OPENING THE BLACK BOX OF BID-ASK SPREAD COMPONENTS IN THAI CURRENCY FORWARD

BY

MR. SAKDA THIRASOPHON

AN INDEPENDENT STUDY SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE PROGRAM IN FINANCE (INTERNATIONAL PROGRAM) FACULTY OF COMMERCE AND ACCOUNTANCY THAMMASAT UNIVERSITY ACADEMIC YEAR 2016

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ABSTRACT

This paper discovers the component of bid-ask spread in Thai FX forward market. The result indicates the overwhelming of order processing cost and inventory holding cost in marker maker pricing. Small bank tends to quote widen spread comparing to bigger ones derived by the higher inventory management component. I extend the investigation to test whether market maker adjust the component during certain economic events; Thai and US monetary policy meeting, US's non-farm payroll and inflation announcement. This article finds the evidence of market maker's component adjusting around the interest rate decision events, especially adverse selection component. Also, I found the variation of spread and component during certain THB movement.[1]

Keywords: Transaction Data, FX Forward, Market Microstructure, bid-ask spread

[1] Disclaimer: the information and views set out in this article are those of the author and do not necessarily reflect the official opinion of the Bank of Thailand. Neither Bank of Thailand nor any person acting on their behalf may be held responsible for the use which may be made of the information contained therein.

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Mr. Sakda Thirasophon

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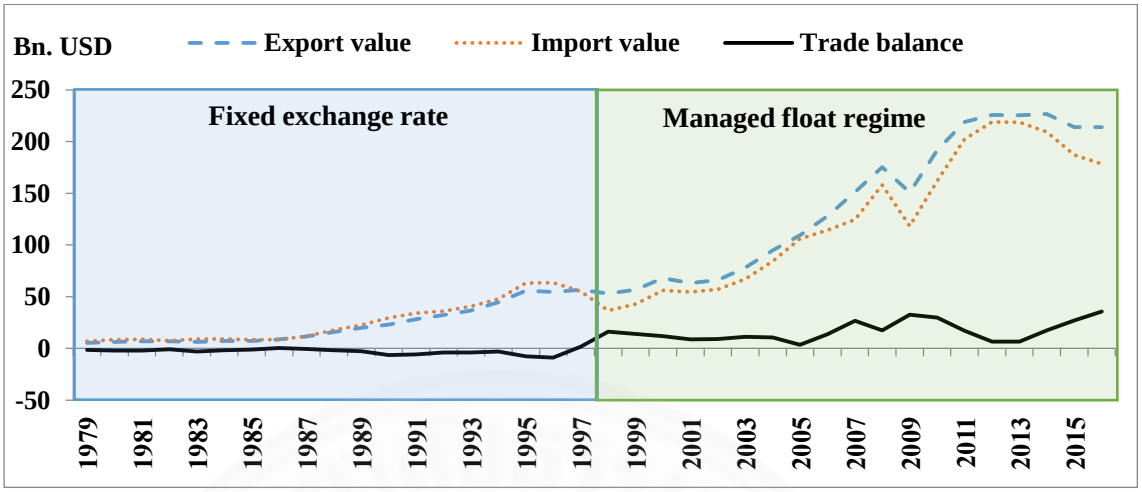
CHAPTER 1
INTRODUCTION

The international trade is the important engine for Thai economic driver for a long time. In 2015, the export and import value accounts for almost 58 and 54 percent of Thai GDP respectively. To trade internationally, the foreign currency plays an important role as the medium of exchange. After Bank of Thailand (BOT) changes the FX regime from fixed regime to managed float regime in 1997, THB has been allowed to move more freely, result the higher volatility in THB movement. The varying in FX causes the entrepreneur's profit volatility because importer (exporter) faces the uncertainty when they buy (sell) foreign currency in the future.

The noted issue about the relationship of currency movement and entrepreneur's profit is that when FX moves, either importer or exporter will sacrifice some profit. Generally, exporter prefers Thai Baht (THB) weakening, since the higher benefit from getting more money in term of THB after they convert the foreign currency as well as the higher price competitiveness. The same scenario will hurt the importer caused by higher price of abroad goods. Vice versa, THB strengthen will benefit to importer and exploit exporter. This kind of uncertainty THB movement is called the currency risk. In Thailand, a lot of firms have shut down because of FX loss (Bank of Thailand (2011)) so that the currency risk management is reasonable to do for business sustainability.

Figure 1.1: Thai export, import and trade balance value

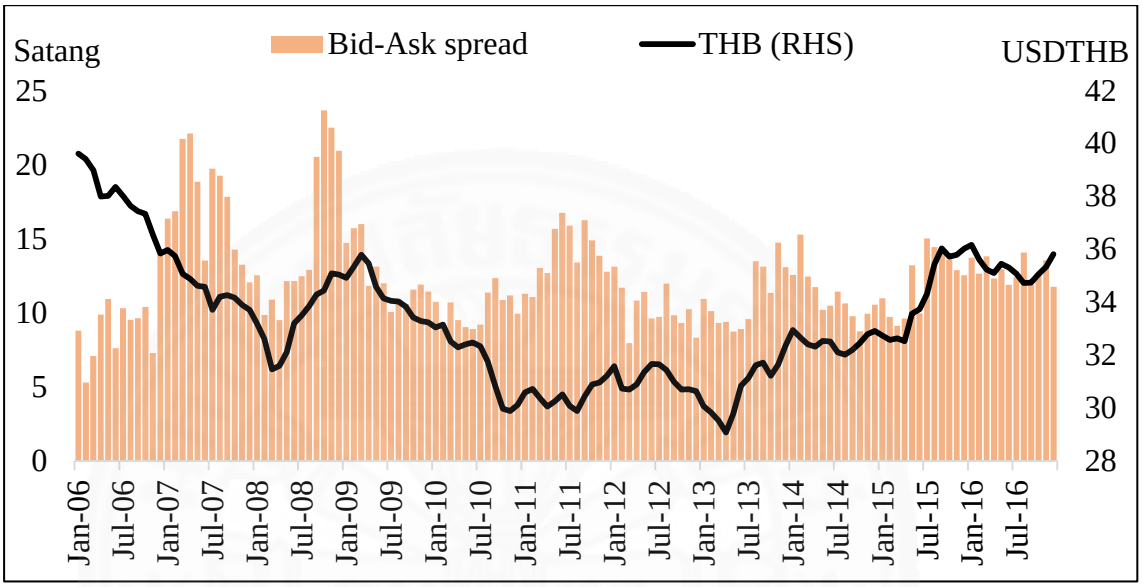


After THB floating, the value of Thai international trade, both import and export value, is expanding continuously (Figure 1.1). This fact is the symptom of how much THB volatility impact Thai's economy. To avoid currency risk, exporter and importer can hedge their FX position by employing financial product and most common tool is currency forward. Exporter (Importer) can get rid of currency risk by selling (buying) forward with certain amount and maturity. Nevertheless, there is a cost to enter this contract, bank will price lower forward rate for exporter (bid price) and higher rate for importer (ask price), ceteris paribus. The different between these two prices is called spread. For market participants, spread is income earned for market maker and cost incurred for investor (Khanthavit (2014)). The wider spread implied the higher cost to exporter and importer to hedge their FX position and consequently impact their willingness to hedge.

Figure 1.2 shows the median of bid-ask spread for 6-month FX forward contract in Thai onshore market. In essence, bank generally quotes the spread around 5 to 15 satang. Nevertheless, in some certain period the spread can deviate from this range, for example the end of 2006 to 2007, 2008 to 2009, and 2011. These deviations have a macro-event around the period. In December 2006, Bank of Thailand imposes the capital control to curb the massive capital inflow, known as Unremunerated Reserve

Requirement (URR). The inducing of this measures causes the sinking almost 15 percent in Thai stock market. The next two widen spread period during second half of 2008 to 2009 and 2011 probably relates to global financial crisis and European debt crisis.

Figure 1.2: Median of Bid-Ask Spread 6-month Forward to Client



In market microstructure theory, spread can be decomposed into three components; (i) order processing component, the fixed cost for order transaction, (ii) inventory holding component, the cost that related to inventory holding risk and management, and (iii) asymmetric information component, the cost that occur to compensate the probability that dealers might losses from trading with informed traders. For last 30 years, a lot of market microstructure models have been developed attempting to decompose these components.

This paper purposes to answer two questions. First, how the bid-ask spread components in Thai FX forward market look like, this will be the early study that employs the FX flows from real sector trading and also be the first paper employing this granular dataset. Second, how commercial banks adjust their component around certain events; US's non-farm payroll and inflation announcement, Federal Reserve and Bank of Thailand's monetary policy meeting. As well as I endeavor to disclose the component in

each THB trend. Knowing these two questions will be useful information for policy maker to design the market and regulation properly.

The remainder of this paper is structured as follows. Section 2 reviews former literatures about bid-ask spread components and market microstructure model. Then, I develop the theoretical framework in section 3. Data and research methodology is presented in section 4. Section 5 and 6 propose the results and conclusion respectively.

CHAPTER 2
LITERATURE REVIEW

2.1 The component of bid-ask spread

Liquidity is one factor of financial market feature to become a successful trading place. The mechanism to enhance the liquidity, generally, is appointing the liquidity provider, called market maker. The main function of market makers is to quote the bid and ask prices to absorb the trading transaction. Bid price is the price that they are willing to buy while the ask price is the price that they willing to sell. To make the profit, market maker must buy at the lower price and sell at the higher one at any moment, thus the ask price will always higher than bid price. The difference between ask price and bid price is called the spread. In other word, spread is income earned for market maker. For the client's view, the narrow spread is more desirable, while the widen spread implies the higher cost to them to trade that certain asset.

After the availability of high frequency data, the market microstructure models have been developed to estimate the components of bid-ask spread (Kim and Murphy (2013)). From the market microstructure theory, the market maker prices the bid-ask spread based on three components; order processing cost, inventory holding cost and asymmetric information cost.

Order processing cost is referred to as a transaction's fixed cost (Kim and Murphy (2013)). It involves the cost of ordering to market, monitoring the order, looking for counterparty, and clearing the transaction (Lertudomsak (2008)). Because the order processing cost is naturally fixed cost, so it should shrink when the trading size increases. The recent work from Bjonnes *et al* (2016) find the negative relationship between trade size and bid-ask spread. This finding supports the economies of scale, reduction in fixed cost per unit. In addition, fixed cost component is involved in almost every market microstructure models for liquidity provider (Glosten and Harris (1988), Ho and Macris (1984)).

A lot of papers that study the stock exchange as the sample, they find the important role of order processing component within the spread. Berchtold (2004) studies the stocks in Sweden market and disclose that order processing cost account around 70 percent in market maker quote. Huang and Stoll (1997) also find the order processing accounting for half of the spread in NYSE market. For FX market, Mcgroarty *et al* (2007) discloses the important of order processing component in EUR (around 49 percent) and JPY (32 percent), while CHF and EURCHF price order processing just about 20 percent.

The next component occurs from the fact that market makers must hold the securities as inventory for readying to supply the liquidity. Therefore, they bear the market risk from inventory price movement. To compensate this risk, market maker might mark-up them into the spread and called this premium as *inventory holding component*. In addition, some researcher propose the idea of market maker's optimal inventory level so they need to adjust their holding back to the optimal level (Smidt (1971), Garman (1976)). King *et al* (2013) proposes that interdealer has preference for hold zero inventories overnight. They show the declining in interdealer's inventory level when market nearly close. Because of market risk and inventory adjustment, market maker should markup on counterparty, called inventory holding cost. The early literatures which focus on this issue is Demsetz (1968). Employing cross-sectional regression and assuming static demand and supply hypothesis, Demsetz finds that trading volume, risk, price and firm size have statistically power to explain the spread. Intuitively, trading volume has positive relationship with spread because market makers can adjust their inventory more simply after the order is transacted. While Stoll (1978) concludes that larger transaction creates more deviation on market maker's inventory optimal level, causing the higher compensation. In addition, a lot of market microstructure models are developed to focus on the market maker's inventory adjustment (Smidt (1971), Garman (1976), Stoll (1978), Amihud and Mendelson (1980), and Ho and Macris (1984)).

The recent evidence from Luo (2017) that picks cross listing stock in London Stock Exchange and NYSE discover the important in inventory holding cost that account

around 50 percent of the spread. Furthermore, in FX market, Mcgroarty *et al* (2007) finds that inventory holding cost play accounts the most component in JPY (61 percent), CHF (70 percent), EUR (42 percent) and EURCHF (45 percent).

The last one is the *asymmetric information* or *adverse selection component*. It is developed from the hypothesis that market participants do not have symmetric information. We call the superior information participant as informed trader. Because they have superior information, informed trader will sell the securities at bid price if they have confirming information that price will decrease and buy at ask price if they have confirming information that price will increase. If the things occur as their expectation, informed trader will gain from trading with uninformed, including market maker. Kyle (1985) proposes market microstructure model which points out that a large trade tend to contain asymmetric information problem so that the market maker raise the price for liquidity providing. Other works which focus in asymmetric information are Glosten and Harris (1988) and Sadka (2006).

Previous studies propose the variation from customer type that they bring information to the market, as well as FX market. Osler and Vandrovych (2009) find the empirical evident that financial customers are superior inform than non-financial customer. They also found that retail customer trading do not bring additional information to the market.

In term of proportion within the spread, a bunch of articles found the significant portion of adverse selection component when market maker quotes the spread. Bleaney and Li (2014) discloses that USDDEM spread is quoted to compensate the adverse selection as high as 65 percent from the total. While McGroarty *et al* (2007) does not find the adverse selection component on JPY, CHF, EUR and EURCHF that much.

2.2 Market microstructure model for market maker pricing

The development of market microstructure model attempting to decompose the bid-ask spread component has been classified into two groups, the serial covariance spread estimation model and the order flow spread estimation model (Zhang and Hodges

(2012)). The serial covariance spread model estimates transaction cost derived from serial covariance of transaction price change. Roll (1984) is the initiator and following by a lot of paper, e.g. Choi *et al* (1988), Stoll (1989), George *et al* (1991) and Zhang and Hodges (2012).

The order flow spread estimation is developed parallels to extract the bid-ask spread component. In the early stage, the progress emphasizes in inventory holding cost, e.g. Amihud and Mendelson (1980), Ho and Stoll (1981) and Stoll (1976). Then, Copeland and Galai (1983), Easley and O'Hara (1987) and Glosten and Milgrom (1985) develop the model considering to adverse selection component.

The inventory cost holding, adverse selection cost and order processing cost are considered as a component of bid-ask spread to develop the following model. Huang and Stoll (1997) develops the model assuming the inventory holding and adverse selection component is the function of trading sign itself. The model allows for the probability of next trading side variation. The logic behind is that the market maker tends to adjust their inventory due to previous transactions; for instance, when market maker get a lot of transactions in buying side (from the ask price), they will adjust the spread to be narrower (increase the bid price or decrease the ask price). Because of this adjustment, the probability that the next transaction will be settled at the bid price is higher.

Some article has been developed the model to handle the certain circumstance which has Huang and Stoll model as a base model, for instance Berchtold (2004), McGroarty *et al* (2007) and Bleaney and Li (2014). McGroarty *et al* (2007) develops to handle the electronic inter-dealer FX spot bid-ask spread. They claim the quote driven market assumption in Huang and Stoll (1997) is inappropriate for their dataset. In quote driven market, market maker can set the price for attracting the next transaction to equilibrate their inventory. Nevertheless, in electronic inter-dealer FX spot, market maker has no necessary feature to do, cause by a lot of market maker. Keeping the most concepts from Huang and Stoll, they extend the model by employing the actual post trade spread in their calculation, enabling them to estimate the order processing cost, inventory

holding cost and asymmetric information cost. Also, Bleaney and Li (2014) improves Huang and Stoll model to handle with multi-dealer market.

Another extended version is Berchtold (2004). Berchtold follows Huang and Stoll model but he explicitly calculates the probability of trading reversion from the actual data to estimate the bid-ask spread component in stock exchange of Sweden. They disclose that order processing cost is account around 70 percent in the spread while the inventory holding cost and asymmetric information account for 20 percent and 10 percent, respectively.

Another interesting issue is how the securities price reacts during the new macro-information event are also one of the interested studied grounds. A lot of literature find that bid-ask spread changes during a certain event. Ruhl and Stein (2015) investigates whether bid-ask spreads sensitive to European Central Bank (ECB) macro announcement. They find the concrete evidences that bid-ask of Euro and UK stock rise sharply if the unexpected information or change in interest rate is announced. Cai *et al* (2009) studies the reaction of nine emerging market to the macroeconomic news from US and domestic during 2000 to 2006. They find the significant impact from US. News on bid and ask price of the exchange rate while domestic announcement do not cause significantly. Although Evans and Lyons (2005) finds the exchange rate reaction after macroeconomic announcement, they also discover the softly price adjustment for days.

Market should not react to all macroeconomic announcements but only actual important one. Bartolini *et al* (2008) investigates three US's financial market reaction; stock, bond, and foreign exchange, after macroeconomic announcement. They select several of data announcements as the event, such as non-farm payroll, unemployment rate and CPI. Predictably, they found just a few data have significantly impact on financial market; consist of non-farm payroll, GDP advance releases, and a private sector manufacturing. Nonetheless, Fatum and Scholnick (2007) finds that the exchange rate reacts only to the unexpected components from data announcement.

For emerging market evidence, Santos *et al* (2016) studies the impact on Brazilian futures market around the macroeconomic announcements. They find the bid-ask spreads will move unaccustomed before the pre-announcement but revert after the release.

In Thailand, there are not much articles applying market microstructure model. One of them is Khanthavit (2014), he applies the Choi *et al* (1998) model to estimate the component of bid-ask yield spread in Thai government bond. Due to data limitation, he employs daily data, low frequency, during 2003 to 2014. Even the same issuance; government, the bond with different maturity is not similar asset. He uses the benchmark bond series to be the proxy of each tenor. The result expresses the U sharped relationship with bond tenors and inventory-control component; in addition, the asymmetric information components statistically correlate with dealer-to-client trading volume

Another work is Lerkudomsak (2008), she uses Madhavan, Richardson and Roomans (1997) or MRR model to extract the bid-ask spread component. The intraday stock in SET50 index is selected as her sample. She find that the market maker prices the spread just a small portion on asymmetric information component. In term of intraday movement, asymmetric information component tends to decline over the day while the order handling component keeps increasing. She also investigates the components around earning announcement and merger and acquisition (M&A) event, which tend to have high information flow and causing the shift in asymmetric information component. Nonetheless, the asymmetric component does not change during earning announcement and surprisingly reduces around the M&A.

This article intends to find out the bid-ask spread components on currency forward around the macroeconomic event; US's non-farm payroll, inflation Federal Reserve monetary policy meeting and Central Bank of Thailand monetary policy meeting. I hypothesize that these intensive new information event, commercial banks should raise their adverse-selection component to compensate for possible information loss.

CHAPTER 3
THEORETICAL FRAMEWORK

In the market microstructure model for estimating bid-ask spread components, it is mostly presented that the spread consists of three components; order processing component, inventory holding component and asymmetric information component.

To calculate the bid-ask spread composition, this paper employs Huang and Stoll (1997) model. The main reasons why I select this model are twofold; first, the underlying assumption of Huang and Stoll (1997) is fit to the characteristic of Thai onshore FX forward market even normally is on-demand quote. In practice, when market maker inventory deviates too much from optimal level, the dealer will contact potential client and offer them the attractive rate to hedge, results approaching to optimal level. The quoted price to potential customer tends to be better than normal price for attracting the flow. By this logic, this behavior is similar to the mid-point adjusting process which is the main underlying assumption of Huang and Stoll model. Secondly, Huang and Stoll is the central of further developed models for certain situation; McGroarty *et al* (2007) and Bleaney and Li (2016), so it is one of the most well-accepted model in current microstructure model.

For deriving the model, starting from from defining the equations as following

$$V_t = V_{t-1} + \alpha \frac{S}{2} I_{t-1} + \nu_t \qquad \text{(Unobservable fundamental price process)} \qquad (1a)$$

$$M_t = V_t + \beta \frac{S}{2} \sum_{i=1}^{t-1} I_i \qquad \text{(The mid-price process)} \qquad (1b)$$

$$P_t = M_t + \frac{S}{2} I_t + e_t \qquad \text{(Transaction price)} \qquad (1c)$$

Where

V_t	is the unobservable fundamental price for transaction *t*
α	is the proportion that attributable to adverse selection cost
β	is the proportion that attributable to inventory holding cost
S	is the average bid-ask spread
I_{t-1}	is the indicator for bid-ask classification of certain transaction *t*. Where $I_t = +1$ if the transaction *t* is initiated by the buyer (or settle at ask price) and $I_t = -1$ if the deal is done by the seller (or settle at bid price)
M_t	is the mid-price for transaction *t*
P_t	is the observable transaction price

The logic behinds Huang and Stoll (HS) model starts from equation (1a), fundamental price process. Equation (1a) shows that the real asset value is derived from 3 components; the whole information from last trading, the private information from the last trade and the public information shock (v_t). It should be noted that V_t is unobservable; we do observe only the transaction price, and do not include any transaction cost. The information from last trade that might attach the private information is captured through α. Since the customers have to pay some spread for market maker when they do trade, in HS model, it assumes the spread, S, for each transaction is constant; therefore, the adverse selection component is the portion to half spread, $S/2$.

Regarded to inventory management theories, the market maker will adjust the midpoint relative to the fundamental value based on their accumulated inventory to achieve the equilibrating trade. Huang and Stoll model assumes the unit in trading size so that the mid-point process can be expressed as equation (1b). The interpretation of (1b) is that the market maker will quote the midpoint derived from the fundamental value and accumulated of past trading. For example, if the market maker buys the asset from the customer, they will move away from the intended inventory level, to achieve the optimal

inventory level, market maker will raise the midpoint to attract the potential selling customer.

After market maker determines the midpoint, the actual transaction price will be added or be subtracted by half spread to represent the profit for liquidity providing, then the observable transaction price process will be the equation (1c).

Considering to each component, the adverse selection cost, α, is the cost that market maker charges for compensating the order flow that might carry private information to the market, thus it marks up on the fundamental value. For inventory holding cost, β, it regard to the market maker's quote to equilibrate the inventory level and is taken in the mid-point quote. And the rest component is order processing cost and it can be evaluated from $1-\beta-\alpha$.

The change in equation (1b) can be derived as equation (2), the derivation is shown in appendix.

$$\Delta M_t = (\alpha+\beta)\frac{S}{2}I_{t-1} + \mu_t \tag{2}$$

In the same fashion, combining equation (1c) and (2) yields the change in transaction price process,

$$\Delta P_t = \Delta\left(M_t + \frac{S}{2}I_t + \mu_t\right)$$

$$\Delta P_t = \Delta M_t + \Delta\frac{S}{2}I_t + \Delta\mu_t$$

$$\Delta P_t = \Delta M_t + \frac{S}{2}I_t - \frac{S}{2}I_{t-1} + \varepsilon_t \tag{3}$$

Combining equation (2) and (3) results the regression of observable transaction price process.

$$\Delta P_t = \frac{S}{2}I_t + (\lambda-1)\frac{S}{2}I_{t-1} + e_t \tag{4}$$

Where

λ is the summation of adverse selection component and inventory holding component, $\alpha + \beta$.

Equation (4) is the basic regression of Huang and Stoll (1997) in two-way decomposition version. This version has some limitation in term of disabling to decompose the adverse selection and inventory holding. In their back-end article, Huang and Stoll propose the methodology to separate these two components by inducing the assumption of serial correlation in trading flows, equation (5).

$$E(I_{t-1}|I_{t-2}) = (1 - 2\pi)I_{t-2} + \omega_t \quad (5)$$

Where

π is the probability of trade flow at *t*-1 will reverse from *t*-2

Equation (5) reflects the ability of market maker to expect the next trading flow that might be non-related to asymmetric information after last transaction. If the probability of trading flow reversal is one-half, which is the case of equal probability for next transaction to be buying or selling, the value of equation (5) is zero which will be the case of basic regression in equation (4). Therefore, the change in transaction price can be rearranged as equation (6)

$$\Delta P_t = \frac{S}{2} I_t + (\alpha + \beta - 1)\frac{S}{2} I_{t-1} - \alpha \frac{S}{2}(1 - 2\pi)I_{t-2} + e_t \quad (6)$$

Ultimately, we can estimate the adverse selection and inventory holding component separately by evaluating equation (5) and (6) simultaneously.

For the robustness test, I also employ Mcgroarty *et al* (2007) model to decompose the spread. Their model is developed for FX spot market in the sense that market maker has limit to quote bid-ask price for equilibrating their inventory caused by a lot of market maker in the market. Their derivation allows the ability to estimate the adverse selection and inventory holding component individually as shown in equation (7).

$$\Delta P_t = (1-\alpha)\frac{S_t}{2} I_t + (\alpha+\beta-1)\frac{S_{t-1}}{2} I_{t-1} + e_t \quad (7)$$

Where

S_t is the actual post-trade spread

CHAPTER 4
DATA AND METHODOLOGY

4.1 Data preparation and model estimation

This article aims to answer the shape of bid-ask spread component in Thai FX forward market. The forward contract is traded privately, over-the-counter (OTC), between financial intermediary and the end-user, e.g. exporter and importer, and the data generally do not be published. In Thailand, Bank of Thailand (BOT) asks for the collaboration from commercial bank to report the whole FX transaction which they trade. In reporting, the transaction that has the value above 50,000 USD needs to be reported in detail, for example, counterparty name and propose, while the lower than 50,000 USD contract will be reported in aggregated amount. These all reported data represent the whole on-shore FX forward transaction.

FX forward is the main hedging tools for exporter and importer so if we know how market maker prices in each component, the regulator can design the market to promote FX risk more appropriately. That is why this article focus just the FX forward transaction that doing for goods trading propose and only against the USD, this should cover almost 80% of total currency forward contract that do for the goods' hedging[2].

I request the data from BOT for the contracts during 2006 to 2016. Due to data limitation, I use only the transaction that has the value above 50,000 USD in this study. For the feature that I ask from BOT can be described as following,

- The commercial bank's internal contract number
- The masked commercial bank
- The contract's forward rate
- The trade and maturity date

To apply the market microstructure model, it is very necessary to know the sequence of each trading transaction. After exploring the data, I found that only some

[2] From Bank of Thailand Statistic

commercial banks account their transaction's internal contract number consecutively while some commercial banks do not. This fact enables estimating market microstructure model for consecutively reporting bank. Then I filter out the bank that has average transaction per day below one hundred contracts. Finally, I have four banks in this article and the rest of paper will call these four banks as bank A B C and D. To give some detail, Bank A has the most transaction amongst four banks, Bank B and Bank C is the following order and Bank D is the least contract during the studied period.

The next issue is the tenors of the forward that make them heterogeneous in each contract even the same underlying. In the study, I group the contract by tenor through rolling the different between contract maturity data and trade date, which represent the contract tenor, to the nearest among 1-month (31 days), 2-month (62 days), 3-month (93 days), 4-month (124 days), 5-month (155 days) and 6 month (186 days). Nevertheless, the clustering contract is 1-month, 3-month and 6-month. From table 4.1, these selecting tenors account more than 80 percent for selling forward transaction (exporter), 55 percent for buying forward (importer) and almost 70 percent of total contract. Therefore, I decide to study these three tenors in this research. It is worth noting that the four selected banks account around 43 percent of these total three tenors. However, one bank has the usable data since July 2009, while other banks have the whole set of selected period.

Then, I apply Huang and Stoll (1997) in both two-way decomposition in equation (4), three-way decomposition in equation (4) and (5), and also Mcgroarty *et al* (2007) in equation (7). The next considering issue is the estimation method. Following Huang and Stoll (1997), I apply the generalized method of moments (GMM) to estimate the parameter. The strength of this procedure is inducing of very weak distribution assumption which is appropriate to the market microstructure model that we do not know certainly data distribution. Besides, Huang and Stoll (1997) emphasizes the appropriateness for this model because of the rounding error in price discreteness, also accounting for conditional heteroscedasticity and unknown form.

This paper imposes the orthogonal condition for estimating, therefore, equation (4) can estimate the parameter from,

$$f(x_t, w) = \begin{bmatrix} e_t I_t \\ e_t I_{t-1} \end{bmatrix} \tag{8}$$

Where

$f(x_t, w)$ is a vector function

w is the vector of parameter of interest which $w = [S \ \ \lambda]$

In the similar fashion, the parameter of three-way decomposition version can be estimated by imposing orthogonal condition by simultaneous solve equation (5) and (6).

$$f(x_t, w) = \begin{bmatrix} e_t I_t \\ e_t I_{t-1} \\ e_t I_{t-2} \\ \omega_t I_{t-2} \end{bmatrix} \tag{9}$$

For robustness test, this article employ Mcgroarty *et al* (2007) model in equation (7) which also be evaluated the parameter by GMM from following moment condition,

$$f(x_t, w) = \begin{bmatrix} e_t \left(\frac{S_t}{2} I_t\right) \\ e_t \left(\frac{S_t}{2} I_{t-1}\right) \end{bmatrix} \tag{10}$$

Where

w is the vector of parameter of interest which is $w = [\alpha \ \ \beta]$

Table 4.1: The number of forward transaction

Unit: contracts

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Total sell (buy) forward by year
Panel A: Sell forward												
<15D	1,663	2,555	2,157	1,661	1,846	1,992	1,981	2,214	1,978	1,614	1,776	**21,437**
1M	5,040	8,858	7,583	7,997	6,730	7,405	8,722	8,678	7,488	6,815	6,820	**82,136**
2M	3,438	5,208	4,393	3,845	3,883	3,875	2,982	3,517	3,352	2,767	3,025	**40,285**
3M	7,504	11,261	10,800	9,366	8,996	8,545	6,436	7,131	6,044	4,957	4,531	**85,571**
4M	1,141	1,467	2,040	1,624	2,512	2,334	1,918	2,224	2,134	2,508	2,234	**22,136**
5M	770	762	946	939	1,321	1,439	780	934	906	904	873	**10,574**
6M	22,819	23,398	28,958	21,809	37,113	37,595	22,867	26,401	20,849	19,625	17,996	**279,430**
Total sell forward by tenor	**42,375**	**53,509**	**56,877**	**47,241**	**62,401**	**63,185**	**45,686**	**51,099**	**42,751**	**39,190**	**37,255**	**541,569**
Panel B: Buy forward												
<15D	13,807	14,494	15,297	11,387	12,245	13,249	13,980	12,103	12,619	10,443	7,554	**137,178**
1M	23,222	17,557	21,236	17,472	19,057	20,258	18,386	20,004	20,737	16,976	15,063	**209,968**
2M	16,707	11,002	12,655	11,545	10,764	9,539	9,058	8,685	9,328	9,588	8,142	**117,013**
3M	17,005	11,426	11,561	11,712	10,380	9,387	9,284	9,265	9,002	9,662	8,117	**116,801**
4M	7,960	5,731	5,029	5,075	4,701	3,738	3,942	3,703	3,630	4,575	4,326	**52,410**
5M	5,040	3,547	2,779	2,954	2,709	2,258	2,479	2,274	2,720	3,229	2,687	**32,676**
6M	9,575	7,118	7,968	11,203	10,066	7,632	9,100	9,570	12,144	17,122	18,055	**119,553**
Total buy forward by tenor	**93,316**	**70,875**	**76,525**	**71,348**	**69,922**	**66,061**	**66,229**	**65,604**	**70,180**	**71,595**	**63,944**	**785,599**
Total forward	**135,691**	**124,384**	**133,402**	**118,589**	**132,323**	**129,246**	**111,915**	**116,703**	**112,931**	**110,785**	**101,199**	**1,327,168**

Notes: Panel A and B present the number of client's selling and buying USD forward contract which the amount greater than 50,000 USD in amount, respectively.

Estimating equation (7), we need the post-trade spread variable, S_t. Unfortunately, FX forward is traded privately and banks quote the price case by case for each customer, so we have no observable bid-ask spread. In this article, I calculate the post trade spread from the difference between the actual transaction price and the last transaction that done in the opposite direction.

Nevertheless, the evaluated parameter in this study cannot be negative value unless we are able to get unreasonable parameter. To avoid this problem, I employ log-transformation to the interested parameter, to force the positive value result, and then take the exponential to them. For instance; α will be transform to $exp(\ln \alpha)$.

4.2 The component of bid-ask spread during macro-event

Since the previous studies find the foreign currency reaction around certain economic event, this article extends the investigation to 4 macroeconomic events; (i) US's non-farm payroll announcement, which be announced on first Friday of every month (ii) US's CPI, which be announced around the mid of every month (iii) FOMC meeting, which be conducted around every 5 week 8 time a year and (iv) BOT's monetary policy meeting, which is also conducted around every 5 week 8 times a year.

The reason why I select US non-farm payroll and US inflation is due to the fact that these two indicators are the mandate for FOMC monetary policy decision. While the reason for adding monetary policy meeting is intuitive in the sense that interest rate is directly impact the forward rate, through interest rate differential, and has high probably to impact forward's bid-ask spread.

Around these selected period announcements tend to have intense information flows in the market. Therefore, I hypothesize that commercial bank might raise the asymmetric information component around these particular periods. It is worth noting that private information in exchange rate market tends to be smaller than equity market, because most currency fundamentals are public information, for example unemployment rate, interest rate and inflation. Market participants, nonetheless, need a time for fundamental's impact realization, which provide informed trader to gather private

information (King *et al* (2013)). Thus, the asymmetric information component might edge up around these periods.

I adopt Huang and Stoll model to answer the above hypothesizes. To compare both spread and its components, I develop the model base on Huang and Stoll (1997) which derivation is shown in appendix,

$$\Delta P_t = \frac{S_{NE}}{2} D_{NE} I_t + (\lambda_{NE} - 1)\frac{S_{NE}}{2} D_{NE} I_{t-1} + \frac{S_{PE}}{2} D_{PE} I_t + (\lambda_{PE} - 1)\frac{S_{PE}}{2} D_{PE} I_{t-1} + \frac{S_{EV}}{2} D_{EV} I_t + (\lambda_{EV} - 1)\frac{S_{EV}}{2} D_{EV} I_{t-1} + e_t \quad (11)$$

Where

S_i is the average spread under window *i*, which consist of non-event, *NE*, pre-event, *PE*, and event, *EV*.

D_i is the dummy variable that equal to 1 in case the window *i* occur and equal to 0 otherwise

λ_i is the summation of adverse selection and inventory holding components under window *i*

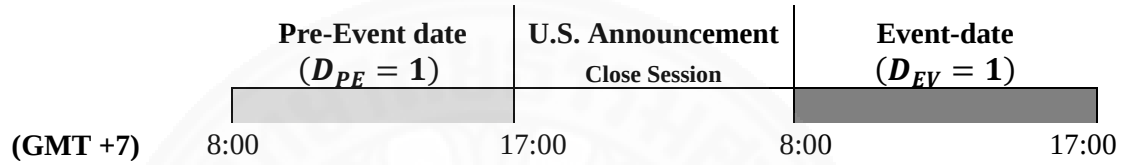
Also, the derivation of event impacts detection for Huang and Stoll three-way decomposition can be evaluated simultaneously two following equations,

$$\Delta P_t = \frac{S_{NE}}{2} D_{NE} I_t + (\lambda_{NE} - 1)\frac{S_{NE}}{2} D_{NE} I_{t-1} + \alpha_{NE}\frac{S_{NE}}{2}(1 - 2\pi_{NE}) I_{t-2} + \frac{S_{PE}}{2} D_{PE} I_t + (\lambda_{PE} - 1)\frac{S_{PE}}{2} D_{PE} I_{t-1} + \alpha_{PE}\frac{S_{PE}}{2}(1 - 2\pi_{PE}) I_{t-2} + \frac{S_{EV}}{2} D_{EV} I_t + (\lambda_{EV} - 1)\frac{S_{EV}}{2} D_{EV} I_{t-1} + \alpha_{EV}\frac{S_{EV}}{2}(1 - 2\pi_{EV}) I_{t-2} + e_t \quad (12)$$

$$I_{t-1} = (1 - 2\pi_{NE}) D_{NE} I_{t-2} + (1 - 2\pi_{PE}) D_{PE} I_{t-2} + (1 - 2\pi_{EV}) D_{EV} I_{t-2} + \omega_t \quad (13)$$

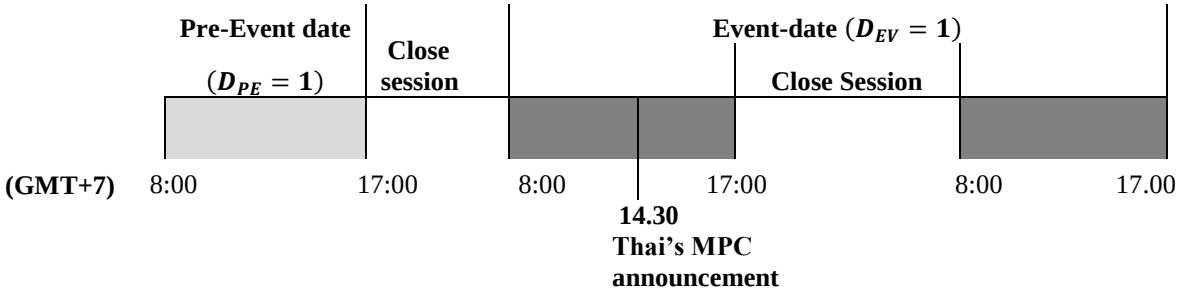
The pre-event date and event date are determined a bit different between U.S. and Thai event. Because the US's event occurs in night session for Thai local time (GMT+7), which the onshore market has already closed, the reaction for Thai commercial bank will be observed in the next trading day. Eventually, I define Asia's trading session on announcement day as a pre-event date and the next trading day as event date. Figure 4.1 shows the window of US event.

Figure 4.1: Event study's window for US event



I also apply the same window with Thai's MPC event. Generally, Thai's MPC announce the monetary policy decision around 14:30, thus we should define the transaction before 14:30 as the pre-event transaction. Unfortunately, the requested data from BOT has no timestamp when they conduct transaction with the client; I have only the transaction sequence and trading day. This paper handles this problem by determining the meeting date and the next trading day as the event window and the day before the meeting as the pre-event window. Figure 4.2 expresses the Thai's MPC window.

Figure 4.2: Event study's window for Thai's monetary policy meeting



The announcement date, benchmark date, pre-event date, and event date are provided in appendix 1 to 4.

Finally, GMM is employed to estimate the parameter by inducing the orthogonal condition, the moment condition to evaluate for two-way and there-way decomposition is equation (14) and (15), respectively.

$$f(x_t, w) = \begin{bmatrix} e_t(D_{NE} I_t) \\ e_t(D_{NE} I_{t-1}) \\ e_t(D_{PE} I_t) \\ e_t(D_{PE} I_{t-1}) \\ e_t(D_{EV} I_t) \\ e_t(D_{EV} I_{t-1}) \end{bmatrix} \tag{14}$$

$$f(x_t, w) = \begin{bmatrix} e_t(D_{NE} I_t) \\ e_t(D_{NE} I_{t-1}) \\ e_t(D_{NE} I_{t-2}) \\ e_t(D_{PE} I_t) \\ e_t(D_{PE} I_{t-1}) \\ e_t(D_{PE} I_{t-2}) \\ e_t(D_{EV} I_t) \\ e_t(D_{EV} I_{t-1}) \\ e_t(D_{EV} I_{t-2}) \\ \omega_t(D_{NE} I_{t-2}) \\ \omega_t(D_{PE} I_{t-2}) \\ \omega_t(D_{EV} I_{t-2}) \end{bmatrix} \tag{15}$$

From our research designed, I do use the whole day trade on event as the measure of market reaction. Some might argue that the price reaction supposed to measure instantly when information is published, but a lot of previous articles propose the evidence that FX price take days for information to contain the macro news announcement (Evan and Lyon (2005) and Carlson and Lo (2006)). Therefore, the designed methodology is applying whole day on event date seem rational.

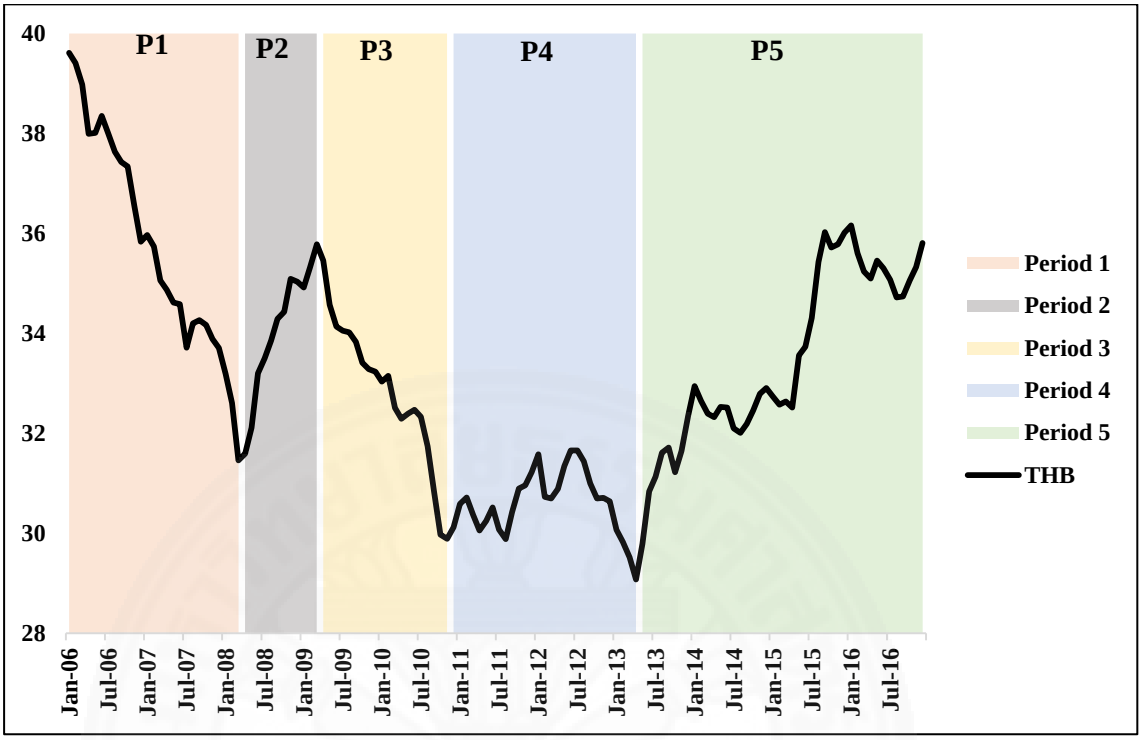
4.3 The component of bid-ask spread along with the THB trend

Some studies disclose the behavior shifting in bid-ask spread during the some market environment, e.g. volatility market. This study need to disclose the shape of spread component regarding to THB movement. THB starting point is considering to big picture of THB in figure 4.3. I then separate sample into 4 cycles as following;

Period 1: Jan 2006 to Feb 2008
Period 2: Mar 2008 to Mar 2009
Period 3: Apr 2009 to Nov 2010
Period 4: Dec 2010 to Apr 2013
Period 5: May 2013 to Dec 2016

For some preliminary analysis, period 1 and 3 can be considered as the strengthen cycle, while period 2 and 5 are the weakening cycle and period 4 is sideway cycle.

Figure 4.3: Daily THB movement during 2006 to 2016



The estimated equation can be derived as the same fashion to equation (4) and (6), also, GMM is also used in this step to estimate the parameter from Huang and Stoll model in each period separately.

CHAPTER 5
RESULT

Table 5.1 shown the descriptive statistic of bid-ask spread for onshore FX forward transactions trading for goods hedging propose during 2006 to 2016. The data is calculated from the daily different between buying and selling transaction rate. The first remarkable point is the spiking of the spread during the global financial crisis (GFC) in 2008 – 2009 and 2013. For 2013, we claim the widen spread caused from the impact of US monetary policy uncertainty, that be triggered in May 2013 when Ben Bernanke; Fed Chairman, frightens the market by stating the potential to start tightening monetary policy after their long time of quantitative easing (QE), this event is known as Taper Tantrum. And ultimately, they are tightening the policy at the end of 2015.

Regarded to tenor, 1-month spread is widen from 5.55 satang in 2006 to 32.51 satang and 2009 in 2008 and 2009, respectively and leap again to 13.64 satang in 2013. In the same manner, 3-month and 6-month tenor have broaden the spread from 11.17 and 10 satang in 2006 to around 40 and 20 satang during the GFC and also edge up in 2013. The median also tells the same story but less volatile in value.

The next point that should be noted is standard deviation aspect. I found the positive relationship between spread and their volatile. Similar fashion to mean and median spread, the volatility increases during the period of high uncertainty, GFC and US tapering. Nevertheless, we discover the less volatile in 6-month tenor while the shorter contract seems to have more spread volatility.

Table 5.2 demonstrates the spread decomposition by Huang and Stoll model and Mcgroarty *et al* (2007) model. In panel A, we estimate two-way decomposition version; which yield the combining of adverse selection and inventory holding. Firstly, the result shows that bank D, which is the smallest bank in term of number of contract, has the widen spread comparing to the others, especially short tenor. This finding might reflect the benefit from economy of scale for more trading volume, such as the fixed cost per

unit and the potential of low inventory holding cost, due to higher chance of opposite transaction.

Considering to tenor and spread dimension, bank A and bank B widen their spread when tenor is longer, while bank D behaves on the opposite. These finding reflect the pricing style as well as market makers' preference on certain tenor. Nevertheless, this paper does not investigate further to disclose what kind of factors determine these market maker behaviors and left this issue as the further study.

In term of component, order processing cost overwhelms around half of the spread for Bank A, bank B and bank C, while the combination of inventory holding cost and adverse selection account for the rest. Dissimilarly, bank D quotes order processing component about 35 to 38 percent and the summation of adverse selection and inventory holding cost are majority cost for them. The implication on these finding indicates the behavior of big bank to quote the spread chiefly for fixed cost while the rest accounts for variable cost. Regarded to narrower spread, we can conclude that big banks price the spread for adverse selection and inventory component a lot lower than smaller bank; bank D.

Table 5.1: Descriptive statistics of FX forward bid-ask spread

Year	Mean	Median	Sigma	Percentile 25	Percentile 75
Panel A: 1-month contract					
2006	5.55	8.16	21.97	-3.36	17.36
2007	10.94	10.51	11.22	5.13	17.06
2008	32.51	14.88	47.24	3.96	46.78
2009	27.45	14.47	34.14	8.00	32.36
2010	3.47	5.83	9.37	-0.08	8.57
2011	10.79	9.95	8.38	6.68	14.22
2012	8.55	7.97	5.90	5.54	10.82
2013	13.64	9.17	16.22	5.61	15.32
2014	11.81	7.73	13.62	5.18	13.64
2015	12.27	7.98	15.55	4.82	13.83
2016	7.95	7.73	6.22	5.10	9.90
Panel B: 3-month contract					
2006	11.17	12.35	30.94	5.27	21.55
2007	18.01	15.07	22.61	6.73	28.35
2008	40.29	27.50	56.30	5.52	65.58
2009	25.58	17.15	23.25	9.94	36.69
2010	6.14	8.69	11.89	3.89	11.22
2011	15.09	14.21	8.56	10.36	19.14
2012	15.60	12.93	12.28	9.73	19.05
2013	31.81	24.54	32.43	7.42	52.49
2014	21.42	14.66	22.37	11.18	21.88
2015	18.27	14.53	15.30	11.86	19.30
2016	12.72	12.01	8.16	9.31	14.66
Panel C: 6-month contract					
2006	9.99	9.15	13.14	5.07	14.00
2007	21.61	16.83	22.00	12.80	22.38
2008	18.05	14.03	16.00	10.24	21.65
2009	14.94	11.75	10.67	10.02	15.89
2010	10.21	10.30	4.16	8.62	12.06
2011	13.30	13.53	4.74	11.07	16.21
2012	10.24	10.29	3.70	8.02	12.33
2013	11.47	10.76	7.10	8.12	14.07
2014	12.06	10.92	6.25	9.02	13.25
2015	12.40	11.80	5.31	9.30	15.01
2016	12.36	12.64	4.11	10.55	14.74

Notes: This table provides the descriptive statistic; mean, median, standard deviation, percentile 25, and percentile 75, for bid ask spread. Spread is calculated from the median of difference between selling and buying rate. Panel A, B and C present the 1-month, 3-month, and 6-month tenor, respectively.

Table 5.2: Component of spread from Huang and Stoll model

	Bank A			Bank B			Bank C			Bank D		
	1M	**3M**	**6M**	**1M**	**3M**	**6M**	**1M**	**3M**	**6M**	**1M**	**3M**	**6M**
Panel A: Huang and Stoll two way decomposition												
Spread (Satang)	5.5	7.9	8.0	3.5	6.9	9.4	8.1	10.0	4.7	20.7	11.7	9.6
IC + AS (%)	48%	46%	48%	41%	50%	49%	49%	45%	48%	63%	65%	62%
OP (%)	52%	54%	52%	59%	50%	51%	51%	55%	52%	37%	35%	38%
Panel B: Huang and Stoll three way decomposition												
Spread (Satang)	5.4	7.9	8.0	3.4	6.9	9.3	8.0	10.6	4.7	20.9	11.8	9.6
Trade reversal	25%	34%	25%	21%	26%	23%	25%	26%	19%	24%	27%	25%
AS (%)	11%	0%	2%	5%	7%	3%	4%	5%	2%	17%	18%	14%
IC (%)	27%	46%	45%	44%	43%	49%	43%	37%	49%	56%	59%	50%
OP (%)	62%	54%	53%	51%	50%	48%	53%	58%	49%	27%	23%	36%
Panel C: McGroarty *et al* (2007) model												
AS (%)	2%	6%	3%	7%	12%	5%	3%	4%	1%	11%	14%	13%
IC (%)	50%	29%	52%	40%	45%	41%	48%	39%	51%	57%	57%	52%
OP (%)	48%	55%	45%	53%	43%	54%	49%	57%	48%	32%	29%	35%

Notes: This table present the component of bid-ask spread for each model. Panel A and B provide the result from Huang and Stoll (1997) model for two-way decomposition (equation (4)) and three-way decomposition (equation (5) and (6)) version, and the panel C provide the result from McGroart *et al* (2007) model (equation (7)).

After inducing serial correlation assumption in trading flow, it enables us to crack the component into three parts yielding more comprehensive interpretation (panel B). We discover that adverse selection accounts just a few portions, less than 10 percent for bank A, bank B and bank C. The small fraction of adverse selection component is not astonishing, since the customer's FX forward flows is the importer and exporter who trade the foreign currency because of the real underlying so that they generally have no intensive private information on THB movement. In contrast, bank D demands around 14 to 18 percent. At the same time, bank D prices the inventory holding component greater than the rest three banks. This evidence answers the above question that the smaller bank has widen spread mainly due to higher inventory holding cost, since they have less two side transaction to equilibrate the inventory.

Also, the higher asymmetric information implies the characteristic of bank D clients that might bring additional private information to the market. The doubtful question is that why informed trader need to trade with small bank. A potential explanation is that the inform clients might trade with a many bank because generally customer need to have credit line with bank before they hedge. Along with the fact that small bank tends to have less customer causing well-known on their client, so that they can look after the client well which might attract the inform customer. Another potential explanation is that small bank tends to compete with their competitors by focusing some specific client group, e.g. foreign companies' subsidiary or multinational company. These customers incline to have internal analysis team resulting better information, especially their own industry information, e.g. oil or agricultural price trend. Even their knowledge is not directly foreign currency, but the whole macroeconomic factors are interactive and ultimately causing the FX movement. For instance, when the oil price rises, the inflation tends to edge up as well resulting the central bank's policy rate hiking. Therefore, owning private information on oil price is also having some specific information on futures interest rate.

The order processing component tends to increase in the short end tenor while the order processing cost is prone to rise for longer tenor. The implication on this fact is the difficulty on finding the reverse transaction or squaring for longer tenor contract.

The next noticeable point is the trade reversal coefficient, they show the value lies between 19 percent and 34 percent. This evidence can be interpreted as the positive serial correlation in trade flows which is consistent with a lot of previous study that found the less than one-half in trade reversal coefficient (Huang and Stoll (1997), Mcgroarty *et al* (2007), and Bleaney and Li (2014)).

Besides, I run robustness check on Mcgroarty *et al* (2007) model and found the consistent result with three-way decomposition model that the order processing cost and inventory holding cost is almost the whole component on bid-ask spread while the adverse selection is diminutive.

Table 5.3: Component of spread from Huang and Stoll model in Thai MPC

		1M			3M			6M		
		NE	**Pre**	**Event**	**NE**	**Pre**	**Event**	**NE**	**Pre**	**Event**
Panel A: Huang and Stoll two-way decomposition model										
Bank A	**Spread (Satang)**	5.5	6.0	5.3	7.9	8.4	7.2	8.0	8.2	8.4
	IC + AS (%)	35%	52%	33%	46%	57%	64%	43%	50%	48%
	OP (%)	65%	48%	67%	54%	43%	36%	57%	50%	52%
Bank B	**Spread (Satang)**	3.5	2.7	2.2	6.8	7.8	8.9	9.4	9.6	10.2
	IC + AS (%)	42%	44%	46%	48%	47%	41%	48%	48%	49%
	OP (%)	58%	56%	54%	52%	53%	59%	52%	52%	51%
Bank C	**Spread (Satang)**	8.4	6.4	0.7	10.0	10.0	9.1	4.7	4.6	4.8
	IC + AS (%)	49%	56%	52%	35%	59%	43%	47%	38%	49%
	OP (%)	51%	44%	48%	65%	41%	57%	53%	62%	51%
Bank D	**Spread (Satang)**	20.2	24.1	30.6	11.3	23.8	11.1	9.4	12.2	11.5
	IC + AS (%)	67%	61%	62%	69%	66%	83%	49%	62%	56%
	OP (%)	33%	39%	38%	31%	34%	17%	51%	38%	44%
Panel B: Huang and Stoll three way decomposition										
Bank A	**Spread (Satang)**	5.4	6.0	5.2	7.9	8.5	7.2	8.0	8.1	8.2
	Trade reversal	25%	14%	13%	35%	7%	14%	25%	21%	23%
	AS (%)	11%	25%	13%	1%	14%	17%	2%	5%	3%
	IC (%)	30%	27%	24%	47%	45%	48%	44%	50%	49%
	OP (%)	59%	48%	63%	53%	41%	35%	54%	45%	48%
Bank B	**Spread (Satang)**	3.5	2.8	2.3	6.8	8.0	9.0	9.3	9.5	9.9
	Trade reversal	21%	16%	3%	26%	17%	21%	23%	35%	36%
	AS (%)	6%	11%	4%	6%	8%	2%	4%	1%	6%
	IC (%)	44%	40%	46%	43%	43%	41%	49%	48%	50%
	OP (%)	50%	49%	50%	51%	49%	57%	48%	51%	44%
Bank C	**Spread (Satang)**	8.3	6.1	0.2	10.7	9.9	9.3	4.7	4.2	5.1
	Trade reversal	25%	27%	27%	27%	25%	30%	1%	27%	25%
	AS (%)	3%	11%	12%	5%	20%	17%	1%	4%	8%
	IC (%)	50%	42%	42%	39%	49%	33%	46%	51%	47%
	OP (%)	47%	47%	46%	56%	31%	50%	53%	45%	45%
Bank D	**Spread (Satang)**	20.5	23.1	30.3	11.5	23.8	11.5	9.5	12.2	11.5
	Trade reversal	24%	7%	27%	27%	13%	22%	16%	16%	20%
	AS (%)	16%	22%	11%	15%	23%	14%	15%	15%	6%
	IC (%)	54%	40%	54%	56%	50%	74%	48%	47%	50%
	OP (%)	31%	38%	35%	29%	28%	13%	36%	38%	44%

Notes: This table present the component of bid-ask spread around Thai's MPC meeting from Huang and Stoll model (equation (11), (12) and (13)) . NE, Pre and Post stand for non-event, pre-event and event period.

Table 5.4: Component of spread from Huang and Stoll model in FOMC meeting

		1M			3M			6M		
		NE	**Pre**	**Event**	**NE**	**Pre**	**Event**	**NE**	**Pre**	**Event**
Panel A: Two-way decomposition model										
Bank A	**Spread (Satang)**	5.5	6.2	5.7	7.9	8.5	8.4	7.9	7.7	11.4
	IC + AS (%)	48%	51%	49%	46%	49%	56%	48%	47%	47%
	OP (%)	52%	49%	51%	54%	51%	44%	52%	53%	53%
Bank B	**Spread (Satang)**	3.4	1.6	5.8	6.9	7.6	7.5	9.3	9.5	11.2
	IC + AS (%)	41%	67%	56%	43%	50%	40%	48%	48%	48%
	OP (%)	59%	33%	44%	57%	50%	60%	52%	52%	52%
Bank C	**Spread (Satang)**	8.3	1.3	7.8	10.1	19.2	4.0	4.6	6.0	5.9
	IC + AS (%)	49%	51%	56%	49%	72%	70%	47%	44%	62%
	OP (%)	51%	49%	44%	51%	28%	30%	53%	56%	38%
Bank D	**Spread (Satang)**	21.0	14.9	18.5	11.8	14.7	4.5	9.6	10.0	7.7
	IC + AS (%)	66%	63%	56%	63%	79%	55%	72%	50%	50%
	OP (%)	34%	37%	44%	37%	21%	45%	28%	50%	50%
Panel B: Three-way decomposition model										
Bank A	**Spread (Satang)**	5.4	6.2	5.6	7.8	8.5	8.3	7.8	7.6	11.2
	Trade reversal	25%	16%	18%	35%	17%	21%	25%	22%	22%
	AS (%)	11%	26%	14%	0%	10%	16%	2%	5%	3%
	IC (%)	30%	40%	32%	46%	49%	46%	45%	48%	48%
	OP (%)	59%	34%	54%	53%	41%	38%	54%	46%	49%
Bank B	**Spread (Satang)**	3.4	1.5	5.7	6.8	7.7	7.8	9.2	9.8	11.5
	Trade reversal	21%	17%	20%	26%	16%	15%	23%	34%	36%
	AS (%)	5%	24%	14%	6%	11%	7%	3%	1%	6%
	IC (%)	43%	47%	42%	43%	48%	39%	49%	49%	40%
	OP (%)	52%	30%	43%	50%	41%	55%	48%	50%	54%
Bank C	**Spread (Satang)**	8.2	1.6	8.4	10.8	19.7	3.9	4.6	5.9	5.3
	Trade reversal	25%	24%	33%	27%	28%	22%	19%	25%	27%
	AS (%)	6%	10%	17%	5%	24%	25%	1%	3%	16%
	IC (%)	43%	41%	49%	37%	46%	43%	46%	45%	50%
	OP (%)	51%	49%	34%	57%	30%	33%	53%	52%	33%
Bank D	**Spread (Satang)**	21.3	14.5	18.2	12.0	14.7	5.0	9.6	10.3	7.9
	Trade reversal	24%	19%	15%	27%	65%	26%	25%	16%	21%
	AS (%)	17%	13%	11%	15%	46%	31%	20%	7%	5%
	IC (%)	52%	56%	45%	50%	40%	22%	49%	47%	49%
	OP (%)	32%	32%	44%	35%	14%	47%	31%	46%	46%

Notes: This table present the component of bid-ask spread around US's MPC meeting from Huang and Stoll model (equation (11), (12) and (13)) . NE, Pre and Post stand for non-event, pre-event and event period.

Table 5.5: Component of spread from Huang and Stoll model in US non-farm payroll announcement

		1M			3M			6M		
		NE	**Pre**	**Event**	**NE**	**Pre**	**Event**	**NE**	**Pre**	**Event**
Panel A: Two-way decomposition model										
Bank A	**Spread (Satang)**	5.5	5.2	5.2	8.0	6.5	8.1	8.1	7.9	7.8
	IC + AS (%)	48%	47%	47%	46%	48%	47%	48%	47%	49%
	OP (%)	52%	53%	53%	54%	52%	53%	52%	53%	51%
Bank B	**Spread (Satang)**	3.4	5.1	2.6	6.8	7.5	8.4	9.5	9.6	7.5
	IC + AS (%)	41%	61%	45%	43%	40%	42%	48%	48%	45%
	OP (%)	59%	39%	55%	57%	60%	58%	52%	52%	55%
Bank C	**Spread (Satang)**	7.8	12.6	7.9	9.4	14.0	15.7	4.6	4.7	5.4
	IC + AS (%)	49%	59%	48%	51%	38%	50%	46%	47%	51%
	OP (%)	51%	41%	52%	49%	62%	50%	54%	53%	49%
Bank D	**Spread (Satang)**	20.7	16.6	25.1	11.9	5.8	11.6	9.7	9.0	7.8
	IC + AS (%)	70%	57%	67%	62%	68%	88%	59%	75%	56%
	OP (%)	30%	43%	33%	38%	32%	12%	41%	25%	44%
Panel B: Two-way decomposition model										
Bank A	**Spread (Satang)**	5.5	5.1	5.1	8.0	6.5	8.0	8.0	7.8	7.7
	Trade reversal	25%	7%	12%	34%	15%	18%	25%	21%	23%
	AS (%)	10%	11%	11%	3%	1%	2%	2%	3%	2%
	IC (%)	30%	33%	29%	42%	48%	38%	44%	48%	50%
	OP (%)	60%	56%	60%	55%	51%	60%	53%	49%	48%
Bank B	**Spread (Satang)**	3.4	4.8	2.4	6.8	7.5	8.5	9.4	9.4	7.7
	Trade reversal	21%	23%	26%	26%	6%	21%	23%	33%	33%
	AS (%)	3%	14%	12%	7%	5%	5%	3%	2%	3%
	IC (%)	43%	45%	46%	44%	39%	40%	49%	49%	44%
	OP (%)	54%	41%	42%	49%	56%	55%	48%	49%	53%
Bank C	**Spread (Satang)**	7.8	12.7	7.2	9.9	15.8	16.6	4.6	4.6	5.6
	Trade reversal	25%	28%	32%	27%	41%	27%	19%	25%	25%
	AS (%)	3%	6%	4%	5%	22%	7%	1%	7%	7%
	IC (%)	45%	59%	45%	40%	29%	49%	46%	48%	49%
	OP (%)	53%	36%	51%	55%	48%	44%	53%	45%	44%
Bank D	**Spread (Satang)**	20.8	16.5	26.0	12.2	4.7	10.5	9.8	9.2	7.3
	Trade reversal	24%	26%	25%	27%	65%	37%	25%	23%	22%
	AS (%)	14%	12%	21%	19%	16%	16%	15%	21%	20%
	IC (%)	53%	48%	45%	47%	50%	60%	48%	54%	50%
	OP (%)	33%	40%	33%	34%	34%	24%	37%	26%	29%

Notes: This table present the component of bid-ask spread around US's non-farm payroll announcement from Huang and Stoll model (equation (11), (12) and (13)) . NE, Pre and Post stand for non-event, pre-event and event period.

Table 5.6: Component of spread from Huang and Stoll model in US CPI announcement

		1M			3M			6M		
		NE	**Pre**	**Event**	**NE**	**Pre**	**Event**	**NE**	**Pre**	**Event**
Panel A: Two-way decomposition model										
	Spread	5.5	6.0	6.0	7.9	7.8	7.6	8.0	8.4	8.5
Bank A	**IC + AS (%)**	48%	44%	47%	46%	46%	45%	48%	47%	48%
	OP (%)	52%	56%	53%	54%	54%	55%	52%	53%	52%
	Spread	3.5	2.7	3.8	6.8	6.8	8.6	9.4	9.1	9.2
Bank B	**IC + AS (%)**	41%	37%	47%	43%	38%	50%	48%	46%	46%
	OP (%)	59%	63%	53%	57%	62%	50%	52%	54%	54%
	Spread	8.3	4.8	6.9	10.0	8.6	11.5	4.9	4.2	1.4
Bank C	**IC + AS (%)**	49%	45%	52%	50%	44%	44%	47%	43%	56%
	OP (%)	51%	55%	48%	50%	56%	56%	53%	57%	44%
	Spread	21.5	7.0	21.4	11.0	22.1	14.3	9.8	8.3	7.1
Bank D	**IC + AS (%)**	68%	58%	73%	64%	76%	73%	69%	47%	50%
	OP (%)	32%	42%	27%	36%	24%	27%	31%	53%	50%
Panel B: Three-way decomposition model										
	Spread	5.4	5.9	5.8	7.9	7.8	7.5	7.9	8.3	8.3
	Trade reversal	25%	15%	16%	34%	19%	14%	25%	18%	25%
Bank A	**AS (%)**	10%	13%	12%	2%	0%	1%	2%	3%	3%
	IC (%)	30%	28%	28%	46%	44%	45%	45%	48%	49%
	OP (%)	60%	59%	59%	51%	56%	54%	53%	49%	48%
	Spread	3.4	2.7	3.8	6.8	6.7	8.5	9.3	9.0	9.0
	Trade reversal	21%	27%	20%	26%	12%	25%	23%	31%	31%
Bank B	**AS (%)**	6%	5%	10%	10%	8%	3%	2%	2%	5%
	IC (%)	44%	42%	47%	42%	40%	49%	49%	47%	48%
	OP (%)	51%	53%	43%	47%	51%	47%	49%	52%	47%
	Spread	8.3	4.7	6.8	10.7	8.8	9.8	4.9	4.0	1.1
	Trade reversal	25%	34%	32%	27%	41%	41%	19%	25%	26%
Bank C	**AS (%)**	4%	5%	4%	9%	1%	19%	2%	6%	6%
	IC (%)	42%	41%	43%	37%	47%	54%	47%	45%	49%
	OP (%)	54%	55%	53%	54%	52%	27%	51%	49%	46%
	Spread	21.7	6.9	20.7	11.0	23.4	16.0	9.8	8.4	7.4
	Trade reversal	24%	31%	18%	27%	65%	20%	25%	24%	20%
Bank D	**AS (%)**	16%	19%	19%	10%	23%	23%	18%	2%	6%
	IC (%)	52%	42%	47%	59%	58%	47%	49%	46%	49%
	OP (%)	32%	39%	34%	31%	19%	30%	33%	52%	46%

Notes: This table present the component of bid-ask spread around US's inflation announcement from Huang and Stoll model (equation (11), (12) and (13)) . NE, Pre and Post stand for non-event, pre-event and event period.

The switching in bid-ask shape around the interested event is presented in table 5.3 to 5.6. Bank A tends to adjust the component around the central bank's interest rate decision, result is shown in table 5.3 and 5.4. The spread leans to wide on the day before interest rate policy announcement (Pre-event date) and narrow down after publication. The spread rising is derived from adverse selection component (panel B), especially 1-month tenor which increase from 11 percent on non-event date to 25 percent on pre-event date. We found this pattern in almost every tenor. For FOMC's mandate economic data announcement, we found ambiguous pattern; the change in spread is mixing while the component is persisting.

For Thai and US monetary policy decision, we disclose the similar pattern of bank B to bank A for 3-month tenor and 6-month tenor. While the short-term contract, 1-month tenor, has reverse adjustment. In contrast to bank A for non-farm payroll announcement, bank B inclines to raise the spread and adverse selection component on pre-event date for 1-month contract but indifferent in 3-month and 6-month is not found. In addition, unexpectedly, bank B narrows spread before CPI announcement and widen it again after the announcement.

Bank C adjusts their 1-month contract in most interested events but mixed direction. For policy rate decision and CPI announcement, they shrink the spread on pre-event mostly from inventory holding cost but asymmetric information component increase. The longer tenor spread widens in almost the whole event caused by adverse selection.

Considering to small bank adjustment, in monetary policy decision, bank D behaves similar to bank A and B that rising the spread due to adverse selection component on pre-event date and shrinking them after the publishing.

There are three key takeaways here from these findings. First, bank tends to adjust bid-ask spread and component during the central banks' monetary policy meeting, especially pre-event date. The explanation might be the directly impact to forward rate when the central bank decide to change the policy rate, through new interest rate differential, even the market might partially price-in the chance.

Secondly, only some banks rebalance their component reacting to US's economic data announcement, this may reflect only pricing style of each market maker and need more further investigation in the future research.

Third, the variation in spread is mainly derived by adverse selection component. The potential reason for adverse selection component leaping during Thai monetary policy meeting probably comes from the market maker concerning that real sector corporation may have some private information. Because the real sector tends to have better information on their business which probably reflects current economy condition, they might forecast the MPC decision more accurately. So market maker might widen the spread to compensate this information lacking.

The potential explanation for adverse selection component adjustment around US monetary policy meeting may be derived from market maker's possible deficient information that corporates' in-house analyst might have, especially their own industry information, e.g. oil and agricultural price trend forecasting.

The last evidence is component in each THB cycle, the result is provided in table 5.7. Since bank C has the data after 2010, we drop them out of this step. We found the dilated spread in period 2, during March 2008 to March 2009. This cycle is the occurrence of global financial crisis so a lot of uncertainty and private information overwhelm the market in this period. The result shows that adverse selection raise in this certain period in almost every tenor. It should be noted that the result reconfirms the visualization in figure 1.2.

Table 5.7: Component of spread from Huang and Stoll model in each THB trend period

		1M					3M					6M				
	Period	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
Panel A: Two-way decomposition																
Bank A	**Spread (satang)**	5.8	6.2	6.3	5.8	5.0	6.5	9.3	7.8	7.2	8.8	8.8	13.6	9.5	6.6	7.4
	IC + AS (%)	65	51	44	38	42	38	37	60	35	52	46	31	43	43	44
	OP (%)	35	49	56	62	58	62	63	40	65	48	54	69	57	57	56
Bank B	**Spread (satang)**	6.1	9.0	4.0	3.8	3.6	6.0	9.4	7.6	7.4	7.5	10.4	13.2	9.4	9.2	9.5
	IC + AS (%)	35	43	46	39	42	63	61	56	63	42	48	53	47	55	46
	OP (%)	65	57	54	61	58	37	39	44	37	58	52	47	53	45	54
Bank D	**spread**	13.8	24.2	9.6	11.1	14.7	10.9	19.4	16.3	15.4	6.5	9.1	10.4	8.2	11.0	7.8
	IC + AS (%)	75	79	64	73	71	71	70	68	71	71	85	62	67	70	76
	OP (%)	25	21	36	27	29	29	30	32	29	29	15	38	33	30	24
Panel B: Three-way decomposition																
Bank A	**Trade reversal**	26	26	40	32	26	23	24	37	21	24	30	32	35	27	27
	Spread (satang)	5.8	6.4	6.3	6.3	5.0	6.4	9.6	7.8	7.2	8.8	8.8	14.1	9.7	7.3	7.4
	AS (%)	15	17	11	5	7	5	6	2	3	1	7	8	2	4	2
	IC (%)	45	31	36	32	30	39	31	61	42	47	40	30	40	39	39
	OP (%)	40	52	53	63	63	56	63	37	55	52	53	62	58	57	59
Bank B	**Trade reversal**	15	20	33	21	19	22	22	35	15	20	24	30	27	27	26
	Spread (satang)	6.0	9.2	4.0	4.2	3.7	6.2	9.5	7.6	7.9	7.5	10.4	13.2	9.4	9.1	9.5
	AS (%)	8	14	3	5	4	24	17	6	7	6	13	14	0	1	3
	IC (%)	26	28	37	34	41	45	41	41	46	39	34	39	47	53	46
	OP (%)	66	58	60	61	55	31	42	53	47	55	53	47	53	46	51
Bank D	**Trade reversal**	22	23	31	28	27	26	25	30	19	24	26	26	24	31	28
	Spread (satang)	13.5	24.1	9.4	11.1	14.6	10.9	19.4	16.3	14.4	6.5	9.1	10.4	8.0	11.0	7.8
	AS (%)	36	43	27	19	15	26	27	14	6	15	21	18	15	10	13
	IC (%)	35	36	37	53	59	45	42	57	64	61	61	54	53	57	58
	OP (%)	29	21	36	28	26	29	31	29	30	24	18	28	32	33	29

Notes: This table present the component of bid-ask spread during each THB trend movement from Huang and Stoll model (equation (4), (5) and (6)) . Period 1, 2, 3, 4 and 5 cover Jan 2006 to Feb 2008, Mar 2008 to Mar 2009, Apr 2009 to Nov 2010, Dec 2010 to Apr 2013, and May 2013 to Dec 2016, respectively.

CHAPTER 6
CONCLUSIONS

In market microstructure model, the bid-ask spread consists of three components; order processing cost, inventory holding cost, and adverse selection cost. Discovering these relative spread is useful for policy maker for designing the market and achieving narrow trading cost.

This presented study attempts to answer at least two questions; first what is the shape of bid-ask spread in FX forward market in Thailand. FX forward is OTC transaction and generally do not observe the transacted price in public. This article obtains unique dataset of all FX forward transaction for goods hedging propose during 2006 to 2016 from Bank of Thailand. The finding shows the important of order processing cost as majority of market maker pricing, around half of the spread. The second major cost is inventory cost, about 40 percent of total spread, while adverse selection is cost in the least proportion. The second question is whether the component varies during some specific event. I define the interested event as Thai and US monetary policy, US's non-farm payroll announcement and US's inflation announcement. The evidence discloses that the market maker tends to raise the spread, mostly derived by adverse selection component, for monetary policy event on the pre-event date. Market maker reacts ambiguous for non-farm payroll announcement; some raise the spread, some shrink the spread and some do not adjust significantly. US's inflation announcement does not impact the component that much.

The implication to policy maker from these findings is that they can reduce the spread by focusing to reduce order processing cost and inventory holding cost. Compressing order processing cost, the policy makers have to enhance the market liquidity which resulting to lower in fixed cost per trade. The example of liquidity improvement is encouraging the entrepreneurs to hedge the FX risk which result to market liquidity improvement; however, BOT has been already promoted this activity all the time. The other suggestion is enhancing more competitive environment by assigning

more market maker. More market maker not only creates narrower spread, due to competitive, but also higher chance to capture more client-base yielding more volume in the overall market. The financial technology (FinTech) is also the considered solution in order processing cost reduction. Currently, some global banks begin offering their corporate clients the online FX trading and hedging. This kind of e-platform originates a lot of cost saving to the bank and derives to lower fixed cost per trading. However, nowadays, this platform is only the service for big company customer. The policy maker might consider enhancing local market makers developing their own platforms and promote this channel to the end-user.

Also, the liquidity improvement is prone to squeeze the inventory holding component, derived from more chance of opposite trading flows. Nevertheless, because market makers do not want to hold the position over the night causing them price the inventory component, the potential way to shrink this component might be allowing bank to square FX forward position among themselves before the end of the day. Notwithstanding, this process works only when overall market has balance between buying and selling flows. Then I calculate to answer how trading daily flows of the whole market look like and the result show in Figure 6.1 to 6.6. Figure 6.1, 6.3 and 6.5 represents the daily trade balance for 1-month, 3-month and 6-month FX forward, respectively, while figure 6.2, 6.4 and 6.6 show the summation by bank that have excess selling flows and buying flows, noted that summation of two line in figure 6.2, 6.4 and 6.6 results the line in figure 6.1, 6.3 and 6.5. In essence, our suggesting benefits a lot for 3-month tenor and 6-month tenor, because, in the whole system, the excess buying is approximate to excess selling lead to the figure 6.3 and 6.5 that the overall system position move around zero. Nevertheless, 1-month tenor might not get the benefit from our idea that much, because this tenor is overwhelmed by importer transaction (figure 6.2). So almost every bank has excess position in selling 1-month FX forward causing non-additional advantage even they can trade among them. Still, our suggestion is certainly benefit to 3-month and 6-month, so the policy maker might consider creating

the platform that allows the market maker to trade between themselves. As a result, the end-user can enjoy with the possible narrower spread.

Figure 6.1: Net transactions for 1-month FX forward

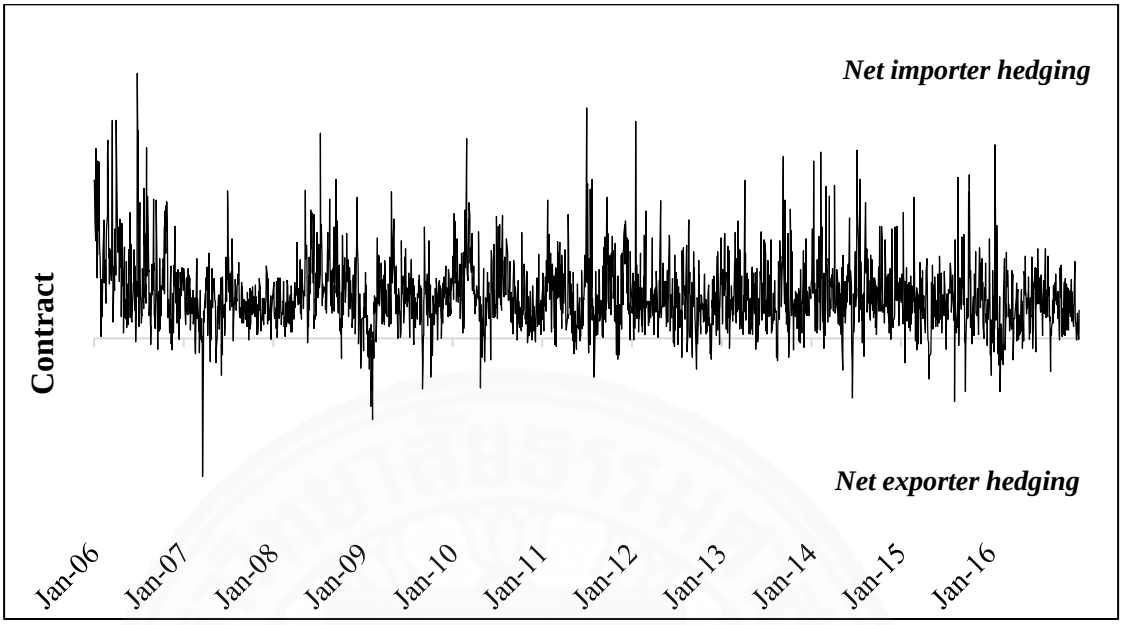


Figure 6.2: Summation of net transaction of 1-month FX forward by bank

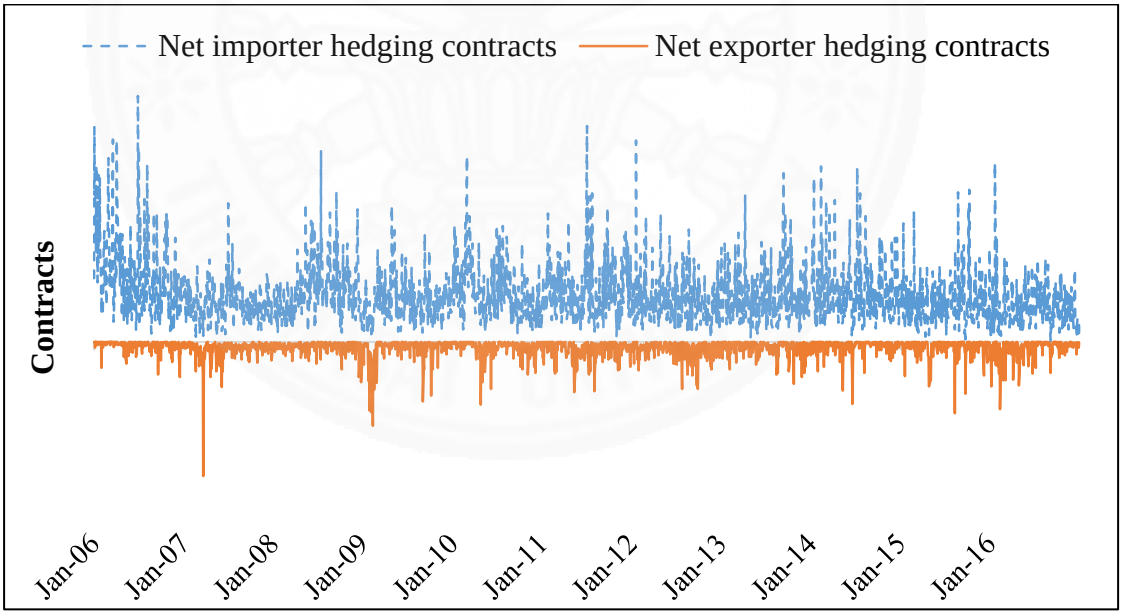


Figure 6.3: Net transactions for 3-month FX forward

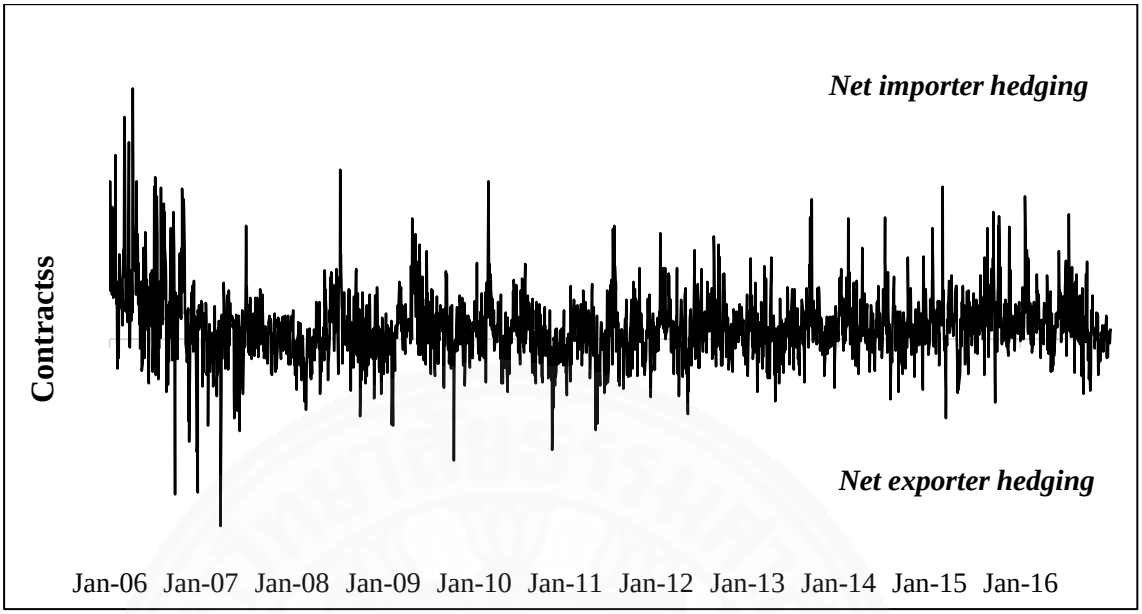


Figure 6.4: Summation of net transaction of 3-month FX forward by bank

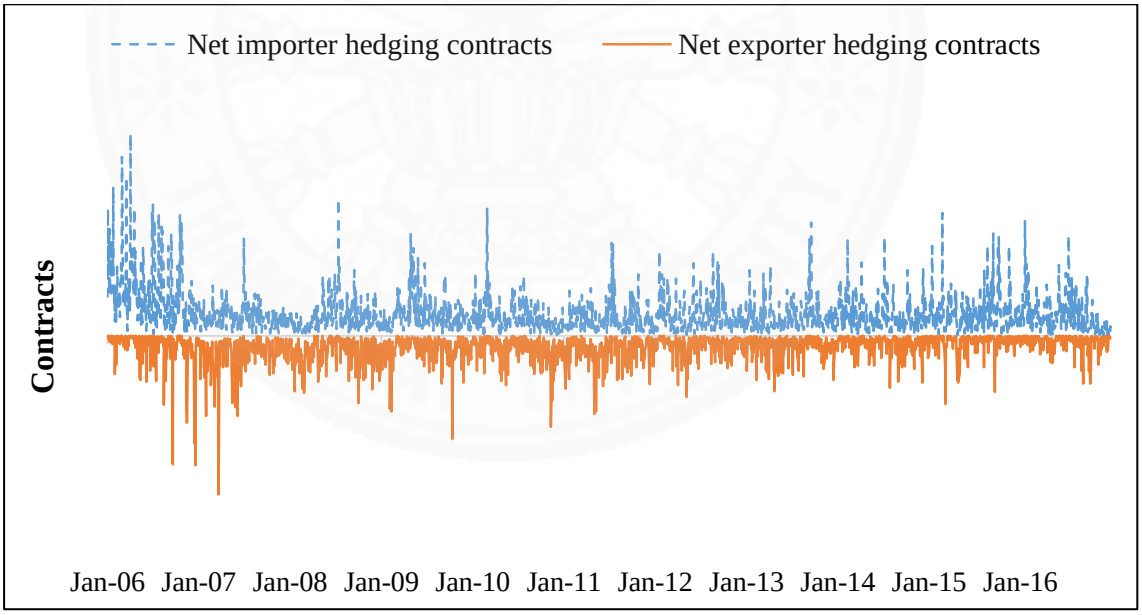


Figure 6.5: Net transactions for 6-month FX forward

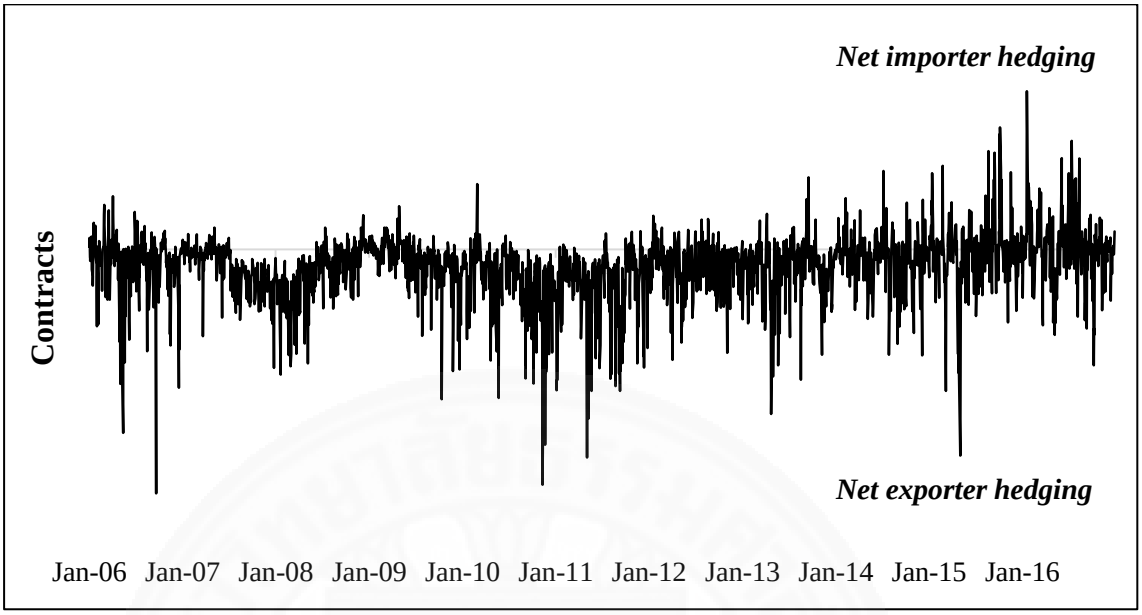
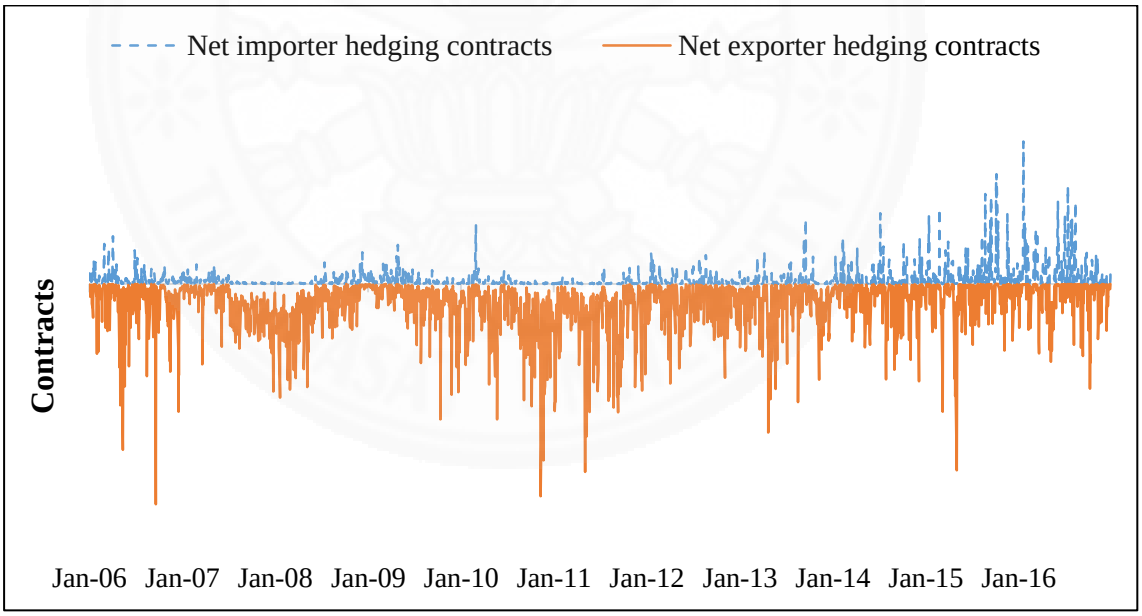


Figure 6.6: Summation of net transaction of 6-month FX forward by bank



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APPENDICES

APPENDIX A
THE DERIVATION OF HUANG AND STOLL (1997) TWO-WAY DECOMPOSITION VERSION

The change in equation (1b) can be derived as,

$$\Delta M_t = V_t - V_{t-1} + \beta \frac{S}{2} \sum_{i=1}^{t-1} I_i - \beta \frac{S}{2} \sum_{i=0}^{t-2} I_{i-1}$$

$$\Delta M_t = V_t - V_{t-1} + \beta \frac{S}{2} \sum_{i=1}^{t-1} I_i - \beta \frac{S}{2} \sum_{i=0}^{t-2} I_{i-1}$$

Then, substitute equation (1a), $V_t = V_{t-1} + \alpha \frac{S}{2} I_{t-1} + e_t$

$$\Delta M_t = V_{t-1} + \alpha \frac{S}{2} I_{t-1} + e_t - V_{t-1} + \beta \frac{S}{2} \sum_{i=1}^{t-1} I_i - \beta \frac{S}{2} \sum_{i=0}^{t-2} I_{i-1}$$

$$\Delta M_t = \alpha \frac{S}{2} I_{t-1} + \beta \frac{S}{2} I_{t-1} + \mu_t$$

$$\Delta M_t = (\alpha + \beta) \frac{S}{2} I_{t-1} + \mu_t$$

Next, we can derive the first difference of equation (1c) as the following,

$$\Delta P_t = \Delta \left(M_t + \frac{S}{2} I_t + \mu_t \right)$$

$$\Delta P_t = \Delta M_t + \Delta \frac{S}{2} I_t + \Delta \mu_t$$

$$\Delta P_t = \Delta M_t + \frac{S}{2} I_t - \frac{S}{2} I_{t-1} + \varepsilon_t$$

Then, combine above equation with equation (2) results the regression of observable transaction price process, equation (3).

$$\Delta P_t = (\alpha + \beta) \frac{S}{2} I_{t-1} + \mu_t + \frac{S}{2} I_t - \frac{S}{2} I_{t-1} + \varepsilon_t$$

$$\Delta P_t = (\alpha + \beta)\frac{S}{2} I_{t-1} + \frac{S}{2} I_t - \frac{S}{2} I_{t-1} + e_t$$

Defining $\alpha + \beta = \lambda$,

$$\Delta P_t = \lambda \frac{S}{2} I_{t-1} + \frac{S}{2} I_t - \frac{S}{2} I_{t-1} + e_t$$

$$\Delta P_t = \frac{S}{2} I_t + (\lambda - 1)\frac{S}{2} I_{t-1} + e_t$$

APPENDIX B

THE DERIVATION OF HUANG AND STOLL (1997) THREE-WAY DECOMPOSITION VERSION

To check whether the spread and component differ during the interest event or not, I start from adjust equation (1a), (1b) and (1c) as following,

$$V_t = V_{t-1} + \alpha_{NE}\frac{S}{2}D_{NE}I_{t-1} + \alpha_{PE}\frac{S}{2}D_{PE}I_{t-1} + \alpha_{EV}\frac{S}{2}D_{EV}I_{t-1} + \nu_t \quad \text{(a)}$$

$$M_t = V_t + \beta_{NE}\frac{S}{2}\sum_{i=1}^{t-1} D_{NE}I_i + \beta_{PE}\frac{S}{2}\sum_{i=1}^{t-1} D_{PE}I_i + \beta_{EV}\frac{S}{2}\sum_{i=1}^{t-1} D_{EV}I_i \quad \text{(b)}$$

$$P_t = M_t + \frac{S}{2}D_{NE}I_t + \frac{S}{2}D_{PE}I_t + \frac{S}{2}D_{EV}I_t + e_t \quad \text{(c)}$$

Then, we can take the first difference in equation (b),

$$\Delta M_t = V_t - V_{t-1} + \left[\beta_{NE}\frac{S}{2}\sum_{i=1}^{t-1} D_{NE}I_i + \beta_{PE}\frac{S}{2}\sum_{i=1}^{t-1} D_{PE}I_i + \beta_{EV}\frac{S}{2}\sum_{i=1}^{t-1} D_{EV}I_i\right] - \left[\beta_{NE}\frac{S}{2}\sum_{i=0}^{t-2} D_{NE}I_i + \beta_{PE}\frac{S}{2}\sum_{i=0}^{t-2} D_{PE}I_i + \beta_{EV}\frac{S}{2}\sum_{i=0}^{t-2} D_{EV}I_i\right]$$

Substitute (a) back and rearrange the term,

$$\Delta M_t = V_{t-1} + \alpha_{NE}\frac{S}{2}D_{NE}I_{t-1} + \alpha_{PE}\frac{S}{2}D_{PE}I_{t-1} + \alpha_{EV}\frac{S}{2}D_{EV}I_{t-1} - V_{t-1} + \left[\beta_{NE}\frac{S}{2}\sum_{i=1}^{t-1} D_{NE}I_i + \beta_{PE}\frac{S}{2}\sum_{i=1}^{t-1} D_{PE}I_i + \beta_{EV}\frac{S}{2}\sum_{i=1}^{t-1} D_{EV}I_i\right] - \left[\beta_{NE}\frac{S}{2}\sum_{i=0}^{t-2} D_{NE}I_i + \beta_{PE}\frac{S}{2}\sum_{i=0}^{t-2} D_{PE}I_i + \beta_{EV}\frac{S}{2}\sum_{i=0}^{t-2} D_{EV}I_i\right]$$

$$\Delta M_t = (\alpha_{NE} + \beta_{NE})\frac{S_{NE}}{2}D_{NE}I_{t-1} + (\alpha_{PE} + \beta_{PE})\frac{S_{PE}}{2}D_{PE}I_{t-1} + (\alpha_{EV} + \beta_{EV})\frac{S_{EV}}{2}D_{EV}I_{t-1} \quad \text{(d)}$$

Defining $\alpha_i + \beta_i = \lambda_i$, we can rearrange the term as,

$$\Delta M_t = \lambda_{NE} \frac{S_{NE}}{2} D_{NE} I_{t-1} + \lambda_{PE} \frac{S_{PE}}{2} D_{PE} I_{t-1} + \lambda_{EV} \frac{S_{EV}}{2} D_{EV} I_{t-1} \quad \text{(e)}$$

Then, taking the first different of equation (c),

$$\Delta P_t = \Delta M_t + \Delta \left[\frac{S}{2} D_{NE} I_t + \frac{S}{2} D_{PE} I_t + \frac{S}{2} D_{EV} I_t \right]$$

$$\Delta P_t = \Delta M_t + \frac{S}{2} D_{NE} I_t - \frac{S}{2} D_{NE} I_{t-1} + \frac{S}{2} D_{PE} I_t - \frac{S}{2} D_{PE} I_{t-1} + \frac{S}{2} D_{EV} I_t - \frac{S}{2} D_{EV} I_{t-1} \quad \text{(f)}$$

Substitute (e) into (f), we get the regression equation.

$$\Delta P_t = \lambda_{NE} \frac{S_{NE}}{2} D_{NE} I_{t-1} + \lambda_{PE} \frac{S_{PE}}{2} D_{PE} I_{t-1} + \lambda_{EV} \frac{S_{EV}}{2} D_{EV} I_{t-1} + \frac{S}{2} D_{NE} I_t - \frac{S}{2} D_{NE} I_{t-1} + \frac{S}{2} D_{PE} I_t - \frac{S}{2} D_{PE} I_{t-1} + \frac{S}{2} D_{EV} I_t - \frac{S}{2} D_{EV} I_{t-1}$$

$$\Delta P_t = \frac{S}{2} D_{NE} I_t + \frac{S}{2} D_{PE} I_t + \frac{S}{2} D_{EV} I_t + (\lambda_{NE} - 1) \frac{S_{NE}}{2} D_{NE} I_{t-1} + (\lambda_{PE} - 1) \frac{S_{PE}}{2} D_{PE} I_{t-1} + (\lambda_{EV} - 1) \frac{S_{EV}}{2} D_{EV} I_{t-1}$$

APPENDIX C

THAI'S MPC MEETING AND RATE DECISION

Date	Interest rate decision	Previous rate	Chg. Policy rate	Date	Interest rate decision	Previous rate	Chg. Policy rate
9-Jun-06	5	4.75	0.25	9-Mar-11	2.5	2.25	0.25
17-Jan-07	4.75	5	-0.25	20-Apr-11	2.75	2.5	0.25
28-Feb-07	4.25	4.75	-0.5	1-Jun-11	3	2.75	0.25
11-Apr-07	4	4.25	-0.25	13-Jul-11	3.25	3	0.25
23-May-07	3.5	4	-0.5	24-Aug-11	3.5	3.25	0.25
18-Jul-07	3.25	3.5	-0.25	19-Oct-11	3.5	3.5	0
29-Aug-07	3.25	3.25	0	30-Nov-11	3.25	3.5	-0.25
10-Oct-07	3.25	3.25	0	25-Jan-12	3	3.25	-0.25
4-Dec-07	3.25	3.25	0	21-Mar-12	3	3	0
16-Jan-08	3.25	3.25	0	2-May-12	3	3	0
27-Feb-08	3.25	3.25	0	13-Jun-12	3	3	0
9-Apr-08	3.25	3.25	0	25-Jul-12	3	3	0
21-May-08	3.25	3.25	0	17-Oct-12	2.75	3	-0.25
16-Jul-08	3.5	3.25	0.25	28-Nov-12	2.75	2.75	0
27-Aug-08	3.75	3.5	0.25	9-Jan-13	2.75	2.75	0
8-Oct-08	3.75	3.75	0	20-Feb-13	2.75	2.75	0
3-Dec-08	2.75	3.75	-1	3-Apr-13	2.75	2.75	0
14-Jan-09	2	2.75	-0.75	29-May-13	2.5	2.75	-0.25
25-Feb-09	1.5	2	-0.5	10-Jul-13	2.5	2.5	0
8-Apr-09	1.25	1.5	-0.25	21-Aug-13	2.5	2.5	0
20-May-09	1.25	1.25	0	16-Oct-13	2.5	2.5	0
15-Jul-09	1.25	1.25	0	27-Nov-13	2.25	2.5	-0.25
26-Aug-09	1.25	1.25	0	22-Jan-14	2.25	2.25	0
21-Oct-09	1.25	1.25	0	12-Mar-14	2	2.25	-0.25
2-Dec-09	1.25	1.25	0	23-Apr-14	2	2	0
13-Jan-10	1.25	1.25	0	18-Jun-14	2	2	0
10-Mar-10	1.25	1.25	0	6-Aug-14	2	2	0
21-Apr-10	1.25	1.25	0	17-Sep-14	2	2	0
2-Jun-10	1.25	1.25	0	5-Nov-14	2	2	0
14-Jul-10	1.5	1.25	0.25	17-Dec-14	2	2	0
25-Aug-10	1.75	1.5	0.25	28-Jan-15	2	2	0
20-Oct-10	1.75	1.75	0	11-Mar-15	1.75	2	-0.25
1-Dec-10	2	1.75	0.25	29-Apr-15	1.5	1.75	-0.25
12-Jan-11	2.25	2	0.25	10-Jun-15	1.5	1.5	0

APPENDIX C

THAI'S MPC MEETING AND RATE DECISION (CONTINUE)

Date	Interest rate decision	Previous rate	Chg. Policy rate
5-Aug-15	1.5	1.5	0
16-Sep-15	1.5	1.5	0
4-Nov-15	1.5	1.5	0
16-Dec-15	1.5	1.5	0
3-Feb-16	1.5	1.5	0
23-Mar-16	1.5	1.5	0
19-Apr-16	1.5	1.5	0
11-May-16	1.5	1.5	0
22-Jun-16	1.5	1.5	0
14-Sep-16	1.5	1.5	0
9-Nov-16	1.5	1.5	0
21-Dec-16	1.5	1.5	0

APPENDIX D

FOMC MEETING

Date	Interest rate decision	Previous rate	Chg. Policy rate	Date	Interest rate decision	Previous rate	Chg. Policy rate
31-Jan-06	4.5	4.25	0.25	28-Apr-10	0.25	0.25	0
28-Mar-06	4.75	4.5	0.25	23-Jun-10	0.25	0.25	0
10-May-06	5	4.75	0.25	10-Aug-10	0.25	0.25	0
29-Jun-06	5.25	5	0.25	21-Sep-10	0.25	0.25	0
8-Aug-06	5.25	5.25	0	3-Nov-10	0.25	0.25	0
19-Sep-06	5.25	5.25	0	14-Dec-10	0.25	0.25	0
25-Oct-06	5.25	5.25	0	26-Jan-11	0.25	0.25	0
12-Dec-06	5.25	5.25	0	15-Mar-11	0.25	0.25	0
31-Jan-07	5.25	5.25	0	27-Apr-11	0.25	0.25	0
21-Mar-07	5.25	5.25	0	22-Jun-11	0.25	0.25	0
9-May-07	5.25	5.25	0	9-Aug-11	0.25	0.25	0
28-Jun-07	5.25	5.25	0	21-Sep-11	0.25	0.25	0
7-Aug-07	5.25	5.25	0	2-Nov-11	0.25	0.25	0
18-Sep-07	4.75	5.25	-0.5	13-Dec-11	0.25	0.25	0
31-Oct-07	4.5	4.75	-0.25	25-Jan-12	0.25	0.25	0
11-Dec-07	4.25	4.5	-0.25	13-Mar-12	0.25	0.25	0
22-Jan-08	3.5	4.25	-0.75	25-Apr-12	0.25	0.25	0
18-Mar-08	2.25	3	-0.75	20-Jun-12	0.25	0.25	0
30-Apr-08	2	2.25	-0.25	1-Aug-12	0.25	0.25	0
25-Jun-08	2	2	0	13-Sep-12	0.25	0.25	0
5-Aug-08	2	2	0	24-Oct-12	0.25	0.25	0
16-Sep-08	2	2	0	12-Dec-12	0.25	0.25	0
28-Oct-08	1.5	1.5	0	30-Jan-13	0.25	0.25	0
16-Dec-08	0.25	1	-0.75	20-Mar-13	0.25	0.25	0
28-Jan-09	0.25	0.25	0	30-Apr-13	0.25	0.25	0
18-Mar-09	0.25	0.25	0	19-Jun-13	0.25	0.25	0
29-Apr-09	0.25	0.25	0	31-Jul-13	0.25	0.25	0
24-Jun-09	0.25	0.25	0	18-Sep-13	0.25	0.25	0
10-Aug-09	0.25	0.25	0	30-Oct-13	0.25	0.25	0
23-Sep-09	0.25	0.25	0	18-Dec-13	0.25	0.25	0
4-Nov-09	0.25	0.25	0	29-Jan-14	0.25	0.25	0
16-Dec-09	0.25	0.25	0	19-Mar-14	0.25	0.25	0
27-Jan-10	0.25	0.25	0	30-Apr-14	0.25	0.25	0
16-Mar-10	0.25	0.25	0	18-Jun-14	0.25	0.25	0

APPENDIX D

FOMC MEETING (CONTINUE)

Date	Interest rate decision	Previous rate	Chg. Policy rate
30-Jul-14	0.25	0.25	0
17-Sep-14	0.25	0.25	0
29-Oct-14	0.25	0.25	0
17-Dec-14	0.25	0.25	0
28-Jan-15	0.25	0.25	0
18-Mar-15	0.25	0.25	0
29-Apr-15	0.25	0.25	0
17-Jun-15	0.25	0.25	0
29-Jul-15	0.25	0.25	0
17-Sep-15	0.25	0.25	0
28-Oct-15	0.25	0.25	0
16-Dec-15	0.5	0.25	0.25
27-Jan-16	0.5	0.5	0
16-Mar-16	0.5	0.5	0
27-Apr-16	0.5	0.5	0
15-Jun-16	0.5	0.5	0
27-Jul-16	0.5	0.5	0
21-Sep-16	0.5	0.5	0
2-Nov-16	0.5	0.5	0
14-Dec-16	0.75	0.5	0.25

APPENDIX E

NON-FARM PAYROLL WINDOW AND DATA ANNOUNCEMENT

Date	Actual	Reuters Poll
18-Jan-06	3.40%	na
22-Feb-06	4.00%	na
16-Mar-06	3.60%	na
18-Apr-06	3.40%	3.50%
17-May-06	3.50%	3.50%
14-Jun-06	4.20%	3.90%
19-Jul-06	4.30%	4.30%
16-Aug-06	4.10%	4.20%
15-Sep-06	3.80%	3.90%
18-Oct-06	2.10%	2.20%
16-Nov-06	1.30%	1.50%
15-Dec-06	2.00%	2.20%
18-Jan-07	2.50%	2.40%
21-Feb-07	2.10%	2.00%
16-Mar-07	2.40%	2.30%
17-Apr-07	2.80%	2.80%
15-May-07	2.60%	2.70%
15-Jun-07	2.70%	2.60%
18-Jul-07	2.70%	2.60%
15-Aug-07	2.40%	2.40%
19-Sep-07	2.00%	2.10%
17-Oct-07	2.80%	2.80%
15-Nov-07	3.50%	na
14-Dec-07	4.30%	4.10%
16-Jan-08	4.10%	4.20%
20-Feb-08	4.30%	4.30%
14-Mar-08	4.00%	4.00%
16-Apr-08	4.00%	4.00%
14-May-08	3.90%	3.90%
13-Jun-08	4.20%	4.50%
16-Jul-08	5.00%	5.10%
14-Aug-08	5.60%	5.50%
16-Sep-08	5.40%	5.00%
16-Oct-08	4.90%	4.00%

Date	Actual	Reuters Poll
19-Nov-08	3.70%	1.50%
16-Dec-08	1.10%	-0.20%
16-Jan-09	0.10%	-0.20%
20-Feb-09	0.00%	0.00%
18-Mar-09	0.20%	-0.10%
10-Apr-09	-0.40%	-0.60%
15-May-09	-0.70%	-0.90%
17-Jun-09	-1.30%	-1.50%
15-Jul-09	-1.40%	-2.00%
14-Aug-09	-2.10%	-1.70%
16-Sep-09	-1.50%	-1.40%
15-Oct-09	-1.30%	-0.30%
18-Nov-09	-0.20%	1.80%
16-Dec-09	1.80%	2.80%
15-Jan-10	2.70%	2.80%
19-Feb-10	2.60%	2.30%
18-Mar-10	2.10%	2.40%
12-Apr-10	2.30%	2.40%
19-May-10	2.20%	2.00%
17-Jun-10	2.00%	1.20%
16-Jul-10	1.10%	1.20%
11-Aug-10	1.20%	1.10%
17-Sep-10	1.10%	1.20%
15-Oct-10	1.10%	1.30%
17-Nov-10	1.20%	1.10%
15-Dec-10	1.10%	1.30%
14-Jan-11	1.50%	1.60%
17-Feb-11	1.60%	2.00%
17-Mar-11	2.10%	2.60%
12-Apr-11	2.70%	3.10%
13-May-11	3.20%	3.40%
15-Jun-11	3.60%	3.60%
14-Jul-11	3.60%	3.30%
18-Aug-11	3.60%	3.60%

APPENDIX E

NON-FARM PAYROLL WINDOW AND DATA ANNOUNCEMENT (CONTINUE)

Date	Actual	Reuters Poll
15-Sep-11	3.80%	3.80%
19-Oct-11	3.90%	3.60%
16-Nov-11	3.50%	3.50%
16-Dec-11	3.40%	3.00%
19-Jan-12	3.00%	2.90%
17-Feb-12	2.90%	2.90%
16-Mar-12	2.90%	2.70%
12-Apr-12	2.70%	2.30%
15-May-12	2.30%	1.80%
14-Jun-12	1.70%	1.60%
17-Jul-12	1.70%	1.60%
15-Aug-12	1.40%	1.70%
14-Sep-12	1.70%	1.90%
16-Oct-12	2.00%	2.10%
15-Nov-12	2.20%	1.90%
14-Dec-12	1.80%	1.80%
16-Jan-13	1.70%	1.60%
21-Feb-13	1.60%	1.90%
15-Mar-13	2.00%	1.60%
12-Apr-13	1.50%	1.30%
16-May-13	1.10%	1.40%
18-Jun-13	1.40%	1.70%
16-Jul-13	1.80%	2.00%
15-Aug-13	2.00%	1.60%
17-Sep-13	1.50%	1.20%
30-Oct-13	1.20%	1.00%
20-Nov-13	1.00%	1.30%
17-Dec-13	1.20%	1.50%
16-Jan-14	1.50%	1.60%
20-Feb-14	1.60%	1.20%
18-Mar-14	1.10%	1.40%
11-Apr-14	1.50%	2.00%
15-May-14	2.00%	2.00%
17-Jun-14	2.10%	2.10%
22-Jul-14	2.10%	2.00%
19-Aug-14	2.00%	1.90%
17-Sep-14	1.70%	1.60%
22-Oct-14	1.70%	1.60%
20-Nov-14	1.70%	140.00%
17-Dec-14	1.30%	70.00%
16-Jan-15	0.80%	-10.00%
26-Feb-15	-0.10%	-10.00%
24-Mar-15	0.00%	0.00%
17-Apr-15	-0.10%	-10.00%
22-May-15	-0.20%	0.00%
18-Jun-15	0.00%	10.00%
17-Jul-15	0.10%	20.00%
19-Aug-15	0.20%	20.00%
16-Sep-15	0.20%	-10.00%
15-Oct-15	0.00%	10.00%
17-Nov-15	0.20%	40.00%
15-Dec-15	0.50%	80.00%
20-Jan-16	0.70%	130.00%
19-Feb-16	1.40%	90.00%
16-Mar-16	1.00%	110.00%
12-Apr-16	0.90%	110.00%
17-May-16	1.10%	110.00%
16-Jun-16	1.00%	110.00%
15-Jul-16	1.00%	90.00%
16-Aug-16	0.80%	100.00%
16-Sep-16	1.10%	150.00%
18-Oct-16	1.50%	160.00%
17-Nov-16	1.60%	170.00%
15-Dec-16	1.70%	210.00%

APPENDIX F

CPI WINDOW AND DATA ANNOUNCEMENT

Date	Actual	Reuters Poll	Date	Actual	Reuters Poll
6-Jan-06	157,000	200,000	7-Nov-08	-474,000	-200,000
3-Feb-06	278,000	225,000	4-Dec-08	-766,000	-340,000
10-Mar-06	315,000	210,000	9-Jan-09	-694,000	-500,000
7-Apr-06	282,000	190,000	6-Feb-09	-793,000	-525,000
4-May-06	183,000	200,000	6-Mar-09	-702,000	-648,000
2-Jun-06	25,000	175,000	3-Apr-09	-823,000	-650,000
7-Jul-06	79,000	155,000	7-May-09	-687,000	-620,000
4-Aug-06	206,000	142,000	5-Jun-09	-349,000	-520,000
1-Sep-06	183,000	120,000	2-Jul-09	-471,000	-363,000
6-Oct-06	153,000	125,000	7-Aug-09	-329,000	-320,000
3-Nov-06	8,000	125,000	4-Sep-09	-213,000	-225,000
8-Dec-06	209,000	110,000	2-Oct-09	-220,000	-180,000
5-Jan-07	171,000	100,000	6-Nov-09	-204,000	-175,000
2-Feb-07	240,000	149,000	4-Dec-09	-2,000	-130,000
9-Mar-07	89,000	100,000	8-Jan-10	-275,000	-8,000
5-Apr-07	190,000	120,000	5-Feb-10	23,000	5,000
4-May-07	80,000	110,000	5-Mar-10	-68,000	-50,000
1-Jun-07	143,000	130,000	2-Apr-10	164,000	190,000
6-Jul-07	75,000	120,000	7-May-10	243,000	200,000
3-Aug-07	-34,000	130,000	4-Jun-10	524,000	513,000
7-Sep-07	-20,000	110,000	2-Jul-10	-137,000	-110,000
5-Oct-07	88,000	94,000	6-Aug-10	-68,000	-65,000
2-Nov-07	84,000	80,000	3-Sep-10	-36,000	-100,000
7-Dec-07	114,000	75,000	8-Oct-10	-52,000	na
4-Jan-08	98,000	na	5-Nov-10	262,000	60,000
1-Feb-08	17,000	63,000	3-Dec-10	119,000	140,000
7-Mar-08	-84,000	25,000	7-Jan-11	87,000	175,000
4-Apr-08	-78,000	-58,000	4-Feb-11	43,000	145,000
2-May-08	-210,000	-80,000	4-Mar-11	189,000	185,000
6-Jun-08	-186,000	-58,000	1-Apr-11	225,000	190,000
3-Jul-08	-162,000	-60,000	6-May-11	346,000	186,000
1-Aug-08	-213,000	-75,000	3-Jun-11	77,000	150,000
5-Sep-08	-267,000	-75,000	8-Jul-11	225,000	90,000
3-Oct-08	-450,000	-100,000	5-Aug-11	69,000	85,000

APPENDIX F

CPI WINDOW AND DATA ANNOUNCEMENT (CONTINUE)

Date	Actual	Reuters Poll
2-Sep-11	110,000	75,000
7-Oct-11	248,000	60,000
4-Nov-11	209,000	95,000
2-Dec-11	141,000	122,000
6-Jan-12	209,000	150,000
3-Feb-12	358,000	150,000
9-Mar-12	237,000	210,000
5-Apr-12	233,000	203,000
4-May-12	78,000	175,000
1-Jun-12	115,000	150,000
6-Jul-12	76,000	90,000
3-Aug-12	143,000	100,000
7-Sep-12	177,000	125,000
5-Oct-12	203,000	113,000
2-Nov-12	146,000	125,000
7-Dec-12	132,000	93,000
4-Jan-13	244,000	150,000
1-Feb-13	211,000	160,000
8-Mar-13	286,000	160,000
5-Apr-13	130,000	200,000
3-May-13	197,000	145,000
7-Jun-13	226,000	170,000
5-Jul-13	162,000	165,000
2-Aug-13	122,000	184,000
6-Sep-13	261,000	180,000
22-Oct-13	190,000	180,000
8-Nov-13	212,000	125,000
6-Dec-13	258,000	180,000
10-Jan-14	47,000	196,000
7-Feb-14	190,000	185,000
7-Mar-14	151,000	149,000
4-Apr-14	272,000	200,000

Date	Actual	Reuters Poll
2-May-14	329,000	210,000
6-Jun-14	246,000	218,000
3-Jul-14	304,000	212,000
1-Aug-14	202,000	233,000
5-Sep-14	230,000	225,000
3-Oct-14	280,000	215,000
7-Nov-14	227,000	231,000
4-Dec-14	312,000	230,000
9-Jan-15	255,000	240,000
6-Feb-15	234,000	234,000
6-Mar-15	238,000	240,000
3-Apr-15	86,000	245,000
8-May-15	262,000	224,000
5-Jun-15	344,000	225,000
2-Jul-15	206,000	230,000
7-Aug-15	254,000	223,000
4-Sep-15	157,000	220,000
2-Oct-15	100,000	203,000
6-Nov-15	321,000	180,000
4-Dec-15	272,000	200,000
8-Jan-16	239,000	200,000
5-Feb-16	126,000	190,000
4-Mar-16	237,000	190,000
1-Apr-16	225,000	205,000
4-May-16	153,000	202,000
3-Jun-16	43,000	164,000
8-Jul-16	297,000	175,000
5-Aug-16	291,000	180,000
2-Sep-16	176,000	180,000
7-Oct-16	249,000	175,000
4-Nov-16	124,000	175,000
2-Dec-16	164,000	175,000

BIOGRAPHY

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Educational Attainment	2017: Master of Science Program in Finance, Thammasat University 2011: The Bachelor's degree of Business Administration (Finance) Thammasat University
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