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Substitution between Net and Gross Settlement Systems: A Concern for Financial Stability?

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Substitution between Net and Gross Settlement Systems: A Concern for Financial Stability?

by Ben R. Craig and Falko Fecht

While net settlement systems make more efficient use of liquidity than gross settlement systems, they are known to generate systemic risk. What does that tendency imply for the stability of the payments (or financial) system when the two settlement systems coexist? Do liquidity shortages induce banks to settle more transactions in the net settlement system, thereby increasing systemic risk? Or do banks require their counterparties to send payments through the gross settlement system when default risks are high, increasing the need for liquidity and the money market rate but reducing overall systemic risk? This paper studies the factors that drive the relative importance of net and gross settlement systems over the short run, using daily data on transaction volumes from the large-volume payment systems of all euro area countries that have had both a net and a gross settlement system at the same time. Applying a large portfolio of different econometric techniques, we find that it is actually the transaction volumes in gross settlement systems that affect the daily price of liquidity and the credit risk spread in money markets.

Keywords: Payment system, financial stability, interbank market, financial contagion.

JEL Codes: E44, G21.

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Non technical summary

The design of large value payments systems is of high relevance for financial stability. Payments resulting from interbank transactions are predominantly settled in those payment systems. Broadly speaking one can classify large value payment systems in gross and net settlement systems.

In net settlement systems payments are accumulated over a certain period, for instance a day. At the end of the period offsetting bilateral and multilateral payments are netted and only the resulting balances are settled in central bank money. Since incoming payments are not finalized during the day, those payments imply an intraday credit of the receiver to the sender of the payment. Therefore, if at the end of the day the sender of a payment has too little liquidity to settle all balances with his counterparties the bilateral and multilateral netting of his payments has to be unwound and the receiver of the payment will not dispose of the expected liquidity. If he, as a result, disposes of too little liquidity also his payments need to be unwound which might again affect the liquidity position of the receivers of his payments. In this way the liquidity shortage of one bank can generate domino effects leading to defaults on payments between large parts of the banking sector.

In gross settlement systems, in contrast, each payment is settled in central bank money one after the other. Consequently, the receiver of the payment has the liquidity immediately and with certainty at his disposal. The domino effect that can occur in net settlement systems cannot emerge in gross settlement systems. However, in order to settle each payment individually banks have to withhold sufficiently liquidity. Thus compared to net settlement systems gross settlement systems impose higher costs on banks because of the higher liquidity buffers that those systems require.

In most developed economies gross and net payment systems coexist for large value payments. In this paper we study whether this coexistence and the potential substitution effects between the payment flow in the two types of systems affect financial stability. One could presume, for instance, that tensions in interbank markets that lead to higher costs of liquidity induce banks to send more payments

through net settlement system in order to save on liquidity. However, in times of tighter money market the probability of a liquidity shortage of an individual banks seems more likely. This would mean that precisely when the probability of an unwinding in net settlement systems is large the transaction volume in those systems is also elevated.

However, in our econometric analysis of the large value payment systems in the euro area for the period from January 2000 to September 2007 we do not find evidence for such a destabilizing substitution effect. But we also do not find evidence that banks send more payments through gross settlement systems in response to an elevated credit risk in the banking sector. Our results rather suggest the opposite causal relation: In times of a high transaction volume in gross settlement systems the demand for liquidity seems to increase which leads to an rise in money market rates. An increased volume settled in net systems, in contrast, seems to bring about a higher credit risk premia in the interbank market.

In sum, during the relatively tranquil period prior to the current financial crisis it were not financial market prices that drove the choice of the payment systems. It is rather the transaction volume in the different payment systems that influences market rates. Thus, generally, the identified mechanisms rather contribute to a more efficient allocation of liquidity and risk and thereby foster the resilience of the financial system. In extreme cases, however, the increase in the transaction volume in net payment systems and the resulting increase in systemic risk might induce a hike in the credit risk spread in the interbank market that leads to a rationing of particularly risky banks in the money market which might make in turn a liquidity crisis and an unwinding more likely. Moreover, during the crises periods as the most recent one the severe spikes in money market rates and the substantial increase in counterparty risk and systemic risk might have very well affected the banks' choice of payment systems.

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1 Introduction

In most countries gross and net settlement systems coexist. While the relative advantages in terms of stability and efficiency of these two types of settlement systems are well-established when they are standalone, the implications of their coexistence for the stability of the financial system have so far been widely neglected. Because the coexistence of the two systems gives rise to substitution effects, it can lead to either an amplification or a diminution of systemic risk in the banking sector, depending on whether the substitution buffers a payment system shock or whether it transmits the shock to the rest of the economy through a pricing mechanism. In this paper we analyze these substitution effects and their drivers.

Net settlement systems incorporate substantial systemic risk. The netting of bilateral or multilateral payments for a given period at a point in time generates an implicit credit exposure among the different counterparties. A failure to provide sufficient liquidity at the settlement date sets in motion "knock-on" effects. If a bank holds too little in reserves to settle its balance at the settlement date, all its payments have to be unwound. If banks that received a payment from the failing bank are holding just enough liquidity to settle their balances, the unwinding can also trigger a settlement failure at these banks.

In contrast, real-time gross settlement systems do not generate financial contagion because in these systems each individual transaction is immediately settled in central bank money. But this also means that they require a far larger amount of reserves to settle a given volume of payments. While in a net settlement system banks have to hold only enough in reserves to meet the requirements of outgoing and incoming payments over the respective settlement period, banks in real-time gross settlement systems have to hold sufficient reserves for any potential outgoing payment at each point in time. Thus a trade-off emerges: while net settlement systems save on required liquidity holdings compared to real-time gross settlement systems, they carry a larger systemic risk.

In order to improve financial resilience, central banks in most developed countries nowadays run real-time gross settlement systems for large-value payments. The cost of maintaining the larger liquidity requirements that those systems require is thought to be offset by externalities inherent in net-settlement systems, namely, externalities that arise in response to the risk of contagion through the payment system, at least for large-value payments.

However, in most countries, net settlement systems exist alongside the central banks' real-time gross settlement systems. The net settlement systems are run either by private banking associations or other private entities. Even though the average transaction amount is much smaller in the net settlement systems, the total value of all transactions is a sizable number. The total transaction volume in net settlement systems of several countries that are part of the European Monetary Union (EMU) actually exceeded that of their gross settlement systems in some recent periods. Currently, the net-settlement transactions make up less than half of the transactions volume (in terms of value), but they still constitute a large percentage of the value transacted in the EMU.

Understanding the factors that govern which of these settlement systems is used at a given point in time is important for discussions of financial stability. The determinants matter because of the basic trade-off between risk and liquidity costs across the two settlement systems. In particular, it is essential to see whether there is substitutability between the systems and if so what its determinants are. For instance, one might suspect that in times of liquidity shortages and high short-term interest rates, banks would have a stronger incentive to save on liquidity and use net settlement systems more intensely. This means, however, that when liquidity is tight and banks are more vulnerable to liquidity crises, the shift towards the net settlement system increases the systemic impact of an individual bank's liquidity shortage. If tighter money market conditions induce banks to settle payments in the net system rather than the gross system, that reaction would endogenously increase systemic risk and financial fragility. Likewise, there are also good reasons to suppose that larger default risks induce banks to send relatively more payments through gross settlement systems. For instance, if a bank that is receiving a payment assigns a high probability to the possibility that its counterparty will be unable to provide the liquidity required to clear the transaction, the bank will likely require that the counterparty settle the payment in a gross settlement system. If the overall default probability of banks increases, the relative importance of gross settlement systems could increase. While this effect might partially offset the increased systemic risk resulting from the higher default probability, it also makes liquidity tighter and drives up money market rates. This effect in turn can feed a liquidity crisis and make an individual bank's default more likely.

At the same time, though, the price of liquidity might actually be the result rather than the driver of the relative importance of gross relative to net settlement systems. If more transactions are sent through gross settlement systems, the need for liquidity increases, which would drive up the overnight interbank rate. Similarly, an increase in the value of payments sent through net settlement systems increases systemic risk and might therefore lead to a larger credit risk spread in the interbank market.

All in all, these theoretical considerations suggest that the question of whether the substitutability between gross and net settlement systems endogenously amplifies or reduces financial fragility is an empirical one. In this paper we try to answer the question for the euro area using a variety of econometric approaches and applying them to the euro area as a whole and to individual countries in the EMU.

We find that the neither the price of liquidity nor the credit risk spread in the money markets substantially affects the fraction of payments that is settled in the net settlement system relative to the gross settlement system. Thus banks do not substitute between the two types of payment systems if the opportunity cost of using one payment system changes compared to the other. Instead, our results indicate that it is the transaction volume in the different payment systems that drives market prices. A higher relative and absolute transaction value settled in the gross settlement system leads to a higher overnight repo rate. A higher absolute and relative transaction value in the net settlement system is associated with a higher credit risk spread in the overnight interbank market.

It is important to note that all of our data come from a relatively quiet period, from the start of 2000 until the end of 2007. Indeed, we feel it is quite likely that a financial crisis may induce very different behavior than what we observe in the period covered by our data. Clearly further work that focuses on the differences in payments during past crises is of crucial interest in research. However, we also feel it is important to establish a baseline result of the behavior of the interacting payments systems during normal times, so that we can determine crisis behavior as a deviation from this baseline once data become available.

The paper is structured as follows: In the remainder of this section we discuss the related literature, briefly sketch out the institutional structure of the large-value payment systems of the euro area, and describe our data set. Section 2 discusses what we can learn about substitution effects from two natural experiments: the closure of two national net settlement systems, EAF and SEPI. From our analysis of the effects of these closures, it is very clear that within the euro area the substitution of payment flows occurs between the net and gross settlement systems of individual countries but not between the payment systems of different EMU member states. Further, as we find later in the paper, the substitution seems confined to events that are perceived to be permanent and large and maybe institutionally driven rather than incremental developments or small temporary shocks. Section 3 briefly discusses a correlation between the downtime of the different gross settlement systems and the relative transaction volumes settled in gross and net settlement systems. In section 4 we apply a simple regression analysis to study the contemporaneous interaction between the market prices for liquidity and counterparty risk and the values settled in gross and net payment systems. In section 5 we use the intertemporal impulse responses in a FAVAR approach in order to further identify causal relations. Section 6 summarizes our main findings and draws some conclusions.

1.1 Related literature

The theoretical foundations of our paper rest on the work of Kahn and Roberds (1998) and Freixas and Parigi (1998), which develops a model of the main trade-off between net and gross settlement. Both papers show that net settlement systems tend to be more efficient in terms of liquidity use while gross settlement systems contain moral hazard, gambling for resurrection, and systemic risks. Gross settlement systems therefore become more preferable when the costs of reserve holdings decline, when the riskiness of bank assets decreases, or when the degree of concentration in the banking industry falls.

However, Kahn, McAndrews, and Roberds (2003) question whether gross settlement system indeed contain systemic risk. They show that even though net settlement systems carry a risk of contagion, they might be stability enhancing. This results from the fact that net settlement systems do not generate an incentive for banks to delay the delivery of their payments to the end of the business day in order to save on their liquidity holdings but instead they encourage banks to reuse incoming liquidity from other banks. Without this incentive to delay, the gridlock effect is avoided. Kahn, McAndrews, and Roberds (2003) argue that the payments' delay can in principle cause similar credit exposure and systemic risks in gross settlement systems. However, they also point out that a delivery-versus-payment approach can eliminate the incentives to delay in a real-time gross settlement system.

Alternatively, Lacker (1997) Angelini (1998) and Kahn and Roberds (2001) show in different frameworks that costless intraday lines of credit provided by the central bank can avoid free-riding on the liquidity provision of others and prevent deadlocks in real-time gross settlement systems.[1] However, as Kahn and Roberds (2001)

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[1] See also Minguez-Alfonso and Shin (2009) on this point.

indicate, collateralized intraday credit lines might not be sufficient if banks are constrained with respect to collateral. Angelini (1998) shows that the efficiency losses due to the higher liquidity requirements of real-time gross settlement systems as well as the incentives to delay payments do not increase as the costs of intraday liquidity rises, but as the overnight interest rate increases.

In sum the theoretical literature suggests that systemic risks that emerge from the incentives to delay payments in gross settlement systems is small as long as the central bank provides intraday credit at a zero interest rate and against a broad set of collateral. This is the case for the National Central Banks in the national RTGS systems. A basic trade-off prevails in this case: Net settlement systems are generally more efficient in their use of liquidity while gross settlement systems limit systemic risk.

In contrast to the bulk of the theoretical literature in payment systems, there is only little empirical work on the design and stability of payment systems. Schoenmaker (1995) estimates the expected costs of mutual loss-sharing arrangements that would be needed to prevent the unfolding of systemic risk in net settlement systems. He compares those with the higher efficiency losses and delay costs that are inherent in gross settlement systems. He concludes that the efficiency gains of net settlement systems outweigh the expected costs of a failure of settlement.

The only papers to our knowledge that address the implications of the de facto coexistence of net and gross settlement systems in most countries are Holthausen and Rochet (2005 and 2006). However, they focus on the pricing of central banks' gross settlement systems given that they compete with privately run net settlement systems. Holthausen and Rochet (2005) also consider the provision of the public good "financial stability" when pricing gross settlement systems. Rochet and Tirole (1996) also focus on issues related to the competition between different payment systems. In addition, they also discus contagion effects that may occur between payment systems and point to the need for coordination between the operators of different systems in order to deal efficiently with these externalities.

Beyond that, however, no other paper to our knowledge has yet studied the apparent implication of the coexistence of the two types of settlement system on the resilience of the financial infrastructure or on financial stability in general. There is only one paper, to our knowledge, that looks at the direction of shocks: Our finding that money market rates are driven by changes in the transaction volume of gross settlement systems is quite in line with Furfine (2000), who reports evidence that deviations of the federal fund rate are driven by higher payment flows on the same day.

1.2 Institutional Background

Our study focuses on payment flows in the euro area up until the end of 2007. Payment systems in the euro area are — and particularly were up to the introduction of TARGET2 — quite fragmented regionally. This abundance of systems provides us with a cross-sectional dimension to our data set, as a number of EMU member countries had both a net and a gross settlement system.

Since the introduction of the euro in 1999 and up until November, 18, 2007, the central banks of each of the EMU member states ran their own real-time gross settlement system, and these were linked across the euro area through the ECB's TARGET.[2] While most of these settlement systems included some liquidity-saving mechanism, like, for instance, multilateral matching, they all shared the main feature of a gross settlement system in that payments were immediately settled in central bank money. The largest of these systems was the German TARGET component run by the Deutsche Bundesbank. Its annual turnover in 2007 was €232 trillion and the number of transactions it settled was 47.5 million. France, with €145 trillion in turnover and 4.9 million in annual transactions, had the second-largest component of the euro area, and Italy, with €42 trillion in turnover and 11.5 million in annual transactions, had the third largest.

In the euro area, central banks provide intraday credit lines to banks participating in their respective real-time gross settlement system without charging them any

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[2] In Belgium, Finland, France, Ireland, the Netherlands, Portugal, and Spain, the changeover to TARGET2 was only effective on February, 18, 2008, and in Denmark, Estonia, Greece, Italy, and Poland it was delayed until May, 19, 2008.

interest. But banks are required to hold sufficient collateral with the central bank to back up the intraday liquidity provision. However, all collateral that is eligible for the open market operations is generally also accepted as a backup for intraday credit lines with the national central banks. Since the set of eligible assets ranges from government bonds, corporate bonds, and mortgage bonds to corporate loans, banks are generally not constrained with respect to collateral. Thus, incentives to delay payment delivery to the settlement system are rather limited, which is also reflected in the fact that about half of the daily payments are settled before noon and only 10% of the TARGET traffic occurs in the last operating hour of TARGET.[3]

In addition to these real-time gross settlement systems of the European System of Central Banks (ESCB), in the year 2000 there were several other large-value payment systems that were either pure net settlement systems or hybrids. These were run by the national central banks or by an association of private banks. The most important large-value payment system in the euro area besides TARGET was and still is Euro1. Euro1 is a net settlement system run by the European Banking Association — an organization consisting of mainly European banks but also including banks from some other countries. There are 68 banks directly linked to Euro1 and 67 banks indirectly connected. The overall transaction value in 2006 amounted to €48.2 trillion. The average value of a transaction was €1,010,000. Before it was discontinued in November 2001, the second-largest payment system in the Euro area was EAF — a net settlement system run by the Deutsche Bundesbank. In 2001 the total transaction value handled in EAF was about 20% smaller than the total handled in Euro1. Nowadays, the second-biggest net settlement system handling large-value payments is the Banque de France's PNS. By the end of 2007 PNS handled an overall transaction value of about 30% of the value handled in Euro1. The average value per transaction in PNS in 2006 was €2,247,000, which was about 11% of the French component of TARGET, TBF.

In addition, there were two smaller net settlement systems operated by national central banks. Until November 2004 the Spanish central bank ran SEPI, which had a monthly transaction value of less than €30 billion in 2004. Thus, the transaction

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[3] See ECB (2008), p.105.

value handled in SEPI was only about 0.4% of the value handled in the Spanish component of TARGET, SLBE, and only 0.7% of the value handled in Euro1 during 2004. Slightly bigger and still operated is the net settlement system POPS, run by the Finnish central bank. The transaction value it handled in 2006 amounted to €460 billion, which was about 12.5% of the Finnish component of TARGET, BoF-RTGS, and about 1% of the transaction value handled in Euro1.

1.3 Data set

Our data set contains the daily value of total transactions and the number of transactions settled in the various large-value payments systems of the euro area. As a measure of the shortage of liquidity, we include the unsecured overnight money market rate, the Euro Area Overnight Index Average (EONIA). We obtain the overnight repo rate, i.e., the interest rate paid on a secured overnight loan, and use the difference between the EONIA rate and it as an indication of counterparty risk. In addition, as a further measure of the tightness of liquidity, we use the overall amount of reserves of the European banking system held with the European Central Bank. Furthermore, our data set contains time series on the availability of the different payment systems, i.e., the daily percentage of the opening hours during which the respective system was out of order due to some operational problem. Table 1 gives some summary statistics for the total daily transactions value and the number of transactions handled daily in the net and the gross settlement system.

2 The closure of EAF and SEPI - two natural experiments

The closure of EAF and SEPI on November 5, 2001, and December 15, 2004, respectively, provides us with two natural experiments that allow us to draw some preliminary conclusions about the substitution in payment flows between the two different types of settlement systems.

Figure 1 presents a graph of frequencies for the sum of the daily value of payments settled in all gross and net settlement systems from 2000 to the end of our series in 2007. A quick glance shows both series to be bimodal. This is the result of a structural break in the series that occurred on the weekend of November 3, 2001, when the German net settlement system, EAF, permanently shut down. The histograms for the post-closing period (December 2001 to the end of the series) show a unimodal pattern, in Figure 2.

The structural break associated with the closing of the EAF settlement system in both series suggests a long-run degree of substitution between the gross and net settlement systems that is not surprising. In the three months before the EAF closed, it averaged €152 billion per day of payments. The other three net settlement systems taken together averaged about €275 billion per day. In the three months after the EAF closed, the other three exchanges experienced an increase in their average daily value of payments of about only €8 billion. In the meantime, the gross settlement system seems to have had an increase in its daily average of €388 billion over the same period. It turns out that this was a permanent, one-time increase in the gross settlement system, which occurred on the day of the EAF's closure. Between the Friday on which the EAF was operating for its final day and the Monday on which it closed, the gross settlement system experienced an increase of €304 billion in value exchanged, whereas the total net settlement systems experienced a drop of €134 billion. So it seems that the users of the EAF, for the most part, substituted into the gross settlement system, at least immediately after the shock.[4]

Figure 3 shows the corresponding histograms for the gross settlement systems in Germany, France, and Italy, the three largest TARGET components, for each of the two time periods. These indicate that the short to medium run effect was similar. It is clear that the EAF volume was taken up only by the German gross settlement system. The other countries have value distributions that stay fairly

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[4] It is interesting to note here that the decline in the transaction volume of the net settlement system was far smaller than the increase in the gross settlement system. A reason for this might be that settling in a gross system requires banks to reallocate more liquidity through the interbank market which by itself generating further payments.

consistent throughout the period. So when the EAF closed, not only did all of the net settlement payments go to the gross settlement system, they also went only to the German system. At least in the short to medium time horizon, payments seem to be a local phenomenon.[5]

Figure 3 also shows the diagram for the Euro1 net settlement system over the same two time periods. Although there is bimodality associated with its distribution, it is a bimodality that is evident independent of the sample period. It is related to the fact that this system has dramatic single-day losses in volume periodically, which are made up the next day. These drops occur throughout the sample period and may be related to exchange closures.

Further evidence for the substitution between payment systems after a large shock is provided by breakpoint tests. Table 2 provides the breakpoints for some of the payments systems of the euro area, obtained by applying a fairly standard test for determining breakpoints of unknown date. These breakpoints are reported for sixth order autoregressive processes of the logarithm of value in the payments systems, although the results are consistent with other specifications. Several points emerge clearly. First, there was clearly a break in the German gross settlement system exactly on the date on which the EAF closed. This breakpoint is also clearly identified in the aggregate time series for payments in the net and gross settlement systems. There is no evidence of a breakpoint on that date in any of the other time series — neither in the other national TARGET components nor in the national net settlement systems. Specifically, there is no breakpoint at all identified in the sample period for the French and Italian TARGET components or for the other euro area net settlement systems. Surprisingly, for the Spanish TARGET component we find a breakpoint at the 90% significance level for a day prior to the closure of the German net settlement system, while we have no breakpoints identified at the actual closure of SEPI — the Spanish net settlement system — on December 15, 2004.

In sum, however, these results confirm that large-value payment streams are not redirected across borders. Thus substitution effects are likely to be relevant only for different payment systems within one country. However, within a country, there

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[5] See ECB (2006) for a more detailed discussion drawing the same conclusions.

seems to be a strong substitution effect between net settlement systems and gross settlement systems. The location of a payment system seems to matter more in the choice of a system than whether it is gross or net.

This substitution of payment system across systems does not seem to be repeated for short-term interruptions. As we shall show in the next section, a variable that reflects temporary interruptions in the gross settlement system does not have any explanatory power for changes in the transaction volumes in the net settlement system, temporary or not.

3 The effect of short-term disruptions

The basic empirical tests reported in the previous section show that some domestic substitutability between net and gross settlement systems occurs in the presence of long-term disruptions. However, in those cases, the disruptions were anticipated; the closure of each of those payment systems did not come as a surprise, and central banks and payment system participants had time to prepare.

From a financial stability perspective, it is more important to know whether unanticipated short-term disruptions generate substitution effects. To study that question, we obtained a time series on the daily downtime of the different national TARGET components. Using that series, we investigate the extent to which the unavailability of TARGET or its components induced banks to switch to domestic net settlement systems. We calculate the extent to which percentage daily downtime is correlated with the proportion of transactions sent through each type of system. In order to do so we aggregate the transaction value sent through all the net settlement systems in the euro area ($NETVAL$) and the value sent through the different gross settlement systems ($GROSSVAL$). A significant positive correlation between TARGET unavailability and the ratio of $NETVAL$ to $GROSSVAL$ could be seen as a first indication that short-run disruptions in the gross settlement system also lead to more frequent use of the net settlement systems. Such a finding would be important to the question of financial stability, because it would indicate that systemic risk increases endogenously precisely in times when the stability of the financial system is at risk due to disruptions in the main large-value payment system.

However, we do not find any indication of a significant impact of TARGET downtime on the relative importance of the net and gross settlement systems. The correlation between the daily unavailability of TARGET and the transaction value settled in the net relative to the gross settlement systems is both economically and statistically insignificant. The correlation coefficient is 0.012 (with a t-statistic of 0.5095 and a P-value of 0.6.), so it is effectively zero.

4 Contemporaneous effects of tensions in the money market

Our results so far indicate that there is some substitutability between gross and net settlement systems for payments, but that substitution occurs only when there is an anticipated, permanent disruption to service. Given that some substitution does occur, however, we argue that disruptions in the gross payment system potentially increase systemic risk, since they can increase the volume of payments flowing through the inherently riskier net settlement systems. What we would like to know, and what our results do not tell us, is whether the observed substitution effect tends to amplify or mute any increase in systemic risk resulting from tensions in money markets. If the substitution is driven by tightness in the money markets or by banks' default probabilities, then the choice of the settlement system might have an endogenously amplifying or damping effect on systemic risk.

As mentioned in the introduction, it is not clear from a theoretical perspective if the prices of liquidity and default risk drive the choice of the net or gross systems or shocks in the payments systems drive the prices. The choice of payments should be affected by the economic environment, in particular, by the relative price of using one system over another. Net settlement systems require less liquidity to complete a transaction, but they involve more default risk than gross payment system. This suggests measuring the substitution between the two settlement systems based upon their response to two prices, the price of liquidity and the price of default risk.

On the one hand, an increase in the price of liquidity will induce banks to send fewer payments through the system with higher liquidity costs (the gross settlement system). Holding the price of liquidity constant, an increase in the price of default risk should cause the users of the net system to substitute into the gross system. On the other hand, from the perspective of a "general equilibrium" approach, one might also expect an increase in the demand for liquidity due to more intense use of the gross settlement system to increase the price of liquidity. Thus depending on whether the pricing shock in money markets is caused by demand or supply, the effect can be different.

Furthermore, when perceived default risk in the banking sector rises, receivers of payments will likely prefer being sent transactions through the gross settlement system, while senders might actually prefer to use the net settlement system. In times of higher default risk, gathering liquidity in the money markets is more costly to collaterally constrained sending banks if they have to pay a high default risk premium in the unsecured interbank market. Consequently, whether gross payment system volumes increase relative to net volumes in response to an increase in the default risk premium in interbank markets also depends on whether it is the sending or the receiving bank that is choosing the payment system.

Thus whether net settlement systems are more intensely used in times of liquidity shortage and high counterparty risk and whether this effect amplifies or mutes systemic risk is an empirical question. To investigate this we analyze the interaction between the daily transaction volume in the two payment systems and contemporaneous daily money market rates. In particular, we measure the price of liquidity and default risk with two price spreads. We take advantage of the several markets for liquidity that are alike in most respects, but which differ in specific dimensions. The rates in these markets vary primarily because of these differences. The Eonia is the interest rate in the euro area unsecured overnight money market. Thus the Eonia reflects liquidity shortages as well as the average counterparty risk in the euro area banking sector. The overnight repo market has the same duration, and because it is fully collateralized, it represents the counterparty-default- free rate for scarce liquidity.[6] The marginal lending rate is the rate applied by the ECB on the fully collateralized standing facility.[7] It is the rate at which all banks in the euro area receive liquidity in any amount against eligible collateral. Consequently, this interest rate measures the price of liquidity that is not affected by temporary liquidity shortages, which might drive the other two rates. It reflects the stance of monetary policy and allows us to correct the other rates for changes in monetary policy.

As the price of liquidity risk ($LIQUIDITY\ RISK$) we use the difference between the repo rate and the marginal lending rate (plus 100 bp to center it around zero).[8] Our measure for the counterparty default risk in the banking sector ($DEFAULT\ RISK$) is the spread between the Eonia and the repo rate.

A first indication of the contemporaneous interrelation between our measures of money market tensions and transaction volume in the different payment systems is given by the correlation analysis presented in Table 3. Here $LNETVAL$ and $LGROSSVAL$ stand for the logarithm of the transaction value in the euro area's net and gross settlement systems, respectively. $LNET2GROSS$ is the log transaction value in the net settlement systems relative to the gross settlement systems.

As Table 3 indicates, there is a positive correlation between our default risk measure and the absolute and relative values of transactions in the net settlement systems. This suggests that banks do indeed use net settlement systems more intensely when the spread between secured and unsecured lending is high and it is costly for collaterally constrained banks to provide enough liquidity. However, the univariate negative effect on the transaction value in the gross settlement system is tiny.

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[6] A problem with this rate is that the market was used in volume only after May 2002, so that a number of our observations in the early part of the sample cannot be used. However, this is the period where structural breaks were evident as discussed above, so that the empirical methods that we use do not have to account for them.

[7] It should be noted that the class of assets eligible for the ECB's repo auctions is broader than the class of assets accepted in interbank repo transactions. However, this effect of collateral constraints only drove the difference between the repo rate and the marginal lending rate during the financial crisis from 2008 onwards.

[8] Thus, effectively the spread reflects the difference between the repo rate and the minimum bid rate set by the ECB for its main refinancing operations.

A comparison of the correlation of $LNETVAL$ and $LNET2GROSS$ with the correlation between $LGROSSVAL$ and $LNET2GROSS$ suggests that the relative importance of the net settlement system is not solely driven by changes in the transaction value in either of the two systems.

Most surprisingly, though, Table 3 shows that the univariate effect of an increase in the spread between the repo rate and the marginal lending rate is negative for the payment volume sent through the gross settlement system. However, at the same time, a higher liquidity risk is associated with a decrease in the transaction value of the net settlement system, which even exceeds the decline in the gross settlement system such that the overall effect on the relative transaction volume sent through the net settlement system actually declines, too. These univariate results are clearly at odds with our theoretical assumptions. Neither do we find that an increase in the price of liquidity is correlated with a substitution from gross to net settlement systems, nor do we find that an increase in payments volume in the gross settlement systems is associated with an increase in the price of liquidity.

These univariate results of course should not be taken at face value. In particular, they might be driven by the strong trend in the transaction volumes. So next we apply an OLS regression to study the contemporaneous effect of our two risk variables on the absolute and relative transaction value in the two payment systems, correcting for respective trends in the transaction value in the two payment systems.

Table 4 reports our OLS estimates for the effects of the two risk spreads on the absolute and relative transaction values settled in the two different types of payment systems. Here $D(LGROSSVAL)$ and $D(LNETVAL)$ are the first-order differences in the transaction values in the two payment systems. The results indicate that there is indeed significant growth in the volume of both the gross and the net settlement systems. The positive trend in the gross settlement systems substantially exceeded the growth in the net settlement systems such that we observe a strong significant negative trend in the ratio of payments settled in net relative to gross payment systems.

Taking these results into account, our OLS regression still indicates that a higher default risk premium in the interbank market leads to a significantly higher transaction volume in the net settlement system. However, our results also indicate that as $DEFAULT\ RISK$ rises, the value sent through the gross settlement system becomes significantly larger.

The regression results reported in the forth column indicate a further insight. Since both the transaction value in gross and net settlement systems, are positively related to $DEFAULT\ RISK$, the relative importance of the net settlement systems does not significantly increase with the credit risks in the overnight interbank market. This is in contrast to our univariate results. The differences in our results suggest that it is the increase in the transaction value that is processed in both payment systems that leads to a higher need for liquidity. This forces collaterally constrained banks to demand more unsecured interbank credit and pay an increasing spread for it.

Regarding the effect of a change in liquidity risk, we find that a higher difference between the overnight repo rate and the ECB's lending rate is associated with a higher value sent through the gross settlement system and a lower value sent through the net settlement system. While individually each effect is insignificant on the respective transaction value, they jointly lead to a significantly negative effect of $LIQUIDITY\ RISK$ on the ratio of the value sent through net relative to gross settlement systems. These results now clearly suggest that it is not the price of liquidity that leads to a substitution from gross to net settlement systems. They rather indicate that the causality is reversed in that liquidity becomes pricier when the need for liquidity is increased because of an increased transaction value settled in the liquidity-intense gross settlement system.

To provide further evidence for this line of reasoning, we switch the endogenous and exogenous variables and run the reverse OLS regression, explaining the counterparty risk spread ($DEFAULT\ RISK$) and the daily price of liquidity as the spread between the repo rate and the marginal lending rate ($LIQUIDITY\ RISK$) with the respective daily transaction value in the payments system.Table 5 reports the results for those regressions.

According to the results in Table 5, the absolute transaction value in gross settlement systems has no significant effect, neither on the daily price of liquidity, i.e., the spread between the repo and the marginal lending rates at the ECB ($LIQUIDITY\ RISK$), nor on the default risk premium in the overnight interbank market ($DEFAULT\ RISK$). In contrast, the effect of a higher absolute transaction value in the net settlement system is significantly negative on the daily price of liquidity and significantly positive on the credit risk in the overnight markets. While the impact on $DEFAULT\ RISK$ confirms our previous results, the negative effect on $LIQUIDITY\ RISK$ cannot be explained with our theoretical assumptions, and it is at odds with our previous results. Regarding the effect of the ratio of transactions settled in net relative to the gross payment systems, we find a positive though insignificant effect on the credit risk in the overnight interbank market and a significant negative effect on the price of liquidity.

In sum, we do not find evidence that scarce liquidity conditions induce banks to substitute transaction volume from the gross to the net settlement system. Furthermore, we cannot confirm the hypotheses that a higher default risk in the banking sector leads banks to switch payments from net to gross settlement systems. Rather, our findings suggest that banks price in the increase in systemic risk due to an absolute or relative increase in the settlement values sent through net systems and charge higher credit risk spreads in the overnight interbank market. From that angle our results all in all suggest that the interaction between transaction volume in different payment systems and spreads in the money markets do not amplify but rather mute systemic risks.

However, the positive relationship between the default risk and the transaction value in net settlement systems could also be driven by the substitution activities of collaterally constrained banks, which try to save on liquidity by using the net settlement system more frequently when they have to pay a higher spread in the unsecured overnight market.

All of our results of this section need to be taken with a grain of salt. Identification is assumed in the sense that the exogenous shocks all are presumed to be on the side of the quantities of payments in the respective systems. In lieu of more finely delineated data, either in the sense of time of day transactions, or in the sense of individual choice of payment system, these assumptions substitute for a more convincing structural approach.

In the next section we try to disentangle these relationships further trying to identify causality along the intertemporal patterns in a vector autoregressive approach.

5 Intertemporal impulse and responses

To examine the reactions of payments shocks and risk shocks to one another for horizons longer than a single day, we estimate impulse responses from structural vector autoregressions (VARs). Part of the challenge of estimating these responses lies in the fact that the payment systems and the markets for liquidity and default risks could be subject to a wide variety of economic shocks. For example, a shock in equity prices might simultaneously affect the prices of risk in the banking sector and the volume of stock trades, which will change the total value of payments.

Accounting for all of the possibilities that might affect the payment system could involve a large number of variables. If each were to be included as a separate shock in a structural VAR, one would quickly run out of degrees of freedom with which to estimate all of the economic parameters, much less be able to handle the complexity of ordering the structural shocks for identification purposes. To address this issue, we follow the suggestion of Bernanke, Boivin, and Eliasz (2005) and extract factors from a large number of high-frequency variables, which we feel might affect payments and risk prices. These factors are then used in the structural VARs as factor-augmented vector autoregressions (FAVARs).

A list of the variables used to estimate the factors is displayed in Table 6. It includes 42 variables representing a wide variety of equity, bond and derivatives prices, and yields and transaction volumes on different exchanges. Some days were thinly traded in some markets, so data on those days is missing. These values were filled in for the purposes of estimating the factors using the expectation-maximization (EM) algorithm of Stock and Watson (2002).

The proportion of the variance explained by the factors is given in Table 7. As can be seen in the table, although the number of relevant factors is larger than for interest rates, most of the variation can be explained with just a few factors. The top four explain more than 90% of the variance, and the top seven account for all but about 3% of it. Interpreting factors is notoriously difficult, especially when such a wide variety of variables is used. However, Table 8 lists the factor loadings for the top five factors, and, at least for the first two factors, an interpretation is straightforward. The first factor represents a level variable, which takes a positive weight for every variable except the long-range bond rate. The second factor represents a spread between the various money market and bond rates and equity prices and volumes. In a sense, it could be interpreted as an equity premium. Further factors are less transparent in what they represent. This is not unusual in factors studies, especially given the large variety of daily variables used. In the spirit of Bernanke, Boivin, and Eliasz (2005), we also use the components of the factors which are orthogonal to the included observed variables within the FAVAR.

Figure 4 displays the impulse responses of a model with three factors, the log ratio of the transaction value in the two payments systems, and the prices of liquidity and default risks. The identification of the model is through standard Cholesky assumptions of the ordering of the shocks. We assume that the shocks proceed very much in the spirit of what our contemporaneous study indicated: the economic shocks drive the payments system, which in turn drives the pricing of the risks. However, the results that we report in this paper are robust to the orderings in some sense. If we change the orderings of the principal component factors with respect to the other variables, then little happens, although in some cases, the results have less statistical significance. If we reverse the effect of the shocks so that the price shocks occur first and then the payments systems is affected, we get results that do not pass the credulity filter. Indeed, the results indicate that the immediate effect has the opposite sign than one would expect, with a liquidity price shock causing an increase in the relative use of the gross settlement system. These orderings would be ruled out by an implicit sign restriction, so we report the impulse response functions that follow the Cholesky orderings implied by our previous discussion.[9]

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[9] An appendix with impulse response functions based on other possible Cholesky orderings are

The left column of Figure 4 shows the responses to a two-standard -deviation shock of the ratio of the value settled in the net relative to gross system. As the figure indicates, such a shock is rather fugacious. Only for the following day does it have a persistent positive effect. Already on the second day, the shock has no further significant impact on the ratio of the transaction values. More importantly, the effect on the two risk spreads lasts only one day. The price for liquidity, i.e., the repo rate and the ECB's marginal lending rate, is significantly positive the day after a relative increase in the value settled in the gross system. This confirms our readings of the results from our contemporaneous analysis: Also our FAVAR results indicate that it is a temporary rise in the transaction value settled in the gross settlement system that increases ceteris paribus the need for liquidity and leads to a higher short-term interest rate. Similarly, a relative increase in the value of transactions settled through net settlement systems leads to a higher default risk spread, i.e., a higher spread between the EONIA and the overnight repo rate but only on the next day. This finding suggests that market participants do indeed respond to the higher systemic risk signaled by the larger transaction value in net settlement systems, and they charge a higher default risk premium in response. However, both effects are economically fairly small.

The second and third columns report the impulse responses to shocks in the prices of liquidity ($LIQUIDITY\ RISK$) and the counterparty credit risk spread in the money market ($DEFAULT\ RISK$), respectively. As the two charts in the first row indicate, there is no significant response of the ratio of payments settled through net relative to gross systems on those market prices for risk. This further confirms our previous result that it is not the price of liquidity or perceived counterparty risk in the banking sector that drives the decision to use one payment system or the other. It is rather the payment volume settled in either system that affects the different spreads. In order to disentangle which of the payment systems actually drives the respective spreads, we include in a second FAVAR analysis the value of the payments settled in the two different types of payment systems separately. We use the same ordering in this analysis as in the first FAVAR estimate. Figure 5

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available from the authors on request.

reports the impulse responses for this FAVAR analysis. The first and second columns show the responses to a shock in the transaction value in the net and in the gross settlement system, respectively. Again the response fades out one day after the shock. While an increase in the payments sent through the net settlement system leads to a higher credit risk spread in the overnight market ($DEFAULT\ RISK$) and a lower overnight repo rate relative to the lending rate ($LIQUIDITY\ RISK$), a rise in the value of payments settled in the gross systems has the opposite effect on each of these variables. It contributes to a lower $DEFAULT\ RISK$ and a higher price for liquidity ($LIQUIDITY\ RISK$).

Consequently, it is not only the higher need for liquidity due to the larger transaction volume in the gross settlement systems that drives up the overnight money market rates. Apparently, a higher transaction volume in the net settlement system is also associated with a slightly lower overnight repo rate the next day. While the former effect is what we would expect, the latter effect is puzzling from a theoretical perspective.

Similarly, that a larger value of payments sent through the net settlement system contributes to a higher systemic risk and thus to an increase in the default risk spread in the money market is fairly intuitive. That an increase in the transaction value settled in the gross system has a damping effect on the default risk spread in the overnight money market is less straightforward. One explanation for this puzzling finding might be that it is driven by greater unsecured overnight interbank lending. A positive shock to overnight interbank lending leads to a higher transaction volume in the gross settlement system on the first day, when credits are granted, and on the second day, when they are repaid. A higher level of unsecured overnight lending should at the same time lead to higher systemic risk and thus a higher default risk spread on the first day, but to a reduced counterparty risk on the second day when the unsecured overnight interbank loans are repaid.

Columns 3 and 4 in Figure 5 report the effects of the different spreads on the settlement value in each of the two systems. Again we do not find any response, which confirms our previous finding. The price for liquidity does not induce banks to reduce the volume of payments sent through the gross settlement system nor does it increase the transaction volume in the net settlement system. We find no evidence that a higher counterparty risk spread affects the volume settled in the net or the gross settlement system.

The northwest quadrant of Figure 5 seems to indicate that a shock in the net settlement system will affect the gross settlement system more than the other way around. However, this is due to the particular ordering of the Cholesky shocks that are generating the impulses reported in that figure. If we order the shocks so that shocks to the gross settlement system precede the net settlement system shocks, we would get a quadrant such as that reported in Figure 6. Note that this ordering implies that the gross settlement system influences the net settlement system more than vice versa. Given that our theory provides no clue as to which shock is likely to occur first, the best interpretation for the response functions in Figure 5 is an agnostic one: the data do not delineate which system influences the other more. All that we can deduce is that the systems are intimately connected, and that the effects of the shocks are felt quickly.

6 Conclusion

All in all, the various approaches that we take in this this paper provide us with a number of very clear results. The price for liquidity does not affect banks' decisions to send payments through net or gross settlement systems. We find no evidence that during the pre-crisis period in Europe a shortage of liquidity induced banks to use net settlement systems more frequently or that liquidity shortages amplified the systemic risk associated with tensions in the money markets as a result. We also find no evidence that general credit risk in the interbank market induced banks to favor one type of payment system over the other.

However, we find that the changes in the transaction value settled in the different payment systems has an economically small but still significant effect on the daily price of liquidity and on the credit risk spread charged in the money markets. In particular, a larger transaction volume sent through gross settlement systems increases the need for liquidity and increases the price paid for overnight liquidity. A larger payment volume sent through the net settlement system increases the credit risk spread charged in the overnight interbank market.

In sum, these results suggest that the interaction between transaction value in the different payment systems and the different prices in overnight money markets do not amplify the systemic threat from tensions in the money markets. Rather, our results suggest that prices in the secured and unsecured money market segments respond to changing transaction volumes and that they adjust effectively to changing systemic risk and scarce liquidity.

Our results must be interpreted with caution. Our empirical modeling is not truly structural in the sense that our results are not derived from an explicit behavioral model of the choice of payments system. Identification in our case is either somewhat ad hoc, as in the case of our cholesky assumptions governing the FAVAR results, or implicit, as in our ordinary least squares results. Although we do some robustness checks of our identifying assumptions, in the case of the FAVAR modeling, for the most part, our identification is asserted rather than examined closely. To transform our correlation results into more potent policy implications of causality, a more structural approach is called for.

Further, our results are derived from data covering a fairly tranquil period in money markets. Thus our findings do not necessarily carry over to crisis periods with severe liquidity shortages and huge credit risks in the banking sector, such as during the recent global financial crisis. Studying the interaction between transaction volumes in the different payment systems and the money markets in the crisis period would be a natural extension of our analysis. Extensions of our analysis in both a more structural direction, and in the direction of examining the deviations of crisis behaviors from our baseline, call for more data than examined in this paper. However, we are pursuing this research as data become available.

Our results indicate other additional directions for further research. First, the theoretical basis of our analysis is fairly loose. A thorough analysis of what determines banks' decisions about which payment system they will use — given that both the sending and the receiving bank have access to a gross and a net settlement system — is highly needed. Second, analyzing related micro-data covering individual banks payments sent and received through different types of payment systems would be important to analyze in greater depth in order to find the drivers of payment system choice and further assess the extent to which this choice affects system risk.

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Appendix

Table 1: Sample statistics for the sum of daily transactions settled in the net and in gross settlement systems

November, 2001 to May, 2007

	Net settlement systems		Gross settlement systems	
	Log(value)	Log(volume)	Log(value)	Log(volume)
Mean	26.2261	12.17628	27.78349	12.26092
Median	26.22733	12.18341	27.77243	12.23287
Maximum	26.82559	12.67217	28.60971	13.00966
Minimum	25.07853	11.49342	27.07343	11.48088
Std. Dev.	0.180286	0.143986	0.155546	0.173012
Skewness	-0.92512	-0.30793	0.099343	-0.03547
Kurtosis	7.993696	4.067027	4.15694	4.688742
Jarque-Bera	1681535	8999473	8170314	1693893
Probability	0	0	0	0
Observations	1423	1423	1423	1423

Table 2: Breakpoint tests

Quandt-Andrews, Maximum likelihood, 15% trim,
null hypothesis-no breakpoints in the sample period,
demeaned sixth-order autoregressive process

Market	Maximum likelihood F-statistic: Date	Value	Probability of the null
Gross settlements			
All EMU	11/02/2001	2.632.303	0.0000
Germany	11/02/2001	5.223.907	0.0000
France	9/13/2004	9.929.660	0.7130
Italy	2/25/2005	1.721.749	0.1242
Spain	11/01/2001	1.802.484	0.0964
Net settlements			
All EMU	11/02/2001	2.205.142	0.0245
Paris	6/23/2003	1.549.204	0.2066
EuroStar	7/25/2002	7.154.893	0.9470

Table 3: Covariance analysis

Sample (adjusted): 3/01/2002 to 11/16/2007
Included observations: 1491 after adjustments

Correlation	LIQUIDITY RISK	DEFAULT RISK	LNET VAL	LGROSS VAL	LNET2 GROSS
LIQUIDITYRISK	1.000000				
DEFAULTRISK	-0.033277	1.000000			
LNETVAL	-0.044337	0.038402	1.000000		
LGROSSVAL	-0.026331	-0.003111	0.502892	1.000000	
LNET2GROSS	-0.020113	0.042617	0.542093	-0.453714	1.000000

Table 4: The effect of contemporaneous risk spreads on transaction volumes in different payment systems.

Each column represents a separate regression for the different transaction value measures.

Standard errors reported in parentheses.

	LNET2GROSS	LGROSSVAL	LNETVAL	D(LGROSSVAL)	D(LNETVAL)
C	**-1.394.454*** **	**27.59749*** **	**26.201250*** **	**-0.004679* **	-0.003016
	(0.010628)	(0.010255)	(0.015047)	(0.002590)	(0.003552)
TREND	**-0.000232*** **	**0.000289*** **	**0.000005*** **		
	(0.000001)	(0.000001)	(0.000001)		
DEFAULTRISK	0.070188	**0.065348* **	**0.138684** **	**-0.056423* **	-0.041408
	(0.047434)	(0.038022)	(0.057228)	(0.031296)	(0.043527)
LIQUIDITYRISK	**-0.132862** **	0.053933	-0.058801	**0.064558** **	0.037995
	(0.056562)	(0.048122)	(0.071134)	(0.028172)	(0.038724)
AR(1)	0.041156	**0.175894*** **	**0.112623*** **	**-0.671794*** **	**-0.777483*** **
	(0.025526)	(0.025508)	(0.025239)	(0.024816)	(0.024088)
AR(2)	**0.183008*** **	**0.196077*** **	**0.238109*** **	**-0.308734*** **	**-0.376285*** **
	(0.025519)	(0.025546)	(0.025236)	(0.024816)	(0.024087)
adj. R-square	0.339785	0.555064	0.093283	0.328641	0.412543
Observations	1489	1489	1489	1488	1488

∗ ∗ ∗ **denotes significance at the 1%-level**

∗∗ **denotes significance at the 5%-level**

∗ **denotes significance at the 10%-level**

Table 5: The effect of transaction volumes in payment systems on contemporaneous risk spreads.

Each column represents a separate regression for the different transaction value measures.

Standard errors reported in parentheses.

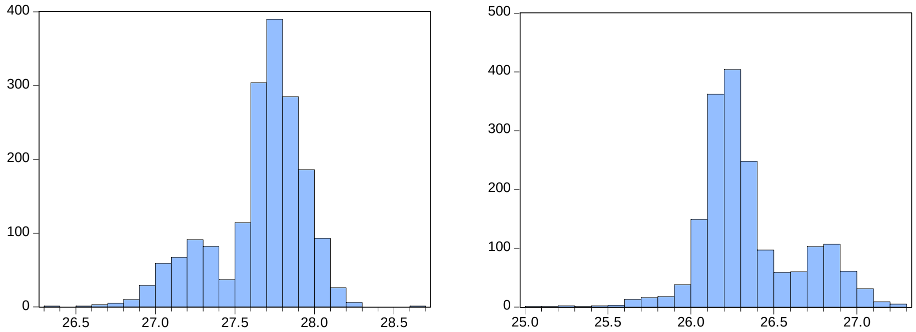
	LIQUIDITYRISK	DEFAULTRISK	DEFAULTRISK	LIQUIDITYRISK
C	0.366636	-0.597254	0.025787	**0.050532*****
	(0.346791)	(0.481026)	(0.020136)	(0.014913)
TREND	**-0.000015***	-0.000001	0.000001	**-0.000018****
	(0.000001)	(0.000001)	(0.000001)	(0.000001)
LGROSSVAL	0.009516	-0.001805		
	(0.014908)	(0.021270)		
LNETVAL	**-0.021016****	**0.024473***		
	(0.009499)	(0.014000)		
LNET2GROSS			0.022610	**-0.020077****
			(0.013931)	(0.009451)
AR(1)	**0.535914*****	**0.097899*****	**0.095409*****	**0.533300*****
	(0.026110)	(0.026056)	(0.025963)	(0.025978)
AR(2)	0.009011	0.041807	0.040397	0.010976
	(0.026068)	(0.025978)	(0.025949)	(0.026009)
adj. R-square	0.296052	0.011058	0.010603	0.295715
Observations	1489	1489	1489	1489

∗∗∗ **denotes significance at the 1%-level**

∗∗ **denotes significance at the 5%-level**

∗ **denotes significance at the 10%-level**

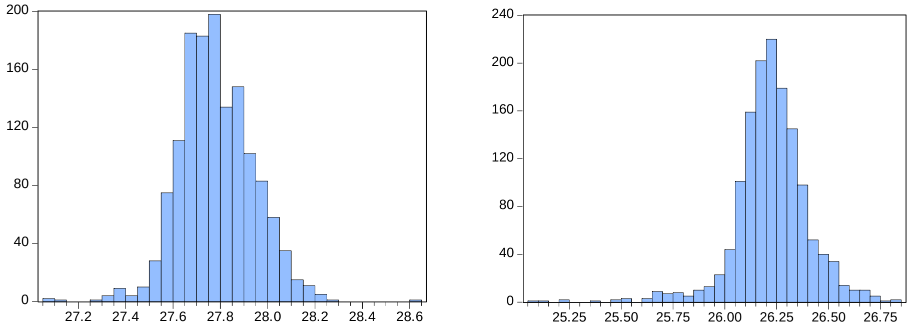
Figure 1: Gross and net settlements levels, March 2000 to May 2007



Left chart: Gross settlement systems. Right chart: Net settlement systems

(Frequencies on the vertical axis, log(value) on the horizontal)

Figure 2: Gross and net settlements levels, December 2001 to May 2007



Left chart: Gross settlement systems. Right chart: Net settlement systems

(Frequencies on the vertical axis, log(value) on the horizontal)

Table 6: Variables used in estimating factors that represent economic shocks

Variable	Definition
EONIA1W	1-week eonia rate
EBFREUTN	Overnight repo rate
EBFREU1W	1-week Repo rate
EBFREU2W	2-week repo rate
EBFREU3W	3-week repo rate
EBFREU1M	1-month repo rate
EONIA2W	2-week eonia rate
DEPOSIT1N	Overnight bank deposit rate
DEPOSIT1W	1-week bank deposit rate
DEPOSIT2W	2-week bank deposit rate
DEPOSIT3W	3-week bank deposit rate
DEPOSIT1M	1-month bank deposit rate
DEPOSIT3M	3-month bank deposit rate
SWAP1W	1-week swap rate
SWAP2W	2-week swap rate
EONIA1N	Euro overnight index average
BUNDPRICE	Short-term bund price
BUNDYIELD	Short-term bund yield
EECBDEPO	ECB deposit rate
EECBMARG	ECB marginal rate
BUND10Y	10-year bund yield
LSX5EINDEX	Log(SX5E Index)
LDAXINDEX	Log(DAX Index)
LCACINDEX	Log(CAC Index)
LSX5EVOL	Log(Volume SX5E)
LDAXVOL	Log(Volume DAX)
LCACVOL	Log(Volume CAC)
LBUNDOI	Log(Bund Index)
LBUNDVOL	Log(Volume Bund)
LDJEURSTPI	Log(Standard Poor Euro Stocks Index)
LS1ESFNEPI	Log(Standard Poor Euro Financial Index)
LS2ESB2EPI	Log(Standard Poor Euro Bank Index)
LS2ESINEPI	
LS2ESFSEPI	
LDAXFOI	Log(DAX Futures Open Interest)
LDAXFPI	Log(DAX Futures Index)
LDAXFVOL	Log(DAX Futures Volume)
LDAXFVOLPX	
LSTOXXFOI	
LSTOXXFPI	
LSTOXXFVOL	
LSTOXXFVOLPX	

Table 7: Proportion explained by the factors

Number	Proportion	Cumulative proportion
1	0.5974	0.5974
2	0.1950	0.7924
3	0.0913	0.8837
4	0.0334	0.9170
5	0.0234	0.9404
6	0.0173	0.9577
7	0.0135	0.9712
8	0.0086	0.9798
9	0.0050	0.9848
10	0.0047	0.9895
11	0.0036	0.9930
12	0.0019	0.9950
13	0.0015	0.9964
14	0.0011	0.9975
15	0.0005	0.9980
16	0.0004	0.9985
17	0.0002	0.9987
18	0.0002	0.9989
19	0.0002	0.9991
20	0.0001	0.9992
21	0.0001	0.9994
22	0.0001	0.9995
23	0.0001	0.9996
24	0.0001	0.9996
25	0.0001	0.9997
26	0.0001	0.9998
27	0.0001	0.9998
28	0.0001	0.9999

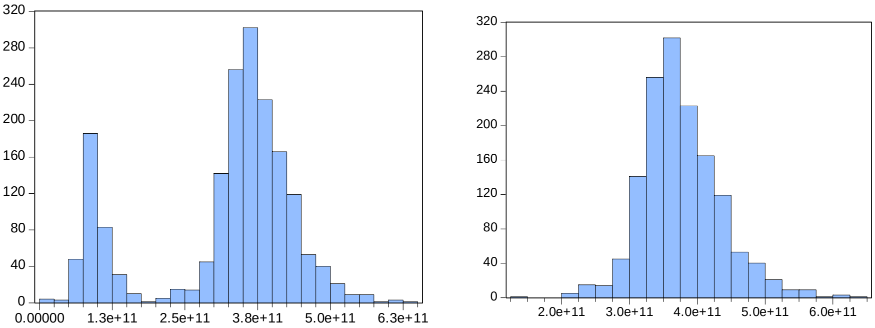
Table 8: Loadings of the first five factors

Variable	PC 1	PC 2	PC 3	PC 4	PC 5
EONIA1W	0.187881	-0.110562	0.016793	-0.075645	-0.037935
EBFREUTN	0.186166	-0.115545	0.017846	-0.084219	-0.036848
EBFREU1W	0.187708	-0.111754	0.016633	-0.073707	-0.038510
EBFREU2W	0.188318	-0.109728	0.016163	-0.068331	-0.037776
EBFREU3W	0.189109	-0.106001	0.014373	-0.062484	-0.038394
EBFREU1M	0.189987	-0.101399	0.011457	-0.055676	-0.036757
EONIA2W	0.188810	-0.106818	0.015715	-0.069082	-0.037468
DEPOSIT1N	0.183443	-0.115860	0.011830	-0.076717	-0.039539
DEPOSIT1W	0.187777	-0.110294	0.015574	-0.074518	-0.038523
DEPOSIT2W	0.188598	-0.106049	0.015214	-0.072982	-0.038706
DEPOSIT3W	0.188511	-0.102404	0.014867	-0.069138	-0.041732
DEPOSIT1M	0.189988	-0.095813	0.012343	-0.065474	-0.041421
DEPOSIT3M	0.192802	-0.074171	-0.002162	-0.045224	-0.035230
SWAP1W	0.188090	-0.109339	0.016395	-0.073793	-0.038561
SWAP2W	0.189007	-0.105482	0.015685	-0.066920	-0.038729
EONIA1N	0.185119	-0.115858	0.015195	-0.083559	-0.037603
BUNDPRICE	-0.059488	0.278551	-0.024987	-0.403974	-0.064246
BUNDYIELD	0.059787	-0.277166	0.024668	0.414045	0.090246
EECBDEPO	0.187298	-0.113798	0.019778	-0.066372	-0.033781
EECBMARG	0.187300	-0.113785	0.019862	-0.066307	-0.033678
BUND10Y	0.060063	-0.275040	0.016214	0.415864	0.078696
LSX5EINDEX	0.161803	0.148397	-0.185502	0.123642	0.044232
LDAXINDEX	0.162123	0.156037	-0.164100	0.123563	0.054277
LCACINDEX	0.155289	0.173744	-0.181640	0.106811	0.029642
LSX5EVOL	0.101350	0.135169	0.257583	0.081643	0.331086
LDAXVOL	0.089547	0.136355	0.306501	0.089038	0.270679
LCACVOL	0.085584	0.050847	0.335679	0.164153	0.247836
LBUNDOI	0.086599	0.248101	-0.065999	-0.060860	-0.030827
LBUNDVOL	0.046676	0.149999	0.242856	0.147486	0.082785
LDJEURSTPI	0.160721	0.167051	-0.168101	0.084822	0.035257
LS1ESFNEPI	0.152186	0.181775	-0.180908	0.092568	0.042873
LS2ESB2EPI	0.145218	0.204837	-0.167224	0.061452	0.045697
LS2ESINEPI	0.157250	0.103340	-0.221709	0.209755	0.045045
LS2ESFSEPI	0.155069	0.194474	-0.139036	-0.012486	0.003798
LDAXFOI	0.079861	-0.021588	0.137134	-0.259483	0.631168
LDAXFPI	0.162279	0.155492	-0.164285	0.123466	0.053883
LDAXFVOL	0.087586	0.198308	0.293192	0.118804	-0.257784
LDAXFVOLPX	0.087586	0.198308	0.293192	0.118804	-0.257784
LSTOXXFOI	0.136822	0.166536	0.046180	-0.320829	0.168996
LSTOXXFPI	0.162408	0.148021	-0.180499	0.122775	0.057340
LSTOXXFVOL	0.119213	0.170442	0.277264	0.036670	-0.249543
LSTOXXFVOLPX	0.119213	0.170442	0.277264	0.036670	-0.249543

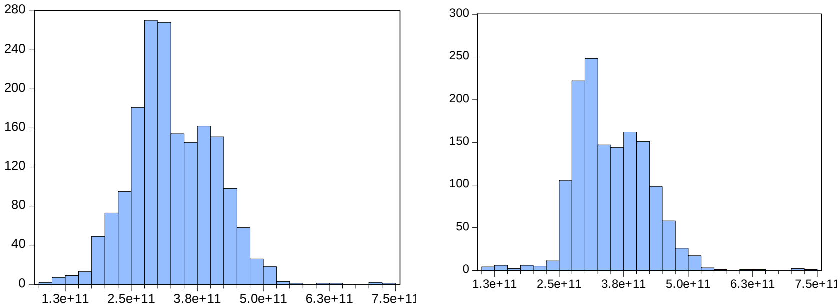
Figure 3: Frequency of log(value) in three EMU countries' gross settlement systems

a. June 2000 to May 2007

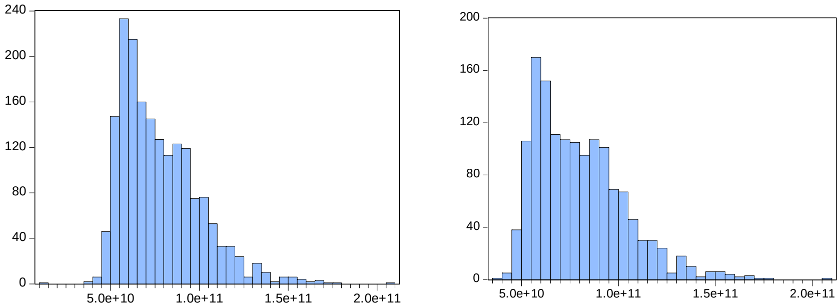
b. November 2001 to May 2007



Germany: a. b.



France: a. b.



Italy: a. b.

(Frequencies on the vertical axis, log(value) on the horizontal)

Figure 4: Impulse-responses for FAVAR incl. relative importance of net settlement system (Response to Cholesky one s.d. innovations ± 2 s.e.)

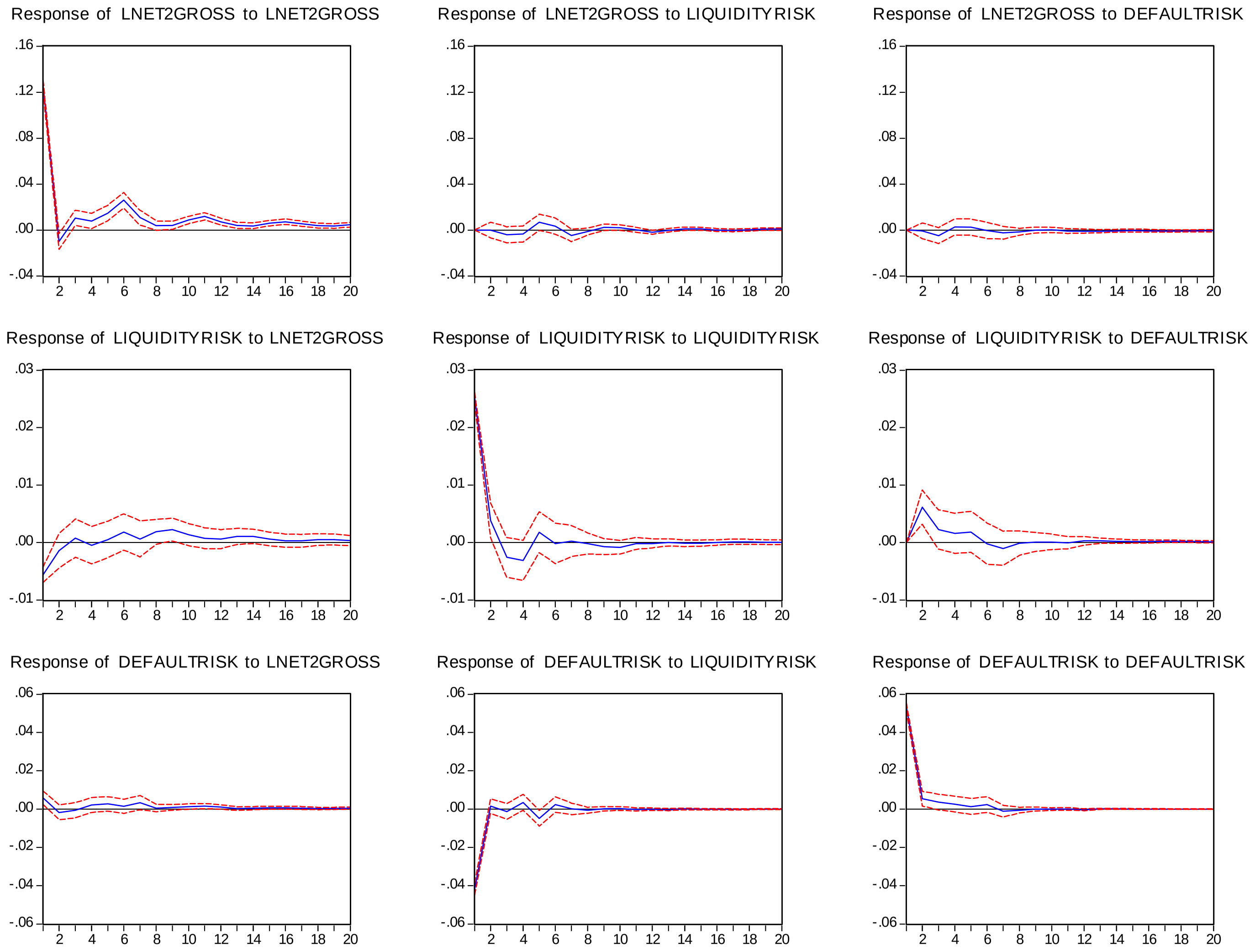


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Figure 5: Impulse-responses for FAVAR incl. differences in transaction value in both settlement systems (Response to Cholesky one s.d. innovations ± 2 s.e.)

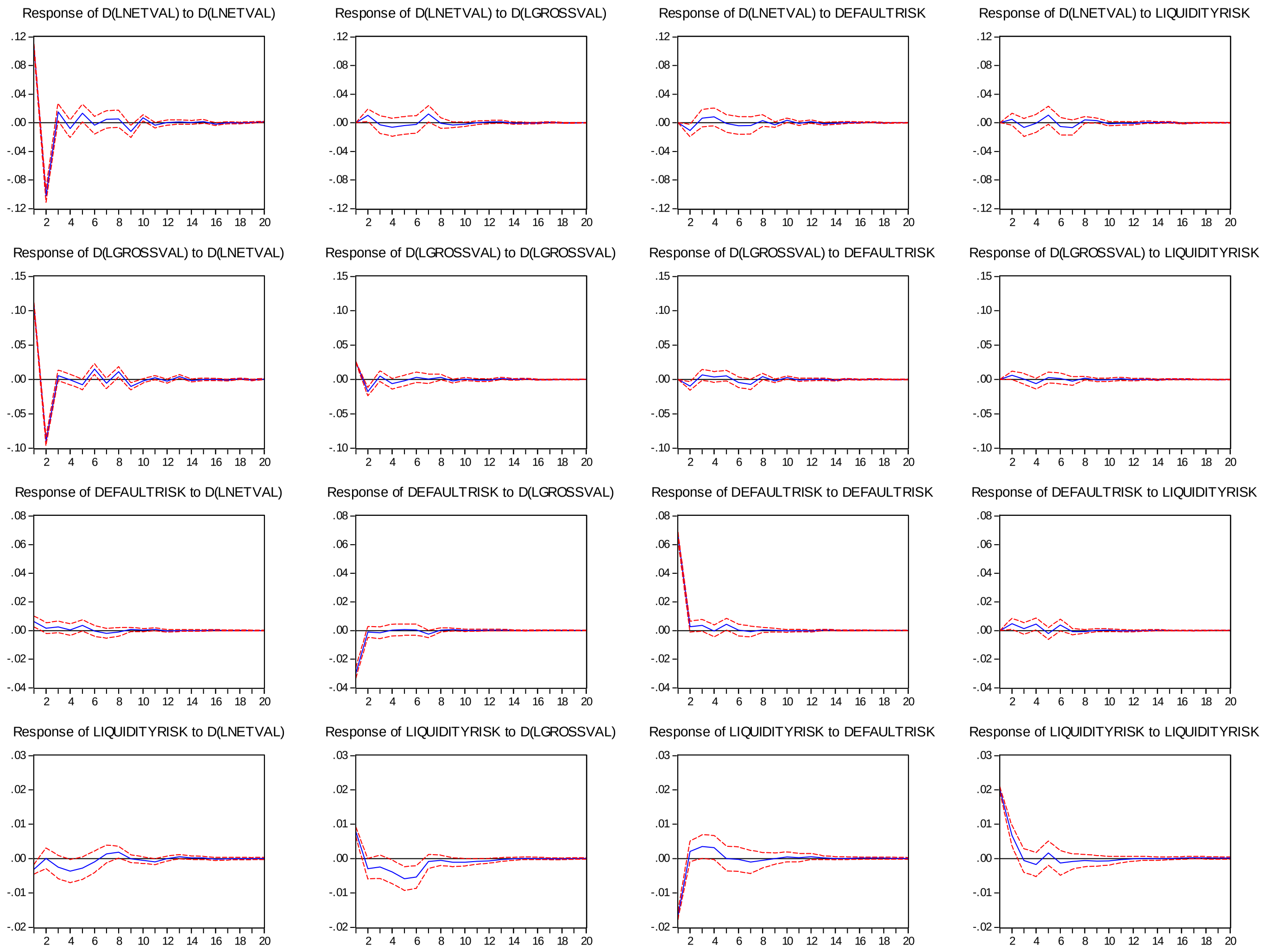

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Figure 6: Accumulated responses to Cholesky one s.d. innovations ± 2 s.e.

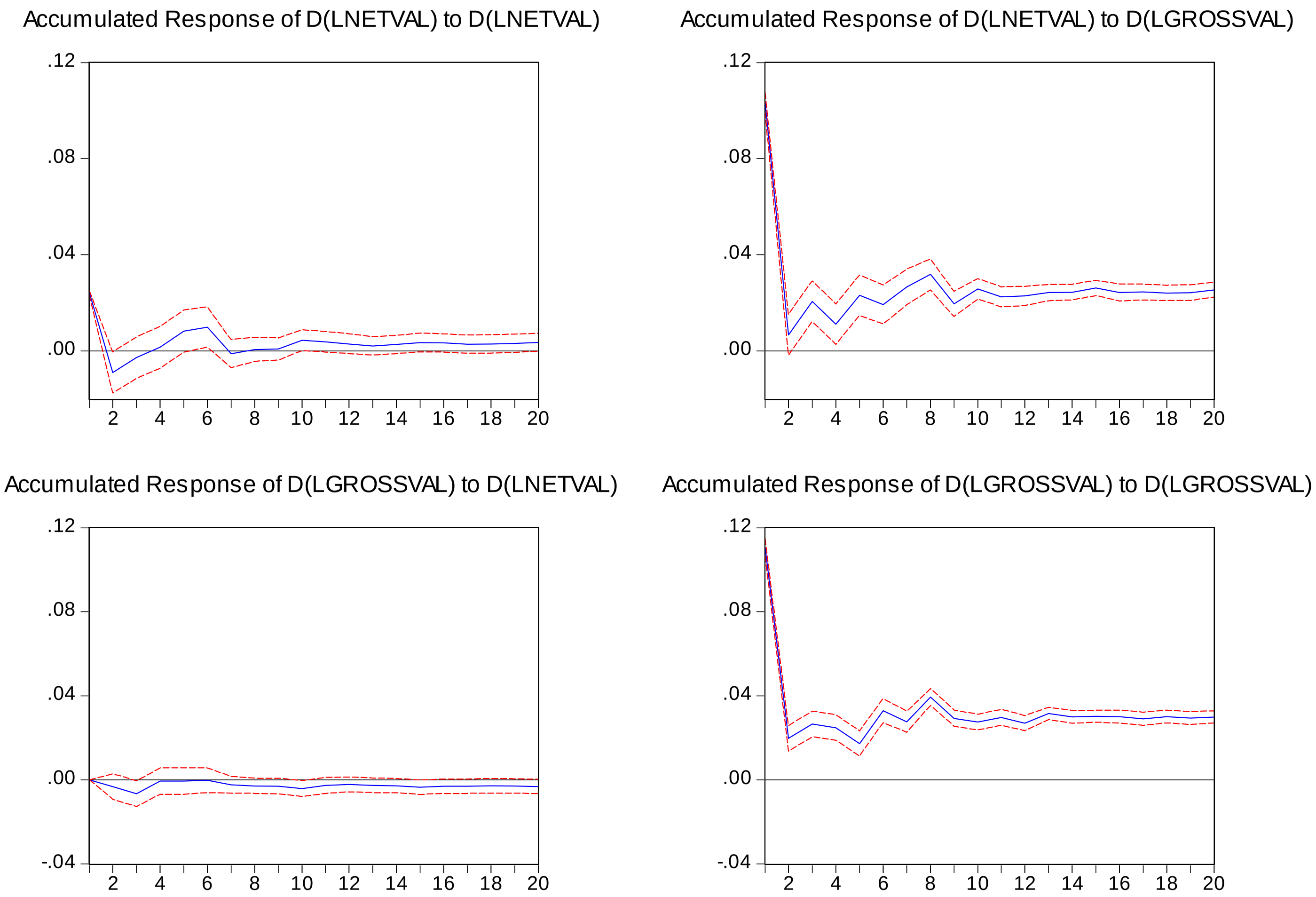

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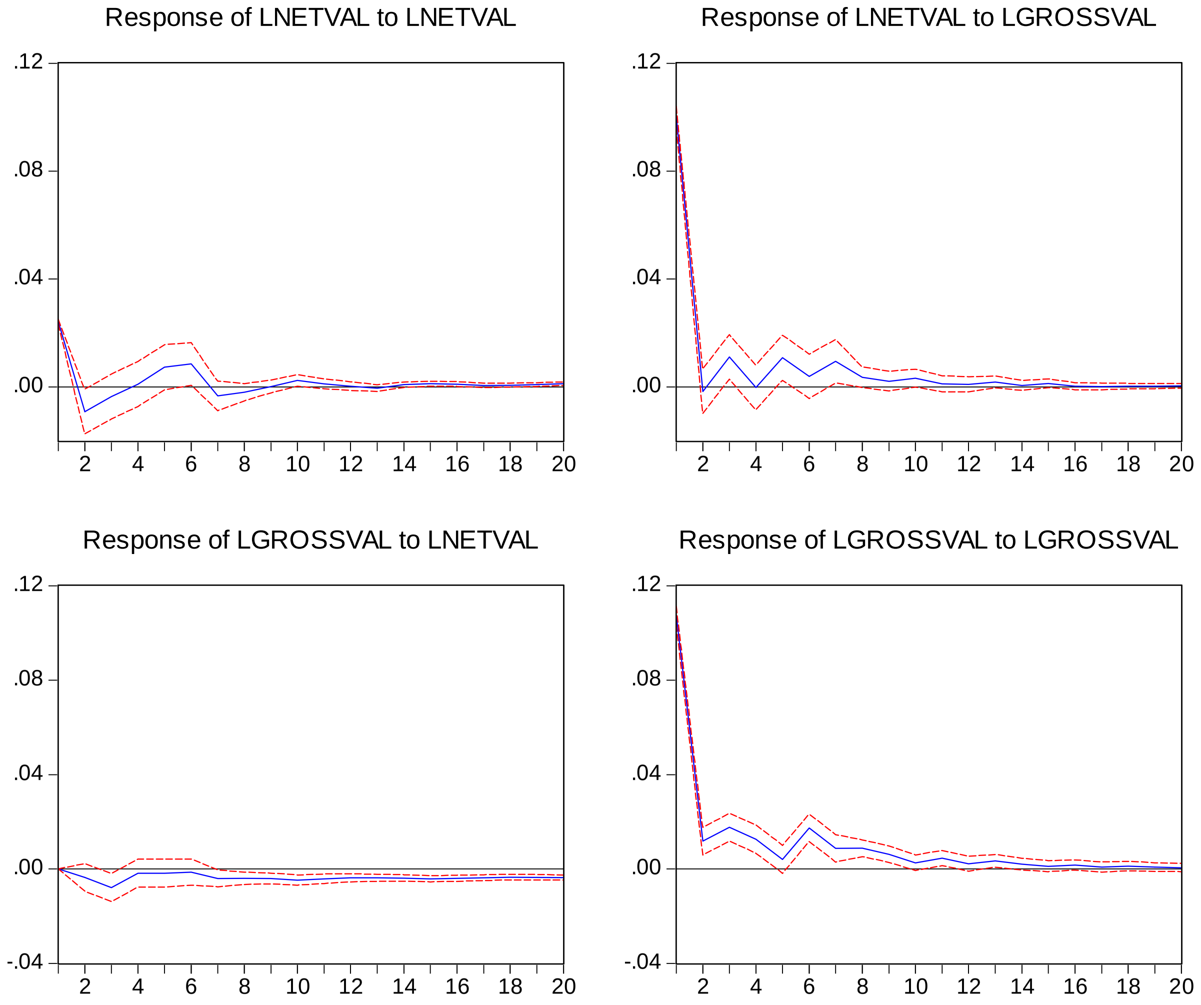
Figure 7: Impulse-responses for simple FAVAR incl. only transaction value in both systems (Response to Cholesky one s.d. innovations ± 2 s.e.)



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