HOW TO INTERVENE IN FX MARKET:
MARKET MICROSTRUCTURE APPROACH

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This paper proposes a market microstructure model of FX intervention to analyze the relationship between central bank intervention and the characteristics of the foreign exchange market. The implication of our model is that the characteristic of the exchange rate movements around central bank intervention is determined by portfolio managers' trading intensity and their boundary weights on the fundamentalist's view, market-makers' price adjustment speed and their speculative trading intensity. When the portfolio managers' trading intensity is low (thin market), central bank must operate heavy interventions to move spot exchange rate toward a target level. As the portfolio managers' boundary weight (minimum or maximum) on the fundamentalist's view increases, the influence of intervention increases. When the market-makers' price adjustment speed is fast, central bank must operate small interventions. Overall, this paper suggests that central banks need to have superior information on the characteristics of the foreign exchange market at the time the intervention operations are performed.

Keywords: Central Bank Intervention, Exchange Rates, Market Microstructure
JEL Classification: F31, G15

1. INTRODUCTION

After the collapse of the Bretton Woods System in 1973 and the move to a managed floating system, central banks of most industrialized countries have intervened in the foreign exchange market to reduce exchange rate volatility. Many European countries agreed to keep exchange rates within a band around a target level by coordinated intervention and U.S. authorities actively engaged in foreign exchange intervention in the 1970s. The conventional view on the effectiveness of intervention in the early 1980s was that central bank intervention, particularly sterilized intervention, does not offer an

effective policy tool for affecting exchange rates.[1]

By early 1985, however, official views were reversed. In the Plaza Agreement of September 1985, the G-5 countries announced that "some further orderly appreciation of the non-dollar currencies is desirable" and that they stood "ready to cooperate more closely to encourage this when to do so would be helpful." Following the Louvre Accord in February 1987, the G-7 countries shifted its goal from depreciating the dollar to stabilizing exchange rates. As they constituted strong supports for concerted intervention, foreign exchange market participants are observed to react to intervention as dynamically as to any other sort of news. Studies of intervention policies in the 1980s find that intervention had a statistically significant effect on exchange rates.[2]

The question of whether central bank intervention operations can effectively influence exchange rates is still both an issue of some debate in academia and a controversial policy option for central banks. The standard monetary approach to exchange rate determination indicates that nonsterilized intervention affects the level of the exchange rate in proportion to the change in the relative supplies of domestic and foreign money. The effects of sterilized intervention are less direct and more controversial. In one view, intervention is not only ineffective in influencing the level of the exchange rate, but also risky because it can increase the volatility of the exchange rate.[3] Others argue that intervention operations can influence the level of the exchange rate, and can also decrease the volatility.[4] Yet others argue that intervention operations are inconsequential since they affect neither the level nor the volatility of exchange rates.[5]

This paper tries to answer the following question which has been the hot issue of the recent research. How do heterogeneous market participants react to the central bank intervention and how does the change in market traders' behavior affect exchange rates? We assume that central bank has private information about fundamentals and thus its intervention operations influence market traders' trading behavior. This is an alternative interpretation of the signalling channel.

Because of the low transparency of nondealer customer order flows in the foreign exchange markets, central bank intervention with private information establishes certain dealers as informed traders. If uninformed dealers interpret the change in informed dealers' quotes as a signal of a change in market trend or future monetary policy stance, they jump on the bandwagon and the efficacy of central bank intervention may increase.

To set up a satisfactory model of exchange rate determination, several distinctive

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[1] See Jurgensen Report (1983), The G-7 Working Group Report.

[2] See Ghosh (1992) and Dominguez and Frankel (1993).

[3] See Rogoff (1984), Lewis (1988), and Baillie and Humpage (1992).

[4] See Mussa (1981), Dominguez and Frankel (1993), and Bonser-Neal, Roley, and Sellon (1997).

[5] See Jurgensen (1983) and Henderson and Sampson (1983). Dominguez (1993) and Bonser-Neal and Tanner (1996) show the mixed effects of interventions on exchange rate volatility.

characteristics of the foreign exchange market need to be considered. First, while equity markets are centralized and based on specialist systems, the foreign exchange market is largely decentralized and organized around interbank dealer networks. The interdealer share of trading is approximately 80%, much larger than other markets.[6] Second, trading motives in the foreign exchange market are different, as they involve both speculative and nonspeculative aspects. Third, the transparency of transactions is very low compared to other financial markets.

Section 2 introduces the model with heterogeneous participants in the foreign exchange market. Section 2.1 describes the heterogeneity of traders. Section 2.2 discusses intradaily exchange rate movements in the absence of central bank intervention. Section 2.3 presents intradaily exchange rate movements in the presence of central bank intervention. Finally, we conclude and summarize the implications of our model in Section 3.

2.   THE MODEL

The standard efficient markets model suggests that prices should reflect underlying fundamentals. To do this, all information available about fundamentals should be incorporated into prices. Yet many of the facts about financial markets seem to be at odds with the efficient market model. For example, in the foreign exchange market, it is easy to see sudden and substantial changes in exchange rates which are so much more volatile than underlying fundamentals. Excessive volatility may happen if market traders mimic behavior of others rather than respond to their private information about fundamentals. This herding behavior can be rational from the perspective of the market-makers whose pricing decision must be consistent with the consensus of the market.

In this section, we investigate the relationship between the efficacy of central bank intervention operations and the state of the foreign exchange market. In general, central bank intervention operations have a common objective of "countering disorderly exchange market conditions" which results in the smoothing of exchange rate volatility from day to day and even during the day.[7] In some cases such as EMS, central banks try to target the exchange rate to some predetermined level through interventions.[8]

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[6] The remaining 20% is between dealers and non-dealer customers. See Federal Reserve Bank of New York (1995).

[7] Almekinders and Eijffinger (1991) find that an increase in the conditional variance of daily exchange rate returns led the Bundesbank and the Federal Reserve to increase the volume of intervention, both in case of dollar-sales and purchases on account of their leaning against the wind policy.

[8] According to Funabashi (1988), at the Plaza Accord of 1985 the G-5 agreed to coordinated intervention to depreciate the dollar: 215 for Yen/$ and 2.60 for DM/$. At the Louvre meeting of 1987, target levels were set at 153.5 and 1.825 respectively.

In the foreign exchange market, risk-averse market-makers do not want to carry open positions. So they begin and end each trading day with a zero net position. When a market-maker receives a central bank intervention order that conveys private information about the fundamentals, he may take speculative inventory positions to profit from his informational advantage (information channel) and try to unload his undesired inventory imbalance (inventory channel) to other market-makers. This trading behavior sparks hot-potato trading hypothesis, a repeated passing of inventory imbalances among market-makers.

In executing intervention operations, central bank can either deal with commercial banks or place limit orders to brokers. In dealing with commercial banks, central bank allows them to make the intervention information public. On the other hand, in dealing with brokers, central bank can delay the market revelation of the intervention. Since the mid-1980s, most G-7 central banks deal directly with bank dealers to allow for a more rapid information flow about intervention activities. Thus, we assume that central bank intervention orders are placed to commercial bank dealers.

In our model, we include two important features of the foreign exchange market, the heterogeneity of traders and interaction between traders. First, traders have heterogeneous horizons and expectations. Some traders such as market-makers may not be allowed to hold open positions overnight while others such as portfolio managers will be taking positions on a much longer-term basis. Second, since traders react to others' behavior in terms of the information that is passed and inferred, interaction between traders plays an important role in determining the dynamics of exchange rates.

2.1.   The Heterogeneity of Traders

There are three types of traders in our model: central bank, portfolio managers, and market-makers. Central bank intervenes in the foreign exchange market to counter disorderly exchange rate movements. Portfolio managers are individual currency investors, offshore hedge fund managers, and other international portfolio managers. Market-makers represent dealers for commercial and investment banks who are involved in every transaction and quote the price.

2.1.1.   Central Bank

Central bank intervenes directly in the spot markets to counter disorderly market conditions. Disorderly markets are characterized by a substantial widening of bid-ask spreads, large daily exchange rate movements, perceptions that trading has become thin or highly uncertain, and, at times, judgments that market psychology was beginning to generate self-sustaining exchange rate movements. A common assumption in the literature is that central bank wishes to limit exchange rate deviations from a target level. To capture intervention carried out on account of a leaning-against-the-wind policy, the target exchange rate level can be thought of as representing past levels of the exchange rate.

Quirk (1977) distinguishes intervention on account of a leaning-against-the-wind policy, given by $INV_t = a(S_t - S_{t-1})$ from intervention consistent with gliding parities calculated as a moving average of previous levels of the exchange rate which has the form $INV_t = b(S_t - \sum_i a_i S_{t-i})$ with $\sum_i a_i = 1$, where INV_t is the volume of intervention expressed in the domestic currency and S_t is the spot exchange rate at time t. Almekinders and Eijffinger (1991) show that central banks use continuous interventions of increasing size as the spot exchange rate moves away from a seven-days moving average.[9]

In this paper, we assume that the central bank targets the exchange rate:

$$C_t = -\psi(S_t - S^T) \times DUM ,\qquad(2\text{-}1)$$

where C_t is the net purchase of foreign currency by the central bank at time t, the positive parameter ψ indicates the intensity of intervention, and S^T is the predetermined target exchange rate unknown to the public.[10] DUM is a dummy variable which is 0 if central bank decides not to intervene, 1 if it decides to intervene. Since intervention is an exogenous variable, other market participants have no learning mechanism about intervention policy.

2.1.2. Portfolio Managers

This group includes nondealer customers such as individual currency investors, offshore hedge fund managers, and other international portfolio managers. We define the portfolio manager's demand for the foreign currency, P_t, as a weighted average of demand by fundamentalist's view, F_t, and noise trader's view, N_t,[11]

$$P_t = \lambda F_t + (1 - \lambda)N_t ,\qquad(2\text{-}2)$$

where λ is the weight given to fundamentalist's view.

Frankel and Froot (1990) assume that past returns determine the dominant view. This can result in explosive foreign exchange movements. On the other hand, De Grauwe and Dewachter (1992) assume that the time-varying weight is endogenous and depends on

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[9] Almekinders and Eijffinger (1991) compare a three-days, five-days and seven-days moving average, respectively. They find that a seven-days moving average gives the best empirical results.

[10] Under the explicit target zone model such as EMS, target exchange rate is publicly known. However, it is unknown to the public under managed floating system.

[11] For a similar hypothesis, see Frankel and Froot (1990).

the deviation of the spot exchange rate from the fundamental level. That is, when the exchange rate continues to deviate from its fundamental level, fundamentalist's view becomes more important. In this case, the exchange rate returns to the fundamental level eventually.

In this paper, we assume that the weight on the fundamentalist's view depends on the size of the central bank intervention because intervention tends to become heavy as the exchange rate deviates from the target level that is close to the fundamental level. As portfolio managers update their demand for a foreign currency based on market-makers' price quote change, the proportion of opinions will vary with central bank intervention operations. For instance, when the central bank intervenes heavily and it affects market-makers' quote, portfolio managers put more weight on fundamentalist's view in their demand for a foreign currency. Thus, portfolio manager's weight on the fundamentalist's view is defined as follows:

$$\lambda = \frac{\underline{\lambda} + \overline{\lambda}\psi}{1 + \psi} \; ; \; 0 < \underline{\lambda} \leq \lambda \leq \overline{\lambda} < 1 \qquad ,$$

(2-3)

where ψ indicates the extent of central bank intervention. When there is no intervention, portfolio managers use the minimum weight on the fundamentalist's view. But, as they observe heavy interventions, the weight increases.

Fundamentalists

Fundamentalists are defined as investors who base expected returns on prices relative to perceived fundamentals. Fundamentalists believe that when the price of a currency is above the fundamental level, it will fall to the fundamental level, thereby selling the currency (and vice versa). Thus, the demand for a foreign currency by the fundamentalists is defined as follows:

$$F_t = \gamma(S^f - S_t),$$ (2-4)

where the positive parameter γ denotes the intensity of the fundamentalist's trading and S^f is the fundamental level of the exchange rate perceived by portfolio managers.[12]

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[12] We assume the perceived fundamental level is constant within a day. This assumption can be justified because fundamentals pertain to low frequency data but the time span of our model is very short.

Noise Traders

Noise traders are investors who are not fully rational and are affected by their beliefs or sentiments that are not fully justified by fundamentals. Many of them are so-called chartists or positive feedback traders. Noise traders believe that if the price of a currency is on the downward trend, it will keep falling even when it is below the fundamental level, thereby selling the currency (and vice versa). Noise trading could result from stop loss orders, from portfolio insurance, from a positive wealth elasticity of demand for risky assets, or from margin call-induced selling after periods of low returns.

A general form of demand for a foreign currency by noise traders is as follows:

$$N_t = \phi \delta(L)(S_t - S_{t-1}),\tag{2-5}$$

where $\delta(L)$ is a lag polynomial. The positive parameter ϕ denotes the intensity of noise trader's positive feedback trading. This is consistent with the popular technical analysis in the foreign exchange market. In our model, we assume that $\delta(L) = 1$ for simplicity. That is, noise trader takes a serious view of most recent exchange rate movement:

$$N_t = \phi(S_t - S_{t-1}).\tag{2-5'}$$

By plugging (2-4) and (2-5)' into (2-2), portfolio manager's demand for a currency is defined as follows:

$$P_t = \lambda \gamma (S^f - S_t) + (1 - \lambda)\phi(S_t - S_{t-1}).\tag{2-6}$$

2.1.3.   Market-Makers

In our model, the role of market-makers are essential because they are involved in every transaction and function as suppliers of liquidity in a market where buyers and sellers do not place their orders simultaneously. In the foreign exchange market, market-makers receive private information from nondealer customers' order flow. Since each market-maker has sole knowledge of his own customer order flow, private information can be exploited in interdealer trading.

Burnham (1991) notes "when a market-maker is hit with an undesired inventory position, he seeks to restore his own equilibrium by going to another market-maker or the broker market. A 'hot potato' trading has begun, which is the search process for a counterparty which is willing to accept a new currency position that accounts for a good deal of the volume in the foreign exchange market." If innovation in nondealer order flow, such as central bank interventions, causes repeated interdealer trading of idiosyncratic inventory imbalances, the central bank may propagate the effect of

intervention by placing orders to a market-maker who has the reputation of dealing with a particular currency in the market.

We assume that a market-maker's price quoting function is expressed as a function of the spot exchange rate and the deviation of inventory from his target level

$$S_{t+1} = S_t - \kappa(I_{t+1} - I_{t+1}^*) , \qquad\qquad\qquad (2\text{-}7)$$

where I_{t+1} is the market-maker's current inventory position and I_{t+1}^* is the market-maker's target inventory position at time $t+1$. The positive parameter κ is market-maker's price adjustment coefficient.

In the following sections, we analyze the evolution of the exchange rate during the daily trading. In Section 2.2, we discuss the case of no central bank intervention. Section 2.3 shows the influence of central bank intervention on the intradaily exchange rate movements. Any round of a daily trading is divided into two stages; morning session and afternoon session. We assume that market-makers have zero open (square) position at the start of the trading.

2.2. Intradaily Exchange Rate Movements in the Absence of Intervention

A market-makers sets price in response to excess demand or supply and at this price meets excess demand from his inventory or accumulates inventory when there is an excess supply. In the absence of central bank intervention, the weight of the fundamentalist's view on the portfolio manager's demand for a foreign currency is a lower bound $\underline{\lambda}$. That is, the portfolio managers heavily depend on the noise trading rule in placing their order. Since we assume that the portfolio managers do not have private information about fundamentals, their order flow does not affect the market-maker's target inventory, but changes the market-maker's current inventory position.

Chart 1 provides an overview of the events and summarizes the information available to market-makers for quoting and trading in each stage where there is no intervention.

Chart 1.   Timing of Events in the Absence of Intervention

Morning Session		Afternoon Session
Opening	Noon	Closing
Quote S_t	Quote Q_t	Quote S_{t+1}

t	Portfolio Manager		Portfolio Manager	$t+1$
	Morning Orders P_t^m		Afternoon Orders P_t^a	
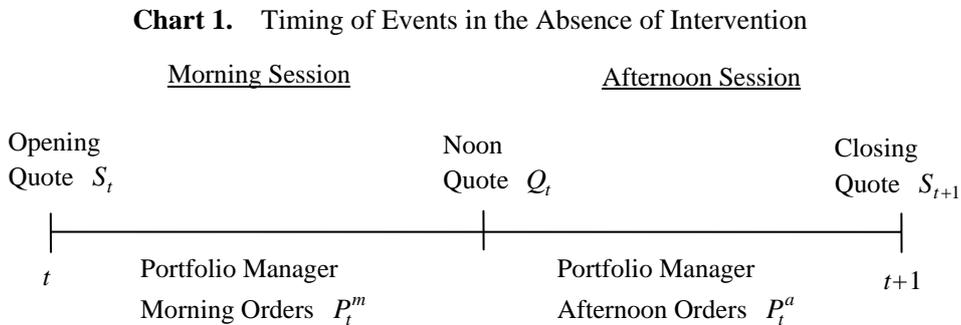
Morning Session

When there is no central bank intervention, a market-maker receives the following order from a portfolio manager.

$$P_t^m = \underline{\lambda}\gamma(S^f - S_t) + (1 - \underline{\lambda})\phi(S_t - Q_{t-1}) .$$ (2-8)

Thus, the market-maker's price quote at the end of morning session is

$$Q_t = S_t - \kappa(-P_t^m) .$$ (2-9)

By plugging (2-8) into (2-9),

$$Q_t = \left(1 - \kappa\underline{\lambda}\gamma + \kappa(1 - \underline{\lambda})\phi\right)S_t - \kappa(1 - \underline{\lambda})\phi Q_{t-1} + \kappa\underline{\lambda}\gamma S^f .$$

Afternoon Session

In the afternoon trading, a market-maker receives the following order from a portfolio manager,

$$P_t^a = \underline{\lambda}\gamma(S^f - Q_t) + (1 - \underline{\lambda})\phi(Q_t - S_t) .$$ (2-10)

Thus, the market-maker's price quote at the end of afternoon session is

$$S_{t+1} = Q_t - \kappa(-P_t^a) .$$ (2-11)

By plugging (2-10) into (2-11),

$$S_{t+1} = \left(1 - \kappa\underline{\lambda}\gamma + \kappa(1 - \underline{\lambda})\phi\right)Q_t - \kappa(1 - \underline{\lambda})\phi S_t + \kappa\underline{\lambda}\gamma S^f .$$

Since the question of convergence versus divergence of the exchange rate path hinges on the values of the parameters, the intensity of fundamentalist's trading γ , the intensity of noise trading ϕ, market-maker's price adjustment speed κ , and portfolio manager's minimum weight on the fundamentalist's view $\underline{\lambda}$, the conditions for convergence and divergence should be expressible in terms of the values of the parameters.

2.2.1. Numerical Calculations

In this section, we make some numerical calculations of the exchange rate path

under different market conditions to analyze the properties of the model. We start with following initial conditions: $Q_{t-1} = 110$, $S_t = 120$, $S^f = 100$, $\kappa = 0.1$, and $\underline{\lambda} = 0.1$. Figures 2.1~2.3 show the intradaily exchange rate movements for different values of the parameters.

Influence of Portfolio Manager's Trading Intensity (γ and ϕ)

In our model, a change in the portfolio manager's trading intensity has an effect on the intradaily movements of the exchange rate. When the portfolio manager's trading intensity is weak (thin market), the exchange rate displays some mean reversion on an intraday horizon. When the market is relatively thin (e.g., $\gamma = 1$ and $\phi = 1$), we have $Q_t = 120.70$ (noon rate) and $S_{t+1} = 120.56$ (closing rate). However, if the portfolio manager's trading is intensive (γ and ϕ larger than 3), we have a diverging daily movements of the exchange rate. For instance, in the thick market (e.g., $\gamma = 10$ and $\phi = 10$), we have $Q_t = 127.00$ and $S_{t+1} = 130.60$. Thus, when the portfolio manager's trading volume is sufficiently high, the exchange rate diverges on the intraday horizon. Figure 2.1 shows the relationship between portfolio managers' trading intensity and intradaily exchange rate movements. The dotted line represents a locus of a noon rate and the solid one is a closing rate.

Influence of Market-Maker's Price Adjustment Speed (κ)

Depending on the market uncertainty, market-makers tend to adjust their price adjustment speed. When the market is highly uncertain, risk-averse market-makers try to resolve inventory imbalance as soon as possible. Therefore, the price adjustment coefficient is assumed to increase as the market uncertainty increases. In general, market-makers widen bid-ask spread to protect themselves from informed traders. Thus, we can conjecture that market uncertainty at the opening and closing of the market is higher.[13] We see that an increase in κ has a bigger impact on the exchange rate in a thick market rather than in a thin market. For example, when κ increases from 0.1 to 0.2, S_{t+1} rises from 120.56 to 121.22 in a thin market, but in a thick market same change in κ causes S_{t+1} to move up from 130.60 to 152.40. Figure 2.2 illustrates the effect of market-makers' price adjustment speed on the exchange rate. The left (right) panel shows the effect in a thin (thick) market.

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[13] Hsieh and Kleidon (1996) supports this argument.
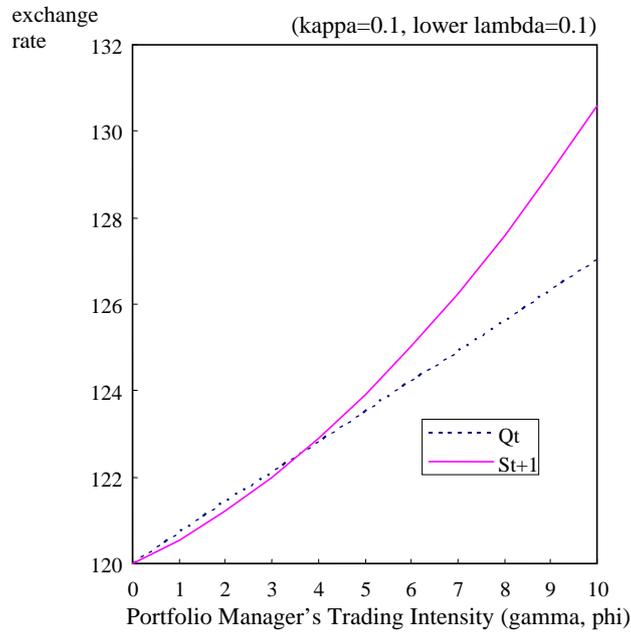
Figure 2.1. Influence of Portfolio Manager's Trading Intensity
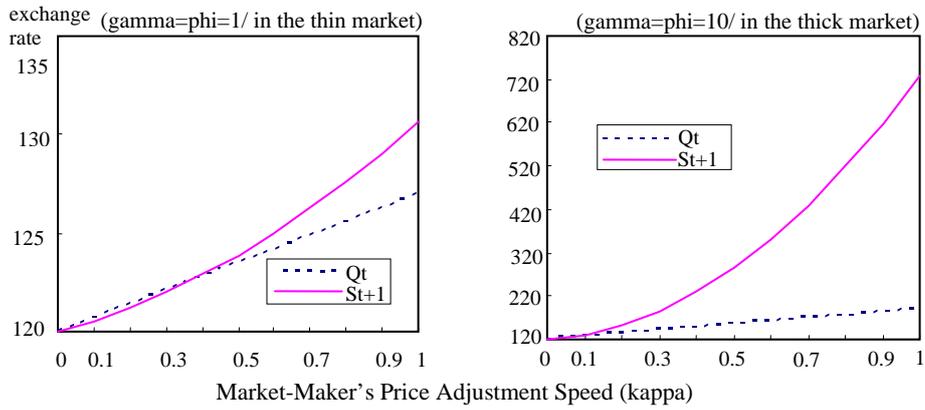
Figure 2.2. Influence of Market-Maker's Price Adjustment Speed
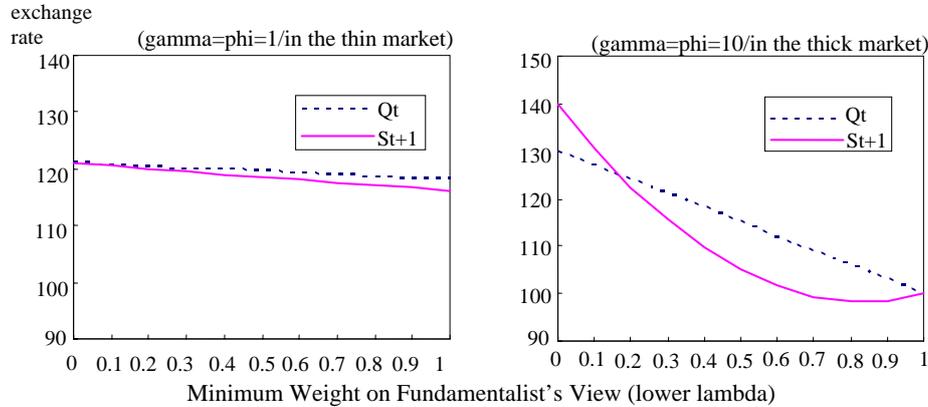
Figure 2.3.   Influence of Minimum Weight on Fundamentalist's View

Influence of Lower Boundary Value of Portfolio Manager's Weight on Views ($\underline{\lambda}$)

Consider the consequences of the increase in the minimum weight on the fundamentalist's view in the portfolio manager's demand. Increase in $\underline{\lambda}$ means that the portfolio manager relies more on the fundamentalist's view. It helps reduce the fluctuation of the exchange rate path. The numerical calculation shows the influence of the change in $\underline{\lambda}$ is greater in a thick market rather than in a thin market. For example, if $\underline{\lambda}$ increases from 0.1 to 0.2, S_{t+1} falls from 120.56 to 120.02 in the thin market, while it drops from 130.6 to 122.4. Figure 2.3 shows the effect of portfolio managers' minimum weight on the fundamentalist's view. The left panel shows the effect in a thin market and the right panel in a thick market.

2.3.   Intradaily Exchange Rate Movements in the Presence of Intervention

We now consider a two-stage sequential trading model when there is central bank intervention. In the morning session, central bank places intervention orders to market-makers (leaders). [14] The leaders take a speculative position to exploit informational rent and unload their undesired inventory imbalance to other market-makers (followers). Since the leaders' order releases private information

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[14] Dominguez (1997) finds that 61% of U.S. interventions occurred in the morning during 1989-1995. 43% of U.S. intervention against the mark occurred in the morning; 13% in the afternoon; 44% over the full day. Against the yen, 57% of U.S. intervention occurred in the morning; 16% in the afternoon; and 24% over the full day.

contained in the intervention order to the dealer market, the followers adjust their target inventory level and try to unload their undesired inventory to other market-makers. It causes a hot potato trading among market-makers. At the end of the hot potato trading, market-makers share inventory imbalance through risk-sharing trades. In addition, market-makers receive orders from portfolio managers who do not know central bank intervention at this point of time. Thus, market-maker's price quote at the end of morning session is determined by his inventory change caused by central bank intervention and portfolio manager's morning order flow.

In the afternoon session, portfolio managers receive a signal of central bank intervention from the change in market-makers' quote. After adjusting the weight of opinions in their demand for a foreign currency, portfolio managers place an order to market-makers. In addition, market-makers try to restore their original target inventory level which they had at the beginning of the trading in this stage. Thus, a market-maker's price quote at the end of afternoon session is determined by both the level of his original target inventory position and portfolio manager's afternoon order flows.

Chart 2 provides an overview of the events and summarizes the information available to market-makers for quoting and trading in each stage where there exists central bank intervention.

Chart 2. Timing of Events in the Presence of Intervention

Morning Session		Afternoon Session	

Opening Quote S_t	Central Bank Orders C_t	Noon Quote Q_t	Market-maker ωC_t	Closing Quote S_{t+1}

t — Portfolio Manager Morning Orders P_t^m — Portfolio Manager Afternoon Orders P_t^a — $t+1$
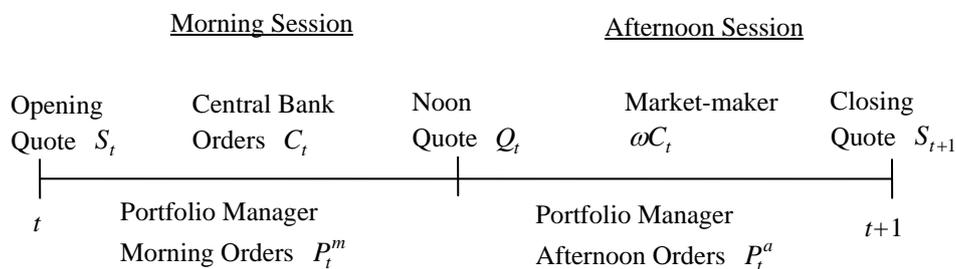
Morning Session

When the spot exchange rate deviates from the target level, the central bank intervenes by dealing directly with many large interbank dealers (leaders) simultaneously to buy or sell currencies in the spot exchange market. Since intervention orders contain private information about the central bank's exchange rate target, the leaders take speculative positions by changing target inventory levels to exploit information rents. Thus, the leader's inventory imbalance is the sum of central bank intervention order received plus his speculative position:

$$I_{Lt} - I_{Lt}^* = -(1 + \omega)C_t , \qquad\qquad (2\text{-}12)$$

where the positive parameter ω indicates the intensity of his speculative position.

When market-makers experience inventory imbalances, they usually shift this imbalance on to other market-makers. There are some reasons why market-makers use interdealer trades; such reasons include market-makers' desire to signal information or desire to change other market-makers' behavior. Thus, the leaders seek to resolve their inventory imbalance by placing orders to other market-makers (followers).

As inventory imbalances are passed from market-maker to market-maker, the followers realize central bank intervention and adjust their target inventory position.[15] The reason for the hot potato trading is that risk-averse market-makers do not want to carry open position. To attain the equilibrium price, market-makers need either to hold some of the inventory imbalance or to use the broker market. Since our model does not consider the broker market, we assume that market-makers share equal amount of inventory imbalance through risk-sharing trades to avoid the explosive hot potato process.

If there are n equally-sized market-makers in the dealer market, on average market-makers possess the following amount of inventory imbalance at the end of hot potato trading,

$$I_t - I_t^* = -\frac{(1 + n\omega)}{n}C_t . \qquad\qquad (2\text{-}13)$$

Since portfolio managers are uninformed about central bank intervention in the morning session, they place a morning order as follows:

$$P_t^m = \underline{\lambda}\gamma(S^f - S_t) + (1 - \underline{\lambda})\phi(S_t - Q_{t-1}) . \qquad\qquad (2\text{-}14)$$

Thus, market-makers' quote at the end of morning session is

$$Q_t = S_t - \kappa\left[-\frac{(1 + n\omega)C_t}{n} - P_t^m \right], \qquad\qquad (2\text{-}15)$$

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[15] The actual transaction prices are private information and are known only by the two participants in the transaction. Thus, the quotes on the news service screens such as Reuters Dealing 2000-1 system that is widely used for non-brokered interdealer trades are the only publicly available information on current prices in the foreign exchange market.

$$Q_t = \left(1 + \kappa(1-\underline{\lambda})\phi - \frac{\kappa\psi(1+n\omega)}{n} - \kappa\underline{\lambda}\gamma\right)S_t$$

$$- \kappa(1-\underline{\lambda})\phi Q_{t-1} + \frac{\kappa\psi(1+n\omega)}{n} S^T + \kappa\underline{\lambda}\gamma S^f.$$

Afternoon Session

Since the Treasury Secretary typically confirms central bank intervention while the central bank is conducting the intervention operations and often statements that reflect the official stance on its exchange rate policy accompany the Treasury's confirmation of intervention activity, the portfolio managers recognize the existence of central bank intervention at this stage. Thus, the portfolio managers ask quotes to market-makers, adjust the weights on the views, and then place orders to market-makers as follows:

$$P_t^a = \lambda\gamma(S^f - Q_t) + (1-\lambda)\phi(Q_t - S_t). \tag{2-16}$$

In the afternoon session, market-makers try to restore their original target inventory level which they had at the beginning of the trading because risk-averse market-makers do not want to carry open positions. Thus, market-maker's price quote at the end of afternoon session is determined by his original target inventory position and portfolio manager's afternoon order flows. Thus, the market-maker sets the price in the afternoon session as follows:

$$S_{t+1} = Q_t - \kappa\left[\omega C_t - P_t^a\right], \tag{2-17}$$

$$S_{t+1} = \left[\Omega\left(1 + \kappa(1-\underline{\lambda})\phi - \frac{\kappa\psi(1+n\omega)}{n} - \kappa\underline{\lambda}\gamma\right) - \kappa\omega\psi - \kappa(1-\lambda)\phi\right]S_t$$

$$- \Omega\kappa(1-\underline{\lambda})\phi Q_{t-1} + \kappa\psi\left(\frac{\Omega(1+n\omega)}{n} + \omega\right)S^T + \kappa\gamma(\Omega\underline{\lambda} + \lambda)S^f,$$

where $\Omega = \left(1 + \kappa(1-\lambda)\phi - \kappa\lambda\gamma\right)$.

By solving the second-order linear difference equation, we derive the equilibrium path of the exchange rate and its stability in the presence of intervention. The conditions for convergence and divergence of the exchange rate in the presence of intervention is determined by the values of the parameters, $\gamma, \phi, \kappa, \lambda, \psi$ and ω.

2.3.1. Numerical Calculations

In this section, we examine how the state of the market influences the efficacy of central bank intervention operations by making some numerical calculations of the

exchange rate path under different market conditions. We start with following initial conditions: $Q_{t-1} = 110$, $S_t = 120$, $S^f = 100$, $S^T = 105$, $\kappa = 0.1$, and $\underline{\lambda} = 0.1$, $\overline{\lambda} = 0.9$, $n = 100$, $\omega = 0.1$. Figures 2.4~2.14 show the intradaily exchange rate movements for different values of the parameters.

Influence of Portfolio Manager's Trading Intensity (γ and ϕ)

First, when the portfolio managers' trading intensity is weak (this market), the exchange rate continues to diverge without intervention. Our numerical calculation shows that a proper amount of central bank intervention helps move the exchange rate toward the target level. To illustrate, we take the small values of the portfolio managers' trading intensity, e.g., $\gamma = 1$ and $\phi = 1$. Without intervention, we have $Q_t = 120.70$ (noon rate) and $S_{t+1} = 120.56$ (closing rate). A small intervention (e.g., $\psi = 6$) induces $Q_t = 119.71$ and $S_{t+1} = 117.26$, while a heavy intervention ($\psi = 46$) induces $Q_t = 113.11$ and $S_{t+1} = 104.97$. Thus, heavy intervention is needed for the exchange rate to converge to target level within a day when the market is thin. The left panel of Figure 2.4 shows the influence of intervention intensity in a thin market.

Second, when the portfolio manager's trading intensity is high (thick market), the exchange rate path diverges fast without intervention. For example, $\gamma = 10$ and $\phi = 10$, we have $Q_t = 127.00$ and $S_{t+1} = 130.60$ without intervention, ceteris paribus. In this case, small intervention helps the exchange rate to converge to the target level, but heavy intervention causes overshooting problem. For example, a small intervention ($\psi = 6$) induces $Q_t = 126.01$ and $S_{t+1} = 105.96$, while a heavy intervention ($\psi = 46$) induces $Q_t = 119.41$ and $S_{t+1} = 95.30$ that is far below the target level. Thus, a small intervention is enough to target the exchange rate when the portfolio managers' trading intensity is relatively strong. The right panel of Figure 2.4 represents the influence of intervention intensity in a thick market.

In sum, our numerical calculations suggest that the optimal size of central bank intervention depends on the market depth. In the thin market, heavy intervention is needed, but small intervention is optimal in the thick market. This result seems to contradict to noise trading approach raised by Hung (1991) that suggests central bank intervention is more effective when the market is thin.
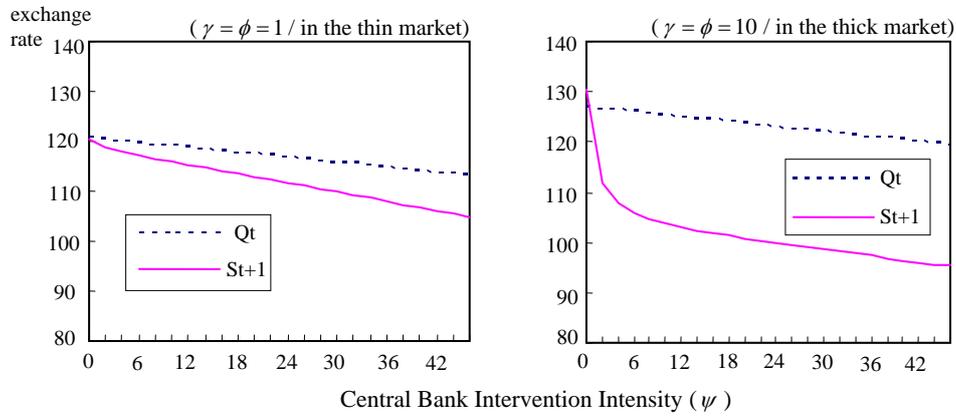
Figure 2.4. Influence of Central Bank Intervention Intensity
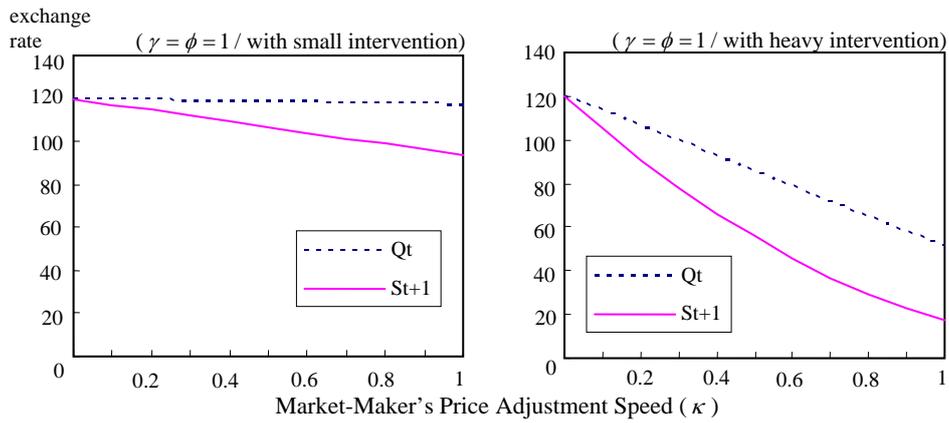
Figure 2.5. Influence of Market-Maker's Price Adjustment Speed in the Thin Market
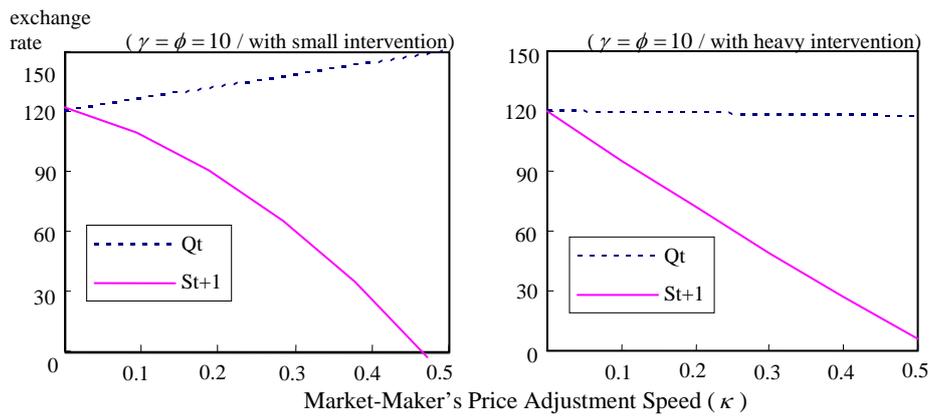
Figure 2.6. Influence of Market-Maker's Price Adjustment Speed in the Thick Market
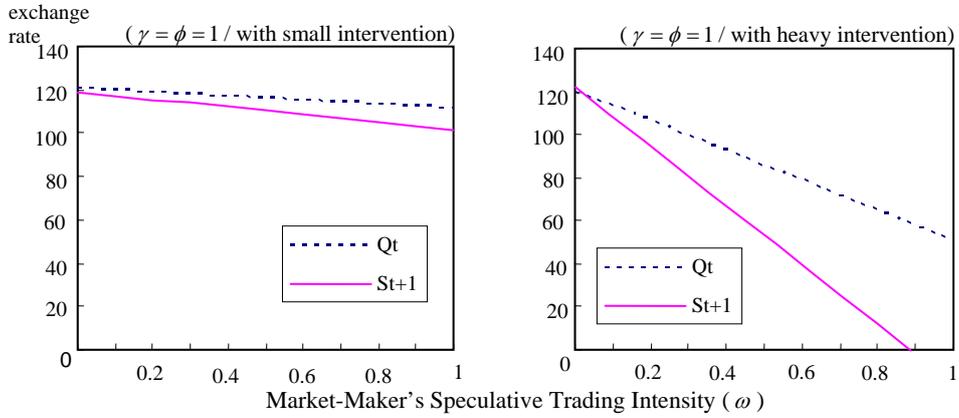
Figure 2.7. Influence of Market-Maker's Speculative Trading Intensity in the Thin Market
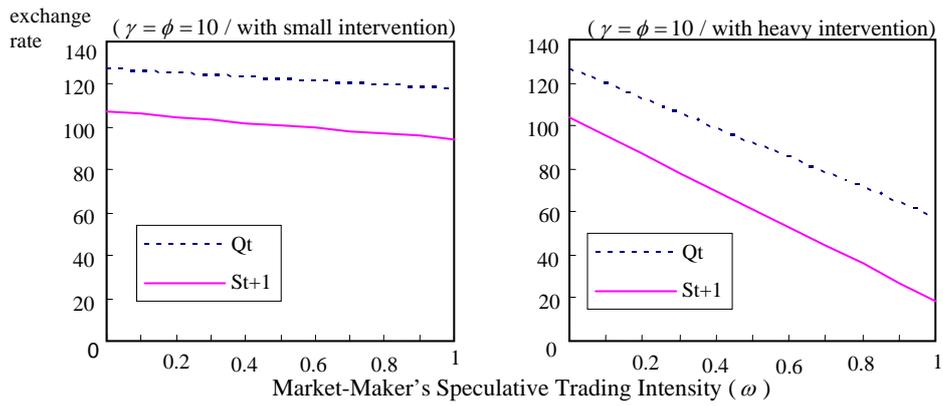
Figure 2.8. Influence of Market-Maker's Speculative Trading Intensity in the Thick Market
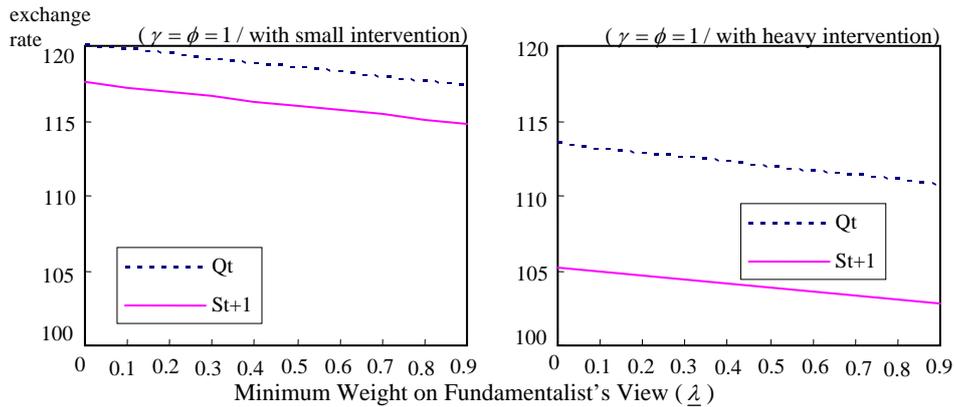
Figure 2.9. Influence of Minimum Weight on Fundamentalist's View in the Thin Market
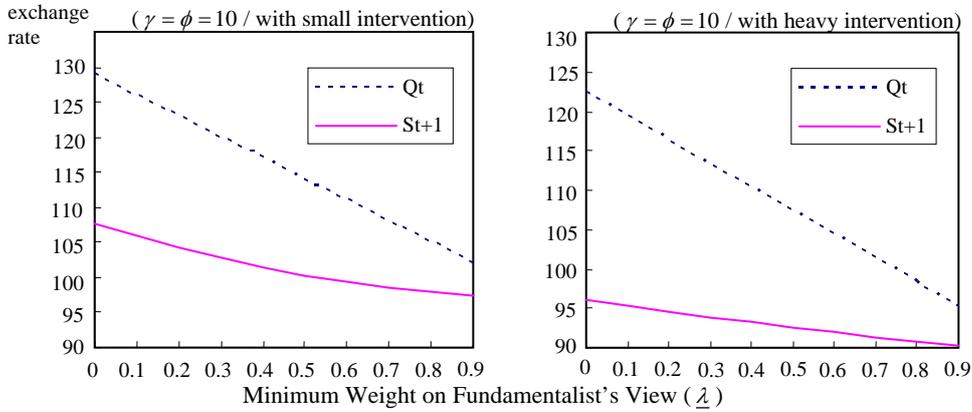
Figure 2.10. Influence of Minimum Weight on Fundamentalist's View in the Thick Market
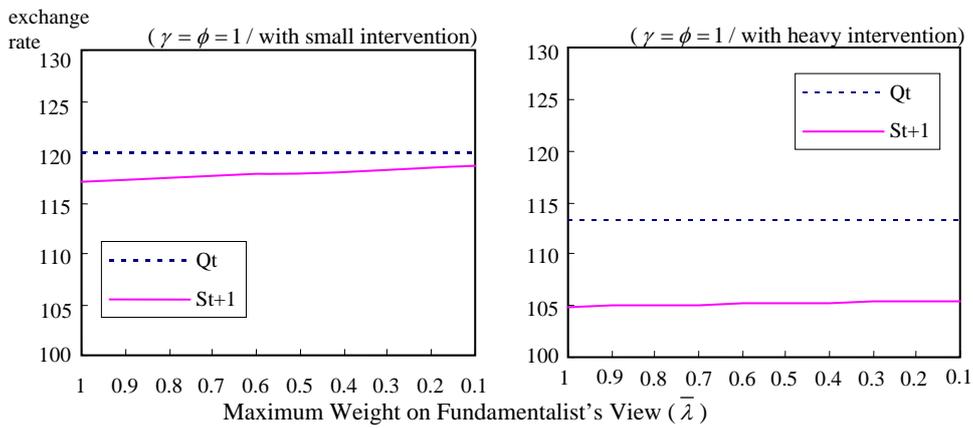
Figure 2.11. Influence of Maximum Weight on Fundamentalist's View in the Thin Market
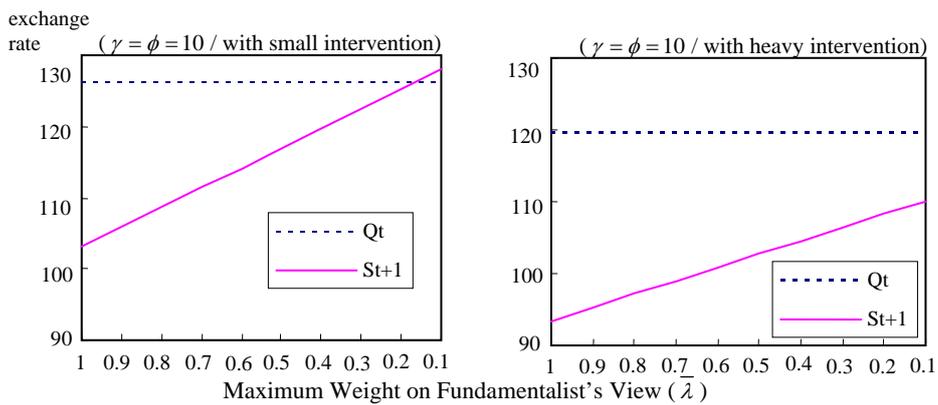
Figure 2.12. Influence of Maximum Weight on Fundamentalist's View in the Thick Market

Influence of Market-Maker's Price Adjustment Speed (κ)

The following numerical calculation shows that an increase in market-maker's price adjustment speed generates overshooting phenomenon on the exchange rate below the target level. This result is opposite to that in the absence of central bank intervention because central bank intervention influences market-makers' speculative inventory position and portfolio managers' weight on the fundamentalist's view. For instance, if the central bank tries to target the exchange rate using heavy interventions (ψ =46) in the thin market ($\gamma = 1$ and $\phi = 1$), an increase in κ from 0.1 to 0.2 pushes down Q_t from 113.11 to 106.22 and S_{t+1} from 104.97 to 91.00 that is far lower than the target level. However, if the central bank reduces the size of intervention to ψ =6, an increase in κ from 0.1 to 0.2 pushes down Q_t to 119.42 and S_{t+1} to 114.54. We find that when the market is thin and an increase in κ from 0.1 to 0.2, the optimal size of intervention is ψ =20 because it pushes Q_t down to 114.80 and S_{t+1} to 106.11 that is close to the target level. Figure 2.5 shows the effect in a thin market. The left panel of Figure 2.5 is the case of small intervention (ψ =6), and the right panel is for heavy intervention (ψ =46).

As the market depth increases, the increase in market-makers' price adjustment speed causes a bigger overshooting problem. For instance, when the market is thick ($\gamma = 10$ and $\phi = 10$) and central bank intervention is small (ψ =6), an increase in κ from 0.1 to 0.2 induces Q_t to drop from 126.01 to 132.02 and S_{t+1} from 105.96 to 85.05, ceteris paribus. Heavy intervention in the thick market causes bigger overshooting effect, that is, Q_t to 118.82 and S_{t+1} to 71.51. In this case, central bank can avoid overshooting by reducing the size of intervention. For example, if κ increases from 0.1 to 0.2 and the central bank uses smaller intervention (ψ =1.5), Q_t drops to 133.51 and S_{t+1} to 105.53 that is close to the target level. Figure 2.6 shows the effect in a thick market. The left panel of Figure 2.6 is the case when ψ =6, and the right panel is for ψ =46. Our results suggest that when the market-makers increase their price adjustment speed, central bank must reduce its size of intervention to target the exchange rate.

Influence of Market-Maker's Speculative Trading Intensity (ω)

An increase in market-makers' speculative trading intensity occurs when the market-makers respond to intervention news more sensitively by holding more speculative positions. We find that the increase in the market-maker's speculative trading (ω) induces overshooting exchange rate movements. When ω increases from 0.1 to 0.2 in the thin market ($\gamma = 1$ and $\phi = 1$) with heavy intervention (ψ =46), Q_t drops from 113.11 to 106.21 and S_{t+1} from 104.97 to 91.70, small intervention (ψ =6) drop Q_t to 118.81 and S_{t+1} to 115.51. Thus, in the thin market, central bank can

effectively target the exchange rate by reducing the size of intervention to 20, thereby dropping Q_t to 114.40 and S_{t+1} to 107.08 that is close to the target level. Figure 2.7 shows the effect of market-makers' speculative trading intensity on the exchange rate in a thin market. The left (right) panel shows a small (heavy) intervention case.

However, the effect of ω in the thick market is not significant when intervention is small. For example, when ω increases from 0.1 to 0.2 in the thick market ($\gamma = 10$ and $\phi = 10$) with small intervention ($\psi = 6$), Q_t drops from 126.01 to 125.11 and S_{t+1} from 105.96 to 104.68. However, heavy intervention in the thick market causes overshooting, thus Q_t drops to 112.51 and S_{t+1} to 86.79. Figure 2.8 shows the influence of market-makers' speculative trading intensity on the exchange rate in a thick market. The left (right) panel shows a small (heavy) intervention case. Our results suggest that central bank must reduce the amount of intervention when the market-maker increases his speculative trading, especially in the thin market.

Influence of Boundary Values of Portfolio Manager's Weight on Views ($\underline{\lambda}$, $\overline{\lambda}$)

Consider the consequences of the change in the weight on the fundamentalist's view in the portfolio manager's trading. An increase in the lower boundary value of λ, $\underline{\lambda}$, amplifies the effect of central bank intervention. This is because more fundamental trading induces faster convergence. However, Figure 2.9 shows that the effect is not significant in the thin market. However, it becomes significant in the thick market (see Figure 2.10). On the other hand, a decrease in the upper boundary value $\overline{\lambda}$ has different effects on the exchange rate movements. Figure 2.11 shows that the effect is not significant in the thin market. However, it becomes significant in the thick market (see Figure 2.12). Thus, we see a larger effect of the change in the boundary values of the portfolio managers' weight on the fundamentalist's view in the thick market.

3.   CONCLUSIONS

This paper has explored whether the state of the foreign exchange market at the moment of central bank intervention operations matters based on market microstructure framework. Making numerical calculations and graphical illustrations, we analyzed the impact of parameters in the model on the exchange rate movements. In Section 2, we analyzed the relationship between the efficacy of central bank intervention operations and the state of the foreign exchange market.

Our model specifies two main features of the foreign exchange market, the heterogeneity of traders and interaction between traders. Our model suggests that central bank intervention affects two main traders in the foreign exchange market. First, central bank intervention influences market-makers' behavior through two channels, information and inventory channels. Information channel works when intervention

orders influence market-makers' speculative position. Inventory channel works when market-makers unload their inventory imbalance through changing their quote. Second, intervention influences portfolio managers' behavior. When the portfolio managers recognize central bank intervention, they put more weight on fundamentalist's view in their demand for a foreign currency.

The implication of our model is that the characteristics of the exchange rate movements around central bank intervention is determined by the parameters in the model such as portfolio managers' trading intensity and their boundary weights on the fundamentalist's view, market-makers' price adjustment speed and their speculative trading intensity. First, when the portfolio managers' trading intensity is low (thin market), central bank must operate heavy interventions to move spot exchange rate toward a target level. When the portfolio managers' trading intensity is high (thick market), however, relatively small interventions help move the exchange rate toward the target level, but heavy interventions cause overshooting problem. Second, an increase in the market-makers' price adjustment speed causes overshooting problem. Thus, when the market-makers adjust so fast, central bank must operate small interventions. Third, market-makers' speculative trading strengthens the efficacy of intervention operations. Thus, when the market-makers speculate heavily on intervention orders, central bank must reduce the amount of intervention. Finally, as the portfolio managers' boundary weight (minimum or maximum) on the fundamentalist's view increases, the influence of intervention increases. The impact of weight is bigger in the thick market rather than in the thin market.

Overall, the results of the model in this paper suggest that central banks need to have superior information on the characteristics of the foreign exchange market at the time the intervention operations are performed. Moreover, this paper suggests that further theoretical and empirical exploration of the market microstructure of the foreign exchange market is warranted to explain the exchange rate movements. First, it is worth developing a theoretical model of risk-sharing trading among market-makers. Second, high frequency data may enable us to investigate the microstructural impact of central bank intervention on the price quote frequency over the intradaily horizon.

REFERENCES

Almekinders, G., and S. Eijffinger (1991), "Empirical Evidence on Foreign Exchange Market Intervention: Where Do We Stand?" *Weltwirtschaftliches Archiv,* 127, 645-677.

Baillie, Richard T., and Owen F. Humpage (1992), "Post-Louvre Intervention: Did Target Zones Stabilize the Dollar?" Federal Reserve Bank of Cleveland, Working Paper, 92/03.

Bonser-Neal, C., V. Roley, and G. Sellon (1997), "Monetary Actions, Intervention, and Exchange Rates: A Re-examination of the Empirical Relationships Using Federal Reserve Funds Rate Target Data," Federal Reserve Bank of Kansas City, Research Working Papers, 97/04.

Bonser-Neal, C., and G. Tanner (1996), "Central Bank Intervention and the Volatility of Foreign Exchange Rates: Evidence From the Options Market," *Journal of International Money and Finance*.

Burnham, J. (1991), "Current Structure and Recent Developments in Foreign Exchange Markets," in: S. Khoury ed., *Recent Developments in International Banking and Finance*, North Holland, Amsterdam, 123-153.

De Grauwe, P., and Hans Dewachter (1992), "Chaos in the Dornbusch Model of the Exchange Rate," *Kredit and Kapital*, 27-54.

Dominguez, K. (1993), "Does Central Bank Intervention Increase the Volatility of Foreign Exchange Rates?" NBER Working Paper, 4532.

_____ (1997), "The Market Microstructure of Central Bank Intervention," Working Paper, Georgetown University.

Dominguez, K., and J. Frankel (1993), *Does Foreign Exchange Intervention Work?* Institute for International Economics, Washington, D.C..

Federal Reserve Bank of New York (1995), *The Foreign Exchange Committee Annual Report*.

Frankel, Jeffrey A., and Kenneth A. Froot (1990), "Chartists, Fundamentalists, and Trading in the Foreign Exchange Market," *American Economic Review,* 80, 181-185.

Funabashi, Yoichi (1988), *Managing the Dollar; From the Plaza to the Louvre,* Institute for International Economics, Washington, D.C.

Ghosh, Atish R. (1992), "Is it Signalling? Exchange Intervention and the Dollar-Deutshemark Rate," *Journal of International Economics*, 32, 201-220.

Henderson, Dale W., and S. Sampson (1983), "Intervention in Foreign Exchange Markets: A Summary of Ten Staff Studies," *Federal Reserve Bulletin*, 69, 830-836.

Hsieh, David and Allan Kleidon (1996), "Bid-Ask Spreads in Foreign Exchange Markets: Implications for Models of Asymmetric Information," in J. Frankel *et al.* ed., *The Microstructure of Foreign Exchange Markets*, NBER Conference Report.

Hung, Juann H. (1991), "The Effectiveness of Sterilized U.S. Foreign Exchange Intervention: An Empirical Study Based on the Noise Trading Approach," Federal Reserve Bank of New York Research Paper, 91/18.

Jurgensen, Philippe (Chairman) (1983), *Report of the Working Group on Exchange Market Intervention,* U.S. Department of Treasury, Washington D.C.

Lewis, Karen (1988), "Testing the Portfolio Balance Model: A Multi-lateral Approach," *Journal of International Economics*, 24, 109-127.

Mussa, M. L. (1981), *The Role of Official Intervention*, Group of Thirty Occasional Papers, New York: Group of Thirty, 6.

Quirk, P. J. (1977), "Exchange Rate Policy in Japan: Leaning against the Wind," IMF

Staff Papers, 24, 642-664.

Rogoff, Kenneth S. (1984), "On the Effects of Sterilized Intervention: An Analysis of Weekly Data," *Journal of Monetary Economics*, 14, 133-150.

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