Capital Allocation Imbalance and the Effects on Monetary Policy

Submitted by

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Abstract

This paper examines the association between liquidity injections and capital allocations in the United States. In the analysis, liquidity injections are proxied by monetary base and the capital allocations are reflected by excess reserves, vault cash, total bank credit, and M2-M1. Monthly data are utilized for all variables for the sample period March 1984 – June 2020. Four Bai-Perron multiple breakpoint regressions and Markov switching estimations are employed to examine changeable patterns and interactions. The results indicate that liquidity injections are imbalanced and are allocated to total bank credit prior to quantitative easing, excess reserves prior to QE through post-QE, vault cash prior to QE and through QE, and M2-M1 post-QE. There is also evidence of a profound portfolio rebalancing effect especially during the post-QE period.

Keywords: Monetary policy; Liquidity injections; Capital allocations; Portfolio rebalancing;
Bai-Perron multiple breakpoint regression; Markov switching

JEL Classifications: E5, E42, E52, E58, G01

Highlights:

- Interactions between capital allocations and liquidity injections are examined.
- The impact of liquidity injections proxied by monetary base on capital allocations are imbalanced, following three or five discernible phases of interactions.
- Early phases reflect low liquidity injections and high total bank credit, and QE liquidity injections cause a shift from total bank credit to vault cash, excess reserves, and M2-M1.
- Surges of liquidity injections are associated with elevated levels of economic fear.
- There is substantial evidence of portfolio rebalancing post-QE.

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I. Introduction

The Federal Reserve has been injecting liquidity into the market as a means of monetary policy for many years. It was a monumental event in U.S. history when the Federal Reserve bank conducted quantitative easing liquidity injections and expanded its balance sheet from $870 billion in August 2017 to $4.5 trillion in early 2015. (Credit and Liquidity Programs and the Balance Sheet, 2020) This paper examines the transmission between monetary base and capital allocations in the United States during the period March 1984 to June 2020 in addition to the portfolio rebalancing effect during QE and post-QE. There are changes in monetary base and the selected variables, but the transmission is state dependent. It is not the same over time, however, there is strong state dependence observed by the Markov Switching models and time dependence depicted in the Bai-Perron estimation results. Monetary base\(^1\) reflects the liquidity injections into the economy and the impact on capital allocations such as: excess reserves, vault cash, total bank credit, and M2-M1. See definition of variables in Appendix.

The Federal Reserve adds money to the system through its open market operations by purchasing treasury securities to keep its key interest rate within an intended range and by entering overnight repurchase agreements. Specifically, they expand the System Open Market Accounts (SOMA)\(^2\) securities through the purchases of large-scale asset purchases (LSAP’s) which in turn increases the Fed’s balance sheet. (Levy, 2018.) The underlying hypothesis is that liquidity injections are evenly distributed among capital allocations. Discerning the conditions that drive capital

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\(^1\) Monetary base is utilized opposed to changes in the Fed balance sheet (total assets) to depict the impact of monetary policy adjustments on excess reserves, vault cash, total bank credit, and money supply during a longer sample period because total assets data are only available as of January 2002.

\(^2\) The FOMC assigned the New York Fed to conduct open market operations for the System Open Market Account (SOMA). SOMA is used for managing reserve balances, performing macroeconomic activities, and collateral for liabilities on the Federal Reserve’s balance sheet. (System Open Market Account Holdings—FEDERAL RESERVE BANK of NEW YORK, 2019.)
allocations is not only critical for monetary policy decisions; it is also an integral component in gaining a deeper understanding of the market’s core workings.

I surmise the amount and intensity of liquidity injections have an association with specific increases or decreases in capital allocations. This would imply an imbalance of capital allocations and have lateral implications during tranquil and turbulent periods in markets. Moreover, I examine the portfolio rebalancing effect as a result of liquidity injections during the quantitative easing and post-quantitative easing periods.

I employ an array of econometric methods to analyze the relationship between liquidity injections and capital allocations from March 1984 to June 2020. Four separate Bai-Perron multiple breakpoint regressions with several breakpoints and discernible phases are utilized. The breakpoints are estimated by minimizing the sum of squared residuals among all sample splits. In addition, heterogeneous errors are allowed to differ across breaks. Within the time frame of the analysis, there is a particular emphasis on the episodes of high and low liquidity injections caused by macroeconomic events.

Four separate bivariate nonlinear Markov switching models are utilized to examine dynamic patterns, intensity, and directional changes in the interactions between the dependent variables: excess reserves, vault cash, total bank credit, M2-M1, and the switching regressor monetary base. I specify a two-state Markov switching model (MSAR(1)) where the errors follow a regime-invariant AR(1) process for total bank credit and M2-M1, a regime-invariant AR(2) process for vault cash, and a regime-invariant AR(3) process for excess reserves. In addition, the independent variable is subject to regime switching. I test to determine if State one or State two is the dominate process from the Markov Switching estimation outputs, smoothed regime probabilities, and transition summaries. The combination of the Bai-Perron breakpoint
models and Markov switching models provide a unique examination by incorporating linear and nonlinear models in the analyses.

Section II includes comparable literature and respective viewpoints. Section III explains the background of quantitative easing, liquidity injections, and delves into the portfolio rebalancing effect as a result of quantitative easing. Section IV provides a description of data and presents the Bai-Perron multiple breakpoint regressions to examine capital allocation imbalances as a result of liquidity injections. Two-state Markov Switching processes of interactions between monetary base and each capital allocation are examined in Section V. Section VI synthesizes the main findings in this paper.

II. Literature Review

The Federal Reserve has strived to provide safety, flexibility, and stability to America’s financial system since its establishment in 1913. (Bernanke, 2009) One of the mechanisms the Federal Reserve attempts to provide stability through is by controlling the money supply which increases through liquidity injections. The liquidity injections can be permanent or temporary by purchasing treasury securities or repurchase agreements in open market operations. Liquidity injections surge during economic downturns e.g. during the financial crisis of 2008. (Huerta et al., 2011, p. 1) Trepidation and panic are ubiquitous emotions during times of economic uncertainty and financial distress which worsen already bleak conditions and thus cause the Fed to act with monetary policy tools such as liquidity injections. It is imperative that we understand where the liquidity injections are being allocated during times of distress. (Orlowski, 2015) finds that liquidity injections implemented through quantitative easing do not translate into credit expansion. Several factors can contribute to the Fed increasing the money supply in the financial
system, but the major causes in recent history are the Great Recession of 2008 and the Covid-19 pandemic in 2020. Central bank liquidity injections in Europe are allocated to banks’ credit supply following a wholesale dry-up while banks that do not experience a wholesale dry-up tend to bolster their holdings of high-yield government bonds. (Carpinalli, 2017) Liquidity injections enacted by the Fed in response to the Covid-19 pandemic aided banks that are capable of increasing the loan supply and bank credit because they have greater equity capital capacity. (Özsoy, 2020)

The liquidity accumulation in the financial system caused from QE also leads us to ponder if there is a portfolio rebalancing effect. Ben Bernanke suggests that QE liquidity injections work through a portfolio rebalancing channel that infers a positive relationship between long-term treasury yields and long-term treasury debt. (Thornton, 2014) The portfolio rebalance channel’s implication that measures the maturity structure of public debt should be positively associated with long-term yields. (Gagnon et al., 2011) It is evident that there is substantial supporting research on liquidity injections and the portfolio rebalancing channel, but there is a lack of research on the association between liquidity injections and capital allocations and how the associations have changed over time.

Before conducting deeper time-varying analyses of interactions between monetary base, excess reserves, vault cash, total bank credit, and M2-M1, Figure 1 depicts the time pattern of the logarithm of each variable for the March 1984 to June 2020 sample period of monthly data.

…..Insert Figure 1 around here…..

I observe mostly synchronous interactions between monetary base and excess reserves. The sharp increase in 2008 is due to the surge of liquidity injections as a result of quantitative
easing. Subsequently, the decline of monetary base in 2014 is due to tapering of quantitative easing liquidity injections whereas the decline in excess reserves in 2014 is due to the beginning of the Fed’s balance sheet normalization. Excess reserves built up as a result of QE and the Fed paid banks interest on excess reserves so they could control the short-term rate, but the Fed ultimately reduced the level of excess reserves as economic conditions stabilized. (Chang, 2018) Monetary base and excess reserves also move synchronously in 2020 with a sharp increase due to liquidity injections in response to the pandemic in March 2020. M2-M1 and total bank credit move synchronously besides the decrease in M2-M1 during the 1995 period and the decrease in total bank credit in 2008 during the first QE liquidity injections. Vault cash has increased gradually over the time period and appears to deviate within a limited range. It can therefore be argued that liquidity injections appear to cause a capital allocation imbalance from the graphical representation.

III. Quantitative Easing and the Portfolio Rebalancing Channel

QE can be regarded as a bold and ambitious extension of a central bank’s open-market operations. The Federal Reserve’s unprecedented quantitative easing (QE) policy, the large-scale mortgage-backed securities and Treasury-purchasing program aimed at bolstering America’s economy on market performance led to a surge in liquidity injections. During QE, the federal government auctions off large quantities of Treasuries to finance expansionary fiscal policy and ultimately raise the liquidity in the economy. As the Fed purchases Treasuries, their demand increases, consequently keeping Treasury yields low. The intention is to manipulate the composition and size of central bank assets. (Butos, 2014) During QE, the Fed artificially increases cash flows
for financial institutions, and research has indicated that increased cash flows lead to higher company earnings. Consequently, higher earnings lead to an appreciation in company stock price. (Bali et al., 2008) Though the original intention for QE1 was to relieve banks of subprime mortgage-backed securities on their balance sheets, it was thought that QE1 could have contributed to other potentially positive effects including the reduction of corporate bond rates, enabling businesses to expand operations more practically, and lowering currency values. In turn, allowing cheaper exports and increased foreign investment as property and stocks appeared significantly more attractive. Central banks essentially print money to execute quantitative easing, which has the same impact as expanding the money supply. QE efforts in the United States can be considered the most sweeping; the Federal Reserve’s balance sheet rose by nearly 60%, from $2.825 trillion in 2008 to $4.482 trillion in 2014, marking it the largest economic stimulus in history. (Bernanke, 2009; Cecchetti, 2009).

Portfolio rebalancing is a critical component in the transmission of asset purchases to the economy. QE purchases work through the portfolio rebalancing channel because it provides investors incentives to shift their investments towards riskier assets with higher expected returns in context of low yields. Some of the investors who sold mortgaged backed securities to the Fed may have replaced them with long-term quality corporate bonds and consequently depressed the yields on those assets. (Weisenthal, 2012) In addition, bond yields tend to drop around QE announcements. (Neely, 2015.). The sellers of the financial assets may try to purchase other assets with similar characteristics and thus rebalance their portfolios. Banks are incentivized to rebalance their portfolios toward longer term assets because they want to restore the duration risk of their holdings. The reduction in the equity risk premium of the S&P 500 brought on by QE
equated to a rise of 9.6% in equity prices which provides evidence of portfolio rebalancing because private sector investors fled to risky assets as a result. (Christensen & Krogstrup, 2018)

IV. The Impact of Liquidity Injections on Capital Allocations: An examination through Bai-Perron Multiple Breakpoint Analyses

The baseline models for the effect of liquidity injections on capital allocations are as specified

\[ \Delta \log(\text{re}_{t+\tau_1}) = \beta_0 + \beta_1 \Delta \log m_{b t} + \epsilon_{1t} \]  
\[ \Delta \log(\text{vc}_{t+\tau_1}) = \beta_0 + \beta_1 \Delta \log m_{b t} + \epsilon_{2t} \]  
\[ \Delta \log(\text{bc}_{t+\tau_1}) = \beta_0 + \beta_1 \Delta \log m_{b t} + \epsilon_{3t} \]  
\[ (\Delta \log(m2 - \Delta \log m1)_{t+\tau_1}) = \beta_0 + \beta_1 \Delta \log m_{b t} + \epsilon_{4t} \]  

The data I employ for the analyses are from the Federal Reserve Economic Database of St. Louis. Key features of the data are documented in Table 1. I examine distributional properties and conduct Augmented Dickey-Fuller unit root tests prior to estimating the equations. In most cases, the standard deviations of the variables are comparable or less than the mean of the variables which indicates minimal variability in the data. However, the standard deviation is 63.8% greater than the mean for excess reserves which indicates substantial variability. This is expected due to drastic increase of excess reserves during the QE phases and subsequent decrease during balance sheet normalization. All the data have a skewness between 0.51 and 1.18 which indicates a positively skewed distribution in the right tail. The kurtosis of each variable is between 2.00 and 2.98 respectively which indicates a distribution that is platykurtic (values less than 3). Augmented Dickey-Fuller unit root tests are conducted, and I conclude that the variables are non-stationary at level as depicted in Table 1. In turn, the \( \Delta \log \) of each variable is
utilized to obtain stationarity. The Δlog of each variable is used opposed to the first difference of each variable to optimize the Bai-Perron and Markov Switching models by achieving the lowest Schwarz information criterions.

…..Insert Table 1 around here…..

I employ four separate Bai-Perron multiple breakpoint regressions with three or five discernible phases. This is to reduce multicollinearity and isolate the impact liquidity injections have on each capital allocation as the stated dependent variable. The Bai-Perron models are a good fit because they are well suited for macroeconomic events split by specific events in time using stationary data to observe the interactions. The Bai-Perron multiple breakpoint model captures sudden outside changes such as quantitative easing liquidity injections that could cause changes in the tested variables and the model. In addition, the multiple breakpoint model captures structural changes through parameters. The structural breaks provide a unique insight into capturing various phases of relationship between capital allocations and monetary base split by outside events opposed to a standard OLS model without structural breaks. (Bai J. &., 1998) The sequential breaks are identified one by one opposed to simultaneously. (Bai, 1994b) The breaks in the phases represent significant events that cause a substantial deviation in capital allocations triggered by macroeconomic events. The baseline models have not been implemented in previous research. However, I build upon the model employed by (Orlowski, 2015) which examines the impact of monetary expansion on credit creation.

I observe the impact of monetary base liquidity injections on excess reserves, vault cash, total bank credit, and M2-M1 optimized with impact lags denoted by the displacement parameters τ one quarter ahead. An impact lag of one quarter ahead is required due to the positive skewness of the
variables and to allow time for transmission of shocks. The Schwarz information criterions in the estimations are optimized by taking the percentage change of first-differenced stationary variables.

The Bai-Perron multiple breakpoint estimation results indicate that the liquidity injections (monetary base) have an overall extremely strong positive association with excess reserves. I observe a statistically insignificant estimated \( \hat{\beta}_i \) coefficient of 1.296 in phase 1 from March 1984 – August 2001. However, a remarkably strong statistically significant estimated \( \hat{\beta}_i \) coefficient of 51.134 occurs in phase 2 for the period September 2001 – September 2008. An astonishing 1% increase in monetary base leads to a 51.134% increase in excess reserves. This is caused by the rapid liquidity injections due to the Enron scandal in October 2001, Sarbanes-Oxley act in 2002, the lack of trust in lending, and the spike of excess reserves to approximately $9 billion in August 2007. Phase 3 depicts a statistically significant estimated \( \hat{\beta}_i \) coefficient of 3.050 from the period October 2008 – June 2020. The relationship is not as strong as phase 2 because QE concluded in 2014 and the Fed started to reduce excess reserves after the financial crisis to control of the short-term interest rate. Banks hold excess reserves to adhere to requirements mandated by the Federal Reserve and as a buffer to meet unknown liquidity needs. For the year 2015, mandate stated that the first $14.5 million in net transactions would be exempt from excess reserves. A 3% reserve ratio was put in place on reserves over $14.5 million and a 10% reserve ratio on reserves over $103.6 million. Clearly, it was important for banks to have additional excess reserves as part of monetary policy in reaction to the financial crisis. (Bernanke, 2016).

…..Insert Table 2 around here…..
The second Bai-Perron multiple breakpoint estimation results indicate that the liquidity injections have a slightly positive statistically significant association with vault cash during QE, but a negative statistically significant relationship post-QE. Initially, vault cash and monetary base have a statistically significant negative association in phase 1 with an estimated $\hat{\beta}_1$ coefficient of -0.978 from the period March 1984 – March 1992. However, I examine a statistically significant relationship in phase 2 from the period April 1992 – January 2014 with an estimated $\hat{\beta}_1$ coefficient of 0.124. Monetary easing contributed to cash holdings in banks during this period. Phase 3 from the period February 2014 – March 2020 depicts a negative statistically significant relationship with an estimated $\hat{\beta}_1$ coefficient of -0.876 due to liquidity injections being allocated to excess reserves and M2-M1 post-QE.

…..Insert Table 3 around here…..

The third Bai-Perron multiple breakpoint estimation results indicate that the liquidity injections have a positive association with total bank credit leading up to the financial crisis of 2008 with a pronounced shift to a negative association triggered by QE 1 and throughout the QE phases. I observe a strong statistically significant positive estimated $\hat{\beta}_1$ coefficient of 0.151 for total bank credit in phase 1 for the period March 1984 – October 2008. Securitization of mortgaged backed securities during this time period led to the increase in bank credit. The strong switch to a negative association with monetary base with a statistically significant estimated $\hat{\beta}_1$ coefficient of -0.065 in phase 2 for the period November 2008 – March 2014 is represented by the QE time period, which led to a shrinkage in credit that made it difficult for individuals and banks to access credit. The longstanding expansionary monetary policy on credit creation eludes to a
negative association between monetary base and total bank credit. (Orlowski, 2015). The relationship for the period April 2014 – June 2020 is inconclusive after the tapering of QE purchases.

…..Insert Table 4 around here…..

The fourth Bai-Perron multiple breakpoint estimation results indicate that the liquidity injections are inconclusive with M2-M1 during the four phases. Notably, the estimated \( \hat{\beta}_i \) coefficient of 0.153 in phase 5 from January 2015 - June 2020 depicts a shift from inconclusive results in phase 4 during the Great Recession to a moderately strong association between M2-M1 and monetary base in phase 5 which represents post-QE. This translates to the allocation of liquidity injections to savings accounts because individuals were holding onto their cash. The positive association occurs after QE because portfolio rebalancing of this magnitude can have a lagged effect. The M2-M1 money spread will widen when the fed expands liquidity, i.e. monetary base increases, and there is considerable equity market risk meaning equity prices are volatile. In turn, households are likely to sell equities and allocate their assets in interest-bearing components of M2, small time deposits, and savings accounts. I conclude there is evidence of portfolio rebalancing with a lagged effect with from the Bai-Perron estimation results.

…..Insert Table 5 around here…..

There is clearly an imbalance of capital allocations as a result of liquidity injections from March 1984 – June 2020 so I reject the null hypothesis. The positive relationship between monetary base and excess reserves in phases 2 and 3 are a result of prolonged monetary policy implemented due to the financial crisis and the pandemic. In essence, the underlying analytical models used in the
Bai-Perron estimations depict a strong positive association between monetary base and excess reserves during QE phases and a strong positive association between monetary base and M2-M1 post-QE. Vault cash switches from a negative relationship with monetary base in the phase prior to QE to a positive relationship in phase 2 which captures prior to QE and the QE phases, ultimately switching to a negative relationship post-QE. There is a positive association between monetary base and bank credit prior to the financial crisis of 2008 with a profound switch to a negative association at the beginning of QE. It is also evident there is lagged portfolio rebalancing triggered by QE from the M2-M1 estimation results.

V. State Dependence in Interactions

Nonlinear two-state Markov Switching time series models are employed to capture complex dynamic patterns and are intended to further verify the estimation results of the Bai-Perron breakpoint analyses. A nonlinear model is appropriate in this case because I am analyzing macroeconomic relationships that are subject to regime change. The model is capable of characterizing time series behavior in different states by utilizing different structures. This model has been widely used for financial and economic time series and is a good addition to linear models because linear models are unable to capture nonlinear volatility clustering and dynamic patterns in asymmetry. (Hamilton, 1989) The Markov property regulates the current value of the state variable and depends on its previous past value. In turn, a structure may dominate for a period and then it will be replaced by another structure when the switching occurs. It enables us to observe stability, directional changes, and relationships between monetary base and capital allocations. Level non-stationary data is used to capture optimal directional changes. (Davig, 2009)
I specify four separate two-state Markov switching models: (MSAR(1)), (MSAR(2)), and (MSAR(3)) in which monetary base is subject to state switching, and where the errors follow a regime-invariant AR(1), AR(2), or AR(3) process for changes in each capital allocation as a function of changes in monetary base. The utilization of AR(1), AR(2), and AR(3) as non-switching regressors helps control autocorrelation and attempts to bring the Durbin-Watson statistics within normal range. Standard errors & covariance are computed using observed Hessian, and ergodic solution method is utilized for initial state probabilities. All tests are optimized by minimizing the Schwarz information criterion. Ultimately, I aim to provide additional insight and reinforce the Bai-Perron estimation results.

A Two-State Markov Process:

**Excess Reserves and Monetary Base**

State 1, A relationship between excess reserves and monetary base:

\[ re_{t|St-1} = c_1 + \gamma_1 mb_t + \epsilon_{1t} \quad \epsilon_{1t} \rightarrow N (0,1) \]  \hspace{1cm} (5)

State 2, A relationship between excess reserves and monetary base:

\[ re_{t|St-2} = c_2 + \gamma_2 mb_t + \epsilon_{2t} \quad \epsilon_{2t} \rightarrow N (0,1) \]  \hspace{1cm} (6)

**Vault Cash and Monetary Base**

State 1, A relationship between vault cash and monetary base:

\[ vc_{t|St-1} = c_1 + \gamma_1 mb_t + \epsilon_{1t} \quad \epsilon_{1t} \rightarrow N (0,1) \]  \hspace{1cm} (7)

State 2, A relationship between vault cash and monetary base:

\[ vc_{t|St-2} = c_2 + \gamma_2 mb_t + \epsilon_{2t} \quad \epsilon_{2t} \rightarrow N (0,1) \]  \hspace{1cm} (8)

**Bank Credit and Monetary Base**
State 1, A relationship between bank credit and monetary base:

\[ bc_{t|St-1} = c_1 + \gamma_1 mb_t + \epsilon_{1t} \quad \epsilon_{1t} \rightarrow N(0,1) \]  

(9)

State 2, A relationship between bank credit and Monetary base:

\[ bc_{t|St-2} = c_2 + \gamma_2 mb_t + \epsilon_{2t} \quad \epsilon_{2t} \rightarrow N(0,1) \]  

(10)

**M2-M1 and Monetary Base**

State 1, A relationship between M2-M1 and monetary base:

\[ M2 - M1_{t|St-1} = c_{11} + \gamma_{11} mb_t + \gamma_{12} mb_{t-1} + \epsilon_{11} \quad \epsilon_{11} \rightarrow N(0,1) \]  

(11)

State 2, A relationship between M2-M1 and monetary base:

\[ M2 - M1_{t|St-2} = c_{21} + \gamma_{21} mb_t + \gamma_{22} mb_{t-1} + \epsilon_{22} \quad \epsilon_{22} \rightarrow N(0,1) \]  

(12)

The corresponding transition probability matrix for the two-state Markov process is specified as:

\[ P = \begin{bmatrix} p_{11} & p_{21} \\ p_{12} & p_{22} \end{bmatrix} \]  

(13)

where \( p_{11} + p_{12} = 1, p_{21} + p_{22} = 1 \)

The results of the Markov switching estimation for excess reserves, vault cash, total bank credit, and M2-M1 as a function of changes in monetary base are shown in Table 6.

…..Insert Table 6 around here…..

The estimated process for monetary base in conjunction with the dependent variables is consistent with my initial assumption of two different directional associations between monetary base and capital allocations. A large coefficient spread from State 1 to State 2 represents a profound switching effect. The statistically significant estimated \( \hat{\gamma}_1 \) is 0.01 and statistically significant \( \hat{\gamma}_2 \)
coefficient is 0.95 for the changes in excess reserves as a function of changes in monetary base which indicates a strong switching from State 1 to State 2. These results are consistent with the Bai-Perron estimation results in Table 2. The estimated vault cash State 1 \( \hat{\gamma}_1 \) coefficient is unchanged compared to the State 2 \( \hat{\gamma}_2 \) coefficient which points to a weak relationship that lacks directional changes. The State 1 estimated \( \hat{\gamma}_1 \) total bank credit coefficient of 0.83 is statistically significant and State 2 has a statistically significant \( \hat{\gamma}_2 \) coefficient value of 0.16 which indicates a strong directional change. The M2-M1 State 1 estimated \( \hat{\gamma}_1 \) coefficient is 0.00 compared to a statistically significant \( \hat{\gamma}_2 \) coefficient value of 0.86 in State 2. This further enforces the claim that there is strong evidence of portfolio rebalancing and that liquidity is being allocated to savings accounts.

Further insight on the stability of the obtained Markov switching regimes can be derived from the graphical displays of filtered regime probabilities of remaining in the given State as shown in Figures 2 through 5.

Figure 2 depicts the probability of remaining in the given State on any given month for excess reserves. State 1 is dominant until a decisive switch to State 2 in 2001/2002 which is due to the liquidity injections in response to the dot.com crash and Enron scandal. Notably, there is a strong departure from State 1 to State 2 in 2008 which is caused by the QE liquidity injections. It is evident that there are directional changes depicted in the graphical representations and liquidity injections have a strong association with excess reserves during the QE period.

…..Insert Figure 2 around here…..
Figure 3 depicts the probability of remaining in the given State on any given month for vault cash. Vault cash switches states erratically and has many departures. Therefore, neither State dominates from the graphical representation results. These results are consistent with our Bai-Perron estimation results because there are many erratic changes in coefficients throughout the three phases. Moreover, this is consistent with the Markov estimation because of the lack of spread between State 1 and State 2.

…..Insert Figure 3 around here…..

The estimated process for total bank credit is consistent with our initial assumption of two different directional associations between total bank credit and monetary base as seen in Figure 4. State 1 dominates until a strong departure occurs to State 2 in 2002 and then switches back to State 1 briefly in 2008 and ultimately remains in State 2 for the remainder of the period through quantitative easing and post-quantitative easing. This demonstrates a weakening of total bank credit during QE as observed by (Orlowski, 2015.)

…..Insert Figure 4 around here…..

Figure 5 depicts the probability of remaining in the given state on any given month for M2-M1. It is evident liquidity injections are being allocated to the remaining components prior to the financial crisis as seen in State 1 prior to the drop to zero. A remarkable departure to State 2 occurs during the onset of the financial crisis in 2008. There is a strong connection between monetary base and M2-M1 in State 2 which starts in 2008 and remains through 2020 so I infer
that there is portfolio rebalancing here as liquidity injections are going to savings accounts as previously observed.

…..Insert Figure 5 around here…..

The transition probability matrix and expected durations are analyzed to further assess the dominate process. The expected duration is important for identifying asymmetric properties of capital allocations. (Phoong et al., 2020) The constant expected durations are measured in months because I am using monthly data.

Expected durations:
State 1: \( E(D) = 1/1 - \rho_{11} \)
State 2: \( E(D) = 1/1 - \rho_{22} \)

States \( i \) and \( j \) communicate if only if each State is available to each other and \( i \leftrightarrow j \). The probability of the first-transition is that starting in \( i \), the first transition to \( j \) occurs after \( n \) transitions:

\[
f_{ij}^{(n)} = \text{Prob}(X_n = j, X_k \neq j, k = 1, ..., (n - 1) | X_0 = i)\]

(Diebold, 2016)

The probability of staying in State 1 on any given month for the change in excess reserves as a function of changes in monetary base is 99.1% and the probability of departing State 1 is 0.09%. There is a high probability of staying in State 2 at 99.3% albeit less than State 1 and a probability of departing State 2 of 0.07%. For excess reserves, State 2 dominates State 1 for the probability of staying in State 2 compared to State 1 on any given month because State 2 has an expected duration of 136.11 months compared to 114.24 months for State 1. State 2 dominates as
expected due to the liquidity injection allocations at the start of QE. The probability of staying in State 1 on any given month for vault cash is 99.8\% and the probability of departing in State 1 is 0.02\%. The probability of remaining in State 2 on any given month is 97.6\% and the probability of switching from State 2 to State 1 is 0.024\%. The expected duration for State 1 is 469.73 months compared to 40.86 months for State 2, so I conclude State 1 dominates. The transition probabilities for total bank credit and M2-M1 are almost identical with neither state dominating the other. The expected durations for total bank credit are indifferent so neither State is dominate. However, State 1 has a longer expected duration of 503.71 months compared to 351.74 months in State 2 for M2-M1, so State 1 dominates.

VI. Summary

The empirical results from the Bai-Perron multiple breakpoint regressions and Markov Switching models suggests that an imbalance of capital allocations exists as a result of liquidity injections from the period March 1984 to June 2020. The surge of liquidity injections during QE infer a strong relationship between monetary base and excess reserves. I attribute this to the buildup of reserves due to Dodd Frank restrictions on banks and interest paid on excess reserves which led to banks hoarding excess reserves opposed to making loans. I examine moderately strong statistically significant results for M2-M1 in phase 5 of the Bai-Perron estimation which aligns with the post-QE period. The bivariate Markov switching models further support that liquidity got allocated to savings accounts as a result of QE. Consequently, there is remarkable portfolio rebalancing effect. The Markov switching models depict strong state switching from State 1 to State 2 for total bank credit leading up to the financial crisis and M2-M1 in 2008. In
sum, there is a capital allocation imbalance created from liquidity injections from the period March 1984 to June 2020 which is most pronounced during QE and post-QE periods. Furthermore, there is a pronounced portfolio rebalancing effect post-QE due to a lagged effect.
References


A. Appendix: Variable Description

Monetary Base: Total balances maintained in addition to currency in circulation.

Excess Reserves: Total reserve balances maintained minus reserve balance requirements institutions hold at Federal Reserve banks to satisfy reserve requirements. Excess balance requirements are the remaining portion of reserve requirements not satisfied by vault cash.

Vault Cash: Institutions’ vault cash to satisfy reserve requirements that is not exempt from reserve requirements. Institutions whose vault cash exceeds their required reserves to satisfy current reserve requirements.

Total Bank Credit: Total amount of credit that financial institutions make available to an institution or individual.

M2-M1 money stock: M2 money stock consists of M1 in addition to savings deposits, time deposits less than $100,000, and balances in retail money market mutual funds. M1 money stock comprises of currency outside the U.S. Treasury, Federal Reserve Banks, and depository institutions, nonbank travel’s checks, demand deposits, and other checkable deposits. M2-M1 is essentially the interest component.
Table 1. Mean, standard deviation, skewness, kurtosis, and unit roots.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Monetary Base</th>
<th>Excess Reserves</th>
<th>Vault</th>
<th>Total Bank Credit</th>
<th>M2 – M1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>1348.44</td>
<td>572.22</td>
<td>37.77</td>
<td>6265.45</td>
<td>5069.51</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>1348.06</td>
<td>896.70</td>
<td>13.46</td>
<td>3678.33</td>
<td>2939.31</td>
</tr>
<tr>
<td>Skewness</td>
<td>1.04</td>
<td>1.18</td>
<td>0.65</td>
<td>0.51</td>
<td>0.68</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>2.48</td>
<td>2.84</td>
<td>2.98</td>
<td>2.00</td>
<td>2.23</td>
</tr>
<tr>
<td>ADF level</td>
<td>1.26</td>
<td>-0.35</td>
<td>-2.48</td>
<td>-5.05</td>
<td>-5.81</td>
</tr>
</tbody>
</table>

The table presents summary statistics from the sample. The time period is March 1984 – June 2020. Monthly data with 436 observations. Mean, Standard Deviation, Skewness, Kurtosis, and Augmented Dickey-Fuller unit root tests are computed. ADF tests in % change of first differences and ADF level unit root tests are depicted. Augmented Dickey-Fuller test critical value at 5% is -2.87. All variables are measured in billions of dollars, monthly intervals, and are not seasonally adjusted.

*Data Source: Federal Reserve Bank of St. Louis FRED*
Table 2. Excess Reserves of the United States Banking System Capital Allocation and Monetary Base of the Federal Reserve Dependent variable: a change in excess reserves (in $billion).

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Phase 1</th>
<th>Phase 2</th>
<th>Phase 3</th>
</tr>
</thead>
<tbody>
<tr>
<td># of Observations</td>
<td>210</td>
<td>85</td>
<td>141</td>
</tr>
<tr>
<td>C (t-statistics)</td>
<td>-0.009 (-0.88)</td>
<td>-0.182*** (-3.15)</td>
<td>-0.009** (-2.28)</td>
</tr>
<tr>
<td>( \hat{\beta} ) ∆log Monetary Base (t-statistics)</td>
<td>1.296 (0.97)</td>
<td>51.134*** (6.28)</td>
<td>3.050*** (4.42)</td>
</tr>
<tr>
<td>Adjusted ( R^2 )</td>
<td>0.558</td>
<td>0.558</td>
<td>0.558</td>
</tr>
<tr>
<td>AIC</td>
<td>-0.314</td>
<td>-0.314</td>
<td>-0.314</td>
</tr>
<tr>
<td>SIC</td>
<td>-0.258</td>
<td>-0.258</td>
<td>-0.258</td>
</tr>
<tr>
<td>DW</td>
<td>2.252</td>
<td>2.252</td>
<td>2.252</td>
</tr>
</tbody>
</table>

Notes: March 1984 – June 2020 sample period (436 observations); all MBP tests allow error terms to differ across breaks. T-statistics in parentheses; *** denotes significance at 1%, ** at 5%, * at 10%. AIC: Akaike Information Criterion; SIC: Schwarz Information Criterion; DW: Durbin Watson statistics.

Source: Author’s own estimation based on the Federal Reserve Bank of St. Louis FRED daily data.
Table 3. Vault Cash of the United States Banking System Capital Allocation and Monetary Base of the Federal Reserve Dependent variable: a change in vault cash (in $billion).

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Phase 1</th>
<th>Phase 2</th>
<th>Phase 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Δlog Vault Cash</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td># of Observations</td>
<td>97</td>
<td>262</td>
<td>74</td>
</tr>
<tr>
<td>C</td>
<td>0.011***</td>
<td>0.002</td>
<td>0.000</td>
</tr>
<tr>
<td>(t-statistics)</td>
<td>(4.40)</td>
<td>(0.92)</td>
<td>(-0.13)</td>
</tr>
<tr>
<td>( \hat{\beta} \Delta \log ) Monetary base</td>
<td>-0.978***</td>
<td>0.124***</td>
<td>-0.876*</td>
</tr>
<tr>
<td>(t-statistics)</td>
<td>(-4.09)</td>
<td>(2.61)</td>
<td>(-1.92)</td>
</tr>
<tr>
<td>Adjusted ( R^2 )</td>
<td>0.112</td>
<td>0.112</td>
<td>0.112</td>
</tr>
<tr>
<td>AIC</td>
<td>-4.300</td>
<td>-4.300</td>
<td>-4.300</td>
</tr>
<tr>
<td>SIC</td>
<td>-4.243</td>
<td>-4.243</td>
<td>-4.243</td>
</tr>
<tr>
<td>DW</td>
<td>1.761</td>
<td>1.761</td>
<td>1.761</td>
</tr>
</tbody>
</table>

Notes: March 1984 – March 2020 sample period (433 observations); all MBP tests allow error terms to differ across breaks. T-statistics in parentheses; *** denotes significance at 1%, ** at 5%, * at 10%. AIC: Akaike Information Criterion; SIC: Schwarz Information Criterion; DW: Durbin Watson statistics.

Source: as in Table 2.
Table 4. Total Bank Credit of the United States Banking System Capital Allocation and Monetary Base of the Federal Reserve Dependent variable: a change in total bank credit (in $billion).

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Phase 1</th>
<th>Phase 2</th>
<th>Phase 3</th>
</tr>
</thead>
<tbody>
<tr>
<td># of Observations</td>
<td>296</td>
<td>65</td>
<td>75</td>
</tr>
<tr>
<td>C (t-statistics)</td>
<td>0.005*** (16.72)</td>
<td>0.002** (2.17)</td>
<td>0.005*** (10.06)</td>
</tr>
<tr>
<td>$\hat{\beta} \Delta \log$ Monetary base</td>
<td>0.151*** (7.43)</td>
<td>-0.065*** (-3.18)</td>
<td>0.066 (1.55)</td>
</tr>
<tr>
<td>Adjusted $R^2$</td>
<td>0.233</td>
<td>0.233</td>
<td>0.233</td>
</tr>
<tr>
<td>AIC</td>
<td>-7.637</td>
<td>-7.637</td>
<td>-7.637</td>
</tr>
<tr>
<td>SIC</td>
<td>-7.581</td>
<td>-7.581</td>
<td>-7.581</td>
</tr>
<tr>
<td>DW</td>
<td>1.838</td>
<td>1.838</td>
<td>1.838</td>
</tr>
</tbody>
</table>

Notes: as in Table 2. Source: as in Table 2.
Table 5. M2-M1 of the United States Banking System Capital Allocation and Monetary Base of the Federal Reserve Dependent variable: a change in M2-M1 (in $billion).

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Phase 1</th>
<th>Phase 2</th>
<th>Phase 3</th>
<th>Phase 4</th>
<th>Phase 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Δlog M2-M1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td># of Observations</td>
<td>69</td>
<td>65</td>
<td>100</td>
<td>136</td>
<td>66</td>
</tr>
<tr>
<td>C</td>
<td>0.005***</td>
<td>0.000</td>
<td>0.007***</td>
<td>0.004***</td>
<td>0.005***</td>
</tr>
<tr>
<td>(t-statistics)</td>
<td>(8.31)</td>
<td>(1.09)</td>
<td>(17.62)</td>
<td>(9.60)</td>
<td>(8.03)</td>
</tr>
<tr>
<td>( \hat{\beta} ) ( \Delta \log ) Monetary Base</td>
<td>0.083</td>
<td>-0.074</td>
<td>0.006</td>
<td>0.021</td>
<td>0.153***</td>
</tr>
<tr>
<td>(t-statistics)</td>
<td>(1.62)</td>
<td>(-1.47)</td>
<td>(0.13)</td>
<td>(1.57)</td>
<td>(4.44)</td>
</tr>
<tr>
<td>Adjusted ( R^2 )</td>
<td>0.326</td>
<td>0.326</td>
<td>0.326</td>
<td>0.326</td>
<td>0.326</td>
</tr>
<tr>
<td>DW</td>
<td>1.934</td>
<td>1.934</td>
<td>1.934</td>
<td>1.934</td>
<td>1.934</td>
</tr>
</tbody>
</table>

Notes: as in Table 2.
Source: as in Table 2.
Table 6. Estimations of Two-State Markov Switching for changes in Excess Reserves, Vault Cash, Total Bank Credit, and M2-M1 in relation to changes in monetary base.

<table>
<thead>
<tr>
<th>State</th>
<th>Changes in Excess Reserves as a function of changes in Monetary Base</th>
<th>Changes in Vault Cash as a function of changes in Monetary Base</th>
<th>Changes in Total Bank Credit as a function of changes in Monetary Base</th>
<th>Changes in M2-M1 as a function of changes in Monetary Base</th>
</tr>
</thead>
<tbody>
<tr>
<td>State I</td>
<td>$\hat{c}_1 = 68.40^{***} (11.26)$</td>
<td>$\hat{c}_1 = 112.58^{***} (4.62)$</td>
<td>$\hat{c}_1 = -667.68 (-1.19)$</td>
<td>$\hat{c}_1 = -1212.78 (-0.60)$</td>
</tr>
<tr>
<td></td>
<td>$\hat{\gamma}_1^{<em>} = 0.01^{</em>**} (3.45)$</td>
<td>$\hat{\gamma}_1 = 0.00 (-0.35)$</td>
<td>$\hat{\gamma}_1 = 0.83^{***} (7.43)$</td>
<td>$\hat{\gamma}_1 = 0.00 (0.25)$</td>
</tr>
<tr>
<td>State II</td>
<td>$\hat{c}_2 = -525.43^{***} (-129.04)$</td>
<td>$\hat{c}_2 = 110.73^{***} (4.54)$</td>
<td>$\hat{c}_2 = -230.35 (-0.40)$</td>
<td>$\hat{c}_2 = -6683.93^{***} (-3.36)$</td>
</tr>
<tr>
<td></td>
<td>$\hat{\gamma}_2^{<em>} = 0.95^{</em>**} (182.52)$</td>
<td>$\hat{\gamma}_2 = 0.00 (-0.52)$</td>
<td>$\hat{\gamma}_2 = 0.16^{***} (3.57)$</td>
<td>$\hat{\gamma}_2 = 0.86^{***} (8.81)$</td>
</tr>
<tr>
<td>AR(1) term</td>
<td>0.97</td>
<td>0.99</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>AR(2) term</td>
<td>0.11</td>
<td>0.01</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>AR(3) term</td>
<td>-0.08</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Diagnostic tests: Log Likelihood</td>
<td>-726.97</td>
<td>-606.09</td>
<td>-2109.76</td>
<td>-1698.64</td>
</tr>
<tr>
<td>Schwartz Info. Crit.</td>
<td>3.50</td>
<td>2.95</td>
<td>9.80</td>
<td>7.92</td>
</tr>
<tr>
<td>Durbin Watson</td>
<td>0.87</td>
<td>1.56</td>
<td>1.81</td>
<td>1.55</td>
</tr>
<tr>
<td>Constant transition probabilities, Probability of staying in:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>State I</td>
<td>0.991 0.009</td>
<td>0.998 0.002</td>
<td>0.993 0.007</td>
<td>0.998 0.002</td>
</tr>
<tr>
<td>State II</td>
<td>0.007 0.993</td>
<td>0.024 0.976</td>
<td>0.007 0.993</td>
<td>0.002 0.998</td>
</tr>
<tr>
<td>Constant expected durations:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>State I</td>
<td>114.24 months</td>
<td>469.73 months</td>
<td>140.99 months</td>
<td>503.71 months</td>
</tr>
<tr>
<td>State II</td>
<td>136.11 months</td>
<td>40.86 months</td>
<td>140.12 months</td>
<td>351.74 months</td>
</tr>
</tbody>
</table>

Notes: as in Table 2; z-statistics in parentheses.
Source: as in Table 2.
Figure 1. Monetary Base, Excess Reserves, Vault Cash, Total Bank Credit, and M2-M1

Source: Author’s own compilation based on the Federal Reserve Bank of St. Louis FRED monthly data for the March 1984 – June 2020 sample period. All variables are depicted as logarithm of each variable.
Figure 2. Probability of remaining in the given State on any given month for Excess Reserves, Markov switching filtered regime probability.

State 1
State 2

Source: as in Table 1.
Figure 3. Probability of remaining in the given State on any given month for Vault Cash, Markov switching filtered regime probability.

State 1
State 2

Source: as in Table 1.
Figure 4. Probability of remaining in the given State on any given month for Total Bank Credit, Markov switching filtered regime probability.

State 1
State 2

Source: as in Table 1.
Figure 5. Probability of remaining in the given state on any given month for M2-M1, Markov switching filtered regime probability.

State 1
State 2

Source: as in Table 1.