Continuous Linked Settlement
An Empirical Approach

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Abstract

The international foreign exchange market is the largest market in the world. The reliability and resilience of its post-trade processes is critical. The work on hand is dedicated to the problems arising in foreign exchange settlement and in particular presents the industry's prevailing solution to these problems: Continuous Linked Settlement (CLS). CLS Bank, located in London and New York, is a settlement institution that is operated based on a payment-versus-payment mechanism that eliminates credit risk exposures during settlement. The work on hand offers an empirical approach to three different aspects of CLS. First, it assesses CLS's achievement of its main goal, the reduction of credit risk in foreign exchange settlement. Based on publicly available data, it is estimated that the credit risk reduction amounts to about 60 to 75 percent, which may well be interpreted as a success. Second, an analysis of the trade relations among CLS' participants provides insights into the characteristics of the system's member structure. Measuring and visualizing the network topology of the trade relations indicates that there are substantial differences in connectivity between the two different member states, i.e. settlement members and third parties. The identification of these differences may help the industry to adequately structure their membership conditions to achieve an optimal level of participation. Third, regression analysis is applied to detect potential dependencies between the level of the participants' connectivity and their liquidity positions. The analysis shows that specific connectivity characteristics of trade relations affect the liquidity positions of the involved trade partners. If and how these results may be implemented in a practical context is yet unclear, but may inspire further research on these topics.

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Contents

Chapter 1

Introduction

Post-trade processing is not a glamorous topic. For most people, clearing and settlement is not of much interest. As a result, the post-trade industry is widely unknown except for the professionals who use and provide post-trade services. On the academic side, comprehensive literature can be found on asset pricing, trade volume, and trading arrangements. Only few work, however, is done on the industrial organization of post-trade activities. Considering the large amounts of economic resources that are consumed by post-trade clearing and settlement processing, the area is under-researched. The work on hand is a contribution to the academic literature regarding post-trade activities in the foreign exchange market.

1.1 The Foreign Exchange Market

The international foreign exchange market is the largest market in the world. Its volume is six times the trading volume of the second largest market, the U.S. Treasury securities market. Since there are always two parties to each foreign exchange transaction, the volume to be settled is even twice the trading volume. In foreign exchange trading, it is not uncommon for two banks to owe each other 2 billion US Dollar overnight because settlement has not yet been completed. The figures make clear that reliability and resilience of the settlement processes are essential. Interruptions or delays may have disastrous consequences for the financial industry. During the past years, financial authorities have started to realize the system's vulnerability and increasingly paid attention to post-trade activities in general and to settlement practices of foreign exchange in particular. In the nineties, several publications have highlighted that most banks had tremendous overnight credit risk exposures due to current settlement and reconciliation practices at that time. Regulators called on the financial industry to take appropriate action to measure and reduce the settlement risks in the foreign exchange market. Since then, the international financial industry has heavily invested in operations and technology to comply with regulators' requests. The most important result from these common industry efforts is the implementation of the Continuous Linked Settlement (CLS) system.

The work on hand offers insights in three different aspects of CLS and is organized as follows. After providing some background information regarding the settlement problems in foreign exchange and how CLS solves these problems, chapter 3 sizes CLS's achievement in risk reduction (fist aspect). Chapter 4 analyzes CLS' settlement structure by modeling CLS transaction data as a network (second aspect). Chapter 5 is assigned to the question if and how the settlement structure impacts the amount of liquidity that participants must bring up to settle their trades (third aspect). Chapter 6 summarizes the results and delivers some food for thought to practitioners.

1.2 Brief History of CLS Bank

In 1996 the Bank for International Settlements (BIS) published a report on "settlement risk in foreign exchange transactions"(CPSS 1996). The report became famous under the name of the working group's chairman Peter Allsopp and was a wake-up call for the industry. As a response to the report a group of major foreign exchange trading banks (G20) started an initiative to develop a foreign exchange transaction system that eliminates credit risk exposures during settlement. That was the birth hour of Continuous Linked Settlement (CLS). It took another two years until in 1997 the G20 formed a company, named CLS Services Ltd. to build and operate the CLS system, which had, however, not been developed yet. In 1999 the Federal Reserve Bank approved the creation of CLS Bank. Finally, in 2002 CLS Bank was brought to operation. Today, CLS Bank counts several hundred participants and settles live transactions in 15 currencies with average daily values of more than USD 5 trillion[1].

[1] www.cls-group.com, 2008.

Chapter 2

Settlement Problems in Foreign Exchange

Settlement of foreign exchange contracts exhibits a number of particularities that are presented in the following. Most issues are based on Perold (1995). The basic problem of settling foreign exchange contracts is caused by the very nature of such a contract, usually involving two currencies from two different countries that settle therefore in two different local payment systems that might be located in two different time zones. The two legs of the transaction cannot be settled simultaneously because due to the time lag, the two relevant payment systems are not open at the same time. Without overlapping opening hours, simultaneous settlement is impossible and credit risk is created. In the context of foreign exchange, this kind of credit risk is often called Herstatt risk, named after the "Bankhaus Herstatt"[1]. It is best explained by assuming a Yen/US Dollar transaction. If a Japanese bank sells Japanese Yen (JPY) and buys US Dollar (USD) from a US bank, it transfers the Yen via the local Japanese payment system to the US bank's correspondent in Japan. This must happen during the opening hours of the Japanese payment system. However, the US bank can only transfer the owed Dollars during the opening hours of the local US payment system. While fulfilling its Yen obligation, the Japanese bank does not know whether the US bank will accomplish the owed Dollar payment. The Japanese bank is exposed to Herstatt risk to the full amount of the contract.

[1]The collapse of Bankhaus Herstatt in 1974 caused serious settlement disruptions.

2.1 Potential Solutions

A number of potential solutions was proposed in literature to solve the problem of Herstatt exposure. According to Perold (1995), three basic approaches are presented in the following: money market fund shares, contracts for differences, and extension of the real-time gross settlement (RTGS) systems' opening hours.

2.1.1 Money Market Fund Shares

One approach that was brought up in the nineties was the idea of money market fund shares (Perold 1995). The proposal was based on a system of money market funds for each currency. Participants willing to enter a currency exchange would buy shares of the respective money market fund. At a mutually agreed point in time, the parties would exchange their shares of the relevant funds. The new owners of the shares could subsequently redeem the shares or use them for future currency exchanges. As an example, assume trader A who needs to pay 1 million US Dollars to trader B which in turn owes 100 million Yen to A. In such a system, trader A would purchase shares worth 1 million US Dollars in the US Dollar money market fund during the opening of the US payment system. Trader B would buy shares of the Yen money market fund worth 100 million Yen during the Japanese payment system operating hours. Once both traders have completed their purchase, they can exchange the shares at any time without consideration of the payment systems' operating hours. This solution effectively eliminates Herstatt risk as the transactions in the local payment systems as well as the exchange of shares can be accomplished through a delivery-versus-payment (DvP) mechanism.

2.1.2 Contracts for Differences

An alternative idea was to settle foreign exchange transactions through so called contracts for differences (CFDs) (Perold 1995). These derivative products allow traders to settle their foreign exchange transactions without principal payments. Only the net gain or loss due to changes in the currency rates is transferred. An example of such a CFD is the rolling spot currency futures contract available at the Chicago Mercantile Exchange (CME) or the deferred spot forex futures contract at the Singapore International Monetary Exchange (SIMEX). These contracts are designed to deliver exactly the same payoff as would be obtained by holding an overnight spot currency position. They eliminate Herstatt risk by replicating the payoff from an overnight spot currency position, but without requiring the payments of the principal amounts. Therefore, derivative instruments may serve as functional substitutes to reduce settlement risks. However, even though approximately 80 percent of all foreign exchange transactions are trades that do not require the delivery of the principal amounts, there are still about 20 percent that do require the delivery of the underlying currency for commercial reasons. These trades cannot be settled by derivative products and require respective counterparties that are willing to deliver the currencies. This market dynamic, leading to a chain reaction, is considered to be the main reason for derivative products of this type not to be able to penetrate the market (Klein 2006).

2.1.3 Extension of Payment Systems' Opening Hours

Actually the most evident approach is to extend the opening hours of all relevant payment systems. Overlapping opening hours would then allow for a so called payment-versus-payment (PvP) settlement mechanism. As described in the following this was the prevailing solution and a prerequisite to develop the CLS system.

2.2 How CLS Solves the Problem

CLS completely eliminates credit risk by introducing a PvP settlement mechanism. Under a PvP settlement standard, funds of two counterparties are transferred simultaneously and one transfer is only considered final if the counter-transfer is final as well. Payments within the CLS system are settled gross on a PvP basis while the funding of the system is handled on a net basis. The combined settlement mechanism of CLS is therefore called "real-time gross settlement with net funding". In contrast to a pure real-time gross settlement mechanism, net funding significantly reduced the liquidity that participants have to come up with to settle their transactions. The participants of CLS are classified in three membership types: (1) settlement members, (2) user members, and (3) third parties. Settlement members hold a multi-currency account with CLS Bank and send transactions directly to the CLS Bank. Settlement members are the shareholders of CLS Bank and are subject to strict eligibility criteria. The category of user members was created to address the pressure from smaller banks and especially from brokers that would either not meet the eligibility criteria for settlement membership or were not involved in settlement at all. Today there is only one user member. This membership type will therefore not be considered any further. About 18 settlement members offer settlement services to the so called third parties. Third parties are not directly connected to CLS Bank but settle through a bilateral arrangement with a settlement member. In 2007 the number of third parties approached 1'000.

The settlement cycle of CLS Bank starts prior to the actual settlement window with the calculation of the individual net positions for each settlement member in each currency for a specific settlement day. For each settlement member an individual pay-in schedule is thus dispatched. The actual settlement window lasts for 5 hours from 7.00 h to 12.00 h Central European Time (CET)[2]. During this period of time the opening hours of all involved national RTGS systems overlap, which enables CLS Bank to perform transactions in all currencies on a real-time basis. From 7.00 h to 12.00 h CET the settlement members must pay in the required funds according to their pay-in schedule on an hourly basis. This characteristic of the CLS system strongly differs from former foreign exchange settlement practices where intra-day sequences of payments where irrelevant. The payments arrive at CLS Bank via the local RTGS systems and are credited to the respective settlement member account. A processing algorithm executes the matched transaction on a FIFO[3] basis. If the required risk management provisions are met the settling of funds is final and irrevocable. In case of non-compliance with one or more of the risk management constraints, CLS Bank does not settle and the transaction is put back in the queue and continually revisited until it settles. By 12.00 h all funds are disbursed back to the settlement members. This process in combination with the specified risk management provisions[4] assures the elimination of credit risk during settlement. Chapter 3 presents an attempt to measure how much of the global foreign exchanges settlement risk is eliminated by CLS.

[2]There is only a 4 hour window for Asia-Pacific due to the time lag.
[3]First in first out principle.
[4]The multi-currency accounts must show a net positive overall value at any time.

Chapter 3

Impact on Global Credit Risk

Credit risk during settlement is one of the most often discussed issues in foreign exchange trading. In 1996 a BIS report (CPSS 1996) for the first time explicitly addressed the fact that credit risk exposures in foreign exchange settlement are enormous. The report calls on banks, industry groups as well as on central banks to improve the current settlement practices to reduce the credit risk exposures. This public demand note from the BIS set a cornerstone for the foundation of CLS. As described in chapter 2, the settlement process of CLS is set up as a PvP mechanism with credit risk elimination being its main objective. Based on publicly available data, the subsequent sections present two attempts to estimate CLS's achievement in credit risk reduction during the past years. For simplification, this chapter uses the terms settlement risk and credit risk as synonyms.

3.1 Data Availability

The BIS (CPSS 1996) conducted a survey including about 80 banks to estimate the current credit risk at that time. The report concludes that a banks's foreign exchange settlement exposure directly depends on the duration of exposure of each single trade. If the average duration of exposure is two business days, this would result in a permanent credit risk exposure of the average sum of two day's foreign exchange trades. It is estimated that for a large number of banks, this exposure exceeds by far their usual short-term credit lines. To calculate the total credit risk exposure in the industry, the sum of individual exposures would provide an indication. Unfortunately, no figures have been published, neither regarding the value of the trades nor regarding the exposures that were reported by the banks in the survey. The only figures available regarding global foreign exchange markets are the ones reported in the Triennial Central Bank Survey conducted by the BIS (2007) and the FX Poll published by Euromoney (2007). In contrast to the Triennial Central Bank Survey which is based on the estimations of 54 central banks (latest version), the current publication of the FX Poll by Euromoney includes more than 8'300 foreign exchange service providers. Both reports release some estimations regarding the global foreign exchange market.

3.1.1 Global Foreign Exchange Turnover

The latest two Triennial Central Bank Surveys were conducted for the month of April in the years 2004 and 2007. According to the survey, the average daily turnover in April 2004 was USD 1'880 billion and USD 3'210 billion in April 2007. Counting both legs of the transactions, results in an average daily turnover of USD 3'760 billion and USD 6'420 billion respectively. The second publication regarding foreign exchange turnover is Euromoney's FX poll. The foreign exchange poll 2004 (Euromoney 2004) reports an annual turnover of USD 24 trillion. If this number is divided by 260 working days, an average daily turnover of USD 92 billion results. Counting both legs, the number sums up to USD 184 billion average daily turnover. This is only a fraction of what is reported in the Triennial Central Bank Survey for the same year. Although the report comprises more than 3'500 valid respondents, it does not cover the entire market. The latest poll (Euromoney 2007) encompasses more than 8'300 respondents and reports an annual foreign exchange turnover of about USD 125 trillion which results in an average daily turnover of USD 960 billion (counting both legs). This figure is still far below the numbers reported by the Triennial Central Bank Survey. Euromoney's poll at least provides an idea on who are the largest players in the market. But with regard to the global foreign exchange market volume the Triennial Central Bank Survey provides the most cited figures.

3.1.2 CLS Turnover

CLS settlement volume gradually increased since the start of operations in September 2002. CLS shows much higher growth in settlement value and volume than any other important Large Value Transfer System (LVTS) in the world[1]. There are, however, two main reasons for which the CLS settlement value cannot directly be compared to the settlement values of other LVTS: (1) in contrast to other LVTS, CLS is not a payment system but a settlement organization. (2)

[1] CLS settlement value and volume was compared to 9 major LVTS such as TARGET, SIC and Fedwire.

The fact that the actual fund transfer to CLS is always completed by a particular LVTS causes the CLS funding values to be included in the settlement value of the LVTS. In other words, the net transaction values that are settled (on a gross basis) in CLS must be transferred by any of the LVTS and therefore also appear in their transaction values. Nevertheless, comparing the growth in settlement values of CLS and other LVTS provides an impression regarding scale and growth of CLS. Comparing the total transaction value of the payment systems to the value of transactions settled by CLS, results in a share of approximately 35 percent in 2005. 35 percent of the payment systems' transfers are therefore assumed to be CLS related. This assumption, however, does not allow for conclusions regarding CLS' share in the foreign exchange market. Payment systems do not exclusively transfer CLS related values but manage a whole range of different payment types. To estimate CLS's share in the foreign exchange market, its settlement value would have to be compared to the portion of foreign exchange related transfers in the payment systems. According to their own statements, CLS's current global market share is estimated to be about 60 to 70 percent. CLS members are assumed to settle even 95 percent of their business with each other via CLS.

3.2 Elimination of Credit Risk

3.2.1 Global Turnover Approach

Under the assumption that the average settlement period during which the face value of the contracts is at risk, is one working day, then the total amount at risk can be estimated as the average daily turnover. For April 2004 this results in an aggregated settlement exposure of USD 3'760 billion. If it is further assumed that all transactions settled via CLS do not include any credit risk, CLS turnover could be subtracted from global turnover. Annual CLS turnover for 2004 was reported as 379'500 billion USD (counting both legs). Dividing this figure by 260 working days results in an estimated daily CLS turnover of 1'460 billion USD. Risky average turnover per day would then equal 2'300 billion USD (3'760 billion USD - 1'460 billion USD). It might be concluded that in 2004, CLS was able to eliminate roughly 40 percent of total settlement risk in the foreign exchange market. Table 3.1 repeats this calculation for the year 2005, 2006 and 2007 by assuming an average growth rate of 20 percent for the global foreign exchange turnover. 20 percent is estimated based on the average growth rate between 2004 and 2007 (BIS 2007). CLS turnover for 2006 is estimated based on the turnover in April 2006 which was provided by CLS. And to estimate CLS turnover for

	2004	2005	2006	2007
Annual values (in billion USD)				
Global turnover	977'600	1'167'400	1'396'200	1'669'200
CLS turnover	*379'500	*545'800	*650'000	780'000
Daily values (in billion USD)				
Global turnover	*3'760	4'490	5'370	*6'420
CLS turnover	1'460	2'099	2'500	3'000
CLS share	**39%**	**47%**	**47%**	**47%**

* figures published by BIS or CLS. Calculation assumptions: one year = 260 days, global turnover growth is constant from 2004 to 2007, CLS turnover estimates are based on BIS figures and on a 20 percent growth assumption.

Table 3.1: Credit Risk Elimination Estimates.

2007, a 20 percent growth rate is assumed. Under these assumptions, CLS can be estimated to eliminate about 50 percent of credit risk in the foreign exchange market. It is clear that this estimation is by far too simple[2]. It does not account for any bilateral or multilateral netting arrangements outside CLS that reduce credit risk in the foreign exchange market. There are no estimations for failure probabilities. It is likely that failure probabilities vary among institutions which is reflected in different bilateral limits they set for each other. However, even if an average failure probability for the industry as a whole could be estimated, it can be expected that the average failure probability of the remaining trades would change significantly when all CLS trades are excluded. This is because CLS members can be assumed to be rather large and strong industry players. Additionally, the expectations of large increases in global foreign exchange turnover as well as in CLS turnover weakens the significance of the figures. As CLS volumes are growing faster than the global foreign exchange market, it can at least be expected that global settlement risk exposures are decreasing. As mentioned before, CLS today is most likely to eliminate more than 50 percent of settlement risk in foreign exchange markets. These are only the most obvious reasons for the weakness of such an estimation. The main reason for the lack of better information is the absence of comprehensive data availability. An alternative way to estimate the elimination of credit risk due to the introduction of CLS would be to look at an individual bank level.

[2]According to CLS Bank's own statement, average daily turnover today is around 5'000 billion USD. That would result in a CLS market share of more than 75 percent.

3.2.2 Individual Bank Approach

Instead of estimating settlement risk on a global level, settlement exposures for individual banks are estimated. Unfortunately, banks in general do not explicitly report on their settlement risk exposures. An exception is UBS. In the UBS (2007) annual report, the bank states that it was able to increase trade volumes without increasing settlement risks to the same extent. The main reason for a reduction in settlement risk is the elimination of credit risk due to an increase in CLS volume. UBS settles about 60 percent of its total foreign exchange volume via CLS and reports a total settlement exposure of 22 percent of gross trade volume. Assuming that the 60 percent CLS volume is settlement risk free, another 18 percent must obviously be eliminated by other means such as netting arrangements. According to the latest FX Poll by Euromoney (2007) UBS is one of the most important players in the global foreign exchange market. It might therefore be a viable assumption that other CLS settlement members playing in the same league regarding foreign exchange trade volume, show a similar risk exposure profile. In the Euromoney (2007) report, the 20 largest market participants (all CLS settlement members) account for more than 90 percent of total turnover. This leads to the assumption, that the volume of all CLS settlement members together represents a substantial part of the global foreign exchange turnover. It might then be estimated that the global settlement risk elimination by CLS is close to 60 percent. It is obvious that this estimation suffers from similar weaknesses as the global turnover approach. Publicly available data regarding individual bank's exposures is rare and imprecise. A more qualitative approach is introduced by TowerGroup that conducted a CLS member survey (TowerGroup 2004). They had 41 responses from settlement members and 137 from third parties. To the question whether CLS has reduced settlement risk, about 80 percent of the respondents answered with a clear yes. None of the settlement members responded with no. Third parties classified risk reduction as the most important factor for the decision to participate in CLS. Altogether these different statements denote a significant increase in CLS' market penetration and a substantial reduction of foreign exchange settlement risk. This points to the fact that CLS has well achieved its main objective and eliminates presumably around 60 to 75 percent of settlement risk in the foreign exchange market. It satisfied the request called on the industry by the BIS in 1996 and helped the market to grow further.

Chapter 4

CLS Participation Network

The previous chapter provided estimations regarding the achievement of credit risk elimination in the global foreign exchange market. It leads to the conclusion that risks could be lowered substantially since the introduction of CLS. As CLS members were able to increase their trading volume and value by more than the corresponding settlement risk, CLS can be assumed to be a driver for market growth. The number of CLS participants, in particular the number of third parties, has grown significantly and might have affected trade relationships among each other. This chapter presents an empirical study regarding the changes in trade relationships among CLS participants. Based on a network model and a unique data set provided by CLS, the structure of trade partners settling their foreign exchange deals in CLS is analyzed over time. The chapter starts off with an overview on network literature and a description of the relevant network statistics before introducing the data set.

4.1 Network Literature Review

Network models are increasingly used by the banking and finance community to describe and analyze divers topics such as payment- and settlement systems, shareholder ownership structures, borrowing and lending relationships, or the importance of financial centers. Besides other things, the network properties allow for conclusions regarding resilience and contagion in case of systemic failure or attacks. Important work in that context has been conducted by Albert & Barabási (2000) who found that networks with highly connected hubs display a high degree of robustness but are extremely vulnerable to systematic attacks. Their and other findings regarding network structure were adapted to several different aspects of corporate dynamics and the banking system. Empirical contributions in the area of measuring network structures of financial flows have been conducted by Inaoka, Ninomiya, Taniguchi, Shimizu & Takayasu (2004), Iori, Masi, Precup, Gabbi & Caldarelli (2005), Rossi & Taylor (2005), Soramäki, Bech, Arnold, Glass & Beyeler (2006), and Lublóy (2006).

4.2 Basics of Network Analysis

Mathematics and physics have proposed a broad set of topological statistics to characterize complex networks (Albert & Barabási (2002), Newman (2003), Newman (2004) and Barthélemy, Barrat, Pastor-Satorras & Vespignani (2005)) which have been adapted by the economic community (Iori et al. (2005) and Soramäki et al. (2006)). The following section presents a set of definitions that are used to analyze the subsequent network model. A network is a set of items, that are called nodes, with connections between them, called links. In most mathematical literature the term graph is used instead of network. Binary networks have links that are either present or not. This kind of network can be represented by $(0, 1)$ or a binary matrix. The matrix, called the adjacency matrix A is defined as an $N \times N$ matrix where N is the number of nodes in the network. If there is a link from a node n_i to a node n_j, then the element a_{ij} of the matrix A is 1, otherwise it is zero:

$$a_{ij} = \begin{cases} 1 & \text{if } n_i \text{ and } n_j \text{ are connected,} \\ 0 & \text{otherwise.} \end{cases} \tag{4.2.1}$$

In this case the links a_{ij} are unweighted. They are simply either existent or non-existent. In a weighted network, links have weights attached to themselves. Mathematically, such a network can be represented by an adjacency matrix with entries that are equal to the weights on the links:

$$w_{ij} = \text{weight of connection from } n_i \text{ to } n_j \tag{4.2.2}$$

The most basic characteristic of a network is its **size** N, defined as the number of nodes in the network. Each node has its own **degree** k_i defined as:

$$k_i = \sum_{j \in \mathcal{V}(i)} a_{ij} \tag{4.2.3}$$

$j \in \mathcal{V}(i)$ represents the set of all neighbor nodes of i. Hence, the degree of a node i is the number of links connected to this particular node i. Links can either be directed or undirected. In a network with directed links, nodes have both, an in-degree and an out-degree. They represent the numbers of incoming and outgoing links respectively. Along with the degree of a node, an important measure of the network properties in terms of the actual weights is obtained by looking at the strength of the nodes. The **strength** s_i of a node is the result of the sum of all weighted links connected to that node:

$$s_i = \sum_{j \in \mathcal{V}(i)} w_{ij} \tag{4.2.4}$$

The **connectivity** c_i of a node is given by the number of links relative to the number of possible links in the network. It is hence the unconditional probability that two nodes are connected by a link:

$$c_i = \frac{k_i}{(n-1)} \tag{4.2.5}$$

The probability distribution that a node has exactly degree k is the so called **degree distribution** $p(k)$. It is a function describing the total number of nodes with a given degree. Equivalently, $p(k)$ is the probability that a node chosen at random has degree k. The degree distribution of a network can be plotted by drawing a histogram of the degrees of all nodes in the network. The degree distribution of most networks observed in the real world are found to be highly right skewed. This means that there are a few nodes with a degree number far above average. Formally, the degree data is best presented by a plot of the cumulative distribution function $P(k)$ which is the probability that the degree of a node is greater than or equal to k:

$$P(k) = \sum_{k'=k}^{\infty} p(k') \tag{4.2.6}$$

The distribution that is most common to real world networks follows a power law. Networks featuring power law degree distributions are often referred to as scale-free networks[1]. Most of their nodes are of low degree but a minority exhibits a high degree and can be interpreted as highly connected hubs.

[1]The term scale-free refers to any functional form $f(x)$ that remains unchanged when the independent variable x is rescaled. Since the only solutions to $f(ax) = bf(x)$ are power law forms, the term power law and scale-free are synonymous in this context.

4.3 The Data Set

The data set for this analysis was provided by CLS Bank. It includes trade values transmitted to CLS for settlement in dollar equivalents of 54 settlement members and 391 third party users aggregated on a daily basis for the month of April in 2006. It is important to understand that the data is reported on a bilateral gross basis. This means that there are three different types of records: the daily gross settlement value between (1) two settlement members, (2) a settlement member and a third party, and (3) two third parties. It does not provide information regarding the settlement arrangements between settlement members and third parties. In other words, a settlement relation between a settlement member and a third party (record type 2) does not necessarily indicate that this particular settlement member is the third party's settlement bank. It only indicates that this particular settlement member has a trade relationship with that third party. The same is true for record type 3. On an operational level, both third parties must settle via their settlement bank as they do not have direct access to CLS. This operational level is not reflected in the data set. It only reflects settlement relations stemming from trade relations. To analyze the development of this trade relationship structure over time, the April 2006 data is compared to the transaction data of April 2005, 2004, and 2003. The month of April as point of reference was chosen to be consistent with the surveys of the Bank for International Settlements. Yet, the figures reported by the Bank for International Settlements cannot directly be compared to the figures presented here. The latter represent settlement values while the former represent trade values. The trades underlying the settlement values may have been completed several days or even months ago. To apply network analysis to these settlement transactions, the following is defined. The participants of CLS form the nodes of the network. The nodes are categorized by sm-, and tp-nodes. Settlement members are represented by sm-nodes, and third party users are reflected by tp-nodes. A link between any two nodes exists if the corresponding CLS participants have settled at least one foreign exchange transaction via CLS. For a particular settlement transaction, both nodes involved can be seen as a sender and receiver node, because each settlement transaction has two legs. Neglecting currency rate fluctuations, the value of these two legs is equal. Each settlement transaction, therefore, consists of a pair of directed links with equal value. For simplification, the following analysis only looks at undirected links, or in other words, only at one side of the transaction. To do so, each node is interpreted as a sender node.

4.4 Research Design

To keep the analysis straight forward and to avoid over interpretation, a set of basic suppositions is defined. Due to the fact that the data is encoded, it does not allow for a detailed analysis regarding specific CLS participants. As a consequence, the following suppositions are intentionally kept at an elementary level.

1. The largest part of settlement value is generated by settlement members.
2. Large settlement members grow even larger in terms of settlement value and number of trade partners.
3. Settlement members with large overall settlement values deal with a larger number of third parties.
4. Settlement members with many trade relations in total, deal with a larger number of third parties.
5. Settlement members with a large number of third parties tend to attract more third parties as trade partners.
6. New third parties tend to be smaller than already existing ones.

After having presented the data's statistics, the subsequent sections elaborate on these suppositions. Section 4.7.1 is dedicated to supposition 1 and 2, section 4.7.2 treats supposition 3, 4, and 5. While these suppositions are from the settlement members' point of view, section 4.7.3 changes side and takes the view of the third parties.

4.5 Descriptive Statistics

Table 4.1 provides the descriptive statistics of the data set. The number of settlement members varies between 53 in 2003 and 57 in 2005. Besides a few new settlement members, merger and acquisition activities are the main reason for the number of settlement members to vary. The gross value (GV) that was settled by settlement members in the month of April 2006 was about 43 trillion USD. Gross value was increasing year by year. The initial pricing scheme assured that settlement members would push CLS transactions during the first years of CLS's operations. This is reflected in high value growth rates in 2003 and 2004. From April 2003 to April 2004 gross value increased by more than 60 percent. Even

	2003	2004	2005	2006
Settlement Members				
Quantity	53	54	57	54
Total gross value	15’400	25’500	36’800	43’000
Mean	290	470	620	800
Median	120	250	340	480
Max	1’680	2’210	3’110	3’770
Min	0	0	0	0
Stdv	380	540	730	900
Third Parties				
Quantity	36	118	257	391
Total gross value	600	2’700	5’000	8’200
Mean	17	23	19	20
Median	0.9	3	0.9	0.2
Max	180	720	880	1’040
Min	0	0	0	0
Stdv	40	80	70	80
Except for ”Quantity”, all values in billion USD.				

Table 4.1: Descriptive Statistics.

though the gross value growth rate is declining, it was still around 17 percent from 2005 to 2006. In April 2006 each settlement member completed transactions worth around 800 billion USD on average. As indicated by mean and median, gross value seems not to be equally distributed among the settlement members. The median being lower than the mean suggests a right skewed distribution of gross value. As displayed in figure 4.1, 75 percent of the settlement members settled gross values less than one trillion USD each. This accounts for only one third of total value settled. At the other tail of the distribution two settlement members settled more than 3 trillion USD. The three largest settlement members generated 25 percent of total gross value in April 2006. The characteristics of this gross value distribution are similar in each year. Average and median gross value have grown roughly in line with total gross value. The number of third parties considerably increased from 36 in April 2003 to 391 in April 2006. Total gross settlement value increased sharply from April 2003 to April 2004 and grew in line with the number of third parties thereafter. In April 2006 around 8 trillion USD were settled by third parties. Mean and median, being far apart from each other, stay around the same levels over the sample years. As figure 4.2 shows, the skewness of the gross value distribution of third parties is much stronger than the one for settlement members. In April 2006, 75 percent of the third parties accounted for only 3 percent of total gross value. The largest 10 percent

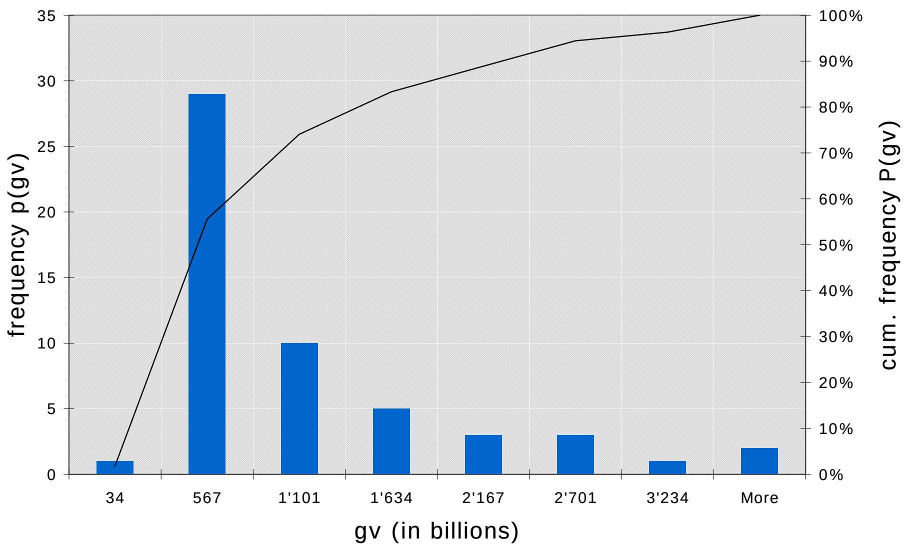

Figure 4.1: GV Distribution of Settlement Members in April 2006.

of the third parties account for more than 80 percent of value. Or to put it differently, almost 90 percent of all third parties generate settlement values less than 55 billion USD. The largest third party accounts for almost twice as much of total value as the second largest third party in the sample. These figures suggest strong power law characteristics. This means that the majority of third parties generates low volumes while a relatively small group of third parties generates a major portion of total value. This is true for all years included in the sample. It seems that among settlement members as well as among third parties, the value distribution characteristics have not changed much over time. The distributions are right skewed in all years and do not indicate any shifts in the value structure within the group of settlement members or third parties. In each year, relatively small groups of settlement members and third parties generated significant portions of the respective settlement value.

4.6 Network Statistics

This section presents the data set in terms of the network statistics introduced in section 4.2 and offers a visualization of the network. In April 2006, the network consists of 54 sm-nodes and 391 tp-nodes which results in an overall network size of 445 nodes. Table 4.2 shows the relevant network statistics from 2003 to 2006. The descriptive statistics in table 4.1 already showed the increase in the network's

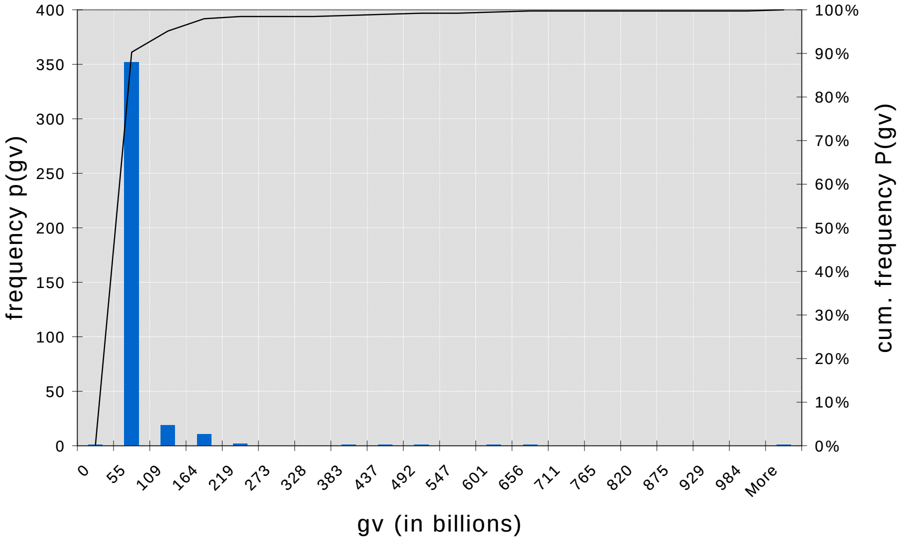

Figure 4.2: GV Distribution of Third Parties in April 2006.

	2003	2004	2005	2006
Size	89	172	314	445
Degree				
Mean	40	49	41	37
Median	49	45	18	10
Min	1	1	1	1
Max	72	128	196	285
Stdv	25	39	48	53
Strength (in billion USD)				
Mean	180	164	131	115
Median	48	13	3	1
Min	32	0	0	0
Max	1'680	2'210	3'110	3'770
Stdv	323	370	397	409
Connectivity				
Mean	45%	29%	13%	8%
Median	56%	26%	6%	2%
Min	1%	1%	0%	0%
Max	82%	75%	63%	64%
Stdv	28%	23%	15%	12%

Table 4.2: Network Statistics.

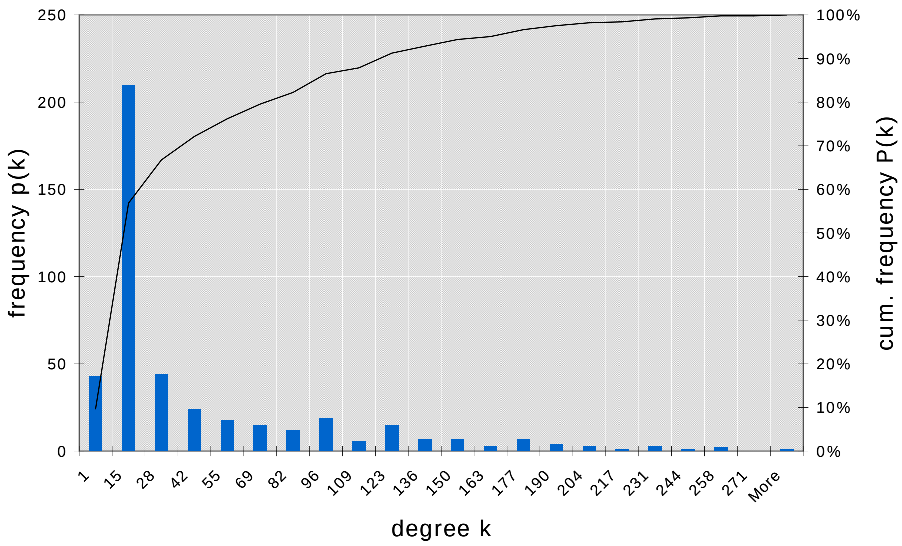

Figure 4.3: Degree Distribution in April 2006.

size. From 89 nodes in 2003 the network grew to 445 nodes in 2006. The degree of a node represents the number of trade partners that a particular settlement member or third party had a relation with in April of the respective year. The minimum degree, consequently, must be at least one. It seems that after 2004, mean and median degree start to drift apart. While the average number of trade partners seems to stay relatively constant, the median degree decreases. This development might indicated that the new nodes in the network are of relatively low degree. This seems to be a reasonable interpretation considering that the new nodes are predominantly third party nodes of which it can be assumed that they are less active in trading than settlement members. Figure 4.3 shows the degree distribution for April 2006. Half of all the nodes have a degree lower than 10 while about 15 percent of the nodes have a degree that is higher than 100. The degrees cannot be considered as approximately normal distributed. In fact, the distribution shows rather power law characteristics. The strength of a node is the sum of its weighted links. A link represents a trade partner relationship and the corresponding weight equals the gross value that is exchanged via this trade relation. Average node strength, therefore, equals the average gross settlement value per participant. Mean and median being far apart indicate that there is a small group of nodes with high strength while the majority of nodes are of low strength. This characteristic was already observed by means of the descriptive statistics in section 4.5. In figures, this means that about 90 percent of all nodes have a strength that is lower than 350 billion USD. This sums up to a little more than 10 percent of gross settlement value. In contrast, the top ten percent of nodes in terms of strength account for almost 90 percent of gross settlement value. The network is highly heterogeneous in terms of its nodes' strengths. The connectivity of the network was higher in 2003 and decreased gradually each year. In 2006 the network shows a connectivity of 8 percent. This figure can be interpreted as the probability that a node has a link to any other particular node in the network. It is clear that over time, the connectivity shows the same development as the degree distribution. Mean and median are drifting farther apart from year to year, indicating the development of power law characteristics. The graphical representation of the network underlines this impression. Due to the fact that a graph of the entire network rather evokes the notion of a massive cotton wool ball, a minimum transaction value had to be set to reduce the number of links. Figure 4.4 and 4.5 at the end of the chapter, show organic layouts of the network in 2003 and 2006 with a minimum link weight of 5 billion USD. The term organic layout refers to the type of graph layout. It arranges nodes as if they were physical objects repulsing each other. The links between the nodes hold them together. Heavier links are colored darker. The position of a node is determined by the number of links of that node. Nodes with more links are located closer to the center of the network. The resulting graphical configuration of the nodes and links represents an equilibrium of their forces. As mentioned earlier, each node is interpreted as a sender node which results in onesided links between them. If both legs of the transactions would be displayed, the links would be two-sided and their weight would double. The direction of the links, therefore, does not provide any additional information. The graphs clearly show the large growth of the network from 2003 to 2006. Nodes that were central in 2003, are also central in 2006. Peripheral nodes in 2003 seem to have moved towards the center and were replaced by new nodes, including also tp-nodes. Additionally, strong triangular relationships among the central sm-nodes evolved and some of them clearly show hub characteristics. In summary, the graphical representation confirms at first glance what was suggested by statistics. The following section takes a closer look at the two different types of nodes. To do so, the network is split into two subgraphs. The first consists of all sm-nodes, the second includes the set of tp-nodes.

4.7 Further Results

4.7.1 Development of SM Size

This section deals with supposition 1 and 2 that were introduced in section 4.4 (p. 16). **Supposition 1** in the research design can easily be confirmed by looking at table 4.1 or the graphical representations of the network. The largest part of gross settlement value is generated by settlement members. As figure 4.1 already demonstrated, gross value is not equally distributed among settlement members. The 5 largest settlement members account for more than 50 percent of gross value. The fraction of value that is produced by third parties is proportionately small. It was 6 percent in April 2003, but grew in each of the following years. In April 2004, 2005, and 2006 third party value contingent amounted to 11, 14, and 20 percent respectively. As third party value seems to grow much faster than settlement member value, it might be a reasonable expectation that the portion of third party value will exceed 20 percent of total settlement value in the next years. Regarding **supposition 2**, the correlations between gross value, gross value growth, degree, and degree growth are calculated. The analysis of these correlations suggests the following two conclusions: (1) large settlement members show positive value growth rates and thus grow larger. But it is not the largest settlement members that have the highest value growth rates. (2) Larger settlement members in terms of settlement value always had more trade partners. In contrast, smaller settlement members tend to have higher growth rates for both, gross value and degree. Based on these observations, the development of settlement member size is assumed to stay relatively constant. As the graphical representation of the network already showed, nodes that were central in 2003 kept their position up to 2006 and increased the number of links as well as their weight. The largest settlement members, therefore, are not likely to give up their position in the short run.

4.7.2 SM Business Structure

This section treats supposition 3, 4, and 5 that were presented in section 4.4 (p. 16). It provides insights into the third party business structure by looking at the development of the relationships between settlement members and third parties. It must be emphasized once again that the linkage between settlement members and third parties in this context does not reveal any information regarding the operational settlement relation between them. The observed relations merely represent trade relationships and not settlement arrangement. A correlation analysis suggests the following results. According to the figures of the years

2003, 2004, and 2005, settlement members with large overall settlement values do not necessarily deal with a larger number of third parties. Consequently, **supposition 3** cannot be confirmed. Only for 2006 it might be stated that larger settlement members in terms of total settlement value deal with a larger number of third parties. **Supposition 4** states that settlement members with many trade relations in total, deal with a larger number of third parties. This supposition can be confirmed by the respective figures, though it might not provide much additional information. Somewhat surprising seems the fact that no correlation was found between the number of third party relationships and the business value generated with them. This means that there are certain settlement members that maintain intensive trade relations to only a few third parties. On the other hand, there must be settlement members with many third party trade partners that do not generate much business with them. It might indicated that the relations between settlement members and third parties are divers and rather randomly distributed. This will further be explored in the context of supposition 6. **Supposition 5** treats the question whether some concentration process in third party relations can be observed. The respective analysis does not confirm this supposition.

Summarizing the insights from supposition 1 to 5 leads to the conclusion that today, settlement members account for about 80 percent of gross CLS settlement value. Settlement member value is highly concentrated as the 5 largest settlement members account for more than 50 percent of total settlement member value and almost 30 percent of overall gross settlement value. They are highly connected to other settlement members and deal with a larger number of third parties. The fraction of value that they generate with them, however, is not above average. The development during the past years shows a relatively stable size ranking and does not suggest any significant future shifts in the settlement member structure. Coming back to supposition 1 to 5, the responses look as follows:

1. Figures confirm that the largest part of settlement value is generated by settlement members.
2. Large settlement members show positive growth rates in settlement value and number of trade partners. Growth rates of smaller settlement members, though, seem to be higher.
3. Except for 2006 it cannot be confirmed that larger settlement members in terms of value also deal with a larger number of third parties.
4. It seems true that settlement members with many trade partners deal with a larger number of third parties. But somewhat surprisingly, the portion of

value that they generate with third parties is not related to that number.

5. It could not be confirmed that settlement members with a large number of third parties tend to attract more third parties as trade partners.

4.7.3 TP Business Structure

This section changes its point of view from settlement members to third parties. Looking at third party gross settlement value reveals that the 5 largest third parties account for almost 40 percent of total third party value. Third party connectivity is clearly more divers than settlement member connectivity. The top 5 third parties show connectivity characteristics similar to settlement members. The majority, however, has only a few settlement members and even fewer third parties that they deal with. A comparison of new third parties over the years suggests a confirmation of **supposition 6**. It seems that new third parties tend to be smaller in value. Even though the majority of third parties is considerably smaller in value and degree than most settlement members, there are a few with connectivity characteristics similar to settlement members. In an isolated network context there is no obvious reason for them not to become settlement members. Figure 4.6 on page 27, offers a graphical approach to this suggestion. It represents an organic layout with a minimum link weight of 2 billion USD. The visualization makes clear that the tp-nodes (tp-nodes are marked in red, corresponding links in blue) tend to be located at the periphery of the network while sm-nodes form the core. There are a few tp-nodes that are highly connected and, referring to their location in the network, could just as well be sm-nodes. In summary, the relationship structure of settlement members is more homogeneous compared to the set of third parties.

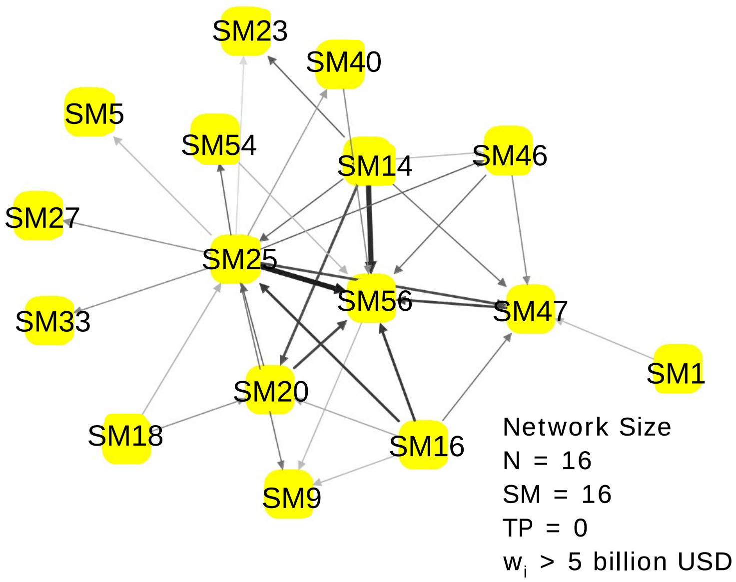

Figure 4.4: Network in April 2003.

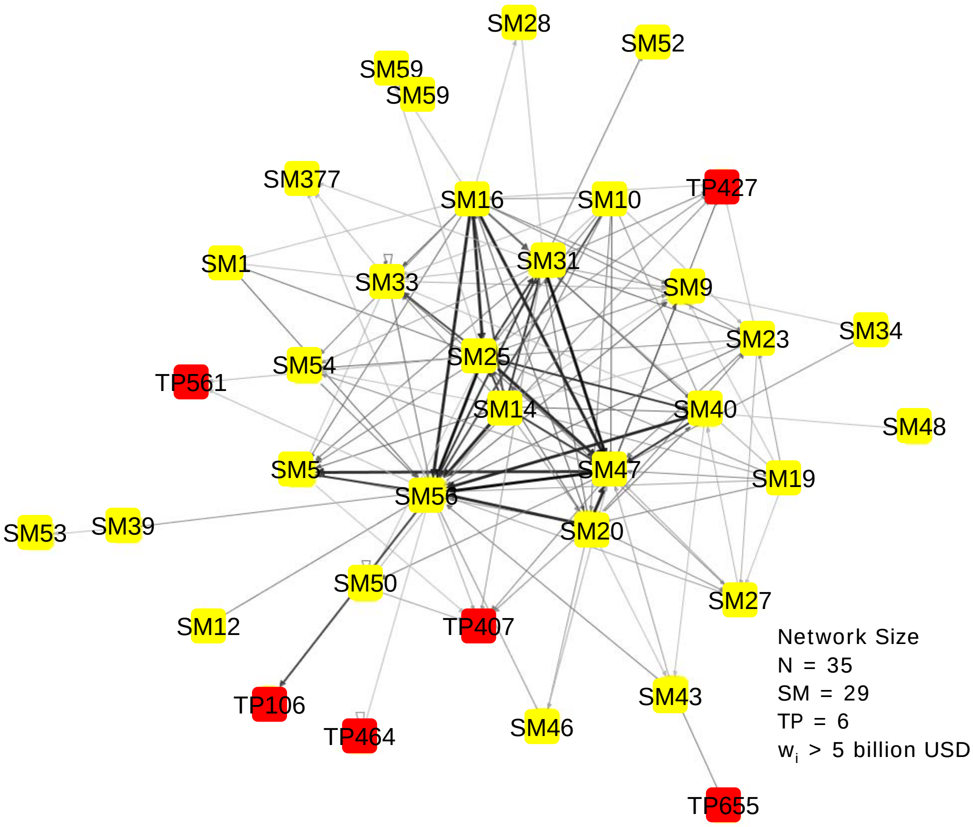

Figure 4.5: Network in April 2006 (I).

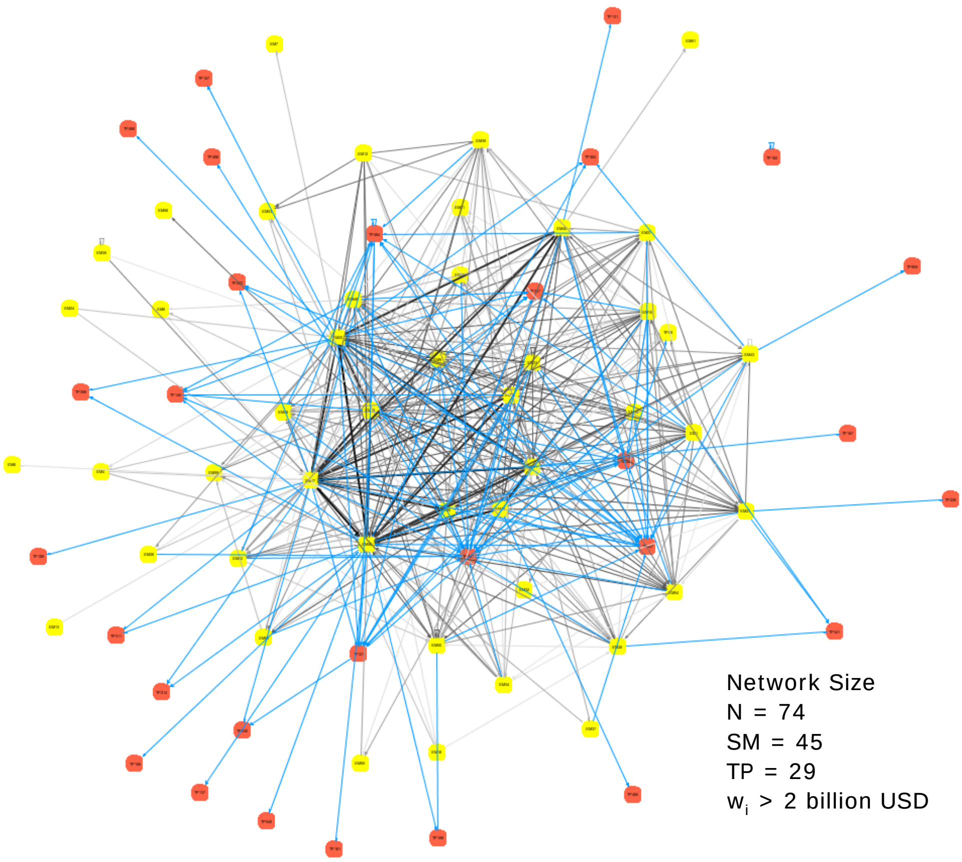

Figure 4.6: Network in April 2006 (II).

Chapter 5

Liquidity Aspects

Liquidity issues are one of the main topics today when it comes to clearing and settlement processes. Due to its net funding mechanism, CLS requires only 2 to 3 percent liquidity of gross settlement value to be paid in. Even though this is a substantial netting performance, the cash amounts are still considerable. The basic problem arising with CLS is caused by the fact that not the entire world of possible counterparties settles their foreign exchange trades through CLS. Settlement members trade not only with other CLS members but also with counterparties that do not settle through CLS. This may cause an imbalance in liquidity needs during the funding hours of CLS and the funding hours of the traditional payment systems. A particular settlement member may have well balanced its trading books but still might experience a mismatch when it comes to settlement. Trades settling through CLS require funding early in the CET morning hours while the liquidity from non-CLS trades may only be available later that day. If the whole universe of counterparties would settle through CLS, this discrepancy would disappear. The net sell and buy positions of all settlement members would balance and funding could be minimized. Today, it is not clear by what the net positions of CLS participants are driven. Bilateral net positions among the participants vary widely day by day without any obvious reason. This chapter takes a closer look at these bilateral net positions. It looks for factors in the CLS participants' connectivity structure that may be identified as drivers for the level of these positions.

5.1 Definition of Bilateral Net Sell Position

Additionally to the gross settlement value already used in chapter 4, chapter 5 introduces the so called bilateral net sell position (BNSP). It is the net sell value

	SM1	**SM2**
trade 1	buy 100 USD	buy 75 EUR
	sell 75 EUR	sell 100 USD
trade 2	buy 50 EUR	buy 80 CHF
	sell 80 CHF	sell 50 EUR
trade 3	buy 150 EUR	buy 200 USD
	sell 200 USD	sell 150 EUR
sell EUR	75 EUR	200 EUR
sell USD	200 USD	100 USD
sell CHF	80 CHF	0 CHF
net sell EUR	0 EUR	125 EUR
net sell USD	100 USD	0 USD
net sell CHF	80 CHF	0 CHF
overall BNSP	168 USD	168 USD

Table 5.1: Calculation of Bilateral Net Sell Position.

of all trades settled by a pair of settlement members and/or third parties on one day. An example illustrates the calculation of the bilateral net sell position. Consider two settlement members, SM1 and SM2, that settle three trades as summarized in table 5.1. To settle trade 1, SM1 needs to deliver 75 EUR and receives 100 USD. SM2 must deliver 100 USD and receives 75 EUR. The same mechanism is true for trade 2 and 3. For SM1 this is equal to a sell position of 75 EUR which implies that SM1 must theoretically come up with 75 EUR in liquidity at a specific time. SM2, in turn, must come up with 200 EUR in liquidity which results in a net sell position of 125 EUR for SM2. Converting it to dollar-equivalents results in an overall bilateral net sell position of 168 USD for SM2. Repeating this calculation for all currencies leads to net positions of 100 USD and 80 CHF for SM1. This corresponds to an overall BNSP of 168 USD for SM1. Neglecting currency fluctuations during the day, the bilateral net sell positions must always be equal. The bilateral net sell position may be interpreted as a driver for the amount of liquidity that must be delivered by the settlement members or third parties. It is important to understand that the bilateral net sell position is not equal to the net pay-in that has to be made by settlement members. The pay-ins are the effective net cash transfers from the settlement members to CLS. The net sell position, in contrast, is a calculatory dimension that reflects a CLS member's position in the market in terms of its trading activity. It is not a direct measure for liquidity needs. It merely indicates a settlement member's net sell position against other CLS participants. Using the cash pay-ins as a proxy for liquidity needs seems more straight forward. Yet, it would not allow for insights into the actual positions of the CLS participants. There are two main reasons for this: (1) third parties do not make any pay-ins. The pay-ins for third parties are accomplished by settlement members. Hence, pay-ins do not reflect the actual positions of the CLS members. In particular the liquidity positions for third parties could not be identified. (2) pay-ins do not reflect the underlying trade relations due to the so called in-out swap mechanism that generates trades only for netting purposes. The bilateral net sell position does not suffer from these two problems and is therefore considered as an adequate proxy for the CLS participant's liquidity positions. On the downside there is the argument that a theoretical liquidity position is not of much interest. It is only the actual liquidity that is of concern. But due to data availability constraints the bilateral net sell position is currently the best applicable measure. In average, the bilateral net sell position is about 50 percent of gross settlement value. This is not only true for the month of April 2006 but also for April in former years. The average bilateral net sell position has increased in line with the average gross settlement value. The following analysis is therefore not focused on the development over time but on the cross sectional data for April 2006.

5.2 Regression Analysis

To identify a possible dependency between CLS' participation network and the level of bilateral net sell positions, regression analysis is applied. It is analyzed whether specific connectivity characteristics of CLS members lead to lower bilateral net sell positions. The degree serves as proxy for the specific connectivity characteristic of a member. It is defined as the number of links from a particular node to all others. The higher the degree of a node in the network, the higher its connectivity. A formal definition of degree and network connectivity can be found in section 4.2. The regression analysis is based on four panel data sets including the four weeks of April 2006. The first data set includes 49'124 bilateral net sell positions from April 3 to April 7. The second set consists of 42'342 records between April 10 and April 14. The data set representing the third week of April includes 42'005 data records from April 17 to April 21, and the fourth week 49'002 from April 24 to April 28. The dependent variable is defined as the bilateral net sell position between a pair of CLS participants: $BNSP_i = Y_i$.

Regression I

	$BNSP_{W1}$	$BNSP_{W2}$	$BNSP_{W3}$	$BNSP_{W4}$
IC	-478.3***	-423.5***	-456.3***	-510.2***
	(-70.7)	(-59.1)	(-60.2)	(-68.6)
DEG	2.5***	2.2***	2.3***	2.6***
	(92.7)	(77.9)	(79.1)	(90.2)
ΔDEG^2	-3'230.6***	-2'881.2***	-2'848.6***	-3'293.5***
	(-27.8)	(-23.4)	(-21.9)	(-26.2)
SMD	103.3***	86.9***	103.2***	99.4***
	(23.2)	(18.5)	(20.7)	(20.2)
TPD	92.6***	88.6***	97.5***	101.2***
	(18.2)	(16.1)	(16.4)	(18.1)
Adj.R^2	0.24	0.20	0.21	0.22

t-statistics in parentheses.*** indicates statistical significance at a 1% level based on a two-sided test. Coefficients for IC, DEG, SMD, TPD in million. IC = intercept. $BNSP_{Wi}$ = bilateral net sell position in week i of April 2006. DEG = sum of counterparties' degrees. ΔDEG^2 = squared difference of counterparties' degrees. SMD = relation type dummy equaling 1 if both counterparties are settlement members, zero otherwise. TPD = relation type dummy equaling 1 if both counterparties are third parties, zero otherwise.

Table 5.2: Basic Regression.

5.2.1 Basic Regression

As a first step, the following regression model is defined:

$$Y_i = \alpha + \beta_1 DEG_i + \beta_2 \Delta DEG_i^2 + \delta_1 SMD_i + \delta_2 TPD_i + \epsilon_i \tag{5.2.1}$$

i refers to the observed pair of settlement members or third parties that is involved in the respective bilateral net sell position. DEG_i is defined as the sum of the degrees of the two involved participants. This independent variable is expected to have a negative effect on the bilateral net sell position. This means that the higher the degree and therewith the connectivity of the involved parties, the lower the bilateral net sell position. The rational for this expectation is the fact that a participant with higher connectivity has more counterparties within CLS that it can trade with. Its world of CLS trade partners is more complete than for a participant with low connectivity. The mismatch caused by the split between CLS trades and non-CLS trades should be smaller because a highly connected participant is less dependent on non-CLS trade partners. ΔDEG_i^2 is the squared difference between the connectivity of the two involved trade partners. This variable provides insights to whether or not large differences in connectivity of the two trading partners play a significant role regarding the level of bilateral net sell positions. While the variable DEG_i controls for the absolute level of connectivity, ΔDEG_i^2 isolates the effect of differences in the connectivity of the two trade partners. SMD_i and TPD_i are dummy variables that specify the type of trade relation. Three relations are possible: (1) a settlement member deals with a third party (sm-tp link). This combination type is defined as the control group. (2) a settlement member deals with a settlement member (sm-sm link). In that case the variable SMD_i equals 1 and zero otherwise. (3) a third party deals with a third party (tp-tp link). If this is true, TPD_i equals 1 and zero otherwise. Table 5.2 shows the results for the four weeks of this regression model. Each of the defined variables shows statistical significance at a high level. The degree variable does not, like expected, indicate a negative impact on the net sell position. In contrast, the degree difference variable shows a negative sign, indicating that the net sell position is smaller, the larger the difference in the degree of the two involved parties. This result is also unexpected. The two dummy variables show that the net sell position is larger in case of sm-sm links and tp-tp links compared to mixed links. The positive dependency between tp-tp links and the net sell position would be inline with what is expected. Namely, that the net sell position resulting from a relationship between two third parties would be larger than from a relationship between a third party and a settlement member, because latter involves at least one party that is highly connected. For the same reason, it would be expected that a relationship between two settlement member would result in a lower net sell position than between a settlement member and a third party. This is not confirmed by the sign of the SMD coefficient. In summary, the regression results are robust over the four different time periods, but do not reflect the expected dependencies. The results raise doubts regarding the adequacy of the model. It provokes the suspicion that the degree variable rather acts as a proxy for size than for connectivity. As described in chapter 4, degree and gross settlement value are correlated. Large participants in terms of gross value also show high degrees. Gross value, in turn, is highly correlated with the net sell position. These dependencies must somehow be excluded from the regression model to isolate the effect of connectivity. As a first step, the following section introduces an amended regression model that controls for the bilateral gross settlement value.

5.2.2 Controlled Regression

To exclude the size effect from the degree variable, the bilateral gross settlement value for each relationship is introduced as a control variable. The revised model looks as follows:

$$\begin{aligned} Y_i = \alpha + \beta_1 gv_i + \beta_2 DEG_i + \beta_3 \Delta DEG_i^2 + \\ + \delta_1 SMD_i + \delta_2 TPD_i + \epsilon_i \end{aligned} \tag{5.2.2}$$

The regression results for this model are displayed in table 5.3. As expected, the control variable turns out to be significantly different from zero. The degree variable, however, does not loose its significance nor does it change its sign. The variable DEG_i still seems to have explanatory power, additionally to the bilateral gross value. The variable representing the degree difference as well as the two dummy variables neither change signs compared to the first regression model. The dependencies do not point to the direction that would be expected. The model still seems to be dominated by the size factor and is not able to isolate the effect of connectivity. It becomes clear that controlling for size by including the bilateral gross settlement position is not sufficient. In a second step, the size effect is therefore controlled by the sum of the aggregated gross settlement values of the involved parties. Additionally, connectivity is examined on a relative basis. To implement these ideas, a third regression model is introduced in the following section.

Regression II

	$BNSP_{W1}$	$BNSP_{W2}$	$BNSP_{W3}$	$BNSP_{W4}$
IC	-72.3***	-52.2***	-47.5***	-51.2***
	(-16.6)	(-12.3)	(-10.6)	(-11.4)
gv	0.3***	0.3***	0.4***	0.4***
	(289.1)	(301.7)	(299.6)	(315.6)
DEG	0.5***	0.4***	0.3***	0.4***
	(27.4)	(21.8)	(19.5)	(21.6)
ΔDEG^2	-732.9***	-700.4***	-605.1***	-723.6***
	(-10.3)	(-10.0)	(-8.2)	(-10.0)
SMD	25.4***	23.2***	25.0***	13.1***
	(23.2)	(8.7)	(8.8)	(4.6)
TPD	9.0***	7.3***	6.5***	2.4
	(2.9)	(2.3)	(1.9)	(0.7)
Adj.R^2	0.72	0.75	0.75	0.74

t-statistics in parentheses.*** indicates statistical significance at a 1% level based on a two-sided test. Coefficients for IC, DEG, SMD, TPD in million. IC = intercept (in million USD). gv = bilateral gross settlement value. $BNSP_{Wi}$ = bilateral net sell position in week i of April 2006. DEG = sum of counterparties' degrees. ΔDEG^2 = squared difference of counterparties' degrees. SMD = relation type dummy equaling 1 if both counterparties are settlement members, zero otherwise. TPD = relation type dummy equaling 1 if both counterparties are third parties, zero otherwise.

Table 5.3: Controlled Regression.

Regression III

	$BNSP_{W1}$	$BNSP_{W2}$	$BNSP_{W3}$	$BNSP_{W4}$
IC	5.3***	4.1**	7.1***	13.2***
	(2.8)	(2.2)	(3.6)	(6.7)
GV	0.0***	0.0***	0.0***	0.0***
	(20.1)	(16.0)	(13.9)	(13.0)
gv	0.3***	0.4***	0.4***	0.4***
	(283.5)	(296.1)	(293.1)	(309.1)
RDEG	-2'126.6***	-7'134.8***	-4'757.8***	-16'916.1***
	(-2.4)	(-3.5)	(-3.2)	(-4.6)
$\Delta RDEG^2$	0.0***	0.1***	0.0***	0.6***
	(2.4)	(3.0)	(3.0)	(3.3)
SMD	52.3***	45.2***	45.5***	36.9***
	(21.3)	(19.1)	(18.0)	(14.5)
TPD	6.2**	6.5**	5.3*	-1.2
	(2.0)	(2.1)	(1.6)	(-0.4)
Adj.R^2	0.71	0.74	0.75	0.74

t-statistics in parentheses.***, **, * indicate statistical significance at a 1%, 5%, 10% level based on a two-sided test. Coefficients for IC, SMD, TPD in million. IC = intercept. GV = gross settlement value in April 2006. gv = bilateral gross settlement value. $BNSP_{Wi}$ = bilateral net sell position in week i of April 2006. DEG = sum of counterparties' degrees. ΔDEG^2 = squared difference of counterparties' degrees. SMD = relation type dummy equaling 1 if both counterparties are settlement members, zero otherwise. TPD = relation type dummy equaling 1 if both counterparties are third parties, zero otherwise.

Table 5.4: Relative Regression.

5.2.3 Relative Regression

The third regression model implements two improvements: (1) it adds an additional control variable to get rid of the size effect that overlays the connectivity effect and (2) it includes the degrees of a participant relative to its aggregated gross settlement value. The new control variable is named GV_i and is defined as the sum of the overall gross values that the two involved parties settled in the month of April 2006. In contrast to gv_i which is the bilateral gross settlement value of two parties on a specific day, GV_i more adequately reflects the actual size of the involved parties. The variable $RDEG_i$ is now defined as the sum of the relative degrees of the two involved parties. The term relative degree refers to the degree divided by the overall gross settlement value of that particular participant. Or in other words, the total gross value per link in April 2006. Correspondingly, $\Delta RDEG_i^2$ represents the squared difference of the two relative degrees. The bilateral gross value variable gv_i has been retained unchanged. The new model can be described as:

$$\begin{aligned} Y_i = \alpha + \beta_1 GV_i + \beta_2 gv_i + \beta_3 RDEG_i + \beta_4 \Delta RDEG_i^2 +& \\ + \delta_1 SMD_i + \delta_2 TPD_i + \epsilon_i& \end{aligned} \tag{5.2.3}$$

Looking at table 5.4 shows that on a 99 percent confidence level, the relative degree variable as well as the relative degree difference variable changed their signs. The variable GV_i differs significantly from zero and seems to effectively control for size. The degree expressed on a relative basis is finally no longer correlated to size in terms of gross value. The revised model mostly reflects what was expected. The relative degree of the two involved parties has a negative effect on the net sell position. This implies that the higher the connectivity of the related parties in relation to their gross settlement values, the lower their bilateral net sell positions. The reason for this dependency being plausible was already explained in 5.2.1. Better connected participants have more counterparties within CLS to trade with. They are less dependent on trade partners outside CLS. The imbalance between inside and outside CLS trades might thus be lower than for participants with low connectivity inside CLS. The negative coefficient for the variable $RDEG_i$ describes this dependency, though on a relative basis. The relative degree difference $\Delta RDEG_i^2$ turns out to have a positive effect on the net sell position. This suggests that the larger the difference of the relative degrees of the two involved parties, the larger their bilateral net sell position. A relationship between two parties with low relative degrees generates a lower net sell position than a mixed relationship. The same is true for a relationship between two parties with high relative degrees. The SMD variable did not change its sign. It suggests that a sm-sm relationship generates larger net sell positions compared to a mixed relationship. As this variable cannot be adjusted on a relative basis as was done with the degree variables it should only be accepted with reservation. It is likely that the variable is simply stamped by the size effect explained earlier. Compared to the relationships between two third parties, the relationships between two settlement members generally involve much higher gross settlement values and with that, also much higher net sell positions. The same considerations are applicable for the TPD variable. On a 99 percent confidence level, TPD is not significantly different from zero. The two dummy variables, therefore, might better be interpreted with caution. Recalling the fact, that in average the bilateral net sell positions relative to the gross settlement values did not change during the past years, suggests that simply increasing the number of participants does not lower the bilateral net sell positions. This, combined with the regression results might indeed indicate that there is a cross sectional relation between the level of bilateral net sell positions and the structure of trade partners. In summary, the third model might bring up the idea that there could be an optimal level of relative connectivity that would minimize the net sell position, at least theoretically. In practice, an optimal level of relative connectivity would be restricted by the maximum number of participants. Large members might not be able to reach this theoretically optimal level of relative connectivity. Furthermore, it should be questioned whether such an optimal level is of interest at all. As mentioned earlier, the net sell position does not represent the actual liquidity needs. The use of its optimization is therefore unclear. Equally unclear is the question whether a minimized bilateral net sell position would in fact lead to lower liquidity needs.

Chapter 6

Conclusions

Today, the so called Allsopp-Report (CPSS 1996) is widely interpreted as a threat from the Bank for International Settlements to the industry. It urged industry players and regulatory authorities to reduce credit risk in foreign exchange settlement. A group of key players, the G20, affiliated to take action. The result was a complex IT project that was more than once at the verge of capitulation in its childhood. Merely the scope of engagement did not allow for failure. Remarkable efforts and painful trade-offs were necessary to bring the system alive. Today, after five years of operation, the system can be considered as the settlement industry's standard in foreign exchange. Around 60 to 75 percent of global foreign exchange turnover is estimated to be settled in CLS. If this equals a 60 to 75 percent credit risk reduction, the urge of the Bank for International Settlements may be considered to be well fulfilled. Though CLS' market share is still increasing there will be a limit as long as not the whole world of possible foreign exchange trade partners participates in CLS. It is yet not clear, whether one day CLS participation will be crucial to find counterparties that are willing to enter a trade. Already today, counterparties that do not settle in CLS experience unfavorable conditions regarding trade limits. This effect may intensify in the future. CLS's mechanism minimizes liquidity needs for settling its transactions, but at the same time imposes new restrictions on liquidity provisions. The exact timing of pay-ins is unique in the settlement industry and bears new challenges. Ideas such as cross-boarder cash pools and the extension of CLS' settlement window are in the air and seem to offer promising improvements compared to current liquidity management. Broad implementations, however, will take time and presumably require financial and/or authoritative pressure.

The empirical part offers insights into the trading structure among CLS members. Substantial differences in the structure of settlement member and third party relationships were found. Settlement members are highly connected among each other and do not show significant changes over time. The connectivity of third parties is much lower and shows the development of power law characteristics. Statistics and visualized network graphs suggest that new third parties tend to be smaller than the existing ones. This means that a relatively small group of members generates an increasing part of the business. In terms of liquidity, the analysis was based on the bilateral net sell position. The fact that these positions did in average not lower during the past years, indicates that simply increasing the number of members does not automatically lead to lower bilateral net sell positions. In contrast, cross sectional regression suggests that there is a certain dependency between the level of the bilateral net sell position and the type of trade relation. It seems that trade relations between members with high relative connectivity lead to lower bilateral net sell positions. If and how these results may be implemented in a practical context is yet unclear.

6.1 Critique and Further Research

Liquidity is a key issue in settlement. Its management is complex, costly, and vital for systemic stability. Academics, however, have just started to focus on these topics. Lack of data might be an important reason for this research area to be underdeveloped. The acquisition of the data that was presented in these chapters was a challenging task. Data protection and editing do not allow for open access. Consequently, the research design was decisively stipulated by data availability which in general is not a desirable starting point. Two main issues of serious criticism arise with this dependency: (1) The data set presented in chapter 4 is enclosed in itself and cannot be related to the outside world of CLS. It frustrates a comprehensive analysis of the CLS trade structure compared to the non-CLS trade structure and does not even allow for insights into the structure of third party service providers. It would be interesting to explore the structural development of inside- and outside CLS transactions and in particular the development of third party service providers. As addressed by industry professionals, a consolidation process is assumed to be going on. Smaller institutions that are active in foreign exchange trading seem to reduce their number of correspondent banking relations and concentrate on a few "one-stop" service providers. If this is true, CLS might be identified as an important driver for such a development. The work on hand, due to lacking data, is not able to provide such insights. (2) Chapter 5 suffers from similar problems. Instead of analyzing the dependency between the trade structure and actual liquidity needs, a proxy had to be employed. Consequently, the interpretation of the results is not quite clear. Despite of, or even because of the critique, these chapters intend to motivate further research on the issues mentioned above. Altogether, it is a contribution to the academic literature in that it provides a sound and unique approach to the world of Continuous Linked Settlement.

6.2 Food for Thought to Practitioners

Continuous Linked Settlement is a topic that is of interest particularly to practitioners. As the setting of the empirical chapters 4 and 5 rather treats theoretical aspects of CLS' settlement member structure, this section intends to provide food for thought to practitioners. In the wake of the network analysis in chapter 4, it appears that there is no distinct difference in the structural importance of settlement members and third parties. In other words, some system participants with the status of third parties exhibit equal or even larger trade values than some of the settlement members. Intuition would suggest that the status of being a settlement member is reserved for large participants. Accordingly, a third party status would be appropriate for smaller participants. Figure 4.6 does not support this intuition. There is more than a dozen of third parties that seem to be at least equally large in trade value than most settlement members. Two explanations are conceivable: (1) compared to a settlement member status, a third party status is more attractive in terms of cost. As a consequence, there might be third parties that from a business point of view would better be classified as settlement members. (2) The third parties in question do not meet certain criteria requested by CLS to become settlement members. Both points might lead to a bias in the participant structure. It is obvious that system stability requires adequate risk profiles for settlement members. The second reason for large participants not becoming settlement members might therefore be well acceptable. But third parties that are prevented from applying for settlement member status due to cost issues might scale down CLS' business. In that case, reconsidering CLS' cost structure might be worthwhile. A starting point for further investigations on this topic could be the idea of an optimal classification scheme for third parties and settlement members, including the relevant cost issues for both, CLS and its members. Results might help to design a cost structure that would entice certain third parties to become settlement members. Considering the difficulties arising with the split of CLS- and non-CLS trades (chapter 5), it should not exclusively be the interest of CLS Bank to increase the number of its members. It is likely that also the industry could benefit from an increased number of participants, especially in terms of liquidity management.

Bibliography

Albert, Réka & Albert-László Barabási (2000), 'Error and Attack Tolerance of Complex Networks', *Nature* **406**, 378–382.

Albert, Réka & Albert-László Barabási (2002), 'Statistical Mechanics of Complex Networks', *Reviews of Modern Physics* **74**, 47–97.

Barthélemy, Marc, Alain Barrat, Romualdo Pastor-Satorras & Alessandro Vespignani (2005), 'Characterization and Modeling of Weighted Networks', *Physica A* **346**, 34–43.

BIS (2007), 'Triennual Central Bank Survey, Foreign Exchange and Derivatives Market Activity in April 2007', Bank for International Settlements, Publications.

CPSS (1996), Settlement Risk in Foreign Exchange Transactions, Allsopp-Report, Bank for International Settlements.

Euromoney (2004), 'UBS and Deutsche race clear of the field', *Euromoney* **35**(421), 54–71.

Euromoney (2007), 'FX Poll 2007', *Euromoney* **38**(457), 170–178.

Inaoka, Hajime, Takuto Ninomiya, Ken Taniguchi, Tokiko Shimizu & Hideki Takayasu (2004), Fractal Network Derived from Banking Transaction - An Analysis of Network Structures Formed by Financial Institutions, Working Paper No. 04-E-04, Bank of Japan.

Iori, Giulia, Giulia De Masi, Ovidiu Vasile Precup, Giampaolo Gabbi & Guido Caldarelli (2005), A Network Analysis of the Italian Overnight Money Market, Discussion Paper Series 05/05, City University London, Department of Economics.

Klein, Fritz (2006), 'Interview regarding Contracts for Difference', November 2006.

Lublóy, Ágnes (2006), Topology of the Hungarian Large Value Payment System, Occasional Papers 57, Magyar Nemzeti Bank.

Newman, Mark (2003), 'The Nature and Function of Complex Networks', arXiv:cond-mat/0303516v1.

Newman, Mark (2004), 'Analysis of Weighted Networks', arXiv:cond-mat/0407503v1.

Perold, André (1995), *The Payment System and Derivative Instruments*, In: The Global Financial System: A Functional Perspective, Harward Business School Press Boston Massachusetts, pp. 33–79.

Rossi, Eliana & Peter Taylor (2005), 'Banking Networks across Brazilian Cities: Within and Beyond Brazil', *Cities* **22**(5), 381–393.

Soramäki, Kimmo, Morten Bech, Jeffrey Arnold, Robert Glass & Walter Beyeler (2006), The Topology of Interbank Payment Flows, Staff Report no. 243, Federal Reserve Bank of New York.

TowerGroup (2004), 'The Continuous Linked Settlement (CLS) System: Building for Tomorrow Through Today's Innovations', TowerGroup 2004 CLS Survey.

UBS (2007), 'UBS Annual Report: Handbook 2005/2006', http://www.ubs.com, june.

Curriculum Vitae

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