Asset Prices in General Equilibrium with Recursive Utility and Illiquidity Induced by Transaction Costs

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Motivation

- Early work: effect of transactions costs on asset prices is small
  - Constantinides (1986), Vayanos (1998)

- More recent work: effect of transaction costs on asset prices is big
  - Jang, Koo, Liu, and Loewenstein (2007): stochastic investment opportunity set
  - Lynch and Tan (2011): idiosyncratic labor income

    "One important limitation of our analysis is that it is a partial equilibrium analysis. Therefore, it says nothing about how transaction costs affect equilibrium prices by limiting the ability of agents to share risk. More work is needed to understand how transaction costs affect prices and returns in a general equilibrium setting."

- Our objective is to fill this gap

Questions

1. What is the effect of transaction costs in general equilibrium on
    - Consumption and portfolio decisions?
    - Asset prices and risk premia?
    - Liquidity premium?

      LP $\equiv$ difference in expected returns of security without and with TC

2. How does stochastic labor income influence the above?

3. How sensitive are these answers to
    - whether the analysis is undertaken in general or partial equilibrium, and
    - to the particular functional form assumed for individual utility functions
        - recursive utility, power utility, exponential utility, log utility

To Answer These Questions We . . .

1. Construct a general-equilibrium model with
   - investors who have Epstein and Zin (1989) and Weil (1990) utility
   - investors who are heterogeneous with respect to their preferences
   - investors who have stochastic (idiosyncratic) labor income
   - financial markets with
     - a single-period discount bond, and
     - two risky stocks, of which "Stock 1" incurs a transaction cost

2. Develop a method to solve for this incomplete-markets model

3. Analyze the solution

Main Findings I

- The main effect of transaction costs is on portfolio turnover
  - Investors reduce substantially frequency with which they trade Stock 1
  - For 1% transaction cost, no trade in Stock 1 for about 85% of states; that is, endogenous illiquidity
- Because of less frequent rebalancing:
  - There is a decrease in risk sharing
  - Consumption of each investor is more highly correlated to endowment
  - The more risk tolerant investor reduces riskiness of her portfolio, while the more risk averse investor increases riskiness of her portfolio.

Main Findings II

- Asset prices respond to change in asset demands
- But, because
  - investors can optimize their trading decisions, and
  - the changes in demands of the two investors offset each other
- Impact of transaction costs
  - on prices is small, and
  - on volatility of stock returns is even smaller.

Main Findings III

- Liquidity premium in general equilibrium is small
  - With deterministic labor income,
    a 1% transaction cost leads to a liquidity premium of only: 0.07%
  - With stochastic labor income, this increases to only: 0.13%
- In partial-equilibrium, the liquidity premium is still only: 0.21%
- To get a liquidity premium that is of the same order of magnitude as the transaction cost, one has to assume
  - a partial-equilibrium setting,
  - cost function that allows consumption only out of financial income,
  - a very low ratio of financial wealth to labor income,
    (about 1, compared to its empirical value of about 5 for U.S. data).

Contribution

- Extend existing models with transactions costs to:
  - Dynamic general equilibrium setting with optimizing investors
  - Multiple heterogeneous agents with Epstein-Zin-Weil utility
  - Nontraded stochastic labor income
  - Multiple risky assets
  - Endogenous interest rate

- Develop method to identify equilibrium in this economy

  Acharya and Pedersen (2005, p. 379): "Perhaps the strongest assumption is that investors need to sell all their securities after one period (when they die). In a more general setting with endogenous holding periods, deriving a general equilibrium with time-varying liquidity is an onerous task."

- Show results in general equilibrium different from partial equilibrium

Outline

Related Literature: Models with Transaction Costs

1. General equilibrium with incomplete markets & transaction costs
    - Buss and Dumas (2013), Heaton and Lucas (1992)

2. Equilibrium models with exogenous interest rates & transaction costs
    - Vayanos (1998), Lo, Mamaysky, and Wang (2004), Acharya and Pedersen (2005),

3. Partial equilibrium models with transaction costs
    - Amihud and Mendelson (1986), Constantinides (1986), Jang, Koo, Liu, and Loewenstein (2007), Lynch and Tan (2011)

Related Literature: Models without Transaction Costs

1. Models with portfolio constraints but without transaction costs
   Basak and Cuoco (1998), Gromb and Vayanos (2002), Pavlova and Rigobon (2008), Garleânu and Pedersen (2011), Dumas and Lyasoff (2012), Chabakauri (2013)

2. Models with labor income but without transaction costs
   Lucas (1994), Telmer (1993), Krusell and Smith (1998), Mankiw (1986), Constantinides and Duffie (1996), Krueger and Lustig (2010)

3. Models with heterogeneous investors but complete financial markets
   Dumas (1989), Wang (1996), Dumas, Uppal, and Wang (2000), Dumas and Uppal (2001), Gollier and Zeckhauser (2005), Dumas, Kurshev, and Uppal (2009), Bhamra and Uppal (2009), Tran (2009), Benninga and Mayshar (2000), Weinbaum (2009), Longstaff and Wang (2012), Cvitanić and Malamud (2009a,b,c), Garleânu and Panageas (2008), Chan and Kogan (2002), Xiouros and Zapatero (2010) Bhamra and Uppal (2013)

4. Models with more than one "tree"
   Menzly, Santos, and Veronesi (2004), Cochrane, Longstaff, and Santa Clara (2008), Santos and Veronesi (2006), Pavlova and Rigobon (2007), Buraschi, Trojani, and Vedolin (2010), Martin (2011), Chen and Joslin (2012), Ehling and Heyerdahl-Larsen (2012)

Outline

The Model

Uncertainty

- Discrete time: $t = \{0, 1, \ldots, T\}$

- Uncertainty is generated by four processes:
  - Two dividend processes: $d(n, t)$
  - Two idiosyncratic labor income processes: $Y(k, t)$

- The set of states is finite, so the filtration is represented by a tree generated by these four stochastic processes.

The Model: Investors

- Two agents, each with recursive utility (Epstein and Zin (1989), Weil (1990))

$$V(k,t) = \left[(1-\beta_k)\, c(k,t)^{1-\frac{1}{\psi_k}} + \beta_k E_t \left[V(k,t+1)^{1-\gamma_k} \right]^{\frac{1}{\phi_k}} \right]^{\frac{\phi_k}{1-\gamma_k}}$$

- Allows for the separation of desire to smooth consumption across
  - states: risk-aversion ($\gamma_k > 0$)
  - time: elasticity of intertemporal substitution ($\psi_k > 0$)
- Investors need to choose
  - consumption: $c(k,t)$, and
  - number of bonds and shares: $\theta(n,k,t)$

The Model: Financial Markets

- One-period riskfree bond

- Two risky stocks (claims to dividends)

- Stock 1 incurs transaction cost, which is
  - Proportional to value of stock being traded
  - Assumed to be a deadweight cost; hence, does not flow to any agent
  - Gives rise to a no-trade region:
    - Agents only trade if their holdings lie outside the no-trade region
    - Agents may disagree on value of Stock 1 if it is not traded:
      $\underbrace{S(1,1,t)}_{\text{Agent 1's price}} \neq \underbrace{S(1,2,t)}_{\text{Agent 2's price}}$

Optimization Problem of the Agents

Maximize utility

$$V(k,t) = \sup_{c(k,t),\theta(n,k,t)} \left[(1-\beta_k)\, c(k,t)^{1-\frac{1}{\psi_k}} + \beta_k E_t \left[V(k,t+1)^{1-\gamma_k} \right]^{\frac{1}{\phi_k}} \right]^{\frac{\phi_k}{1-\gamma_k}}$$

subject to the dynamic budget constraint

$$\underbrace{c(k,t) + \sum_{n=0}^{2} \theta(n,k,t) S(n,k,t) + \overbrace{\sum_{n=0}^{2} \tau\big(\theta(n,k,t), \theta(n,k,t-1)\big)}^{\text{transaction costs}}}_{\text{uses of funds}}$$

$$\leq \underbrace{Y(k,t) + \sum_{n=0}^{2} \theta(n,k,t-1) \Big(S(n,k,t) + d(n,t) \Big)}_{\text{sources of funds}}$$

Equilibrium

1. Portfolio shares first-order conditions
   As in standard models, but now adjusted for transaction costs

2. Consumption first-order conditions

3. Budget constraint

4. Market-clearing conditions for bond and stocks

Solution Method: Existing Methods

1. "Cox-Huang trick:" Solving separately
   - first, for optimal allocation of consumption, and
   - then, for the portfolios,

   not possible because markets are incomplete

2. Global approach: solving the system of equations for all nodes simultaneously, is not feasible because
   - large number of equations
   - system depends on whether we are in no-trade region or not

3. Backward-forward approach
   - Investors optimization problems are backward
   - Prices are forward-looking variables
   - Iterate forward and backward until system converges

Solution Method: Backward-only Approach

- Two key challenges to developing a recursive solution method

  1. System of equations is backward-forward
     - **Solution**: Time-shift proposed by Dumas and Lyasoff (2012)
     - At date t, solve for current $\theta(n, k, t)$ and future $c(k, t + 1)$
     - This makes system backward-only

  2. No-trade region leads to endogenous change in optimality conditions
     - **Solution**: Exploit structure of proportional transactions costs
     - Derivative can take only the values $\{-1, 0, 1\} \times S \times \kappa$
     - Identify no-trade bounds and trading decision {sell, no-trade, buy}
     - Inside the no-trade region: set $\theta(n, k, t) = \theta(n, k, t - 1)$

- Details provided in Appendix of paper

Outline

Quantitative Analysis of Model: Parameter Values

Parameter	Symbol	Base case value	Range considered
Horizon			
Number of dates in the model (each period is one year)	T	10	10
Parameters of the utility functions			
Time discount factor for Investors 1 and 2	β	0.97	0.97
Elasticity of intertemporal substitution of Investor 1	ψ_1	1.04	1.04–1.50
Elasticity of intertemporal substitution of Investor 2	ψ_2	1.04	1.04–1.50
Relative risk aversion of Investor 1	γ_1	3.00	1.00–6.00
Relative risk aversion of Investor 2	γ_2	6.00	1.00–8.00
Parameters for both dividend processes			
Level of initial dividends		0.35	0.15–0.35
Drift of dividend processes	μ_1	0.05	0.05–0.10
Volatility of dividend processes	σ_1	0.20	0.20
Correlation between dividends of Stock 1 and 2	ρ	0.00	0.00
Parameters for both labor-income processes			
Level of initial labor incomes		0.65	0.65–0.85
Drift of labor income processes	$\overline{g}_1$	0.04	0.04
Volatility of labor income processes	$\sigma_{u,1}$	0.16	0.00–0.25

Equilibrium with Transaction Costs

Setup	GE21
RRA	$\gamma_{1,2} = 4$
TC	0%
Consumption volatility, Agent 1	0.0687
Consumption volatility, Agent 2	0.0687
Bond investment, Agent 1	0.0000
Stock 1 investment, Agent 1	0.5000
Stock 2 investment, Agent 1	0.5000
Turnover, Bond	0.0000
Turnover, Stock 1	0.0000
Turnover, Stock 2	0.0000
Risk-free rate	0.0634
Expected Return, Stock 1	0.0970
Expected Return, Stock 2	0.0970
Volatility, Stock 1	0.2382
Volatility, Stock 2	0.2382
Liquidity Premium	0.0000
Equity premium, Stock 1	0.0336

Equilibrium with Transaction Costs

Setup	GE21	GE22
RRA	$\gamma_{1,2} = 4$	$\gamma_{1,2} = 3, 6$
TC	0%	0%
Consumption volatility, Agent 1	0.0687	0.0914
Consumption volatility, Agent 2	0.0687	0.0461
Bond investment, Agent 1	0.0000	-0.7733
Stock 1 investment, Agent 1	0.5000	0.6682
Stock 2 investment, Agent 1	0.5000	0.6682
Turnover, Bond	0.0000	0.2352
Turnover, Stock 1	0.0000	0.0386
Turnover, Stock 2	0.0000	0.0386
Risk-free rate	0.0634	0.0635
Expected Return, Stock 1	0.0970	0.0970
Expected Return, Stock 2	0.0970	0.0970
Volatility, Stock 1	0.2382	0.2386
Volatility, Stock 2	0.2382	0.2386
Liquidity Premium	0.0000	0.0000
Equity premium, Stock 1	0.0336	0.0335

Equilibrium with Transaction Costs

Setup	GE21	GE22	GE23
RRA	$\gamma_{1,2} = 4$	$\gamma_{1,2} = 3, 6$	$\gamma_{1,2} = 3, 6$
TC	0%	0%	1%
Consumption volatility, Agent 1	0.0687	0.0914	0.0893
Consumption volatility, Agent 2	0.0687	0.0461	0.0480
Bond investment, Agent 1	0.0000	-0.7733	-0.6944
Stock 1 investment, Agent 1	0.5000	0.6682	0.6298
Stock 2 investment, Agent 1	0.5000	0.6682	0.6710
Turnover, Bond	0.0000	0.2352	0.2093
Turnover, Stock 1	0.0000	0.0386	0.0266
Turnover, Stock 2	0.0000	0.0386	0.0394
Risk-free rate	0.0634	0.0635	0.0641
Expected Return, Stock 1	0.0970	0.0970	0.0983
Expected Return, Stock 2	0.0970	0.0970	0.0976
Volatility, Stock 1	0.2382	0.2386	0.2383
Volatility, Stock 2	0.2382	0.2386	0.2388
Liquidity Premium	0.0000	0.0000	0.0007
Equity premium, Stock 1	0.0336	0.0335	0.0342

Equilibrium with Transaction Costs

Setup	GE21	GE22	GE23	GE24
RRA	$\gamma_{1,2} = 4$	$\gamma_{1,2} = 3, 6$	$\gamma_{1,2} = 3, 6$	$\gamma_{1,2} = 3, 6$
TC	0%	0%	1%	1% (refund)
Consumption volatility, Agent 1	0.0687	0.0914	0.0893	0.0894
Consumption volatility, Agent 2	0.0687	0.0461	0.0480	0.0481
Bond investment, Agent 1	0.0000	-0.7733	-0.6944	-0.6944
Stock 1 investment, Agent 1	0.5000	0.6682	0.6298	0.6298
Stock 2 investment, Agent 1	0.5000	0.6682	0.6710	0.6710
Turnover, Bond	0.0000	0.2352	0.2093	0.2093
Turnover, Stock 1	0.0000	0.0386	0.0266	0.0266
Turnover, Stock 2	0.0000	0.0386	0.0394	0.0395
Risk-free rate	0.0634	0.0635	0.0641	0.0634
Expected Return, Stock 1	0.0970	0.0970	0.0983	0.0976
Expected Return, Stock 2	0.0970	0.0970	0.0976	0.0969
Volatility, Stock 1	0.2382	0.2386	0.2383	0.2382
Volatility, Stock 2	0.2382	0.2386	0.2388	0.2386
Liquidity Premium	0.0000	0.0000	0.0007	0.0007
Equity premium, Stock 1	0.0336	0.0335	0.0342	0.0342

Equilibrium with Transaction Costs

Setup	GE21	GE22	GE23	GE24	PE/GE22
RRA	$\gamma_{1,2} = 4$	$\gamma_{1,2} = 3, 6$	$\gamma_{1,2} = 3, 6$	$\gamma_{1,2} = 3, 6$	$\gamma = 3$
TC	0%	0%	1%	1% (refund)	1%
Consumption volatility, Agent 1	0.0687	0.0914	0.0893	0.0894	0.0744
Consumption volatility, Agent 2	0.0687	0.0461	0.0480	0.0481	-
Bond investment, Agent 1	0.0000	-0.7733	-0.6944	-0.6944	-0.4733
Stock 1 investment, Agent 1	0.5000	0.6682	0.6298	0.6298	0.4442
Stock 2 investment, Agent 1	0.5000	0.6682	0.6710	0.6710	0.5197
Turnover, Bond	0.0000	0.2352	0.2093	0.2093	0.2611
Turnover, Stock 1	0.0000	0.0386	0.0266	0.0266	0.0271
Turnover, Stock 2	0.0000	0.0386	0.0394	0.0395	0.1001
Risk-free rate	0.0634	0.0635	0.0641	0.0634	0.0641
Expected Return, Stock 1	0.0970	0.0970	0.0983	0.0976	0.0972
Expected Return, Stock 2	0.0970	0.0970	0.0976	0.0969	0.0972
Volatility, Stock 1	0.2382	0.2386	0.2383	0.2382	0.2349
Volatility, Stock 2	0.2382	0.2386	0.2388	0.2386	0.2349
Liquidity Premium	0.0000	0.0000	0.0007	0.0007	0.0018
Equity premium, Stock 1	0.0336	0.0335	0.0342	0.0342	0.0331

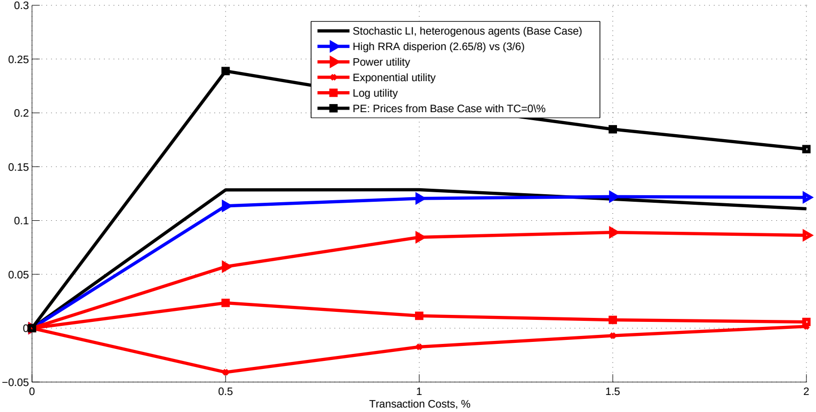
Equilibrium: Transaction Cost & Stochastic Labor Income

Setup	GE31	GE33	PE/GE32
RRA	$\gamma_{1,2} = 3, 6$	$\gamma_{1,2} = 3, 6$	$\gamma = 3$
TC	1%	1%	1%
Labor Income	Det	Stoch	Stoch
Consumption volatility, Agent 1	0.0893	0.1548	0.1468
Consumption volatility, Agent 2	0.0480	0.1029	-
Bond investment, Agent 1	-0.6944	-1.5876	-1.3618
Stock 1 investment, Agent 1	0.6298	0.7683	0.5434
Stock 2 investment, Agent 1	0.6710	0.8176	0.6611
Turnover, Bond	0.2093	0.5177	0.4855
Turnover, Stock 1	0.0266	0.0550	0.0412
Turnover, Stock 2	0.0394	0.0844	0.1383
Risk-free rate	0.0641	0.0109	0.0127
Expected Return, Stock 1	0.0983	0.0556	0.0553
Expected Return, Stock 2	0.0976	0.0543	0.0553
Volatility, Stock 1	0.2383	0.2198	0.2133
Volatility, Stock 2	0.2388	0.2196	0.2133
Liquidity Premium	0.0007	0.0013	0.0021
Equity premium, Stock 1	0.0342	0.0447	0.0426

Sensitivity of Liquidity Premium to Modeling Assumptions

Setup	GE	PE/GE	PE/GE	PE/GE
Modeling assumptions	Base case	Low WI ratio	Lynch-Tan TC Low WI ratio	Lynch-Tan TC Lower WI ratio
Consumption volatility, Agent 1	0.1548	0.1590	0.1504	0.1478
Consumption volatility, Agent 2	0.1029	-	-	-
Bond investment, Agent 1	-1.5876	-0.9918	0.0000	0.0000
Stock 1 investment, Agent 1	0.7683	0.5596	0.2797	0.0969
Stock 2 investment, Agent 1	0.8176	0.7800	0.4389	0.2692
Turnover, Bond	0.5177	0.3345	0.0000	0.0000
Turnover, Stock 1	0.0550	0.0329	0.0775	0.0519
Turnover, Stock 2	0.0844	0.1847	0.0595	0.0492
Risk-free rate	0.0109	-0.0101	-0.0101	-0.0101
Expected Return, Stock 1	0.0556	0.0224	0.0224	0.0224
Expected Return, Stock 2	0.0543	0.0224	0.0224	0.0224
Volatility, Stock 1	0.2198	0.2112	0.2112	0.2112
Volatility, Stock 2	0.2196	0.2112	0.2112	0.2112
Liquidity Premium	0.0013	0.0020	0.0022	**0.0048**
Equity premium, Stock 1	0.0447	0.0325	0.0325	0.0325

Liquidity Premium Relative to the Transaction Cost



Outline

Empirical Implications of the Model

- What would an econometrician find if she studied relation implied by our model between liquidity premium and observable quantities.
- The liquidity premium in our model depends on the desire to trade and the illiquidity induced by the presence of transaction costs.
- Desire to trade, or "dispersion in reservation prices," is not observable.
- We utilize our model to find quantities that can be used as instrumental variables for this.
- There are two groups of variables that one could use as instruments:
  1. Macro-variables, such as aggregate consumption, volatility of consumption, and consumption dispersion across investors;
  2. Financial variables, such as aggregate dividends, equity risk premium, volatility of stock returns, price-dividend ratio, etc.

Empirical Implications of the Model: Results

Coefficient	Regression 1	Regression 2	Regression 3
Intercept	0.0001	-0.0010	-0.0007
(p-value)	(0.0000)	(0.0000)	(0.0000)
Dispersion in reservation price of Stock 1	0.0595	—	—
(p-value)	(0.0000)		
Dispersion in reservation price of Stock 1 (Instr.)	—	0.1367	0.1150
(p-value)		(0.0000)	(0.0000)
R^2, %	34.45	38.11	62.59

- Regression 1: regress liquidity premium on "dispersion in reservation price of Stock 1"
- Regression 2: regress liquidity premium on instrumented value of dispersion in reservation price from three macroeconomic variables, namely, aggregate consumption, volatility of consumption growth, and consumption dispersion across investors, and one financial variable, "equity risk premium of Stock 1"
- Regression 3 we use the same set of instruments as in "Regression 2," but add add the "level of transaction costs."

Outline

Conclusion

- Transaction costs have a substantial effect on turnover of assets

- Consequently, investing in financial assets is more risky
  - Thus, there is drop in demand for bond and stock with transaction cost
  - Because change in net demand for assets is small, there is only a small effect on equity risk premia and stock-return volatility

- The change in demand for stock is reflected in the liquidity premium
  - A 100 bp transaction cost results in a liquidity premium of only 7 bp.
  - With stochastic labor income, liquidity premium increases to 13 bp.
  - In partial equilibrium, liquidity premium increases to 21 bp.
  - To get a larger liquidity premium, need to reduce ratio of financial wealth to labor income, and also change transaction-cost function.
  - Thus, insight of Constantinides (1986) & Vayanos (1998) is correct even with stochastic labor income, if evaluated in general-equilibrium.

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