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Technological Progress and its Effects on the Interaction Between Money Supply and Demand: A Cointegration Approach

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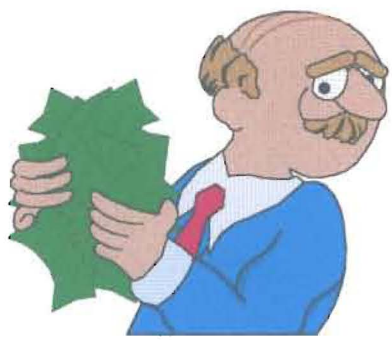

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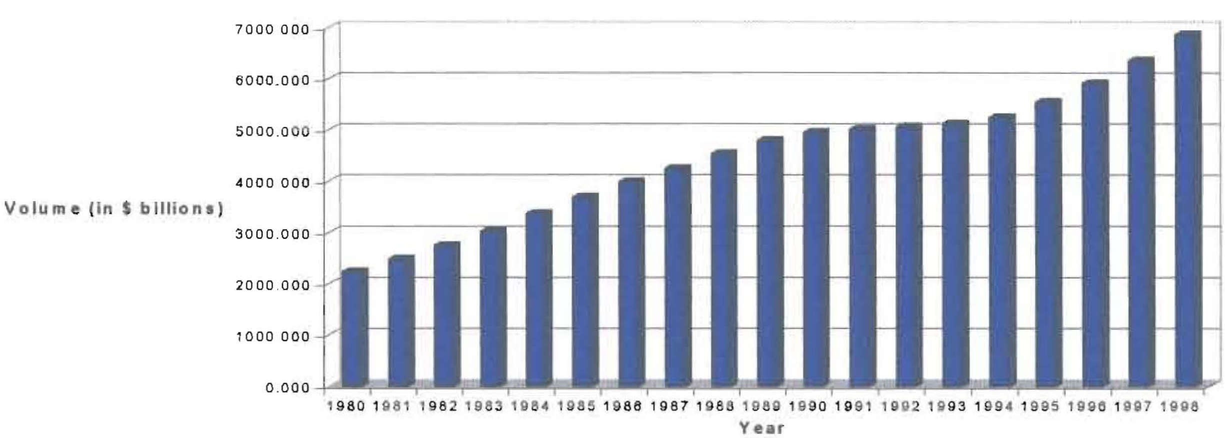
I. INTRODUCTION

The 1990's has been a prosperous decade economically, characterized by notable surges in technological innovation and adaptation. Certain economic historians, Mokyr in particular, believe we are experiencing growth that is parallel to that of the Industrial Revolution, which places late 20th century America at the forefront of a new "Technological Revolution." (1996). Only time will dictate the accuracy of that designation. However, there is no doubt that substantial technological development has had a profound impact on U.S. economic evolution over the last 10-15 years. More specifically, significant technology growth has placed the nation's monetary structure at a dynamic crossroads. New purchase and payment methods have developed that are eclipsing older, more paper based forms. In fact, this financial innovation led the Financial Services Policy Committee of the Federal Reserve System to form a task force in 1996 that will further research emerging payment technologies. Specifically, the task force is concerned with the added liquidity these technologies bring to current money

Figure 1
U.S. Liquid Asset Holdings
1980-1998



Source: Federal Reserve Bank of St. Louis, FRED

storage options (see Figure 1) and the impacts they have had and will continue to have on money supply and demand (Marjanovic, 1996).

The purpose of this paper is to analyze the significance of the effects current payment technologies have had on money supply and demand. Specific attention will be given to M1 and M2 stocks and velocities, the Fed Funds Rate and National Income, and how their interaction with each other has been affected by technology development. Using Electronic Funds Transfer and Automated Teller Machine introduction as a proxy for current technological development in a cointegration test model, it is found that current payment technologies have had mixed effects on money supply and demand, and the interaction between their associated factors within the IS-LM framework. Section II summarizes the existing literature concerning payments technologies and their impact on the economy. Section III details the resulting theory and hypothesis. Section IV introduces the empirical model used to test the hypothesis and Section V presents the results of these models. Section VI concludes the study, presenting possible implications and directions for further research.

II. BACKGROUND & LITERATURE REVIEW

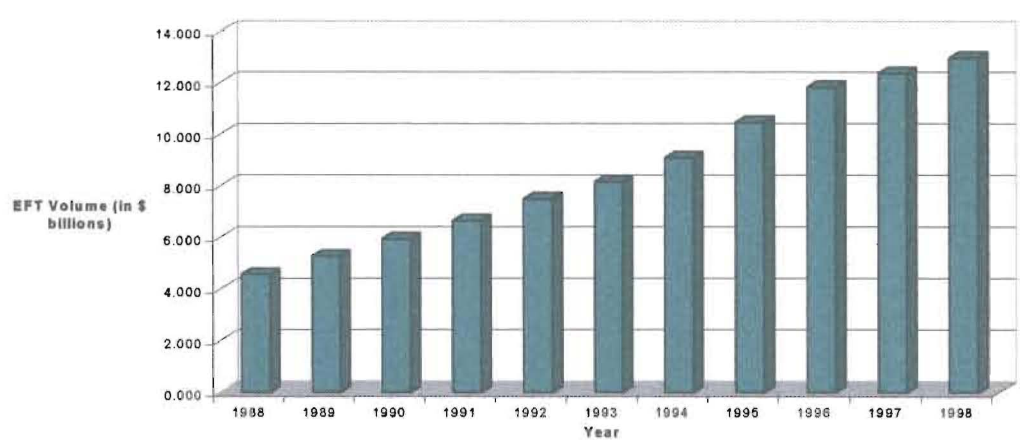
The emergence of computer technology in banking and financial services is well documented and observed. All it takes is a trip to a local bank to witness the ease in transfer of money that technology affords. Whether it is through an Automated Teller Machine (ATM), an Electronic Fund Transfer (EFT) from one account to another, or an instant computer credit check for loan purposes, technology's effects on the way we do business through the banking structure are highly significant. What is more startling is

that most of the widely used technological payment mechanisms have been around for a relatively short period of time.

When the ATM made its national, commercial debut in 1980, there were 18,500 machines online nationwide. By the close of 1996, there were 140,000 of these machines. There are currently 140 million ATM cardholders in the U.S. and 210 million ATM cards in circulation. More noteworthy, according to a study by an AT&T Global Information Solutions team, the typical ATM customer spends 20-25% more of his/her income than a non-ATM customer (AT&T, 1997).

In addition, EFT volume has almost tripled in the last ten years (see Figure 2). Visa branded debit cards alone accounted for $37.3 billion in transaction volume in 1996 whereas in 1990 they only accounted for $7.5 billion. Other companies have experienced similar results. In fact, debit card issuance as a whole has experienced a 500% growth rate in the 1990's (Faulkner & Gray, 1998).

Figure 2
EFT Volume Growth
1988-1998



Source: Faulkner & Gray Inc.

There is little doubt that these developments have played a significant role in the shaping of our current banking and purchasing behaviors. In fact, there are few who refute that technology growth in payment systems has had an effect on the behavior of money and the monetary system.

T. M. Podolski has offered much of the theoretical economic analysis concerning these effects. Citing a 1971 study by Laidler that observed a slow shift over time in the demand-for-money function, he hypothesizes that this shift is one "that has yet to be explained, but which may well be the result of the increasing financial sophistication of the American economy" (1986). He asserts that the technological advances used in modern finance have been the common denominator in all major financial innovations and have a strong consequential impact on macroeconomic demand for "narrowly defined money," (M1, M2, MZM) mostly by reducing transactions costs (Podolski, 1986).

He uses the IS-LM framework to outline the possible changes in money demand and its elasticity at the hands of technological sophistication. More specifically, he adopts the view that LM within the IS-LM framework represents the monetary system rather than just money as an asset. "Hicks, the principal creator of the IS-LM model, did not necessarily interpret M as a single asset, money... but rather as representing the monetary system and the activities of the monetary sector" (Podolski, 1986). He further explains that since all modern money emanates from the monetary system, "narrowly defined" money supply and demand at various incomes and interest rates was intended by Hicks to be a quasi-proxy for monetary system activity and resulting LM derivation. As such, he presents technological innovation in the payment systems as an improvement to the

monetary system that results in an increase of its use. Because the monetary system is used more, narrowly defined money demand and supply must increase to a certain degree; their combined interaction with the interest rate and income levels becomes more precise because transaction costs are lower and the existing "monetary infrastructure" is made more efficient. This leads to either possible shifts in the LM curve or movements along the LM curve, depending upon the type of innovation and its effects.

Basic to this interpretation, however, is the idea that the representation of financial influences through IS-LM at the hands of technological innovation can be of value only if one assumes that narrowly defined money supply in this state of change is demand determined rather than "exogenously proscribed" (Podolski, 1986). Basically speaking, he states that this money supply is not constant as it is normally assumed under the IS-LM model because technological innovations in payment systems have a tendency to increase liquidity preferences. As such, Podolski concludes that technology growth in payment systems induces a positive and more pronounced co-movement between money supply, demand and their determinants (income and the interest rate) within the IS-LM framework. Because technology improvements allow narrowly defined money supply to move freely within the IS-LM framework, its interaction with and among money demand, the interest rate and income is more dynamic.

Valerie A. Ramey argues along similar lines, positing that money treated as a factor of production "responds passively to fluctuations in production induced by technological shocks and innovations" rather than being an exogenous, static factor in economic and technological growth. Furthermore, she asserts that money demand and supply are positively correlated to technological progress. Consequently, the economic

output of all industries collectively may be loosely determined by technology advancement through its influence on the availability of trade credit and other very short-term loan/discount vehicles that provide quick financing (Ramey, 1992).

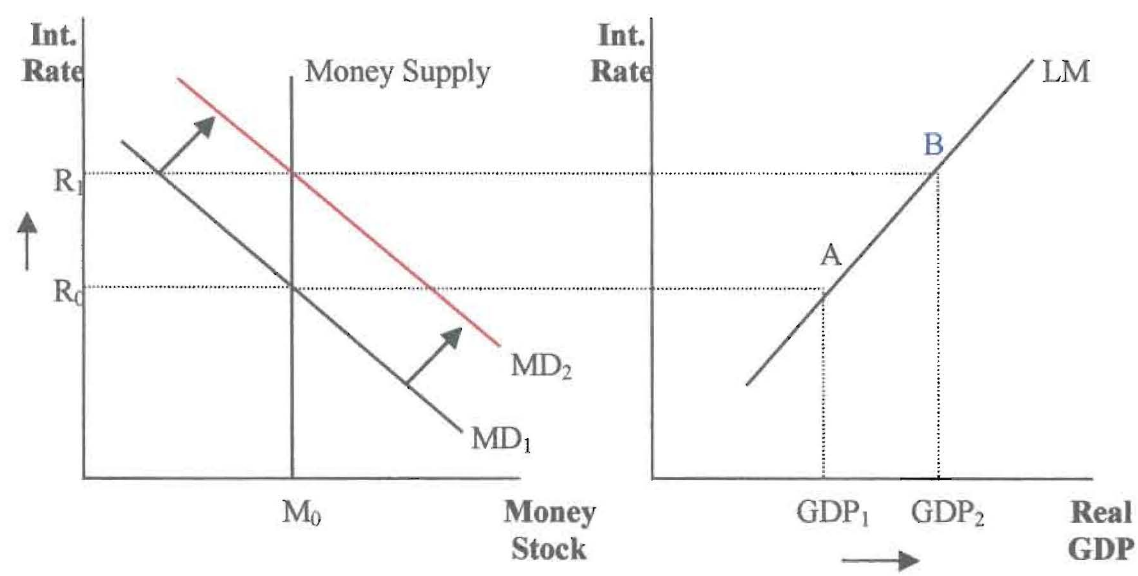
However, Lawrence H. White, in one of a collection of essays edited by James Dorn, disagrees with the above ideas that improvements in payment technology have been revolutionary and have had profound effects on the levels of money supply and demand. He states that we are merely witnessing a period of monetary evolution rather than revolution, characterized by a superficial transfer from one transactions vehicle to another. "What happens behind the scenes—deposit transfer—remains the same, and has existed for hundreds of years" (Dorn, 1997). In essence White argues that money, narrowly defined or otherwise, is not created or destroyed in this process; it is just changing in form.

Furthermore, he criticizes the idea that the movement towards electronic currency and transaction vehicles will radically change the monetary landscape, allowing the potential for money velocity (demand) and supply growth to go unchecked and unregulated. To White this development represents nothing more than the loss of government's monopoly on currency manufacture. "The transition from analog to digital currency does not change the monetary standard: the base money remains fiat money controlled by the government" (Dorn, 1997). Again, he states that the eventual changeover to electronic methods of payment is merely an evolution in monetary system development, not a cause of dramatic shifts in the measurement of its aggregates or the real amounts of these aggregates.

III. THEORY & HYPOTHESIS

Borrowing from the basis of Podolski's assertions, the IS-LM framework is used to analyze the effects of payment technologies on the supply of and demand for money. The *traditional* premise of the IS-LM framework as it relates to the demand for real money balances shows that an advancement in technology can lead to a corresponding shift in money demand and upward pressure on interest rates, *holding money supply constant*. This movement creates an upward-sloping LM curve and displays the dynamic relationship between GDP, LM, money demand and the interest rate. These movements are shown in Figure 3. Money demand increases in response to economic conditions (like rapid technology growth), moving from MD_1 to MD_2. We thus move from point A to point B on the LM curve; real GDP increases and upward pressure is put on interest rates. This is the traditional sequence of events that the IS-LM framework outlines to explain a shift in money demand.

Figure 3



However as previously discussed, Podolski states that the representation of financial influences through IS-LM at the hands of technological innovation can be of value only if one assumes that money supply in this state of change is demand determined. This implies that money supply (as part of the proxy for monetary system activity) must be assumed to be endogenous within the model rather than exogenously proscribed in order to take technological improvement into account. If money supply is made endogenous, rapid improvements in payment technologies have a tendency to affect money demand *and* supply outright through reductions in transactions costs and increases in liquidity preferences—independent of increases in GDP—within the IS-LM model.

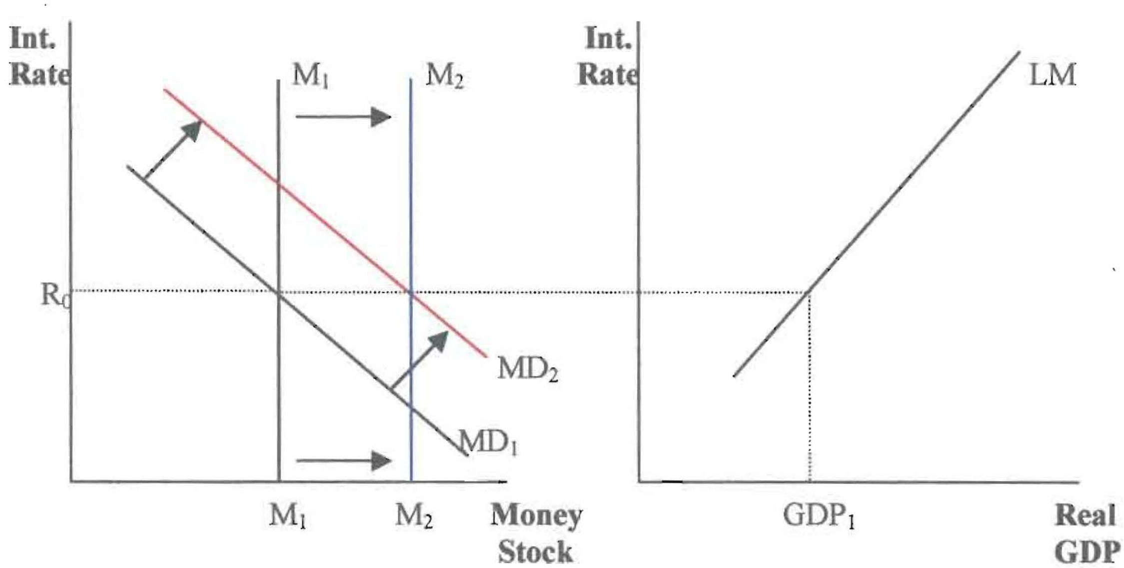
For example, Super-NOW accounts offer the liquidity of cash (due to electronic transfer capabilities) and the advantage of interest accumulation. It can be hypothesized that people will demand these savings mechanisms more and move their asset holdings from less liquid mechanisms (that are not included within "narrowly defined" monetary system aggregate measurements like M2) toward these Super-NOW accounts (which are included within "narrowly defined" monetary system aggregate measurements). As a result, money supply and demand in the context of the IS-LM framework increase without necessarily affecting GDP or being affected by GDP.

This does not necessarily mean that GDP loses its significance within the IS-LM framework or is unaffected by improvements in payment technology and corresponding changes in money supply and demand. As evidenced by the graphs in Figure 4, these movements merely dictate that money supply and demand are not dependent upon GDP movements when taking into account improvements to payment technologies, nor does

GDP necessarily increase with increases in money demand if money supply is endogenous.

Continuing with the Super-Now example on the previous page, money demand (as defined within the context of the IS-LM framework) increases from MD_1 to MD_2 due to payment technology advances that make these accounts more liquid and accessible. Simultaneously, narrowly defined money supply increases from M_1 to M_2; to satisfy demand, people either move their asset holdings from less liquid savings mechanisms to these accounts or they place increased income in these accounts while holding their rate of saving constant. Since these movements occur simultaneously, GDP is unaffected.

Figure 4



This is just a specific example. Different technological innovations will cause different movements within the IS-LM model, perhaps increasing either money supply or demand more than the other, thus increasing or decreasing real GDP. The point is that technological innovation in payment systems has an effect on money demand and supply that is independent of movements in GDP within the IS-LM framework. These

independent movements allow for a more dynamic and pronounced interaction between money supply, demand, the interest rate and income.

Given the evidence presented in Section II by Podolski and Ramey combined with the above theoretical explanations, it is hypothesized that recent technological innovation in payment systems has effectively increased the supply of and demand for "narrowly defined money" and provided for a more integrated interaction between money supply, demand and their determinants.

IV. EMPIRICAL MODEL

The primary determinants of money supply and demand according to the IS-LM framework are income and the interest rate. Income is a shift parameter for money supply and demand, and the interest rate is simply the cost of this money supply and demand as indicated by Figures 3 and 4. As a result of the hypothesis presented in section III, a technology parameter is also included as a participant in money supply and demand interaction with income and the interest rate. More specifically, since the national, commercial debut of EFT and the ATM in 1980 represents a technology shock to the monetary system, this event is used as a structural break in testing for improved linear relationships among money supply, demand, the interest rate and income.

Since their debut, the ATM and other EFT transaction mechanisms have taken center stage in the payment system, experiencing large growth rates (Daniels, 1994). As such, they have been relied upon as variable approximations in a number of other studies addressing payment technology issues. Kenneth N. Daniels and Neil B. Murphy of Virginia Commonwealth University used ATM volume as a proxy for technology's effects on household transaction account balances. They further asserted that the

national, commercial debut of EFT and the ATM in 1980 represented a significant technological shock to the monetary structure that has permanently changed the way consumers interact with the monetary system and the overall economy (Daniels, 1994). J. L. Ford, W. S. Peng and A. W. Mullineaux blamed EFT transaction volume increases in the U.K. for the poor performance of its Divisia monetary aggregate in indicating economic growth, leading them to conclude that technology growth is not reflected well in any of the current monetary aggregates (Ford, 1992).

Given the shortage of accurate technology representations, EFT and the ATM appear to be the proxies of choice among those studying technology's effects on the economy. Therefore, they are used here in the form of a structural parameter. It is hypothesized that increases in payment technology use and innovation, specifically after 1980, have improved the co-movement and interaction between money supply, demand, the interest rate and income through reductions in transaction costs.

The above IS-LM components as variables are discussed below in accordance with the previously outlined theory. Since these time-series variables are non-stationary, they require the use of an empirical model other than OLS regression to uncover their explanatory power. A more specific explanation of their structure and the resulting empirical method follows the descriptions below.

A. Variable Descriptions[1]

Velocity is measured and calculated as the ratio of nominal expenditure to money supply. According to the quantity theory of money equation within the IS-LM framework, velocity represents the demand for money (Petersen, 1995). Theory states

[1] Data for all variables was obtained from the Federal Reserve Economic Data (FRED) database found on the Federal Reserve Bank of St. Louis Internet Site.

that various interest rate and income levels dictate velocity. It is also hypothesized that technology has an effect on the measurement of velocity and its interaction with money supply, the interest rate and income.

Money Stock is the level of a particular monetary aggregate dictated by the Federal Reserve System. Data used are M1 and M2 levels. MZM levels are not used because they have only been measured since 1974 and therefore do not provide enough cases to perform a thorough cointegration test given a 1980 technology parameter. IS-LM theory states that various interest rate and income levels dictate money stock volume. In addition, it is hypothesized that technology has an effect on money stock and its interaction with the above factors.

Income is approximated by the National Income measurement calculated by the Federal Reserve. IS-LM theory states that as the income level increases, money demand and supply also increase.

Interest Rate movements are best represented by the Fed Funds Rate. It is this rate that is used by the Federal Reserve to dictate monetary policy and is most likely to have a direct effect on money supply and demand. IS-LM theory states that as the interest rate decreases, supply and demand for money increases, and vice versa.

Table 1: Variable Descriptions

Variable/Parameter	Description
Velocity	Ratio of nominal expenditure to money supply. According to MV=PY, represents money demand within IS-LM. Calculated for M1 and M2 levels.
Money Stock	Money supply as measured and controlled by the Federal Reserve. M1 and M2 levels are used.
Income	National Income as measured by the Federal Reserve. One of the two primary determinants of money supply and demand in the traditional IS-LM model.
Interest Rate	Fed Funds Rate as dictated by the Federal Reserve. The other primary determinant of money supply and demand in the traditional IS-LM model.
Technology	Proxied by the 1980 ATM and EFT national, commercial debut and used as a structural break in testing for linear relationships among the above four variables. Hypothesized facilitator of money supply, demand, interest rate and income co-movement.

B. Stationarity Conditions and Cointegration Models

The above variables cannot be used in a simple OLS regression to determine technology's effects on money supply, demand, interest rate and income co-movement because they are not consistent in structure. More specifically, some of these variables are not stationary time series measurements, while others are.

A stationary variable is one that has a tendency to return to an equilibrium level or trend over a period of time. As such, the mean, variance, autocorrelation and coefficients of such independent variables regressed against a dependent variable in an OLS estimation can be approximated well by sufficiently long time-series data (Enders, 1995). An example of a stationary time-series would be seasonally adjusted quarterly sales figures for a large, stable company.

Conversely, a non-stationary variable is one that meanders in value without any tendency to return to a long run level or trend. An OLS regression estimation that incorporates either all non-stationary time-series variables, or non-stationary variables in conjunction with stationary variables, is not BLUE. The unknown variable errors in such a regression will not have a zero mean and won't always be independent, and the variance of the unknown variable errors will not always be constant (Enders, 1995). Simply correcting for autocorrelation through Cochrane-Orcutt or Prais-Winsten estimates is not a reliable solution to stationarity problems because the unknown variable errors *can* still be independent with non-stationary variables in OLS regressions. Correcting for autocorrelation requires unknown variable errors to be dependent upon the independent variables in OLS regressions (Ramanthan, 1997).

Coincidentally, money demand studies have stimulated much of the literature concerning stationarity problems and cointegration solutions—the hypothesis presented in Section III serves as good example of an economic situation that contains stationarity and cointegration conditions in its empirical framework. Take the simple money demand function:

$$\mathbf{MD} = \alpha_1 + \alpha_2\mathbf{Inc} + \alpha_3\mathbf{Rate} + \alpha_4\mathbf{Tech} + \varepsilon_t$$

where **MD** = long run money demand (proxied by Velocity), or money supply (as provided for by Podolski)
Inc. = real income
Rate = interest rate
Tech = technology (EFT and ATM debut)
ε_t = stationary disturbance term
α = coefficients to be estimated

The hypothesis that a third variable can be used to measure technology's effects on money demand, supply and their determinants allows me to collect time series data on the above variables and run an OLS regression to determine the effects. For this to make sense, however, any deviation in the demand for money must be temporary. A key assumption of a normal OLS regression is that the error term (ε_t) is stationary. If the error term has a stochastic trend (the unknown variable errors are not random or independent) the errors in the model will be cumulative so that deviations from equilibrium will not be eliminated through OLS regression. The error term will have a stochastic trend if one or more of the independent variables in an OLS regression is non-stationary.

Interest rate and money demand have always been traditionally characterized as non-stationary time series measurements. In fact, after performing Augmented Dickey-Fuller tests for stationarity on the variables presented in Table 1, it was found that M1

and M2 velocity, the Fed Funds Rate and National Income were all non-stationary variables. M1 and M2 stock were also found to be non-stationary, but of a "weaker order" (see Appendix A). Basic OLS estimates of the above regression won't be BLUE and the error term won't be stationary with these variables.

However, the empirical theory presented here suggests that there still exists a linear combination of these non-stationary variables that is stationary (Enders, 1995). Solving for the error term, we can rewrite the above equation as:

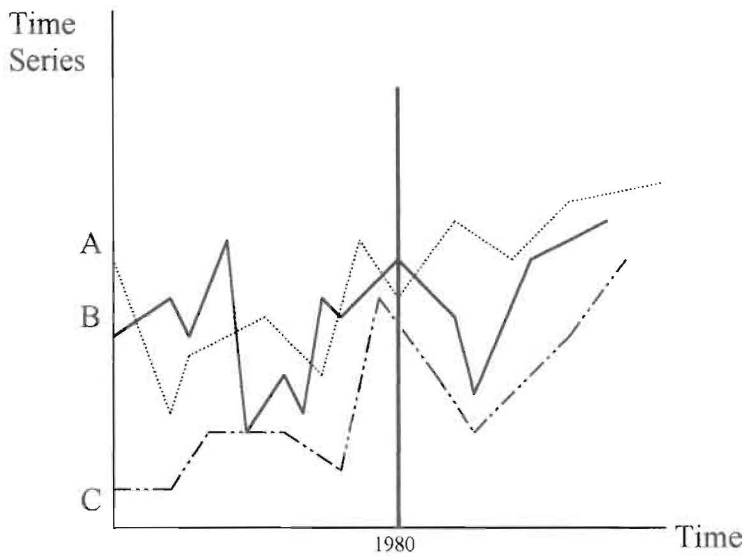
$$\varepsilon_t = \mathbf{MD} - \alpha_1 - \alpha_2\mathbf{Inc} - \alpha_3\mathbf{Rate} - \alpha_4\mathbf{Tech}$$

Since ε_t must be stationary, it makes sense that the *linear combination* of the integrated variables shown by the right side of the above equation must also be stationary; the time paths of these variables must be linked, even though they do not return to equilibrium levels. Simply put, "equilibrium theories involving non-stationary variables require the existence of a combination of the variables that is stationary" (Enders, 1995).

As a result, the beta coefficients of an OLS regression analysis involving the money demand function and its components would not be statistically valid. But they could be made so through the use of a cointegration model. A cointegration model is a variant of the ARMA model whereby one can test for linear cointegrating relationships among non-stationary variables. See, for example, the variables A, B and C in Figure 5. Each of these variables is meant to represent a non-stationary variable. A cointegration model will test for linear relationships between and among these non-stationary variables by combining their movements in an econometric test. In accordance with the previously mentioned IS-LM analysis by Podolski, a cointegration model will test the strength of the

co-movement of money supply, demand, the interest rate and income at the hands of a defined technology parameter. That parameter is the national, commercial debut of the ATM and EFT in 1980.

Figure 5



As such, two cointegration tests will be performed to measure technology's effects on money supply, demand, the interest rate and income. The first will test co-movement among the above variables in the 19 years previous to the ATM and EFT introduction (1961-1979). The second will test co-movement among these variables in the 19 years after the ATM and EFT introduction (1980-1998). It is hypothesized that this co-movement will be stronger (there will be more cointegrating equations among the variables) in the 1980-1998 cointegration tests due to technology growth and the resulting reductions in transaction costs and increases in monetary system efficiency.

In addition, separate pairs of cointegration test will be performed, as follows:

Pair 1

1961-1979	M1 Stock, M1 Velocity, Fed Funds Rate, Income
1980-1998	M1 Stock, M1 Velocity, Fed Funds Rate, Income

Pair 2

1961-1979	M2 Stock, M2 Velocity, Fed Funds Rate, Income
1980-1998	M2 Stock, M2 Velocity, Fed Funds Rate, Income

Pair 3

1961-1979	M1 Stock, M1 Velocity, M2 Stock, M2 Velocity, Fed Funds Rate, Income
1980-1998	M1 Stock, M1 Velocity, M2 Stock, M2 Velocity, Fed Funds Rate, Income

M1 measurements and M2 measurements are first tested separately to compare how each has been affected by technology growth when combined with the other two variables. It is quite possible that M1 and M2 measurements could react very differently to technology growth, which would in turn dictate, for economic policy purposes, how to emphasize or de-emphasize each measurement when analyzing periods of rapid technology growth. Indeed, less liquid aggregates like M2 may have a more pronounced effect on their co-movement with the interest rate and income after a technology shock because of the added liquidity that technology adds to them at the hands of reduced transaction costs. Conversely, liquid aggregates like M1 may have less of an effect because they are already as liquid as can be. If there is a significant difference between M1 and M2 measurements and their relationship to the interest rate and income before and after a technology shock, a cointegration test that includes both measurements will not be able to separate that difference.

At the same time, however, it is also likely that the 1980 ATM/EFT technology shock could have also caused increased co-movement among M1 *and* M2 measurements when tested with the interest rate and income. If technology growth in the monetary system has indeed reduced transaction costs significantly, it is possible that less liquid measurements (like M2) could start to mimic more liquid measurements and strengthen

the "bond" between them, the interest rate, income and the more liquid aggregates. Therefore, a third pair of cointegration tests is performed to account for this possibility.

V. RESULTS

There are no designated dependent or independent variables in a cointegration test. The model simply tests for linear trends among a set of non-stationary variables. The stronger the linear trends between the variables, the more "cointegrating equations" will be found by the model, as dictated by the software program Econometric Views.® The results of the paired cointegration tests performed for this study, as outlined in the previous section, are presented in Table 2.

Table 2: Test Results

Test Pair	Time Period	Variables Included	Number of Cointegrating Equations
Pair #1	1961:1 – 1979:4	M1 Stock, M1 Velocity, Fed Funds Rate, National Income	2
	1980:1 – 1998:4	M1 Stock, M1 Velocity, Fed Funds Rate, National Income	1
Pair #2	1961:1 – 1979:4	M2 Stock, M2 Velocity, Fed Funds Rate, National Income	1
	1980:1 – 1998:4	M2 Stock, M2 Velocity, Fed Funds Rate, National Income	2
Pair #3	1961:1 – 1979:4	M1 Stock, M1 Velocity, M2 Stock, M2 Velocity, Fed Funds Rate, National Income	6
	1980:1 – 1998:4	M1 Stock, M1 Velocity, M2 Stock, M2 Velocity, Fed Funds Rate, National Income	3

As seen, the results from test pair #1 and test pair #3 contradict the hypothesis presented in this study. The number of cointegrating equations found in these test pairs decreased from the first time period (1961-1979) to the second time period (1980-1998), suggesting that the 1980 ATM/EFT technology shock had a negative effect on the co-movement between money supply, demand, the interest rate and income since its occurrence.

In the case of test pair #1, the decreased number of cointegrating equations indicates that technology growth since 1980 has had negative effects on M1 measurements and their co-interaction with the interest rate and income. In the case of test pair #3, the decreased number of cointegrating equations (from 6 to 3) indicates that the ATM/EFT technology shock has had a negative impact on the co-movement between all of the variables involved in the IS-LM framework. The finding of fewer cointegrating equations in test pairs 1 and 3 contradicts the hypothesis that more harmony is brought to the movement of money supply, demand, the interest rate and income through technology improvement. This finding instead suggests that the 1980 ATM/EFT technology shock has fragmented the movements and relationships between these variables.

Only test pair #2 coincided with the hypothesis presented by this study. The number of cointegrating equations increased from 1 to 2 for M2 measurements and their interaction with the interest rate and income, meaning that the ATM/EFT technology shock has had a positive effect on the co-movement among these variables. More specifically, technology growth since 1980 has decreased transaction costs and increased monetary system efficiency enough to increase the co-movement harmony between M2 measurements (supply and demand), the interest rate and income.

A possible explanation for the findings of test pairs #1 and #3 is the idea that present day monetary aggregates aren't measured well enough to account for technologically diverse payment mechanisms and thus will not react well in *any* empirical tests involving growth—technological and otherwise—in the monetary system. A study done by Michael Belongia and James Chalfant concluded that mechanisms like Super NOW's and Money Market Deposit Accounts (MMDAs) have characteristics that

lie right between those of M1 and M2 measurements. Because they are as liquid as cash, but retain certain M2 characteristics (they are still technically time deposits and not withdrawn from as frequently) their inclusion into M1 measurements may disrupt the ability of M1 to reflect economic performance and the interaction between it, interest rate and other economic variables (Belongia, 1986). The previously mentioned Ford et al. study also alluded to this problem in U.K. monetary measurements.

Drawing from these conclusions, it is not unreasonable to presume that while Podolski's hypotheses and the hypothesis presented in this paper may be accurate, there exists no measurement that adequately represents monetary system activity and thus tests for its changes at the hands of technology growth. M1 may be a poor measurement and thus a culprit for numerous empirical problems. That may also explain why test pair #2 was the only test that succeeded—it was the only one to leave out M1 measurements.

At the same time, it is also likely that these tests are picking up other historical events that could explain part of the apparent hypothesis failure dictated by them. The elimination of Regulation Q by the Depository Institution's Deregulation and Monetary Control Act (DIDMCA) of 1980 and the Garn-St. Germain Act of 1982 may have had a huge hand in disrupting the economic co-movement of money supply, demand, the interest rate and income, independent of technology advancement. These acts eliminated restrictions on interest rates offered on time deposits and no doubt affected money supply and money demand movements, representing an offsetting, *regulatory* shock to the monetary structure.

Also noteworthy was the S&L crisis of the mid 1980's. This, of course, was a period of constant turmoil, marked by notable interest rate uncertainty and the consumer

attitudes that accompanied that uncertainty. Over-extended Savings and Loan institutions saw client after client default on their loans while the Federal Savings and Loan Insurance Corporation (FSLIC) went insolvent. The "silent bank run" became a real phenomenon. This crisis no doubt caused fragmentation among factors affecting money supply, demand, the interest rate and income that may have diminished the gains that technology growth made in terms of harmonizing the movements of these factors throughout the 1980's and into the early 1990's.

VI. CONCLUSION & SUGGESTIONS FOR FUTHER RESEARCH

Taken together, the results of the above cointegration tests provide little evidence that technology advancement in payment systems has had a positive effect on the co-movement of money supply, demand, the interest rate and income. However, historical circumstances and the possible inadequacy of key measurements used in these empirical tests provide some argument that the hypothesis presented in this study is still well founded. In addition, the theory supporting these ideas is too strong to be ignored. Technological advancement is changing the business and banking landscape almost daily, and it is impossible to ignore the significant effects that it is having on the movement of its key factors—money supply and demand.

A number of policy implications arise from these conclusions nonetheless. If technology use and innovation do indeed affect the related movements of money supply, demand, the interest rate and income, it means that the government loses a certain amount of control over monetary policy. When more advanced payment mechanisms—like e-commerce—come to bear, that may spell trouble for the Federal Reserve, despite White's

claims that technological development is merely a transfer from one transaction mechanism to another.

In addition, monetary aggregates may be growing increasingly inaccurate. The Federal Reserve has already had to de-emphasize M1 stock as an economic indicator because its amounts were not correlating with economic activity. There is no doubt that technological improvements to the payment system had a partial hand in the demotion of M1. Furthermore, the increased liquidity that technological improvements bring may be raising liquidity preference to the point where the U.S. is increasing its potential for falling into Keynes' fabled liquidity trap.

As such, further research needs to be done. First and foremost, better representations of monetary system activity must be found to continue the study of technological advancement in the payments system. The apparent inadequacy of M1 as a monetary aggregate leads to the necessity of better measurements. In addition, a method to either isolate or control for historical events and their effects on monetary measurements is needed to perform a more thorough examination of technology's effects of the monetary system. Finally, a better representation of technology advancement may be in order.

Appendix A
Results from the Augmented Dickey-Fuller Tests for Stationarity*

Variable	Test	ADF Test Statistic	Unit Root Presence
M1 Stock	Level 1st Difference 2nd Difference	-2.321012 -2.844954 -5.784253	No No Yes
M2 Stock	Level 1st Difference 2nd Difference	-0.922591 -1.049873 -7.180859	No No Yes
M1 Velocity	Level 1st Difference	-1.392345 -3.346488	No Yes
M2 Velocity	Level 1st Difference	-2.485315 -4.484747	No Yes
Fed Funds Rate	Level 1st Difference	-2.622138 -4.138494	No Yes
National Income	Level 1st Difference	-0.271319 -5.515384	No Yes

*The presence of a Unit Root in an Augmented Dickey-Fuller Test indicates that a particular variable is non-stationary. A Unit Root presence at a Level test indicates a stronger case of non-stationarity than does a Unit Root presence at a 1st Difference test, and so on. Therefore, M1 and M2 Stock variables are non-stationary, but of a weaker order than the other variables.

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