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

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Main Questions

- We revisit a traditional question in monetary economics: the relationship between asset prices and monetary policy

- Can assets carry a liquidity premium even when they do not serve as media of exchange?

- Does the effect of monetary policy on asset prices depend on the way trade is organized in asset markets? How?
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 over-the-counter (OTC) markets of Duffie-Garleanu-Pedersen (2005)
Main Findings

- Assets can carry a liquidity premium even when they do not serve as media of exchange

- 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
Contributions

- 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
Contributions (Cont’d)

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

- 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.

- Integrate the alternative- and quite different- definitions of asset liquidity, in monetary theory and finance, answering the challenge of Lagos (2008).
Related Literature A

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

- Lagos and Rocheteau (2008)
- Geromichalos, Licari, and Suarez-Lledo (2007)
- Lester, Postlewaite, and Wright (2008)
- Lagos (2011)
- Jacquet and Tan (2010)
Related Literature B

Papers that study asset-related puzzles, building on models of asset liquidity

- Lagos (2010)
  Equity-premium and risk-free rate puzzle

- Geromichalos and Simonovska (2012)
  Consumption/asset home bias and high turnover rate of foreign assets

- Jung (2012)
  International reserves held by emerging market countries
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 hold 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

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

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

- 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

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

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

\[ W^S(m) = \max_{X, H} \left\{ U(X) - H + V^S \right\} \]

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
Bargaining in LW

Consider a meeting in LW between a seller and a buyer with $m$ units of money. The bargaining problem is

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

s.t.  

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

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

$$\max_{q} \left\{ u(q) - q \right\} \quad \text{s.t.} \quad q \leq \beta \hat{\phi} m$$
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

\[ \Omega^C(m, a) = a_c \mathcal{V}^B (m + \chi \psi_I, a - \chi) + (1 - a_c) \mathcal{V}^B (m, a), \]
\[ \Omega^N(m, a) = a_n \beta \mathcal{W}^B (m - \chi \psi_I, a + \chi) + (1 - a_n) \beta \mathcal{W}^B (m, a), \]

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:

• \( V^B(m + \chi \psi_I, a - \chi) - V^B(m, a) = \)
  \[
  = \frac{\lambda}{1 - \lambda} \left[ \beta W^B(\tilde{m} - \chi \psi_I, \tilde{a} + \chi) - \beta W^B(\tilde{m}, \tilde{a}) \right]
  \]

• \( \chi \in [-\tilde{a}, a] \)

• \( \chi \psi_I \in [-m, \tilde{m}] \)
After replacing for the value functions, we obtain

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

Subject to:

- $$u[q(m + \chi \psi_i)] - u[q(m)] + \beta [\hat{\chi} \psi_i + \hat{\phi} p(m) - \hat{\phi} p(m + \chi \psi_i) - d\chi] = \frac{\lambda}{1-\lambda} \beta (d\chi - \hat{\chi} \psi_i)$$
- $$\chi \in [-\tilde{a}, a]$$
- $$\chi \psi_i \in [-m, \tilde{m}]$$
The bargaining solution depends only on \((m, \tilde{m}, a)\). Define the cutoff point
\[
\bar{a}(m, \tilde{m}) \equiv \begin{cases} 
\frac{1}{\beta d} \left\{ (1 - \lambda) \left\{ u \left[ \beta \hat{\phi}(m + \tilde{m}) \right] - u(\beta \hat{\phi} m) \right\} + \lambda \beta \hat{\phi} \tilde{m} \right\}, & \text{if } m + \tilde{m} < m^* \\
\frac{1}{\beta d} \left\{ (1 - \lambda) \left\{ u(\beta \hat{\phi} m^*) - u(\beta \hat{\phi} m) \right\} + \lambda \beta \hat{\phi} (m^* - m) \right\}, & \text{if } m + \tilde{m} \geq m^* 
\end{cases}
\]

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:
\[
(1 - \lambda) \left\{ u \left[ \beta \hat{\phi}(m + a\psi^a_i) \right] - u(\beta \hat{\phi} m) \right\} + \lambda \beta \hat{\phi} a\psi^a_i = \beta da.
\]
**Objective Function**

Replace bargaining solutions into the CM value function to obtain objective function of the typical buyer:

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

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

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

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

unmatched N-type \(\rightarrow\)  \[+ [1 - \ell - f(\ell, 1 - \ell)] \left[ \beta \hat{\varphi}(\hat{m} + \mu M) + \beta d\hat{a} \right].\]

It is understood that

- \(\chi = \chi(\hat{m} + \mu M, \tilde{m}, \hat{a}), \psi_I = \psi_I(\hat{m} + \mu M, \tilde{m}, \hat{a})\)
- \(\check{\chi} = \chi(\hat{m}, \hat{m} + \mu M, \tilde{a}), \text{ and } \check{\psi}_I = \psi_I(\tilde{m}, \hat{m} + \mu M, \tilde{a})\)
- 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 6 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?
Optimal Choice of the Agent (Cont’d)

The 6 relevant regions are:

1) $\hat{m} + \mu M > m^*$

2) $\hat{m} + \mu M \in (m^* - \tilde{m}, m^*)$ and $\hat{a} > \bar{a}(\hat{m} + \mu M, \tilde{m})$

3) $\hat{m} + \mu M < m^* - \tilde{m}$, $\hat{a} > \bar{a}(\hat{m} + \mu M, \tilde{m})$, but $\tilde{a} < \bar{a}(\tilde{m}, \hat{m} + \mu M)$

4) $\hat{m} + \mu M < m^* - \tilde{m}$, $\hat{a} > \bar{a}(\hat{m} + \mu M, \tilde{m})$, and $\tilde{a} > \bar{a}(\tilde{m}, \hat{m} + \mu M)$

5) $\hat{m} + \mu M < m^* - \tilde{m}$, $\hat{a} < \bar{a}(\hat{m} + \mu M, \tilde{m})$, but $\tilde{a} > \bar{a}(\tilde{m}, \hat{m} + \mu M)$

6) $\hat{a} < \bar{a}(\hat{m} + \mu M, \tilde{m})$, and either $\tilde{a} < \bar{a}(\tilde{m}, \hat{m} + \mu M)$ or $\hat{m} + \mu M \in (m^* - \tilde{m}, m^*)$
Figure: Regions of individual choice, with expectations $\beta \hat{\phi} \hat{m} = 0.35$ and $\beta d \ddot{a} = 0.4$. 

$\hat{a}$

$\beta \hat{\phi}(\hat{m} + \mu M)$

$q^* - \beta \hat{\phi} \hat{m}$

$q^*$
Figure: Regions of individual choice, with expectations $\beta \hat{\phi} \hat{m} = 0.35$ and $\beta d \hat{a} = 0.5$. Sliced at $\hat{a} = 0.3$ (red) and $\hat{a} = 0.7$ (blue).
Figure: FOC with respect to money, with expectations $\beta \hat{\phi} \hat{m} = 0.35$ and $\beta d\bar{a} = 0.5$. 

\[
\frac{1 + \mu}{\beta} = \frac{1}{1 + \mu} = \beta \hat{\phi} (\hat{m} + \mu M)
\]
Steady State Equilibrium

**DEFINITION:** A steady state equilibrium can be summarized by a list \( \{\psi, \varphi, q_1, q_2\} \), 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:

- \( \psi \) satisfies \( J_{\hat{a}}(\hat{m}, \hat{a}) = 0 \)
- \( \varphi \) satisfies \( J_{\hat{m}}(\hat{m}, \hat{a}) = 0 \)
- \( q_1 = \beta \varphi M \)
- \( q_2(q_1) = \begin{cases} q^*, & \text{in Regions 1 and 2,} \\ 2q_1, & \text{in Region 4,} \\ \tilde{q}(q_1), & \text{in Region 6,} \end{cases} \)

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: \( m = \bar{m} = M \), \( a = \bar{a} = A \)
Regions of Equilibrium

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 C-type’s money alone buys him little $q \Rightarrow$ more desperate for money ⇒ 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 $[\mu_i, \bar{\mu}_i]$, where $\psi$ is indeterminate
- The price $\psi$ satisfies:
  - For all $\mu > \bar{\mu}_i$, $\psi = \beta d$
  - For all $\mu < \mu_i$, $\psi > \beta d$, and $\psi$ is strictly increasing in $\mu$
  - For all $\mu \in [\mu_i, \bar{\mu}_i]$, we have $\psi \in [\beta d, \bar{\psi}]$
- We have $\partial \mu_i / \partial A < 0$
- OTC asset price could increase or decrease in $\mu$. Depends mainly on $\lambda$
- $q$ is decreasing in $\mu$, strictly for all $\mu$ outside of $[\mu_i, \bar{\mu}_i]$
- Welfare is decreasing in $\mu$, strictly for all $\mu$ outside of $[\mu_i, \bar{\mu}_i]$
  - But could also be flat in Region 2, if all C-types match
Equilibrium $\psi$, $\psi_1$, $q$ and Welfare as Functions of $\mu$

Figure: CM asset price, OTC asset price, Real Balances, Production in LW
Conclusion

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

- In a model where 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
Future Work

- Make the supply side of the asset non-trivial

- Test the unique empirical prediction of the model: as inflation rises the volume of trade in OTC increases

- Incorporate another important aspect of OTC markets, intermediaries
  ⇒ examine how inflation affects bid-ask spreads etc