Interest Rate Pass-through: Divisia User Costs and the Federal Funds Rate

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Do we need to worry about money?

Money has essentially disappeared from U.S. monetary policy

- **In practice:** Federal Reserve Governor, Lawrence Meyer
  “...money plays no role in today’s consensus macro model...
and virtually no role in the conduct of monetary policy, at least in the United States.”

- **In theory:** Michael Woodford’s treatise: Money, Interest and Prices
  “...interest-rate policy can be used to achieve an inflation target without control of a monetary aggregate.”
Does money matter?

• Today most models of monetary policy do not include money.
  • Economic activity can be affected by interest rates which are directly controlled by central banks.
  • Money supply responds endogenously to accommodate changes in the interest rate
  • See e.g. *How important is money in the conduct of monetary policy?* (Woodford, 2006)

• Clarida, Gali, and Gertler (1999) argue that monetary aggregates do not suffer from the same informational delays as inflation and output.

• McCallum (2001) argues that a separable transactions demand function (common in the New Keynesian framework) allows money to aggregate away” from the equilibrium conditions, but it is probably wrong.
Problems with Monetary Aggregates

- **Friedman and Kuttner (1996)** concluded that targeting broad money may be destabilizing since it exposes the economy to money market shocks that are traditionally more volatile than other types of aggregate demand shocks.

- The 1980s experienced important regulatory changes (**Teles and Zhou, 2005**) and shifts in the Fed’s operating Procedures (**Lindsey et al, 2013**)

- Long standing empirical relationships linking monetary aggregates like M1, M2 and the monetary base to movements in prices and interest rates began to deteriorate in the 1980s.

- A broad consensus was reached that no measure of liquidity in an economy was of any value in conducting monetary policy. (**Lucas and Nicolini, 2015**)
Monetary Aggregates

• THE BARNETT CRITIQUE:
The key problem with the simple-sum aggregation methodology is that it fails to account for the dual nature of monetary assets. It assumes perfect substitutability of the sub-aggregates.

• Barnett (1980) and others have long argued that the use of simple-sum monetary aggregates is theoretically indefensible in a modern economy.

• Barnett, Kelly, and Keating. (2011) argue that these problems cannot be avoided by simply narrowing the definition of money to include fewer assets as this arbitrarily ignores assets that provide monetary services.

“...if pressed on this issue, virtually all monetary economists today would no doubt concede that the Divisia aggregates proposed by Barnett are both theoretically and empirically superior to their simple-sum counterparts.”
Belongia and Ireland (2014)
DIVISIA Monetary Aggregates

Belongia (1996) shows qualitative inference on various empirical estimations of the effects of monetary aggregates on the economy are generally reversed when a simple-sum measure of money is replaced with a Divisia index.

Keating, Kelly and Valcarcel (2014) find a Divisia index resolves the price and output puzzles that commonly arise in VARs where money aggregates or short-term rates enter as the policy indicator.

Serletis and Gogas. (2015) find empirical evidence that differences in simple-sum and Divisia aggregates carry important information for the Great Ratios and long-run relationships between major real and nominal macroeconomic variables.
Figure 6 - Components of CFS Divisia M4 - Highlights for March 2017

Components in this table build from the narrowest aggregate at the top to the broadest at the bottom. For example, the darkest green in the left column includes components of DM1. The next tier shows the components included in DM2, but not within DM1.

<table>
<thead>
<tr>
<th>Component</th>
<th>Weighted Contribution To DM4 Money Annual Growth Rate*</th>
<th>Divisia Growth-Rate Weights (Average of Last 12 Months)</th>
<th>Unweighted Year-Over-Year Percentage Growth Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>DM1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Currency</td>
<td>0.5%</td>
<td>7.6%</td>
<td>6.4%</td>
</tr>
<tr>
<td>Traveler’s Checks</td>
<td>0.0%</td>
<td>0.0%</td>
<td>-12.5%</td>
</tr>
<tr>
<td>Demand Deposits **</td>
<td>1.4%</td>
<td>12.3%</td>
<td>12.0%</td>
</tr>
<tr>
<td>OCDs at Commercial Banks **</td>
<td>0.2%</td>
<td>2.6%</td>
<td>6.2%</td>
</tr>
<tr>
<td>OCDs at Thrift Institutions **</td>
<td>0.2%</td>
<td>2.1%</td>
<td>10.6%</td>
</tr>
<tr>
<td>Added into DM2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Savings Deposits at Commercial Banks **</td>
<td>2.0%</td>
<td>33.2%</td>
<td>6.2%</td>
</tr>
<tr>
<td>Savings Deposits at Thrift Institutions **</td>
<td>0.5%</td>
<td>5.0%</td>
<td>9.8%</td>
</tr>
<tr>
<td>Retail Money-Market Funds</td>
<td>-0.2%</td>
<td>3.3%</td>
<td>-6.3%</td>
</tr>
<tr>
<td>Small Time Deposits at Commercial Banks</td>
<td>-0.2%</td>
<td>1.4%</td>
<td>-10.4%</td>
</tr>
<tr>
<td>Small Time Deposits at Thrifts</td>
<td>0.0%</td>
<td>0.5%</td>
<td>-7.1%</td>
</tr>
<tr>
<td>Added into DM3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Institutional Money-Market Funds</td>
<td>-0.4%</td>
<td>8.8%</td>
<td>-5.0%</td>
</tr>
<tr>
<td>Large Time Deposits</td>
<td>-0.6%</td>
<td>7.8%</td>
<td>-7.6%</td>
</tr>
<tr>
<td>Repurchase Agreements</td>
<td>0.4%</td>
<td>5.3%</td>
<td>8.0%</td>
</tr>
<tr>
<td>Added into DM4-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Commercial Paper</td>
<td>-0.4%</td>
<td>3.1%</td>
<td>-11.1%</td>
</tr>
<tr>
<td>Added into DM4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T-Bills</td>
<td>0.7%</td>
<td>7.0%</td>
<td>9.1%</td>
</tr>
</tbody>
</table>

Note: The row labels in the first column are shaded to show which components are included into which aggregates. Each data column is shaded on a gradient from dark green (maximum) to dark red (minimum). See the figures 10-15 for these calculations over time and a chart version of the above table.

* Average of last 12 monthly weighted contributions to CFS Divisia M4 growth rates (annual rates). Unlike the other percent calculations in this report, the weighted contributions use continuous percent changes computed from natural logs.
MP Transmission through interest rate pass-through

A reductive characterization:

• Through OMO the Fed can control the overnight Federal Funds Rate which in turn affords the Fed substantial influence over other interest rates.

• Since late 2008 the collapse of the Federal Funds rate to its ZLB opened the door for investigations of unconventional monetary policy.

• Multiple attempts to quantify the effects of forward rate guidance, asset purchases, or compositional changes in the Fed’s balance sheet (broadly termed ZIRP).
MP Transmission through interest rate pass-through

- The transmission avenues of unconventional MP to various financial markets and the overall economy are not yet well understood.

- In principle EHTS could also apply during periods of ZIRP if, e.g., large scale asset purchases have an impact on selected rates which in turn could influence other rates though expectations and substitution effects.

- Vayanos and Vila (2009) offer a model that shows how the supplies of assets of different maturities affect their respective yields.

- Gagnon et al. (2011) show the Fed's large-scale asset purchases led to reductions in interest rates of various securities including securities that were not part of the purchase program. The authors conclude these effects are not consistent with EHTS but indicative of lower risk premia instead.

- Krishnamurthy and Vissing-Jorgensen (2011) posit that focusing on Treasury rates as a policy target is misplaced given that large-scale purchases only affected yields of those assets that were purchased.
Thus, since 2008, the evidence of policy transmission passing through interest rates of other securities is, at best, mixed.

During periods of above zero FFR, EHTS has been rejected by an even larger literature that considered various interest rates, sample periods, and monetary policy regimes (see for example, Campbell and Shiller 1991; Bekaert et al. 1997; Cochrane and Piazessi 2005; Thornton 2005 and Sarno et al. 2007).

Thus interest rate pass-through seems to be rejected by the data during periods of unconventional MP and more normal conditions.
MP Transmission through interest rate pass-through

• Importantly, a key assumption of EHTS is the perfect substitutability among the assets in the term structure.

• This assumption is palatable if the basket of yields in the term structure is limited to sovereign debt instruments only—as indeed most of the EHTS literature focuses on the term structure of treasury debt.

• However, the assumption of perfect substitutability becomes more difficult to justify when considering other interest rates in financial markets.

• Presumably, the yields of private debt matter most for economic activity (and these are unlikely to be perfect substitutes)
Considerations when modeling FFR
Pass-through to other rates

Allow for less-than-perfect substitutability among various rates.

Consider rates associated with private and public debt

Relationship between the Federal Funds rate and other rates may not be uniform over time
Role of FFR re other rates evolves

Up to early-to-mid 1960s banks would access Federal Funds mkt to meet statutory reserve requirements.

*A more segmented Federal Funds mkt?*

Regulation Q implemented in 1936 but begins to get traction in the mid 1960s. Massive shift by commercial banks to accessing Federal Funds mkt as a continuous source of funds.

*Leads to a reduction in the segmentation?*

1980s see many important regulatory changes and shifts in Federal Reserve’s operating procedures. Regulation Q is relaxed to allow banks to begin issuing NOW and MMD accounts

In late 2008 Federal Funds rate reaches ZLB

In 2011 Dodd-Frank Act repeals Regulation Q.

*Any or all of these might have impacted Federal Funds rate pass-through to rates of other private and/or public debt.*
The Paper’s Goal:

To investigate the pass-through in the volatility of the Federal Funds rate and the user cost of various monetary assets.

• I focus on the user cost of money/monetary assets because:

• There is a rich theoretical framework that establishes the concept from first principles. See Barnett (1978) and Donovan (1979) for seminal treatment.

• There is a close theoretical link between the concept of user cost and monetary aggregation. See Barnett (1980) for seminal treatment...and others since.

• Because, generally, monetary assets are durable enough during the period from use, their own user costs constitute the price of the assets. See Belongia and Ireland (2006).
Windows of Potential Contribution

• While some recent theoretical research has incorporated the user cost of monetary aggregates in DSGE models, fewer papers have focused on empirical applications of the user cost; and to my knowledge this is the first paper that considers the user cost of individual assets—rather than an exclusive focus on the user cost of monetary aggregates.

• This is the first paper to highlight a strong co-movement between the Federal Funds rate, or Shadow Federal Funds rate, and the user costs of various monetary assets.

• In another first, this paper presents volatility profiles of the user costs of monetary aggregates as well as individual assets and contrasts them with those of the Federal Funds rate.
User Costs

Keating, Kelly, Smith & Valcarcel (WP)

build a medium-scale DSGE model with a “DIVISIA-like” monetary aggregate that allows for less-than-perfect substitutability among its sub-aggregates and compare it to the model with a “simple-sum-like” monetary aggregate to provide theoretical justification for a DIVISIA monetary aggregate as a better indicator of monetary policy than simple-sum.

Eq. conditions suggest user costs of more liquid assets are proportional to short-term interest rates and user costs of less liquid assets are subject to a wider variety of financial shocks.

Implication: Differences in user costs could be informative regarding transmission of monetary and financial shocks.
The User Cost of Money

“The user cost [of money] is analog to the well-known Jorgensonian user cost (rental price) of durable consumer goods” Donovan (1979)

“The nominal value of client services—when bank compensation comes via an interest margin—can be inferred as the interest foregone by depositors when they accept a lower rate than the yield on market instruments with the most comparable risk profile” Basu and Wang (2013)

“A function of the interest foregone by holding a specific asset rather than an alternative asset that does not provide any monetary services and earns a higher rate of return (referred to as the “benchmark rate”)” Anderson and Jones (2011)

$$\Psi_{n,t} = \frac{R_t - r_{n,t}}{1 + R_t}$$
The User Cost of Money

User cost of money serves a number of theoretical functions:

A monetary aggregate that can be classified as a superlative index (Diezert, 1976) requires weights to be assigned to each of its components. These weights are functions of the user costs of its respective assets.

“Differential user costs can arise in the solution to the optimization problem households face which may reflect the differing amounts of monetary services furnished by the assets.” Holstrom and Tirole (2011)

User costs appear in some DSGE applications that place money in the utility function (MIUF) of the household or with a shopping time mechanism. See Basu and Wang (2013), Belongia and Ireland (2014) and Keating et al. (2014) for recent examples.
Monetary Aggregates

According to the Board of Governors of the Federal Reserve:

"M1 consists of (1) currency outside the U.S. Treasury, Federal Reserve Banks, and the vaults of depository institutions; (2) traveler's checks of nonbank issuers; (3) demand deposits at commercial banks (excluding those amounts held by depository institutions, the U.S. government, and foreign banks and official institutions) less cash items in the process of collection and Federal Reserve float; and (4) other checkable deposits (OCDs), consisting of negotiable order of withdrawal (NOW) and automatic transfer service (ATS) accounts at depository institutions, credit union share draft accounts, and demand deposits at thrift institutions. Seasonally adjusted M1 is constructed by summing currency, traveler's checks, demand deposits, and OCDs, each seasonally adjusted separately."

"M2 consists of M1 plus (5) savings deposits (including money market deposit accounts); (6) small-denomination time deposits (time deposits in amounts of less than $100,000), less individual retirement account (IRA) and Keogh balances at depository institutions; and (7) balances in retail money market mutual funds, less IRA and Keogh balances at money market mutual funds. Seasonally adjusted M2 is constructed by summing savings deposits, small-denomination time deposits, and retail money funds, each seasonally adjusted separately, and adding this result to seasonally adjusted M1."
Monetary Aggregation

\[
\ln(g_t^{M2}) = \ln \left( \frac{c_t + tc_t + dd_t + ocd_t + sd_t + std_t + rmf_t}{c_{t-1} + tc_{t-1} + dd_{t-1} + ocd_{t-1} + sd_{t-1} + std_{t-1} + rmf_{t-1}} \right)
\]  

\[
\ln(g_t^{DM2}) = \left( \frac{s^c_t + s^c_{t-1}}{2} \right) \ln \left( \frac{c_t}{c_{t-1}} \right) + \left( \frac{s^{tc}_t + s^{tc}_{t-1}}{2} \right) \ln \left( \frac{tc_t}{tc_{t-1}} \right) + \\
\left( \frac{s^{dd}_t + s^{dd}_{t-1}}{2} \right) \ln \left( \frac{dd_t}{dd_{t-1}} \right) + \left( \frac{s^{ocd}_t + s^{ocd}_{t-1}}{2} \right) \ln \left( \frac{ocd_t}{ocd_{t-1}} \right) + \\
\left( \frac{s^{sd}_t + s^{sd}_{t-1}}{2} \right) \ln \left( \frac{sd_t}{sd_{t-1}} \right) + \left( \frac{s^{std}_t + s^{std}_{t-1}}{2} \right) \ln \left( \frac{std_t}{std_{t-1}} \right) + \\
+ \left( \frac{s^{rmf}_t + s^{rmf}_{t-1}}{2} \right) \ln \left( \frac{rmf_t}{rmf_{t-1}} \right)
\]  

(1)
Monetary Aggregation

For

\[ (j_t \equiv u^c_t, u^{tc}_t, u^{dd}_t, u^{ocd}_t, u^{sd}_t, u^{std}_t, \text{ or } u^{rmf}_t) \quad (\theta_t \equiv c_t, tc_t, dd_t, ocd_t, sd_t, std_t, \text{ or } rmf_t) \]

The expenditure share for each asset

\[ S^\theta_t = \frac{j_t \theta_t}{\Theta_t} \quad (3) \]

Given

\[ \Theta_t = u^c_t c_t + u^{tc}_t tc_t + u^{dd}_t dd_t + u^{ocd}_t ocd_t + u^{sd}_t sd_t + u^{std}_t std_t + u^{rmf}_t rmf_t \]
User Costs and Fed Fund rates exhibit similar behavior up to the ’07 financial crisis and aftermath.

Suggesting similar informational content.

**BUT...** UC does not bump against the lower bound during the financial crisis and beyond.
The Model

\[ Z_t = \sum_{i=1}^{p} \Phi_i Z_{t-i} + u_t \quad \text{E}(u_t'u_t) = V \]  

Variance decompositions readily available from:

\[ Z_t = \sum_{i=0}^{\infty} \left( A_{i-1} + A_{i-2} + \ldots + A_{i-p} \right) u_{t-i} \]  

if provided with an identification scheme

Various techniques available to facilitate orthogonalization of innovations

However, most techniques yield variance decompositions that may not be unique to a reordering of the variables. A stand on a particular ordering of the variables requires structural knowledge of the economy.
The Model

Because I am interested in ascertaining how volatilities spill over between variable in both directions I opt for GVAR specifications.

The generalized vector autoregression (GVAR) approach {Koop, Pesaran and Potter (1996) and Pesaran and Shin (1998)} allows for correlated shocks, rather than orthogonalizing the innovation errors.

Advantages

1. Yields variance decompositions that are independent of how variables are ordered in the VAR.
2. it does not rely on pre-assumptions about the contemporaneous relationship between the variables

Disadvantages

1. the sum of the contributions to the variance of the forecast error may not add up to one.
2. Can only be interpreted as an approximation (up to some normalization) rather than an exact decomposition.
Volatility Spillovers VAR Forecasts

Model is an application of Diebold and Yilmaz (2010) methodology

\( \theta_{ij}^g(H) \) denote the \( H \)-step-ahead FEVD from a GVAR estimation of (5) above

\[
\theta_{ij}^g(H) = \frac{\sum_{h=0}^{H-1} \left( s_i' A_h V s_j \right)^2}{\sigma_{ii} \sum_{h=0}^{H-1} \left( s_i' A_h V A_h s_i \right)}
\]

For \( H=1,2,3,... \)

**Own variance shares**

The fraction of the \( H \)-step-ahead variances in forecasting \( z_i \) due to shocks to \( z_i \)

\[
\text{for } i = 1,2,...N
\]

**Cross variance shares**

The fraction of the \( H \)-step-ahead variances in forecasting \( z_i \) due to shocks to \( z_j \)

\[
\text{for } i, j = 1,2,...N \quad \text{s.t. } i \neq j
\]

Normalizing...

\[
\tilde{\theta}_{i,j}^g(H) = \frac{\theta_{i,j}^g(H)}{\sum_{j=0}^{N} \theta_{i,j}^g(H)}
\]

\[
\begin{cases} 
\left\{ \begin{array}{l} 
\sum_{j=1}^{N} \tilde{\theta}_{ij}^g(H) = 1 \quad \text{and} \quad \sum_{i,j=1}^{N} \tilde{\theta}_{ij}^g(H) = N \\
\text{even if } \sum_{j=1}^{N} \theta_{ij}^g(H) \neq 1
\end{array} \right.
\end{cases}
\]
VAR Forecasts

Volatility Spillover Index

Diebold and Yilmaz (2010)

\[
\zeta^g(H) = \frac{\sum_{i,j=1}^{N} \tilde{\theta}_{i,j}^g(H)}{\sum_{i,j=1}^{N} \tilde{\theta}_{i,j}^g(H)} \cdot 100 = \frac{\sum_{i,j=1}^{N} \tilde{\theta}_{i,j}^g(H)}{N} \cdot 100
\]

Directional Volatility Spillover received by asset \(i\) from all other assets \(j\)

\[
\xi_{i\leftarrow}(H) = \frac{\sum_{j=1}^{N} \tilde{\theta}_{ij}^g(H)}{\sum_{j=1}^{N} \tilde{\theta}_{ij}^g(H)} \cdot 100
\]

Directional Volatility Spillover transmitted by asset \(i\) to all other assets \(j\)

\[
\xi_{i\rightarrow}(H) = \frac{\sum_{j=1}^{N} \tilde{\theta}_{ji}^g(H)}{\sum_{j=1}^{N} \tilde{\theta}_{ji}^g(H)} \cdot 100
\]

Net Volatility Spillover Index

\[
\xi^g_i = \xi_{i\rightarrow}(H) - \xi_{i\leftarrow}(H)
\]
Data

Monthly Data.
1967:m1 – 2015:m7

User Costs data from the Center for Financial Stability
Federal Funds Rate from FRED.

Select two volatility measures for FFR and each UC
(one parametric and one nonparametric)

1. univariate Student's $t$ generalized autoregressive score (GAS) model
Creal, Koopman, and Lucas (2013)

2. Three-month rolling standard deviations of each rate (henceforth RSD)
General co-movement in volatilities

High volatility in FFR and most UCs in early 1980s

UCs also “greatly moderated”

Volatility hikes in the Financial Crisis

FFR volatility co-moves more tightly with UCs of more liquid assets or narrower aggregates
Volatilities: RSD
Three Model Specifications

Model a \[ Z_t = \{ UC_1, UC_2, UC_3, UC_4, FFR \} \]

Model b \[ Z_t = \{ DD, OCD, SD, STD, RMF, FFR \} \]

Model c \[ Z_t = \{ IMM, LTD, REPO, CP, TB, FFR \} \]
**Volatility Spillover Estimates Model A: Fixed Parameters**

### Table 1: Volatility Spillover from 1st GVAR Specification
**GAS (1967:1-2008:12)**

<table>
<thead>
<tr>
<th>GIRF</th>
<th>UC1</th>
<th>UC2</th>
<th>UC3</th>
<th>UC4</th>
<th>FFR</th>
<th>Contributions from others</th>
</tr>
</thead>
<tbody>
<tr>
<td>UC1</td>
<td>39.4</td>
<td>10.8</td>
<td>4.2</td>
<td>4.4</td>
<td>41.3</td>
<td>61</td>
</tr>
<tr>
<td>UC2</td>
<td>19.9</td>
<td>34.9</td>
<td>19.2</td>
<td>15.7</td>
<td>10.3</td>
<td>65</td>
</tr>
<tr>
<td>UC3</td>
<td>13.1</td>
<td>21.6</td>
<td>28.8</td>
<td>28.2</td>
<td>8.4</td>
<td>71</td>
</tr>
<tr>
<td>UC4</td>
<td>13.9</td>
<td>17.2</td>
<td>26.5</td>
<td>30.1</td>
<td>11.4</td>
<td>69</td>
</tr>
<tr>
<td>FFR</td>
<td>26.0</td>
<td>3.3</td>
<td>1.7</td>
<td>1.9</td>
<td>67.1</td>
<td>33</td>
</tr>
</tbody>
</table>

**Contributions to Others**
- UC1: 73
- UC2: 53
- UC3: 52
- UC4: 50
- FFR: 71

**Spillover index**: 59.8%

**Contributions Including own**
- UC1: 112
- UC2: 88
- UC3: 80
- UC4: 81
- FFR: 138

### Table 1b: Volatility Spillover from 1st GVAR Specification
**3-month RSD (1967:1-2008:12)**

<table>
<thead>
<tr>
<th>GIRF</th>
<th>UC1</th>
<th>UC2</th>
<th>UC3</th>
<th>UC4</th>
<th>FFR</th>
<th>Contributions from others</th>
</tr>
</thead>
<tbody>
<tr>
<td>UC1</td>
<td>28.7</td>
<td>19.8</td>
<td>15.3</td>
<td>14.2</td>
<td>22.0</td>
<td>71</td>
</tr>
<tr>
<td>UC2</td>
<td>22.9</td>
<td>23.4</td>
<td>21.6</td>
<td>20.9</td>
<td>11.4</td>
<td>77</td>
</tr>
<tr>
<td>UC3</td>
<td>19.6</td>
<td>23.5</td>
<td>24.8</td>
<td>24.8</td>
<td>7.3</td>
<td>75</td>
</tr>
<tr>
<td>UC4</td>
<td>19.0</td>
<td>23.3</td>
<td>25.3</td>
<td>25.7</td>
<td>6.7</td>
<td>74</td>
</tr>
<tr>
<td>FFR</td>
<td>24.2</td>
<td>8.1</td>
<td>3.8</td>
<td>3.0</td>
<td>60.9</td>
<td>39</td>
</tr>
</tbody>
</table>

**Contributions to Others**
- UC1: 86
- UC2: 75
- UC3: 66
- UC4: 63
- FFR: 47

**Spillover index**: 67.3%

**Contributions Including own**
- UC1: 114
- UC2: 98
- UC3: 91
- UC4: 89
- FFR: 108

A sizable portion (59.8%-67.3%) of the FEV in the system comes from spillovers

FFR contributes the most (outside its own) to the volatility of UC1 (41.3-GAS, 22.0-RSD)

A relatively low portion of FFR volatility is explained by volatility spillovers from UCs (33%/39%) but the vast majority of it comes from UC1 (26/24.2)

Overall suggesting more similar information content between FFR and the UC of narrower aggregate (UC1)
Volatility Spillover Estimates Model B: Fixed Parameters

Here again a sizable portion (55.9%-66.9%) of the FEV in the system comes from spillovers.

The largest share in the volatility of the FFR is explained by volatility in the user cost of demand deposits (at 26.8% and 16.9% for the GAS and RSD models, respectively).

Similarly, the largest share of the volatility in the user cost of demand deposits is explained by volatility in the FFR (30.1% GAS/24.4% RSD).

Overall suggesting the highest degree of (bi-directional) volatility spillover occur between the FFR and the UC of DD.
Volatility Spillover Estimates Model C: Fixed Parameters

Table 3: Volatility Spillover from 3rd GVAR Specification
GAS Estimated Conditional Volatilities (1974:8-2008:12)

<table>
<thead>
<tr>
<th>GIRF</th>
<th>IMM</th>
<th>LTD</th>
<th>REPO</th>
<th>CP</th>
<th>TB</th>
<th>FFR</th>
<th>Contributions from others</th>
</tr>
</thead>
<tbody>
<tr>
<td>IMM</td>
<td>67.8</td>
<td>0.3</td>
<td>8.7</td>
<td>9.7</td>
<td>7.6</td>
<td>5.8</td>
<td>32</td>
</tr>
<tr>
<td>LTD</td>
<td>8.7</td>
<td>32.3</td>
<td>10.6</td>
<td>26.0</td>
<td>12.2</td>
<td>10.2</td>
<td>68</td>
</tr>
<tr>
<td>REPO</td>
<td>18.0</td>
<td>4.1</td>
<td>28.8</td>
<td>16.2</td>
<td>25.1</td>
<td>7.8</td>
<td>71</td>
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<tr>
<td>CP</td>
<td>24.2</td>
<td>3.8</td>
<td>7.2</td>
<td>32.1</td>
<td>13.5</td>
<td>19.2</td>
<td>68</td>
</tr>
<tr>
<td>TB</td>
<td>19.8</td>
<td>2.2</td>
<td>16.8</td>
<td>20.5</td>
<td>26.8</td>
<td>14.6</td>
<td>73</td>
</tr>
<tr>
<td>FFR</td>
<td>24.2</td>
<td>2.3</td>
<td>0.4</td>
<td>2.3</td>
<td>0.2</td>
<td>70.7</td>
<td>29</td>
</tr>
</tbody>
</table>

Contributions to Others 95 13 43 75 59 58 Spillover index 56.9%
Contributions Including own 163 45 72 107 85 128

A negligible share of REPO & TB (less than 1% combined for GAS in Table 3 and less than 6.1% combined for the RSD model in Table 3b) explain FEV of FFR. And LTD and CP account for less than 5%/8% (GAS/RSD) of the FEV of FFR—IMM explain more but not as much as what DD explained in model B.

There's less evidence of bi-directional spillovers here.
REPO, CP & LTD explain little of FFR (0.4%, 2.3%, and 2.3%), whereas the FFR explain, more (7.8%, 19.2%, and 10.2%) of REPOs, CP, and LTD respectively.

Table 3b: Volatility Spillover from 3rd GVAR Specification
3-month RSD (1974:8-2008:12)

<table>
<thead>
<tr>
<th>GIRF</th>
<th>IMM</th>
<th>LTD</th>
<th>REPO</th>
<th>CP</th>
<th>TB</th>
<th>FFR</th>
<th>Contributions from others</th>
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<tbody>
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<td>IMM</td>
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<td>10.8</td>
<td>11.0</td>
<td>11.4</td>
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<tr>
<td>LTD</td>
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<td>30.0</td>
<td>16.3</td>
<td>21.5</td>
<td>17.7</td>
<td>7.2</td>
<td>70</td>
</tr>
<tr>
<td>REPO</td>
<td>7.2</td>
<td>13.6</td>
<td>29.2</td>
<td>18.0</td>
<td>26.6</td>
<td>5.3</td>
<td>71</td>
</tr>
<tr>
<td>CP</td>
<td>7.8</td>
<td>16.8</td>
<td>19.0</td>
<td>28.2</td>
<td>22.3</td>
<td>6.8</td>
<td>72</td>
</tr>
<tr>
<td>TB</td>
<td>6.7</td>
<td>13.4</td>
<td>24.4</td>
<td>19.6</td>
<td>29.6</td>
<td>6.3</td>
<td>70</td>
</tr>
<tr>
<td>FFR</td>
<td>12.1</td>
<td>1.9</td>
<td>2.6</td>
<td>6.1</td>
<td>3.5</td>
<td>74.0</td>
<td>26</td>
</tr>
</tbody>
</table>

Contributions to Others 41 53 73 76 81 34 Spillover index 59.9%
Contributions Including own 91 83 102 104 111 108

at 29% for GAS (26% for RSD), the directional volatility spillover from the user costs included in the VAR to the Federal Funds rate is much lower (less than half as much) than those spillovers from the user costs included in the previous VAR to the FFR.
Volatility Spillover Estimates: Fixed Parameters

**Summarizing:**

Volatilities in the FFR seem to *bi-directionally* spill over to the user cost of more liquid assets to a higher extent than to the user cost of less liquid assets.

This explains the seemingly closer co-movement between both the levels and the volatilities of the Federal Funds rate and the user cost of narrower monetary aggregates (which are comprised of more liquid assets).

Higher volatility in the FFR may lead to higher volatility in the user cost of more liquid assets first, with subsequent propagation to the user costs of less liquid assets.

In addition, the volatility of these less liquid assets do not seem to pass through to variations in the FFR, at least not as intensely. This is consistent with a large class of VAR models that impose short-run restrictions that connote delay reactions to movements in the Federal Funds rate when ordered last in a Choleski ordering.
Volatility Spillover Estimates: Time-Varying Parameters

These conclusions may be useful for characterizing aggregate behavior over the sample.

But these volatilities spillovers may have experienced important changes over time—as suggested by the level and volatility figures earlier.

A fixed-prmtr model may miss critical changes in the way these volatilities spill over across various rates.

So I re-estimate each GVAR using a 96-month rolling window and report rolling volatility indexes for GAS and RSD.
Volatility Spillovers From UCs $\rightarrow$ to FFR

1a Model II: Percent Spillover Contributed by User Costs TO FFR Volatility

1b Model II: Share of Volatility Spillover TO FFR Explained by the Other Shocks

1c Model III: Percent Spillover Contributed by User Costs TO FFR Volatility

1d Model III: Share of Volatility Spillover TO FFR Explained by the Other Shocks
Volatility Spillovers From FFR $\rightarrow$ to UCs

2a Model II: Percent FROM FFR Volatility Contributing to Volatility of each UC

2b Model II: Share of VAR Rolling Volatility Spillover Explained by the FFR Shock

2c Model III: Percent FROM FFR Volatility Contributing to Volatility of each UC

2d Model III: Share of VAR Rolling Volatility Spillover Explained by the FFR Shock
Multiple horizons

3a Model II: Share of Volatility Spillover TO FFR Explained by the Other Shocks

3c Model III: Share of Volatility Spillover TO FFR Explained by the Other Shocks

3b Model II: Share of VAR Rolling Volatility Spillover Explained by the FFR Shock

3d Model III: Share of VAR Rolling Volatility Spillover Explained by the FFR Shock
We may also be interested in the rate level pass-through

estimate two structural VARs that mirror models II and III with three important differences:

one, interest rate data is in levels

two, we invoke a Cholesky factorization in order to interpret disturbances in the Federal Funds rate as policy shocks.

three, we replace the effective Federal Funds rate with the Wu and Xia (2015) Shadow Federal Funds rate and re-estimate each specification for a longer sample that encompasses the ZIRP period.
Figure 4. Rolling Percent Spillover Contributions To/From Funds Rate Cholesky VAR Specification Model II (in levels)

DD account for the largest share of this spillover

Some attenuation of spillovers during ZLB period
Spillovers from UC to FFR are large and take place quickly.

Relatively speaking, spillovers in the other direction are somewhat lower.
While there is a very large spillover from the user costs to the Federal Funds rate...

...there are significantly lower spillovers from the Federal Funds rate to the user costs of these less liquid assets.
Figure 7. 3-D Rolling Percent Share of Spillover Index To/From Funds Rate Model III (in levels)
Conclusions

Even in the presence of strong assumptions in the literature, empirical evidence of a robust pass-through between the Federal Funds rate and other rates is, at best, mixed.

In contrast, this paper finds evidence of substantial pass-through among the Federal Funds rate and other interest rates.

Larger volatility spillover from the Federal Funds rate to the user cost of more liquid assets or narrower monetary aggregates.

Volatility in user costs of liquid assets also have a relatively large effect on the volatility of the Federal Funds rate.

These volatility spillovers between the Federal Funds rate and user costs propagates faster for more liquid assets.

There is also a substantial spillover in the levels of user costs and the Federal Funds rates.

A preponderance of evidence suggests a much tighter link between the user cost of more liquid assets and the Federal Funds rate.