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The Implementation of Monetary Policy in an Era of Electronic Payment Systems*

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In the past few decades the way in which central banks implement monetary policy has undergone fundamental changes. Not only have monetary aggregates effectively ceased to play any role, but in recent years the role of open market operations has also declined substantially. Central banks have set up real-time electronic payment systems that now play a central role in the implementation of monetary policy. Furthermore, an increasing number of central banks have completely eliminated reserve requirements. Due to these changes, central banks are now able to control short-term interest rates more effectively than before while only carrying out a tiny amount of open market operations.

These changes have come about due to the evolving role of money in the economy and in particular the increased prevalence of electronic transactions, which has decreased the demand for non-interest bearing money. Unfortunately, the description in economics textbooks and, more generally, in academic discussion of the way in which central banks control interest rates has not reflected these changes. Consequently a substantial gap has opened up between the way economists think about the implementation of monetary policy and actual practice.

While most central banks in developed countries have adopted a system for implementing monetary policy that is based on the same basic ingredients, the details are different from country to country. Some have adopted systems that are much more complicated and opaque than others and not all central banks have yet adopted all the features that lead to successful control of interest rates in an age of mostly electronic transactions. The Bank of Canada, the Reserve Bank of Australia and the Reserve Bank of New Zealand have adopted very similar systems that are both extremely simple and also well suited to successfully control interest rates in an electronic era. Today these banks define the best practice in the implementation of monetary policy. In the rest of this article I describe the system these banks use to control interest rates and contrast it with the textbook model most economists use to think about monetary policy.

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THE STANDARD TEXTBOOK MODEL OF THE IMPLEMENTATION OF MONETARY POLICY

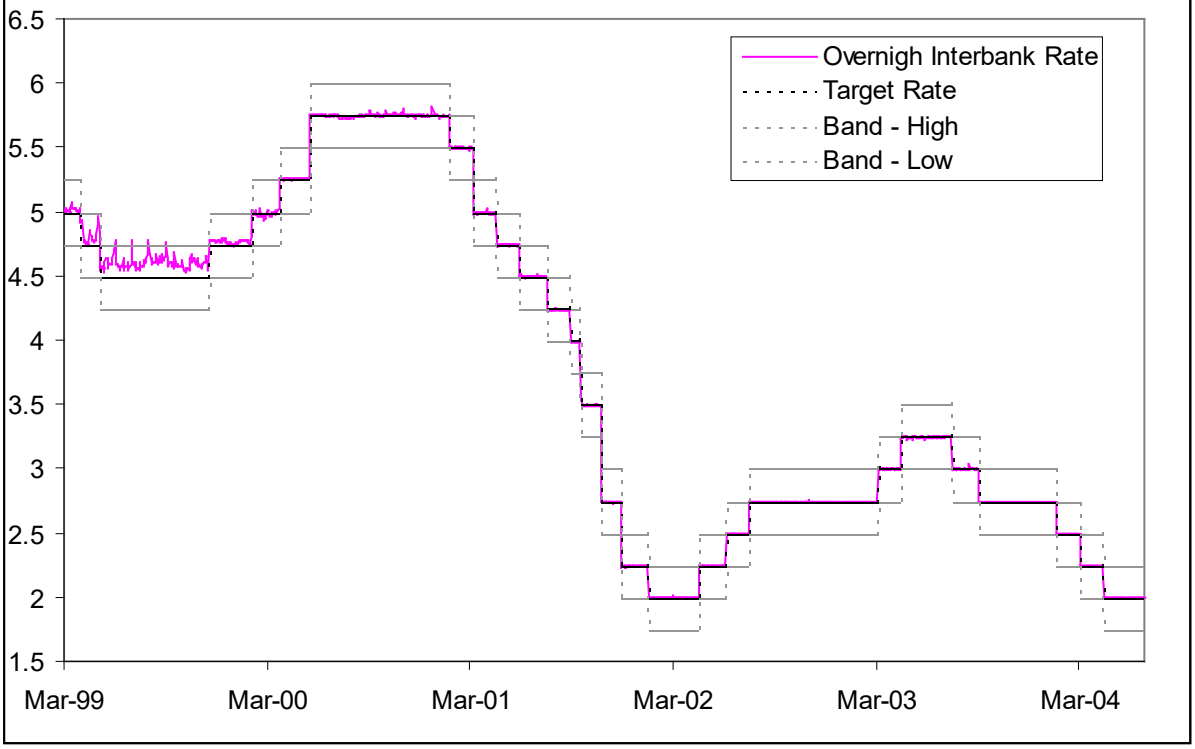
Money is a non-interest bearing asset. As a store of value, nominally riskless government bonds strictly dominate it. Money must therefore have some special attribute or else demand for money would be zero. The standard textbook model of money assumes that money facilitates transactions. This creates a positive demand for money in spite of its low return.

The short-term interest rate is the opportunity cost of holding money. Higher interest rates should lead agents to economize on their money holdings. Money demand should thus be a downward sloping function of interest rates. The short-term nominal interest rate is the policy variable that the central bank seeks to control. According to the standard model, the central bank exercises control over this variable by conducting open market operations. More specifically, the central bank affects the level of interest rates by buying and selling bonds in exchange for money. When the central bank decides to raise the interest rate it sells bonds in exchange for money. This decreases the supply of money. As money becomes scarcer, the interest rate is bid up since agents are willing to hold the remaining supply of money at higher cost. When the central bank decides to lower interest rates it buys bonds in exchange for money, thereby increasing the supply of money and lowing the interest rate. This is how monetary policy is implemented according to the standard textbook model.

The existence of a non-trivial demand for money that is interest-elastic is crucial for this model. Several authors have noted over the last few years that technological innovations in banking and the operation of payment systems have seriously eroded the demand for money (see, e.g., Friedman, 1999). Today, the vast majority of transactions are performed through real-time electronic payment systems, which entails that the parties to these transactions need not hold non-interest bearing money for any non-trivial period (i.e. overnight). These authors have voiced concerns that financial innovation may weaken the central bank's control over short-term interest rates. They worry that if these developments continue (which certainly seems likely) central banks may end up completely loosing their ability to control short-term interest rates. In the words of Friedman (1999), central banks may become "an army with only a signal corps".

Most analysis of this issue has focused on the experience of the United States. However, the erosion of demand for money has actually been much more pronounced in some other countries, such as Canada. The monetary base in a country may be divided into two parts: central bank settlement balances (also called reserves) and cash. Banks hold settlement balances to fulfill reserve requirements and in order to be able to settle payments on their own behalf and on behalf of their clients. Individuals hold cash to make payments for many smaller items. The Bank of Canada completely eliminated reserve requirements in 1992. This drastically decreased the demand for money by banks. In February 1999 the Canadian Payment Association began operating its current real-time electronic payment system. Since then, the aggregate demand for central bank settlement balances in Canada

Figure 1.: The Interbank Rate in Canada and its Target



has been zero! In other words, the demand for money by banks in Canada to facilitate transactions has been zero for the last 5 years!

This may seem puzzling. How can it be that banks in Canada don't need to hold any money for settlement purposes? Also: If demand for money by banks to facilitate transactions is zero, how can the central bank control the interbank interest rate? Can it really be the case that demand for cash by individuals to pay for minor expenses such as groceries plays a central role in the Bank of Canada's ability to control interbank interest rates? Or is the model described above perhaps missing some important elements of the story?

A related issue that many economists have found puzzling in recent years is the fact that central banks are able to exercise extremely precise control over short-term interest rates without conducting any sizable open market operations. Figure 1 shows the evolution of the overnight interbank interest rate in Canada and the Bank of Canada's target for this interest rate. Daily deviations from the Bank's target are less than one basis point on average since 2000.[1] However, during this period, the Bank of Canada has followed a policy of keeping the aggregate quantity of settlement balances in the Canadian large-value payment system constant at zero.[2] The small amount of open market operations

[1] It is hard to see the line for the over-night interbank rate after April 2001 since it tracks the Bank of Canada's target rate very closely.

[2] Actually, the Bank of Canada kept the aggregate balance of the banking sector in the LVTS constant at zero from February 1999 until April 2001. On April 2nd 2001 the Bank raised this target from zero to $50 million (less than $4 million per bank in the system). The zero target had led to slight upward pressure on

conducted by the Bank of Canada over this period have been dominated by transactions to neutralize the net impact of public sector flows between the Bank of Canada and the financial system. Open market operations due to fluctuations in the demand for coins and bills have been trivial and largely unrelated to movements in interest rates.

From the point of view of the standard model, it is most important that, on days when the Bank of Canada changes its target for the overnight interbank interest rate, this rate immediately jumps to the new target rate without the Bank conducting any special open market operations. It seems as though the central bank can simply indicate what it wants the level of interest rates to be and they will jump to that level without the central bank having to act in any way. How can this be the case?

This mystery turns out to be no mystery at all when one looks carefully at the rules that the Bank of Canada has designed for settlement of payments in the Large Value Transfer System in Canada. It is this cleverly designed electronic payment system that yields the Bank of Canada such magical control over interest rates. In other words, in order to make sense of the developments discussed above, the standard textbook model of monetary policy implementation must be augmented with a description of how central banks influence interest rates through the rules governing settlement of payments in electronic payment systems. It is to this that I now turn. For concreteness I will use the payment system in Canada as an example.[3]

CONTROLLING INTEREST RATES THROUGH ELECTRONIC PAYMENT SYSTEMS

With the exception of cash payments, all payments involve the transfer of claims on financial institutions. In Canada, all non-cash payments are cleared through one of two national payment systems: the Large Value Transfer System (LVTS) and the Automatic Clearing Settlement System (ACSS). The vast majority of payments are cleared through the LVTS.[4] This is a real-time electronic payment system that large banks use to clear all large-value or time-critical payments, either on their own behalf or on behalf of their clients. The LVTS began operating in February 1999. In November 2002, thirteen of the largest banks in Canada as well as the Bank of Canada were direct participants in the LVTS. Other banks must be clients of these banks in order to clear payments through the LVTS.[5] The ACSS is a deferred net settlement system that handles all payments not processed by the LVTS. These include checks, ATM payments and point of sale (POS) payments. Before the LVTS started operating, all non-cash payments in Canada were cleared through ACSS.

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the interbank interest rate (see figure 1). Since April 2001, however, the interbank interest rate has been very stable at the Bank's target. The reason that $50 million has worked better than literally zero has to do with an asymmetry in the transaction costs faced by the banks in the LVTS. This is discussed in more detail in footnote number 9.

[3] Similar payment systems are used by the central banks of most OECD countries, e.g., the ECB, the Reserve Banks of Australia and New Zealand, the Bank of England and Sweden's Riksbank.

[4] On an average business day in 2001 the LVTS cleared payments with a total value of $113 billion while the ACSS cleared payments with a total value of $20.5 billion.

[5] See Dingle (1998) for a detailed description of the LVTS.

In order to understand the implementation of monetary policy by the Bank of Canada it is imperative to have a firm understanding of how payments clear in the LVTS. Consider the following fairly typical payment: Alcan would like to pay Air Canada $20 million for airfares and other services. Suppose Alcan is a client of Bank of Montreal and Air Canada is a client of Royal Bank of Canada (RBC). Suppose, for simplicity, that the positions of all banks in the LVTS are zero before this payment is made.

The payment is then made in the following manner: First, Alcan contacts Bank of Montreal and asks it to make this payment. Bank of Montreal debits Alcan's account by $20 million and contacts RBC. Bank of Montreal asks RBC to credit Air Canada's account with $20 million in exchange for Bank of Montreal crediting RBC's account in the LVTS with $20 million. Bank of Montreal then contacts the LVTS and asks it to credit the account of RBC with $20 million in exchange for debiting the account of Bank of Montreal by the same amount. When all these exchanges have occurred the payment has cleared.[6]

From the point of view of the LVTS, what has happened is that Bank of Montreal's balance has fallen by $20 million while RBC's balance has risen by the same amount. Notice that the aggregate balance of the banking sector in the LVTS has not changed. On a normal business day the banks that are direct participants in the LVTS are parties to thousands of such payments. On any given day the clients of one particular bank may be paid more than they pay out. In this case that bank builds up a positive balance in the payments system. Other banks, the clients of which paid out more than they received on that particular day, will build up corresponding negative balances in the payment system.

The rules of the LVTS entail that at the end of each business day these positions are settled with the Bank of Canada. Banks that end the day with a negative balance in the LVTS must borrow this amount overnight from the Bank of Canada at an interest rate called the Bank Rate. Banks that end the day with a positive balance in the LVTS can deposit them into their settlement account and receive the Bank Rate less 50 basis points overnight. I will refer to these two interest rates as the lending and deposit rates of the Bank of Canada, respectively.

For simplicity, suppose the payment from Alcan to Air Canada is the only payment made in Canada that day. Suppose furthermore that the Bank of Canada's lending rate is 6.25%. Then, towards the end of the business day, the Bank of Montreal will have a $20 million dollar negative balance in the payment system, and face the prospect of having to borrow this amount overnight from the Bank of Canada at 6.25%. RBC, however, faces the prospect of receiving an over-night interest rate of 5.75% on the $20 million positive balance it has in the payment system. These two banks therefore have an obvious incentive to transact on the overnight interbank market at some interest rate between the

[6] Notice that I do not describe this transaction in terms of money being withdrawn from one account and deposited into another account. That terminology is unfortunate since it may lead the reader to think that money in paper form is changing hands. Such a view can lead to confusion when one is thinking about payments clearing in an electronic payment system in which no paper money exists, only credits and debits.

lending rate and the deposit rate of the Bank of Canada. For example, if RBC lends the Bank of Montreal $20 million overnight at 6%, both banks gain 25 basis points.

More generally, the fact that the Bank of Canada offers lending and deposit facilities has several important implications. First, the interbank interest rate must stay between the lending rate and the deposit rate of the Bank of Canada. If it deviates from this band, an arbitrage opportunity arises. For example, if the interbank rate is higher than the lending rate, banks can lend on the interbank market and finance this lending by borrowing overnight at the Bank of Canada at a lower rate.

Second, if the interbank rate is strictly between the lending and deposit rates of the Bank of Canada, all banks have an incentive to end the business day with a zero position in the payment system. For example, if the interbank rate is 6% while the lending rate is 6.25% and the deposit rate is 5.75%, then a bank with a negative balance would like to borrow on the interbank market at 6% rather than have to borrow at the Bank of Canada at the end of the day at 6.25%; conversely, a bank with a positive balance would prefer to lend on the interbank rate at 6% rather than deposit its funds with the Bank of Canada at the end of the day at 5.75%.

In order for all banks to be able to end the day with a zero position in the payment system, the aggregate balance of the banking sector in the payment system must be zero. In the example above I assumed that the banking sector started off with a zero aggregate balance. Furthermore, the payment made in the example did not change the aggregate balance of the banking sector in the payment system. It turns out that the vast majority of payments made in the economy do not change the aggregate balance of the banking sector in the payment system. In fact, only payments that involve the Bank of Canada itself change the aggregate balance of the banking sector in the payment system. All payments between two private banks (or clients of two private banks) keep the aggregate balance in the payments system unchanged.

Abstract for the moment from payments that involve the Bank of Canada (these will be discussed in the next section) and assume that the aggregate balance of the banking sector in the payment system is zero. In this case, the Bank of Canada is able to guarantee that the interbank interest rate stays within the 50 basis point band created by the lending and deposit facilities. When the band is moved, the interbank rate will move with the band. The Bank of Canada need not conduct any open market operations. Furthermore, its lending and deposit facilities will not end up being used, since banks have an incentive to undo the positions they build up in the payment system by transacting with each other in the interbank market before the end of each business day.

The discussion above shows that the lending and deposit facilities determine the overnight interbank rate up to a 50 basis point band. But, it is not clear what determines the level of the interbank rate within the band. Actually, in the story presented above, the interbank rate is indeterminate within the band. In practice the interbank rate has been very stable at the midpoint of the band in Canada since April 2001. Several explanations may be given for this. Woodford (2001) shows that a slight amount of uncertainty about

the aggregate balance in the payment system at the end of the day can yield a determinate equilibrium in the middle of the band. However, if there is no uncertainty and the banks are therefore completely indifferent, it should be easy for the Bank of Canada to tip the balance in favor of one particular point in the band by announcing a target rate and threatening action if the interbank market does not conform to this rate. The midpoint of the band is the Bank of Canada's announced target rate for the interbank interest rate.

MANAGEMENT OF AGGREGATE SETTLEMENT BALANCES

Now consider a slightly more complicated situation than the one analyzed in the last section. Suppose that the position of the Bank of Montreal in the payment system is negative $20 million, the position of RBC is positive $40 million and the position of all other banks is zero. The aggregate position of the banking sector is then positive $20 million.[7]

As in the example in the last section, the Bank of Montreal has an incentive to borrow $20 million overnight from RBC. Such a transaction is also desirable from RBC's perspective. Suppose therefore that this transaction occurs at the prevailing overnight interbank rate, say 6%. After it has occurred, RBC's position in the payment system is still positive $20 million while all other banks have a zero balance in the payment system. If RBC is not able to lend out these $20 million at a better interest rate, it faces the prospect of having to deposit them with the Bank of Canada overnight at an interest rate of 5.75%. Since all other banks have a zero position in the payment system, none of them has an incentive to borrow from RBC at the prevailing interbank rate of 6% since such a transaction would simply transfer RBC's troubles to them. RBC will therefore offer to lend these $20 million at a lower and lower interest rate until it has driven the overnight interbank rate all the way down to the deposit rate of the Bank of Canada. The other banks have no incentive to transact at any higher interest rate.[8]

This example shows that, if the aggregate balance in the payment system is positive, then the overnight interbank rate will fall to the deposit rate of the Bank of Canada before the end of the business day. Similar logic shows that, if the aggregate balance in the payment system is negative, then the overnight interbank rate will be bid up to the lending rate of the Bank of Canada before the end of the day.

While the existence of deposit and lending facilities at the Bank of Canada guarantees that the overnight interbank rate remains within a 50 basis point band, the discussion above shows that banks have incentives to drive this rate to the upper edge of the band when the aggregate balance in the payment system is positive and to the lower edge of

[7] Below I will discuss in detail how the aggregate position of the banking sector in the payment system changes.

[8] Transactions may of course occur as the interbank interest rate is bid down. That is, RBC may be able to hit some other bank's bid order because that bank was not quick enough to get rid of it. But this doesn't change the basic story. It just means that this other bank will turn around and start bidding down the interest rate to get rid of the funds RBC was able to dump on it.

the band when the aggregate balance is negative. One might therefore expect that this system would lead to extreme fluctuations of the interbank rate within the band.

Notice, however, that these kinds of fluctuations in the overnight rate haven't occurred in Canada in the last few years. Instead, the overnight interbank rate has been extremely stable in the middle of the band. In fact the overnightrate has never even approached the edges of the band since 1999. This is due to that fact that the Bank of Canada has actively managed the aggregate balance in the LVTS on a daily basis so as to keep it constant at zero throughout this period.[9]

There are four types of transactions that change the aggregate balance of the banking sector in the payment system. These are: 1) Payments made or received by direct clients of the central bank (most notably the government); 2) Changes in the demand for coins and bills; 3) Payments by banks into and out of reserve accounts at the central bank;[10] and 4) Payments made or received by the central bank itself (most notably due to open market operations or foreign exchange interventions).

As was mentioned above, payments made or received by the government are the dominant source of fluctuations in the aggregate balance of the banking sector in the payment system in Canada. Such payments affect the aggregate balance in the payment system since the central bank is on one side of these payments. Take a simple example: The government would like to pay Air Canada $20 million for airfares. The government asks the Bank of Canada to make this payment. The Bank of Canada debits the government's account by $20 million, contacts RBC and asks it to credit Air Canada with $20 million in exchange for the Bank of Canada crediting RBC's account in the LVTS by the same amount. The Bank of Canada then contacts LVTS and asks it to credit RBC with $20 million and debit the Bank of Canada by $20 million. Notice that in this transaction RBC's position in the payment system rose by $20 million and no other private bank's position changed. The aggregate balance of the banking sector in the payment system therefore rose by $20 million.

Changes in the demand for coins and bills and payments into and out of reserve accounts at the central bank affect the aggregate balance of the banking system in the LVTS for the same reason. When customers of a particular bank, e.g. RBC, demand more coins and bills, e.g. over Christmas or at the end of the month, RBC purchases coins and bills from

[9] As was mentioned in footnote 2, since April 2001 the Bank of Canada has actually kept the aggregate balance in the LVTS constant at a very small positive amount ($50 million). This seems to work better than targeting a balance of zero. The reason is that there is a slight asymmetry in the transaction costs faced by the banks in the LVTS. There are slightly higher transaction costs associated with using the lending facility than with using the deposit facility. Also, interbank lending at the end of the day has slightly higher transaction costs than using the deposit facility of the Bank of Canada. As a consequence, the banks prefer to end the day with a small positive balance in the payment system.

[10] This third type of payment is not relevant in Canada since reserve requirements have been abolished. However, changes in the demand for reserves are an important souce of fluctuations in the aggregate balances of the banking sector in the payment systems of countries that still have reserve requirements. Notice that I am distinguishing between reserve accounts and settlement accounts for expositional purposes. In many countries, each bank has only one account at the central bank that serves both settlement and reserve purposes.

the Bank of Canada in order to have enough to meet costumer demand. RBC pays for the coins and bills through the LVTS. RBC's balance in the LVTS therefore falls because of this transaction but the balance of no other bank changes. In countries in which reserve requirements still exist, banks pay for an increase in their reserve account at the central bank out of their account in the payment system.

Another important type of transaction that changes the aggregate balance of the banking sector in the payment system is foreign exchange intervention by the Bank of Canada. Suppose the Bank of Canada would like to sell 100 million Canadian dollars (CAD) in exchange for American dollars (USD) and that it is able to agree to terms with Bank of Montreal. Suppose the exchange rate in this transaction is 0.65 USD/CAD. In order to carry out this transaction, the Bank of Canada and Bank of Montreal must be clients of banks in the American payment system. Suppose the Bank of Canada is a client of the Federal Reserve Bank of New York while the Bank of Montreal is a client of JP Morgan Chase. Then the transaction is carried out in the following manner: The Bank of Canada pays Bank of Montreal 100 million CAD through the LVTS. Bank of Montreal asks JP Morgan Chase to pay 65 million USD into the Bank of Canada's account at the Federal Reserve Bank of New York. This payment is made through the U.S. electronic payment system in the same way a corresponding payment between Canadian agents would be made through the LVTS. As a result of this payment, the aggregate balance of the Canadian banking sector in the LVTS has risen by $100 million.

Throughout a typical day, many transactions like the ones discussed in this section occur. They entail that the aggregate balance of the Canadian banking system in the LVTS drifts away from zero. Periodically throughout the day, the Bank of Canada therefore performs open market operations that bring the aggregate balance of the banking sector back to zero.[11] These open market operations take the form of direct purchase and sale of government securities and/or repurchase and reverse repurchase agreements of government securities. The last such neutralization is towards the end of the business day, at a time after which no further payments will be made that change the aggregate balance of the banking sector in the LVTS. This guarantees that the aggregate balance in the LVTS is zero at the end of the day. The banks that participate in the LVTS know this is the policy of the Bank of Canada and therefore know that they will be able to cancel any long or short position they may have at the end of the day with some other bank that has a corresponding position with the opposite sign. To further guarantee that this works smoothly, banks have 30 minutes to transact with each other, after the LVTS has been closed for payments on behalf of clients.

To summarize, the system that the Bank of Canada uses to control the overnight interbank interest rate with the spectacular success that is evident in figure 1 is based on the following principles: First, all non-zero balances in the payment system are settled with the Bank of Canada at the end of each business day. Second, the lending rate at the Bank of Canada is set 50 basis points higher than the deposit rate. These rates create a floor and a ceiling for the overnight interbank rate. They also imply that banks have an incentive to eliminate their positions in the payment system through interbank lending

[11] All open market operations of the Bank of Canada are therefore "defensive" in nature.

before the end of the business day. Third, the Bank of Canada manages the aggregate balance in the payment system intraday in such a way to keep it constant at zero.

WHAT IF THE BOND MARKET DOESN'T AGREE?

A question that may be bothering readers is: What if the bond market doesn't agree with the Bank of Canada on where interest rates should be? Say the bond market thinks rates should be higher. How can the Bank of Canada get its way without having to move the market by buying large amounts of bonds? The answer to this question is that the banks themselves have strong incentives to move the Treasury bill rate on their own.

Suppose the Bank of Canada's target for the interbank rate is 6%. Its overnight lending rate is then 6.25% and its overnight deposit rate is 5.75%. For simplicity, suppose that the Bank of Canada has announced credibly that these rates will not be changed in the next three months. Suppose, however, that the bond market is pricing the 3-month Treasury bill at 7%, i.e., the most favorable ask offer in the market is at a price that corresponds to a 7% yield to maturity. Suppose, for simplicity, that all Treasury bills are held by banks.[12] One of these banks must be responsible for the ask offer at 7%. Let's call this bank A. Suppose the offer is for $100 million and suppose that all banks have a zero position in the payment system.

Suppose some other bank, say bank B, takes bank A's offer. Bank B pays for the Treasury bills through the payment system. After the transaction bank B therefore has a $100 million negative balance in the payment system. The worst-case scenario for bank B is that it will have to borrow this amount at the Bank of Canada at 6.25% until the Treasury bill matures. In the worst case, bank B therefore receives a 7% yield to maturity on the Treasury bill and pays 6.25% to finance its purchase. This logic, of course, implies that bank B (and all other banks) have a strong incentive to buy Treasury bills until their yield has fallen to below 6.25%.

This is, however, not the end of the story. When bank B paid for the Treasury bill through the payment system, its own account was debited by $100 million and the account of bank A was credited by the same amount. The aggregate balance of the payment system therefore remained zero. Just as in the Alcan-Air Canada example above, the two banks in this example have a strong incentive to transact on the interbank market before the end of the business day in order to avoid having to make use of the lending and deposit facilities at the Bank of Canada. After they have done this (i.e., bank A has lent bank B $100 million overnight), all banks again have a zero balance in the payment system. The Bank of Canada therefore need not do anything.

If the Bank of Canada can be relied on to manage the aggregate balance in the payment system effectively (i.e., keep it constant at zero) so that the interbank rate is expected to stay constant at 6%, then profit opportunities exist while the Treasury bill rate is different

[12] The example would not change in any significant way if Treasury bills were also held by clients of banks. This would only complicate the exposition slightly.

from the interbank rate. The Treasury bill rate will therefore fall all the way to the interbank rate.

The logic of this example of course carries over to more complicated settings. The example therefore shows that all other nominal interest rates in the economy are determined by the Bank of Canada's target for the overnight interbank rate and expectations of future movements of this target rate (plus markups due to default risk, liquidity premia, etc.).

THE CRUCIAL DIFFERENCE: REAL-TIME CLEARING OF PAYMENTS

The crucial difference between the LVTS and Canada's older payment system, the ACSS, is that the LVTS is a real-time payment system while ACSS is a differed net settlement system. Real-time electronic payment systems are a relatively recent phenomenon. Before their time, all payments were cleared and settled through differed net settlement systems. This means that all payments were cleared overnight in a manner similar to that by which checks are cleared. After the end of a business day, all the payments made and received by a particular bank (and its clients) were tallied up and the net amount was credited or debited to that bank's settlement account with the central bank. During the day, the bank did not have detailed information about the quantity of payments made and received by its clients. The bank was also not able to know which payments might fail to clear due to insufficient credit of the party making the payment.

The bank therefore faced quite a bit of uncertainty about the net amount that it would need to have in its settlement account at the end of the business day in order to be able to settle payments made that day. If the bank did not have sufficient funds in its settlement account it had to borrow the difference from the central bank overnight. The central bank penalized banks that made use of such loans.[13] This gave the banks an incentive to have a positive balance in their settlement account. However, the settlement account did not pay interest. The bank therefore had an incentive not to have too high a balance in this account. Finally, the incentive to economize on the settlement balances was stronger the higher the interest rate. This implied that the quantity of settlement balances was a downward sloping function of the interest rate. The central bank could therefore control the interest rate by changing the aggregate supply of settlement balances.

Contrast this with the way payments clear in real-time payment systems. In this case it is useful to distinguish between the clearing and final settlement of payments. Final settlement still occurs at the end of the business day at the central bank. However, payments are cleared in real-time throughout the business day. Banks have clearing accounts in the payment system. Each time a payment, made or received by a particular bank or one of its clients, is cleared this is registered as a credit or debit in the bank's account in the payment system. Banks therefore have current information throughout the

[13] Apart from the high interest rate that central banks charge on such loans as a penalty, there are also conditions that banks need to meet to be eligible for such loans. For instance, the central bank may require that banks post collateral. If banks are not able to meet these conditions, they do not get loans from the central bank and some of the payments they and their clients make may fail to clear.

day about the position of their account in the payment system. They can thus manage this position within the day. For example, if a client of a particular bank makes a large payment that entails that the balance in its clearing account becomes negative, the bank can borrow funds on the interbank market before the end of the day.[14]

At the end of the business day, the positions of banks in their accounts in the payment system are settled by crediting or debiting these balances in their settlement accounts at the central bank. However, since banks are able to manage their accounts in the payment system within the day, they will aim at ending the day with a zero position in the payment system. Whether it is possible for all banks to achieve this aim depends on the aggregate balance of the banking sector in the payment system. If this aggregate balance is zero, then all banks can end the day with a zero balance in the payment system. In this case banks need not hold any settlement balances overnight.

THE ROLE OF RESERVE REQUIREMENTS

Students who take introductory economics classes are taught that the amount of base money issued by the central bank effectively determines the amount of bank lending in the economy. A simplified version of this story is as follows: When the central bank increases the money supply by $1 and this dollar is deposited into a bank, the bank must keep a fraction *r* as reserves. It can increase its lending by *1-r* dollars. That loan ends up being deposited at some other bank, which must keep a fraction *r* of it as reserves and can lend out the rest. Etc. Etc. Thus, an extra dollar of base money will lead to a *1/r* dollar increase in bank lending. The factor *1/r* is called the money multiplier.

The way this story is told in most textbooks, it implies that the causation runs from money to credit. It implies that in order to be able to increase lending, a bank must first acquire excess reserves. In other words, the funds that a bank lends must exist in the system before the loan is made. The central bank therefore controls the quantity of credit by controlling the quantity of money.

While the textbook story may once have been a broadly accurate description of the link between money and credit, it no longer is. On the contrary, this story is grossly misleading today since the causation now runs in the opposite direction. In countries that implement monetary policy the way I describe above and still have reserve requirements, it is an increase in the quantity of credit that causes an increase in the quantity of base money, not the other way around.

The policy of the ECB is an important example of this type of policy. However, since I have been using the Canadian system as an example in this paper, let me explain how reserve requirements affect the system for implementing monetary policy by supposing that Canada still had a reserve requirement.

[14] To guarantee that last-minute payments don't leave a bank with an undesirable position in its account in the payment system at the end of a business day, banks are allowed to transact with each other for half an hour after the payment system is closed for regular payments.

Suppose Canadian banks were required to hold *2%* percent of deposits and other short-term liabilities as reserves. Suppose each bank has a reserve account at the Bank of Canada where these reserves are deposited. Suppose that on a particular day all banks have zero excess reserves, i.e., they have exactly the required quantity of reserves in their reserve accounts. As usual, suppose that all banks have a zero balance in the LVTS.

Now suppose that Bank of Montreal agrees to lend Alcan $200 million. Upon signing the loan agreement, Bank of Montreal credits Alcan's account with $200 million of deposits and furthermore enters Alcan's $200 million debt as an asset in its balance sheet. These $200 million didn't exist in the system before the loan was made. In some sense, they were created when the loan was signed. Alcan may then use these $200 million to purchase assets, pay for goods and services or it may wish to deposit them with another bank. The consequences of such actions were explained above.

Since Bank of Montreal is subject to reserve requirements, this new loan entails that it must deposit an additional $4 million into its reserve account at the Bank of Canada.[15] Bank of Montreal makes this payment through the LVTS. It lowers Bank of Montreal's position in the LVTS but doesn't increase the position of any other private bank. This increase in aggregate reserves therefore decreased the aggregate balance in the payment system. Now recall that a key element of the policy of the Bank of Canada is to keep the aggregate balance of the banking sector in the payments system constant at zero. The increase in aggregate reserves will therefore cause the Bank of Canada to conduct an open market operation that increases the aggregate balance of the banking sector in the payment system back to zero before the end of the day. In other word, the new loan caused the Bank of Canada to increase the money supply.

Notice that no excess reserves existed in the banking system when the loan was made. This did not deter Bank of Montreal from making new lending. Bank of Montreal knew that the Bank of Canada would accommodate the increased demand for reserves after the fact. Such action is necessary for the Bank of Canada to be able attain its goal of keeping the interbank interest rate stable at its target level.

The traditional argument for reserve requirements has been twofold: First, reserve requirements were considered necessary as a prudential measure to make sure banks had enough cash to meet the needs of clients who wished to withdraw cash from their accounts. Second, reserve requirements provided the central bank with control over broader monetary aggregates than just base money. A more recent argument is that reserve requirements create a demand for base money and are therefore important in providing the central bank with control over interest rates.[16]

[15] Notice that the loan increased the deposits with the Bank of Montreal by $200 million. If Alcan decides to spend these funds, Bank of Montreal will need to replenish its position in the LVTS by borrowing the amount Alcan spends. So, whether or not Alcan spends the funds, Bank of Montreal must increase its reserves.

[16] This argument has been made by, e.g., the ECB. (*** ADD REFERENCE***)

The first of these arguments is outdated. Today banks hold reserves mostly in the form of settlement balances at the central bank rather than as cash in their vaults. Settlement balances are of no use when an unusually large number of customers decide they want to walk around with a lot of cash or put their money under their mattress. Regulations to ensure prudent banking now focus on managing risk of insolvency. These include capital adequacy requirements and rules limiting maturity mismatch.

The example above shows that the second traditional argument is not compatible with the type of implementation of monetary policy that the central banks of most developed countries have been adopting over the last decade in response to the evolution of electronic payment systems. When monetary policy is implemented in this way, central banks must accommodate all increases in demand for reserves.

Furthermore, the argument that reserve requirements create a demand for base money that is important in providing the central bank with control over interest rates is not correct. In this paper I have described a system for implementing monetary policy in which the central bank has complete control over interest rates even if aggregate demand for money is zero.

Reserves held at the central bank have traditionally not paid interest (or have at most paid a sub-market rate). This has meant that central banks have traditionally made a profit from reserves. Reserve requirements have therefore traditionally been a tax on the banking system. One might argue that the financial independence of central banks is important and that reserve requirements contribute to this financial independence. However, almost all central banks have sufficient other sources of revenue that the elimination of reserve requirements would not put their financial independence at risk. In recent years, most central banks of developed countries that still have a reserve requirement have begun to pay a market rate on reserves. This is true of, e.g., the ECB. The Federal Reserve is a notable exception to this trend.

The discussion above highlights the fact that today reserve requirements serve a very limited purpose. Acknowledging this fact, a number of central banks have completely eliminated reserve requirements. As was noted above, the Bank of Canada is one of these banks. The Reserve Banks of Australia and New Zealand are other examples. Actually, for central banks that use the system described above to implement monetary policy, eliminating reserve requirements has the benefit that it eliminates one source of fluctuation in the aggregate balance of the banking sector in the payment system. In a sense, reserve requirements are simply a nuisance in such a system. Eliminating them makes it easier for the central bank to conduct policy.[17]

[17] Some central banks have gone even further in trying to eliminate sources of fluctuations in the aggregate balance of the banking sector in the payment system. For example, in Sweden, the government is no longer a direct client of the Riksbank (Sweden's central bank). It is simply a client of commercial banks just like everyone else. This eliminates the vast majority of fluctuations in the aggregate balance of the banking sector in the payment system in Sweden.

CONCLUSIONS

The purpose of this paper has been to explain in detail how monetary policy is implemented through real-time electronic payment systems by the central banks of most developed countries. Such a detailed description of this topic seems warranted since some aspects of the implementation of monetary policy are difficult to understand for those who still use the standard textbook model of the relationship between money and interest rates when thinking about the actions of central banks. The fact that most people, including most academic economists, still think in terms of this model has lead to quite a bit of confusion in the last few years. And it will continue to do so until the model of the implementation of monetary policy that is used in standard textbooks is replaced with a model that more closely resembles actual practice. I hope this paper shows that it should be relatively simple to explain the system used by most major central banks to even undergraduate students.

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