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A Microscopic View of Thailand's Foreign Exchange Market: Players, Activities, and Networks

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A Microscopic View of Thailand's Foreign Exchange Market: Players, Activities, and Networks

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Abstract

This paper explores Thailand's foreign exchange (FX) market landscape by utilizing the Bank of Thailand's supervisory Financial Market Statistics (FMST) data which covers the universe of onshore foreign exchange transactions in Thailand. Historical developments regarding different groups of market players and the use of foreign exchange instruments, as well as the overall market structure are documented. Through the lens of network analysis, we also provide topological descriptions of Thailand's FX market landscape, with applications on interbank network stability. We observe low degree of concentration among the dealer banks in terms of market turnover share. In contrast, from a customer's perspective, market share is highly concentrated within a handful of large FX customers. The network connectivity among different groups of players suggests that the Thai FX market is one that is rather segmented and clustered among similar players. A substantial degree of specialization is evident across banks in terms of FX instruments and market segments, both in the interbank network and in the retail market. Probing into the interbank network stability, we find a small subset of banks to be truly central to the FX market network, though the system appears to hold up well in stress times supported by fluidity among interbank players.

JEL classification: F31, G20, L14

Keywords: Foreign exchange market, Network analysis, Thailand

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Introduction

With an increasing degree of complexity and interconnectedness in financial markets, the evolving market structure and inter-linkages among players play an important role in the price dynamics as well as the emergence of financial instabilities. For a particular financial market, a clear picture of the market landscape, including the interplay between key dominant players and the network properties of the system, is essential for identifying shock propagation mechanisms. This is particularly important from a policy perspective because understanding the market structure is critical for assessing the stability of the system and for designing policies to foster specific areas of market development needed for building system resiliency. This applies to the foreign exchange (FX) market which—despite being the world's largest and the most important over-the-counter financial market—has been one of the least understood both at the global and national level in terms of the structure of the market and interlinkages among players.

For the first time, this paper offers a comprehensive view of the market landscape and network of the foreign exchange market in Thailand. We utilize the unique database available to the Bank of Thailand—namely, the Financial Market Statistics data—which covers all onshore FX trading activities at the transaction level. Analyses in this paper will be exploratory rather than methodological, focusing on establishing key stylized facts on players, activities, and networks, in both the cross-sectional dimension and the time evolution. Key facts learned from this study will provide a groundwork important for guiding policy decisions and theoretical modelling efforts in a way that is aligned with market realities. More specific research questions will be tackled in the future phases of this project.

This work adds to the existing literature in several dimensions. First, while network analysis has been applied to interbank networks before, the focus has often been on payment systems and interbank loan markets (e.g. Bargigli et al. (2015), Bech and Atalay (2011), Minoiu and Reyes (2013), Roukny et al. (2014), and Soramäki et al. (2007)). FX markets have rarely been examined through this lens, partly due to the opaque nature of over-the-counter FX markets and the lack of comprehensive transaction-level datasets. In this regard, this paper leverages on a national-level supervisory FX transaction database to provide a more thorough investigation of the FX market landscape. Second, by studying an FX network the case of an emerging market, we add to the existing body of empirical interbank network literature which are currently limited to advanced economies. Financial markets in emerging market economies, such as Thailand, are likely to be structurally different, and lessons learned from studies conducted on advanced economies' data might not be applicable to the case of emerging markets. Lastly, to the best of our knowledge, this paper is also the first that moves beyond the interbank segment and attempts to provide a complete account on the entire FX market landscape – that is, including the *retail* segment of the market. The larger scope allows us to explore the FX market from both supply-side and demand-side perspectives.

Key findings on the Thai FX market structure and networks can be summarized as follows. With regard to market concentration, from the perspective of FX service providers, we observe low degree of concentration in terms of market turnover share, and a moderate level of concentration in terms of customer base. From customer's perspective, turnover share appears to be highly concentrated among a handful of large customers. These patterns of market concentration remain more or less stable over time. The network connectivity among different groups of players suggests that the Thai FX market is one that is quite segmented and contains clusters of similar players that tend to trade mainly with one

another. In addition, we find different banks to be important in different ways in the Thai FX network, and banks with largest FX turnover are not necessarily the ones that are most central to the system. A substantial degree of specialization is evident across banks in terms of FX instruments and market segments, both in the interbank network and in the retail market. In terms of network centrality, we find a small subset of banks to be truly central to the FX market network. Nevertheless, based on case studies around stress events related to USD liquidity, we show that the interbank system continued to function smoothly through the stress periods, supported by fluidity among interbank players.

The rest of the paper is structured as follows. Section 1 describes the FX transaction database used in this paper. The following three sections then explore the FX market landscape from various angles. Section 2 provides a broad overview of the FX market at an aggregate level. Section 3 investigates different groups of FX market participants and their activities. Section 4 discusses various dimensions of market concentration. Taking on a more granular perspective, Section 5 employs network analysis to visualize the entire market landscape with applications on interbank network stability. Section 6 concludes.

1. Data description

This paper uses Bank of Thailand's Financial Market Statistics (FMST) database, the comprehensive supervisory database covering all FX transactions with authorized dealers in Thailand. For supervisory and statistical purposes, authorized FX dealers are required to report to the Bank of Thailand all transactions that involve purchasing, selling, depositing, or withdrawing of foreign currencies between reporting dealers and their counterparties in an amount equivalent to $50,000 or above. FX transactions of value less than $50,000 can be reported in aggregate on a daily basis. For each transaction, key variables recorded in the FMST database include dealer identification, customer identification, FX instrument,[1] contract date, maturity date, currencies involved, transaction amount, exchange rate, nationality of customer, as well as purpose of transaction. In this paper, we analyze the FMST database for the period spanning from 2004 to 2015.[2]

By construction, each transaction recorded in the FMST database is a transaction between a reporting dealer and a counterparty, which could be another reporting entity or a non-reporting entity. Reporting dealers consist of local commercial banks, foreign banks and subsidiaries, and reporting government financial institutions. On the other hand, non-reporting entities can be non-financial businesses, non-reporting financial entities, or individuals; and in terms of residency, they can be residents of Thailand or non-residents. More details on our classification of market participants are provided in Section 3.1.

We would like to highlight three unique features of this supervisory database. *(1) Coverage:* The database covers the universe of onshore FX trading, and includes both interbank and retail segments. The inclusion of players in the retail segment, especially non-financial businesses, is very unique to this study and helps provide a more complete picture of the entire FX market landscape. *(2) Granularity:*

[1] In our analysis, FX instruments are classified into five categories: (1) spots (2) outright forwards (3) foreign exchange swaps (FX swaps) (4) currency swaps and (5) options and others.

[2] While more recent data are available, we introduce lag time to ensure that the results are not sensitive and cannot be used for trading purpose.

The database contains transaction-level data in a relatively high frequency (i.e. daily), with detailed information on each transaction that could be used for further study. *(3) Identification:* The database allows us to study FX trading behavior of market participants over time, across instruments, and across banks. Thus, there are many potential uses of this database, including topics on market microstructure, firms' hedging behaviors, and linkages between exchange rates and order flows.

Adjustments have been made on the FMST database prior to our analysis, mainly to eliminate double-counting. Because all reporting dealers are required to report all transactions, double-counting arises for transactions between two reporting dealers, which appear twice in the database. We take care of this double-counting issue by halving the transaction amount of every transaction where both counterparties are reporting dealers, and use this adjusted transaction amount when measuring market turnover at an aggregate level. Another double-entry issue arises from swap transactions (both FX swaps and currency swaps), where the short and the long legs of swaps are reported as separate entries. Following the reporting guideline of the BIS Triennial Central Bank Survey, we only sum over the long legs of swap transactions and disregard the short leg entries when measuring aggregate transaction amount. In any case, we keep all reported transactions in the dataset for our analysis at a disaggregate level, keeping in mind the double-reporting attribute in some portion of the dataset as mentioned above.

It is also important to note that the data used in this paper is highly confidential. While the richness of the dataset could provide meaningful insights into the FX market, constraints exists on the granularity level of the disclosed results. Therefore, we refrain from revealing and discussing information on individual banks and customers. The results presented in this paper are either in an aggregate term or visualized at a granular level but without any identification disclosed.

2. Market overview

This section presents an overview of Thailand's FX market based on the FMST database. The focus will be on transaction volume (turnover) with breakdown by instrument, market segment, and currency involved.

2.1 Overall market turnover and breakdown by instrument

We start by taking a comprehensive look at the FMST database to document historical developments of FX market activity over the 2004-2015 period. Figure 1 shows Thailand's historical FX market turnover viewed from several angles. Panel (a) aggregates trading activities of all participants in all instruments on a particular day, and plots daily historical turnover from 2004 to 2015. Panel (b) looks at the same turnover data but in terms of distribution across the days in a given year, tracking the evolution of median and percentiles over the years. From Panel (a) and (b), some observations are worth noting. *(1) Market turnover has been rising over the years, with a brief drop following the global financial crisis.* This is broadly consistent with the historical pattern of FX market activity reported globally. *(2) Thailand's FX market activity has been responsive to large shock events.* As shown in Panel (a), several external and domestic shock events have induced heightened activity in the short term, on top of usual seasonal patterns that persist over the years. Lastly, *(3) daily variations in market activity within a given year have widened over the years.* Panel (b) shows a widening gap between upper and

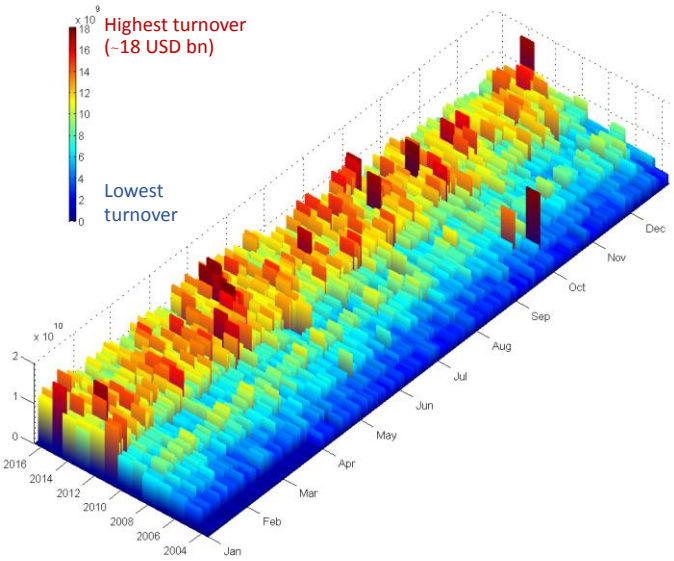
lower percentiles, reflecting an increasingly volatile marketplace. Following the global financial crisis, turnover in the median day has picked up from $7.45 billion in 2010 to about $9.28 billion in 2015, while the ratio of maximum to median daily turnover has also increased from 1.76 times in 2010 to 1.87 times in 2015. That is, market turnover on the busiest day of the year is about twice as much as the turnover on the median day.

Figure 1 (c) plots averages of daily turnover in the overall FX market, along with average daily turnover in each FX instrument. Overall market turnover averaged at about $10 billion per day in 2015. Given the global FX market turnover of about $6,500 billion per day, Thailand's FX market accounts for only 0.2 percent of the global market (BIS Triennial Central Bank Survey, April 2015). However, at the regional level, Thailand's current market size of $10 billion is considered sizeable compared with the peer countries[3]. Between 2004 and 2015, turnover in the Thai FX market grew by 14 percent on average, with a sharp contraction in 2009 following the global financial turmoil and a slight decline during 2014-2015.

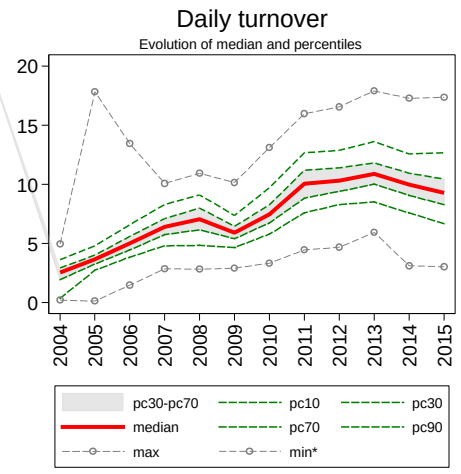
[3] For comparison with peer countries, average daily turnover figures in 2015 are $8 billion for Malaysia, $5 billion for Indonesia, and $3 billion for the Philippines.

Figure 1: Thailand's historical foreign exchange turnover (2004-2015)

(a) Historical daily turnover (2004-2015)

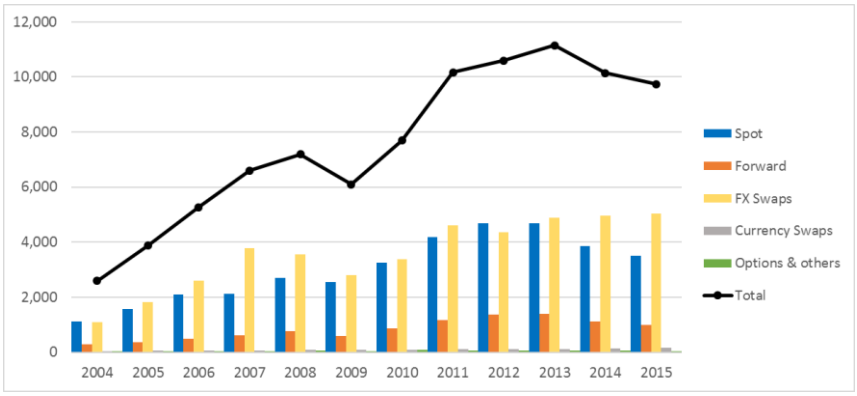


(b) Distribution of daily turnover and selected turnover statistics (in billions of US dollars)



	2005	2010	2015
Median	3.64	7.45	9.28
Max	17.82	13.10	17.34
Max/Median	4.89	1.76	1.87

(c) Historical daily averages of foreign exchange turnover by instrument (in millions of US dollars)

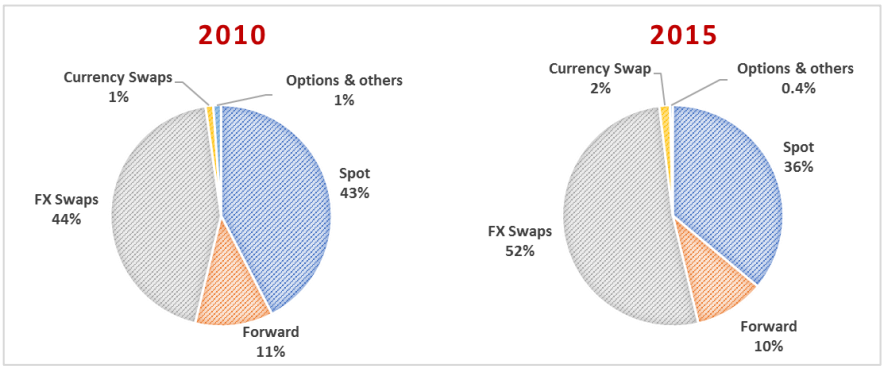


Source: Bank of Thailand; authors' calculation

In terms of composition of FX instruments, trading volumes in spots and FX swaps clearly dominate with turnover share of 36 and 52 percent, respectively, in 2015 (Figure 2). This is consistent with a pattern generally observed in other national and global FX markets. Trading volume in outright forwards — a main hedging instrument for exporters, importers and international investors — has increased over time in tandem with spot turnover, although its share has not risen much, remaining at roughly 10 percent of total market turnover. The market for currency swaps — an FX derivative primarily used for hedging against exchange rate risks associated with long-term investment — remains small in Thailand, accounting for only 2 percent of the total turnover. At the same time, trading

in currency options and other instruments has so far been limited in Thailand's case, with their turnover accounting for merely less than 1 percent of total market turnover, compared with 5 percent at the global level. Broadly speaking, the composition of market turnover by instrument has been largely unchanged over time, except that trading in FX swaps came to surpass trading in spots as spot turnover declined markedly in 2014 and 2015.

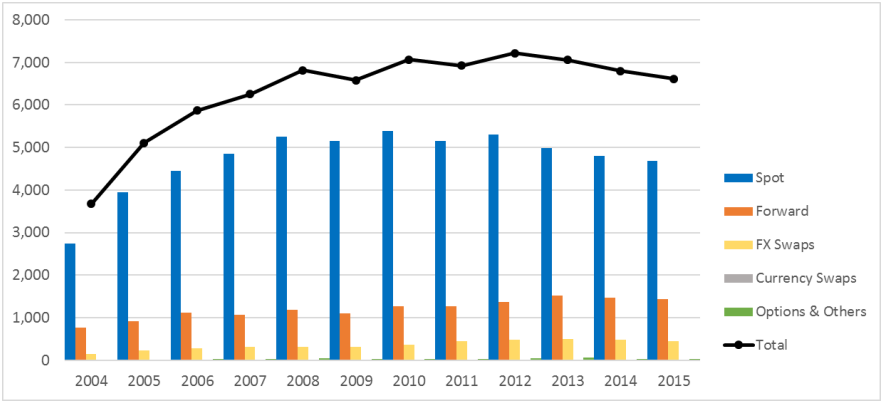
Figure 2: Breakdown of foreign exchange turnover by instrument (2010 and 2015)



Source: Bank of Thailand; authors' calculation

In terms of the number of transactions recorded in the FMST database, spot is the most actively traded FX instrument by far (Figure 3). Out of roughly 7,000 FX transactions occurring on a typical day, about 5,000 transactions belong to spot trading, while about 1,500 transactions are for forwards. FX swaps record only about 400 entries per day on average, although their share in the overall market turnover is the largest among all instrument groups. This reflects a much larger notional size of a typical swap transaction compared with a spot transaction. The overall average number of transactions per day increased rapidly during 2004 to 2008, and has been relatively stable thereafter.

Figure 3: Average number of foreign exchange transactions per day (2004-2015)



Source: Bank of Thailand; authors' calculation
Note: Data used for calculation of average daily number of transactions does not include those very small transactions of an amount equivalent to 50,000 US dollars or less.

2.2 Turnover breakdown by market segment

Table 1 provides a snapshot of a breakdown of FX turnover in 2015 by market segment. The market can be divided into two segments or two tiers: (1) the interbank or wholesale market, and (2) the retail market, depending on the type of counterparties transacting with reporting dealers. More than two-thirds of FX trading activity takes place in the interbank market, that is, between banks. About half of the interbank turnover is done between local banks, primarily reporting dealers, which could also be Thai subsidiaries and branches of foreign banks. The other half of interbank turnover is associated with transactions between reporting local banks and banks located outside of Thailand (cross-border interbank transactions).

Retail market—that is, FX trading activity between reporting dealers and non-bank customers—represents 30 percent of total market turnover, with most of the activity belonging to non-financial firms. Notice that this non-financial firm category by far dominates in terms of the number of market participants. This category mainly consists of Thai exporting/importing firms that enter the FX market during the year, roughly over 30,000 firms in 2015.

Table 1: Thailand's foreign exchange turnover by market segment (2015)

Market segment	Total turnover (bil. USD)	Share	Number of participants*
Interbank market	**1,675**	**70%**	**534**
Local	823	34%	35
Cross-border	852	35%	499
Retail market	**734**	**30%**	**49,311**
Other financial entities	208	9%	1,306
Non-financial customers	526	22%	48,005
o/w Thai firms	*396*	*16%*	*31,730*
Total	**2,409**	**100%**	**49,845**

Source: Bank of Thailand; authors' calculation
Note: The number of participants excludes those who conduct FX transactions of an amount less than $50,000.

2.3 Turnover breakdown by currency[4]

Market turnover breakdown by currency in Table 2 shows that the US dollar has continued to be the dominant currency traded in Thailand's FX market, taking up a lion's share of over 80 percent in overall trading activity. This reflects the dominance of the US dollar as an invoice currency for Thai exports and imports, a payment currency for cross-border investments, and a vehicle currency for trading in non-major currency pairs. The second most actively traded currency in the market is the Japanese yen, though its share has been on a decline over the past decade. The shares of European currencies including the euro, the pound sterling and the Swiss franc also appear to have fallen over the past ten years; at the same time, Asian currencies such as the Chinese renminbi, the Singapore dollar, and the

[4] Total turnover includes transactions across all FX instruments. Most of the transactions involve trading of a foreign currency against Thai baht. In this case, we count only one side of the trade and omit Thai baht from the currency distribution. In the case of transactions between two foreign currencies (not involving Thai baht), we halve the trading size of the particular transaction and allocate each half to each of the currency pair.

Hong Kong dollar have gained in terms of market share. This could partly be a result of changes in the pattern of international trade and investment after the global financial crisis of 2008-2009 whereby Asian trade has become more concentrated within the region, especially with China, while trade and investment with Europe has retreated notably.

Table 2: Thailand's foreign exchange turnover by currency

Currency	2005	2010	2015
US DOLLAR	83.9%	83.0%	86.7%
YEN	8.8%	6.6%	5.2%
EURO	4.2%	6.2%	4.1%
SINGAPORE DOLLAR	0.4%	0.6%	0.9%
AUSTRALIAN DOLLAR	0.5%	1.6%	0.7%
POUND STERLING	1.4%	1.1%	0.7%
CHINESE RENMINBI	0.0%	0.1%	0.6%
HONG KONG DOLLAR	0.1%	0.2%	0.4%
UAE DIRHAM	0.0%	0.0%	0.2%
SWISS FRANC	0.4%	0.2%	0.1%
Memo item: Others	0.2%	0.4%	0.4%

Source: Bank of Thailand; authors' calculation

3. Players and trading activities

3.1 Classification of market participants

Reporting dealers are requested to provide information on the "primary involved party" or the counterparty for each FX transaction. For our purpose of establishing stylized facts on Thailand's FX market landscape, we divide market players into four main categories: (A) reporting dealers, (B) non-financial customers, (C) non-reporting financial entities, and (D) non-resident and others. Note that all information on FX trading activity used in this study is obtained solely from the first group of players, i.e. reporting dealers, while the rest of the players (categories B, C, D) can be viewed as bank customers or end users. Also, note that the breakdown by player type here (and throughout this paper hereafter) is different from the breakdown by market segment in Table 1. Here, category D (non-resident customers and others) include foreign banks located outside of Thai jurisdiction. Thus, interbank trading activity can take place either among reporting banks in category A, or between reporting banks and non-reporting foreign banks in category D.

Each of the four main categories is broken down further into subcategories as shown in Figure 4. To provide an idea of how large each group is, we indicate the total number of participants in each subcategory in the parentheses based on the 2015 data. Further discussion on each category is as follows:

(A) Reporting dealers[5]

This group consists of commercial and other banks that are granted FX licenses by the Minister of Finance and are authorized to conduct FX transactions in Thailand. There are a total of 35 reporting dealers, including 14 Thai commercial banks, 16 branches and subsidiaries of multinational banks, and 5 government's specialized financial institutions that are authorized dealers.

(B) Non-financial customers

The dominant players in this category are non-financial firms and state-owned enterprises (SOEs). Majority of these firms participating in the FX market are involved in exports and/or imports of goods and services and can be considered as real-sector end users of FX receipts. Some of our analyses will focus on this category as their usage of FX instruments and trading behavior may have important implications on financial stability and financial market development. The next subcategory is government-sector entities which play only minor role in the FX market. Lastly, we also include individuals (Thai residents) in this category. Despite their large size in terms of headcounts, their total turnover size is small as most of the FX transactions by individuals are for the purpose of travelling abroad, studying abroad, and personal transfers, which are relatively small-ticket entries.

(C) Non-reporting financial entities

These are financial institutions that are not reporting dealers, as well as investment funds. The "funds" subcategory is the more active group of players compared with "other financial entities". Funds include mutual funds, pension funds, provident funds, foreign investment funds, and other investment funds. Other financial entities comprise of insurance companies, finance companies, asset management companies, securities houses, credit card companies, and saving cooperatives.[6]

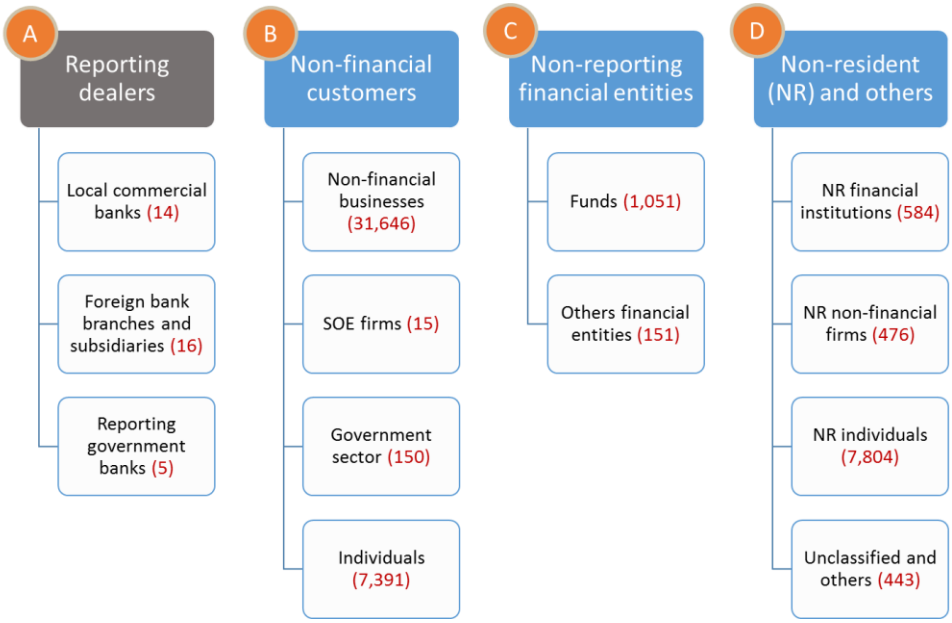
(D) Non-residents and others

We group all non-resident (i.e. non-Thai) participants under this category in order to separate the trading activities carried out by Thai residents and those carried out by cross-border participants. Foreign banks, which belong to the "non-resident financial institutions" subcategory, play a major role in the Thai FX market in terms of turnover, particularly in spots and FX swaps. The other subcategories play a much less significant role. These include non-resident businesses, non-resident individuals (mostly tourists), and other types of players that are not classified above.

[5] Note that In this paper we will use 'reporting dealers', 'reporting financial institutions', and 'banks' interchangeably depending on the context of discussion.

[6] According to the BIS reporting guideline, central bank would belong to this category as a non-reporting financial entity. However, due to the sensitivity of central bank's foreign exchange trading information, we exclude Bank of Thailand from all analyses that involve a breakdown by counterparty type.

Figure 4: Classification of foreign exchange market participants



Source: Bank of Thailand; authors' calculation
Note: Numbers in parentheses are the number of players belonging to each category in year 2015.

3.2 Foreign exchange trading by type of players

Table 3 presents basic summary statistics on trading activity of the three main customer groups based on the classification scheme described above. The table reports total trading volume, number of players, average frequency of trade within the year, average transaction size, and average number of bank relationships. Average figures here are cross-section averages with respect to the particular customer group. We focus mainly on the three most actively traded instruments, namely, spots, outright forwards, and FX swaps. For currency swaps, options and other instruments, we will note findings when they are of particular interest. We highlight some interesting stylized facts emerging from these statistics:

- First, non-resident entities, primarily foreign banks, are the key players in the spot and swap market in terms of trading volume, accounting for nearly 70 percent of total turnover (Table 3, panel 1, excluding turnover between reporting dealers).
- Meanwhile, outright forwards are most used by non-financial businesses, conceivably as a hedging instrument for their exports/imports receipts and payments (Panel 2). However, out of about 32,000 non-financial firms (from Figure 4), only less than one-third have used forwards in that particular year and very few have accessed to currency options.
- Financial companies and funds are the most active players in the spot market as they entered the market the most frequently with the mean of 18 days and the median of 8 days per year (Panel 1). Their average trade size per day is also the largest across all three instruments.

- The mean and the median figures of average trade days per year markedly differ for all instruments, signifying a skewed distribution where few players very actively engage in trading activity while many players enter the market only a few times over the year.
- The average numbers of bank relationships — that is, how many banks each participant conducted his FX transactions with — are very smaller across all instruments and all customer groups. Most players engage with only one bank for their FX trading activity. Even financial customers who are more active players carrying out larger trading volume still trade with only two banks on average.

Table 3: Summary statistics of foreign exchange trading by customer group and by instrument

Panel 1: Spot market

Spot market 2015 **Trade by non-reporting customers**	**Group B** **Non-financial customers**	**Group C** **Financial customers**	**Group D** **Non-resident entities**
Total **trade volume** in 2015 (USD mil)	217,405	21,633	524,973
Share of total	*28%*	*3%*	*69%*
Number of **players**	38,023	796	9,221
Share of total	*79%*	*2%*	*19%*
Avg number of **trade days** per year			
Mean	11	18	7
Median	3	8	1
Avg **trade size** per trade day (USD)			
Mean	281,244	3,683,061	568,625
Median	91,000	393,121	95,928
Avg number of **bank relationships**			
Mean	1.3	2.4	1.1
Median	1.0	2.0	1.0

Table 3: Summary statistics of foreign exchange trading by customer group and by instrument (continued)

Panel 2: Outright forward market

Forward market 2015 **Trade by non-reporting customers**	**Group B** **Non-financial customers**	**Group C** **Financial customers**	**Group D** **Non-resident entities**
Total **trade volume** in 2015 (USD mil)	183,479	26,134	32,391
Share of total	*76%*	*11%*	*13%*
Number of **players** (excl. FTU)	8,568	602	277
Share of total	*91%*	*6%*	*3%*
Avg number of **trade days** per year			
Mean	16	13	24
Median	6	5	3
Avg **trade size** per trade day (USD)			
Mean	891,397	7,825,091	6,822,421
Median	155,755	1,105,749	1,792,772
Avg number of **bank relationships**			
Mean	1.5	2.2	1.4
Median	1.0	2.0	1.0

Panel 3: FX swap market

Swap market 2015 **Trade by non-reporting customers**	**Group B** **Non-financial customers**	**Group C** **Financial customers**	**Group D** **Non-resident entities**
Total **trade volume** in 2015 (USD mil)	32,420	68,302	424,626
Share of total	*6%*	*12%*	*76%*
Number of **players** (excl. FTU)	2,476	844	266
Share of total	*69%*	*24%*	*7%*
Avg number of **trade days** per year			
Mean	6	7	55
Median	2	2	17
Avg **trade size** per trade day (USD)			
Mean	1,561,171	27,243,698	15,041,542
Median	64,405	7,726,070	4,461,544
Avg number of **bank relationships**			
Mean	1.1	2.1	3.0
Median	1.0	2.0	1.0

Source: Bank of Thailand; authors' calculation

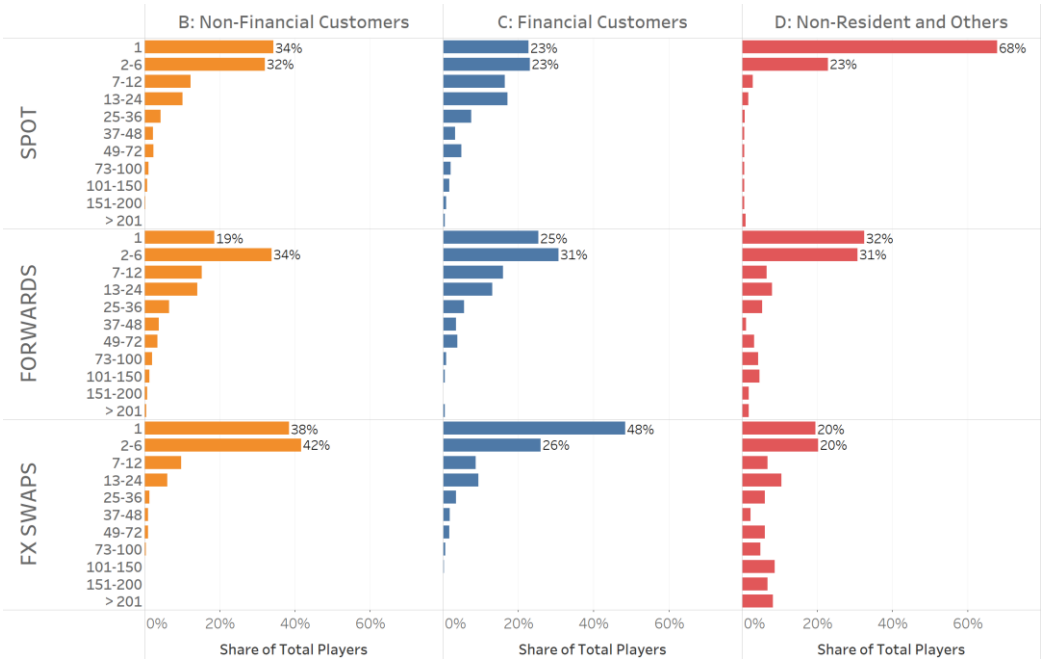
3.3 Trading frequency and intensity

Figure 5 presents a more detailed breakdown of trade frequency by each group of customers. Trade frequency (trade days per year) is divided into different bins, ranging from 1 day per year, to more than 201 days per year (the y-axis). The bars indicate the share of players in each customer group falling into each frequency range. As noted above, the distribution is positively skewed. Strikingly, considerable share of players in each group entered the FX market only once over the year, and more than half of each group exercised foreign exchange trading less than 6 times a year. This is with an exception of FX swap trading by non-resident customers that appear to be more active.

So far, we have looked only at a snapshot of the year 2015. Figure 6, left panel, presents an evolution of the frequency of trade statistics over 2004-2015. Here we focus only on non-financial businesses and SOE firms which represent the real sector-related foreign exchange trading activity. The skewed distribution has not changed much over time, confirming this stylized feature of market participation. Note that a median firm participates in the market for about 5 days per year. And for 70 percent of the firms, days of participation never exceed 14 days per year, or roughly once a month.

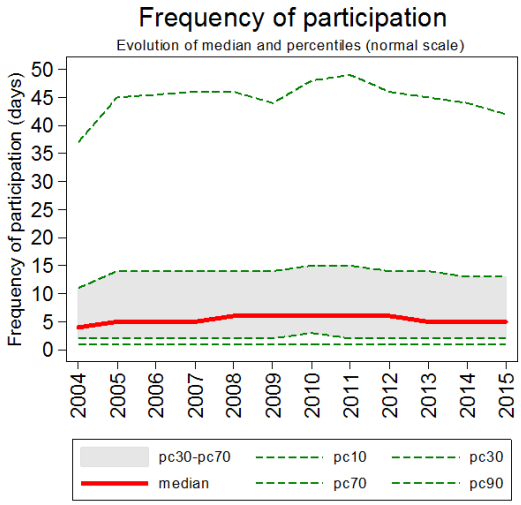
Figure 6, right panel, shows an evolution of the intensity of trade, i.e. annual turnover for each player. The distribution is once again positively skewed, meaning many players are of small scale while only a few are of heavy volume. A median firm's turnover has been close to $0.5 million per year over the whole period. For 70 percent of the firms, annual turnover never exceeds the threshold of about $2 million per year. It is interesting to note that participation frequency remained quite stable during and after the global financial crisis of 2008-2009, in contrast to participation intensity that spiked in 2008 when at the onset of the crisis followed by a sharp decline in 2009 as the crisis intensified.

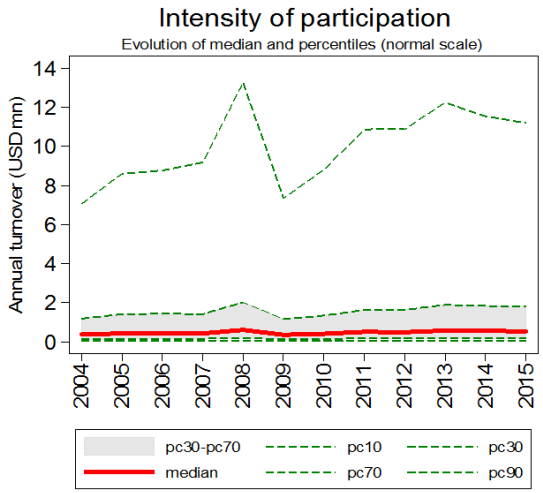
Figure 5: Distribution of number of trade days per year by customer group and by instrument (2015)



Source: Bank of Thailand; authors' calculation

Figure 6: Evolution of trading frequency and intensity distribution (2004-2015)





AVERAGE FREQUENCY OVER 2004-2015 (days)

p10	p30	p50	p70	p90
1.00	2.08	5.33	13.75	44.79

AVERAGE INTENSITY OVER 2004-2015 (USD mn)

p10	p30	p50	p70	p90
0.05	0.16	0.47	1.56	9.97

Source: Bank of Thailand; authors' calculation

4. Market concentration

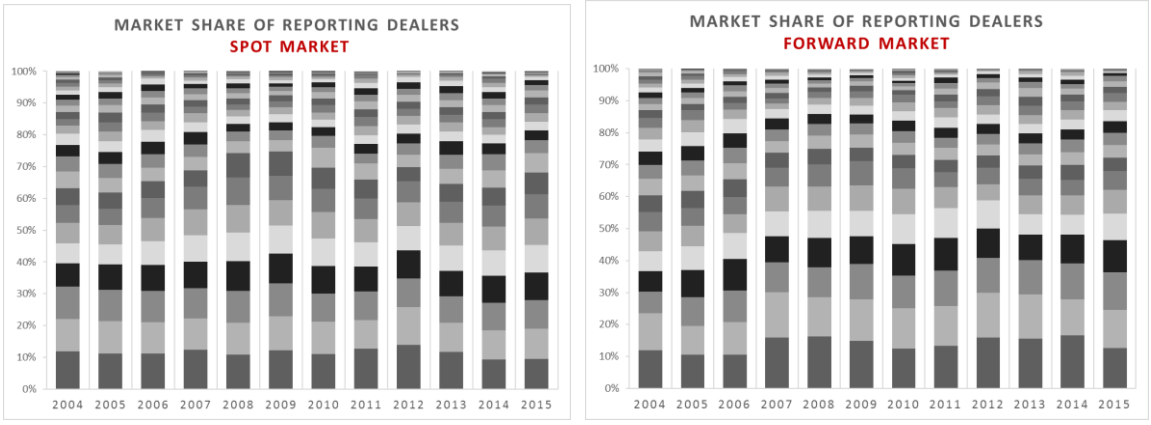
This section analyzes market concentration which is an important aspect for understanding a financial market structure as it has implications on the degree of competition and the risks to market stability. We examine concentration of Thailand's FX market in various dimensions: concentration of market share among FX providers (reporting banks), concentration among users, and concentration of FX customers in a bank's portfolio.

4.1 Concentration from FX provider's perspective

Starting from FX provider perspective, Figure 7 shows market shares of all individual reporting banks in Thailand providing FX trading service to non-reporting customers. The size of each bank's market share is represented as each shaded area of the total turnover bar.[7] The total number of reporting banks active in the customer market each year varies between 30 to 35 banks, and standing at 32 banks in 2015. One salient feature emerges from Figure 7 is that, the shares of individual FX providers appear to be well spread out without a clear dominating player with respect to market share. This is true for both spots and outright forwards, although the forward market tends to have relatively more concentrated market shares among the top banks compared to the spot market. This pattern persists over the past decade, implying that the competitive structure of the market may not have changed much over time.

[7] The shaded areas are ordered from the largest share at the bottom to the smallest at the top of the bar for each particular year without tracking the same institution over time.

Figure 7: Market share of all reporting dealers



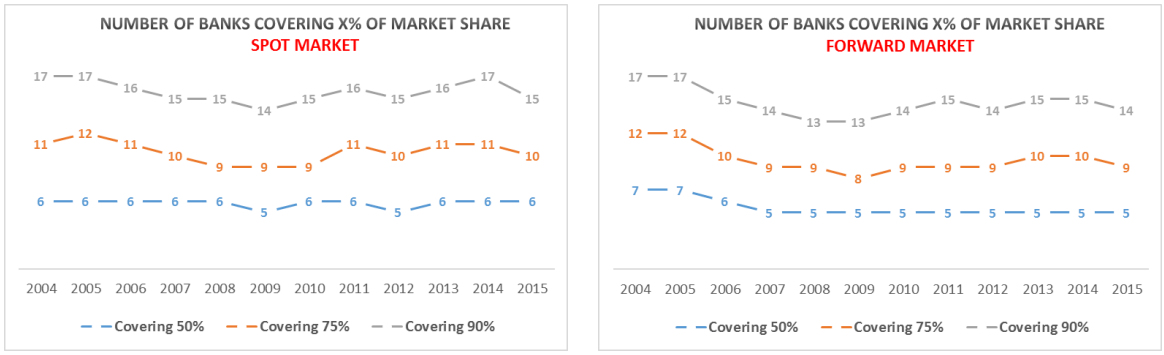
Source: Bank of Thailand; authors' calculation

Another way to assess the degree of market concentration is to count how many banks accounting for a majority of market turnover. Figure 8 does this for the spot and the forward market over time. The result shows that it takes 5-6 banks to cover 50 percent of the total market turnover, about 10 banks to cover 75 percent, and roughly 15 banks to cover 90 percent. These figures are considered rather high. For comparison, out of 52 reporting countries in the BIS Triennial Survey 2016, as many as 44 countries report to have fewer than 10 banks (Thailand's benchmark) covering 75 percent of the market turnover, with the median of 5 banks. This implies that Thailand's FX market is more inclined to be one in which there exist many suppliers, each with moderate or small share of the market, rather than a few very large players that supply most of the market. In other words, the market appears to be relatively unconcentrated with respect to suppliers' market share.

The conclusion above is confirmed by another measure of market concentration, the Herfindahl-Hirschman index (HHI).[8] We calculate the HHI for all five groups of FX instruments as shown in Figure 9. According to the guidelines by the US Department of Justice used in antitrust analysis, markets with HHIs below 0.15 are considered "unconcentrated", between 0.15 and 0.25 "moderately concentrated", and above 0.25 "highly concentrated." Clearly, the HHIs for spots, outright forwards, and even FX swaps are well below 0.15, indicating an unconcentrated market structure for these instruments in Thailand. The market for currency swaps and options tend to be more concentrated which are conceivable given fewer players and a thin trading volume in these less active market segment.

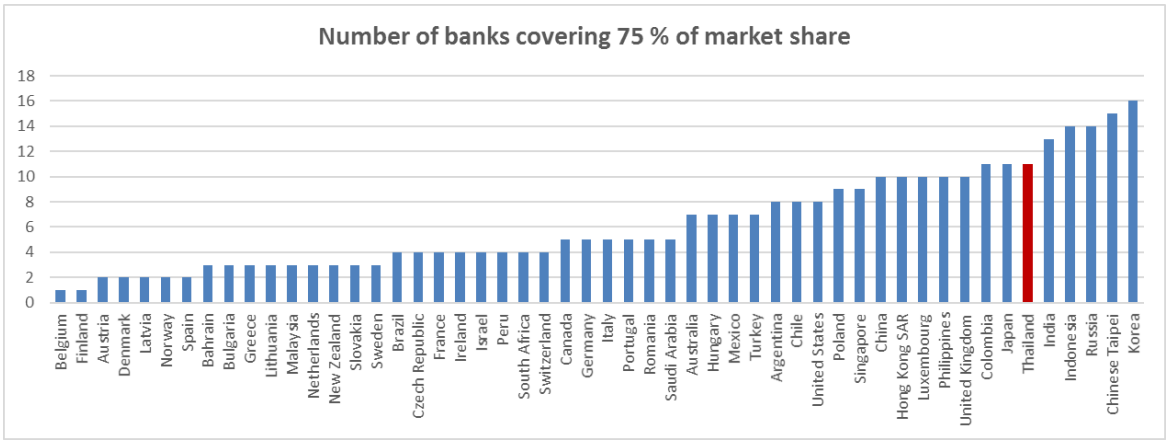
[8] The HHI is calculated as the sum of the market shares of all firms in the market. The index ranges from 0 for a market with an infinite number of equally sized competitors, to 1 for a market with a single player. The higher the index the more concentrated is the market with only a few firms taking over larger market shares.

Figure 8: Number of banks accounting for certain percentage of market turnover



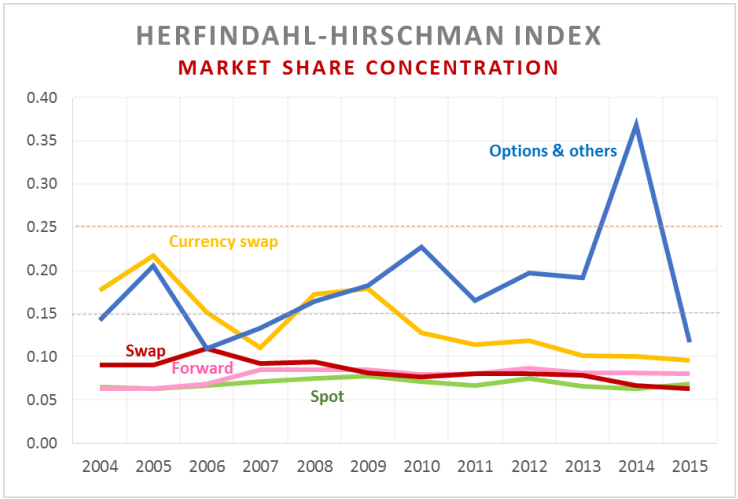
Source: Bank of Thailand; authors' calculation

Figure 9: Market concentration, cross-country comparison



Source: BIS Triennial Survey 2016 (Annex Table 2) and Bank of Thailand

Figure 10: Herfindahl-Hirschman Index of market share concentration

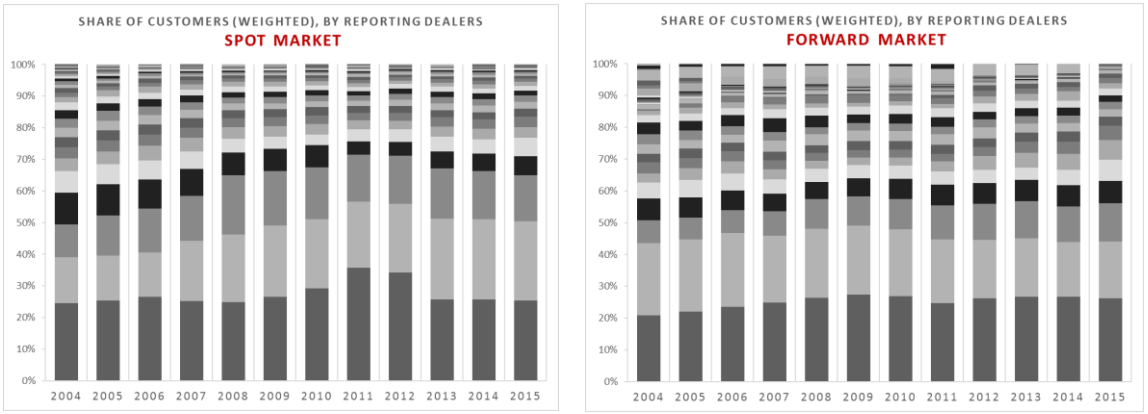


Source: Bank of Thailand; authors' calculation

Turning to market concentration in terms of customer share, Figure 10 features similar bar charts as Figure 7 above but with each shaded area representing each banks' share of total number of customers in the market (all three types of customers as defined in Section 3.1). Note that unlike turnover share, calculating customer share is not as clear cut since each customer may access to more than one bank for FX services. Thus, the customer bases of individual banks can be overlapped. We take care of this issue by counting each customer as 1/*n* where *n* is the number of banks the customer conducted FX transaction with in a specific instrument and in a particular year, and summing over these adjusted number of customers for each bank. This is done regardless of their transaction size, so large and small customers are treated in the same way under this measure.

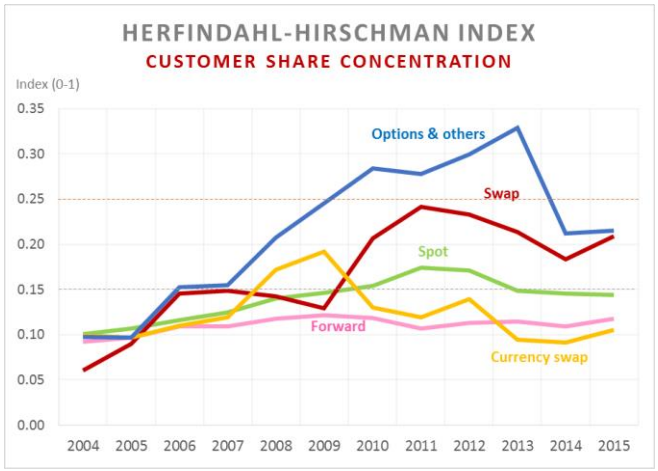
The results presented in Figure 10 show that concentration with respect to customer share appears to be higher than that based on market turnover share, with only a few banks taking up significant shares of number of customers. Consistently, the HHIs of customer share are generally higher than the HHI of turnover share (Figure 11), though concentration in forward and currency swap markets remain at a low level. It will become clear in a later section that this customer share concentration is a result of specialization of customer segment, whereby some banks that specialize in the retail market sector would naturally acquire a significantly greater number of smaller retail customers.

Figure 11: Customer share across all reporting dealers



Source: Bank of Thailand; authors' calculation

Figure 12: Herfindahl-Hirschman Index of customer share concentration



Source: Bank of Thailand; authors' calculation

4.2 Concentration from customer's perspective

Now we turn to look at the FX market concentration from a customer or a user perspective. Figure 13 provide a visual summary of the landscape of FX users in Thailand. The area of the picture represents the total volume of customer turnover in 2015 and each box represents each customer's share of total turnover. The color of each box indicates the type of the customer according to our classification in Section 3.1, with *yellow* associated with non-financial customers (Group B), *red* representing financial customers (Group C), and *green* denoting non-resident entities and others (Group D). We exclude reporting dealers from this exercise since we want to focus on the landscape and concentration of end users here, although at times reporting dealers are also customer to other dealers.

From the color code, we can clearly see which customer group dominates in each FX instrument. For the spot and FX swap markets, top players are almost exclusively non-resident entities—foreign banks to be specific. Local non-financial customers and non-bank financial customers are generally of smaller size. In contrast, for the forward, the currency swaps and the options markets, the dominant players belong to local non-financial customers, which is intuitive since these instruments are primarily used by businesses as hedging tools against exchange rate risk.

In terms of concentration, the distribution of customers' turnover shares appears to be highly concentrated, with only a handful of top customers accounting for the lion's share of total customer market turnover. Table 4 reports that half of the total turnover is covered by merely 31 (0.06% of total number of customers), 81 (0.86%) and 16 (0.45%) customers in the spot, forward, and swap market, respectively. This is in a stark contrast to the market concentration from the bank perspective discussed above. It implies that the retail FX market is dominated by a few very large customers who have extensive relationships with many banks.

Figure 13: A mosaic of foreign exchange users, by instrument (2015)

Source: Bank of Thailand; authors' calculation

Table 4: Number of top customers accounting for X% of customer turnover share (2015)

Cum. Share	Spot	Forward	Swap
50%	31	81	16
75%	282	357	47
90%	3,317	1,106	151
Total	*48,041*	*9,448*	*3,587*

Source: Bank of Thailand; authors' calculation

4.3 Bank-customer concentration

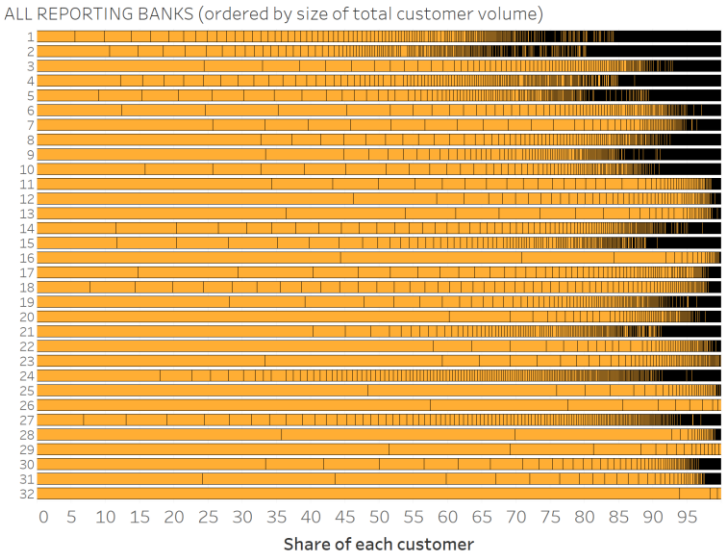
We also examine concentration in a bank's portfolio of FX customers to see how exposed each bank is to very large customers which may have implications for bank stability as regards to the risk of disruption in FX position. Banks' portfolio concentration is illustrated in Figure 14 where each bar representing each bank's total customer turnover. The total customer portfolio is divided into individual customers' shares by thin black lines separating each customer. The darker color towards the right-hand side of the bars depicts numerous customers with very small turnover size. Banks are ordered by their total size of customer turnover, with the ranking of 1 (largest) to 32 (smallest). One can see that some banks seem to be exposed to very large customer relative to the size of their customer portfolio, which can make them prone to demand shocks from these significant customers. However, larger banks that are systemically more important tend to have more well-diversified customer base with respect to the number of customers and their relative shares. Thus, we may infer that the risk of instability to the whole market system stemming from individual-level demand shocks may be limited.

Figure 15 employs the same plotting scheme as Figure 14, but instead we lump customers' shares by customer group, and separate the reporting banks (each represented by each bar) into local banks, foreign bank branches and subsidiaries, and government banks. Doing this allows us to observe bank' specialization in different customer segments. Regardless of the overall dominating group of customers in each instrument, each individual bank still exhibits its own specialization, with some banks focusing more on non-financial customers, while others dealing more with non-resident customers. Customers of government banks[9] are almost entirely local non-financial firms and individuals, which is consistent with the mandate of government financial institutions on financial access for all especially those very small retail customers with limited access to commercial banks' services. Note that government banks do not carry out any transactions in FX swaps and other advanced instruments.

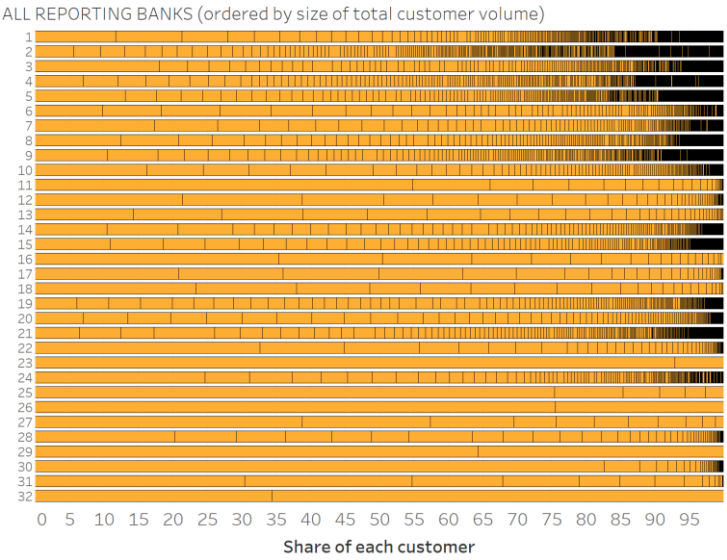
[9] Among government's specialized financial institutions, the most active in the FX market is, as one would expect, the Export-Import Bank of Thailand.

Figure 14: Customer share in banks' foreign exchange customer base (2015)

SPOT MARKET

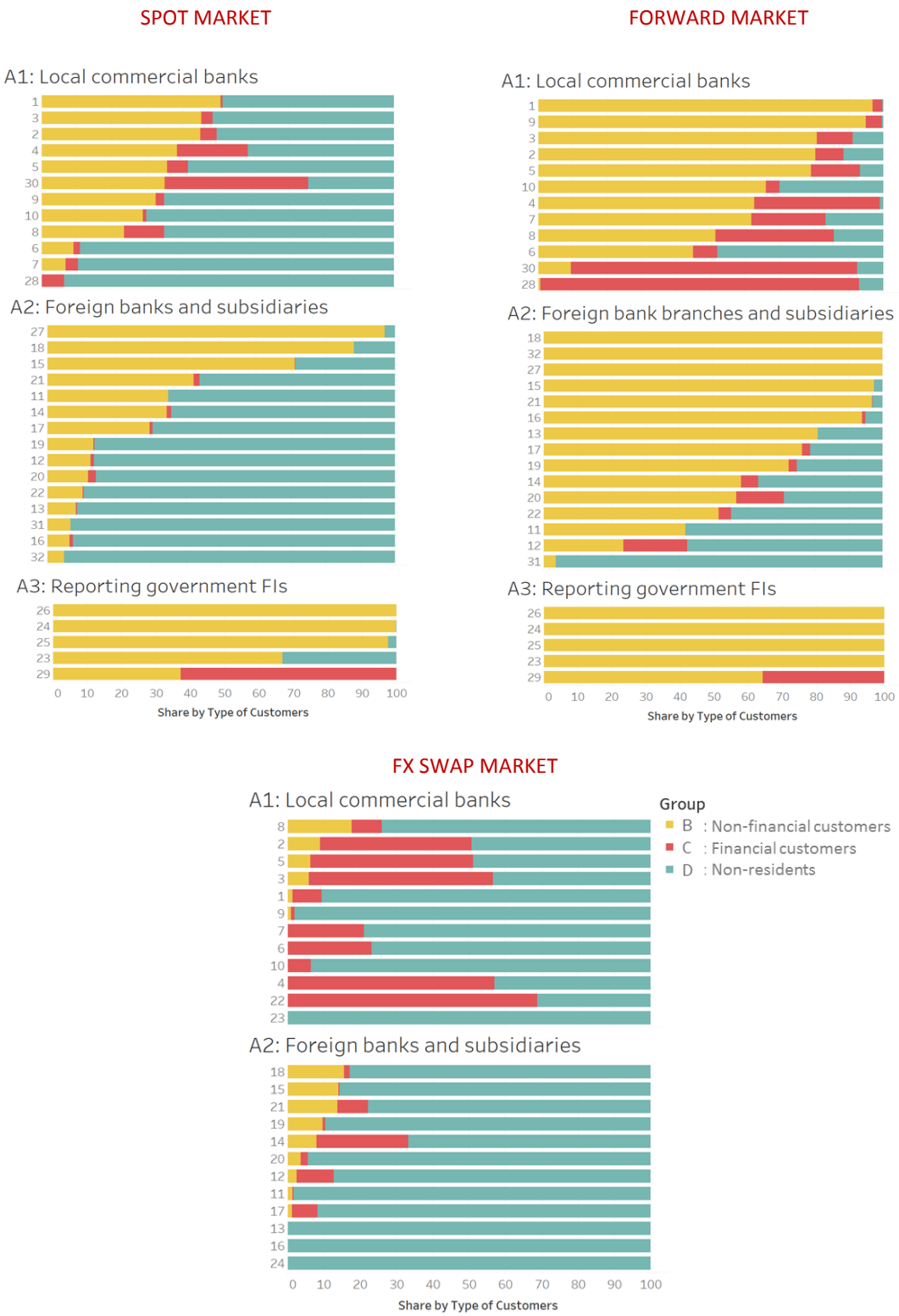


FORWARD MARKET



Source: Bank of Thailand; authors' calculation

Figure 15: Banks' customer base by customer group (2015)



Source: Bank of Thailand; authors' calculation

5. Network topology of Thailand's foreign exchange market

Global financial markets could be viewed as an intricate nexus of financial transactions among various groups of market participants. As made clear by the recent global financial crisis, these interlinkages could serve as a channel through which shocks propagate during stress times. It is therefore essential, especially for regulators, to understand these interlinkages and shock propagation mechanics so that systemic risks could be limited and managed. In this regard, network analysis has gained a widespread acceptance, given its exceptional ability in visualizing a large collection of micro-level granular data and the resulting macro-level structural features in an intuitive and insightful manner.

Using tools from network analysis, this section provides topological descriptions of Thailand's FX market landscape based on the FMST database. We then present two exercises as an example of how network analysis tools could be applied to the real-world FX market network: identifying systemically important nodes in the interbank FX network and zooming into the FX network during liquidity stress times to shed light on the dynamics among interbank players.

5.1 Network representation

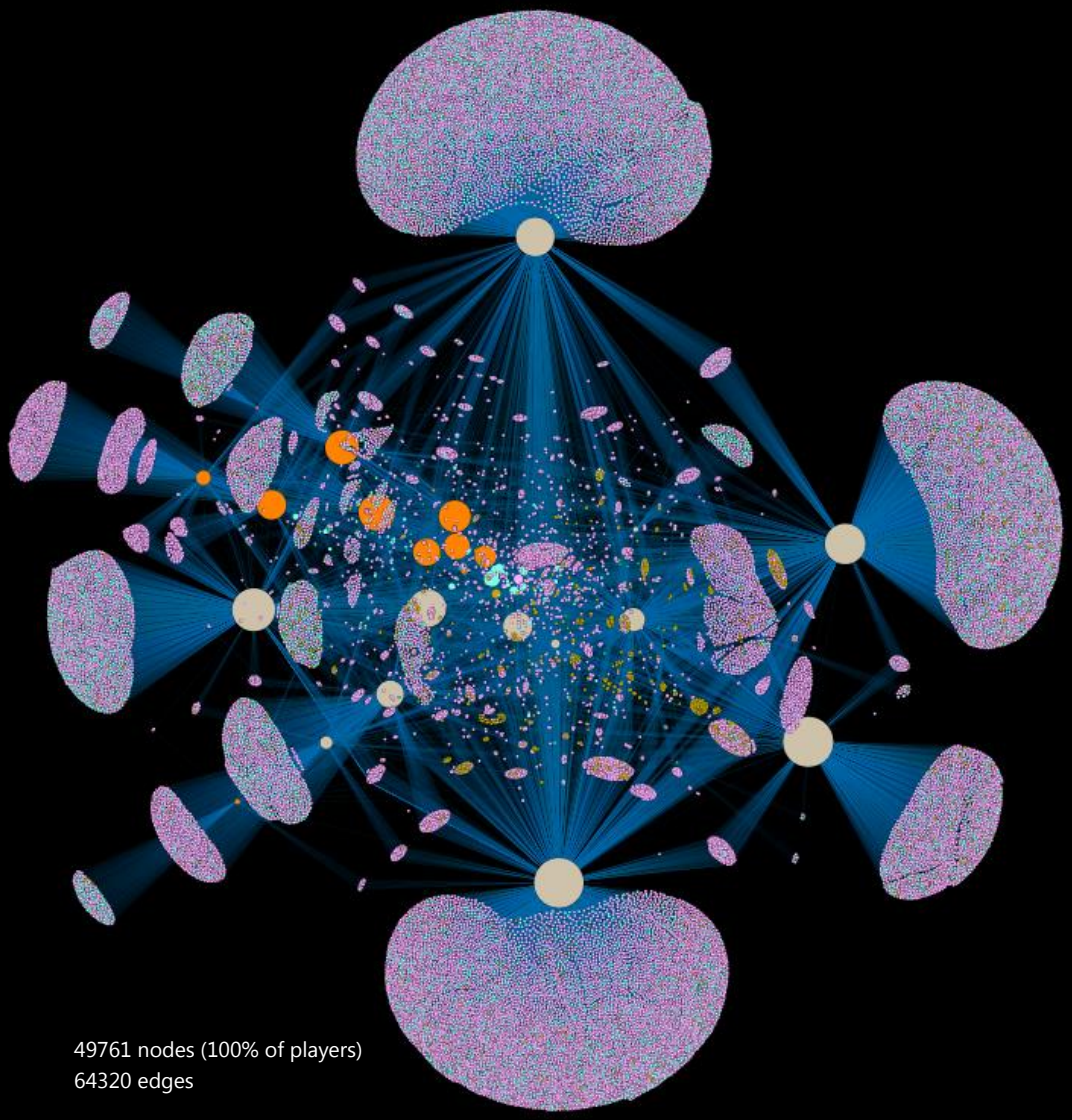
Throughout this section, we rely on a graphical representation in documenting the real-world market topology. In our representation, a network consists of two types of elements – *nodes* and *edges*. Each node represents a market participant, with node size proportional to participant's annual turnover and node color showing participant's entity type.[10] Each *edge* represents a bilateral relationship between two participants, with edge width proportional to the *annual* transaction size between the two participants. That is, all transactions between two same counterparties are aggregated over a given year into one observation. The annually aggregated dataset will be the basis for most networks presented in this section, and we will note explicitly when we use an aggregation period different than one year in constructing networks. Given the dataset we use, it should also be noted that edges in these networks represent new FX transaction *flows* during the aggregation period, not stocks of existing FX exposures.

5.2 Visualizing Thailand's foreign exchange market landscape

Figure 16 presents Thailand's FX market landscape in 2015 in its entirety. All participants that entered the FX market in 2015 are presented, and bilateral turnover is aggregated over all FX instrument categories. The master network for 2015 consists of 49,761 nodes, representing market participants from all categories as designated by node color. The network contains 64,320 edges, with edge width representing bilateral turnover between the two connected nodes. Given that a transaction in this dataset always involves a reporting dealer and a counterparty, it should be noted that a core-periphery structure is inherently embedded in the network. That is, two nodes that are not reporting dealers can be connected only indirectly through a reporting dealer.

[10] Note that throughout Section 5, we will refer to the subset of non-financial customers that are businesses as "non-financial businesses" (i.e. including both non-financial businesses and SOE firms shown in Figure 4) for brevity.

Figure 16: Thailand's foreign exchange market landscape (2015)



Source: Bank of Thailand; authors' calculation
Note: Node size is proportional to annual turnover, including all FX instruments. Edge thickness is proportional to bilateral transaction size.

Although node's position in *absolute* term is not inherently interpretable, node's position *relative* to one another conveys information as follows. (1) Nodes that are located closer to one another tend to be more related – both directly (i.e. a bank and a customer trading with the bank in large amount tend to be located near one another) and indirectly (i.e. customers that conduct transaction with a particular bank tend to be located closely). (2) Node's proximity to the center of the network tells whether the node is well-connected in this network. For instance, a large exporting firm that trades with many reporting dealers has multiple edges connected to the dealers, and this pushes the firm's node toward the center of the network. On the other hand, a small importing firm that trades with only one bank has only one edge connected to that bank, and thus located in the fan-shaped area connected to that particular bank. This tends to push the firm's node toward the outer area of the network.

We would like to discuss some notable features of the FX market network, as follows.

(1) Two-tiered structure

In the market microstructure literature, many theoretical models rely on a tiered structure, where a customer bring his private information to a dealer while initiating a trade, then the information is incorporated into dealer's quotes. This implies a two-tiered market where a customer and a dealer act sequentially. The network topology above shows how the two-tiered structure might look like in the real-world FX market – a market that is composed of the *interbank* layer and the *retail* layer. Interbank players, especially reporting local banks (ivory nodes), serve as the main pillars of the entire FX market. Reporting local banks are well-connected among themselves in the interbank layer, and also serve as hubs where non-financial customers can connect to participate in the FX market.

(2) Clusters

Figure 16 also suggests the presence of several clusters in the FX market network. Most notably, foreign banks and subsidiaries (orange nodes) appear to cluster in the upper left portion of the network. This reflects the fact that foreign banks tend to conduct FX transaction among themselves and with only a small subset of local banks (five ivory nodes near the orange node cluster). On the other hand, local non-reporting financial entities (gold nodes) tend to stay close in the lower right portion of the network, surrounded by a different subset of local banks. There is also a cluster of large non-resident players (light blue nodes) in the center of the network, showing that these non-resident players tend to conduct FX transaction with many banks and are thus located in the center. The emergence of these clusters show that there is a substantial degree of segmentation in the FX market landscape.

(3) Dominant FX product providers

In Figure 16, we can observe that there are a handful of reporting dealers who are dominant providers of FX products. This includes dominance in terms of turnover (i.e. reporting dealer's node size) and customer base (i.e. the size of the fan-shaped area connected to each reporting dealer). With regard to turnover volume, there are about ten reporting dealers that could be considered major FX product providers, consisting of about six local banks and four foreign banks and subsidiaries. In terms of customer base, three local banks seem to dominate the customer base, as reflected in the large size of the fan-shaped area (which is larger when more nodes are connected to a given reporting dealer).

The dynamic evolution of the composition of dominant FX providers is also worth discussing. Having tracked the FX market landscape from 2005 to 2015, we have observed the following. (1) Dominant

banks that are local banks tend to be the same over the years, serving as the main pillars of the FX market landscape and contributing to overall network stability. (2) Dominant banks that are foreign banks, in contrast, seem to take turn over the years. These foreign banks would occupy the top spot for no more than two to three consecutive years. (3) Over the 2005-2015 period, dominant banks that are local banks have been gaining market share both in terms of turnover and customer base, at the expense of foreign banks. This reflects an increasing role of domestic banks in the overall functioning of the Thai FX market.

(4) Topological differences across instruments

We now extend our analysis by investigating the master network in Figure 16 further, filtering the network in such a way that gives us more insights on the cross-sectional properties of the FX market landscape. Based on Figure 16, which incorporates transaction in all five FX instrument categories, we can filter the master network to consider subnetworks with market participants and FX transactions in each of the five FX instrument categories. The purpose of this exercise is to highlight the topological differences and the different level of active participation across the markets.

Figure 17 shows the subnetworks for three selected FX instrument categories - namely spots, outright forwards, and options.[11] The spot network in 2015 contains 48,090 nodes (96% of nodes in the master network) and 60,504 edges, reflecting the fact that almost all FX market participants conduct spot transactions and bilateral linkages are the densest compared to other FX instruments. In the middle, the outright forward network contains only 9,483 nodes (19% of nodes in the master network) and 14,713 edges. That is, the outright forward network is about four to five times less populated and less dense compared to the spot network. Note that only two reporting dealers seem to dominate the non-financial customer segment (pink nodes), as reflected by two bundles of pink edges connecting to two reporting dealer nodes. A closer inspection also reveals that many non-financial businesses tend to conduct outright forward transactions with the same bank that they trade spots. This observation suggests that most non-financial businesses, especially those with small and medium size, engage in the FX market in a relationship-based manner (i.e. trading all instruments with the same bank), rather than being price-sensitive and ready to search around for the best quotes from multiple dealers. The third network, the FX options network on the right, looks somewhat different and represents a typical network for more advanced FX instruments. The FX options network contains only 235 nodes (0.5% of nodes in the master network) and 294 edges, indicating a network that is very sparsely populated and still in a nascent stage in terms of market development. Demand-side participation in the FX options market is still limited to a handful of sophisticated participants, mostly large exporters and non-resident players. Given the currently low level of penetration among non-financial businesses, there is an ample room for growth and development in this market.

(5) Density and intensity of bilateral relationships

To close this subsection, we discuss more on the density and intensity of bilateral linkages (i.e. edges) in the FX network, which is an important aspect of the network that could be hard to discern due to the limitations of our visualization scheme. Choosing the spot market as an example, we filter the 2015 spot network by the minimum number of counterparty reporting dealers that each node trades with.

[11] In Figure 17, we take a demand-side perspective in coloring the edges by prescribing edge color based on the entity type of source node. For instance, transactions originating from non-financial customers (pink nodes) to reporting dealers are represented by pink edges.

Results are shown in Figure 18. Starting from the 2015 spot network with 48,090 nodes, the spot network with only nodes trading with two or more reporting dealers contains only 7,483 nodes with 19,897 edges remaining (about one-third of edges in the original spot network). And as the minimum threshold of counterparty reporting dealers increases, the number of nodes declines more than proportionally. At the threshold of five reporting dealers, we are left with only 478 nodes and 3,699 edges. Only a small number of nodes in the center remain, which mainly consist of petroleum firms, commodity exporters, food exporters, as well as non-resident institutions. Many of these nodes conduct transaction with more than ten reporting dealers, suggesting that these dominant players from the demand side seek quotes from many dealers and have bargaining power.

To characterize this property more precisely, Figure 19 (left) plots the distribution of non-financial businesses' relationships with reporting dealers (i.e. non-financial businesses' *out-degrees*) for all FX instrument categories in 2015. A downward sloping nature of the plotted lines implies that most non-financial businesses trade with only a few reporting dealers (i.e. having low out-degree), while few non-financial businesses trade with many reporting dealers (i.e. having high out-degree). This is an instance of the so-called *power law,*[12] which has been established for many real-world complex networks.

These non-financial businesses are not only well-connected with many reporting dealers, but also highly active in terms of trading volume. Figure 19 (right) relates each non-financial business' number of dealer relationships to its annual FX turnover, with each small blue dot representing a non-financial business. The red line connects the median firm at each number of dealer relationships. The plot shows an upward sloping line, reflecting a positive correlation between non-financial businesses' FX turnover and their number of reporting dealer relationships. That is, non-financial businesses who trade with many reporting dealers tend to trade in large volume as well, which is intuitive given the bargaining power of large corporate players and the competition among reporting dealers for high-volume customers. To estimate this relationship quantitatively, we can regress turnover on out-degree and obtain an OLS slope coefficient estimate, which is 2.96 when trading in all FX instruments are taken into account (Table 5). This could be interpreted as follows: a doubling in firm's out-degree from k to $2k$ corresponds to an increase of firm's FX turnover to $2^{2.96}k \approx 7.78k$. Table 5 also shows the difference in estimates across FX instrument categories, with equally low values for spot and forward markets indicating that the majority of firms participating in these two markets are fairly homogeneous.

[12] Studies on real-world complex networks often focus on *degree distribution*, which is simply characterized by the frequency of nodes with degree k, denoted as $p(k)$. In network parlance, many real-world networks have been found to have degree distribution that follows the so-called *power law*, which stipulates that $p(k)$ could be parameterized as:

$$p(k) = ck^{-\gamma}$$

where c is a normalization constant and the exponent γ is a positive parameter, which could be estimated directly from data and usually lies between 2 and 3 in real-world complex networks. Networks with this characteristic are also known as *scale-free* networks (Albert, Jeong, and Barabási (1999)). Conceptually, a network where degree distribution follows the power law has few nodes with many connections and many nodes with few connections. The estimated exponent γ could characterize the degree to which such property holds: lower γ indicates high edge density for many nodes, while higher γ indicates high edge density for few nodes. Drawing results from network theory, the power law property has important implications for network stability: networks with degree distribution following the power law tend to be robust with respect to random node failures, but vulnerable to targeted attacks at important nodes.

Figure 17: Topological structures of selected FX instruments (2015)

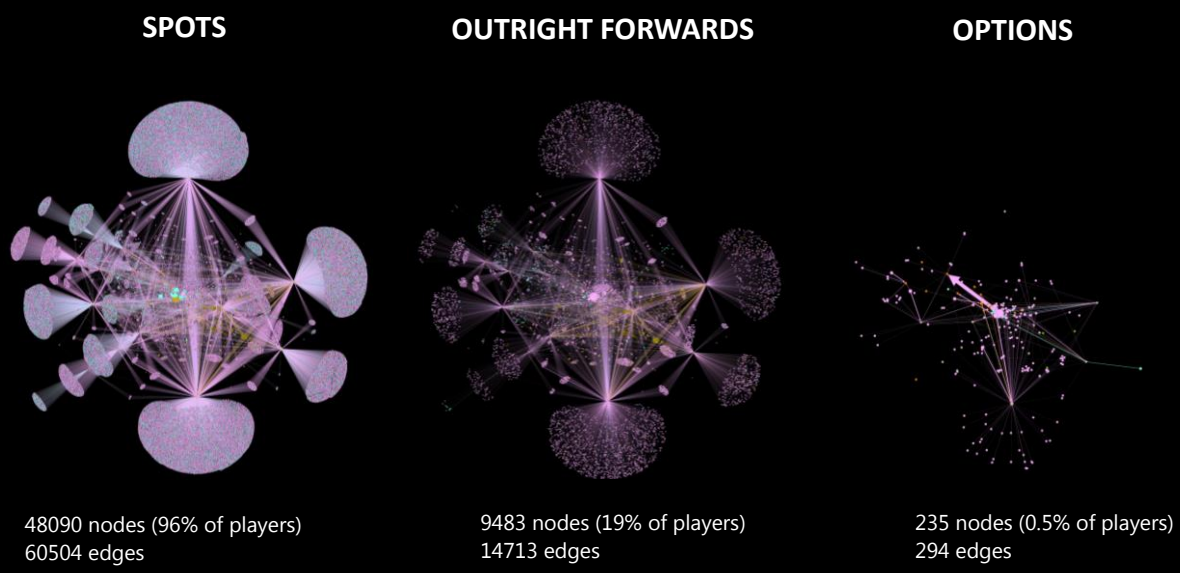
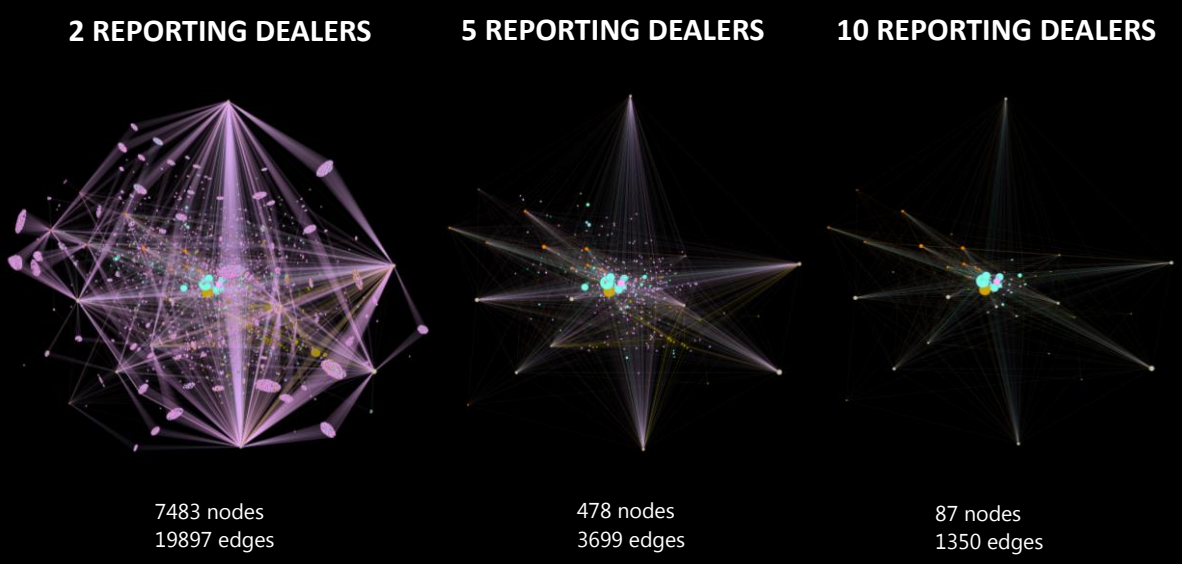
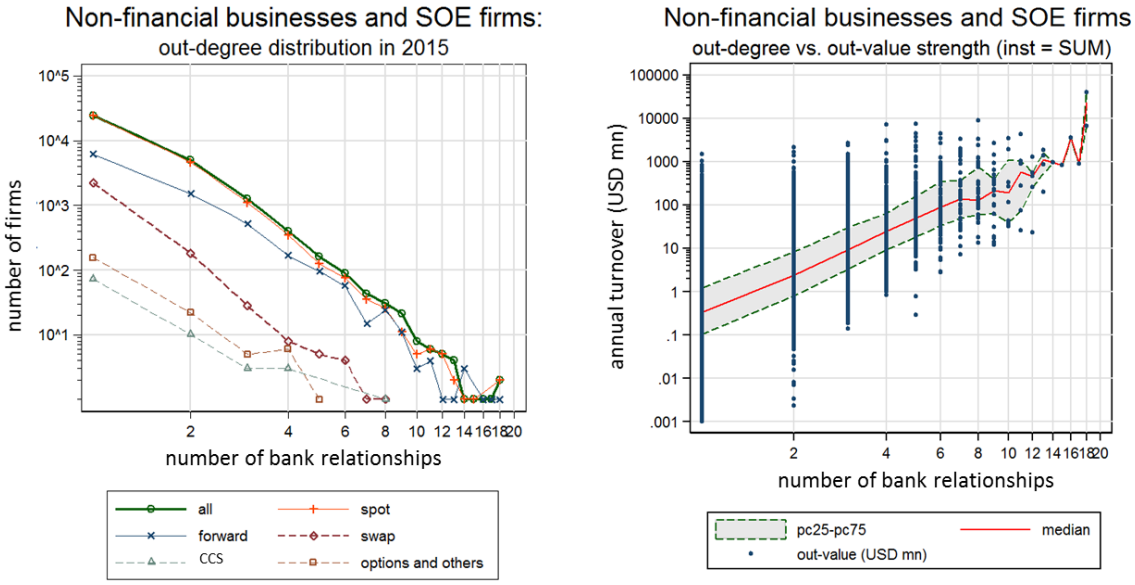


Figure 18: Networks of spot transactions (2015)
filtered by minimum number of counterparty reporting dealers



Source: Bank of Thailand; authors' calculation
Note: Node size is proportional to annual turnover, including all FX instruments. Edge thickness is proportional to bilateral transaction size.

Figure 19: Empirical distributions of non-financial businesses' reporting dealer relationships and annual FX turnover (2015)



Source: Bank of Thailand; authors' calculation

Table 5: Results from OLS regression of non-financial businesses' FX turnover on out-degree, by instrument (2015)

	Overall	Spot	Forward	Swap
Elasticity (beta)	2.96	2.60	2.71	4.59
2^beta	7.78	6.06	6.54	24.08

Source: Bank of Thailand; authors' calculation
Note: All results are statistically significant at 1% level. Both regressors are in log term.

5.3 The evolution of some basic network statistics

So far we have investigated Thailand's FX network topology from several angles, but our analysis has been somewhat limited to the *cross-sectional* properties of the 2015 FX network. In this subsection, we set out to gain more insights on the *time-dimension* of Thailand's FX market landscape. Looking back over the ten-year period (2005-2015), we will detect shifts in FX market network properties over time by comparing the empirical distributions of selected network metrics. For this paper, we start with two simplest measures, namely node degree and node strength, and leave more sophisticated network measures for future work.

Node degree

The number of connections with a node is known as its *degree*. For a directed network such as ours, there are two types of node degree: *in-degree* (i.e. the number of incoming edges toward a node) and *out-degree* (i.e. the number of outgoing edges from a node). In the context of our FX market network,

reporting dealer i's in-degree represents the number of its customers, and thus could serve as a proxy for the level of diversification of its customer base. On the other hand, *customer j's out-degree* counts the number of reporting dealers that the customer trades with, thus capturing whether the customer is well-connected and has choices when conducting FX trades. Note that node degree captures whether a particular node is widely connected with many other nodes, using information only from the binary representation of the network without caring about weight (i.e. turnover volume).

Node strength

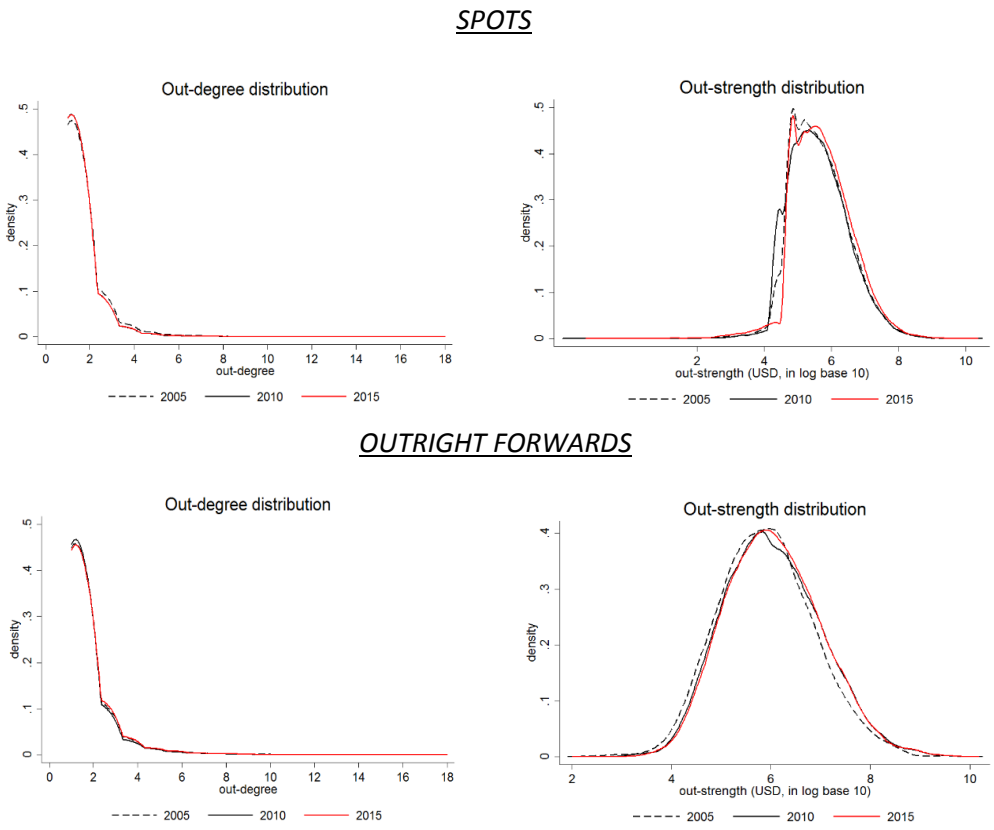
Node strength is the total value of flows going out from or coming into a particular node. As is the case with node degree, we define two types of node strength: *in-strength* (i.e. the total amount of transaction it receives from other nodes) and *out-strength* (the total amount of transaction it sends to other nodes). Given that a transaction is always between a reporting dealer and another counterparty in our context, only reporting dealers can have in-strength values while all participants can have out-strength values. That is, *reporting dealer i's in-strength* is the total amount of FX transactions it receives from other market participants, including financial and non-financial customers. On the other hand, *participant j's out-strength* is the total amount of FX transactions it conducts with reporting dealers.

Empirical distributions of network metrics

Using nonparametric kernel density estimation, we characterize the empirical distributions of node degree and node strength for three annual snapshots in 2005, 2010, and 2015, and compare the shifts over the years. Figure 20-22 present results based on three perspectives in looking at the FX market – from the viewpoints of non-financial businesses, reporting dealers, and interbank players. First, viewing from non-financial businesses' perspective, Figure 20 shows the estimated distributions of these firms' *out-degree* (i.e. the number of reporting dealers that these firms trade with) and *out-strength* (i.e. these firms' annual FX turnover). Second, viewing from reporting dealers' perspective, Figure 21 shows the estimated distributions of reporting dealers' *in-degree* (i.e. the number of non-financial businesses trading with these reporting dealers) and *in-strength* (i.e. reporting dealers' annual FX turnover coming from non-financial businesses). It should be noted explicitly that all results in Figure 21 consider reporting dealers' transactions with non-financial businesses only, not with other customer groups. Lastly, Figure 22 focuses only on the interbank segment of the FX market, considering only transactions where one counterparty is a reporting dealer and another is a participant in the interbank market.[13] Because we cannot assume the direction of FX trade when both counterparties are interbank players, we will use the terms *node degree* and *node strength* neutrally without implying who initiates the trade.

[13] Interbank market participants include reporting dealers (local commercial banks, foreign banks and subsidiaries, and reporting government financial institutions), non-resident financial institutions, and other interbank institutions. So, interbank participant headcounts could exceed the number of reporting dealers in our results.

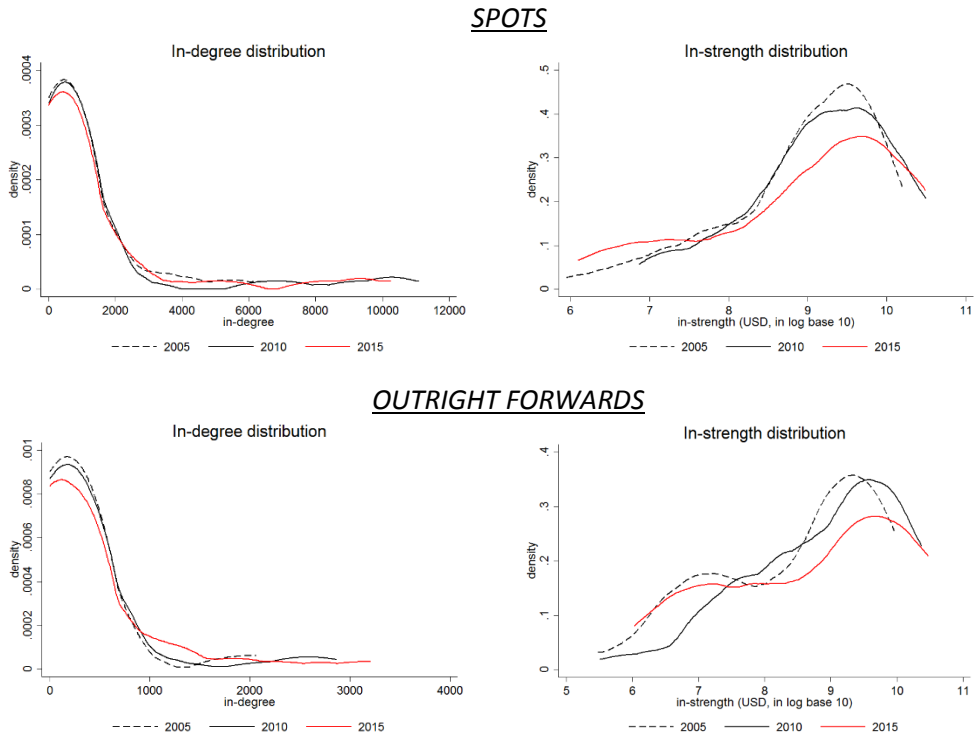
Figure 20: Empirical distributions of basic network properties: non-financial businesses' out-degree and out-strength



Source: Bank of Thailand
Note: Nonparametric kernel density estimates are constructed using the Epanechnikov kernel, with optimal bandwidth (Silverman (1992)) for node strength distribution and calibrated bandwidth for node degree distribution.

Viewing the FX market from the perspective of non-financial businesses, Figure 20 plots non-financial businesses' out-degree and out-strength distributions for spots and outright forwards. For both instruments, out-degree distributions (left columns) have preserved their shape over the years. As expected, most non-financial businesses trade with only one reporting dealer during a given year, resulting in out-degree distributions that are heavily concentrated at one reporting dealer. For spots, there is a slight shift upward toward one reporting dealer in 2015 compared to the past years, reflecting the fact that more non-financial businesses entered the spot market in later years and traded with only one reporting dealer. For out-strength distributions (right columns), density plots are shown in logarithmic scale due to the high level of heterogeneity in out-strength values. For both instruments, the distributions remain quite stable over the years. But for spots in 2015, there is a downward shift in the out-strength distribution at the annual FX turnover of about $10,000, along with a shift toward the right compared to 2005 and 2010. This indicates that if non-financial businesses entered the spot market at all in 2015, they would not trade in small amount such as $10,000, but with higher amount compared to the past years. The rightward shift can also be observed in the forward market.

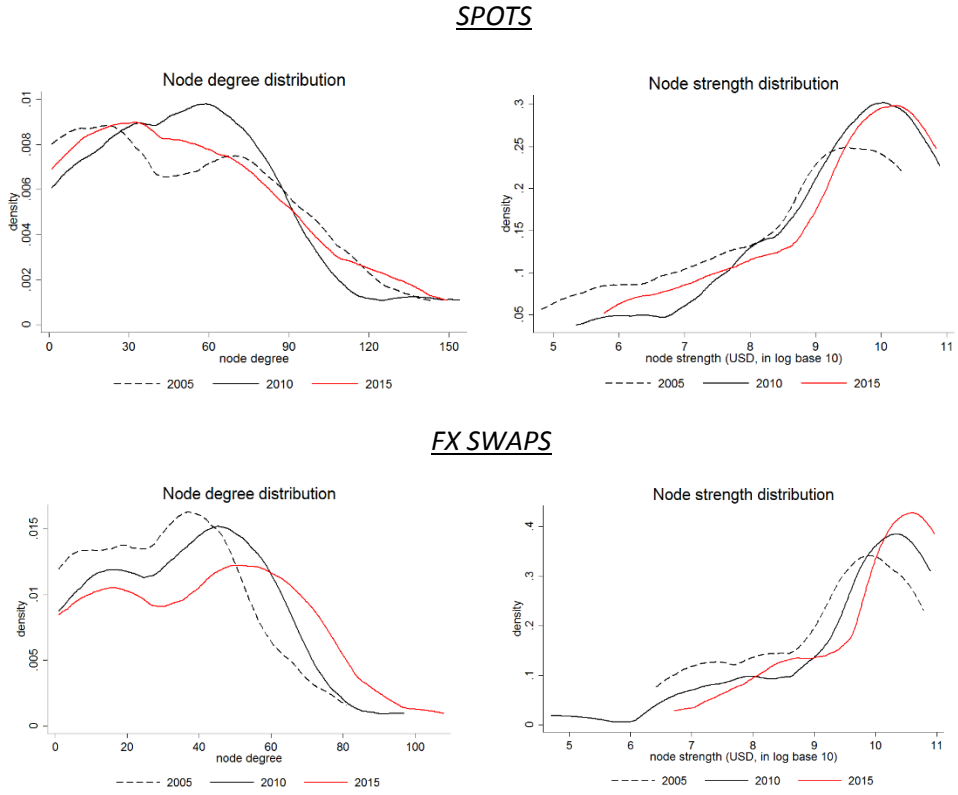
Figure 21: Empirical distributions of basic network properties: reporting dealers' in-degree and in-strength (from non-financial businesses)



Source: Bank of Thailand
Note: Nonparametric kernel density estimates are constructed using the Epanechnikov kernel, with optimal bandwidth (Silverman (1992)) for node strength distribution and calibrated bandwidth for node degree distribution.

In contrast, Figure 21 views the FX market network from the perspective of FX product providers (i.e. reporting dealers) and documents their relationships with non-financial business customers. In overall, the estimated distributions of in-degrees are much more stable than those of in-strengths. For in-degree distributions (left columns), the 2015 distributions for both instruments exhibit a slight downward shift at low number of customers compared to 2005 and 2010. This suggests that the customer base has become more evenly distributed among reporting dealers, although most of the dealers still have less than 2,000 non-financial business customers for spots and less than 1,000 for forwards. Meanwhile, for in-strength distributions (right columns), there seem to be more shifts over the years. For both instruments, there is a significant downward shift at high turnover value, suggesting a more even distribution of FX turnover among reporting dealers. The redistribution in FX turnover appears to be more substantial than observed in in-degree distributions. For the forward market in particular, we observe bi-modality in the 2005 in-strength distribution, with two peaks at around $10 million and $1 billion. This reflects that the forward market back then were quite divided: some reporting dealers emerged as more active in the retail segment, receiving around $1 billion in turnover, while others (a smaller subset of dealers) were not active in this segment at all. The situation in 2015 was quite different. While bi-modality remained as in 2005, forward turnover seemed to be more evenly distributed across reporting dealers. The peak at the high in-strength value had a much lower density in 2015, although the corresponding turnover value seemed to increase to around $5 billion.

Figure 22: Empirical distributions of basic network properties: interbank players' node degree and node strength



Source: Bank of Thailand
Note: Nonparametric kernel density estimates are constructed using the Epanechnikov kernel, with optimal bandwidth (Silverman (1992)) for node strength distribution and calibrated bandwidth for node degree distribution.

Figure 22 shows the results for the interbank FX market for the two most active instruments, namely spots and FX swaps. For FX swaps, degree distribution has shifted downward at lower degree values and also toward the right, reflecting the fact that overall connectivity has increased and reporting dealers could tap into a larger group of non-resident counterparties over the years. For node strength distributions (right columns), we observe the same patterns for both instruments – the distributions have shifted toward the right and the peaks are at higher node strength values. This reflects that most interbank players have increased trading in spots and FX swaps consistently over the years. Taken node degree and node strength distributions together, we can say that the interbank spot and FX swap markets have higher connectivity and heightened activity in the recent years.

5.4 Identifying central nodes in the interbank FX network

This section focuses exclusively on the interbank segment of the FX market.[14] The interbank segment serves as the backbone of the FX market, and is instrumental in facilitating transaction and risk sharing among retail and interbank players. The robustness of the interbank segment is essential in ensuring a proper functioning of the entire FX market, and thus should be adequately understood by regulators. One aspect of this lies in identifying systemically important banks that are critical to the FX market. These banks tend to have relationships with many other banks, or play an intermediary role in facilitating transaction between banks. Also, given that the FX market network seems to follow the power law (as discussed in Section 5.2), studies have shown that such network is vulnerable to targeted attacks at key nodes but resilient to random attacks (e.g. Albert, Jeong, and Barabási (1999)). In other words, while failure of most nodes present no risk to network stability, failure of a few key nodes could destabilize the entire network. It is thus important to identify the central players in the network, so that appropriate measures could be introduced to safeguard stability of these vital institutions.

In this section, we will employ two standard network centrality measures – namely, eigenvector and betweenness centrality – in quantifying systemic importance of banks.

Eigenvector centrality

Conceptually, eigenvector centrality asserts that nodes that are connected to many other central nodes are considered central. Eigenvector centrality is defined as the vector e sastisfying:

$$\lambda e = Ae$$

where λ is the largest eigenvalue, and A is an adjacency matrix (i.e. matrix where $a_{ij} = 1$ if bank i and j are connected, and 0 otherwise). So, the eigenvector centrality measure of bank i is given by:

$$e_i = \frac{1}{\lambda} \sum a_{ij} e_j$$

Note how this measure takes into account the centrality of node's neighbors in computing the centrality of each node, and how the measure only uses information from the binary representation of the network (i.e. ignoring weights). In addition, the parameter λ is used for scaling purpose so that the most central node has eigenvector centrality equal to one.

Betweenness centrality

Conceptually, nodes where a lot of transfers could happen are considered central according to this metric. More formally, betweenness centrality of bank i is defined as the number of shortest paths in the network going through bank i, excluding the shortest paths starting or ending at bank i itself. This means it is more likely that a transaction between a random pair of nodes in the network would go through nodes with high betweenness centrality. To facilitate comparison across networks of different sizes, we normalize our betweenness measure by $(n-1)(n-2)/2$, where n is the number of nodes in the network.[15]

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[14] That is, we consider the subnetworks of bilateral relationships where both counterparties are interbank market players. Recall that interbank market players can be reporting dealers, non-resident financial institutions, or other interbank institutions.

[15] For a network with n nodes, this is the maximum possible number of shortest paths going through a particular node that do not start or end at that node.

It is important to stress that eigenvector centrality and betweenness centrality identify nodes that are central in fundamentally different ways. Eigenvector centrality identifies nodes that are well-connected with other well-connected nodes, which tend to be the ones in the core of networks exhibiting the core-periphery structure. It is often used as a proxy for overall influence and systemic importance. In good times, nodes with high eigenvector centrality play a key role in facilitating transactions among key nodes. But in stress times, if hit by shocks, these nodes are also the ones that pose highest risks to overall network stability, since they could propagate shocks to other fellow central nodes quickly. On the other hand, betweenness centrality tends to identify nodes that serve as a bridge through which transactions could flow. In our interbank context, these nodes are in strategic position for liquidity flows throughout the network, or tend to be the gates through which offshore flows enter the domestic interbank market.

Interbank centrality results

We compute eigenvector and betweenness centrality of nodes in the interbank spot network, and present results in Figure 23. The left figure presents the interbank spot network in 2015, with nodes colored by eigenvector centrality score (white denoting highest score). The right figure presents the same interbank spot network, but with nodes colored by betweenness centrality score (white denoting highest score). In both figures, node size represents bank's total FX turnover in 2015. The networks are constructed using the standard Fruchterman-Reingold algorithm, which helps illustrate the core-periphery structure of the interbank FX network. Numerical centrality scores are presented in Table 6 for both spots and FX swaps, showing the top five banks in each centrality metric (randomly assigned a pseudo bank identifier as A, B, C, D, or E). We would like to note two general observations from the results as follows.

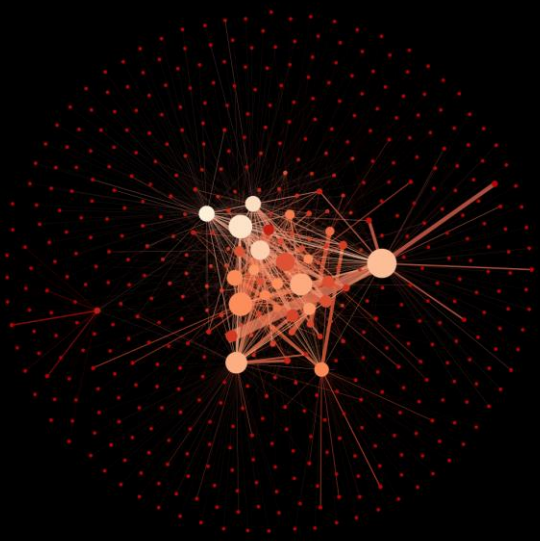
(1) Banks with largest FX turnover are not necessarily the ones that are most central to the system. For example, Bank E, which is ranked at the top for both eigenvector and betweenness centrality, is not the one with highest interbank transaction volume. The bank's importance does not come solely from its total transaction volume; its interlinkages with a large pool of interbank institutions, both domestic and non-resident, play a much greater role.

(2) There is a strong evidence of specialization across banks. A closer inspection reveals that banks are specialized in terms of their counterparties (i.e. local banks vs. non-resident banks), their roles in the interbank network, and their main instruments. For instance, one particular bank is not ranked as the most significant when analysis is conducted based on the entire interbank network (i.e. including all non-resident financial institutions). However, this bank becomes extremely central in the subnetwork where only local banks are considered. This hints at the bank's focus on the local interbank market. In contrast, another bank is important only with respect to betweenness centrality, and only in the network where non-resident financial institutions are included. This suggests the latter bank's role as a gateway for cross-border flows.

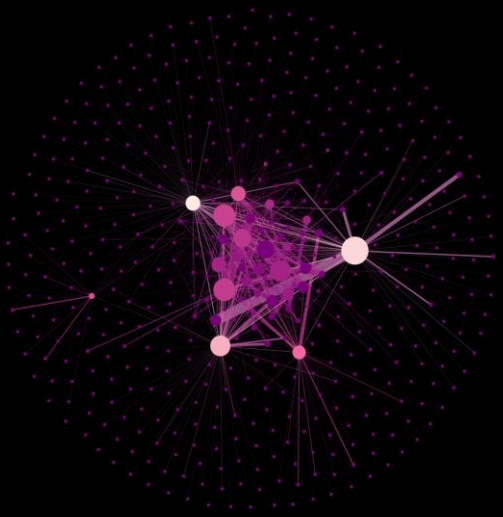
(3) Only a small subset of banks are truly central to the interbank FX market. From Table 6, only seven banks are represented, and the rankings for each metric are remarkably stable across instruments. To safeguard these vital institutions, additional capital and liquidity requirements could be considered for banks that are systemically important to the FX market. Alternatively, the rankings could also serve as an additional input into an existing prudential framework, such as in determining the domestic systemically important banks (D-SIBs). However, more thorough research is needed to ensure that regulators can strike the fine balance between supporting market efficiency and preserving stability.

Figure 23: Interbank spot market in 2015

EIGENVECTOR CENTRALITY
(White denoting highest score)



BETWEENNESS CENTRALITY
(White denoting highest score)



Source: Bank of Thailand; authors' calculation

Table 6: Centrality rankings of interbank players in 2015, for selected FX instruments*

	# FIs	Eigenvector Centrality		Betweenness Centrality	
		FIs	Score	FIs	Score**
Spots	492	1. Bank E 2. Bank D 3. Bank C 4. Bank G 5. Bank H	1.000 0.973 0.964 0.932 0.894	1. Bank E 2. Bank H 3. Bank A 4. Bank J 5. Bank C	0.250 0.233 0.198 0.133 0.107
FX swaps	225	1. Bank E 2. Bank D 3. Bank C 4. Bank G 5. Bank H	1.000 0.977 0.974 0.939 0.896	1. Bank E 2. Bank H 3. Bank A 4. Bank C 5. Bank J	0.276 0.165 0.139 0.111 0.084

Source: Bank of Thailand; authors' calculation
Note: * Calculations are performed on the entire interbank network (i.e. including non-resident institutions and Bank of Thailand).
** For comparability across networks, betweenness centrality scores are normalized by (n-1)*(n-2)/2, where n is the number of nodes in the network.

5.5 Case study: the foreign exchange market network under stress

Up to this point, we have focused mainly on exploring the FX market landscape using annual bilateral transaction data. While this helps uncover the overall *structural* features of the FX market, there remains a need to "zoom in" on some critical periods with large shocks hitting the FX market to see market participants' responses and dynamics in the FX network. Over the years, there have been numerous shock events that not only induce unprecedented responses from market participants, but could also play a key role in shaping the market landscape into what we are observing today.

In this section, we demonstrate how we could use network visualization to probe into the FX market during stress times. We present the FX swap network surrounding two episodes with tight liquidity conditions – namely, the global financial crisis and the Greek sovereign debt crisis.[16] The FX swap network is chosen given its close connection with interbank and cross-border lending activity, thus a possibility of tracing transmission of external liquidity shocks into the domestic interbank network.

(1) The global financial crisis

Our first focus will be the periods around the global financial crisis in 2008, where Lehman Brothers' bankruptcy in September 2008 led to an escalation of the already ongoing financial crisis. Figure 24(a) presents network visualization of the FX swap market in 2007H2 and 2009H1. To highlight key interbank players, local commercial banks and foreign banks are presented by separate nodes, while entities in other groups are lumped together. Two features are observed. First, the FX swap network became less connected in 2009H1 compared to 2007H2, with fewer active interbank players and lower turnover in line with a general decline in activity. Following the peak of the crisis, it seems to be the case that few strong banks gained market share quickly and activities of most other banks became muted. Second, foreign banks (orange nodes) seemed to switch roles among themselves before and after the crisis. In 2007H2, there were about three foreign banks who were the major players in the FX swap market, serving as a bridge that transferred liquidity from non-resident players (light blue node) to the domestic interbank market. But following the crisis in 2009H1, the activities of two out of these three foreign banks became negligible, partly due to the fact that many parent banks in Europe and the US were hit by the crisis and reduced operations overseas. In the 2009H1 network, other foreign banks and a local bank stepped in and served as liquidity provider for the domestic interbank network.

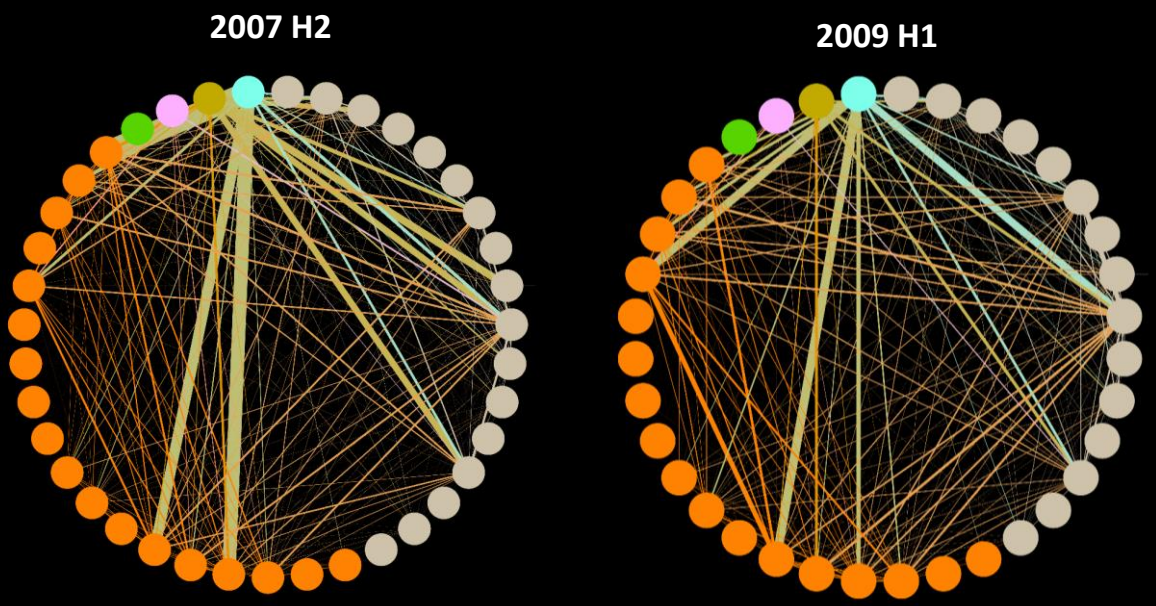
(2) The Greek sovereign debt crisis

Figure 24(b) presents a similar exercise for 2011H1 and 2011H2, the periods surrounding the Greek sovereign debt crisis that escalated in October 2011. As in Figure 24(a), we observe that some foreign banks gained market share at the expense of other foreign banks, obtaining USD liquidity from parent banks abroad and injecting the liquidity into the domestic interbank market especially through short-term FX swaps. As was the case with the global financial crisis, the density of interbank relationships decreased during and following the Greek debt crisis, reflecting reduced liquidity and activity in the interbank market. In both selected episodes, it is fair to conclude that the interbank system has held up well in stress times, supported by fluidity among interbank players.

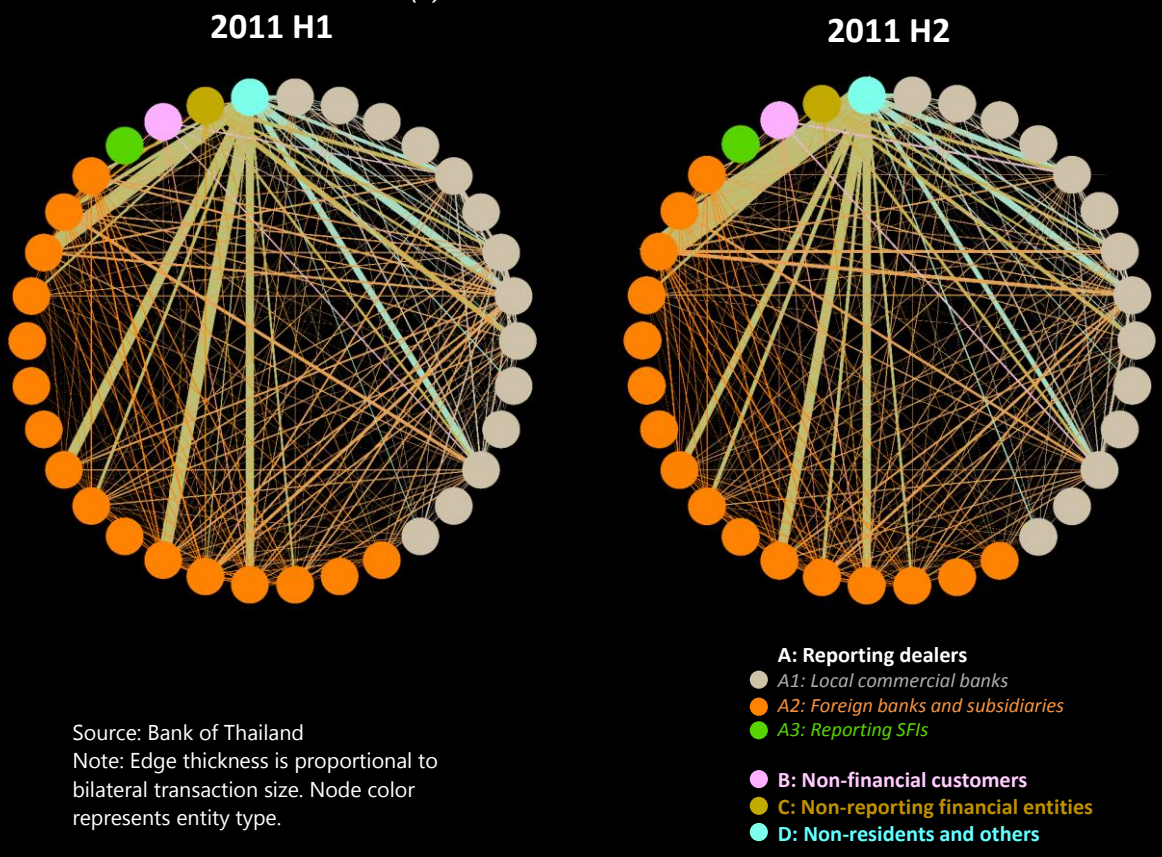
[16] The Greek debt crisis in October 2011 was the period where USD liquidity was arguably even tighter than the global financial crisis in 2008, as reflected by the 3-year basis swap (the difference between currency swap and interest rate swap rates) that reached the trough of about -180 basis points in early October 2011.

Figure 24: Thailand's FX swap market network around selected historical episodes

(a) The Global Financial Crisis



(b) The Greek Debt Crisis



Source: Bank of Thailand
Note: Edge thickness is proportional to bilateral transaction size. Node color represents entity type.

6. Conclusion

This paper is the first to explore Thailand's FX market structure, using the universe of all onshore FX trading transactions. Several aspects of the market landscape and players' activities are documented. Historical transaction data have shown steady growth in volume and the number of market participants over the years, with increasing variances across trading days reflecting an increasingly volatile marketplace. With regard to market concentration, from the perspective of FX service providers, we observe low degree of concentration in terms of market turnover share, and a moderate level of concentration in terms of customer base. From customer's perspective, turnover share appears to be highly concentrated among a handful of large customers. These patterns of market concentration remain more or less stable over time.

The paper also analyzes the network topology of Thailand's FX market from various angles. The network connectivity among different groups of players suggests that the Thai FX market is one that is quite segmented and contains clusters of similar players that tend to trade mainly with one another. In addition, we find different banks to be important in different ways in the Thai FX network, and banks with largest FX turnover are not necessarily the ones that are most central to the system. A substantial degree of specialization is evident across banks in terms of FX instruments and market segments, both in the interbank network and in the retail market. Probing into the interbank FX swap market during stress times, we show that the market continued to function smoothly, supported by fluidity among interbank players.

Several policy implications could be drawn from the results presented. First, high concentration of FX turnover on the customer side suggests that a small subset of large corporates might have dominated the market in terms of FX flows. Due to intense competition among dealers, this could possibly lead to price discrimination favoring large corporates, which could in turn affect affordability and accessibility to the FX market by smaller firms. This issue on the pricing of FX instruments is thus worth exploring in a future study. Secondly, there remains an ample room for market development for advanced FX instruments. As a case in point, evidence shows that the FX options market network is still in a nascent stage in Thailand and customer participation remains limited. With appropriate pricing and sufficient liquidity as well as efforts to promote understanding of more advanced instruments, local firms could benefit from having alternative FX hedging tools that suit their needs. Policies in the direction of accelerating market development for advanced FX instruments should be conducive to strengthening the overall resilience of the country to FX volatility. Lastly, based on our finding that only a small subset of banks has shown to be truly central to the interbank FX market, prudential measures could be considered to safeguard the stability of these vital institutions, although it remains a challenge to strike the balance between supporting market efficiency and preserving stability.

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