Convergence of European Retail Payment Systems? A Reassessment

Markus Kontny and Francesco Paolo Mongelli[1]

17th July 2020

Abstract

The paper examines convergence in the European cashless retail payment system during 2000-2018. Our aim is to update and expand on Martikainen, Schmiedel and Takalo (2015), still the most advanced European study in this area. Validating their study, we find that there has been convergence in the usage of cashless retail payment instruments, especially among euro area countries. However, we also observe changes in the speed of convergence. The speed of sigma convergence decreases for Cards, Credit Transfers, and Direct Debits after the 2008 break (at the onset of the Global Financial Crisis). Whereas, for E-money we find that dispersion started to increase again after the 2008 break. As a novel contribution to the literature on Retail Payment Instruments, we look for clustering and "clubs of convergence" to determine whether changes are taking place at different speeds across clusters of countries and across RPS instruments. We identify two groups of countries, which one can either frame as cash-intensive vs. non cash-intensive countries, or fast vs. slow adopters. We find that traditional market-based economies exhibit remarkably similar behaviours in the usage of retail payment system instruments since the start of our sample. Considering that our sample period includes the Global Financial Crisis and the Euro Area Crisis, our findings indicate that euro area countries are witnessing RPI convergence. Looking ahead, we should monitor how new technologies change cashless retail payment behaviour in the euro area.

Keywords: Retail payments, Convergence, Financial integration, SEPA, Clusters, Club-convergence.
JEL classification: F20, G20

[1] We are grateful for comments and suggestion from Daniel McLean, Teet Puusepp, Helmut Wacket, Francisco Tur Hartmann, Elke Wunstorf, Nadya Jahn, Emanuela Cerrato, Hanna Häkkinen, Ariana Gilbert, plus participants to several ECB presentations. Andrea Pinna, Monika Hartmann and Viviana Maftei contributed to earlier stages of this project. We are however responsible for any errors or omissions and the views may not reflect those of the ECB. All graphs and results are computed either in Excel, EViews, or using R Code. Code and data for replications will be made available on markuskontny.weebly.com.

1. Introduction

The retail payment system plays an important role in the functioning of the economy, yet it entails *social and private costs.* The costs of providing retail payment services have been estimated to amount to approximately one percent of the Gross Domestic Product (GDP) of the European Union (Schmiedel et al. (2012)).[2] Thus, if the retail payment system could be rendered more efficient, this might reduce such costs. Greater efficiency might also yield indirect benefits by facilitating trade, improving the global supply chain, supporting consumption, enhancing bank sector performance, as well as promoting overall economic growth (Hasan et al. (2012) and (2013)).

The focus of this paper is the convergence of retail payment usage across the European Union, particularly in the euro area. Such convergence might generate some additional favourable effects. As retailers and customers of different European countries increasingly encounter familiar payment methods, the cross-border movement of people, goods, and capital, as well as the provision of cross-border services would become more commonplace (Hasan et al. (2015)). Convergence of retail payment arrangements also brings network externalities (because of the wider circulation of the euro), and economies of scale (from wider usage of similar platforms). Thus, the study of the retail payment system is an economically significant question.[3]

Our aim is to update and expand the findings in Martikainen, Schmiedel and Takalo (2015); thus far the most advanced study in this area (henceforth denoted as Martikainen et al. (2015). These authors note that "*Unlike large value payments, the procedures, instruments and services offered to customers in the field of retail payments have not yet been harmonized in the EU*".[4] Yet, Martikainen et al. (2015) find that cross-country dispersion in the use of payment instruments has declined over time in Europe, and the pace of convergence has picked up since the launch of the euro. The shortcomings identified by Martikainen et al. (2015) are being addressed with the Single Euro Payments Area (SEPA) as well as other initiatives to foster financial integration (see Section 2).

Our analysis (also) differs from that in Martikainen et al. (2015) in diverse ways. In terms of width, Martikainen et al. (2015) investigates the most diffused retail payment instruments at the time: i.e., cash, debit cards, credit cards, direct debits, credit transfers, cheques, and e-money. However, we restrict our analysis by leaving out cash and cheques: the former, because of

[2] Retail payment systems are generally defined as funds transfer systems which typically handle a large volume of payments of relatively low value in forms such as cash, debit cards, credit cards, direct debits, credit transfers, cheques, and e-money. They are generally used for the bulk of payments to and from individuals and between individuals and corporates.

[3] An aspect not discussed here is that the retail payment market is a two-sided market where new payment instruments need to reach a critical mass of users to become viable and grow further (Rochet and Tirole (2006) and Bolt and Humphrey (2007)).

[4] These echoes (ECB (2010) that noted that "*Retail payments are still based largely on national payment instruments and systems. While national payment systems may be cheap and very efficient and offer their users high levels of service when it comes to domestic payments, this is not yet the case for cross-border retail payments in the euro area*".

the different nature of the exercise and the latter because the usage of cheques has faded in most European countries. Specifically, we analyse transaction volumes and values for four different retails payment instruments, i.e. cards (debit and credit cards combined), credit transfers, direct debits, and E-Money. Hence, we concentrate on cashless retail payment instruments. In terms of time span, the sample of Martikainen et al. (2015) ranges from 1995 to 2011 for the whole European Union; our sample, however, ranges from 2000 to 2018 and differentiates between the European Union and the Euro Area. In fact, some of the time series underwent important revisions as documented in the ECB Statistical data Warehouse (SDW). In terms of scope, we replicate all tests in Martikainen et al. (2015) but also expand by testing for "clubs of convergence", a novel approach in the study of the retail payment systems.

In this paper we address three questions: First, has there been convergence in the usage of cashless retail payment instruments during the period 2000–2018 within the EU and, more specifically, the euro area? Second, considering the many economic developments over the past two decades, do we observe changes in the speed of convergence, or even divergence, in the usage of cashless retail payment instruments? Third, is there evidence of clustering in the usage of cashless retail payment instruments in the EU and the euro area? The answers to these questions are respectively yes, yes, and yes. Yet, there are nuances and lessons in the answers. Similarly, to Martikainen et al. (2015), by answering these questions, we document the state of European retail payment markets whilst also provide information about the direction of its evolution.

The paper is structured as follows. In Section 2, we review the main functions of a retail payment system and the institutional steps promoting retail payment integration. In Section 3, the relevant literature is reviewed. In Section 4, we describe the sample data and present some summary statistics, as well as some of the data-limitations we face. In Section 5, we present new evidence on the beta and sigma convergence of retail payments (thus updating the Martikainen et al. (2015) convergence tests). In Section 6, we present evidence about "clubs of convergence" as we are not only interested in overall beta and sigma convergence. In Section 7, we present some final remarks.

2. Institutional steps to overcome slow retail payment integration

After the launch of the euro in January 1999, the implementation of the single monetary policy required the establishment of a harmonized money market covering euro area countries.[5] The single currency also implied that cross-border payments within the euro area were in principle not different from payments within individual euro area countries: they became domestic

[5] Presently there are 19 euro area countries. While there were 12 founding euro area countries, gradually over the years more countries have joined the euro area,

within the euro area. Large value payments integrated rapidly: they involve fewer agents and platforms that supported economies of scales fairly rapidly.

Instead, cashless retail payments integrated far less rapidly.[6] Still in 2010, the ECB noted that "*Retail payments are still based largely on national payment instruments and systems. While national payment systems may be cheap and very efficient and offer their users high levels of service when it comes to domestic payments, this is not yet the case for cross-border retail payments in the euro area*" (see ECB (2010), page 187). Martikainen et al. (2015) also note that "*Unlike large value payments, the procedures, instruments and services offered to customers in the field of retail payments have not yet been harmonized in the EU*". These shortcomings have mostly been addressed with the Single Euro Payments Area (SEPA) regulation -- establishing a single set of tools and standards that make cross-border payments in euro as easy as national payments -- as well as other initiatives to foster financial integration.

Retail payments play several important functions in the economy. They enable one of the key functions of money – be an acceptable mean of payment – jointly with being a unit of account and store of value. Thus, retail payments provide an essential public service for the functioning of a market economy. Yet, this services costs, both at an individual level and to the economy as a whole. A 2012 study estimates the social and private costs of all retail payment instruments to be in the range of 1% of euro area GDP (Schmiedel et al. (2012)). Managing retail payment instruments contributes to banks' revenues. Furthermore, more effective retail payment services are associated with higher bank stability and overall performance. Studies find a positive relationship between improvements in retail payment technology and GDP (Hasan et al. (2013)).

This explains why market participants and regulators encouraged the development of an integrated area for retail payments across euro area countries. The ECB provided help and moral suasion when needed. It enabled individuals, businesses, and public administrations to make easier and cheaper cashless payments. They could do so from a single payment account using a single set of payments instrument as easily, efficiently, and safely as at the national level (see ECB (2013)). The first cross border payments regulation forced banks to rethink how they sent payments to other euro countries. Significant legislation has been implemented to force convergence with significant work done by the ECB to catalyze these legislative initiatives. Therefore, the EPC and the STEP2 clearing house were setup to make euro payments pan-European using common schemes. SEPA

[6] Cash is still a widely used payment method in the EU and euro area ((Esselink and Hernández (2017)) and Schneider et al. (2010)). Yet, not much is known about the actual use of cash by households. Often surveys are used to estimate the number and value of cash transactions in euro area countries. Other studies calculate it only indirectly as a residual of household expenses. Moreover, diverse studies illustrate that cash usage has been declining steadily in several European countries over the past decade (Skingsley (2019)). Hence, we would not have time series comparable to those for cashless RPIs. Thus, we chose to leave cash out of this study. Cheque usage is dropping rapidly in most European countries during the period under review. Thus, we left it out of this study as well.

was launched in 2008 and "SEPA migration" for credit transfers and direct debits was only finished in 2014 for euro area countries.

From a functional standpoint, the ECB and the national central banks of the countries that adopted the euro took on the task of promoting the smooth operation of the payment system in the euro area, as in the Treaty on the Functioning of the European Union (TFEU).[7] The banking and payment service industry created the European Payments Council (EPC). The EPC then established a roadmap which brought to a SEPA for credit transfer (SCT) and a SEPA for direct debit (SDD) rulebooks.

The Payment Services Directive of 2007 (PSD) opened the market for non-bank payment service providers. The retail payment landscape is being reshaped by the emergence of a stream of innovative retail payment instruments, and the digitalization of payment services (see Hartmann et al (2017) and Norges Bank (2019). Such innovations are driven by new providers, often non-banks, new intermediaries, and new processors. This poses huge pressure on the incumbents like banks. Payment System Directive (PSD) has been revised in October 2015 (PSD2) to promote more competition by the introduction of payment initiation service providers (PISP). Yet, it is still too early to see the effects of the PSD2 (Bijlsmaa et al (2019)).

3. Literature review

Martikainen et al. (2015), whose findings we update and expand upon in this paper, find evidence that some degree of convergence for different payment instruments occurred between 1995 and 2011. The only exceptions are for cheques and e-money, for which they find no evidence of either beta or sigma convergence. Overall convergence is more significant when it is measured as a decrease in the cross-country dispersion of the use of payment instruments over time. Evidence of sigma convergence is most evident during the last twelve years of their sample (i.e., after the euro was introduced). Moreover, the speed of convergence has increased since the introduction of the single currency for most of the payment instruments in their study, when looking at both the volume and the value of retail payments. Evidence of beta convergence is found for the volume of debit card and credit card transactions and for the value of the electronic remote payment instruments, that is, for direct debits and credit transfers.

Studies on retail payment instruments (RPIs) are also related to the literature on measuring financial integration and convergence on one hand, and that on the economics of retail payments on the other hand. Concerning the former, very few studies investigating financial integration deal with RPIs.

[7] The ECB's involvement in retail payments is one of its three core functions jointly with monetary, and banking supervision (see Article 3 Statute of the ESCB and of the ECB). All three functions contribute to the ECB's mandate and help maintain the level of public confidence in the euro. The ECB and the Eurosystem must ensure that the payment system remains safe, efficient, and reliable.

ECB reports on financial integration also look at the evolution of payment habits in Europe (Leinonen (2008)), yet in a qualitative manner.

Prior to Martikainen et al. (2015), quantitative evidence on convergence behavior in the retail payments market was provided by Deungoue (2008), but covering mostly the period before the introduction of the euro (1990–2002). In contrast, Martikainen et al. (2015) have a longer and more recent coverage thus allowing the effect of the adoption of the euro on the convergence process to be estimated. Martikainen et al. (2015) also covers more countries and payment instruments to provide pioneering estimations of the sigma convergence process by using retail payment data.

Some experts claim that even very recently the retail payment system providers had not yet provided "*payment services that work across borders and that are also faster, cheaper and easier to use*" (Cœuré (2019)). Therefore, some fresh pan-European market initiatives to support retail payments at the location of purchase were needed (Cœuré (2019)). This could be based on the SEPA instant credit transfer (SCT Inst) scheme.

In more recent years, advancements in technology, evolving consumer demand and intensifying competition have started reshaping the retail payment landscape. Banks are competing with fintech companies, tech giants, and other new entrants. New ways for initiating and processing payments are emerging. These are too recent to be captured by today's data. Moreover, consumers are reluctant to share payments data (see Bijlsmaa et al. (2019)).

For our empirical analyses, we look at two strands of convergence literature. First, we look at the literature on beta and sigma convergence. The main application of such measures of convergence in the economics literature can be found in the field of economic growth. Most prominently Barro and Sala-i-Martin (1992) and Mankiw et al. (1992) use Beta Convergence tests to arrive at statements concerning economic growth. However, some authors stress the sigma convergence might be of greater interest.[8] In this paper, we will use both approaches to measures of convergence. Secondly, we apply cluster methods to uncover clubs of convergence. In that respect, we use the clustering algorithm introduced by Phillips and Sul (2007).

4. Data and sample statistics

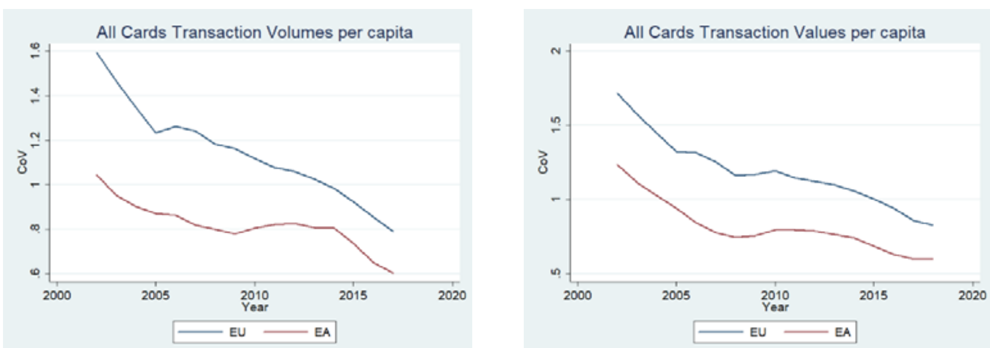
We use retail payment instruments (RPI) data that are publicly available from the ECB's Statistical Data Warehouse. Our sample statistics covers all EU countries -- and thus also euro area countries -- for the 2000 – 2018 period. We analyze ***transaction volumes and values*** for four different retails payment instruments, i.e. cards (debit and credit cards combined), credit transfers, direct debits, and E-Money. Our goal is to compute

[8] See for example Quah (1993) and Friedman (1992), and Young et al. (2008) for a discussion on the prevalence of the usage Beta Convergence in the economic literature against the use of Sigma Convergence.

convergence indicators of these cashless retail payment instrument transactions (in volumes and values) for the EU and euro area over the whole sample period. Therefore, the need for an unbalanced data panel arises. However, the data currently available in the SDW do not enable that because for some countries, diverse annual observations are missing. Therefore, for our analysis, for each RPI instrument, we had to choose a specific subset of countries and time series sample to be used.[9]

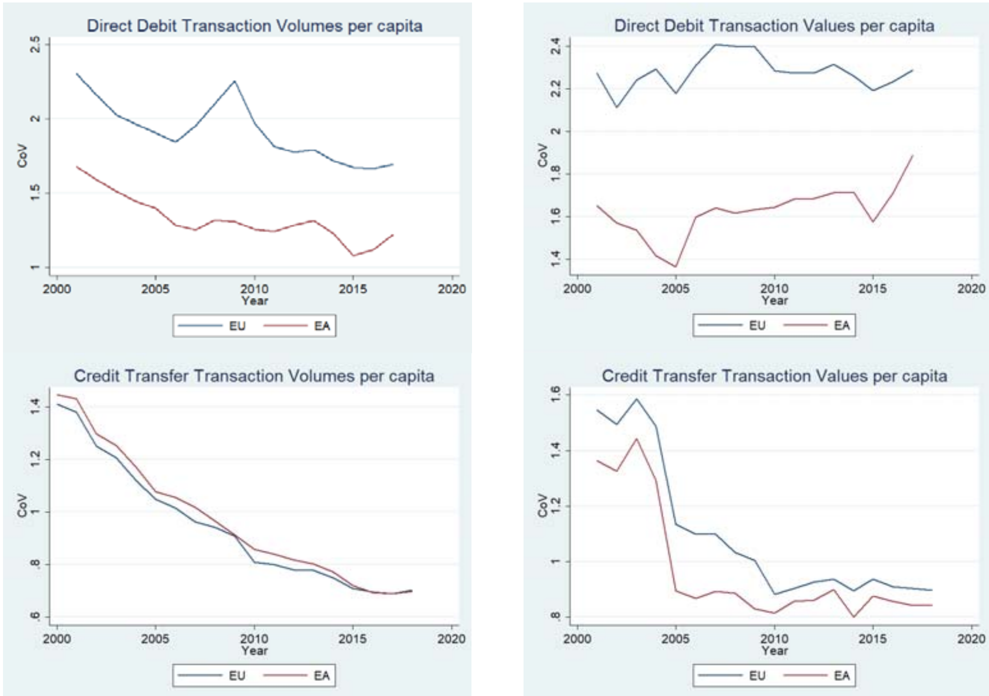
We start by visually inspecting all RPI variables for some evidence of convergence by calculating the coefficient of variations (CoV) over the sample period.[10] Each chart exhibits the respective CoV for the euro area as well the EU (a larger pool of countries). In our view, the evidence presented here even strengthens the findings in Section 3 of Martikainen et al. (2015). Card transactions converge for both the volume and value of transactions. This development is more pronounced for euro area countries in our sample (see Figure 1). Martikainen et al. (2015) exhibit the same trend, but only following the introduction of the euro in 1999 (see their figures on page 86). Similarly, to Martikainen et al. (2015), evidence is more mixed for the volume and the value of direct debit transactions (the former converges, albeit unevenly, whereas the latter does not). Instead, convergence is more evident, albeit with some fluctuations, in the case of credit transfers.

Figure 1 - Coefficient of variations of selected cashless retail payment instruments for the EU (blue) and euro area (red) for the 2000 – 2018 period.



[9] Our choices of subsamples and respective time frame can be found in Tables B.1 and B.2 in Appendix B. Note that we only rarely resorted to interpolation techniques. This was the case, when for individual country data only one or two points of data were missing, and if earlier or later data points are given, such that no extrapolation would be necessary. In fact, no single data point was extrapolated. Both tables also provide details on the specific data points, computed via linear interpolation.

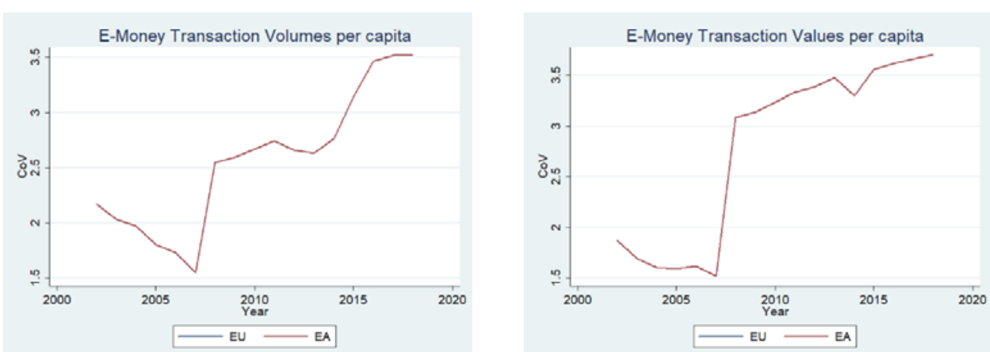
[10] Instead, Martikainen et al. (2015) inspect the yearly evolution of the standard deviation for the log (real) volume of per capita transactions for different payment instrument the all EU countries. This measure approximates the coefficient of variation we use.



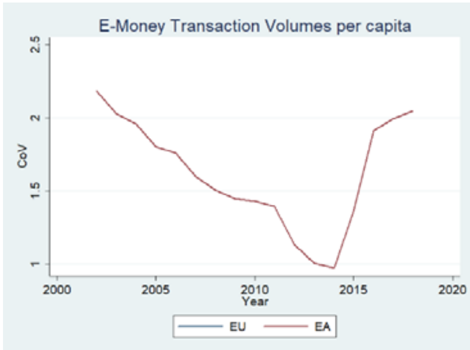
Source: ECB Statistical Data Warehouse (SDW) and authors' calculations.

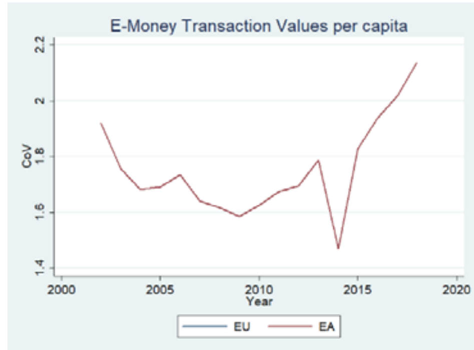
E-Money transactions amounts and values in Figure 2 exhibit instead some overall divergence. However, this finding changes after excluding Luxembourg from the sample. Without Luxembourg, both transaction volumes and values first converge, but then start to diverge around 2014.[11]

Figure 2 - Coefficient of variations for E-Money transactions with (upper) and without (bottom) Luxembourg for the 2000 – 2018 period.



[11] Given the limited number of countries used in the analysis for E-Money, result should only be taken with caution as purely illustrative.





Notes: Due to data limitations, all countries in the sample are Euro Area countries, which is way results for EU and EA countries are identical. Source: ECB Statistical Data Warehouse (SDW) and authors' calculations.

5. Estimating sigma and beta convergence of retail payments

In this section, we take a more systematic look at the convergence of retail payment system usage and values as originally computed in Martikainen et al. (2015). While updating their results, by recalculating sigma and beta convergence indicators, we need to bear in mind that our sample, spans the 2000 – 2018 period (whereas Martikainen et al. (2015) cover the 1995-2011 period). Our sample covers approximately two decades capturing an eventful period for payment systems in the EU, with the Global Financial Crisis, the Euro Area Crisis and the Introduction of SEPA (plus other regulations discussed in Section 2). Although, we have insufficient data to assess the impact of each of these developments on the evolution of retail payment instruments' usage and values, we can observe, if dynamics changed over the course of these events.

5.1 Sigma Convergence

We start by computing sigma convergence measures using the standard deviation of log-transformed measures for the usage and values of retails payment instruments. Sigma convergence measures the dispersion of the respective country specific series around the EU and euro area averages, respectively. A decreasing value of the sigma convergence coefficient would capture more similar retail payment instrument usage and values across countries: i.e., convergence in retail payment instrument usage and values in the euro area and/or the EU.

The analysis is conducted in two steps. In the first step, we perform a regression of our measure of sigma convergence on a constant and a trend to ascertain if sigma convergence points to convergence (less dispersion) or divergence (more dispersion) over time. This puts our discussion of overall trends in convergence of RPI's in the last section on a more quantitative foundation. In the second step, we test for breaks in the speed of convergence. We do so by allowing for breaks on the constant and trend parameters during 2008 (the start of the GFC). Regression results are computed via OLS using Newey-West robust standard errors with lags up to three. Again, to conduct the analysis on a balanced data set, we had to exclude some countries from the analysis. For a detailed list of the time span used and the excluded countries for each retail payment instrument, see the data adjustments tables in Appendix B.

Formalizing the previous paragraph, we estimate two regressions specifications. First, we want to infer, if we can find evidence for sigma convergence over the full sample by estimating

$$y_t = \mu + \gamma t + \epsilon_t,$$

where y_t represent the respective payment instrument data. Further we check for a break in the speed of convergence by estimating

$$y_t = \mu_0 \chi_{t \leq 2008} + \mu_1 \chi_{t > 2008} + \gamma_0 t \chi_{t \leq 2008} + \gamma_1 t \chi_{t > 2008} + \epsilon_t.$$

Here, y_t is again the volume or value of transactions for the respective payment instrument.

Concerning Euro area convergence, Table 1 displays results for sigma convergence in the Euro Area for four different payment instruments: All Cards, Credit Transfers, Direct Debits, and E-money. Over the whole sample period (2000-2018) considered, we can see that dispersion decreases for all instruments except for E-Money. Adding a break in 2008 at the start of the Great Financial Crisis (GFC) in Table 2, we can still observe decreasing dispersion for all instruments except E-money with two notable differences: 1) The speed of the decrease in dispersion for Cards, Credit Transfers, and Direct Debits is lower after the 2008 break. 2) For E-money, we find that dispersion started to increase again after the 2008 break. All breaks in trends are statistically significant, thus we can reasonably argue that per capita usage of the three main payment instruments' convergence has slowed considerably over past two decades.

Table 1 - Sigma convergence results for transaction volumes per capita. Results for euro area.

VARIABLES	(1) Cards	(2) Credit transfers	(3) Direct debits	(4) E-money
Trend	-0.0194***	-0.0400***	-0.0271***	0.109***
	(0.00347)	(0.00351)	(0.00493)	(0.0183)
Constant	1.023***	1.371***	1.597***	1.357***
	(0.0370)	(0.0431)	(0.0668)	(0.253)
Observations	16	19	17	17
Adjusted R-squared:	0.732	0.953	0.745	0.778

*Notes: Numbers in brackets are standard errors computed using HAC covariance matrix estimation. Newey-West (Lag 4). *** p<0.01, ** p<0.05, * p<0.1 Source: ECB Statistical Data Warehouse (SDW) and authors' calculations.*

Table 2 - Sigma convergence results for transaction volumes per capita using a break in 2008. Results for euro area.

VARIABLES	(1) Cards	(2) Credit transfers	(3) Direct debits	(4) E-money
Time trend before GFC	-0.0408***	-0.0591***	-0.0716***	-0.119***
	(0.00543)	(0.00540)	(0.00163)	(0.00425)
Time trend after GFC	-0.0185**	-0.0297***	-0.0187***	0.108***
	(0.00784)	(0.00257)	(0.00436)	(0.0180)
Before GFC-dummy	1.134***	1.461***	1.810***	2.533***
	(0.0324)	(0.0242)	(0.00755)	(0.0228)
After GFC-dummy	1.014***	1.223***	1.491***	1.423***
	(0.104)	(0.0346)	(0.0531)	(0.258)
Observations	16	19	17	17
Adjusted R-squared:	0.997	0.999	0.999	0.997
F-test on Trends:	0.0219	0.000604	3.27e-08	5.95e-09

*Notes: Numbers in brackets are standard errors computed using HAC covariance matrix estimation. Newey-West (Lag 4). *** p<0.01, ** p<0.05, * p<0.1 Source: ECB Statistical Data Warehouse (SDW) and authors' calculations.*

Concerning EU convergence, Tables 3 and 4 show evidence of sigma convergence without and with the 2008 break, respectively. Again, over the past two decades, usage of payment instruments, except for E-Money converges also in the European Union. However, Table 4 shows that the break for the usage in Direct Debits is no longer statistically significant. This indicates that factors specific to some non-euro area EU countries are partially driving the slowdown in convergence of Direct Debits in the EU.

Table 3 - Sigma convergence results for transaction volumes per capita. Results for EU.

VARIABLES	(1) Cards	(2) Credit transfers	(3) Direct debits	(4) E-money
Trend	-0.0439***	-0.0384***	-0.0313***	0.109***
	(0.00367)	(0.00414)	(0.00516)	(0.0183)
Constant	1.607***	1.329***	2.233***	1.357***
	(0.0496)	(0.0488)	(0.0780)	(0.253)
Observations	16	19	17	17
Adjusted R-squared:	0.670	0.935	0.599	0.778

*Notes: Numbers in brackets are standard errors computed using HAC covariance matrix estimation. Newey-West (Lag 4). *** p<0.01, ** p<0.05, * p<0.1 Source: ECB Statistical Data Warehouse (SDW) and authors' calculations.*

Table 4 - Sigma convergence results for transaction volumes per capita using a break in 2008. Results for EU.

VARIABLES	(1) Cards	(2) Credit transfers	(3) Direct debits	(4) E-money
Time trend before GFC	-0.0715***	-0.0616***	-0.0644***	-0.119***
	(0.0142)	(0.00455)	(0.0154)	(0.00425)
Time trend after GFC	-0.0423***	-0.0261***	-0.0580***	0.108***
	(0.00327)	(0.00372)	(0.0109)	(0.0180)
Before GFC-dummy	1.751***	1.439***	2.346***	2.533***
	(0.0793)	(0.0214)	(0.0785)	(0.0228)
After GFC-dummy	1.589***	1.154***	2.630***	1.423***

	(0.0420)	(0.0543)	(0.156)	(0.258)
Observations	16	19	17	17
Adjusted R-squared:	0.999	0.999	0.998	0.997
F-test on Trends:	0.0528	0.000155	0.773	5.95e-09

*Notes: Numbers in brackets are standard errors computed using HAC covariance matrix estimation. Newey-West (Lag 4). *** p<0.01, ** p<0.05, * p<0.1 Source: ECB Statistical Data Warehouse (SDW) and authors' calculations.*

Table 5 and 6 show sigma convergence for the average value of payment instruments in the Euro Area. Table 5 does not include a break point, whereas table 6 does.

The value of payments for Direct Debits and E-Money has diverged over the past two decades. However, Table 6 implies that this is a recent phenomenon, as before 2008 per capita values for both instruments were decreasing in dispersion across countries.

Table 5 Sigma convergence results for transaction values per capita. Results for euro area.

VARIABLES	(1) Cards	(2) Credit transfers	(3) Direct debits	(4) E-money
Trend	-0.0310***	-0.0165**	0.0156***	0.156***
	(0.00578)	(0.00765)	(0.00524)	(0.0202)
Constant	1.157***	1.233***	1.469***	1.070***
	(0.0876)	(0.108)	(0.0672)	(0.290)
Observations	17	18	17	17
Adjusted R-squared:	0.652	0.317	0.399	0.781

*Notes: Numbers in brackets are standard errors computed using HAC covariance matrix estimation. Newey-West (Lag 4). *** p<0.01, ** p<0.05, * p<0.1 Source: ECB Statistical Data Warehouse (SDW) and authors' calculations.*

Table 6 - Sigma convergence results for transaction values per capita using a break in 2008. Results for euro area.

VARIABLES	(1) Cards	(2) Credit transfers	(3) Direct debits	(4) E-money
Time trend before GFC	-0.0914***	-0.0764***	-0.00553	-0.0561***
	(0.00250)	(0.0138)	(0.0205)	(0.0126)
Time trend after GFC	-0.0191***	0.00138	0.0168**	0.0608***
	(0.00552)	(0.00195)	(0.00664)	(0.00259)
Before GFC-dummy	1.494***	1.537***	1.566***	1.959***
	(0.0147)	(0.0732)	(0.104)	(0.0756)
After GFC-dummy	0.988***	0.980***	1.458***	2.556***
	(0.0838)	(0.0302)	(0.0769)	(0.0405)
Observations	17	18	17	17
Adjusted R-squared:	0.998	0.994	0.997	0.999
F-test on Trends:	2.54e-09	6.74e-05	0.325	3.49e-07

*Notes: Numbers in brackets are standard errors computed using HAC covariance matrix estimation. Newey-West (Lag 4). *** p<0.01, ** p<0.05, * p<0.1 Source: ECB Statistical Data Warehouse (SDW) and authors' calculations.*

In the EU as a whole, as indicated in Tables 7 and 8, the picture is again quite similar, with one main difference. The per capita value of Direct Debits starts to disperse less over time. Before the 2008 break, we can see statistically significant divergence, and statistically significant convergence thereafter.

Table 7 - Sigma convergence results for transaction values per capita. Results for EU.

VARIABLES	(1) Cards	(2) Credit transfers	(3) Direct debits	(4) E-money
Trend	-0.0451***	-0.0304***	0.00140	0.156***
	(0.00496)	(0.00729)	(0.00418)	(0.0202)
Constant	1.686***	1.474***	2.264***	1.070***
	(0.0730)	(0.0941)	(0.0555)	(0.290)
Observations	17	18	17	17
Adjusted R-squared:	0.657	0.674	-0.0579	0.781

*Notes: Numbers in brackets are standard errors computed using HAC covariance matrix estimation. Newey-West (Lag 4). *** p<0.01, ** p<0.05, * p<0.1 Source: ECB Statistical Data Warehouse (SDW) and authors' calculations.*

Table 8 – Sigma convergence results for transaction values per capita using a break in 2008. Results for EU.

VARIABLES	(1) Cards	(2) Credit transfers	(3) Direct debits	(4) E-money
Time trend before GFC	-0.0922***	-0.0755***	0.0260**	-0.0561***
	(0.0111)	(0.0116)	(0.00984)	(0.0126)
Time trend after GFC	-0.0365***	-0.00711*	-0.0159***	0.0608***
	(0.00573)	(0.00384)	(0.00498)	(0.00259)
Before GFC-dummy	1.947***	1.721***	2.128***	1.959***
	(0.0623)	(0.0639)	(0.0543)	(0.0756)
After GFC-dummy	1.565***	1.135***	2.506***	2.556***
	(0.0838)	(0.0612)	(0.0691)	(0.0405)
Observations	17	18	17	17
Adjusted R-squared:	0.999	0.996	0.999	0.999
F-test on Trends:	0.000112	7.56e-05	0.00550	3.49e-07

*Notes: Numbers in brackets are standard errors computed using HAC covariance matrix estimation. Newey-West (Lag 4). *** p<0.01, ** p<0.05, * p<0.1 Source: ECB Statistical Data Warehouse (SDW) and authors' calculations.*

5.2 Beta Convergence

We proceed by examining convergence in retail payment instruments via the use of conditional beta convergence measures. To estimate beta convergence, we make use of dynamic panel data methods. More specifically, we apply the two-step difference GMM estimator introduced and developed in Arellano and Bond (1991) and further elaborated by Arellano and Bover (1995), and Blundell and Bond (1998).

The dynamic panel data specification is given by

$$\Delta y_{i,t} = \alpha + \beta y_{i,t-1} + \Theta x_{i,t} + \nu_i + \epsilon_{i,t},$$

Where $\Delta y_{i,t}$is the difference of the volume or value of retail payment instrument transactions for a country i at time t. $y_{i,t}$. The set of (exogenous) control variables $x_{i,t}$consist of the number of electronic fund transfers at point of sale terminals (EFTPOS), number of ATMs (Automatic Teller Machine banking terminals accepting deposits and dispensing cash), and real GDP.[12] This choice is driven by the need to control for demand determinants in the regression specifications. More specifically, for Cards we add the full set of controls. For Credit Transfers and Direct Debits relevant control are EFTPOS and Real GDP. For E-Money we only add Real GDP. If the coefficient β is negative and statistically significant, we have evidence for the existence of beta convergence.[13]

Concerning beta convergence for transaction volumes per capital in the Euro Area and the EU in Tables 9 and 10, we find significant and negative beta coefficients for Cards, Direct Debits, and E-Money. However, the coefficient for beta convergence of cards becomes insignificant though negative for the EU. Furthermore, the result for E-money should be taken with a grain of salt because only seven countries could be included in the sample.

[12] We estimate the econometrics specification using “xtabond2”. See Roodman (2009) for more details. Given the small sample size, we reduce the instruments count by using the collapse command. We evaluate the validity of our dynamic panel specification using tests for instrument exogeneity, i.e. Sargan and Hansen test, and a test for AR(2) specification of the residuals.
[13] Data Appendix B.3 provides information on the data used for EFTPOS, ATM, and Real GDP.

Table 9 - Beta convergence results for transaction volumes per capita using dynamic panel data regression. Results for euro area.

VARIABLES	(1) Diff Cards	(2) Diff Direct Debits	(3) Diff Credit Transfers	(4) Diff E-Money
beta	-0.234***	-0.323**	-0.275	-0.899**
	(0.0535)	(0.136)	(0.476)	(0.380)
EFTPOS	0.0513*	-0.130*	0.0222	
	(0.0311)	(0.0750)	(0.0325)	
ATM	0.0734			
	(0.167)			
Real GDP	0.0280	0.589**	0.118	3.787**
	(0.0945)	(0.281)	(0.251)	(1.563)
Observations	223	170	216	118
Number of id	14	10	12	7
AR(2)	0.361	0.146	0.755	0.540
Hansen p	0.105	0.654	0.254	0.482
Sargan p	0.529	0.742	0.231	0.0798

*Notes: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Source: ECB Statistical Data Warehouse (SDW) and authors' calculations.*

Table 10 - Beta convergence results for transaction volumes per capita using dynamic panel data regression. Results for EU.

VARIABLES	(1) Diff Cards	(2) Diff Direct Debits	(3) Diff Credit Transfers	(4) Diff E-Money
beta	-0.974	-0.285***	-0.244	-0.899**
	(0.943)	(0.0684)	(0.380)	(0.380)
EFTPOS	1.098*	-0.0815*	0.0235	
	(0.649)	(0.0483)	(0.0329)	
ATM	0.0139			
	(0.744)			
Real GDP	0.112	0.663***	0.113	3.787**
	(1.278)	(0.211)	(0.223)	(1.563)
Observations	303	221	287	118
Number of id	19	13	16	7
AR(2)	0.860	0.105	0.654	0.540
Hansen p	0.0410	0.626	0.171	0.482
Sargan p	0.521	0.792	0.162	0.0798

*Notes: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1 Source: ECB Statistical Data Warehouse (SDW) and authors' calculations.*

For transaction values per capita in Tables 11 and 12, the only retail payment instruments for which we find evidence of beta convergence is Cards in the EU. For all other instruments in the EU and euro area the coefficient is negative, but statistically insignificant. These findings might be due to the small sample size used in this study, as the number of countries is exceedingly small compared to standard application of dynamics panel data regressions.[14]

[14] In general, small N, small T environments such as the application here or in Martikainen et al. (2015), might suffer from large bias. See for example Judson et al. (1999). For this reason, we advocate for the use of sigma convergence in evaluating convergence in retail payment

Table 11 - Beta convergence results for transaction values per capita using dynamic panel data regression . Results for euro area.

VARIABLES	(1) Diff Cards	(2) Diff Direct Debits	(3) Diff Credit Transfers	(4) Diff E-Money
Beta	-0.114	-0.0924	-0.113	-0.709
	(0.0755)	(0.259)	(0.336)	(0.845)
EFTPOS	0.0105	-0.0358	0.00489	
	(0.00675)	(0.163)	(0.0193)	
ATM	-0.00111			
	(0.0701)			
Real GDP	0.0726	0.252	0.193	2.435
	(0.0760)	(0.659)	(0.383)	(3.466)
Observations	236	170	204	117
#Countries	14	10	12	7
AR(2)	0.0509	0.517	0.620	0.565
Hansen p	0.571	0.265	0.282	0.0771
Sargan p	0.555	0.450	0.464	0.232

*Notes: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1 Source: ECB Statistical Data Warehouse (SDW) and authors' calculations.*

Table 12 – Beta convergence results for transaction values per capita using dynamic panel data regression. Results for EU.

VARIABLES	(1) Diff Cards	(2) Diff Direct Debits	(3) Diff Credit Transfers	(4) Diff E-Money
beta	-0.167***	-0.0546	-0.125	-0.709
	(0.0585)	(0.249)	(0.202)	(0.845)
EFTPOS	0.0153	-0.0367	-0.00469	
	(0.0143)	(0.135)	(0.0176)	
ATM	0.0191			
	(0.0903)			
Real GDP	0.159*	0.140	0.160	2.435
	(0.0814)	(0.837)	(0.235)	(3.466)
Observations	320	221	271	117
#Countries	19	13	16	7
AR(2)	0.0562	0.124	0.842	0.565
Hansen p	0.319	0.186	0.0976	0.0771
Sargan p	1.88e-05	0.0130	0.168	0.232

*Notes: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1 Source: ECB Statistical Data Warehouse (SDW) and authors' calculations.*

5.3 Comparison of our findings with those of Martikainen et al. (2015)

We now compare our findings on sigma and beta convergence with those in Martikainen et al. (2015). It should be borne in mind, that we compare results only for the EU sample, as only these are available in Martikainen et al. (2015). Furthermore, some caution is advised in interpreting this comparison. Given our choice of data to generate a balanced panel, without

instruments, since that measure does not suffer from the lack of data in the same degree as beta convergence.

the need of excessive imputation of data, the countries used in the analyses are slightly different than those used by Martikainen et al. (2015).

Table 13 presents the comparison for convergence of transaction volumes, whereas Table 14 presents the comparison of transaction values. We observe that concerning the presence of sigma-convergence, our results mostly agree with those in Martikainen et al. (2015). The only difference is that we do not find evidence of sigma convergence of transaction values for direct debits. However, for beta-convergence we barely find matching results, transaction values for E-money being the sole exception.

Concerning results on beta convergence, it should again be noted that dynamic panel data analysis with sample sizes used in this study and in Martikainen et al. (2015), might be susceptible to small changes in data and the exact set of instruments used. Result might therefore be driven by a potentially sizable bias in estimation of the convergence parameter β due to the small N, small T environment.

Table 13 - Comparison of convergence results for transaction volumes of retail payment instruments between Kontny and Mongelli (2020) and Martikainen et al. (2015).

	Kontny - Mongelli				Martikainen et al. (2015)			
	Cards	CF	DD	E-money	Cards	CF	DD	E-money
σ	Yes	Yes	Yes	No	Yes	Yes	Yes	No
β	No	Yes	No	Yes	Yes	No	No	No

Notes: "Yes" indicates convergence. "No" indicated either divergence or not statistically significant convergence.

Table 14 - Comparison of convergence results for transaction values of retail payment instruments between Kontny and Mongelli (2020) and Martikainen et al. (2015). "Yes" indicates convergence. "No" indicated either divergence or not statistically significant convergence.

	Kontny - Mongelli				Martikainen et al. (2015)			
	Cards	CF	DD	E-money	Cards	CF	DD	E-money
σ	Yes	Yes	No	No	Yes	Yes	Yes	No
β	Yes	No	No	No	No	Yes	Yes	No

Notes: "Yes" indicates convergence. "No" indicated either divergence or not statistically significant convergence.

6. Club convergence and searching for patterns

Could countries RPI usage evolve at different speeds over time, e.g., because of slowly changing habits? Differences in historical financial developments, regional preferences, or social differences might lead to groups of countries which exhibit similar patterns to exhibit similar dynamics of retail payment system usage and convergence behavior. Then, if countries in the EU or euro area differ according to habits and preferences of their populations, differences between similar groups of countries in the evolution of RPI usage might manifest themselves as "clubs" or clusters of convergence. The presence of such clubs of convergence might hold lessons for the usage of cashless RPIs concerning the future evolution of today's RPI cashless instruments and the adoption of possibly new electronic means of retail payment.

As similarly discussed in Phillips and Sul (2007), in principle there are two approaches to uncover such clusters of convergence. First, the researchers might think of some a priori reason why groups of countries might differ and analyze the difference in RPI usage accordingly. Second, the researchers can take an agnostic approach, where statistical methods are employed to uncover groups of countries which differ across some targeted statistics. We follow the latter approach. We let the data speak.

To uncover such clubs, we employ methods first introduced by Phillips and Sul (2007). They propose a new panel data model able to capture economic behavior, which exhibits strongly differing time paths and individual heterogeneity. Using that model, they construct a method which allows for clustering panels into club convergence groups. This method is well suited for our needs, as we aim to uncover groups of countries with similar convergence patterns.[15] To our knowledge, this paper is the first in the literature on Retail Payment Instruments to apply this approach (to both transaction volumes and values of various payment instruments). In Phillips and Sul (2009), the authors apply this approach to GDP data to uncover club convergence with respect to GDP growth. We provide a brief description of the algorithm in Appendix A.[16]

We now compute clubs of convergence for All Cards, Credit Transfers, and Direct Debits and present the identified clubs of convergence as well as the respective evolution of the cluster-specific coefficient of variation. Given the underlying properties of the algorithm, we would expect to see distinct paths of convergence for the identified clusters, if they converge at a different pace than the whole sample or other clubs. Due to limited available data on E-Money, we omit its analysis here. Where the evolution of the CoV of different clusters seemed to be quite similar, we choose to regard those clusters as one group.

[15] The clustering algorithm by Phillips and Sul (2007) heavily relies on the computation of the cross-sectional variation of a variable y using

$$H_t = N^{-1} \sum (h_{it} - 1)^\wedge 2,$$

where

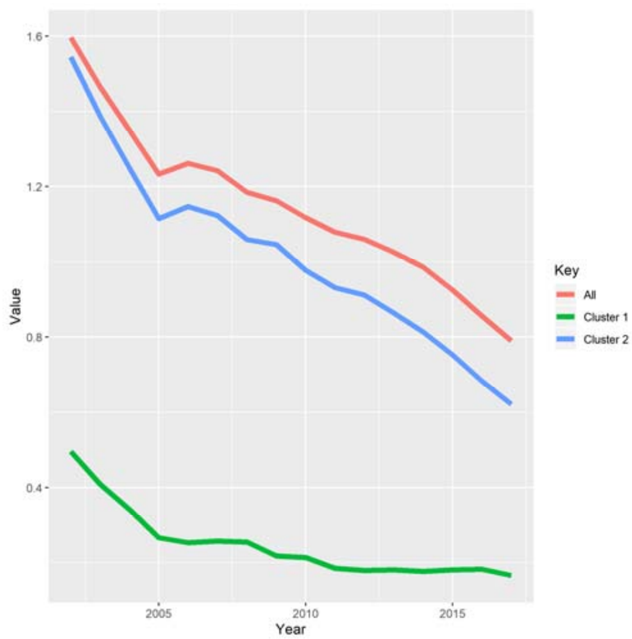
$$h_{it} = \frac{\log y_{it}}{N^{-1} \log \sum y_{it}}.$$

It can be easily shown that H_t equals the square of the coefficient of variation. This makes the algorithm uniquely useful for our purposes, as it relates to sigma convergence.

[16] Moreover, a detailed derivation and outline of the clustering procedure is provided in Phillips and Sul (2007). We use here the implementation of the club convergence algorithm available in the ‘R’ package ‘ClubConvergence’. See Sichera and Pizzuto (2019) for a detailed description of that package.

Figures 3 and 4 show the evolution of the coefficient of variation over time for the EU as a whole and juxtapose that evolution against its clusters' coefficient of variation.

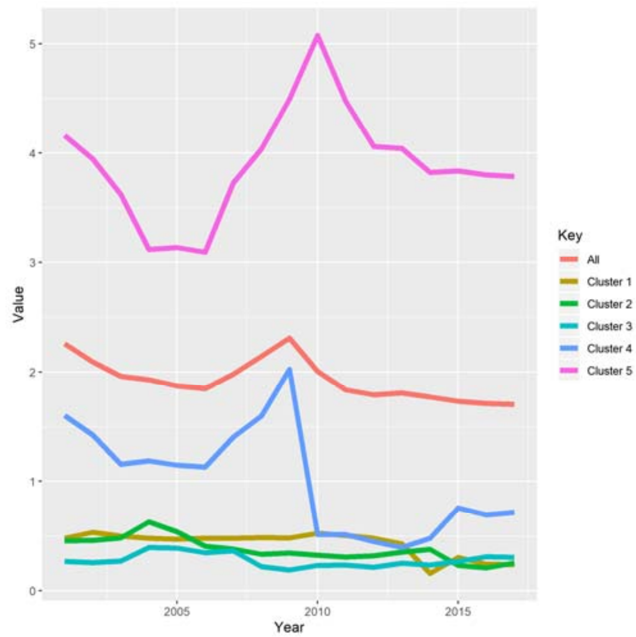
Figure 3 - Coefficient of variation for transaction volume for All Cards with respect to individual clusters.



*Notes: **Cluster 1**: DK,SE,GB,FI,NL,LU,EE **Cluster 2**: IE, FR, BE, PT, LV, PL, LT, SI, ES, AT, CZ, SK, HU, CY, MT, DE, GT, IT, RO, BG **Excluded:** None. Input data was log-transformed. Source: ECB Statistical Data Warehouse (SDW) and authors' calculations.*

Cluster 1 comprises countries traditionally perceived as being less cash–intensive: i.e., Denmark, Sweden, Great Britain, Finland, the Netherlands, Luxembourg, and Estonia. We are not surprised that per capita transaction volumes for credit and debits cards are remarkably similar within this club. For all remaining countries, no discernible subgroups could be found.

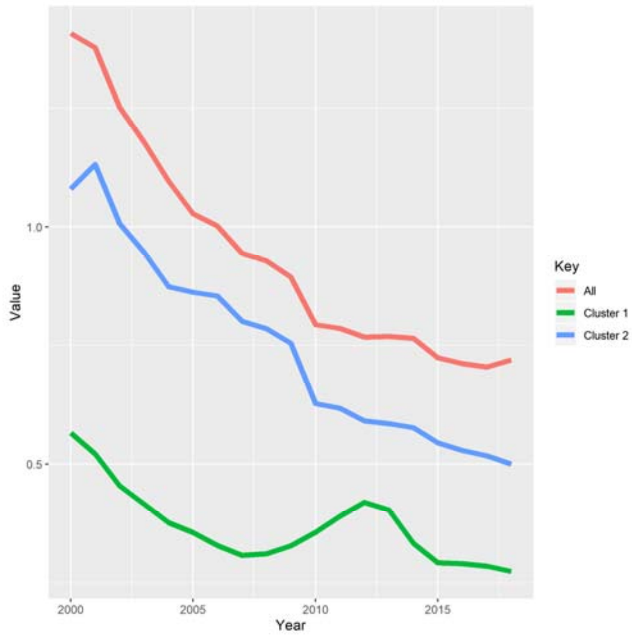
Figure 4 - Coefficient of variation for transaction volume for Direct Debits with respect to individual clusters.



*Notes: **Cluster 1-3**: Nl, GB, FR, BE, ES, SE, LU, IE, PT, IT, CY, HU **Cluster 4:** GR, BG, PL **Cluster 5(divergent)**: DE, RO **Excluded:** "AT", "CZ", "DK", "EE", "FI", "MT","LT", "SI", "SK", "LV" (Additionally, to the country exclusion presented in Appendix B, "AT" is excluded due to an anomalously large drop in the transaction volume during 2013/2014.) Input data was log-transformed. Source: ECB Statistical Data Warehouse (SDW) and authors' calculations.*

Concerning Direct Debits, the picture is somewhat more varied and diverse clubs emerge. Because the Netherlands, Great Britain, France, Belgium, Spain, Sweden, Luxembourg, Ireland, Portugal, Italy, Cyprus, and Hungary -- grouped in Clusters 1, 2 and 3 -- show remarkably similar patterns for their coefficient of variation, when compared to the overall level of sigma convergence, we report those countries as one group in Figure 4. Again, we can find less cash-intensive economies, together with Spain, Portugal, Italy, Cyprus, and Hungary. Greece, Bulgaria, and Poland constitute their own group. Only Germany and Romania could not be grouped successfully as these were identified as a divergent group. Some caution is advised when putting excessive weight on the interpretations of these findings concerning Direct Debits club convergence. The spikes showing up in the 2010 CoV might indicate some data issues that we were not able to analyze.

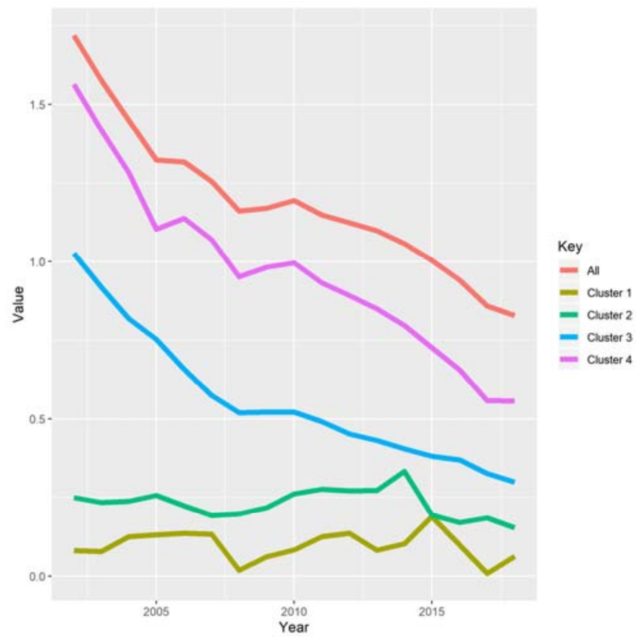
Figure 5 - Coefficient of variation for transaction volume for Credit Transfers with respect to individual clusters.



*Notes: **Cluster 1:** FI, NL, SE, BE, EE, DK, LV, DE **Cluster 2:** PL, GB, LT, IE, FR, BG, HU, GR, MT, PT, ES, CY, IT, RO **Excluded:** "AT","LU","CZ", "SI", "SK" (Additionally, to the country exclusion presented in Appendix B, "AT", "LU" are excluded due to " is excluded due to an anomalously large drop in the transaction volume during 2013/2014.) Input data was log-transformed. Source: ECB Statistical Data Warehouse (SDW) and authors' calculations.*

A recurring observation seems to be that less cash intense countries form convergence clubs. Here this also holds per capita usage of Credit transfers. However, for this payment instrument Belgium and Germany can also be found in that group.

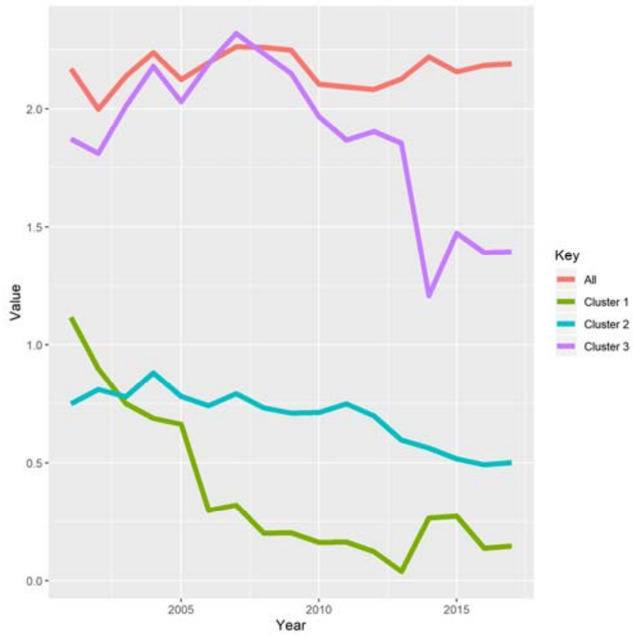
Figure 6 - Coefficient of variation for transaction values for All Cards with respect to individual clusters.



Notes: ***Cluster 1-2:*** *LU, GB, DK, IE, SE, FI* ***Cluster 3:*** *FR, PT, NL, BE, EE, MT* ***Cluster 4:*** *CY, AT, ES; DE, IT, SI, LV, CZ, LT, GR, SK, HU, PL, RO, BG* ***Excluded:*** *None. Input data was log-transformed.*
Source: ECB Statistical Data Warehouse (SDW) and authors' calculations.

For transaction values of All Cards we can broadly identify groups of cash-intensive vs. non-intensive countries (Figure 6). However, Cluster 3 comprising France, Portugal, the Netherland, Belgium, Estonia, and Malta seems to represent an "odd man out", by incorporating a mixture of some traditional and less traditional market-based economies. This club's evolution of dispersion seems to be struck right in between all the other clusters.

Figure 7 - Coefficient of variation for transaction values for Direct Debits with respect to individual clusters.



Notes: ***Cluster 1:*** *FR, IE, GB, LU* ***Cluster 2:*** *NL, ES, BE, IT, SE, PT* ***Cluster 3:*** *CY; GR, HU, PL, FI, RO, BG* ***Excluded:*** *"AT","DE","CZ", "DK", "EE", "MT", "SI", "SK", "LV","LT". (Additionally, to the country exclusion presented in Appendix B, "AT", "DE" are excluded due to an anomalously large drop in the transaction value during 2013/2014.) Input data was log-transformed. Source: ECB Statistical Data Warehouse (SDW) and authors' calculations.*

Differently to previous observations, for the value of Direct Debits, low cash-intensive economies split into two groups, i.e. Clusters 1 and 2. Whereas countries in Cluster 1 became steadily more similar, countries in Cluster 2 exhibited a slower decline in heterogeneity. The overall level of convergence for the EU seems to be driven by Cluster 3, this also become more similar over time, but still exhibits a high degree of dispersion when compared to Cluster 1 and 2. (Note the large group of excluded countries).

For values of credit transfers no evidence for club convergence could be found.

7. Final remarks and future research

We set out to address three questions. The first question was: *has there been convergence in the usage of cashless retail payment instruments during the period 2000–2018 within the EU and the euro area?* The evidence on dispersion using coefficient of variations over whole sample supports and further strengthens the findings of Martikainen et al. (2015). Card transactions converge for both the volume and value of transactions; moreover, this development is more pronounced for euro area countries. Evidence is more mixed for the volume and the value of Direct Debit transactions, whereas convergence is more evident, albeit with some fluctuations in the case of Credit Transfers. Concerning E-Money, when excluding Luxembourg, both transaction volumes and values first converge, but then start to diverge around 2014.

The second question was: *considering the many economic developments over the past two decades, can we observe changes in the speed of convergence, or even divergence, in the usage of cashless retail payment instruments?* We address this question when performing tests for sigma and beta convergence. We find a statistically significant break in 2008, coinciding with the Global Financial Crisis. The speed of sigma convergence decreases for Cards, Credit Transfers, and Direct Debits after the 2008 break. Hence, per capita usage of these three main payments instruments has slowed considerably since the Global Financial Crisis. Instead, for E-money we find that dispersion started to increase again after the 2008 break. Concerning beta convergence, the small number of years and countries available make a robust estimation of dynamic panel data models difficult. For this reason, we recommend analysing convergence of cashless retail payment instruments using sigma convergence, as long as the numbers of available data points remains small.

The third question was: *is there evidence of clustering in the usage of cashless retail payment instruments in the EU and the euro area?* Concerning "clubs of convergence", we can broadly identify two types, which one can either categorise as cash-intensive vs. non cash-intensive countries or fast vs. slow adopters.

Some important nuances and qualifications emerge from our analyses. Changes are taking place at different speeds across clusters of countries, and across RPS instruments. We suspect that there might be path-dependency of retail payment usage over short-time horizons in some countries. The use of cashless retail payment instruments in the European Union still displays some cross-country heterogeneity for some cashless retail payment instruments, despite the convergence trends observed for most cashless retail payment instruments. At the same time, the period that we cover is characterised by powerful shocks and financial transformation.

Traditional market-based economies, such as Sweden, the Netherlands, Great Britain, etc., exhibit remarkably similar behaviour in the usage of retail payment system instruments since the start of our sample. While these countries have become even more similar over time, the decrease in dispersion among them is relatively small. This becomes even more apparent when comparing the remaining cluster of countries. These were highly dispersed in terms of card usage at the beginning of our sample, and then converged quickly, but remain more dispersed than the fast adopters at the end of our sample. Here it would be interesting to explore if slow adopters of cashless retails payments instruments might also be slower to adopt to novel cashless payment instruments. In light of the attention given by central banks and researchers to possible future implementations of CBDC, understanding the speed of adoption in different euro area countries is of utmost importance.

Further research should investigate whether such heterogeneity is costly for banks and retail payment services providers, but less efficient for households and firms at large. As already mentioned concerning results for beta convergence, due to the small cross-section of countries considered, the overall quality of the data, its annual frequency, findings are not as robust as we would like. Therefore, these findings should be interpreted cautiously. As more data becomes available, these analyses should be updated. Nevertheless, most papers in this literature suffer from this caveat. Still, considering that our sample period has been rather tumultuous, our findings indicate that euro area countries are witnessing RPI convergence. Finally, we should also monitor how new technologies change payment behaviour and the provision of RPIs in the euro area.

A different type of challenge pertains to the impact of the institutional steps to promote retail payment integration (i.e., SEPA). How do we reconcile them with the slow-down in the usage of cashless RPI instruments over the time-period where these initiatives and efforts have been implemented? Are we seeing a problem with these instruments or did RPI usage just reach a satiation point? Our cluster results would speak against the latter since the slow adopters are still more dispersed than the fast adopters. But then the fast adopters consist to a large part of non-Euro EU countries.

References

Arellano, Manuel, and Stephen Bond. "Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations." The Review of Economic Studies 58.2 (1991): 277-297.

Arellano, Manuel, and Olympia Bover. "Another look at the instrumental variable estimation of error-components models." Journal of Econometrics 68.1 (1995): 29-51.

Barro R.J. and X. Sala-i-Martin (1992) “Convergence” *Journal of Political Economy*, 100, 223-251.

Bijlsmaa, M., C. van der Cruijsena, J. de Haan and N. Jonkera (2019) “The impact of PSD2 on the functioning of the retail payment market”, mimeo.

Blundell R. and S. Bond (1998) “Initial conditions and moment restrictions in dynamic panel data models”, Journal of Econometrics, 87, 115-143.

Bolt W. and D. Humphrey (2007) “Payment network scale economies, SEPA, and cash replacement”, *Review of Network Economics*, 6, pp. 453-473.

Bolt W. and H. Schmiedel (2011) “Pricing of payment cards, competition and efficiency: a possible guide for SEPA”, *Annals of Finance*, February.

Cœuré B. (2019) “Towards the retail payments of tomorrow: a European strategy”, speech at the Joint Conference of the ECB and the National Bank of Belgium, on 26 November 2019.

Deungoue S. (2008) “Will we pay in the same way?”, *European Journal of Finance*, 14, 49-67.

ECB (2010) ”Financial Integration in Europe”, Frankfurt am Main, April.

ECB (2012) “Financial Integration in Europe”, Frankfurt am Main, April.

Esselink H. and L. Hernández (2017) “The use of cash by households in the euro area”, ECB Occasional paper nr 201, September 2017.

Judson, Ruth A., and Ann L. Owen. "Estimating dynamic panel data models: a guide for macroeconomists." Economics letters 65.1 (1999): 9-15.

Milton, F. (1992). Do Old Fallacies Ever Die?,“. *Journal of Economic Literature*, 30(4), 2129-2132.

Hartmann, Monika, Lola Hernandez, Mirjam Plooij and Quentin Vandeweyer (2017) “Are Instant Retail Payments Becoming the New Normal? A Comparative Study”, see ECB website https://www.ecb.europa.eu/pub/conferences/shared/pdf/20171130_ECB_BdI_conference/payments_conference_2017_academic_paper_hartmann_hernandez_plooij_and_vandeweyer.pdf

Hasan, Iftekhar, Heiko Schmiedel, and Liang Song. "Returns to retail banking and payments" Journal of Financial Services Research 41.3 (2012): 163-195.

Hasan, Iftekhar, T. De Renzis, and Schmiedel, H.(2013). „Retail payments and real economy” Working Papers Series, European Central Bank, (1572).

Hasan, Iftekhar, Emmi Martikainen, and Tuomas Takalo. "Promoting efficient retail payments in Europe" Journal of Payments Strategy & Systems 8.4 (2015): 395-406.

Leinonen, H. (2008) “Payment habits and trends in the changing E-landscape 2010+”, *Bank of Finland Expository Studies* A: 111.

Mankiw G., D. Romer, and D.N. Weil (1992) “A contribution to the empirics of economic growth”, *Quarterly Journal of Economics*, 107, 407-437

Martikainen, E., Schmiedel, H., Takalo, T. (2015) “Convergence of European retail payments”, *Journal of Banking & Finance*, 2015, vol. 50, issue C, 81-91

Norges Bank (2019) “Retail payment services 2018”, Norges Bank Papers nr. 1/2019.

Phillips, P. C., & Sul, D. (2007). Transition modeling and econometric convergence tests. Econometrica, 75(6), 1771-1855.

Phillips, P. C., & Sul, D. (2009). Economic transition and growth. Journal of Applied Econometrics, 24(7), 1153-1185.

Quah, D. (1993) “Galton's fallacy and tests of the convergence hypothesis. *The Scandinavian Journal of Economics,* 427-443.

Rochet J.-C. and J. Tirole (2006) “Two-sided markets: a progress report”, *RAND Journal of Economics,* 37, 645-667

Rochet J.-C. and J. Wright (2010) “Credit card interchange fees”, *Journal of Banking and Finance,* 34, 1788-1797

Roodman, D. (2009) “How to do Xtabond2: An introduction to difference and system GMM in Stata”, *The Stata Journal*, 9(1), 86-136.

Schmiedel, H., Kostova, G., Ruttenberg, W., (2012) “The Social and Private Costs of Retail Payment Instruments: A European Perspective”, Occasional Paper Series No 137, ECB, Frankfurt am Main.

Schneider, Friedrich, Andreas Buehn, and Claudio E. Montenegro. "New estimates for the shadow economies all over the world." International Economic Journal 24.4 (2010): 443-461.

Shy O. and J. Tarkka (2002) “The market for electronic cash cards”, *Journal of Money, Credit and Banking*, 34, 299-314

Skingley C. (2019) “Money, payments and digitalization”, presentation at Joint Conference of the ECB and the National Bank of Belgium on “Crossing the chasm to the retail payments of tomorrow”, see: https://www.ecb.europa.eu/pub/conferences/shared/pdf/20191126_payments_conference/keynote_skingsley_riksbank.pdf

Sichera, R., & Pizzuto, P. (2019) “ConvergenceClubs: A Package for Performing the Phillips and Sul's Club Convergence Clustering Procedure”, *The R Journal*, 142-151.

Appendix A. Log-t-test and Clustering Algorithm – Phillips and Sul (2007)

This section provides a summary of the clustering algorithm used in this paper. To test for the presence of convergence among different countries Phillips and Sul (2007) set up a test procedure based on the OLS estimation of

$$log\frac{H_1}{H_t} - 2log\big(log(t)\big) = \alpha + \gamma log(t) + u_t, for\ t = [rT], [rT]+1, \dots, T$$

where $H_t = N^{-1}\sum(h_{it}-1)^2$ and $h_{it} = \frac{\log y_{it}}{N^{-1}\log\sum y_{it}}$. In our application we choose $r = \frac{1}{3}$.

In the log-t test by Phillips and Sul (2007) the null hypotheses of convergence is tested using a one-sided t-test of $\gamma > 0$. If the null hypothesis is rejected for the whole sample, Phillips and Sul (2007) propose to look for subgroups of convergence by use of a cluster algorithm. The following outline is adapted from Phillips and Sul (2007). The outline also provides our choices of parameters used in the algorithm.

(Step 1) (Cross-section ordering): Order the countries according transaction volumes (values) to either its value in the final period.

(Step 2) (from a core primary group of k^* countries): Select the first k highest countries in the panel to form the subgroup G_k for some $2 \le k < N$, run the log t regression and calculate the convergence test statistic $t_k = t(G_k)$ for this subgroup. Choose the core group size $k^*$by maximizing t_k over k according to the criterion

$$k^* = \arg\max_k t_k \text{ subject to } \min t_k > -1.65.$$

If the condition $\min t_k < -1.65$ does not hold for $k = 2$, then the highest individual in G_k can be dropped from each subgroup and new subgroups $G_{2j} = \{2, .., j\}$ formed for $3 \le j \le N$. The step can be repeated with test statistics $t_j = t(G_{2j})$.

(Step 3) (sieve the data for new club members): Add one country at a time to the core primary group k^*members and run the log t-test again. Include the new country in the convergence club if the associated t-statistic is greater than the criterion $c^* = 0$.

(Step 4) (recursion and stopping rule): Form a second group from those countries for which the sieve condition fails in Step 3. Run the log t-test to see if $t_{\hat{\gamma}} > -1.65$ on this group, i.e., if this group satisfies the convergence test. If so, conclude that there are two convergence club groups: the core primary group and the second group. If not, repeat step 1 through step 3 to see if this second group can itself be subdivided into convergence clusters. If there is no k in Step 2 for which $t_{\hat{\gamma}} > -1.65$, conclude that the remaining countries do not contain a convergence subgroup; therefore, the remaining countries have divergent behavior.

Appendix B. Data Adjustments for convergence results:

Table B.1 Retails Payment Instruments – Transaction volumes

	All Cards	Direct Debits	Credit Transfers	E-Money
Sample start	2002	2001	2000	2002
Sample end	2017	2017	2018	2018
Excluded countries	- none	CZ, DK, EE, FI, MT, SI, SK, LV, LT	CZ, SI, SK	BG, CY, CZ, DK, EE, FI, HU, GB, IE, LT, LV, MT, PL, RO, SE, SI, SK, ES, GR
Comments	- none	Interpolation for IE	- none	Interpolation for ES
SDW code	PSS.A..F000.I1A.Z00Z.NT.X0.20.Z0Z.Z	PSS.A..F000.I34.Z00Z.NT.X0.20.Z0Z.Z	PSS.A..F000.I31.Z00Z.NT.X0.20.Z0Z.Z	PSS.A..F000.IEM.Z00Z.NT.X0.20.Z0Z.
Description	Number of Card Transactions in millions	Number of Direct Debit in millions	Number of Credit Transfer Transactions in millions	Number of E-Money Transactions in millions

Table B.2 Retails Payment Instruments – Values

	All Cards	Direct Debits	Credit Transfers	E-Money
Sample start	2002	2001	2001	2002
Sample end	2018	2017	2018	2018
Excluded countries	- none	CZ, DK, EE, MT, SI, SK, LV, LT	CZ, SI, SK	BG, CY, CZ, DK, EE, FI, HU, GB, IE, LT, LV, MT, PL, RO, SE, SI, SK, ES, GR
Comments	- none	Interpolation for FI	Interpolation for FI	Interpolation for ES
SDW code	PSS.A..F000.I1A.Z00Z.VT.X0.20.Z01.E	PSS.A..F000.I34.Z00Z.VT.X0.20.Z01.E	PSS.A..F000.I31.Z00Z.VT.X0.20.Z01.E	PSS.A..F000.IEM.Z00Z.VT.X0.20.Z01.E
Description	Value of Card Transactions in million euro	Value of Direct Debit in million euro	Value of Credit Transfer Transactions in million euro	Value of E-Money Transactions in million euro

Table B.3 Auxiliary variables

	EFTPOS	ATM	Population
Sample start	2001	2001	2000
Sample end	2017	2017	2018
Excluded countries	BG, CY, FI, FR, GB, IE, MT, SE	- none	- none
Comments	Interpolation for BE, CZ	Interpolation for LV	-
SDW code	PSS.A..S102.I00.I100.NC.X0.20.Z0Z.Z	PSS.A..S102.I00.I210.NT.X0.20.Z0Z.Z	ENA.A.N..W0.S1.S1._Z.POP._Z._Z._Z.PS._Z.N
Description	Number of EFTPOS - (pure number) - Number of EFTPOS terminals	Number of ATMs per million inhabitants	Population in thousands

	Real GDP	HICP
Sample start	2000	2000
Sample end	2018	2018
Excluded countries	- none	- none
Comments	- none	- none
SDW code	MNA.A.N..W2.S1.S1.B.B1GQ._Z._Z._Z.EUR.LR.N	ICP.A..N.000000.4.AVR
Description	Real GDP at market prices (chain-linked-volume) in millions of euros	CPI

General comments: Croatia excluded for the whole sample. No data points have been extrapolated, only interpolated. (linear)