting in a relatively small sample of 42 observations. An F-test on the joint significance of Quarter 1 and 2 yield a p-value of 0.101 against the null hypothesis that both have a coefficient of 0. Hence, in Model 11.2. I remove both controls and find that Card Share is highly significant in the expected direction: an increase in Card Share increases C-efficiency. Moreover, in Model 11.3., I show that removing Card Share from this equation significantly lowers the explanatory power of the model, dropping the R squared from 0.346 to 0.250.

4.4. Discussion and Limitations

In this part of my thesis, I demonstrated how easily available macroeconomic data can be used to demonstrate an association between the share of card payments in consumption and VAT

compliance. While I used data from Hungary, these findings are in line with findings in Greece, relying on a similar indicator of VAT compliance (Hondroyiannis and Papaoikonomou 2017).

Nevertheless, this analysis has important limitations. As discussed above, the indicator used for VAT compliance (called C-efficiency) is crude and does not differentiate between VAT evaded and VAT not paid due to legal exemptions and VAT reductions. Besides, the small sample size of the study did not allow for additional controls, and therefore, omitted variable bias cannot be ruled out. Both VAT evasion and the share of card payments in consumption can be expected to positively correlate with advancements in the VAT enforcement regime, for instance. To mitigate some of these shortcomings, in the next section I use a more robust indicator of VAT compliance, as well as a larger panel dataset that allows to control for multiple country-level characteristics.

CHAPTER FIVE: EUROPEAN PANEL ESTIMATES

This chapter presents estimates of Equation 8 using data from a panel of 21 European countries. Section 5.1. introduces the model. Section 5.2. discusses the datasets used and their properties. Section 5.3. presents the results and Section 5.4. discusses them.

5.1. Regression Model

Beyond Equation 8, I hypothesize that the VAT Gap is driven by multiple country-level factors in Europe. Moreover, VAT Gap may be driven both by unobserved constant country-level characteristics (such as cultural determinants of corruption), and may trend over time downwards as European countries develop. To model this relationship, I include both country-level controls as well as time and country fixed effects.

$$\begin{aligned} VAT\ Gap_{i,t} = & \beta_0 + \beta_1 Card\ Share_{i,t} + \beta_2 GDP\ Per\ Capita_{i,t} + \beta_3 Tax\ of\ GDP_{i,t} \\ & + \beta_4 Imports\ of\ GDP_{i,t} + \beta_5 Services\ of\ GDP_{i,t} + \beta_6 VAT\ Rate_{i,t} \\ & + \sum_{i=1}^{I-1} \gamma_i + \sum_{t=1}^{T-1} \delta_t + u_{i,t} \end{aligned}$$

Equation 12. European Panel Model

My key parameter of interest will be $\widehat{\beta}_1$, I expect it to be negative (higher share of card payments should reduce VAT Gap) and statistically significant. The γ_i -s and δ_t -s are the coefficients on dummies of all periods and entities (countries in our case), and filter out common effects on VAT Gap and Card Share present by year (e.g. a common time trend expected in both) or by country (e.g. some countries may have both low VAT Gap and high Card Share). To get more reliable estimates of the R-squared of this model, I will replace these dummies with panel-OLS time and entity demeaned data, which yields identical coefficients and standard errors (Wooldridge 2013, 488-489).

I also include numerous other control variables, primarily to avoid omitted variable bias on $\widehat{\beta}_1$, but they may reveal important information about efficient VAT design. GDP per capita is included mainly since development can be assumed to correlate negatively with tax evasion but positively with card payments. Tax of GDP (in % terms) controls for the overall size of the state, which again may carry important information about the effectiveness of the state. Imports of GDP are often theorised to be correlated with VAT compliance, both because VAT is believed to be a good replacement for tariffs in an open economy (Aizenman and Jinjarak 2009) and because VAT collection at borders is often deemed to be more effective than on domestic consumption (Morrow, Smart, and Swistak 2022). Services of GDP are included because it may be that VAT on services is harder to collect than VAT on goods, the two key components of consumption. The coefficient on VAT Rate, if positive, may be a sign of a Laffer curve as found by many authors: namely, that VAT rate increases on the one hand increase VAT revenue directly, but on the other hand decrease compliance by making it more costly for economic actors to comply (Agha and Haughton 1996; Hondroyiannis and Papaoikonomou 2017).

5.2. Data

5.2.1. Data Sources

I use yearly data for European countries that is made available freely online by the international organisations mentioned below. The period covered is 2000-2020, and since both EU and OECD sources were used, only those countries were included on which both organisations report data (21 in total). There were some missing observations, yielding a number of observations of 423.

Data on the VAT Gap is taken from the revised panel data of the 2024 VAT Report of the European Commission (European Commission et al. 2024). The authors estimated a theoretical

VAT revenue under full compliance (taking into account exemptions and VAT reductions), and measured by what percentage points does actual VAT revenue deviate from that.

Data on card payments is taken from the European Central Bank’s dataset (European Central Bank 2022). This variable measures the number of card transactions as a share of all transactions in each EU country in each year. This is different from the variable I construct and use above in the Hungary-level estimates, which measures the share of card transaction value in the value of all consumption. I need to note here that the indicator used in Part 4 was more in line with Equation 8 I theorised, as it is based on the share of card payment value in all transaction value.

Data on GDP per capita is taken from Eurostat (Eurostat 2025). I use purchasing-power-adjusted data since I use it as a proxy for development, as explained above. Data on services and imports as % of GDP is taken from the World Bank’s databases (World Bank 2023a; 2023b). Data on tax revenues as % of GDP come from OECD’s database (OECD 2024). Lastly, data on the standard VAT rate in each country and year were taken from the OECD’s Consumption Tax Trends website, specifically its accompanying datasets (OECD 2022).

5.2.2. Descriptive Statistics

<i>Variable</i>	<i>Mean</i>	<i>Standard Deviation</i>	<i>Minimum</i>	<i>Maximum</i>	<i>Count</i>
<i>VAT Gap</i>	13.43	8.02	-0.88	37.27	423
<i>Card Share</i>	42.9	17.32	2.57	81.37	423
<i>GDP Per Capita</i>	32608.52	19981.22	6550	109090	423
<i>Tax of GDP</i>	37.03	5.66	19.37	50.02	423
<i>Imports of GDP</i>	55.53	26.45	22.77	169.15	423
<i>Services of GDP</i>	62.26	5.71	51.84	80.08	423
<i>VAT Rate</i>	20.93	2.65	15	27	423

Table 2. Descriptive statistics for a panel of European countries.

As we can see in Table 2, the average VAT Gap was 13.43% in this period in the selected European countries, whereas Card Share was 42.9%. The countries collected on average 37%

of their GDP as tax revenues. The studied countries import a significant amount, at 55% of GDP, hence are quite open economies, which is unsurprising given the fact that all of them are members of the EU Single Market. They are also heavily service-based, with 60% of their GDP coming from services. The average VAT rate was roughly 21%.

As a next illustration, we may try to plot a regression line between the two variables. Since we are using panel data, it may be misleading to use a scatter plot in itself, for it may only illustrate common time trends or differences among countries. One way to resolve this issue is to ‘control’ for country and year by demeaning the data by country and year (Wooldridge 2013, 484-485). Essentially, this means subtracting from each observation its corresponding country and year mean. I show this plot in Figure 6. The negative slope of the fitted regression line is by our expectations: a unit positive deviation of Card Share from country and year means

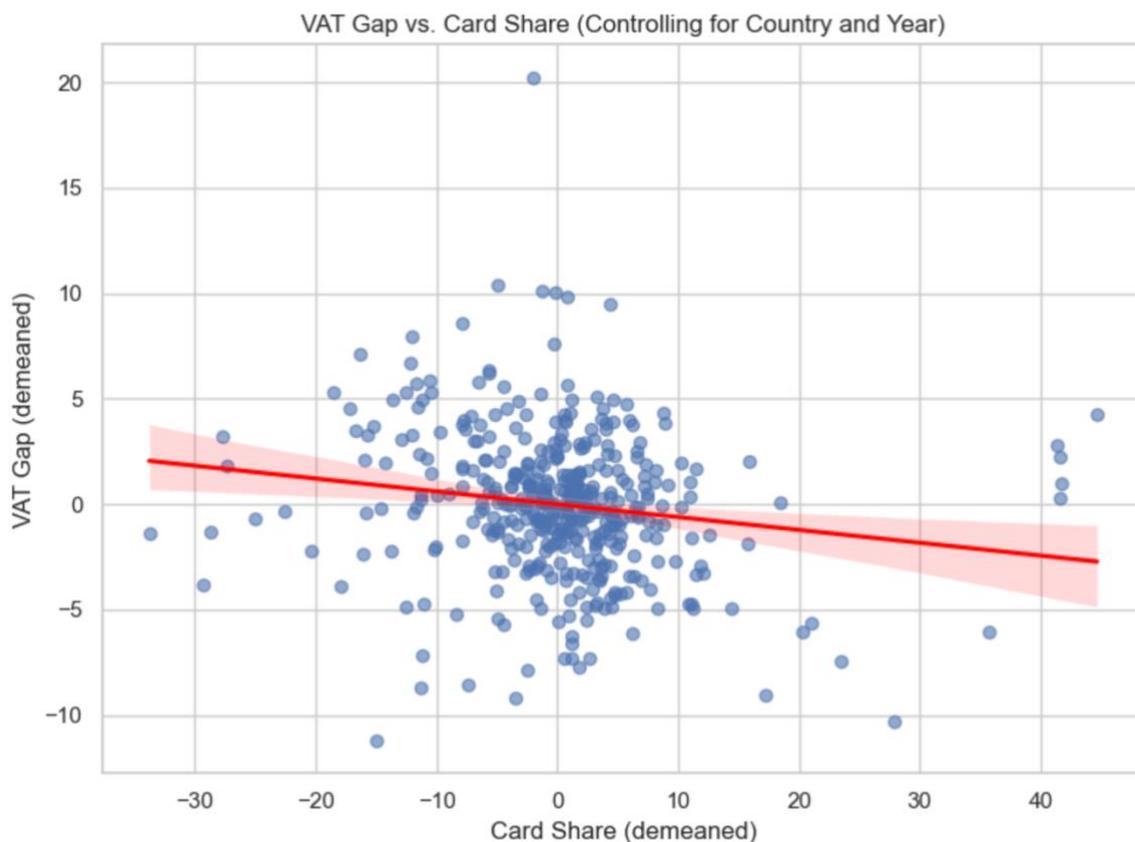


Figure 6. Scatter plot of Card Share and VAT Gap, demeaned by year and country. Shaded areas show 95% confidence intervals.

translates to a negative deviation of VAT Gap from country and year means. I will test this hypothesis more rigorously in what follows.

It is worth looking at the pairwise correlations of the variables I aim to include in my model. This is because too high correlations between the explanatory variables explode the standard errors, as the model fails to estimate marginal effects. I present a correlation heatmap in Figure 7. As we can see, there is a good variation in the data, and none of the variables exhibit a correlation above, say, 0.8 or 0.9, which could be a cause for concern in using them in the same regression. Card Share and VAT Gap are negatively correlated, as expected.

Lastly, in Chapter 4, I found unit roots in both GDP and Card Share in the case of Hungary using simple time series unit root tests. Testing for the stationarity of panel data, however, goes beyond the scope of this thesis. This limitation will be discussed below in more detail.

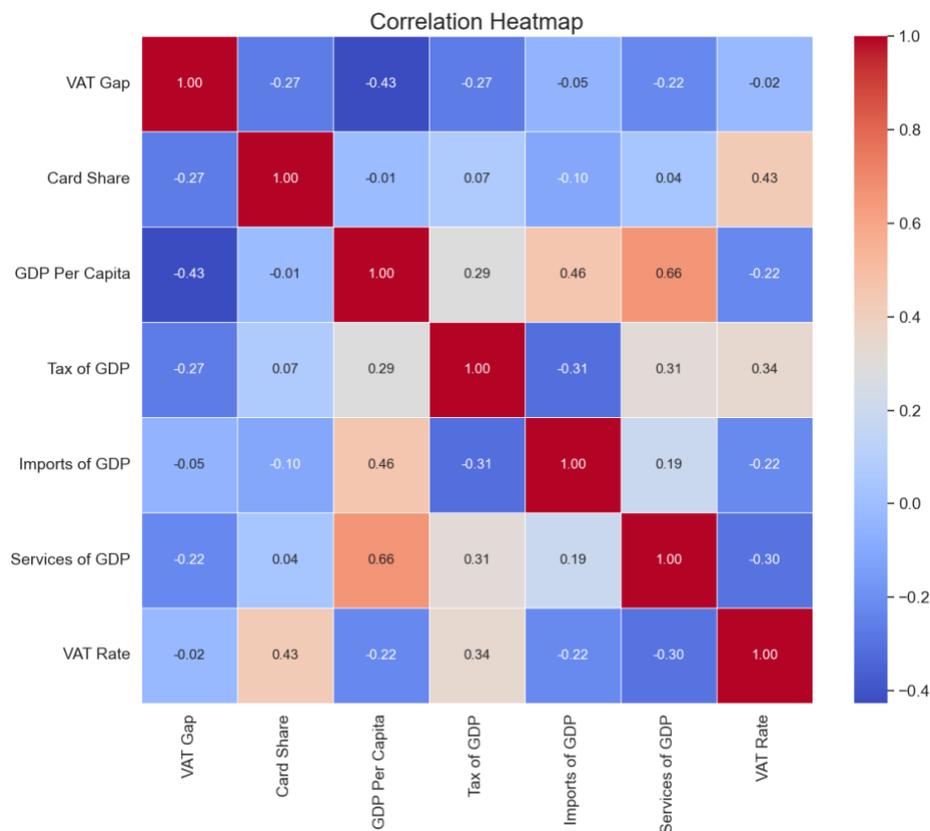


Figure 7. Correlation heatmap for variables in panel of European countries.

5.3. Results

I present in Tables 3 and 4 the panel OLS estimation results of Equation 12. Since I am using panel data, autocorrelation between the errors may occur because observations are made over time and among countries. A general method to use standard errors that are both heteroskedasticity and autocorrelation robust is clustered standard errors (Wooldridge 2013, 483). Recently, it has been argued that in certain circumstances, clustering can unnecessarily inflate the estimated standard errors (Abadie et al. 2023). A critical discussion of this question is beyond the scope of this thesis; hence, for the sake of transparency, I report both heteroskedasticity robust p-values and clustered (by time and entity) p-values below.

	<i>Model</i> <i>12.1.</i>	<i>Model</i> <i>12.2.</i>	<i>Model</i> <i>12.3.</i>	<i>Model</i> <i>12.4.</i>	<i>Model</i> <i>12.5.</i>	<i>Model</i> <i>12.6.</i>	<i>Model</i> <i>12.7.</i>
<i>Dependent variable</i>	VAT Gap	VAT Gap		VAT Gap	VAT Gap	VAT Gap	VAT Gap
<i>Card Share</i>	-0.0577** (0.0244)	-	-0.0611** (0.0133)	-0.0609** (0.0247)	-0.0511** (0.0253)	-0.0538** (0.0252)	-0.0629** (0.0248)
<i>GDP p.c.</i>	-7.338e-05 (0.0001)	-5.683e-05 (0.0001)	-	-1.013e-05 (0.0001)	2.639e-05 (0.0001)	5.53e-05 (0.0001)	-8.561e-05 (0.0001)
<i>Services</i>	0.1188 (0.1148)	0.2074* (0.1172)	-	-	0.1909 (0.1177)	0.1796 (0.1174)	0.1238 (0.1185)
<i>Imports</i>	-0.0391 (0.0399)	-0.0174 (0.0358)	-	-	-	-0.0329 (0.0409)	-0.0460 (0.0411)
<i>Tax</i>	-0.3978** (0.1626)	-0.3315* (0.1718)	-	-	-	-	-0.3615 (0.1667)
<i>VAT Rate</i>	0.4336* (0.2379)	0.4907** (0.2448)	-	-	-	-	-
<i>R squared</i>	0.0645	0.0451	0.0252	0.0253	0.0340	0.0357	0.0512
<i>Fixed Effects</i>	Time, Entity						
<i>n</i>	423	423	423	423	423	423	423

Table 3. Panel OLS estimates for a European panel of countries. Standard errors are computed using heteroskedasticity-robust standard errors. ***: $p < 0.01$, **: $p < 0.05$, *: $p < 0.1$

	<i>Model</i> 12.1.	<i>Model</i> 12.2.	<i>Model</i> 12.3.	<i>Model</i> 12.4.	<i>Model</i> 12.5.	<i>Model</i> 12.6.	<i>Model</i> 12.7.
<i>Dependent variable</i>	VAT Gap	VAT Gap	VAT Gap	VAT Gap	VAT Gap	VAT Gap	VAT Gap
<i>Card Share</i>	-0.0577 (0.0623)	-	-0.0611 (0.0634)	-0.0609 (0.0636)	-0.0511 (0.0670)	-0.0538 (0.0647)	-0.0629 (0.0645)
<i>GDP p.c.</i>	-7.338e-05 (0.0002)	-5.683e-05 (0.0002)	-	-1.013e-05 (0.0002)	2.639e-05 (0.0002)	5.53e-05 (0.0002)	-8.561e-05 (0.0002)
<i>Services</i>	0.1188 (0.1927)	0.2074 (0.1902)	-	-	0.1909 (0.2148)	0.1796 (0.2168)	0.1238 (0.1948)
<i>Imports</i>	-0.0391 (0.0533)	-0.0174 (0.0527)	-	-	-	-0.0329 (0.0618)	-0.0460 (0.0602)
<i>Tax</i>	-0.3978 (0.2756)	-0.3315 (0.3206)	-	-	-	-	-0.3615 (0.3105)
<i>VAT Rate</i>	0.4336 (0.4998)	0.4907 (0.5406)	-	-	-	-	-
<i>R squared</i>	0.0645	0.0451	0.0252	0.0253	0.0340	0.0357	0.0512
<i>Fixed Effects</i>	Time, Entity	Time, Entity	Time, Entity	Time, Entity	Time, Entity	Time, Entity	Time, Entity
<i>n</i>	423	423	423	423	423	423	423

Table 4. Panel OLS estimates for a panel of European countries. Standard errors are computed using two-way clustered standard errors (by time and entity). ***: $p < 0.01$, **: $p < 0.05$, *: $p < 0.1$

The first thing to notice from Table 4 is that under clustering by time and entity, all of my coefficients become statistically insignificant. Whether these standard errors are inflated comes down to an application of recent findings by Abide et al. 2023. It certainly suggests, however, that all my findings in Table 3, using merely heteroskedasticity robust standard errors, should be treated with some caution.

With this limitation in mind, the heteroskedasticity robust estimates in Table 3 look promising. The coefficient of my key variable of interest, Card Share, remains significant under all specifications and has the expected sign. Moreover, the magnitude of the coefficient does not change drastically under the different specifications of the model, indicating that no significant confounding factor was found. Its interpretation is that a one percentage point ceteris paribus increase in the share of card transactions in the number of all transactions translates to an approximately 0.05-0.06 decrease in the VAT Gap on average. Moreover, while all specifications suffer from a low R-squared (which in part can be explained by the fact that the data has been demeaned by year and country in the panel OLS model), removing and adding Card Share to

the equation increased the R-squared from 0.045 to 0.066, which is a larger increase than in the case of other variables. These findings are in line with recent findings by other authors, relying on similar indicators (Holá, Arltová, and Zídková 2022).

My findings also give weak evidence for my expectation that services are more prone to VAT noncompliance. However, this coefficient becomes insignificant once we include Card Share as a variable, which may suggest that part of the reason why services may be more risky in terms of compliance is that cash usage is more widespread in these sectors.

There is more compelling evidence that the overall size of the state (measured by tax revenue as % of GDP) reduced VAT non-compliance. This may be because a larger state also has more resources to enforce its tax system.

Lastly, my results also give some weak evidence for the existence of the Laffer curve: that is, that a higher VAT rate increases non-compliance, and therefore does not unambiguously lead to higher VAT revenue. To illustrate this, let's assume that an economy starts with VAT Rate = VAT GAP = 0, has a constant consumption of 1000 units, and gradually increases VAT Gap by 0.43 (coefficient estimate from Model 12.1) for each unit increase in VAT Rate. Under these assumptions, actual VAT revenue can be described as a function of VAT rate only:

$$\text{Actual VAT Revenue} = \text{Vat Rate} \times \text{Consumption} \times (1 - \text{VAT Gap}),$$

where: VAT Gap = 0.43 × VAT Rate, Consumption = 1000

Equation 13: VAT Laffer Curve

Using Equation 13., I plot actual and ideal VAT revenue for each VAT rate that is implied by this set of assumptions in Figure 8. Earlier authors found a VAT Laffer curve and a revenue maximising VAT rate at 25%, using data from 1987 (Agha and Haughton 1996). My results suggests that such worries, at least in Europe, are no longer a reality – which is consistent with my thesis that the rise of electronic payments improved compliance over time. Nevertheless,

the plot suggests that for high levels of VAT rates, their impact on VAT compliance is still non-negligible.

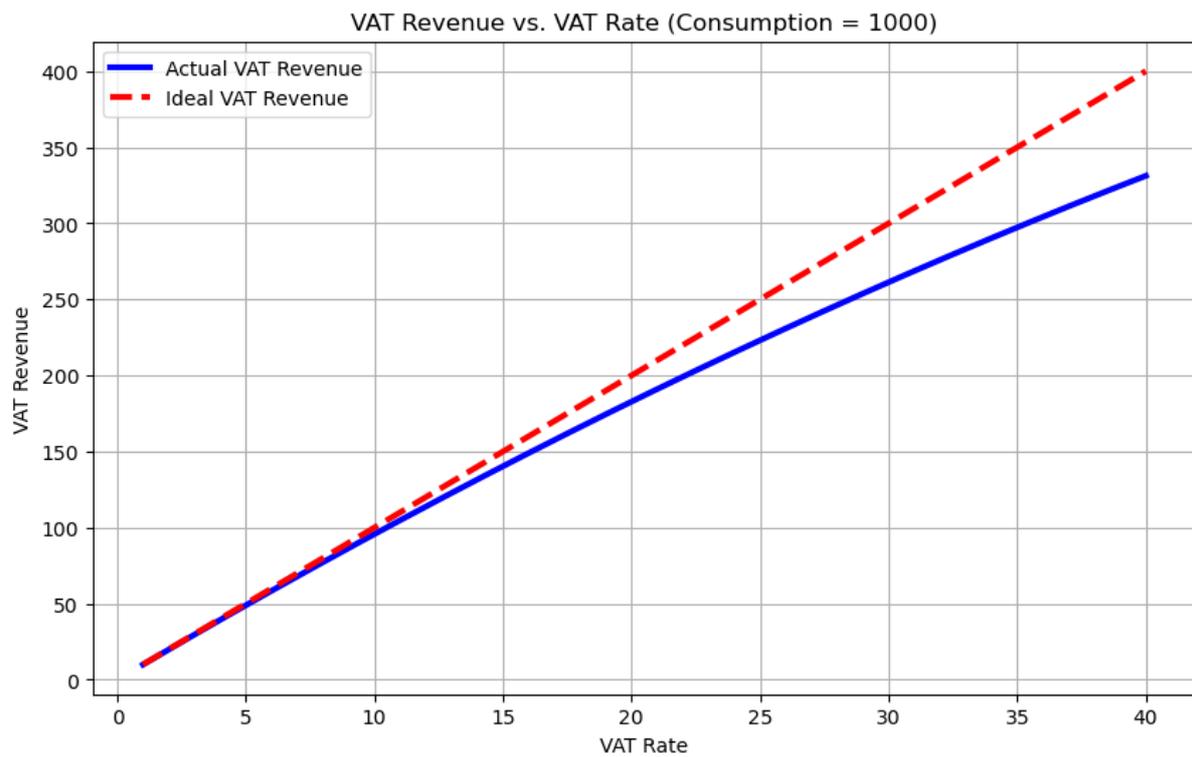


Figure 8: Ideal and actual VAT revenues for different levels of VAT rate.

5.4. Discussion and Limitations

In this section, I provided limited evidence that a higher share of card payments translates to lower VAT non-compliance. I used the European Commission's VAT Gap to indicate VAT non-compliance, which is significantly more robust than the widely used C-efficiency indicator, as it accounts for differentiated VAT rates on products. I also employed a large sample of 21 European countries observed over 20 years, allowing for a rich set of controls. With this toolkit, I have shown that, using heteroskedasticity robust standard errors, a *ceteris paribus* unit increase of the share of card transactions in the number of all transactions translates to a 0.05-0.06 lower VAT Gap on average. These results held under alternative specifications of the model.

However, my findings are not without limitations. The results became statistically insignificant once I used two-way clustering to compute the standard errors (by time and entity). Also, testing for panel-cointegration went beyond the scope of my thesis; hence, should any variables suffer from the presence of a unit-root, spurious regression estimates cannot be ruled out. In both cases, it may be argued that these robustness checks are unnecessary: in the first case, it has been argued that two-way clustered standard errors can unnecessarily inflate standard errors (Abadie et al. 2023), whereas in the second case, the non-stationarity of variables was not formally established. A formal treatment of these questions goes beyond the scope of the thesis, however, they give reasons not to accept my initial heteroskedasticity-robust results immediately.

CHAPTER SIX: CONCLUSION

This thesis empirically analysed the relationship between card payments and VAT compliance. It did so in two ways: first, by using quarterly time-series data from Hungary, and second, by using yearly panel data from 21 European economies. In both cases, limited evidence was found for a positive impact of card payments on VAT compliance. More specifically, in the second test, it was estimated that a *ceteris paribus* percentage-point increase in the share of card payments in all transactions reduced VAT non-compliance by 0.05-0.06 percentage points on average. This is in line with recent and rare findings in the literature (Hondroyiannis and Papoikonomou 2017; 2020; Holá, Arltová, and Zidková 2022; Madzharova 2020).

It must be noted that both tests suffer from limitations. The first empirical test was primarily limited by the crudeness of the indicator for VAT compliance. C-efficiency lumps together two kinds of deviations from an ideal VAT revenue levied on all consumption at a uniform rate: those caused by VAT reductions and exemptions, and those by non-compliance. I used it as a proxy only for the latter one. While the second empirical test used a more robust indicator, as well as a much larger sample, I failed to demonstrate statistical significance once I used two-way clustered standard errors on top of heteroskedasticity robust ones. While these limitations should be kept in mind, my findings are among the first empirical tests of the relationship between card payments and VAT compliance.

There are two kinds of policy implications of my findings. The first is that as countries become more technologically advanced, and as card payments are becoming more widespread, VAT efficiency is likely to increase. There are two channels via which this is likely to happen: given the traceability of electronic payments, retailers are likely to perceive the probability of punishment as higher; and given the possibility of automatic transmission of electronic payments to VAT authorities, costs of compliance may become lower. The first of these two

can materialize even when there is no intervention on the side of the government. This suggests that VAT is likely to become a more efficient tax than it used to be in the past.

The second policy implication is that governments may incentivise the use of card payments to fight VAT evasion. Many possible avenues exist: taxing cash withdrawals, subsidising the opening of bank accounts, or making it obligatory for retailers to accept card payments. While academic research on the costs and benefits of such policies is rare, some warn that in certain circumstances, the costs associated with restricting the use of cash (such as higher exposure to online fraud) can outweigh the benefits of lower VAT noncompliance (Immordino and Russo 2018; Alvarez et al. 2022). Hence, future research is needed before a clear policy recommendation can be made.

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ANNEX 1: UNIT-ROOT TESTS FOR HUNGARIAN DATA

ADF Test for 'GDP':

Test Statistic: 1.3995

p-value: 0.9971

Lags Used: 7

Number of Observations: 35

Critical Values:

1%: -3.6327

5%: -2.9485

10%: -2.6130

Conclusion: Fail to reject the null hypothesis – the series is likely non-stationary.

ADF Test for 'Compliance':

Test Statistic: -1.7833

p-value: 0.3888

Lags Used: 3

Number of Observations: 39

Critical Values:

1%: -3.6104

5%: -2.9391

10%: -2.6081

Conclusion: Fail to reject the null hypothesis – the series is likely non-stationary.

ADF Test for 'Card Share':

Test Statistic: -1.5405

p-value: 0.5134

Lags Used: 6

Number of Observations: 36

Critical Values:

1%: -3.6267

5%: -2.9460

10%: -2.6117

Conclusion: Fail to reject the null hypothesis – the series is likely non-stationary.

ANNEX 2: HUNGARIAN TIME-SERIES REGRESSION OUTPUTS

OLS Regression Results

Dep. Variable:	D_Compliance	R-squared:	0.401			
Model:	OLS	Adj. R-squared:	0.299			
Method:	Least Squares	F-statistic:	5.837			
Date:	Sat, 24 May 2025	Prob (F-statistic):	0.000270			
Time:	03:21:24	Log-Likelihood:	-131.68			
No. Observations:	42	AIC:	277.4			
Df Residuals:	35	BIC:	289.5			
Df Model:	6					
Covariance Type:	HAC					
	coef	std err	t	P> t	[0.025	0.975]
const	248.7851	340.880	0.730	0.470	-443.237	940.807
D_Card_Share	1.4370	2.112	0.680	0.501	-2.850	5.724
D_GDP	8.817e-07	2.36e-06	0.374	0.711	-3.91e-06	5.67e-06
Year	-0.1254	0.170	-0.739	0.465	-0.470	0.219
Q1	1.5393	9.131	0.169	0.867	-16.997	20.075
Q2	6.2482	5.900	1.059	0.297	-5.729	18.225
Q3	6.3912	2.557	2.500	0.017	1.201	11.582
Omnibus:		1.643	Durbin-Watson:		2.868	
Prob(Omnibus):		0.440	Jarque-Bera (JB):		0.759	
Skew:		0.038	Prob(JB):		0.684	
Kurtosis:		3.654	Cond. No.		1.15e+09	

OLS Regression Results

Dep. Variable:	D_Compliance	R-squared:	0.346			
Model:	OLS	Adj. R-squared:	0.275			
Method:	Least Squares	F-statistic:	6.574			
Date:	Sat, 24 May 2025	Prob (F-statistic):	0.000422			
Time:	03:16:29	Log-Likelihood:	-133.54			
No. Observations:	42	AIC:	277.1			
Df Residuals:	37	BIC:	285.8			
Df Model:	4					
Covariance Type:	HAC					
=====						
	coef	std err	t	P> t	[0.025	0.975]

const	134.5495	320.257	0.420	0.677	-514.353	783.452
D_Card_Share	3.5884	1.127	3.185	0.003	1.306	5.871
D_GDP	1.091e-06	5.75e-07	1.898	0.066	-7.39e-08	2.26e-06
Year	-0.0677	0.159	-0.427	0.672	-0.389	0.254
Q3	1.2170	2.165	0.562	0.577	-3.169	5.603
=====						
Omnibus:		1.441	Durbin-Watson:		2.644	
Prob(Omnibus):		0.486	Jarque-Bera (JB):		0.716	
Skew:		0.286	Prob(JB):		0.699	
Kurtosis:		3.285	Cond. No.		1.10e+09	
=====						

OLS Regression Results

```

=====
Dep. Variable:          D_Compliance    R-squared:                0.250
Model:                  OLS             Adj. R-squared:           0.191
Method:                 Least Squares   F-statistic:              6.421
Date:                   Sat, 24 May 2025  Prob (F-statistic):       0.00126
Time:                   03:38:24        Log-Likelihood:           -136.42
No. Observations:      42              AIC:                      280.8
Df Residuals:          38              BIC:                      287.8
Df Model:               3
Covariance Type:       HAC
=====

```

```

=====
              coef    std err          t      P>|t|      [0.025    0.975]
-----+-----
const         283.3953    293.006     0.967     0.340    -309.764    876.554
D_GDP         1.608e-06    6.43e-07     2.501     0.017     3.07e-07    2.91e-06
Year          -0.1412         0.145    -0.973     0.336     -0.435     0.152
Q3             5.0044         1.897     2.638     0.012     1.165     8.844
=====

```

```

=====
Omnibus:                 4.394    Durbin-Watson:           2.778
Prob(Omnibus):           0.111    Jarque-Bera (JB):       3.292
Skew:                    0.659    Prob(JB):               0.193
Kurtosis:                3.378    Cond. No.               1.10e+09
=====

```

ANNEX 3: EUROPEAN PANEL REGRESSION OUTPUTS (HETEROSKEDASTICITY-ROBUST STANDARD ERRORS)

PanelOLS Estimation Summary

Dep. Variable:	VAT Gap	R-squared:	0.0451
Estimator:	PanelOLS	R-squared (Between):	0.1296
No. Observations:	423	R-squared (Within):	0.0635
Date:	Thu, May 15 2025	R-squared (Overall):	0.1120
Time:	11:10:45	Log-likelihood	-1112.9
Cov. Estimator:	Clustered		
		F-statistic:	3.5584
Entities:	21	P-value	0.0037
Avg Obs:	20.143	Distribution:	F(5,377)
Min Obs:	16.000		
Max Obs:	21.000	F-statistic (robust):	2.5962
		P-value	0.0252
Time periods:	21	Distribution:	F(5,377)
Avg Obs:	20.143		
Min Obs:	17.000		
Max Obs:	21.000		

Parameter Estimates

	Parameter	Std. Err.	T-stat	P-value	Lower CI	Upper CI
const	5.3666	14.676	0.3657	0.7148	-23.491	34.224
GDP Per Capita	-5.683e-05	0.0001	-0.4304	0.6671	-0.0003	0.0002
Services of GDP	0.2074	0.1172	1.7694	0.0776	-0.0231	0.4380
Imports of GDP	-0.0174	0.0358	-0.4851	0.6279	-0.0878	0.0531
Tax of GDP	-0.3315	0.1718	-1.9288	0.0545	-0.6694	0.0064
VAT Rate	0.4907	0.2448	2.0045	0.0457	0.0094	0.9720

F-test for Poolability: 31.686

P-value: 0.0000

Distribution: F(40,377)

Included effects: Entity, Time

PanelOLS Estimation Summary

Dep. Variable:	VAT Gap	R-squared:	0.0645
Estimator:	PanelOLS	R-squared (Between):	0.2282
No. Observations:	423	R-squared (Within):	0.1503
Date:	Thu, May 15 2025	R-squared (Overall):	0.2104
Time:	11:11:15	Log-likelihood	-1108.5
Cov. Estimator:	Clustered		
		F-statistic:	4.3203
Entities:	21	P-value	0.0003
Avg Obs:	20.143	Distribution:	F(6,376)
Min Obs:	16.000		
Max Obs:	21.000	F-statistic (robust):	3.9277
		P-value	0.0008
Time periods:	21	Distribution:	F(6,376)
Avg Obs:	20.143		
Min Obs:	17.000		
Max Obs:	21.000		

Parameter Estimates

	Parameter	Std. Err.	T-stat	P-value	Lower CI	Upper CI
const	18.741	14.760	1.2697	0.2050	-10.281	47.763
Card Share	-0.0577	0.0244	-2.3618	0.0187	-0.1057	-0.0097
GDP Per Capita	-7.338e-05	0.0001	-0.5548	0.5794	-0.0003	0.0002
Services of GDP	0.1188	0.1148	1.0349	0.3014	-0.1069	0.3446
Imports of GDP	-0.0391	0.0399	-0.9807	0.3274	-0.1175	0.0393
Tax of GDP	-0.3978	0.1626	-2.4472	0.0149	-0.7175	-0.0782
VAT Rate	0.4336	0.2379	1.8228	0.0691	-0.0341	0.9013

F-test for Poolability: 28.380

P-value: 0.0000

Distribution: F(40,376)

Included effects: Entity, Time

PanelOLS Estimation Summary

```

=====
Dep. Variable:          VAT Gap   R-squared:              0.0357
Estimator:             PanelOLS  R-squared (Between):   -0.2512
No. Observations:      423     R-squared (Within):    0.0840
Date:                  Wed, May 14 2025  R-squared (Overall):  -0.1640
Time:                  18:56:50   Log-likelihood         -1115.0
Cov. Estimator:        Clustered

                               F-statistic:            3.4936
Entities:              21       P-value                 0.0081
Avg Obs:               20.143   Distribution:           F(4,378)
Min Obs:               16.000
Max Obs:               21.000   F-statistic (robust):  2.2615
                               P-value                 0.0620
Time periods:         21       Distribution:           F(4,378)
Avg Obs:               20.143
Min Obs:               17.000
Max Obs:               21.000
  
```

Parameter Estimates

```

=====
                Parameter  Std. Err.    T-stat    P-value    Lower CI    Upper CI
-----
const           4.6258      9.5887     0.4824    0.6298    -14.228    23.480
Card Share     -0.0538      0.0252    -2.1402    0.0330    -0.1033    -0.0044
GDP Per Capita 5.53e-05      0.0001     0.4644    0.6427    -0.0002    0.0003
Services of GDP 0.1796      0.1174     1.5299    0.1269    -0.0512    0.4105
Imports of GDP -0.0329      0.0409    -0.8037    0.4221    -0.1134    0.0476
=====
  
```

F-test for Poolability: 28.293

P-value: 0.0000

Distribution: F(40,378)

Included effects: Entity, Time

PanelOLS Estimation Summary

```

=====
Dep. Variable:          VAT Gap    R-squared:              0.0340
Estimator:             PanelOLS   R-squared (Between):    -0.1689
No. Observations:      423      R-squared (Within):     0.0765
Date:                  Wed, May 14 2025  R-squared (Overall):    -0.1040
Time:                  18:56:33    Log-likelihood           -1115.3
Cov. Estimator:        Clustered

                               F-statistic:             4.4462
Entities:              21      P-value                  0.0044
Avg Obs:               20.143   Distribution:            F(3,379)
Min Obs:               16.000
Max Obs:               21.000   F-statistic (robust):   2.8174
                               P-value                  0.0389
Time periods:         21      Distribution:            F(3,379)
Avg Obs:               20.143
Min Obs:               17.000
Max Obs:               21.000
  
```

Parameter Estimates

```

=====
                Parameter  Std. Err.    T-stat    P-value    Lower CI    Upper CI
-----
const           2.9177      9.2480     0.3155    0.7526    -15.266    21.101
Card Share     -0.0511      0.0253    -2.0188    0.0442    -0.1009    -0.0013
GDP Per Capita 2.639e-05     0.0001     0.2234    0.8234    -0.0002     0.0003
Services of GDP 0.1909      0.1177     1.6217    0.1057    -0.0405     0.4222
=====
  
```

F-test for Poolability: 29.481

P-value: 0.0000

Distribution: F(40,379)

Included effects: Entity, Time

PanelOLS Estimation Summary

```

=====
Dep. Variable:          VAT Gap   R-squared:              0.0253
Estimator:             PanelOLS  R-squared (Between):    0.0765
No. Observations:     423       R-squared (Within):     0.0683
Date:                 Wed, May 14 2025  R-squared (Overall):    0.0747
Time:                 18:56:10    Log-likelihood          -1117.2
Cov. Estimator:       Clustered

                          F-statistic:              4.9230
Entities:              21       P-value                 0.0077
Avg Obs:              20.143    Distribution:            F(2,380)
Min Obs:              16.000
Max Obs:              21.000    F-statistic (robust):   3.1424
                          P-value                 0.0443
Time periods:         21       Distribution:            F(2,380)
Avg Obs:              20.143
Min Obs:              17.000
Max Obs:              21.000
  
```

Parameter Estimates

```

=====
              Parameter  Std. Err.   T-stat   P-value   Lower CI   Upper CI
-----
const          16.393    3.6821    4.4521   0.0000    9.1532    23.633
Card Share    -0.0609    0.0247   -2.4699   0.0140   -0.1094   -0.0124
GDP Per Capita -1.013e-05  0.0001   -0.0891   0.9290   -0.0002    0.0002
=====
  
```

F-test for Poolability: 29.627
P-value: 0.0000
Distribution: F(40,380)

Included effects: Entity, Time

PanelOLS Estimation Summary

Dep. Variable:	VAT Gap	R-squared:	0.0512
Estimator:	PanelOLS	R-squared (Between):	0.2393
No. Observations:	423	R-squared (Within):	0.1386
Date:	Wed, May 14 2025	R-squared (Overall):	0.2157
Time:	18:57:18	Log-likelihood	-1111.5
Cov. Estimator:	Clustered		
		F-statistic:	4.0654
Entities:	21	P-value	0.0013
Avg Obs:	20.143	Distribution:	F(5,377)
Min Obs:	16.000		
Max Obs:	21.000	F-statistic (robust):	3.0564
		P-value	0.0102
Time periods:	21	Distribution:	F(5,377)
Avg Obs:	20.143		
Min Obs:	17.000		
Max Obs:	21.000		

Parameter Estimates

	Parameter	Std. Err.	T-stat	P-value	Lower CI	Upper CI
const	27.160	13.068	2.0784	0.0383	1.4657	52.855
Card Share	-0.0629	0.0248	-2.5387	0.0115	-0.1116	-0.0142
GDP Per Capita	-8.561e-05	0.0001	-0.6412	0.5218	-0.0003	0.0002
Services of GDP	0.1238	0.1185	1.0444	0.2970	-0.1092	0.3568
Imports of GDP	-0.0460	0.0411	-1.1200	0.2634	-0.1267	0.0348
Tax of GDP	-0.3615	0.1667	-2.1678	0.0308	-0.6893	-0.0336

F-test for Poolability: 28.450

P-value: 0.0000

Distribution: F(40,377)

Included effects: Entity, Time

PanelOLS Estimation Summary

```

=====
Dep. Variable:          VAT Gap    R-squared:              0.0252
Estimator:              PanelOLS  R-squared (Between):    0.0491
No. Observations:      423      R-squared (Within):     0.0666
Date:                   Wed, May 14 2025  R-squared (Overall):    0.0538
Time:                   18:55:52   Log-likelihood           -1117.2
Cov. Estimator:        Clustered

                               F-statistic:             9.8510
Entities:                21      P-value                  0.0018
Avg Obs:                 20.143   Distribution:             F(1,381)
Min Obs:                 16.000
Max Obs:                 21.000   F-statistic (robust):    6.1918
                               P-value                  0.0133
Time periods:           21      Distribution:             F(1,381)
Avg Obs:                 20.143
Min Obs:                 17.000
Max Obs:                 21.000

```

Parameter Estimates

```

=====
                Parameter  Std. Err.    T-stat    P-value    Lower CI    Upper CI
-----
const           16.071     1.0596    15.167    0.0000     13.988     18.154
Card Share     -0.0611     0.0245    -2.4883    0.0133     -0.1093    -0.0128
=====

```

F-test for Poolability: 39.420
P-value: 0.0000
Distribution: F(40,381)

Included effects: Entity, Time

ANNEX 4: EUROPEAN PANEL REGRESSION OUTPUTS (CLUSTERED STANDARD ERRORS)

PanelOLS Estimation Summary

Dep. Variable:	VAT Gap	R-squared:	0.0451
Estimator:	PanelOLS	R-squared (Between):	0.1296
No. Observations:	423	R-squared (Within):	0.0635
Date:	Thu, May 15 2025	R-squared (Overall):	0.1120
Time:	11:13:56	Log-likelihood	-1112.9
Cov. Estimator:	Clustered		
		F-statistic:	3.5584
Entities:	21	P-value	0.0037
Avg Obs:	20.143	Distribution:	F(5,377)
Min Obs:	16.000		
Max Obs:	21.000	F-statistic (robust):	1.0164
		P-value	0.4076
Time periods:	21	Distribution:	F(5,377)
Avg Obs:	20.143		
Min Obs:	17.000		
Max Obs:	21.000		

Parameter Estimates

	Parameter	Std. Err.	T-stat	P-value	Lower CI	Upper CI
const	5.3666	22.752	0.2359	0.8137	-39.369	50.102
GDP Per Capita	-5.683e-05	0.0002	-0.2986	0.7654	-0.0004	0.0003
Services of GDP	0.2074	0.1902	1.0906	0.2761	-0.1666	0.5814
Imports of GDP	-0.0174	0.0527	-0.3301	0.7415	-0.1209	0.0862
Tax of GDP	-0.3315	0.3206	-1.0338	0.3019	-0.9619	0.2990
VAT Rate	0.4907	0.5406	0.9077	0.3646	-0.5723	1.5537

F-test for Poolability: 31.686

P-value: 0.0000

Distribution: F(40,377)

Included effects: Entity, Time

PanelOLS Estimation Summary

Dep. Variable:	VAT Gap	R-squared:	0.0645
Estimator:	PanelOLS	R-squared (Between):	0.2282
No. Observations:	423	R-squared (Within):	0.1503
Date:	Thu, May 15 2025	R-squared (Overall):	0.2104
Time:	11:13:21	Log-likelihood	-1108.5
Cov. Estimator:	Clustered		
		F-statistic:	4.3203
Entities:	21	P-value	0.0003
Avg Obs:	20.143	Distribution:	F(6,376)
Min Obs:	16.000		
Max Obs:	21.000	F-statistic (robust):	1.6293
		P-value	0.1378
Time periods:	21	Distribution:	F(6,376)
Avg Obs:	20.143		
Min Obs:	17.000		
Max Obs:	21.000		

Parameter Estimates

	Parameter	Std. Err.	T-stat	P-value	Lower CI	Upper CI
const	18.741	20.283	0.9239	0.3561	-21.142	58.624
Card Share	-0.0577	0.0623	-0.9265	0.3548	-0.1801	0.0648
GDP Per Capita	-7.338e-05	0.0002	-0.4094	0.6825	-0.0004	0.0003
Services of GDP	0.1188	0.1927	0.6165	0.5379	-0.2601	0.4978
Imports of GDP	-0.0391	0.0533	-0.7346	0.4631	-0.1438	0.0656
Tax of GDP	-0.3978	0.2756	-1.4437	0.1497	-0.9397	0.1440
VAT Rate	0.4336	0.4998	0.8675	0.3862	-0.5491	1.4162

F-test for Poolability: 28.380

P-value: 0.0000

Distribution: F(40,376)

Included effects: Entity, Time

PanelOLS Estimation Summary

```

=====
Dep. Variable:          VAT Gap    R-squared:              0.0512
Estimator:             PanelOLS   R-squared (Between):    0.2393
No. Observations:     423      R-squared (Within):     0.1386
Date:                  Wed, May 14 2025  R-squared (Overall):    0.2157
Time:                  18:49:30    Log-likelihood          -1111.5
Cov. Estimator:       Clustered

                               F-statistic:            4.0654
Entities:              21      P-value                 0.0013
Avg Obs:               20.143   Distribution:           F(5,377)
Min Obs:               16.000
Max Obs:               21.000   F-statistic (robust):   0.9446
                               P-value                 0.4520
Time periods:         21      Distribution:           F(5,377)
Avg Obs:               20.143
Min Obs:               17.000
Max Obs:               21.000
  
```

Parameter Estimates

```

=====
                Parameter  Std. Err.    T-stat    P-value    Lower CI    Upper CI
-----
const           27.160     17.541     1.5484    0.1224    -7.3309    61.651
Card Share      -0.0629     0.0645    -0.9753    0.3300    -0.1897    0.0639
GDP Per Capita -8.561e-05    0.0002    -0.4411    0.6594    -0.0005    0.0003
Services of GDP  0.1238     0.1948     0.6353    0.5256    -0.2593    0.5068
Imports of GDP  -0.0460     0.0602    -0.7638    0.4455    -0.1644    0.0724
Tax of GDP      -0.3615     0.3105    -1.1642    0.2451    -0.9720    0.2491
=====
  
```

F-test for Poolability: 28.450
P-value: 0.0000
Distribution: F(40,377)

Included effects: Entity, Time

PanelOLS Estimation Summary

Dep. Variable:	VAT Gap	R-squared:	0.0357
Estimator:	PanelOLS	R-squared (Between):	-0.2512
No. Observations:	423	R-squared (Within):	0.0840
Date:	Wed, May 14 2025	R-squared (Overall):	-0.1640
Time:	18:49:09	Log-likelihood	-1115.0
Cov. Estimator:	Clustered		
		F-statistic:	3.4936
Entities:	21	P-value	0.0081
Avg Obs:	20.143	Distribution:	F(4,378)
Min Obs:	16.000		
Max Obs:	21.000	F-statistic (robust):	0.6919
		P-value	0.5979
Time periods:	21	Distribution:	F(4,378)
Avg Obs:	20.143		
Min Obs:	17.000		
Max Obs:	21.000		

Parameter Estimates

	Parameter	Std. Err.	T-stat	P-value	Lower CI	Upper CI
const	4.6258	18.379	0.2517	0.8014	-31.512	40.764
Card Share	-0.0538	0.0647	-0.8328	0.4055	-0.1810	0.0733
GDP Per Capita	5.53e-05	0.0002	0.2914	0.7709	-0.0003	0.0004
Services of GDP	0.1796	0.2168	0.8285	0.4079	-0.2467	0.6059
Imports of GDP	-0.0329	0.0618	-0.5320	0.5950	-0.1545	0.0887

F-test for Poolability: 28.293

P-value: 0.0000

Distribution: F(40,378)

Included effects: Entity, Time

PanelOLS Estimation Summary

Dep. Variable:	VAT Gap	R-squared:	0.0340
Estimator:	PanelOLS	R-squared (Between):	-0.1689
No. Observations:	423	R-squared (Within):	0.0765
Date:	Wed, May 14 2025	R-squared (Overall):	-0.1040
Time:	18:48:43	Log-likelihood	-1115.3
Cov. Estimator:	Clustered		
		F-statistic:	4.4462
Entities:	21	P-value	0.0044
Avg Obs:	20.143	Distribution:	F(3,379)
Min Obs:	16.000		
Max Obs:	21.000	F-statistic (robust):	0.7830
		P-value	0.5040
Time periods:	21	Distribution:	F(3,379)
Avg Obs:	20.143		
Min Obs:	17.000		
Max Obs:	21.000		

Parameter Estimates

	Parameter	Std. Err.	T-stat	P-value	Lower CI	Upper CI
const	2.9177	17.355	0.1681	0.8666	-31.207	37.042
Card Share	-0.0511	0.0670	-0.7627	0.4461	-0.1829	0.0807
GDP Per Capita	2.639e-05	0.0002	0.1261	0.8997	-0.0004	0.0004
Services of GDP	0.1909	0.2148	0.8884	0.3749	-0.2315	0.6132

F-test for Poolability: 29.481

P-value: 0.0000

Distribution: F(40,379)

Included effects: Entity, Time

PanelOLS Estimation Summary

Dep. Variable:	VAT Gap	R-squared:	0.0253
Estimator:	PanelOLS	R-squared (Between):	0.0765
No. Observations:	423	R-squared (Within):	0.0683
Date:	Wed, May 14 2025	R-squared (Overall):	0.0747
Time:	18:47:44	Log-likelihood	-1117.2
Cov. Estimator:	Clustered		
		F-statistic:	4.9230
Entities:	21	P-value	0.0077
Avg Obs:	20.143	Distribution:	F(2,380)
Min Obs:	16.000		
Max Obs:	21.000	F-statistic (robust):	0.4814
		P-value	0.6183
Time periods:	21	Distribution:	F(2,380)
Avg Obs:	20.143		
Min Obs:	17.000		
Max Obs:	21.000		

Parameter Estimates

	Parameter	Std. Err.	T-stat	P-value	Lower CI	Upper CI
const	16.393	6.3672	2.5746	0.0104	3.8737	28.912
Card Share	-0.0609	0.0636	-0.9584	0.3385	-0.1859	0.0641
GDP Per Capita	-1.013e-05	0.0002	-0.0530	0.9578	-0.0004	0.0004

F-test for Poolability: 29.627

P-value: 0.0000

Distribution: F(40,380)

Included effects: Entity, Time

PanelOLS Estimation Summary

Dep. Variable:	VAT Gap	R-squared:	0.0252
Estimator:	PanelOLS	R-squared (Between):	0.0491
No. Observations:	423	R-squared (Within):	0.0666
Date:	Wed, May 14 2025	R-squared (Overall):	0.0538
Time:	18:47:14	Log-likelihood	-1117.2
Cov. Estimator:	Clustered		
		F-statistic:	9.8510
Entities:	21	P-value	0.0018
Avg Obs:	20.143	Distribution:	F(1,381)
Min Obs:	16.000		
Max Obs:	21.000	F-statistic (robust):	0.9287
		P-value	0.3358
Time periods:	21	Distribution:	F(1,381)
Avg Obs:	20.143		
Min Obs:	17.000		
Max Obs:	21.000		

Parameter Estimates

	Parameter	Std. Err.	T-stat	P-value	Lower CI	Upper CI
	const	16.071	2.7034	5.9448	0.0000	10.756 21.386
	Card Share	-0.0611	0.0634	-0.9637	0.3358	-0.1857 0.0635

F-test for Poolability: 39.420
P-value: 0.0000
Distribution: F(40,381)

Included effects: Entity, Time