Abstract

The U.S. dollar serves as a vehicle currency or medium of exchange in the global foreign exchange markets. After reviewing some of the existing theories on vehicle currencies, the hypothesis put forth is that the dollar's role is linked to the relatively low cost of payments-related intraday credit available to payment system participants. Differences in the types of measures used by payment system operators to reduce settlement and systemic risk in the payment system give rise to liquidity differentials between currencies.

After reviewing the types of intraday credit facilities extended to participants on payment systems settling the major currencies, a foreign exchange market is simulated. Results from the simulation indicate that if there are sufficient differences in the availability of intraday credit between one settlement system and the others, a vehicle currency emerges. Furthermore, vehicle currency trades have narrower bid-ask spreads than other foreign exchange transactions.

Key Words: payment systems, foreign exchange and liquidity.

Payments-Related Intraday Credit Differentials and the Emergence of a Vehicle Currency

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1 Introduction

Advances in telecommunications and computing technologies along with the easing of capital controls over the last twenty years have contributed to the rapid growth in the value and volume of foreign exchange transactions around the world. The daily turnover in foreign exchange markets increased from \$294.3 billion in 1986 to \$1,260 billion in 1995 according to the Bank for International Settlements (BIS) (1990a and 1996a).[1] Part of this rapid growth can be attributed to the technological improvement in the clearing and settlement of the underlying currencies. Differences in the adoption of payment system policies between countries may have contributed to one country's currency being the least costly to use in foreign exchange transactions.

The apparatus used to transfer monetary value is the payment system. The settlement of foreign exchange transactions occurs over two different payment systems– one for each currency.[2] For example, the settlement of a deutsche mark/ US dollar transaction will involve payment systems in Germany and the United States. The bulk of foreign exchange settlement occurs on large-value interbank payment systems of the respective currencies.

The U.S. dollar plays the role of a vehicle currency in foreign exchange markets around the world. A vehicle currency is used to facilitate exchanges between two other currencies. According to BIS (1996a), the U.S. dollar was involved in 83 percent of the foreign exchange transactions. In addition, according to BIS (1990a), the activity in large-value domestic payment systems of the other major countries was reduced by up to 90 percent of their normal activity during U.S. banking holidays. This evidence indicates that a large part of payments volume in other countries results from transac-

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[1]The figure for 1986 is based on the foreign exchange markets in four countries–Canada, Japan, the United Kingdom and the United States. BIS (1990a) estimates that the activity in these four countries accounted for 70 percent of global net foreign exchange turnover. While no similar global estimates exist before 1986, the difference in foreign exchange turnover in the United States between 1977 and 1995 illustrates the rapid growth. For 1977, Grilli and Roubini (1993) cite the daily foreign exchange turnover in the U.S. at \$5 billion. For 1995, BIS (1996a) estimates the U.S. daily turnover as \$244.4 billion.

[2]There are book entry transactions that occur at certain institutions that may not be settled in the country where the currency originates. However, in cases where a participant wants to use the funds for alternate uses, delivery of the currency takes place in the country where the currency is issued. For a description of payment systems that handle foreign exchange transactions, see Chakravorti (1995).

tions involving the dollar. I will argue that the U.S. dollar's role is linked partly to how efficiently dollar payments are processed by U.S. payment systems. Although modeling efforts to study differences in the institutional features of the payment system of major currencies and their relationship to the emergence of a vehicle currency do not exist, some have suggested such a linkage. Juncker, Summers and Young (1991) claim that "the U.S. dollar's role as an international currency depends partly on the efficiency and soundness of its settlement arrangements."

In this article, I simulate a foreign exchange market with three currencies, three dealers and three submarkets to observe the effect of the level of payments-related intraday credit extended by the payment system operator or other participants on the bid-ask spreads set by foreign exchange dealers operating in a competitive market.[3] If there are sufficient differences between the bid-ask spreads associated with one currency and those involving other currencies, a vehicle currency emerges. The results indicate that if there are sufficient differences in the level of payments-related intraday credit among the payment systems, a vehicle currency emerges.

After a discussion of some existing theories about vehicle currencies in section two, differences in payment system design are discussed in section three. In section four, foreign exchange settlement is discussed. In section five, a foreign exchange market is modeled. In section six, the model is simulated. In section seven, the results are discussed. Section 8 concludes the paper.

2   Vehicle Currency

Foreign exchange dealers choose whether or not to use a vehicle currency. Figure 1 diagrams two extreme choices given three currencies. In panel i, no currency is chosen as the vehicle. In panel ii, currency A is chosen as the vehicle and only bilateral exchanges with A are conducted by foreign exchange dealers. In reality, non-U.S. dollar trades do exist and they have grown. From April 1989 to April 1995, the dollar's share has

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[3]Folkerts-Landau, Garber and Schoenmaker (1996) predict an increase in foreign exchange spreads as the price of payments-related intraday credit increases.

decreased from 90 percent to 83 percent.[4]

The choice of a vehicle currency may be influenced by the stability of its exchange rate and the home country's inflation rate. When comparing the stability of any two currencies, a third currency is used as a numeraire. However, it is difficult to judge the stability of the numeraire. Furthermore, certain countries may choose to explicitly or implicitly peg their currency to another. Comparing monthly exchange rate movements from 1973 to 1997 (figure 2), it is difficult to argue that the U.S. dollar as been the most stable. Three of the four currencies have appreciated against the dollar during that period. Looking at yearly consumer price indices over the same period (figure 3), it is difficult to argue that the U.S. dollar is chosen because it has the lowest inflation rate.

A vehicle currency's role is similar to the medium of exchange role of money in a closed economy. The medium of exchange literature provides insight to the technical characteristics necessary for a vehicle currency to exist. Brunner and Meltzer (1971) argue that a medium of exchange emerges in exchange economies due to uncertainty. The uncertainty arises for two reasons. First, in a multi-good economy an individual may have to trade several times before he acquires his final consumption good. For example, in a barter economy, a seller of one product may accept another product in exchange for his and later trade that for some other product that he wishes to consume. In these economies, there are search costs to find the ultimate consumption item. Second, every agent in the economy may not have accurate information about every other good in terms of its price with respect to other goods. Without a medium of exchange, there are greater variations in the price ratios of the goods.

Kiyotaki and Wright (1989) endogenously determine a medium of exchange from a group of traded commodities based on storage costs and agents' beliefs about those commodities. They conclude that the commodity with the lowest storage cost will emerge as the medium of exchange.[5] Others, such as Jones (1976) and Oh (1989),

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[4]BIS (1996a). This decrease could be partly associated with improvements in clearing and settlement systems of other industrialized countries, especially improvements in the German large-value settlement system.

[5]In the context of foreign exchange markets, storage costs could be viewed as the length of time

emphasize the emergence of a medium of exchange based on transactions costs.

Krugman (1980) models the emergence of a vehicle currency based on transactions costs. He assumes that transactions costs decrease as the volume of payments increase. He concludes that the currency that has the lowest transactions costs will emerge as the vehicle currency.

Another explanation of the existence of a vehicle currency is the size of its home country's trade flows. Home country refers to the country that issues the currency being discussed. Tavlas (1990) argues that a vehicle currency is determined by the home country's share of world exports, the percentage of those exports that are in specialized manufactured products and the amount of trade with developing countries. However, comparing the share of home country's exports to world exports of the three largest exporters— Germany, Japan and the United States— and their currency's share of foreign exchange transactions, one finds that while their individual export shares do not differ significantly, the difference in foreign exchange transactions associated with each of their currencies is significantly different. In 1995, exports of these countries comprised 10 percent for Germany, 9 percent for Japan and 12 percent for the United States of world exports, while their currencies were involved in 37 percent, 24 percent and 83 percent of foreign exchange transactions, respectively.[6] Furthermore, the growth in foreign exchange activity cannot be explained by trade flows alone. Corsetti, Grilli and Roubini (1990) state that most of the growth in the volume of foreign exchange transactions cannot be explained only by the increase in the volume of trade in goods and services.

In this article, I propose a theory about vehicle currencies that incorporates the transactions costs hypothesis of Krugman (1980), Jones (1976) and Oh (1989), but suggest an explanation of the origin of these different transactions costs based on differences in clearing and settlement arrangements between currencies. The results of the model indicate that a vehicle currency may emerge based on payments-related intraday credit differentials between payment systems. Specifically, I consider the effects of the avail-

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required to match foreign exchange positions.

[6] BIS (1996a) and International Monetary Fund (1996).

ability and cost of intraday payments-related credit on the behavior of foreign exchange dealers.

3 Payment Systems

Because central banks are concerned with the potential risk that the inability of one participant to settle its end-of-day clearing balance may affect the ability of other participants to settle their end-of-day obligations, they have implemented various risk-reducing measures. In the payment systems context, this type of risk is referred to as systemic risk. Although there is a general consensus on the importance of adopting risk-reducing measures, central banks differ in their choice of these measures.

One area where payment systems differ is whether they settle their payments in gross or net. In gross settlement systems, participants settle each transaction individually, whereas in net settlement systems, participants settle the net of their incoming and outgoing payments at the end of a specified period of time. Gross settlement systems that settle transactions continuously as they are sent are known as real-time gross settlement (RTGS) systems.[7] Although RTGS systems are associated with substantially reduced systemic risk, they tend to require a greater quantity of good funds to settle payments than net settlement systems.[8] On the other hand, net settlement systems economize on reserve holdings at the central bank, but are associated with intraday exposures that may increase systemic risk.[9] Central banks have tended to design payment system policies to decrease the cost of gross settlement systems or decrease systemic risk in netting systems.

To decrease the cost associated with greater reserve holdings in gross settlement systems, central banks often grant intraday credit. Although some gross settlement systems granted nearly unlimited free intraday credit in the past, central banks have recently

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[7]There are examples of gross settlement systems that settle at the end of the day. However, these systems are not the norm in the industrialized countries. For a description of RTGS systems, see BIS (1997).

[8]In the context of large-value settlement systems, good funds are reserves held at the central bank. In most cases, these reserves do not earn interest. Therefore, participants tend to minimize their reserve holdings.

[9]For a numerical example of the cost savings to payment system participants, see Chakravorti (1997).

adopted or are considering to offer intraday repurchase agreements, pricing intraday credit or extending fully collateralized intraday credit to payment system participants. For example, in the Clearing House for Automated Payment System (CHAPS), U.K.'s RTGS system, the Bank of England stands ready to engage in intraday repurchase agreements to increase intraday liquidity.[10] In Fedwire, the U.S.' RTGS system, the Federal Reserve charges fees for the intraday credit it extends. Alternatively, in the German RTGS system, EIL-ZV, the Bundesbank extends fully collateralized intraday credit. However, there are some central banks that choose not to extend intraday credit such as the Swiss National Bank. Table 1 provides a comparison of central bank policies concerning intraday credit on their respective RTGS systems.

Table 1: Central Bank RTGS Intraday Credit Policies

Country	Name of RTGS	Year Est.	C.B. Intraday Liquidity
Germany	EIL-ZV	1988	Collateralized Credit
Japan	BOJ-NET	1988	None
Switzerland	SIC	1987	None
United Kingdom	CHAPS	1984	Intraday Repos
United States	Fedwire	1918	Caps and Fees

Source: BIS (1997)

A common risk-reducing instrument used in net settlement systems are intraday net debit caps. During the day, participants cannot send payments if that payment results in their debit position being greater than the cap. Debit caps attempt to minimize the potential of large credit exposures during the day as well as at the end of the day. These caps can either be determined by the recipient or sender of the payment. In systems with receiver caps, participants receiving payments set maximum intraday credit limits. In systems with sender caps, sending participants set their debit limits. In addition to debit caps, such systems may also impose collateral requirements. For example, the Clearing House Interbank Payments System (CHIPS), requires participants to set intraday net debit caps and post collateral of 5 percent of the highest bilateral credit granted by that

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[10]For a description of CHAPS' shift from a netting system to a gross settlement system, see Bank of England (1994) and (1996).

participant.[11] In Germany, EAF2 participants must hold 100 percent collateral against their sender caps. In addition to restricting the level of intraday credit granted, there are other policies that can be adopted to decrease systemic risk such as high standards for participation, explicit loss-sharing rules in case of settlement failures and more frequent settlement of net positions.

Recently, there has been a trend to move towards RTGS systems in industrialized and developing countries. All of the European Union member countries are in the process of converting to RTGS systems. Principle four of the report on "Minimum Common Features for Domestic Payment Systems" submitted by the Working Group on EU Payment Systems to the Committee of Governors in November 1993 states that: "As soon as feasible, every Member State should have a real-time gross settlement system into which as many large-value payments as possible should be channelled." In addition, the Bank of Japan has decided to convert its designated-time settlement component of BOJ-NET to RTGS by the end of the year 2000.[12]

Although there is a strong trend towards RTGS systems, not all net settlement systems are being abolished. In Germany, Japan and the United States, large-value net settlement systems operate along side of gross settlement systems. Although many have argued in favor of RTGS systems based on the increased safety, net settlement systems would still play a role in providing low cost payment processing especially in the delivery of funds associated with foreign exchange transactions. Currencies that are settled on net settlement systems are less costly to deliver than currencies that are settled on RTGS systems with limited intraday credit facilities.

In this article, I will focus on the level of payments-related intraday credit that is available to payment system participants settling foreign exchange transactions. In some cases, foreign exchange transactions are settled on gross settlement systems, such as pound sterling and Swiss franc transactions. In other cases, foreign exchange transactions are settled via net settlement systems. The deutsche mark, Japanese yen and U.S.

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[11] New York Clearing House Association (1996).

[12] For more details, see Matsushita (1997). Although there is an RTGS component of BOJ-NET, most transactions are settled via the designated-time settlement component.

dollar legs of foreign exchange transactions are settled via net settlement systems.[13] In table 2, funds transfer systems that settle components of foreign exchange transactions are listed.

Table 2: Payment Systems that Settle Foreign Exchange

Country	Name	Year Est.	Gross/Net	Debit Caps	Collateral
Germany	EAF2	1996	Net	Sender Caps	Full
Japan	FEYCS	1989	Net	Sender Caps	50 %
Switzerland	SIC	1987	Gross	N/A	N/A
United Kingdom	CHAPS	1984	Gross	N/A	N/A
United States	CHIPS	1970	Net	Receiver Caps	Partial

Source: BIS (1997).

As seen in table 2, in Germany, Japan and the United States, the delivery of funds associated with foreign exchange transactions occurs via net settlement systems whereas in Switzerland and the United Kingdom, no separate settlement system is used. All of the net settlement systems impose debit caps with varying degrees of collateral requirements. In SIC, participants are not granted intraday credit by the central bank. In this system, every payment is made with good funds. Therefore, by design SIC cannot have debit caps or collateral requirements. In CHAPS, the Bank of England extends intraday repurchase agreements to provide intraday credit. Thus, debit caps and collateral limits do not apply in this case either.

One comparison of intraday credit facilities is to compare debit caps. RTGS systems with no extension of intraday credit from the central bank or 100 percent collateralized systems can be viewed as systems where the intraday debit cap is zero.[14] Although systemic risk is substantially less in these systems, they are more expensive to use than net settlement systems that are not fully collateralized.

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[13]Most net settlement systems eventually use RTGS systems to settle the participants' final net positions.

[14]There are differences between an RTGS system where there is no intraday credit and one where the credit is fully collateralized. A comparison of these systems would depend on the depth and liquidity of the market for interbank funds and the market for the underlying collateral. If there are high reserve requirements and the reserve maintance periods are long or payment system participants hold significant quantities of the instrument used for collateral, the relative cost of payment system participation on such systems may be low.

Lower debit caps are expensive because payment system participants must acquire or wait for good funds before they can continue to send payments more frequently. After a bank has reached its debit cap, it can choose from three options to continue sending payment messages that day. First, the bank can try to raise its limit with the payment system operator by placing additional collateral. However, aggregate net debit caps may be fixed during the day. Second, it can wait for incoming messages and then send more payments. If banks wait for incoming messages, this could create a backlog of payments waiting to be sent. In the worst case, banks could be waiting for other banks to send messages resulting in no bank sending messages but every bank waiting for them. Third, the bank can borrow funds in the interbank funds market. In most cases, banks access the interbank funds market to meet their intraday liquidity needs. Lower debit caps lead to higher costs for banks since the probability of accessing the interbank funds market to send payments increases due to timing differences between incoming and outgoing payments. Alternatively, banks may hold more reserves. However, these additional reserve holdings also increase the cost of processing payments.

4   Foreign Exchange Transactions

The settlement of foreign exchange transactions can be viewed as a funnel (figure 4). Most foreign exchange transactions start at the top of the funnel and proceed to the bottom of the funnel. At the top of the funnel is the foreign exchange market. Foreign exchange market participants include non-bank entities, brokers and dealers. For the most part, banks are dealers that make the market in foreign exchange. Banks are ready to accept trades for the exchange rate that they set. During the day, banks take positions that they try to offset by the end of the day.

Banks comprise the next level of the funnel. Banks interact with one another in the interbank foreign exchange market where the bulk of foreign exchange transactions take place. In this market, banks try to offset retail orders. Banks also lend and borrow from each other in the domestic funds market of each currency which is the main source for good funds.

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The next level of the funnel is the payment system. Banks are the main participants in the payment systems. The payment system provides clearing and settling for foreign exchange transactions. Currencies are delivered via their respective payment systems. The last level is the central bank. Some central banks operate the payment system that clears and settles foreign exchange transactions. Even in systems that are privately run, the settlement medium is usually central bank reserves.

The level of intraday credit associated with payments processing affects the decisions of foreign exchange dealers. A significant portion of payments over large-value payment systems are associated with foreign exchange transactions.[15] Most foreign exchange transactions usually take at least two days to settle.[16] A foreign exchange dealer has an expectation of its payments traffic at the end of the trading day which is two days prior to settlement. However, incoming payments and outgoing payments do not arrive in any particular order two days later on settlement day. Although banks have an expectation of their end of day position, banks may be constrained by their caps during settlement day since they may process their outgoing funds before they receive funds.

Given the uncertainty in the timing of payments, banks may place limits on the net amount of currency that they will deliver on a given day. Because banks want to limit the potential for liquidity shortfalls, banks may restrict themselves to a maximum debit position in any given currency during the trading day. Alternatively, banks could widen the bid-ask spread on these transactions to compensate for the higher transaction costs associated with currencies clearing and settling on payment systems with more expensive intraday credit.

Differences in intraday credit facilities lead to liquidity differentials between payment systems. These liquidity differentials arise because of differences in the availability, the cost and the amount of good funds required to settle a given value of payments among payment systems. Liquidity is a measure of convertibility of one asset into another. In

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[15]According to BIS (1996b), foreign exchange transactions comprise fifty percent of CHIPS and CHAPS transactions, eighty percent of EAF (the precursor to EAF2) transactions, and ninety percent of SIC transactions.

[16]There are some foreign exchange transactions that settle the next day, but these transactions do not comprise the bulk of transactions.

this case, the currency that is delivered at the lowest cost is the most liquid.

5 The Model

A foreign exchange market is constructed consisting of three submarkets: the retail foreign exchange market, the interbank foreign exchange market and the interbank domestic funds market.[17] The main players in the market are the three foreign exchange players (FXPs) who trade in three currencies: p, d and y. Each currency is cleared and settled on its own payment system. All FXPs have equal access to all three payment systems. FXPs conduct transactions in each market separately as diagrammed in figure 5. All submarkets meet sequentially on the same day.

FXPs are market makers ready to sell currencies in the retail market based on bid-ask spreads. They face random foreign exchange orders in the retail market. FXPs hope to match trades, so they do not have net negative positions in any currency at the end of the day. After the close of the retail market, FXPs trade amongst themselves in the interbank foreign exchange market to offset negative net positions. As a last resort, FXPs settle negative positions by borrowing in the interbank funds market.

FXPs set the bid-ask spreads to maximize profits. FXPs operate in a competitive environment which limits the upper bound on how wide they can set the bid-ask spreads. The model will show that given large enough differentials in payments-related intraday credit between payment systems, FXPs will set lower bid-ask spreads for trades involving the vehicle currency. This model assumes fixed exchange rates. FXPs trade with one another at the fixed exchange rates. The fixed exchange rates are:

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\begin{aligned}
e_{pd} &= 2\,,\\
e_{py} &= 3\,,\\
e_{dy} &= 1.5\,,
\end{aligned}
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[17]An alternate interpretation of this model would be to view the retail market as a market where smaller banks come to large "money center" banks to offset their positions from participating in the foreign exchange market. The interbank foreign exchange market can be viewed as a market only consisting of the "money center" banks. In reality, different rates are quoted to different customers in the foreign exchange market based on reputation and presence in the market. In most cases, the best rates are given to large banks by other large banks.

where:

$$
\begin{aligned}
e_{jk} &\equiv j/k \ interbank \ exchange \ rate \,, \\
j &\equiv p, \ d \ or \ y \,, \\
k &\equiv p, \ d \ or \ y \,, \\
j &\neq k \,.
\end{aligned}
$$

This model does not provide any insight into exchange rate determination or the equilibrium exchange rate. The model is a partial equilibrium model constructed to understand decisions of FXPs based on parameters set by payment system operators. The interbank funds market interest rate for each currency is given exogenously and it is assumed that there is never a shortage of funds at that interest rate.[18]

The model is used to determine under what conditions a vehicle currency emerges. The model is simulated to highlight the institutional features not captured in analytical models. This model provides explicit analysis on how bid-ask spreads are derived based on the institutional features of the settlement systems. No model to date considers the level of payments-related intraday credit as a factor in determining a vehicle currency in foreign exchange markets. Specifically, I study the optimizing behavior of banks based on intraday debit caps and its effect on the bid-ask spreads.

The goal of the simulation is to show under what conditions a vehicle currency emerges. The simulation restricts certain types of transactions to see if FXPs earn more profits by not accepting certain trades. In reality, customers can request any transaction from a foreign exchange dealer. Existence of a vehicle currency does not exclude non-vehicle currency trades, but non-vehicle trades will have wider bid-ask spreads.

5.1 The Retail Market

In the retail market, customers arrive sequentially to a foreign exchange player with their orders. Each customer wants to convert one currency to another currency of a specific

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[18]Allowing the interbank funds rate to be determined by supply and demand conditions of the market would not qualitatively affect the result if the costs associated with borrowing funds in this market are higher than the cost of intraday credit extended by the payment system operator.

amount. The type of transaction and the amount of desired currency by customers are random. Given three currencies, there are six types of transactions possible. The six types of transactions include: p for d, d for p, p for y, y for p, d for y and y for d. Each type of transaction has a probability of 1/6 of occurring. The amount of each currency purchase is drawn from a normal distribution specific for each currency.

FXPs earn revenue on every trade based on a bid-ask spread. For example, if there is a .1% bid-ask spread that means the bid price, the price at which the FXP buys the currency, is .05% lower than the interbank rate and the ask price, the price the FXP sells the currency, is .05% higher than the interbank rate. For example, the bid-ask spread set by a foreign exchange player of .1% for trades involving p and d would be:

$$.10\% \; spread = \begin{cases} 2.001 & \text{rate at which FXP sells d for p} \\ 2.000 & \text{interbank rate} \\ 1.999 & \text{rate at which FXP buys d for p.} \end{cases}$$

If the FXP has a zero or positive position in each currency after the close of the retail market, it could earn around a .10% return on half the volume of transactions for that day's activity before accounting for costs. After the retail market closes, FXPs meet in the interbank foreign exchange market and attempt to offset their negative positions resulting from their retail activity.[19] Negative positions that remain after interbank foreign exchange activity are offset by borrowing on the interbank domestic funds market.[20]

FXPs may decline trades because of self-imposed net debit caps based on intraday caps placed by the payment system operator on the processing of payments.[21] The net debit cap can be viewed as the maximum limit that the FXP is willing to expose itself to at any instant during the trading process in a given currency. For simplicity, in this model, FXPs set the same intraday debit cap that the payment system operators will set for them two days later during the settlement process in each of the currencies. The results would not qualitatively change if FXPs were willing to set higher debit caps for themselves as long as they were functions of the intraday debit caps placed by the

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[19]The interbank market is discussed in detail in the next section.

[20]In reality, banks can lend on the domestic funds market of each currency. This model does not allow FXPs to lend funds. This assumption is discussed at length in the next section.

[21]For the purposes of this model, net debit caps, debit caps and caps are synonymous.

payment system operators in a given currency. In other words, FXPs set higher self-imposed intraday caps for a currency where the payment system clearing and settling that currency has higher intraday debit caps.

As described above, foreign exchange transactions occur two days in advance of settlement. However, uncertainty is not eliminated since the order of payments processing is unknown. All other things being equal, intraday debit caps will affect the volume of transactions that FXPs will process over a given payment system. FXPs will attempt to process greater volumes of payments over systems that have higher debit caps.

Each FXP allocates the same amount of collateral for each currency's payment system. As mentioned above, customers arrive sequentially so the net delivery amounts are calculated after trading with each customer. If the FXP goes beyond the cap as a result of a transaction, it must decline that transaction and lose the revenue for that trade.

Payment system net debit caps are related to the collateral posted. The model assumes that FXPs place the same amount of collateral in each payment system.[22] Alternatively, FXPs can set the same debit caps for each payment system by placing different amounts of collateral. In this case, the payment system requiring the least collateral to achieve the same level of intraday credit would be the least costly and the most liquid given all else being equal. Each FXP sets a debit cap in each currency that is given by:

$$P_{cap} = (1/\alpha)P_{co} , \tag{1}$$

$$D_{cap} = (1/\beta)D_{co} , \tag{2}$$

$$Y_{cap} = (1/\gamma)Y_{co} , \tag{3}$$

$$\alpha, \beta, \gamma \leq 1 ,$$

where:

$$P_{cap} \equiv net\, debit\, cap\, for\, p ,$$

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[22]The same amount of collateral means that if each collateral amount were compared in one currency converted at the interbank exchange rates, the values would be identical.

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$$
\begin{aligned}
D_{cap} &\equiv \quad net\,debit\,cap\,for\,d\,, \\
Y_{cap} &\equiv \quad net\,debit\,cap\,for\,y\,, \\
P_{co} &\equiv \quad collateral\,holdings\,for\,the\,payment\,system\,clearing\,p\,, \\
D_{co} &\equiv \quad collateral\,holdings\,for\,the\,payment\,system\,clearing\,d\,, \\
Y_{co} &\equiv \quad collateral\,holdings\,for\,the\,payment\,system\,clearing\,y\,, \\
\alpha &\equiv \quad percentage\,collateral\,requirement\,for\,currency\,p\,, \\
\beta &\equiv \quad percentage\,collateral\,requirement\,for\,currency\,d\,, \\
\gamma &\equiv \quad percentage\,collateral\,requirement\,for\,currency\,y\,.
\end{aligned}
$$

Once the debit cap has been reached, trades that involve the delivery of that currency are not conducted by that FXP, unless the FXP received that currency from another customer after reaching the cap.

5.2   The Interbank Foreign Exchange Market

After trading ceases in the retail market, FXPs enter the interbank foreign exchange market. The bulk of foreign exchange trading occurs in the interbank market. However, a significant portion of interbank foreign exchange transactions occurs to offset positions created in the retail market.[23] In this model, the role of the interbank foreign exchange market is to offset positions created in the retail market.

The only possibility the model provides FXPs to reduce borrowing costs is to offset negative positions in the interbank foreign exchange market. FXPs are not allowed to lend on the interbank domestic funds markets. The results do not qualitatively change if FXPs are allowed to lend. By not allowing FXPs to lend, the model allows us to compare differences in interbank activity as a result of constraints placed on retail activity.[24]

The model assumes no bid-ask spread in the interbank foreign exchange market. The results will not change qualitatively if there were bid-ask spreads because interbank bid-ask spreads are generally narrower than retail bid-ask spreads.[25] If a FXP is positive in all

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[23]See Appendix B for a numerical example of an interbank foreign exchange market session.
[24]I will discuss this tool more in depth in the Results section of the paper.
[25]In reality, large banks offer each other better rates because of reciprocal treatment over time.

three currencies, it still trades because it is made no worse off. If negative positions still exist, FXPs must borrow from the interbank domestic funds market at an exogenously given interest rate.

In reality, the retail market and the interbank market operate simultaneously. Banks attempt to offset large orders in the retail market by using the interbank market immediately because of exchange rate fluctuations and the uncertainty that other customers will arrive to supply the currency the bank is short. However, in this model, the number of customers and the distributions of the types and values of transactions are known in advance. Since exchange rate fluctuations are not considered in this model, it is more profitable for FXPs to wait until the retail market closes before participating in the interbank foreign exchange market.

5.3 The Interbank Funds Market

In this model, the interbank domestic funds market exists for every currency. The interest rate is assumed to be fixed. The interbank funds market is used as a last resort to fill retail orders. Each FXP attempts to limit its borrowing costs. The model does not consider different borrowing rates for different currencies. Given different borrowing rates for good funds, the currency with the lowest interest rate may result as the vehicle currency.

5.4 The FXPs Profits

The parameters studied in this model are self-imposed debit caps, collateral requirements and the bid-ask spreads in the retail market. Before trading begins, each FXP chooses the self-imposed debit cap and the bid-ask spreads for each type of transaction. Collateral requirements are given by the payment system operators. All FXPs are identical in that they set the same bid-ask spreads and face the same parameters, but face a different set of retail customers.

FXPs want to maximize their expected profits at the end of foreign exchange activity or:

$$max \ E[Profits] = E[Revenue] - E[Costs] \, ,$$

where:

$$E[\ ] = Expected\ Value\,.$$

Revenue is defined as:

$$E[Revenue] = E[(P_{net}) + (D_{net})e_{pd} + (Y_{net})e_{py}]\,, \tag{4}$$

where:

$$P_{net} \equiv net\ holdings\ of\ p\ after\ the\ close\ of\ the\ interbank$$
$$foreign\ exchange\ market\,,$$

$$D_{net} \equiv net\ holdings\ of\ d\ after\ the\ close\ of\ the\ interbank$$
$$foreign\ exchange\ market\,,$$

$$Y_{net} \equiv net\ holdings\ of\ y\ after\ the\ close\ of\ the\ interbank$$
$$foreign\ exchange\ market\,.$$

The amounts of net currency holdings are determined by the activity in the retail and interbank foreign exchange markets. An FXP may have zero or negative amounts of any two currencies, but it must have a positive amount of one currency, because it trades based on a bid-ask spread.[26]

Costs are separated into three components – liquidity costs, operating costs and borrowing costs. Liquidity costs are associated with each FXP having to hold collateral with the payment system operator. The cost of holding collateral is the return on an alternate investment opportunity minus the return on a safe asset which is used as collateral. Liquidity cost is the sum of the forgone interest differences as a result of the FXPs holding collateral in each of the three payment systems.

Operating costs are fixed for participation in each currency's payment system. Operating costs include per month fees for accessing the system, hardware costs and other administrative costs of being a member of a payment system. These costs are independent of the volume of transactions. The total operating cost is the sum of the participation costs for each of the three payment systems.

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[26]The revenue is received in the currency that is used by the customer to buy the other currency from the FXP. Therefore, the net value indexed in one currency of currency holdings before accounting for costs must be greater than zero.

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Both liquidity and operating costs are known before foreign exchange activity begins. Unlike liquidity and operating costs, borrowing costs, BC, are not known at the beginning of trading since it depends on the net positions of the FXPs after the interbank foreign exchange market closes. A FXP is forced to borrow if it has a negative position in any currency. Therefore, BC can be stated as:

$$BC = E[(Z_P)\,i_p + ((Z_D)\,i_d)\,e_{pd} + ((Z_Y)\,i_y)\,e_{py}] \tag{5}$$

where:

$$Z_l = \begin{cases} 0 & \text{if } l_{net} \geq 0 \\ -l_{net} & \text{if } l_{net} < 0 \end{cases}$$

$$l \;=\; p,\; d,\; or\; y\,,$$

$$i_p \;\equiv\; the\,interbank\,funds\,rate\,for\,borrowing\,p\,,$$

$$i_d \;\equiv\; the\,interbank\,funds\,rate\,for\,borrowing\,d\,,$$

$$i_y \;\equiv\; the\,interbank\,funds\,rate\,for\,borrowing\,y\,.$$

6   The Simulation

Twenty random customers arrive at each foreign exchange player sequentially and want to purchase one currency for another. Each customer has access to one FXP. If the trade is denied, the customer cannot change her currency that day.[27] All trades are conducted at the bid-ask spreads that are set by the FXPs at the beginning of the day. At the end of the retail market, the three FXPs attempt to offset positions in all currencies amongst themselves in the interbank foreign exchange market. Any remaining shortages are filled by borrowing in the interbank funds market for that specific currency. Each simulation is run 1000 times. A simulation is defined as a sequence of transactions that takes place during the day for a given set of parameters.

At the end of each simulation, profits are calculated for each FXP. Profits will vary between simulation runs for two reasons. First, since the order of customers and types

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[27]The results do not change qualitatively if customers are allowed to approach more than one FXP. By approaching more than one FXP, the customer requires additional time to make the transaction. I define liquidity in terms of the immediacy of converting one asset into another. This additional time can be interpreted as a decrease in liquidity.

of transactions are random, the FXP does not know its revenue stream because it may have to decline trades due to self-imposed debit caps. Second, the FXP does not know its borrowing costs because it is dependent on the positions of other FXPs that it trades with in the interbank market.

The measure of liquidity used in this simulation is the number of no trades. A no trade is defined as a foreign exchange transaction that is declined in the retail market because the FXP reached its cap for the currency to be delivered. Liquidity is defined by the relative immediacy that an asset can be converted into some other asset. If a customer is declined a transaction delivering a certain currency more often than other currencies, that currency is not as liquid as others. Since the bid-ask spreads are fixed at the same level during the trading period, FXPs decline trades instead of widening the bid-ask spread. Later, I will allow the bid-ask spread to vary.

A set of simulations are conducted where all retail trades are possible. I will refer to this state as a non-vehicle world. Another set of simulations are conducted where one currency is involved in all the retail transactions. I will refer to this state as a vehicle world. Both sets of simulations are compared with each other for the same parameters to see if there are certain conditions where FXPs find the vehicle world more profitable.

If p is used as the vehicle currency for all transactions, the possible trades in the retail market would include: p for d, d for p, p for y and y for p. Each type of transaction has a probability of $1/4$ of occurring. Currency p is involved in all the transactions as opposed to $2/3$ of the transactions on average in the non-vehicle world. Currency p is being delivered by the FXP in $1/2$ of the transactions on average as opposed to $1/3$ of the transactions on average in the case without the vehicle. The other two currencies, d and y, are being delivered $1/4$ of the time on average as opposed to $1/3$ of the time on average in the non-vehicle case. The payment system that delivers p sees a greater volume of payments.

In the vehicle world, customers arriving at their FXP are limited in the types of transactions that can be conducted. The FXP will decide whether to use a vehicle in the retail market based on its expected profits. If expected profits are higher using a vehicle, the FXP will offer trades that only involve the vehicle. If a customer cannot exchange

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the two non-vehicle currencies directly, it may choose to hold the vehicle currency as its reserve currency.[28]

However, there are trades in the foreign exchange markets that do not involve the vehicle currency. Trades that do not involve the vehicle currency should have higher bid-ask spreads because of the higher transactions costs associated with them. The simulation is run again to find the wider bid-ask spread for non-vehicle trades that compensates for the lost revenue.

7   The Results

All three FXPs face the same values for the above parameters. Different values for the bid-ask spread, α, β and γ are compared for profitability and liquidity of the currencies involved. α, β and γ are collateral requirements that are used to determine the debit caps (see page 19). The results are compiled in tables 3-10 which are located in the Appendix A.

There are two tables for each set of parameters. The first table, referred to as a, lists the average profits of FXPs. The second column, labeled "Profits w/o IB," is the profit earned by a FXP before participating in the interbank foreign exchange market and the third column, labeled "Profits w/ IB," is the profit earned after participating in the interbank foreign exchange market. The profits including interbank foreign exchange market participation should be higher than profits based on no interbank foreign exchange participation. The primary reason to calculate profits at two different stages is to highlight any differences in the value of interbank transactions as a result of a change in the parameters that affect the retail market. The differences in profit are listed in the last column, labeled "Diff. in Profits."

The second or bottom table, referred to as b, lists the liquidity measures for each set of simulations. The columns PNT, DNT and YNT list the average number of no trades for each currency. The last column labeled "Trades" lists the average number of retail trades conducted.

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[28]Here, I define reserve currency to be the currency that customers hold to conduct business in the international marketplace.

Initially, FXPs trade all three currencies directly. These results are given in tables 3-5. The bid-ask spread is set at .10%. The zero profit condition for competitive markets should be met for each simulation, but for comparisons between the tables most profits are shown at above zero.[29] All profits are calculated in currency p using the interbank exchange rates to convert currency positions in d and y.

In table 3a, β and γ are set at .1. Looking at table 3a, as α increases, on average profits decrease. Specifically, profits with interbank participation decrease from $35.14p$ (table 3a, column 3) to $25.78p$ (table 3a, column 3). The standard deviation of profits on average increases as α increases. Specifically, the standard deviation of profits increases from 16.05 (table 3a, column 3) to 19.19 (table 3a, column 3). Profits are more uncertain as α increases, because a lower cap increases the chance that trades involving p will be declined resulting in reduced profits. These results indicate that lower collateral requirements lead to greater profits with reduced variance.

The results in table 3a also show that as α increases, the difference in profits between the market with an interbank foreign exchange market and the market without one (column 4) decreases. Specifically, for α equal to .1, the difference is $16.65p$ (table 3b, column 4) and for α equal to 1 the difference reduces to $12.37p$ (table 3b, column 4). The difference in profits result from FXPs offsetting positions in the interbank foreign exchange market. At lower values of α, borrowing costs are less than at higher values of α because of the higher probability of FXPs to offset foreign exchange transactions in the interbank market. As a result, borrowing costs increase as the cap decreases. These results are consistent with increases in β and γ as seen in tables 4a and 5a.

The PNT column, in table 3b, shows that as α increases so does the percentage of no trades involving currency p on average. Specifically, at α equal to .1, the value of PNT is 0.00 (table 3b, column 2) and at α equal to 1, the value of PNT is equal to 19.22 (table 3b, column 2). In other words, 19.22% of the trades on average in which the FXPs deliver p are declined. Thus, as α increases the liquidity of p decreases.

For the simulations reported in tables 4 and 5, the collateral requirement for the

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[29]Changing one of the parameters would lead to reduced profits. Tables 9 and 10 look into decreasing and increasing the bid-ask spread.

other two currencies are increased. For table 4 simulations, the values of β and γ are set at .5 and in table 5 simulations, they are set at 1. Comparing results for the three sets of simulations where α is set at .1, there is a decline in profits from 35.14p (table 3a, column 3) when β and γ are set at .1 to 30.57p (table 4a, column 3) when β and γ are set at .5 and a further decline to 14.56p (table 5a, column 3) when β and γ are set to 1. These results indicate that increases in collateral requirements of the two other currencies lead to reduced profits on average. The standard deviation of profits on average also increased.

Tables 6 through 8 report on simulations where all transactions involve p. In other words, p serves as the vehicle currency. Comparing tables 3a and 6a, one notices that profits on average are lower for higher values of α in the case of using a vehicle. Specifically, for α equal to 1, the average profit without a vehicle is 25.78p (table 3a, column 3) and with a vehicle is 21.69p (table 6a, column 3). In the non-vehicle case, about .47 more trades on average are conducted versus the vehicle case. Given low collateral requirements for the other two currencies and high collateral requirements for p, p would not be chosen as a vehicle.

Simulation runs reported in tables 4a and 7a, where β and γ are set at .5, are not significantly different from each other with the exception for low values of α. Overall, the difference in the number of trades conducted is fairly small. However, there is a reduction in the variance at lower values of α. A vehicle currency might be used to reduce the variance in profits.

For simulation runs reported in tables 5a and 8a, where β and γ are set at 1, profits on average are greater when p is used as a vehicle, especially at lower values of α. Specifically, the average profit is 14.56p (table 5a, column 3) for the no vehicle case and 20.97p (table 8a, column 3) for the vehicle case where α equal to .1. The increase in average profit is related to more trades being conducted when a vehicle currency is used. Specifically, the number of trades conducted on average increases from 17.09 (table 5b, column 5) in the non-vehicle case when α equals .1 to 18.15 (table 8b, column 5) in the vehicle case. FXPs find it more profitable to use a vehicle given these specific parameters.

The results indicate that a vehicle currency emerges if differences in debit caps are large enough. Since FXPs operate in competitive markets, the bid-ask spreads between the vehicle and the other currencies become narrower to force profits to zero. In tables 9 and 10, changes in bid-ask spreads are compared when the value of α is set at .1 and the values of β and γ are set at 1. The results in table 9a indicate that as the bid-ask spread decreases so does profit. The purpose of this set of simulations is to show that there exists a lower bid-ask spread that would drive profit to the non-vehicle profit of $14.56p$ (table 5a, column 3). At this level of profit, FXPs make the same amount of profit as in the non-vehicle state. Therefore, FXPs would be indifferent between using a vehicle and setting the bid-ask spread at around .096% and offering all trades at a bid-ask spread of .10%.

Alternatively, FXPs could increase the bid-ask spreads of the non-vehicle trades. A set of simulations are conducted where there are two different bid-ask spreads. Trades with the vehicle currency have narrower bid-ask spreads than trades without the vehicle. In table 10a, we see that non-vehicle trades would have to have a spread somewhere between .11% to .115% to match profits of the case where all transactions are conducted through p.

Summarizing the results:

1. Higher debit caps lead to greater expected profits.

2. Higher debit caps lead to reduced variance in expected profits.

3. As the debit cap of a given currency's payment system increases, the liquidity of that currency increases.

4. As the debit cap of a given currency's payment system decreases, the potential to offset positions from the retail foreign exchange market in the interbank foreign exchange market decreases.

5. If one currency has a payment system that grants sufficiently greater intraday credit than the payment systems of the other currencies, that currency will emerge as the vehicle currency given all else being equal.

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6. The bid-ask spreads for transactions involving the vehicle will be lower.

8 Conclusion

In this article, I suggest a link between payment system policies and the existence of a vehicle currency. Specifically, I investigate the effects of payments-related intraday credit facilities and the bid-ask spreads set by foreign exchange dealers. If there are sufficient differences between payments-related intraday credit facilities across payment systems, a vehicle currency may emerge. Furthermore, if a vehicle currency exists, transactions involving it will have a lower cost than those not involving it.

As policymakers consider various risk-reducing measures for their settlement systems, they should also consider the effects of their policies on global financial markets. The major industrialized countries differ on the types of risk-reducing measures they employ. Some currencies clear via net settlement systems that eventually settle a relatively small amount over their domestic RTGS systems. Net settlement systems differ in their collateral requirements. Such differences may lead to cost differentials among net settlement systems. On the other hand, other currencies are cleared and settled over RTGS systems. RTGS systems where the central bank does not extend intraday credit or extends fully collateralized credit are more expensive to use than net settlement systems that are not fully collateralized. Differences in the cost of intraday credit between U.S. settlement systems and those of other countries could help maintain the dollar's status as vehicle currency in foreign exchange markets.

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Appendix A: Simulation Results

This appendix contains the results of the simulations. The results are presented in tables 3-10. The following parameters are set at:

$$e_{pd} = 2, \quad i_p = .0005, \quad P_c = 30000,$$

$$e_{py} = 3, \quad i_d = .0005, \quad D_c = 15000,$$

$$e_{dy} = 1.5, \quad i_y = .0005, \quad Y_c = 10000.$$

The amount of currency requested by customers are taken from the following distributions for each currency:

$$X_p \quad \sim \quad N(15000, 1500),$$

$$X_d \quad \sim \quad N(7500, 750),$$

$$X_y \quad \sim \quad N(5000, 500),$$

where:

$$X_j \quad \equiv \quad the \ distribution \ of \ amounts \ of \ currency \ j \ demanded \ by \ customers,$$

$$j \quad \equiv \quad p, \ d, \ or \ y.$$

Tables 3-8 contain results for simulations where α is changed while other parameters are held constant. Tables 3-5 contain results concerning simulations where all trades are possible. Tables 6-8 consider only trades through p. Tables 9-10 show results where the bid-ask spread is allowed to vary.

Tables 3, 4 and 5 show results for simulations where FXPs accept all trades. In the top and bottom tables, the first column represents the values of α used. Column 2, in the top tables (designated by a), labeled "Profits w/o IB" records the profits of FXPs before they enter the interbank foreign exchange market. Column 3 labeled "Profits w/ Interbank" records profits after foreign exchange interbank participation. Both column 2 and 3 give the average profits and the standard deviation of those profits. The profits for each currency is given in p. Column 4 records the differences in the two types of profits. The interbank exchange rates are used for converting profits into p.

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The bottom table, labeled b, records the measures of liquidity. The second, third and fourth columns labeled PNT, DNT and YNT, respectively, are the liquidity measures of each currency. They represent the percentage of times that a trade was declined because the FXP reached its debit cap. The no trade percentage for currency p is calculated by:

$$PNT = \frac{trades\ declined\ which\ deliver\ p}{6.66} * 100\%\,,$$

where

$$PNT \equiv percentage\ of\ no\ trades\ associated\ with\ the\ delivery\ of\ p\,.$$

Since all currencies have equal probability of being delivered, DNT and YNT are calculated in a similar manner. DNT and YNT are defined as:

$$DNT \equiv percentage\ of\ no\ trades\ associated\ with\ the\ delivery\ of\ d\,,$$

$$YNT \equiv percentage\ of\ no\ trades\ associated\ with\ the\ delivery\ of\ y\,.$$

The last column records the average number of total trades. Table 3, 4 and 5 differ in terms of the values of β and γ. β and γ are set at .1 in table 3, at .5 in table 4, and at 1 in table 5.

Tables 6, 7 and 8 differ from tables 3, 4 and 5 in that the only transactions that involve p are allowed. The calculations for PNT, DNT, and YNT differ from the previous case where all trades were possible. The calculation for PNT changes to:

$$PNT = \frac{trades\ declined\ which\ deliver\ p}{10} * 100\%\,.$$

DNT and YNT are calculated as:

$$DNT = \frac{trades\ declined\ which\ deliver\ d}{5} * 100\%\,,$$

$$YNT = \frac{trades\ declined\ which\ deliver\ y}{5} * 100\%\,.$$

These calculations are based on p being delivered 10 times on average and d and y being delivered 5 times on average.

Tables 9 and 10 study the differences in bid-ask spreads on FXPs' profits. In table 9, all transactions must involve p. Instead of the value of α changing as in the previous simulations, the bid-ask spread changes between simulations. Column 1, labeled "Bid-Ask Spread" states the bid-ask spread that the simulation was run at. All other columns are the same as table 1. In table 10, all transactions are permitted. In this set of simulations non-vehicle trades are conducted at different bid-ask spreads than trades with the vehicle.

Table 3: All Trades Possible with β and γ Equal to .1

Table 3a

α	Profits w/o IB		Profits w/ IB		Diff. in Profits
0.1	18.49	(17.29)	35.14	(16.05)	16.65
0.2	17.87	(18.11)	34.98	(16.15)	17.11
0.3	18.77	(17.53)	35.14	(16.05)	16.37
0.4	18.12	(17.83)	34.42	(16.29)	16.30
0.5	19.03	(18.09)	33.26	(16.90)	14.23
0.6	16.96	(18.47)	31.17	(17.61)	14.21
0.7	15.07	(19.96)	28.92	(18.84)	13.85
0.8	13.20	(19.98)	26.20	(19.34)	13.00
0.9	14.92	(19.42)	27.27	(18.55)	12.35
1.0	13.41	(19.72)	25.78	(19.19)	12.37

(·) – Standard Deviation of Profits
Profits w/o IB – Profits without Interbank Participation
Profits w/ IB – Profits with Interbank Participation
Diff. in Profits – [Profits w/ IB − Profits w/o IB]

Table 3b

α	PNT	DNT	YNT	Trades
0.1	0.00	0.00	0.00	20.00
0.2	0.06	0.00	0.00	20.00
0.3	1.50	0.00	0.00	19.90
0.4	4.35	0.00	0.00	19.71
0.5	6.16	0.00	0.00	19.59
0.6	9.76	0.00	0.00	19.35
0.7	13.21	0.00	0.00	19.12
0.8	17.71	0.00	0.00	18.82
0.9	17.11	0.00	0.00	18.86
1.0	19.22	0.00	0.00	18.72

PNT – % of no trades with the delivery of p
DNT – % of no trades with the delivery of d
YNT – % of no trades with the delivery of y
Trades – Ave. number of trades conducted
       in the retail market

Table 4: All Trades Possible with β and γ Equal to .5

Table 4a

α	Profits w/o IB		Profits w/ IB		Diff. in Profits
0.1	17.83	(19.32)	30.57	(18.11)	12.74
0.2	17.62	(18.83)	30.49	(17.99)	12.87
0.3	16.06	(20.05)	29.90	(17.92)	13.84
0.4	15.68	(19.01)	29.02	(17.83)	13.34
0.5	15.29	(20.47)	28.23	(18.70)	12.94
0.6	15.14	(20.99)	27.02	(19.38)	11.88
0.7	13.31	(20.58)	25.05	(19.00)	11.74
0.8	12.76	(21.31)	23.58	(19.35)	10.82
0.9	10.38	(21.90)	21.63	(20.08)	11.25
1.0	10.21	(21.45)	20.86	(20.01)	10.65

(·) – Standard Deviation of Profits
Profits w/o IB – Profits without Interbank Participation
Profits w/ IB – Profits with Interbank Participation
Diff. in Profits – [Profits w/ IB – Profits w/o IB]

Table 4b

α	PNT	DNT	YNT	Trades
0.1	0.00	6.30	7.50	19.08
0.2	0.09	6.45	6.60	19.12
0.3	1.43	7.80	7.95	18.85
0.4	3.90	7.50	6.60	18.80
0.5	8.10	6.90	6.60	18.56
0.6	10.80	7.50	6.60	18.34
0.7	13.20	8.40	7.50	18.06
0.8	15.90	8.40	6.90	17.92
0.9	17.25	9.30	8.25	17.68
1.0	20.10	7.95	8.25	17.58

PNT – % of no trades with the delivery of p
DNT – % of no trades with the delivery of d
YNT – % of no trades with the delivery of y
Trades – Ave. number of trades conducted
in the retail market

Table 5: All Trades Possible with β and γ Equal to 1

Table 5a

α	Profits w/o IB		Profits w/ IB		Diff. in Profits
0.1	6.24	(21.52)	14.56	(21.26)	8.32
0.2	6.48	(22.13)	15.22	(21.06)	8.74
0.3	7.69	(21.56)	15.99	(20.63)	8.30
0.4	5.97	(21.99)	14.59	(21.19)	8.62
0.5	5.80	(20.75)	14.31	(20.27)	8.51
0.6	4.40	(22.09)	12.53	(20.96)	8.13
0.7	3.80	(21.39)	11.62	(20.08)	7.82
0.8	2.34	(22.34)	9.64	(21.32)	7.30
0.9	0.01	(23.56)	7.27	(22.07)	7.26
1.0	[1.34]	(22.90)	5.73	(21.39)	7.07

(·) – Standard Deviation of Profits
[·] – Negative Profits
Profits w/o IB – Profits without Interbank Participation
Profits w/ IB – Profits with Interbank Participation
Diff. in Profits – [Profits w/ IB − Profits w/o IB]

Table 5b

α	PNT	DNT	YNT	Trades
0.1	0.00	22.05	21.60	17.09
0.2	0.13	21.30	21.45	17.14
0.3	1.80	20.70	21.30	17.08
0.4	5.25	20.70	21.90	16.81
0.5	9.00	21.15	21.00	16.59
0.6	12.45	21.90	22.35	16.22
0.7	15.60	22.95	21.90	15.97
0.8	20.25	21.60	22.80	15.69
0.9	20.85	25.65	23.40	15.34
1.0	25.05	22.80	24.45	15.18

PNT – % of no trades with the delivery of p
DNT – % of no trades with the delivery of d
YNT – % of no trades with the delivery of y
Trades – Ave. number of trades conducted
in the retail market

Table 6: All Retail Trades Go Through p with β and γ Equal to .1

Table 6a

α	Profits w/o IB		Profits w/ IB		Diff. in Profits
0.1	19.48	(18.36)	35.92	(16.70)	16.44
0.2	17.52	(20.02)	33.79	(18.30)	16.27
0.3	18.85	(19.10)	33.43	(17.17)	14.58
0.4	18.09	(19.49)	31.61	(17.01)	13.52
0.5	16.80	(19.05)	30.01	(17.61)	13.21
0.6	15.94	(20.31)	28.05	(19.26)	12.11
0.7	14.47	(19.68)	25.57	(18.64)	11.10
0.8	13.65	(20.28)	24.35	(19.51)	10.70
0.9	11.48	(20.97)	21.43	(20.57)	9.95
1.0	11.68	(20.38)	21.69	(19.75)	10.01

(·) – Standard Deviation of Profits
Profits w/o IB – Profits without Interbank Participation
Profits w/ IB – Profits with Interbank Participation
Diff. in Profits – [Profits w/ IB − Profits w/o IB]

Table 6b

α	PNT	DNT	YNT	Trades
0.1	0.00	0.00	0.00	20.00
0.2	0.46	0.00	0.00	19.95
0.3	2.60	0.00	0.00	19.74
0.4	4.80	0.00	0.00	19.52
0.5	8.00	0.00	0.00	19.20
0.6	10.07	0.00	0.00	18.93
0.7	13.60	0.00	0.00	18.64
0.8	15.60	0.00	0.00	18.44
0.9	17.90	0.00	0.00	18.21
1.0	17.50	0.00	0.00	18.25

PNT – % of no trades with the delivery of p
DNT – % of no trades with the delivery of d
YNT – % of no trades with the delivery of y
Trades – Ave. number of trades conducted
in the retail market

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Table 7: All Retail Trades Go Through p with β and γ Equal to .5

Table 7a

α	Profits w/o IB		Profits w/ IB		Diff. in Profits
0.1	18.75	(18.93)	32.95	(16.90)	14.20
0.2	18.42	(19.27)	32.51	(17.85)	14.09
0.3	17.64	(18.62)	31.29	(16.96)	13.65
0.4	17.77	(20.01)	30.97	(17.81)	13.20
0.5	16.96	(20.10)	28.92	(18.35)	11.96
0.6	15.53	(20.53)	26.70	(18.73)	11.17
0.7	14.53	(20.18)	24.83	(18.93)	10.30
0.8	12.78	(21.11)	23.01	(19.82)	10.23
0.9	11.82	(20.51)	21.44	(19.48)	9.62
1.0	10.82	(20.50)	19.46	(19.77)	9.18

(·) – Standard Deviation of Profits
Profits w/o IB – Profits without Interbank Participation
Profits w/ IB – Profits with Interbank Participation
Diff. in Profits – [Profits w/ IB − Profits w/o IB]

Table 7b

α	PNT	DNT	YNT	Trades
0.1	0.00	6.20	5.40	19.42
0.2	0.49	5.20	5.00	19.44
0.3	2.30	6.20	6.40	19.14
0.4	5.00	6.00	7.40	18.83
0.5	7.70	6.80	5.80	18.60
0.6	10.70	7.20	6.60	18.24
0.7	13.30	6.40	6.00	18.05
0.8	15.40	6.60	5.60	17.85
0.9	16.80	7.40	6.00	17.65
1.0	17.80	6.80	6.80	17.54

PNT – % of no trades with the delivery of p
DNT – % of no trades with the delivery of d
YNT – % of no trades with the delivery of y
Trades – Ave. number of trades conducted
in the retail market

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Table 8: All Retail Trades Go Through p with β and γ Equal to 1

Table 8a

α	Profits w/o IB		Profits w/ IB		Diff. in Profits
0.1	12.49	(19.92)	20.97	(19.78)	8.48
0.2	12.42	(20.04)	20.97	(20.01)	8.55
0.3	11.96	(20.03)	20.35	(20.01)	8.39
0.4	11.45	(20.09)	19.48	(19.72)	8.03
0.5	9.61	(21.19)	17.72	(19.74)	8.11
0.6	7.43	(22.01)	15.28	(20.67)	7.85
0.7	6.76	(21.07)	14.25	(19.36)	7.49
0.8	3.72	(22.06)	11.16	(20.72)	7.44
0.9	3.20	(21.60)	10.78	(20.43)	7.58
1.0	0.41	(21.76)	7.64	(20.57)	7.23

(·) – Standard Deviation of Profits
Profits w/o IB – Profits without Interbank Participation
Profits w/ IB – Profits with Interbank Participation
Diff. in Profits – [Profits w/ IB − Profits w/o IB]

Table 8b

α	PNT	DNT	YNT	Trades
0.1	0.00	18.00	19.00	18.15
0.2	0.50	18.80	19.20	18.05
0.3	2.40	19.80	18.80	17.83
0.4	7.20	17.60	17.60	17.52
0.5	10.80	19.60	18.80	17.00
0.6	14.40	21.00	20.60	16.48
0.7	16.20	20.80	21.00	16.29
0.8	18.60	22.80	23.40	15.83
0.9	19.80	22.80	22.40	15.76
1.0	22.90	24.00	23.40	15.34

PNT – % of no trades with the delivery of p
DNT – % of no trades with the delivery of d
YNT – % of no trades with the delivery of y
Trades – Ave. number of trades conducted
in the retail market

Table 9: All Retail Trades Go Through p with β and γ Equal to 1 and α Equal to .1

Table 9a

Bid-Ask Spread	Profits w/o IB		Profits w/ IB		Diff. in Profits
0.100%	12.49	(19.92)	20.97	(19.78)	8.48
0.099%	10.97	(19.92)	19.51	(19.79)	8.54
0.098%	10.20	(18.98)	18.83	(18.59)	8.63
0.097%	8.41	(19.47)	17.41	(19.57)	9.00
0.096%	6.11	(20.32)	14.34	(20.05)	8.23
0.095%	5.55	(19.07)	14.04	(18.97)	8.49
0.094%	3.48	(18.97)	11.71	(18.73)	8.23
0.093%	1.99	(19.37)	10.74	(18.56)	8.75
0.092%	0.85	(18.53)	9.45	(18.39)	8.60
0.091%	[1.90]	(18.79)	7.65	(18.77)	9.55
0.090%	[1.34]	(19.70)	6.57	(19.11)	7.91

(·) – Standard Deviation of Profits
[·] – Negative Profits
Profits w/o IB – Profits without Interbank Participation
Profits w/ IB – Profits with Interbank Participation
Diff. in Profits – [Profits w/ IB − Profits w/o IB]

Table 9b

Bid-Ask Spread	PNT	DNT	YNT	Trades
0.100%	0.00	18.00	19.00	18.15
0.099%	0.00	19.00	19.00	18.10
0.098%	0.00	18.00	18.20	18.19
0.097%	0.00	19.00	18.80	18.11
0.096%	0.00	18.80	20.80	18.02
0.095%	0.00	19.20	19.60	18.06
0.094%	0.00	20.20	17.80	18.10
0.093%	0.00	18.00	19.40	18.13
0.092%	0.00	18.80	18.40	18.14
0.091%	0.00	19.60	18.00	18.12
0.090%	0.00	20.20	17.80	18.10

PNT – % of no trades with the delivery of p
DNT – % of no trades with the delivery of d
YNT – % of no trades with the delivery of y
Trades – Ave. number of trades conducted
in the retail market

Table 10: All Trades Possible with β and γ Equal to 1 and α Equal to .1

Table 10a

Non-p Bid-Ask Spread	Profits w/o IB		Profits w/ IB		Diff. in Profits
0.100%	6.24	(21.52)	14.56	(21.26)	8.32
0.105%	9.87	(21.01)	18.54	(20.94)	8.67
0.110%	11.46	(21.90)	19.67	(19.67)	8.21
0.115%	13.47	(22.67)	22.07	(22.04)	8.60
0.120%	16.21	(22.56)	24.90	(21.91)	8.69
0.125%	17.23	(23.72)	25.71	(23.21)	8.48
0.130%	18.79	(23.83)	27.14	(23.31)	8.35

(·) – Standard Deviation of Profits
Profits w/o IB – Profits without Interbank Participation
Profits w/ IB – Profits with Interbank Participation
Diff. in Profits – [Profits w/ IB – Profits w/o IB]

Table 10b

Non-p Bid-Ask Spread	PNT	DNT	YNT	Trades
0.100%	0.00	22.05	21.60	17.07
0.105%	0.00	19.65	22.20	17.19
0.110%	0.00	20.85	21.30	17.17
0.115%	0.00	19.80	22.35	17.17
0.120%	0.00	20.55	21.45	17.18
0.125%	0.00	21.75	21.30	17.11
0.130%	0.00	21.30	22.80	17.04

PNT – % of no trades with the delivery of p
DNT – % of no trades with the delivery of d
YNT – % of no trades with the delivery of y
Trades – Ave. number of trades conducted
in the retail market

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Appendix B: An Interbank Foreign Exchange Session

An example of an interbank foreign exchange session is given in figure 6. In panel i, the positions of the FXPs are given after the retail market has closed. FXP A has $30,000p$, $5,000d$ and $-10,000y$. Using the interbank exchange rates given above, the value of FXP A's portfolio denominated in p is $10,000p$. FXP B has $-80,000p$, $30,000d$ and $10,000y$. The total value of FXP B's exchange position denominated in p is $10,000p$. FXP C has $80,000p$, $-35,000d$ and $3,000y$. The total value of FXP C's portfolio is $19,000p$.

If there was no interbank foreign exchange market, each FXP would incur borrowing costs because each is short in one currency. Given a .05% borrowing rate in each currency, FXP A would incur a borrowing cost of $5y$ or $15p$. FXP B would incur a borrowing cost of $40p$ and FXP C would incur a borrowing cost of $17.50d$ or $35p$. Given an interbank foreign exchange market, these costs could be reduced.

Panel ii illustrates the transactions that the FXPs would undertake to reduce borrowing costs. All transactions are conducted using the interbank exchange rates given above. The first transaction, labeled 1, takes place between FXP A and FXP B in which FXP A buys $10,000y$ with $30,000p$ from FXP B. This transaction leaves FXP A with $0p$, $5,000d$ and $0y$ and leaves FXP B with $-50,000p$, $30,000d$ and $0y$.
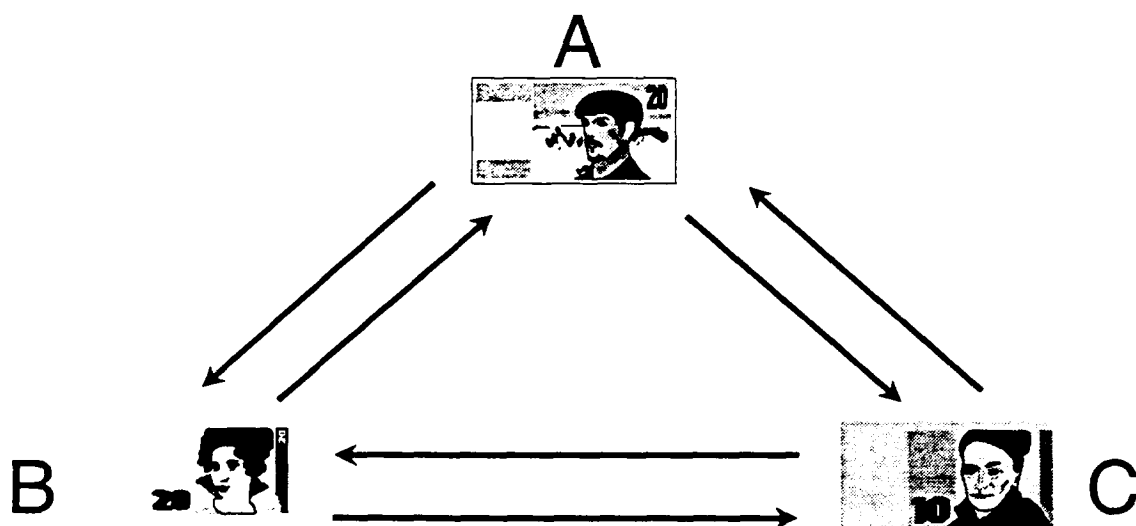
Transaction 2 occurs between FXP B and FXP C. FXP B buys $60,000p$ with $30,000d$ from FXP C. FXP B now has $10,000p$, $0d$ and $0y$ and FXP C has $20,000p$, $-5,000d$ and $3,000y$. FXP B only needed to buy $50,000p$ from FXP C to offset its negative position, but it was willing to buy more since FXP C needed more of d to offset its negative position in d. However, FXP C is still short d so it buys $5,000d$ from FXP A for $10,000p$ in transaction 3. FXP C has a final position of $10,000p$, $0d$ and $3,000y$ and FXP A ends with a position of $10,000p$, $0d$ and $0y$.

At the end of the interbank foreign exchange market, no FXP has a negative position in any currency. The final positions of each FXP is shown in panel iii. FXP A saved $15p$ in borrowing costs by interbank participation. FXP B saved $40p$ in borrowing costs. FXP C saved $35p$ in borrowing costs. In this specific example, all FXPs benefit from

the interbank foreign exchange market. All three maintain the same portfolio value but reduce borrowing costs. In general, no one FXP will be left worse off as a result of interbank participation and at least one FXP will be left better off.

Figure 1: Non-Vehicle and Vehicle Trades

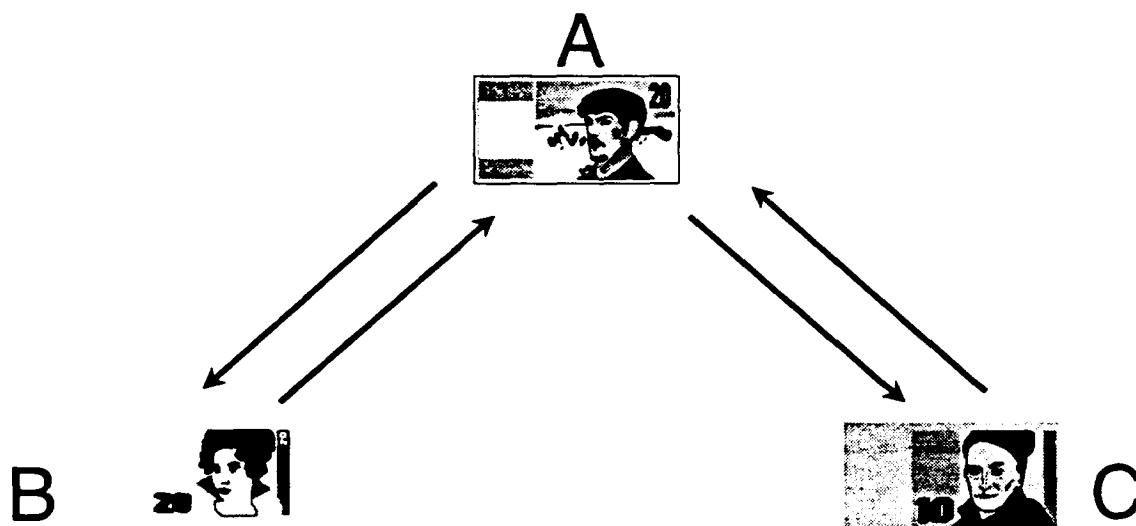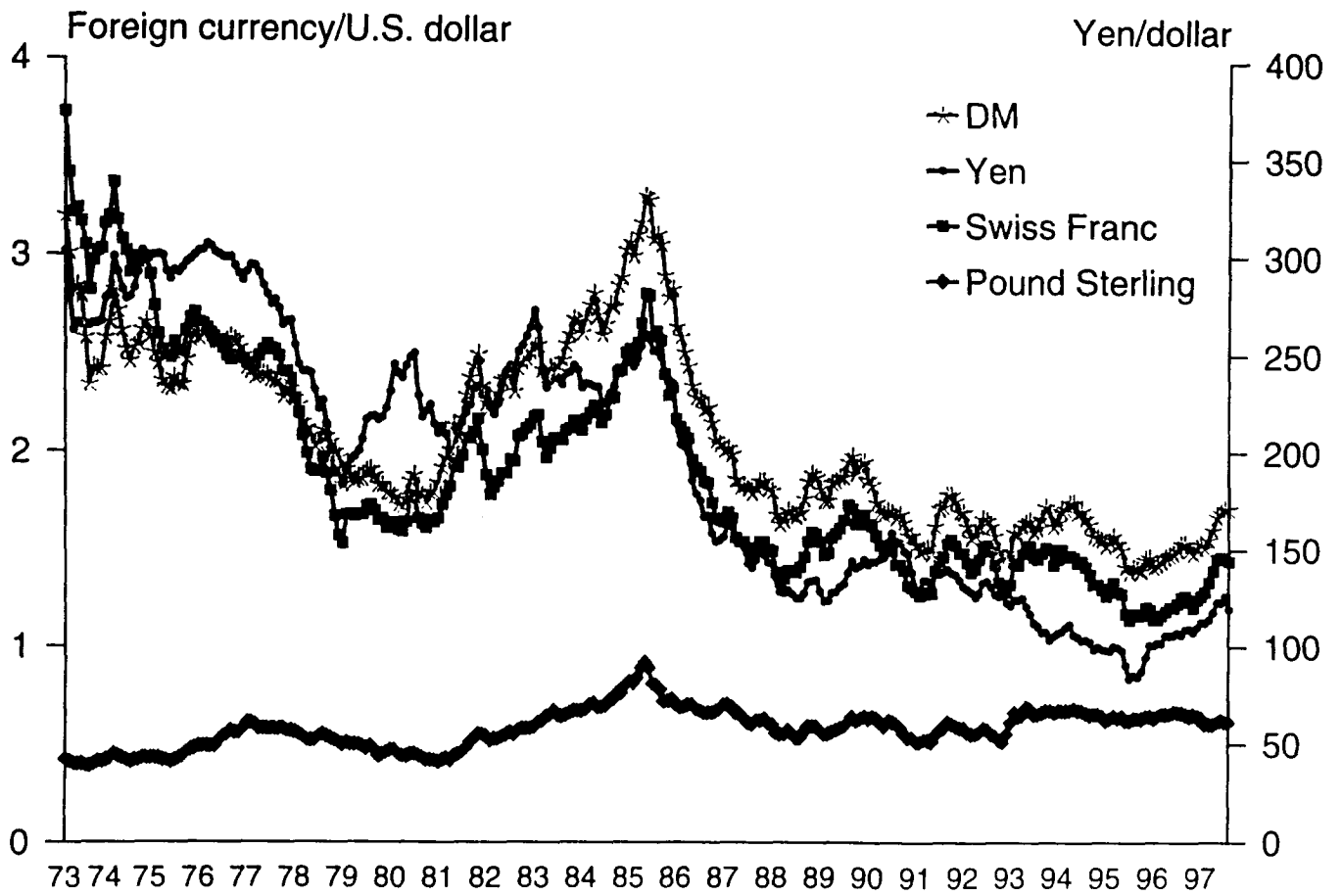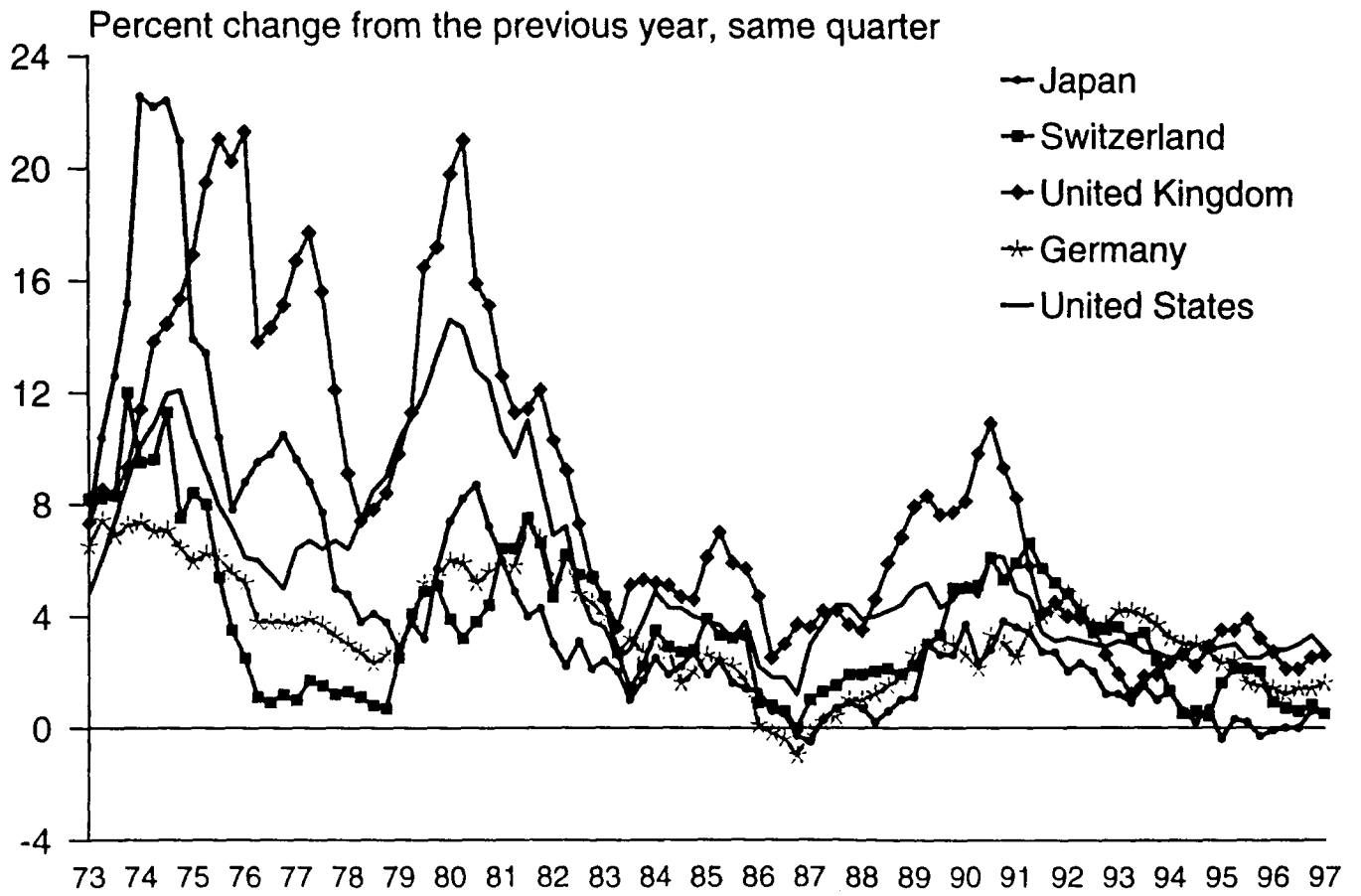i) Non-Vehicle Trades

ii) Vehicle Trades

Figure 2: Exchange Rates

Foreign currency/U.S. dollar

Yen/dollar

-×- DM
-- Yen
-■- Swiss Franc
-◆- Pound Sterling

73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97

Source: Federal Reserve Board

Figure 3: Yearly Change in Consumer Price Indices

Percent change from the previous year, same quarter

— Japan
— Switzerland
— United Kingdom
— Germany
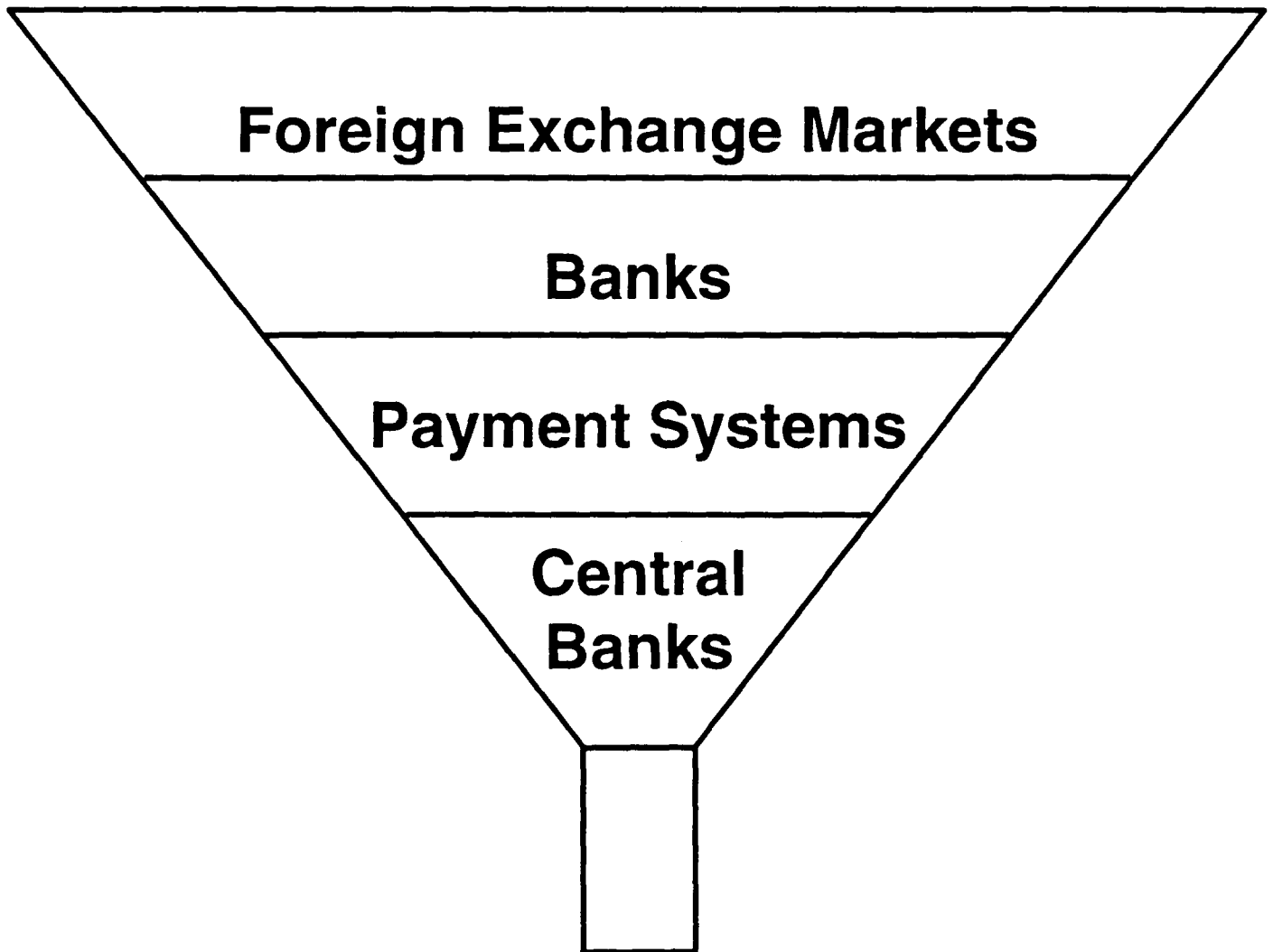— United States

Figure 4: The Funnel

Figure 5: The Market

Retail
Foreign Exchange Market

↓

Interbank
Foreign Exchange Market

↓
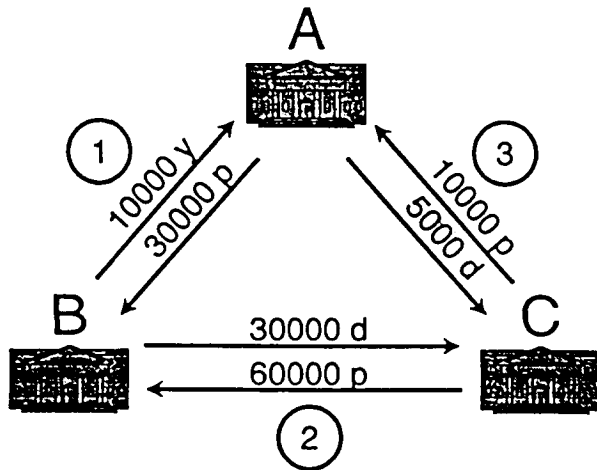
Interbank
Domestic Funds Market

Figure 6: Interbank FX Transactions

i) FXPs' Positions after Retail Market

FXP A

30000 p
5000 d
-10000 y

FXP B

-80000 p
30000 d
10000 y

FXP C

80000 p
-35000 d
3000 y
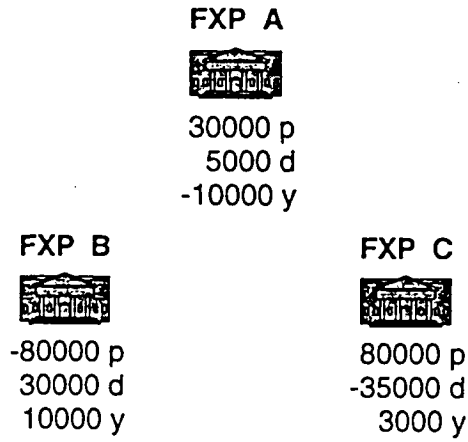
ii) Transactions in the Interbank Market

iii) FXPs' Positions after Interbank Trading

FXP A

10000 p
0 d
0 y

FXP B

10000 p
0 d
0 y

FXP C

10000 p
0 d
3000 y