Monetary Policy, Asset Prices, and Liquidity in Over-the-Counter Markets

Wisconsin School of Business
4th Annual Conference on Money, Banking, and Asset Markets

Athanasios Geromichalos
UC Davis

Lucas Herrenbrueck
UC Davis

April 22, 2013
Motivation

- One of the most traditional questions in monetary theory: the relationship between asset prices and monetary policy

- In the majority of papers assets trade in Walrasian markets

- Duffie, Gârleanu, and Pedersen (2005) argue that many assets are traded in OTC markets characterized by search and bargaining frictions

- We revisit the relationship between asset prices and monetary policy but allow assets to trade in OTC markets
How we do it...

We use a model in tradition of modern monetary theory (Lagos-Wright 2005)

- Money is the only liquid asset (medium of exchange)

- Real assets serve as a store of value, as is standard in finance

- Once a consumption opportunity arises, agents can visit a secondary asset market in order to rebalance their positions depending on liquidity needs

- The secondary asset market is frictional and resembles the OTC markets of Duffie-Gărleanu-Pedersen (2005)

- The primary asset market is competitive: allows us to compare our findings with existing literature
Main Findings

- For intermediate levels of inflation:
  - Assets can carry a liquidity premium even though they do not serve as MOE
  - This premium is increasing in inflation

- The effects of monetary policy on asset prices depend crucially on the organization of asset markets
  - Inflation typically increases the asset price in the primary market (asset and money are effectively substitutes)
  - The OTC asset price can increase or decrease with inflation, because factors such as bargaining and agents’ outside options play a crucial role

- The volume of trade in the OTC is hump-shaped in inflation
Contributions

• Extensions to the DGP framework

  ▶ We provide micro-foundations for the different asset valuations among agents, which is the driving force in all DGP based models

  ▶ In DGP, agents have access to unlimited funds. We bring money into the picture and create a link between monetary policy and OTC asset pricing

• In traditional asset pricing theory agents hold assets to maturity by default. Relaxing this assumption has important implications for asset pricing

• Integrate the alternative- and quite different- definitions of asset liquidity, in monetary theory and finance, answering the challenge of Lagos (2008)
Papers that study monetary policy and asset liquidity assume that assets have direct liquidity properties (media of exchange). This assumption is subject to criticism. Lagos (2011) argues that asset liquidity is relevant as long as assets help facilitate exchange (media of exchange, collateral, or re-pos). We show that assets have indirect liquidity properties even if they do not serve any of these roles. Hence, our paper enhances the findings of previous literature and shows that asset liquidity is relevant in even more general frameworks.
Related Literature A

Liquidity properties of assets other than fiat money have been explored by, among others:

- Lagos and Rocheteau (2008)
- Lester, Postlewaite, and Wright (2008)
- Lagos (2011)
- Jacquet and Tan (2010)
Related Literature B

Papers in which agents get an opportunity to rebalance their portfolios when a consumption opportunity arises:

- Kocherlakota (2003)
- Boel and Camera (2006)
- Berentsen, Camera, and Waller (2007)
- Berentsen and Waller (2011)
Papers in finance, addressing interesting questions regarding asset trade in markets with search frictions:

- Vayanos and Weill (2006)
- Lagos, Rocheteau, and Weill (2011)
- Chiu and Koepppl (2011)
The Model

- Infinite horizon, discrete time, discount factor is $\beta \in (0, 1)$ between periods

- Period divided in three sub-periods:
  - Centralized market (CM)
  - Secondary asset market (OTC)
  - Decentralized goods market (LW)

- Two types of agents depending on their role in LW market

- Buyers with measure 1 and preferences: $U(X) - H + u(q)$

- Sellers’ with preferences: $U(X) - H - q$

- $X$ is consumption in CM, $H$ is work in CM, and $q$ is quantity of special good consumed and produced in LW
Unique Feature of the Model

- After leaving CM buyers learn whether they will have a consumption opportunity in LW
  - Since only money can be used as a medium of exchange in LW
    - Buyers with a consumption opportunity visit OTC to sell assets for money
    - Buyers who do not have such opportunity visit OTC to provide liquidity
  - Gains from trade could arise even though the different agents have exactly the same valuation for the asset...

- ...because they have different needs for liquidity
First Sub-Period: Centralized Market (CM)

- Access to technology that turns one unit of labor into one unit of good
- Agents can buy any quantity of money and asset at ongoing prices $\varphi$, $\psi$
- Supply of money controlled by a monetary authority, follows rule
  \[ M_{t+1} = (1 + \mu)M_t \]
- Assets are 1-period real bonds. Their supply is $A$, fixed over time
  Each unit pays a dividend $d$
- Interesting decisions are made by buyers
- Sellers never carry money and are at best indifferent to holding any assets
Second Sub-Period: Secondary Asset Market (OTC)

- A measure \( \ell < 1 \) learns that they will consume in LW (C-types)  
  \( \Rightarrow \) They may want to rebalance their portfolios (obtain money)

- Buyers are ex ante identical, therefore the \( 1 - \ell \) buyers (N-types) have cash that they will not use in the current period

- Hence, potential gains from trade arise

- A CRS matching function \( f(\ell, 1 - \ell) \) brings the two sides together

- Terms of trade are determined through proportional bargaining

- C-type’s bargaining power is \( \lambda \in [0, 1] \)
Third Sub-Period: Decentralized Goods Market (LW)

- This is a standard LW decentralized market
- C-type buyers meet bilaterally with sellers
- For simplicity all $\ell$ buyers match
- Buyers make take-it-or-leave-it offers
Timing

Consumption
Shock

CM
- Consume X
- Work H
- Buy money
- Buy assets
- Receive dividend

OTC
- C types need liquidity
- N types provide liquidity
- N&C types meet bilaterally and bargain

LW
- C type buyers meet sellers
- Buyers make take or leave offers
- Buyers need to use cash

Figure: Timing of events.
Primary vs Secondary Asset Market

- Periodical access to Walrasian markets (and quasi-linear preferences) is a methodological innovation that gives rise to degenerate asset distributions

- However, in many cases, the issue prices of assets are indeed determined in a competitive setting

- But the assets are then traded in OTC markets, as documented by DGP

- W.R. Hambrecht & Co. persuaded Google to use an Internet-based auction for their IPO, now called an Open IPO
CM Value Function for Buyers

\[ W^B(m, a) = \max_{X, H, \hat{m}, \hat{a}} \left\{ U(X) - H + \mathbb{E}_i \left\{ \Omega^i(\hat{m}, \hat{a}) \right\} \right\} \]

s.t. \[ X + \varphi \hat{m} + \psi \hat{a} = H + \varphi (m + \mu M) + da \]

- Where \( \Omega^i \) is the OTC value function for type \( i \in \{C, N\} \)
- Recursive representation: variables with hats denote next period’s choices
- Three observations about value function:
  - At optimum, \( X = X^* \), where \( U'(X^*) = 1 \)
  - Choice of \( (\hat{m}, \hat{a}) \) does not depend on \( (m, a) \) (no wealth effects)
  - \( W^B \) is linear
- These observations imply

\[ W^B(m, a) = \varphi m + da + \Upsilon \]

\[ \Upsilon = U(X^*) - X^* + \mu M + \max_{\hat{m}, \hat{a}} \left\{ -\varphi \hat{m} - \psi \hat{a} + \mathbb{E}_i \left\{ \Omega^i(\hat{m}, \hat{a}) \right\} \right\} \]
CM Value Function for Sellers

- Sellers never leave the CM with any money or assets
- But they enter the CM with some money obtained in preceding LW
- Sellers’ CM value function is:
  \[ W^S(m) = \max_{X,H} \left\{ U(X) - H + V^S \right\} \]
  \[ \text{s.t. } X = H + \varphi m \]
- Hence, we can write
  \[ W^S(m) = \varphi m + U(X^*) - X^* + V^S \]
- \( V^S \) is seller’s value (function) in the LW sub-market
Consider a meeting in LW between a seller and a buyer with $m$ units of money. The bargaining problem is

$$\max_{p,q} \left\{ u(q) + \beta W^B(m - p, a) - \beta W^B(m, a) \right\}$$

subject to

$$-q + \beta W^S(p) - \beta W^S(0) \geq 0$$

and

$$p \leq m,$$

$p$ is the amount of dollars and $q$ the amount of special good exchanged.

Using the linearity of $W$, we obtain

$$\max_q \{ u(q) - q \} \quad \text{s.t.} \quad q \leq \phi m$$
Bargaining Solution in LW

Define

\[ q^* = \arg \max_q \{u(q) - q\} \]

\[ m^* = \frac{q^*}{\beta \hat{\phi}} \]

Then, the bargaining solution is given by

\[ p(m) = \begin{cases} m^*, & \text{if } m \geq m^*, \\ m, & \text{if } m < m^*. \end{cases} \]

\[ q(m) = \begin{cases} q^*, & \text{if } m \geq m^*, \\ \beta \hat{\phi} m, & \text{if } m < m^*. \end{cases} \]
LW Value Functions

In the LW market, the value functions are as follows:

- For a buyer

\[ V^B(m, a) = u[q(m)] + \beta W^B[m - p(m), a], \]

where \( q(m), p(m) \) are the solutions to bargaining problem defined above

- For a seller

\[ V^S = -q(m) + \beta W^S[p(m)], \]

where \( m \) is the money holdings of the buyer that this seller met
OTC Value Functions

In the OTC market, the value functions are given by

\[
\Omega^C(m, a) = a_c \ V^B(m + \chi \psi_I, a - \chi) + (1 - a_c) V^B(m, a),
\]

\[
\Omega^N(m, a) = a_N \ \beta W^B(m - \chi \psi_I, a + \chi) + (1 - a_N) \beta W^B(m, a),
\]

where

- \( \chi \) is the amount of assets that change hands from C-type to N-type
- \( \psi_I \) is the price (in dollars) per unit of asset exchanged
- \( \chi \) and \( \psi_I \) will be determined through bargaining
- Finally,

\[
a_c = \frac{f(\ell, 1 - \ell)}{\ell}, \quad a_N = \frac{f(\ell, 1 - \ell)}{1 - \ell}
\]
Bargaining Problem in OTC

Consider a meeting between C-type with \((m, a)\) and N-type with \((\tilde{m}, \tilde{a})\)

The bargaining problem is

\[
\max_{\chi, \psi_i} \left\{ V^B(m + \chi \psi_i, a - \chi) - V^B(m, a) \right\}
\]

Subject to:

- \( V^B(m + \chi \psi_i, a - \chi) - V^B(m, a) = \frac{\lambda}{1-\lambda} \left[ \beta W^B(\tilde{m} - \chi \psi_i, \tilde{a} + \chi) - \beta W^B(\tilde{m}, \tilde{a}) \right] \)
- \( \chi \in [-\tilde{a}, a] \)
- \( \chi \psi_i \in [-m, \tilde{m}] \)
Bargaining Problem in OTC (Cont’d)

After replacing for the value functions, we obtain

$$\max_{\chi, \psi_i} \{u[q(m + \chi \psi_i)] - u[q(m)] + \beta [\hat{\phi}_\chi \psi_i + \hat{\phi} p(m) - \hat{\phi} p(m + \chi \psi_i) - d\chi]\}$$

Subject to:

- $u[q(m + \chi \psi_i)] - u[q(m)] + \beta [\hat{\phi}_\chi \psi_i + \hat{\phi} p(m) - \hat{\phi} p(m + \chi \psi_i) - d\chi] = \frac{\lambda}{1-\lambda} \beta (d\chi - \hat{\phi}_\chi \psi_i)$
- $\chi \in [-\bar{\alpha}, \alpha]$
- $\chi \psi_i \in [-m, \tilde{m}]$

Solve the constraint with respect to $\beta d\chi$, we get the more intuitive:

$$\beta d\chi = \beta \hat{\phi}_\chi \psi_i + (1-\lambda) \{u[q(m + \chi \psi_i)] - u[q(m)] + \beta \hat{\phi} [p(m) - p(m + \chi \psi_i)]\}.$$
The bargaining solution depends only on \((m, \tilde{m}, a)\). Define the cutoff point
\[
\bar{a}(m, \tilde{m}) \equiv \begin{cases} 
\frac{1}{\beta d} \{ (1 - \lambda) \{ u[\beta \hat{\phi}(m + \tilde{m})] - u(\beta \hat{\phi}m) \} + \lambda \beta \hat{\phi} \tilde{m} \}, & \text{if } m + \tilde{m} < m^* \\
\frac{1}{\beta d} \{ (1 - \lambda) [ u(\beta \hat{\phi}m^*) - u(\beta \hat{\phi}m) ] + \lambda \beta \hat{\phi}(m^* - m) \}, & \text{if } m + \tilde{m} \geq m^* 
\end{cases}
\]
Then the solution is:
\[
\chi(m, \tilde{m}, a) = \begin{cases} 
\bar{a}(m, \tilde{m}), & \text{if } a \geq \bar{a}(m, \tilde{m}), \\
a, & \text{if } a < \bar{a}(m, \tilde{m}). 
\end{cases}
\]
\[
\psi_I(m, \tilde{m}, a) = \begin{cases} 
\frac{\min\{m^* - m, \tilde{m}\}}{\bar{a}(m, \tilde{m})}, & \text{if } a \geq \bar{a}(m, \tilde{m}), \\
\psi^a_I, & \text{if } a < \bar{a}(m, \tilde{m}), 
\end{cases}
\]
where \(\psi^a_I\) is implicitly defined by:
\[
(1 - \lambda) \{ u[\beta \hat{\phi}(m + a\psi^a_I)] - u(\beta \hat{\phi}m) \} + \lambda \beta \hat{\phi} a\psi^a_I = \beta da.
\]
Replace bargaining solutions into the CM value function to obtain objective function of the typical buyer:

\[
J(\hat{m}, \hat{a}) = -\varphi \hat{m} - \psi \hat{a}
\]

\[
\text{matched C-type} \rightarrow + f(\ell, 1 - \ell) \left\{ u \left[ \beta \hat{\varphi} (\hat{m} + \chi \psi_I) \right] + \beta d (\hat{a} - \chi) \right\}
\]

\[
\text{unmatched C-type} \rightarrow + [\ell - f(\ell, 1 - \ell)] [u (\beta \hat{\varphi} \hat{m}) + \beta d \hat{a}]
\]

\[
\text{matched N-type} \rightarrow + f(\ell, 1 - \ell) \left[ \beta \hat{\varphi} (\hat{m} - \tilde{\chi} \tilde{\psi}_I) + \beta d (\hat{a} + \tilde{\chi}) \right]
\]

\[
\text{unmatched N-type} \rightarrow + [1 - \ell - f(\ell, 1 - \ell)] (\beta \hat{\varphi} \hat{m} + \beta d \hat{a})
\]

It is understood that

- \(\chi = \chi(\hat{m}, \tilde{m}, \hat{a}), \psi_I = \psi_I(\hat{m}, \tilde{m}, \hat{a})\)
- \(\tilde{\chi} = \chi(\tilde{m}, \hat{m}, \tilde{a}), \text{ and } \tilde{\psi}_I = \psi_I(\tilde{m}, \hat{m}, \tilde{a})\)
- where \(\chi(\cdot)\) and \(\psi_I(\cdot)\) represent the OTC bargaining solutions
- \((\hat{m}, \hat{a})\) are choice variables and \((\tilde{m}, \tilde{a})\) are expectations
Optimal Choice of the Agent

The domain of the objective function can be divided into 5 regions, arising from three questions. Given prices and my beliefs about other agents’ holdings:

- When C-type and N-type pool their money in the OTC market, can they achieve the first-best in the LW market? (They would want to do that since the inflation cost is sunk at this point)

- Do I carry enough assets to compensate an N-type if I am a C-type?

- Do I expect a C-type to carry enough assets to compensate me for my money if I am an N-type?
The 5 relevant regions are:

1) \( \hat{m} \in (m^* - \tilde{m}, m^*) \) and \( \hat{a} > \bar{a}(\hat{m}, \tilde{m}) \)

2) \( \hat{m} < m^* - \tilde{m}, \hat{a} > \bar{a}(\hat{m}, \tilde{m}), \) but \( \tilde{a} < \bar{a}(\tilde{m}, \hat{m}) \)

3) \( \hat{m} < m^* - \tilde{m}, \hat{a} > \bar{a}(\hat{m}, \tilde{m}), \) and \( \tilde{a} > \bar{a}(\tilde{m}, \hat{m}) \)

4) \( \hat{m} < m^* - \tilde{m}, \hat{a} < \bar{a}(\hat{m}, \tilde{m}), \) but \( \tilde{a} > \bar{a}(\tilde{m}, \hat{m}) \)

5) \( \hat{a} < \bar{a}(\hat{m}, \tilde{m}), \) and either \( \tilde{a} < \bar{a}(\tilde{m}, \hat{m}) \) or \( \hat{m} \in (m^* - \tilde{m}, m^*) \)
Figure: Regions of individual choice, with expectations $\tilde{m} = 0.35m^*$ and $\tilde{a} = 0.5$. 
**Figure:** Regions of individual choice, with expectations $\hat{m} = 0.35m^*$ and $\hat{a} = 0.5$.
Sliced at $\hat{a}_1 = 0.3$ (red) and $\hat{a}_2 = 0.7$ (blue).
Figure: Money demand, with expectations $\tilde{m} = 0.35m^*$ and $\tilde{a} = 0.5$. 
Steady State Equilibrium

**DEFINITION:** A symmetric steady state equilibrium can be summarized by a list \( \{\psi, z, q_1, q_2\} \), where \( z = \varphi M \) represents real balances, where \( q_2 \) (\( q_1 \)) is the amount of special good exchanged in LW when the buyer was (not) matched in the preceding OTC, and such that:

- Agent behaves optimally
- \( q_1 = \beta z \)

\[
q_2(q_1) = \begin{cases} 
q^*, & \text{in Region 1}, \\
2q_1, & \text{in Region 3}, \\
\tilde{q}(q_1), & \text{in Region 5},
\end{cases}
\]

where \( \tilde{q} \) is defined by \( (1 - \lambda) [u(\tilde{q}) - u(q_1)] + \lambda (\tilde{q} - q_1) = \beta dA \)

- Markets clear and expectations are rational: \( m = \tilde{m} = (1 + \mu)M, \)
  \( a = \tilde{a} = A \)
Regions of Equilibrium (real balances on the $x$-axis)

**Figure**: Aggregate regions of real balances and asset holdings.
Regions of Equilibrium (money growth on the x-axis)

Figure: Aggregate regions of real balances and asset holdings.
Characterization of Equilibrium

**PROPOSITION:** Define $\bar{A} \equiv \frac{1}{\beta d} \left\{ (1 - \lambda) \left[ u(q^*) - u \left( \frac{q^*}{2} \right) \right] + \lambda \frac{q^*}{2} \right\}$.

**CASE 1:** If $A \geq \bar{A}$, then

- $\psi = \beta d$
- $\psi$ does not depend on monetary policy
- However, the OTC (real) asset price, $\varphi \psi_i$, is affected by inflation
- There are two opposing effects:
  - High inflation means the N-type wants to get rid of money (↑ price)
  - High inflation means the C-type carries few real balances ⇒ desperate for more ⇒ willing to accept a lower price for his asset
- $\partial[\varphi \psi_i]/\partial \mu > 0$ could go both ways
CASE 2: If \( A < \bar{A} \), then

- There exists a region of policies \([\mu'', \mu''']\), where \( \psi \) is indeterminate
- The price \( \psi \) satisfies:
  - For all \( \mu < \mu' \) or \( \mu > \mu''' \), \( \psi = \beta d \)
  - For all \( \mu \in (\mu', \mu'') \), \( \psi > \beta d \), and \( \psi \) is strictly increasing in \( \mu \)
  - For all \( \mu \in [\mu'', \mu'''] \), we have \( \psi \in [\beta d, \psi(\mu'')] \)
- We have \( \partial \mu' / \partial A > 0 \), \( \partial \mu'' / \partial A < 0 \), and \( \partial \mu''' / \partial A < 0 \)
- OTC asset price could increase or decrease in \( \mu \). Depends mainly on \( \lambda \)
- \( q \) is decreasing in \( \mu \), strictly for all \( \mu \) outside of \([\mu'', \mu''']\)
- Welfare is decreasing in \( \mu \), strictly for all \( \mu \) outside of \([\mu'', \mu''']\)
  - Except: it could also be flat in Region 1 (\( \mu < \mu' \)), if all C-types match
Equilibrium $\psi, \psi_1, q$ and Welfare as Functions of $\mu$ (high $A$)

Figure: CM asset price, OTC asset price, Real Balances ($\times \beta$), Production in LW
Equilibrium $\psi, \psi_1, q$ and Welfare as Functions of $\mu$ (low A)

Figure: CM asset price, OTC asset price, Real Balances ($\times \beta$), Production in LW
Equilibrium $\psi, \psi_1, q$ and Welfare as Functions of $\mu$ (lower A)

Figure: CM asset price, OTC asset price, Real Balances ($\times \beta$), Production in LW
Comparison to Related Literature

- We find that $\psi > \beta d$ and $\partial \psi / \partial \mu > 0$

- This result has also been pointed out by papers such as Geromichalos, Licari, and Suárez-Lledó (2007), Lester, Postlewaite, and Wright (2008), Lagos (2011), and Jacquet and Tan (2010)

- In these papers money and assets compete as MOE (substitutes)

- Here asset helps agents avoid inflation tax

- In our analysis these results hold only for intermediate levels of inflation
Equilibrium $\psi, \psi_1, q$ and Welfare as Functions of $\mu$ (low $\ell$, low $\lambda$)

Figure: CM asset price, OTC asset price, Real Balances ($\times \beta$), Production in LW
Trade volume

(a) Case $A > \bar{A}$

(b) Case $A < \bar{A}$

Figure: Volume of trade in the OTC market
Conclusion

- We revisit a traditional question in monetary theory: the link between inflation and asset prices.

- In our model, assets do not have direct liquidity properties. Nevertheless, in equilibrium, asset price can exceed fundamental.

- We offer a new perspective of looking at asset pricing, since our theory explicitly models the possibility of selling assets before maturity.

- The model integrates the two definitions of asset liquidity used in monetary theory and finance within a tractable model.

- We provide a micro-foundation for the assumption of different asset valuations among agents, adopted by DGP.