A Liquidity-Based Theory of Closed-End Funds

Martin Cherkes[a], *Jacob Sagi*[b] *and Richard Stanton*[b*]

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ABSTRACT

This paper develops a rational, liquidity-based model of closed-end funds (CEFs) that provides an economic motivation for the existence of this organizational form: They offer a means for investors to buy illiquid securities, without facing the potential costs associated with direct trading and without the externalities imposed by an open-end fund structure. Our theory predicts the patterns observed in CEF IPO behavior and the observed behavior of the CEF discount, which results from a tradeoff between the liquidity benefits of investing in the CEF and the fees charged by the fund's managers. In particular, the model explains why IPOs occur in waves in certain sectors at a time, why funds are issued at a premium to net asset value (NAV), and why they later usually trade at a discount. We also conduct an empirical investigation, which, overall, provides more support for a liquidity-based model than for an alternative sentiment-based explanation.

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*[a]Princeton University; [b]Haas School of Business, U.C. Berkeley. We gratefully acknowledge helpful comments and suggestions from Michael Brennan, Joe Chen, Darrell Duffie, Wayne Ferson, Mike Fishman, Itay Goldstein, Martin Gruber, Joel Hasbrouck, Robert McDonald, Jeff Pontiff, Mark Rubinstein, Ronnie Sadka, Clemens Sialm, Matthew Spiegel, Phil Strahan, Marti Subrahmanyam, Russ Wermers, Youchang Wu, Josef Zechner and seminar participants at NYU, Northwestern, the University of Alberta, U.C. Berkeley, the University of Calgary, the 2005 Financial Research Association meeting, the 2006 Utah Winter Finance Conference and the 2006 Caesarea Center conference. We are grateful for financial support from the Fisher Center for Real Estate and Urban Economics. Corresponding author: Richard Stanton, Haas School of Business, 545 Student Services Building #1900, University of California, Berkeley, CA 94720-1900, or via email: stanton@haas.berkeley.edu.

1 Introduction

A closed-end fund (CEF) is a publicly traded firm that invests in securities. While investors can, in principle, trade either in the CEF's shares or directly in the underlying securities, a CEF rarely trades at a price equal to the value of the securities it holds (its Net Asset Value, or NAV). CEFs usually trade at a discount to NAV, though it is not uncommon for them to trade at a premium. The existence and behavior of this discount, usually referred to collectively as the "closed-end fund puzzle," poses one of the longest standing anomalies in finance: Why do CEFs generally trade at a discount, and why are investors willing to buy a fund at a premium at its IPO, knowing that it will shortly thereafter fall to a discount?

These considerations have led most authors to conclude that investor irrationality is the only possible explanation. For example, Lee et al. (1991) observe that "it seems necessary to introduce some type of irrational investor to be able to explain why anyone buys the fund shares at the start . . . ," Pontiff (1996) concludes that "Pricing theories that are based on fundamentals have had very little, if any, ability to explain discounts," and Chay and Trzcinka (1999) conclude that, "The investor sentiment hypothesis of the formation of closed-end funds appears to be the only plausible explanation for the initial public offering . . . ." This leads to a further, even more fundamental question: Do CEFs exist primarily to exploit investor irrationality, or is there another reason for their existence?

In this paper, we provide a simple economic explanation for the existence of CEFs, motivated by the observation that CEFs tend to hold illiquid securities, while their shares are relatively liquid. We model the existence of closed-end funds as an indirect means for small investors, facing high transaction costs, to invest in a basket of illiquid securities that would be prohibitively expensive to invest in directly. Investors who trade illiquid securities directly incur potentially large transaction costs. On the other hand, if investors buy or sell the relatively liquid shares of an exchange-traded CEF, the underlying illiquid assets do not change hands, and these large illiquidity costs are avoided.

The premium or discount at which the CEF trades emerges naturally from the tradeoff between these liquidity benefits and the fees charged by the fund's management, without needing to appeal to investor irrationality. In the absence of fees, the CEF will trade at a premium to NAV. With fees, the CEF may trade at either a discount or a premium, depending on the size of the fees relative to the liquidity benefit. Moreover, the discount will vary over time with the liquidity difference between the CEF shares and its underlying asset. Empirically, because at least a portion of liquidity is sector-specific, changes in the discount can be expected to be more correlated between funds of the same type, and less correlated between funds in different sectors (a pattern observed by Lee et al., 1991).

Our model not only provides a simple rational explanation for the discount on CEFs, but also makes predictions about their IPO behavior, and sheds light on the behavior of the discount at and after a fund's IPO. In the model, new funds come to market when the premium on existing CEFs (determined endogenously by the model) reaches a level where investors are indifferent between buying a seasoned fund at a premium, or paying a premium for the newly IPOed fund; this premium should be high enough to compensate for the underwriters' fees. Thus, IPO investors in our model pay the underwriters' fees not because they are irrational, but because they are interested in the services provided by a CEF, and these services are currently trading at a high price. The entry of a new CEF effectively decreases demand for the services of other CEFs in that sector, and thus puts downward pressure on the CEF premium, much as the entry of producers into a product market places downward pressure on commodity prices. An equilibrium is characterized by mean-reversion in the premium, and hence, consistent with empirical observation (see Lee et al., 1991; Sharpe and Sosin, 1975), investors buy the fund even though they expect that the premium will subsequently decline. The model also predicts that we should see IPOs occurring in waves in different sectors, since if the liquidity premium in a given sector is high for one fund contemplating coming to market, it tends to be high for other funds in the same sector.

A further contribution of this paper is the construction of a comprehensive data set that allows us to calibrate the model, reexamine previously documented stylized facts using substantially more data, and explore the extent to which the model is qualitatively and quantitatively consistent with reality, especially relative to alternative explanations such as the sentiment model of Lee et al. (1991). On balance, the data do not support the predictions of a sentiment-based model, but do support both the liquidity tradeoffs underlying our model, and its predictions for the behavior of CEF discounts. Specifically, we find that (i) the majority of closed-end funds specialize in illiquid securities such as municipal, corporate and international bonds while CEFs are, themselves, relatively liquid; (ii) consistent with the theory, the CEF premium is negatively related to the manager's fee and the degree of CEF share illiquidity, while it is positively related to the fund's payout and leverage, (iii) both the CEF premium and number of IPOs are related to systematic variables measuring the liquidity benefits provided by the fund; (iv) there is no consistent evidence that investor sentiment measures are positively related to the CEF premium or number of IPOs; (v) for realistic parameter values, the model is able to match the times-to-discount and average premia observed in the data.

Despite the success of the theory in accounting for most of the key stylized facts, there are some discrepancies. First, our model predicts that the returns on new CEFs will be comparable with those on seasoned CEFs managing similar assets. After controlling for leverage, we find (contrary to prior studies that do not control for leverage) that this is indeed the case for domestic and foreign equity funds. However, stock returns on newly issued muni and taxable fixed income CEFs tend to significantly under-perform those of matched seasoned CEFs. Another inconsistency is the fact that, while IPOs take place in waves when premia are high, and are somewhat correlated with measures of liquidity benefits (both as predicted by the model), the prevailing premium on seasoned funds during an IPO wave is typically lower than the cost of an IPO.

There are other CEF models in which investors earn a fair rate of return despite the predictable behavior of the discount. The closest is Berk and Stanton (2006), in which the behavior of the discount results from a tradeoff between managerial ability and fees, rather than our tradeoff between liquidity and fees.[1] Unlike ability-based models, our model can explain the patterns observed in CEF IPO behavior, and why discounts on related funds tend to move together. However, the models are complementary. Our explanation does not rule out the existence of managerial ability, and, in principle, we could include both features in a single model. Spiegel (1999) considers a frictionless overlapping generations economy in which agents have finite lives. His economy supports a self-fulfilling beliefs equilibrium in which zero-payoff portfolios sell for nonzero prices, implying that a CEF need not trade at its NAV. He does not, however, explicitly model IPOs or the time-series dynamics of the discount.

The paper is organized as follows: Section 2 gives basic facts about closed-end funds and the behavior of the discount. Section 3 motivates the model, discussing the interaction between liquidity and closed-end funds, and paying particular attention to evidence that supports a liquidity rationale for the services provided by CEFs. Section 4 develops a formal model that implements the ideas laid out in prior sections, and calibrates the model to the data. Section 5 conducts a detailed empirical investigation of the model, focusing in particular on tests that can distinguish the liquidity explanation from alternatives such as the sentiment theory of Lee et al. (1991). Section 6 concludes with a summary of our findings and provides a brief set of model-based policy recommendations that might mitigate the apparent overpricing of CEF IPOs, and yet preserve the role of this institutional structure in serving the liquidity needs of small investors.

[1] A related model is that of Ross (2002b). He also explains the post-IPO discount via a tradeoff between managerial ability and fees. However, unlike Berk and Stanton (2006), IPO investors in his model do not earn the fair rate of return.

2 Closed-End Funds and the Discount

The stylized facts reported in this section are based on closed-end fund data described in Appendix A. We separate the funds into five classes, based on their prospectus objectives: Municipal bond, taxable fixed income, domestic equity, foreign equity, and other funds. The taxable fixed income category includes funds whose assets mainly include corporate bonds, though some funds also manage government bonds, mortgages and international bonds. 'Other' funds manage convertible preferred stocks and other equity-related high income assets.

Table 1 shows CEF IPOs in the years 1986–2004. It can be seen that the new funds invest primarily in illiquid assets such as municipal bonds, corporate bonds, and foreign securities. Though not included in our sample, real estate – another illiquid asset class – also tends to be held by Real Estate Investment Trusts (REITs), which are similar to closed-end funds. The table also reports the total value of assets as of 2005. On a value-weighted basis, well over 50% of the CEFs are bond funds. Table 1 also makes it clear that IPOs occur in waves, a regularity documented in Lee et al. (1991). These waves occur at different times in different sectors. For example, IPOs of foreign equity funds peaked in 1990, a year in which there was only one taxable fixed income IPO (these peaked two years earlier and two years later, in 1988 and 1992). Similarly, there was a wave of muni and taxable fixed income IPOs between 1999 and 2004, yet during this period there were only four foreign equity CEF IPOs, all in 2003 and 2004.

Table 2 documents equally weighted averages of payout ratios, expense ratios, leverage ratios, underwriting costs, trading costs and NAV. The payout ratio, expense ratio and underwriting costs are defined as the percentage of NAV paid out to shareholders, managers and underwriters (in the event of an IPO), respectively. The payout ratio, while 6.2% on average, varies substantially across fund types, from 1.9% for foreign equity funds up to almost 9% for taxable fixed income funds. The expense ratio is more similar across fund types, though the standard deviations indicate that within types there is substantial variation across funds. It is clear that, across types (with the possible exception of foreign equity funds), CEFs make substantial use of leverage (usually in the form of issued preferred shares), despite the widespread impression that U.S. closed-end funds do not use leverage.[2] CEFs are in general small, averaging just over $250 million in assets. Across fund types, trading costs are not high, averaging under half a percent per share. The number of trades per day is comparable to that of mid and small capitalization stocks on the NYSE (see

[2]For example, Dimson and Minio-Paluello (2002) state that, "Although only a few U.S. closed-end funds take on any leverage, U.K. closed-end funds more frequently make use of leverage through their own capital structures."

Year		Muni	Taxable FI	Dom. Equity	For. Equity	Other	Total
1986		1	1	5	3		10
1987		7	8	5	7		27
1988		11	25		5	3	44
1989		15	9	1	5	2	32
1990		7	3		17	1	28
1991		30	3		2	1	36
1992		57	15	3	9	2	86
1993		63	28	2	6	3	102
1994		4	8	5	15	1	33
1995			1		1		2
1996				2	1		3
1997		4	1		1		6
1998		7	8			4	19
1999		27	1				28
2000				1			1
2001		31	3			2	36
2002		57	5			11	73
2003		8	18	6	1	16	49
2004			11	18	3	11	43
Total		329	148	48	76	57	658
2005 NAV ($B)		63	53	33	13	28	190
FundAge	median	5.6	8.6	10.2	6.9	3.8	6.7
	sd	4.3	8.4	24.0	6.6	5.7	10.2

Table 1: **CEF IPOs.** This table documents the number of CEF IPOs in various sectors from 1986–2004, using data described in Appendix A.

Chordia et al., 2005).

		Muni	Taxable FI	Dom. Equity	For. Equity	Other	All
		N = 332	N = 187	N = 65	N = 81	N = 60	N = 725
a. Balance sheet or income statement attributes							
PayRatio	mean	5.9	8.8	5.1	1.9	7.4	6.2
	sd	1.3	7.2	11.6	10.0	4.7	6.8
ExpRatio	mean	1.1	1.2	1.5	1.8	1.5	1.3
	sd	0.7	0.5	1.5	0.7	0.9	0.8
Leverage	mean	31%	22%	16%	8%	30%	25%
	sd	13%	15%	15%	9%	10%	15%
IPO costs	mean	5.6	5.9	5.9	6.5	4.8	5.7
	sd	1.0	1.1	1.2	0.7	0.9	1.1
NAV	mean	219	282	489	173	324	257
	sd	231	325	597	182	330	314
b. Market attributes							
Trading Cost	mean	0.40%	0.54%	0.51%	0.68%	0.52%	0.49%
	sd	0.18%	0.26%	0.30%	0.52%	0.27%	0.29%
Daily Trades	mean	18	63	64	42	76	42
	sd	25	107	61	36	76	70
Premium	mean	-3.4	-2.6	-6.2	-7.9	-3.6	-4.0
	sd	6.5	9.1	11.9	16.1	8.3	9.9
Tdisc	mean	1.01	1	0.78	1.08	0.74	0.97
	sd	1.22	1.31	1.26	2.15	0.87	1.35
c. Correlations with average premium in sector:							
Muni		0.558	0.336	0.078	0.160	0.256	
Taxable FI		0.308	0.509	0.284	0.170	0.522	
Dom. Equity		0.149	0.287	0.458	0.203	0.374	
For. Equity		0.185	0.126	0.144	0.490	0.023	
Other		0.280	0.355	0.223	0.246	0.663	

Table 2: **CEF statistics.** This table reports panel statistics for different sectors of CEFs.

2.1 The Premium/Discount

The CEF premium is defined by

$$\frac{P_t - \mathrm{NAV}_t}{\mathrm{NAV}_t}, \tag{1}$$

where P_t is the price of one share of the CEF, and NAV_t is the net asset value (NAV) per share. Many researchers refer instead to the CEF *discount*, which is the negative of the premium.

The "closed-end fund puzzle" primarily concerns the predictable behavior of the discount over time: Although closed-end funds are issued at a premium commensurate with their underwriting costs, they typically fall to a discount shortly thereafter. Table 2 documents the equally weighted average time-to-discount for each fund type in our sample, calculated according to the procedure described in Appendix A. It is clear from this table that, although rapid, the speed with which CEFs drop from their initial premium to a discount following their IPO is slower than the 120 days noted by Weiss (1989) in her small sample of (equity) CEFs (see also Levis and Thomas, 1995). In our much larger sample, the fall to a discount takes, on average, closer to one year.

Panel c. of Table 2 shows the average correlation between the premium on funds of each type (rows) and the average sector premia (columns). All correlations are positive, but it can be clearly seen that, for each fund type, the correlation between a fund's premium and the average premium in its own sector is higher than the correlation between the fund's premium and the average premium in different sectors.

Finally, Figure 1 shows, for each sector, the six-month equally weighted moving average of the number of IPOs per month plotted against the average premium. It can be seen that, in general, IPOs occur at times when existing funds of the same type are trading well above their average premium, as noted by Lee et al. (1991).

3 Liquidity and closed-end funds

In this section, we begin by arguing that costs arising from the mechanics of trade are key to understanding the liquidity service offered by CEFs. We then go on to survey the advantages that CEFs provide to their intended investors, both in absolute terms, and in relation to OEFs and ETFs.

3.1 Sources of illiquidity

There is a huge literature on liquidity, and its links to market frictions, asset prices, and returns.[3] While there is not unanimous agreement on exactly what liquidity is, or how to measure it, most would agree with O'Hara (2004), who defines a liquid market as "... one in which buyers and sellers can trade into and out of positions quickly and without having large price effects." The overwhelming conclusion of this literature is that expected returns are positively related to illiquidity, regardless of the exact definition used.

In a frictionless setting, an asset's fair market value is obtained by discounting its cash flows for their exposure to systematic risk variables. In the presence of market frictions,

[3]For a comprehensive survey of this literature, see Amihud et al. (2005).

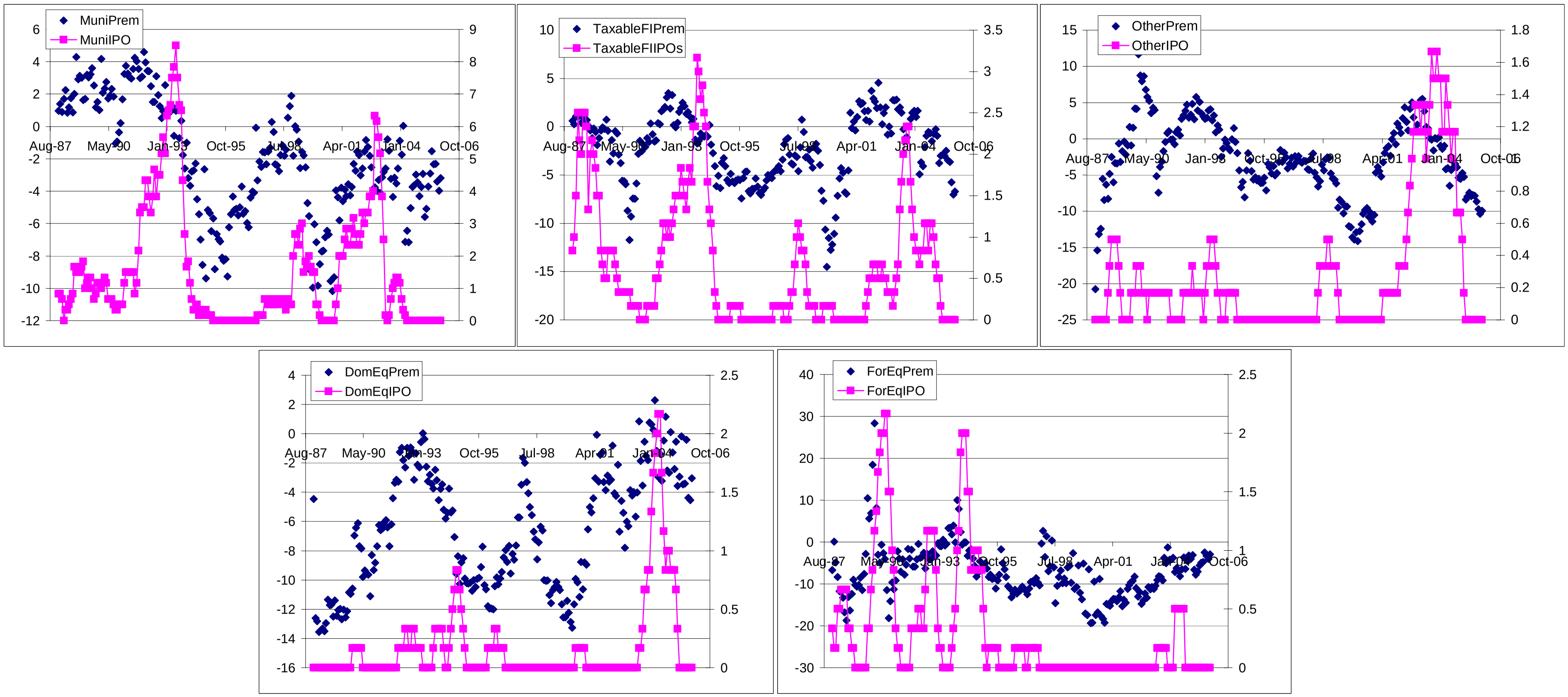

Figure 1: **IPOs vs. premium**. The unconnected blue diamonds show the average premium for each sector, and the connected red squares show the six-month moving average of the number of IPOs each month.

additional discounting, or illiquidity, may be rationalized as compensation for asymmetric information or clearing costs.[4] Although we do not preclude asymmetric information as a reason for pooling assets within a CEF, the focus in comparing closed-end funds to other investment alternatives ought to be on the clearing component of liquidity costs. This is because CEFs have no apparent advantage over OEFs or ETFs in reducing asymmetric information through the pooling of assets. Moreover, it is unlikely that asymmetric information plays an important role in the cost of trading federal, municipal, and foreign government bonds. As indicated in Table 1, funds specializing in these sectors dominate the CEF universe in terms of market value. At the same time, there is much empirical evidence documenting clearing costs associated with assets frequently held by CEFs. For example, Longstaff (2004) compares Treasury securities with bonds issued by a government agency (Refcorp) that are both backed by Treasury securities and guaranteed by the government. He finds that the (more liquid) Treasury securities trade at a significant premium. Similarly, Dimson and Hanke (2004) compare prices and returns on an equity index with those on a set of equity index-linked bonds that provide the same payoff, and find that the (less liquid) bonds sell at a discount relative to the index. Green et al. (2004) find that bid-ask spreads for small trades in municipal bonds are much larger than for large trades, the exact opposite of what we would expect if the spreads in this market were primarily driven by asymmetric information, but consistent with the idea that market makers can exploit their market power relative to small, but not large, investors.[5] The fact that so much of these assets' illiquidity is driven purely by the trading mechanism, rather than asymmetric information, lends supports to the idea that these costs could be reduced merely by changing the trading mechanism.[6]

3.2 The liquidity benefits provided by closed-end funds

To understand whether CEFs provide a liquidity service to their shareholders, one must first identify who holds CEF shares. Empirical evidence indicates that a large proportion of CEF shares are owned by small investors. Weiss (1989) reports that, in her sample of CEFs, an

[4]For a discussion of asymmetric information and illiquidity, see Glaeser and Kallal (1997), DeMarzo (2005), and Eisfeldt (2004). The term 'clearing costs' refers to a spread between the buying and selling price of an asset that cannot be arbitraged away, and arises for reasons other than informational asymmetry (see, for example, Duffie et al. (2005)).

[5]Harris and Piwowar (2006) have similar results. See Edwards et al. (2006) for evidence on corporate bonds.

[6]There are other examples where changing the trading mechanism for an asset can significantly affect its liquidity. For example, O'Hara (2004) comments that "...the introduction of EBay has transformed the trading of hitherto illiquid assets (such as antique clocks) by providing a venue for buyers and sellers to meet electronically. This new microstructure has thus enhanced the liquidity of the market, and with it the desirability of holding these assets."

average of only 3.5% of the funds' equity was held by institutions one quarter after the IPO, compared with 21.82% for her control sample of similar size (non-CEF) IPOs. Over the next three quarters, the difference became even larger; the fraction of CEFs held by institutions stayed roughly constant, whereas the fraction of the control group held by institutions rose by about 7%. Lee et al. (1991) report similar results, and also report that, in 1987, 64% of all CEF trades were less than $10,000 in size (compared with 79% for the smallest decile of NYSE stocks, and 28% for the largest decile of NYSE stocks).

Illiquidity costs associated with trading the assets in which CEFs specialize (see Table 1) are particularly severe for small investors—the largest clientele of CEFs. Green et al. (2004) provide compelling evidence that municipal bond intermediaries impose a (one-way) mark-up on small trades (those below $100,000) averaging 2.5%. Moreover, mark ups of 5% are not unusual. This is to be compared with a far smaller mark-up for institutional sized trades (over $500,000) averaging *minus* nine basis points, and rarely above 1%.[7] A small investor with a horizon of one year would thus face annual trading costs averaging 5% higher than those faced by an institutional investor such as a CEF. According to Table 2, the one-way cost for municipal funds averaged 0.4% over the period studied. An individual investor with horizon < 5 years could potentially gain substantially by purchasing municipal bonds indirectly, through a CEF. Table 2 also reports the average number of daily trades per fund by type. To compare with trades in the underlying assets, consider that Edwards et al. (2006) find that corporate bonds trade an average of 1.9 times per day, whereas the average taxable fixed income CEF in our sample trades 67 times per day.[8]

Beside the direct savings in trading costs, an additional important advantage to the CEF structure is the use of leverage. The Investment Company Act of 1940 allows CEFs to lever up to 100% of shareholders' assets (this is usually done through the issuance of preferred shares). Because institutions typically enjoy lower financing costs than individuals, it is less costly for a CEF to hold a levered portfolio than it is for a small investor. In addition, the fund's shareholders enjoy the protection of limited liability, a right that does not extend to an individual who attempts to replicate the fund's portfolio. Thus, the ability of a CEF to cheaply and efficiently construct a levered portfolio represents an additional liquidity (i.e., cost saving) benefit to its investors.

CEFs vs. OEFs Deli and Varma (2002) test the relation between liquidity and fund

[7] Green et al. (2004) argue within a structural model that intermediaries compete over larger trades, while competition for smaller trades is rare. Harris and Piwowar (2006) corroborate this, while Edwards et al. (2006) report qualitatively similar results for corporate bonds.

[8] In the one-year sample of municipal bond trades studied by Harris and Piwowar (2006), the average municipal bond traded less than once per *week*.

type statistically, and find that, for both equity and bond funds, the more illiquid a fund's investments, the more likely is the fund to be a CEF rather than an OEF. This is consistent with the idea that CEFs provide substantial liquidity benefits over OEFs, and that the benefits are larger for more illiquid securities. Additional empirical evidence on this is provided by Cherkes (2003), who compares the holdings of muni CEFs vs. OEFs. He finds that CEFs have a smaller turnover ratio, consistent with lower trading volume in illiquid securities. Indeed, there are at least two disadvantages to investing in assets with high clearing costs through an OEF, rather than a CEF. First, fund flows force the sale or purchase of OEF underlying assets, and this imposes direct and indirect costs on OEF investors. Second, OEFs face legal limitations on their holdings and capital structure. We now elaborate on these two points.

Unlike investing either directly or in an OEF, when an investor in a CEF sells his or her position, CEF shares are transferred from one investor to another, but the underlying assets do not change hands—they remain owned by the fund. As noted in Fama and Jensen (1983), this differs from buying or selling shares in OEFs, where net in/outflows from the fund may result in inefficient and costly purchases/sales of the underlying assets. Edelen (1999), in a random sample of equity OEFs, estimates the direct liquidity costs from forced transactions to average 1.5–2% annually. Presumably, these costs would be even higher for OEFs that specialize in illiquid securities. In addition to these direct liquidity costs, there are also indirect costs. Among these, Chordia (1996) lists adverse selection costs of trading, brokerage and operating expenses, and unexpected capital gains or losses. He also notes that OEF managers may need to maintain a cash position larger than they would otherwise desire in order to mitigate the impact of redemptions. The presence of such externalities, anticipated by OEF investors, creates the potential for a fund-run, the risk growing with the illiquidity of the underlying assets and the liquidity needs of investors.[9] A CEF, on the other hand, can never experience a 'bank run' on its assets. Chordia (1996) and Nanda et al. (2000) suggest that the direct and indirect costs arising from OEF flows can be reduced by imposing loads. However, this increases the illiquidity of the fund shares, undermining their ability to provide liquidity benefits to short-horizon investors. If the costs resulting from fund flows are sufficiently acute, an efficient solution, and the one offered by the market, is to organize the investment company as a CEF instead of an OEF.

OEFs face both legal and self-imposed restrictions on borrowing, trading on margin, short selling, derivative trading, and trade in certain illiquid securities such as privately

[9]This is analogous to a bank-run (see Diamond and Dybvig, 1983). As a specific example of such a fund-run, more than $32 billion of assets managed by Putnam were redeemed in a single month (see WSJ, 12/8/03).

placed issues (see Almazan et al., 2004). No doubt, the presence of restrictions is related to the vulnerability of OEFs to the vagaries of fund flows, and thus correspond to the negative externalities that fund flows impose. By contrast, CEFs are relatively exempt from these restrictions. The substantial leverage used by CEFs (see Table 2) is evidence that the added flexibility afforded by this organizational form is consequential.

CEFs and ETFs Some readers may wonder whether an exchange-traded fund (ETF) might serve the liquidity needs of small investors without the possibility of trading at a discount to NAV.[10] An ETF must trade at or very near its NAV. To see this, note that an ETF that trades above its NAV can be forced to issue new shares by large investors, who will purchase the shares using the cheaper underlying securities. The new shares can then be sold in the secondary market for an arbitrage profit. Alternatively, an ETF that trades at a discount relative to NAV can have its shares bought by arbitrageurs who subsequently force the ETF to redeem the shares for the underlying basket of securities. The securities thus obtained can then be sold at a higher price.[11]

What is the drawback of setting up an ETF to invest in illiquid securities? Arguably, the ETF provides small investors with liquid access to the underlying securities, as well as 'protection' from discounts. Such a benefit, though, cannot come without a cost to some stake holder, and, in the case of ETFs, the manager pays the cost. Specifically, consider an ETF of illiquid assets whose price is pegged at 100% of NAV. Suppose, moreover, that the manager charges an annual fee of 1% to manage the fund. Now, no large or mid-size investor would agree to hold shares in such a fund for long. The reason is that any share can be redeemed for its underlying portfolio, and the cash flows from this portfolio would not be subject to the manager's fee. Moreover, there are no 'liquidity costs' to holding the underlying portfolio, since the large investor can always force the manager to accept the portfolio in return for liquid ETF shares which could then be sold in the secondary market. Worse yet, any mid-size investor who might normally incur hefty transaction costs when purchasing a well-diversified portfolio of illiquid assets could attain these assets at lower cost by purchasing the ETF shares and then redeeming them. For instance, a well-diversified portfolio of municipal bonds worth $5 million might contain 50 bonds ($100k of each issue). As indicated in Green et al. (2004), purchasing or selling such quantities may entail large

[10] An ETF is functionally similar to a CEF with essentially two major differences: Investors can redeem their shares for the underlying portfolio of assets at any time, and investors also have the right to purchase (directly from the fund company) large blocks of newly issued ETF shares with a basket of securities that mirrors that ETF's portfolio.

[11] It is much more difficult for an arbitrageur to force liquidation of a CEF's underlying securities (see Bradley et al., 2005). Holding the CEF's shares is also unattractive to arbitrageurs, since they earn higher returns by investing in the underlying securities directly (see Table 2 in Wermers et al., 2005).

costs. An institutional investor wishing to hold this portfolio would use the ETF as a cheap liquidity supplier, purchasing ETF shares on the open market and then forcing redemption.

In summary, an ETF of highly illiquid securities will attract *only* small investors and, in addition, provide an uncompensated liquidity service to other market participants. Since it is to be expected that such service requires effort by the manager, it is not in their interest to manage such funds. For any size ETF, the manager would be better off managing the same size CEF (thereby 'keeping out' market participants who do not hold CEF shares but use them to provide liquid access to and from the underlying assets).

These observations are supported in practice. Indeed, ETFs almost universally hold very liquid portfolios, as noted by Gastineau (2001) (page 92):

> *To date, all ETFs are based on equities, and with the exception of a hiccup affecting the Malaysian WEBS the underlying markets have a high degree of liquidity .... We expect underlying market liquidity to be a universal characteristic of exchange-traded funds going forward.*
>
> *Any time you are dealing with a large-scale creation or redemption of shares, whether in cash or in-kind, the underlying market must be highly liquid under most circumstances .... Wide spreads and illiquidity are inimical to the use of a market as an underlying source of exchange-traded fund portfolios.*

4 The Model

The discussion in the preceding sections builds a persuasive case that CEFs can provide small investors with relatively liquid access to what otherwise would be illiquid assets, and that this can explain the existence of both discounts and premia on CEFs. Whether this explanation can generate the magnitude of observed discounts and premia, or their dynamics over time, is a question that can only be answered with a formal model.

The model we develop is based on a tradeoff between the liquidity benefits of a CEF, described earlier, and the fees charged by management. The intuition is simple: Investors can choose to buy illiquid assets directly, incurring costs if they unexpectedly have to leave the market and sell their holdings. Alternatively, they may buy indirectly via a closed-end fund. In the latter case, they can always sell their CEF shares to another investor without the underlying assets needing to be sold, thus avoiding the illiquidity costs. In the absence of fees, they will be willing to pay more for the CEF shares than they would pay for the underlying assets purchased directly. Whether the fund trades overall at a discount or a premium to its NAV depends on whether or not these liquidity benefits outweigh the fees paid to the managers of the fund.

The more investors are willing to pay for the liquidity service of a CEF, the more attractive it is to pool assets under this structure. Since underwriting a CEF is costly, CEFs will only enter when other similar CEFs trade at a premium to NAV. In order to model the dynamics of the IPO process, we allow the liquidity premium to vary over time and posit a negative relation between the liquidity premium and the proportion of the total supply of the illiquid assets that is held by CEFs. The IPO process in equilibrium has important implications for the behavior of the liquidity premium on the underlying asset. As soon as the liquidity premium reaches a particular value (determined endogenously in equilibrium), new funds enter the market via an IPO, putting downward pressure on the liquidity premium by attracting the marginal investors in the illiquid security. The equilibrium effect of these IPOs by new funds is to impose an upper reflecting boundary on the liquidity premium process (which also determines how often CEFs trade at a large discount, rather than at a large premium).[12]

4.1 CEFs, Liquidity, and Equilibrium

Assume an illiquid asset pays a continuous dividend at rate C_t, which follows the (risk-adjusted) process:

$$\frac{dC_t}{C_t} = g\,dt + \sigma_C\,dZ_t.$$

Assume also that the asset earns a liquidity premium, ρ_t, which is uncorrelated with the growth rate of dividends.

The net asset value of a fund at time t, NAV_t, is equal to the expected value of all future gross dividends, discounted at the risk-free rate plus the liquidity premium, i.e.

$$\text{NAV}_t = E_t\Big[\int_t^\infty C_{t'} e^{-\int_t^{t'}(r+\rho_{t''})dt''}dt'\Big], \tag{2}$$

$$= C_t\,E_t\Big[\int_t^\infty e^{-\int_t^{t'}(r-g+\rho_{t''})dt''}dt'\Big], \tag{3}$$

where the second equality is a result of our assumption that changes in the liquidity premium are uncorrelated with shocks to C_t.

In assessing the market value of the fund, P_t, and its potential deviation from the NAV, we will make use of the following assumptions:

1. Unlike the underlying assets, the CEF is perfectly liquid, so shareholders do not require

[12] The economic story described is reminiscent of Dixit (1989) and agrees with the intuition in Gemmill and Thomas (2002), who state (page 2575) that "The lower bound to the discount ... [a]rises from the relative ease with which new funds can be issued."

a liquidity premium on the CEF, discounting cash flows from the fund's investments at the (lower) rate r.

2. Shareholders do not receive all of the cash flows from the fund, because, as long as the fund is in existence, the management receive a fraction k of the fund's cash flows.
3. Shareholders can force the liquidation of a fund at a cost $K \times \text{NAV}_t$, thereby receiving the current value of the assets net of costs, $(1 - K) \times \text{NAV}_t$. The cost K reflects both physical expenses as well as less tangible agency costs (e.g., the cost of overcoming a free-rider problem if the fund shares are dispersed). To solve the model analytically, we assume that K is sufficiently large to deter investors from forcing liquidation in equilibrium. Later, we discuss how CEF exits impact the model predictions.[13]
4. New CEFs can enter at a cost $u \times \text{NAV}_t$, paid to an underwriter.
5. The management, liquidation and underwriting fees are the same across all funds. In particular, the management fee cannot be renegotiated. This essentially characterizes the labor market for CEF managers and underwriters. Specifically, we are assuming that anyone who can manage or underwrite a CEF will exhibit the same reservation wage or outside opportunities, and that, subject to this wage, the labor market is perfectly competitive. We note that this assumption is consistent with the absence of heterogeneous skill in the managerial labor market, and that relaxing this assumption entails consideration of a model such as the one explored in Berk and Stanton (2006).[14]

Given these assumptions, the value of the fund is the present value of the fund's cash flows discounted by r, added to the present value of proceeds from liquidating the fund at some future date, τ:

$$\begin{aligned} P_t &= E_t\Big[\int_t^\tau (1-k) C_{t'} e^{-\int_t^{t'} r dt''} dt'\Big] + (1-K) E_t[e^{-r\tau}\text{NAV}_\tau] \\ &= C_t(1-k) E_t\Big[\int_t^\tau e^{-(r-g)(t'-t)} dt'\Big] + (1-K) E_t[e^{-r\tau}\text{NAV}_\tau]. \end{aligned} \tag{4}$$

The optimal stopping time at which shareholders exercise their option to liquidate the fund, τ, maximizes shareholders' cash flows, and is therefore generally stochastic. A valuation of the fund consists of finding the optimal tradeoff between the value of liquidity service provided by the manager, the cost of management, and the option value of terminating the fund.

[13] Bradley et al. (2005) discuss the sources of these costs in more detail.

[14] In practice, managing a portfolio of illiquid assets entails skill, albeit, not necessarily 'stock-picking' or 'market-timing' skill. For instance, the manager will have to possess detailed institutional knowledge and/or industry relationships in order to minimize the transaction costs when trading in the underlying. Moreover, trading in the underlying is generally unavoidable (e.g., a bond fund might replace maturing securities) and their tax treatment is often complicated.

Time variation in the liquidity premium can lead to discounts or premiums relative to NAV. If the liquidity premium becomes too high, existing CEFs will trade at a premium, and new CEFs will enter the market. As long as no new supply of the illiquid asset is introduced to accompany the entry of CEFs, market clearing implies that the new CEFs acquire their assets from the marginal (or price setting) investor in the illiquid security. By definition, the infra-marginal investor values the asset more, and becomes the new marginal investor through the entry of CEFs. The price of the underlying must subsequently increase, or alternatively, the liquidity premium decreases. We capture the logic of this feedback between CEF entry and the liquidity premium with the following additional assumptions:

6. There is a continuum, $x_t \in [0, 1]$, of existing CEFs at any particular point in time corresponding to the proportion of the underlying asset currently managed by CEFs. In other words, the proportion of the total supply of the asset currently in *illiquid* form is $1 - x_t$.
7. The observed liquidity premium on the underlying is $\rho_t = \rho_t^f \, q(x_t)$, where q is a monotonically decreasing function with $q(0) = 1$ and $q(1) = 0$. ρ_t^f is the liquidity premium in the absence of CEFs, and is assumed to evolve as

$$\frac{d\rho_t^f}{\rho_t^f} = \mu \, dt + \sigma \, dW_t.$$

8. CEFs enter and exit as infinitesimal units.

Assumption 7 models a monotonic relation between the number of CEFs and the liquidity premium (the multiplicative form is chosen for tractability). Intuitively, as closed-end funds own more of the asset, more and more investors with high trading costs are able to buy the asset indirectly, so the illiquidity cost faced by the marginal direct investor in the underlying asset falls, lowering the required liquidity premium. Note that we do not assume that the liquidity premium is mean-reverting. In the absence of mitigating market forces (such as those supplied by CEF entry), the liquidity premium is given by ρ_t^f, which does not mean-revert. The relation $\rho_t = \rho_t^f \, q(x_t)$ is reminiscent of the price-demand relation often postulated in equilibrium models with production (see, for example, Grenadier, 2002). Such relations may also, in principle, feature a forward looking aspect (e.g., the price elasticity for a storable commodity may depend on future expectations). As is customary with equilibrium models positing price-demand relations, Assumption 7 dispenses with the dependence on forward looking variables. Instead, we assume that ρ_t can be written exclusively as a function of x_t. The last assumption guarantees that CEFs are homogeneous and non-strategic entities.

Some readers may be concerned that the proportion of illiquid assets, like municipal bonds, held by CEFs is too small for CEF entry to affect the liquidity premium in that sector. To address this, one could modify Assumptions 1, 6, and 7 to assert that the liquidity premium ρ_t is constant (or exogenously mean-reverting), while the *relative* liquidity benefit provided by CEFs varies with time, and decreases with the entry of new CEFs. The equilibrium premium in such a model would exhibit behavior similar to ours, but the equilibrium analysis would be more involved, and analytically intractable. Aside from tractability, another advantage of our setup is that the mean-reversion in the liquidity premium can only arise endogenously.

Our assumptions lead to the following results:

Theorem 1. *Assume $K \geq k$, and that ρ follows the reflected Brownian motion process*

$$\frac{d\rho_t}{\rho_t} = \mu\, dt + \sigma\, dW_t, \qquad \rho_t \in [0, \bar{\rho}].$$

Then the values for the NAV and CEF are given by

$$\begin{aligned} P(\rho_t) &= C_t \times \frac{1-k}{r-g}, & (5)\\ NAV(\rho_t) &= C_t \times \hat{V}(\rho_t), \qquad \text{where} \\ \hat{V}(\rho_t) &= \frac{4}{\sigma^2} U_+(\rho_t)\Big(\int_{\rho}^{\bar{\rho}} \rho'^{\frac{2\mu}{\sigma^2}-2} U_-(\rho') d\rho' - \frac{U'_-(\bar{\rho})}{U'_+(\bar{\rho})} \int_0^{\bar{\rho}} \rho'^{\frac{2\mu}{\sigma^2}-2} U_+(\rho') d\rho' \Big) + \\ &\quad \frac{4}{\sigma^2} U_-(\rho) \int_0^{\rho} \rho'^{\frac{2\mu}{\sigma^2}-2} U_+(\rho') d\rho', & (6) \end{aligned}$$

$$\begin{aligned} U_+(\rho) &= \rho^{\frac{1}{2}-\frac{\mu}{\sigma^2}} I\Big(\sqrt{\big(1-\frac{2\mu}{\sigma^2}\big)^2 + 8\frac{r-g}{\sigma^2}}, \sqrt{\frac{8\rho}{\sigma^2}} \Big), \\ U_-(\rho) &= \rho^{\frac{1}{2}-\frac{\mu}{\sigma^2}} K\Big(\sqrt{\big(1-\frac{2\mu}{\sigma^2}\big)^2 + 8\frac{r-g}{\sigma^2}}, \sqrt{\frac{8\rho}{\sigma^2}} \Big), \end{aligned}$$

and where $I(\nu, y)$ and $K(\nu, y)$ are the modified Bessel functions of the first and second kind, respectively.

Proof: See Appendix B.

Theorem 2. *Assume $r > g$, $K \geq k$, and that one of k and u is strictly positive. Then there exists a unique threshold $\bar{\rho} > 0$ determined as the solution to the equation*

$$\frac{1-k}{r-g} = \hat{V}(\bar{\rho})(1+u). \qquad (7)$$

and characterizing an equilibrium in which

$$\rho_t = \bar{\rho}\,\frac{\rho_t^f}{s_t^f}, \quad s_t^f \equiv \max\{\bar{\rho},\ \sup_{\tau \le t} \rho_t^f\}. \tag{8}$$

CEFs only enter when $\rho_t = \bar{\rho}$, the dynamics of x_t are given by

$$q(x_t) = \frac{\bar{\rho}}{s_t^f},$$

and the probability of becoming managed by CEFs for an arbitrary fraction, Δ, of the $1 - x_t$ supply of illiquid asset not yet under CEF management is

$$-\bar{\rho}\frac{1}{q'(x_t)}d\frac{1}{s_t^f}.$$

Proof: See Appendix C.

The model is crafted so as to depend on only a single state variable. This makes the model tractable and its implementation straightforward. The absence of CEF liquidation (i.e., the assumption $K > k$) is crucial to this. If, instead, investors might find it optimal to exercise their option to liquidate a fund, then x_t (or the supply of illiquid asset) will enter as a second state variable into the dynamics of ρ_t and the IPO threshold will vary with x_t.

Assumption 6 and Theorem 2 imply that the proportion of illiquid asset under CEF management can never decrease with time. Although seemingly bizarre, the model can be readily re-interpreted so as to do away with this peculiar feature. We provide details in Appendix C, following the proof of the Theorem.

Substituting into Equation (1), the CEF premium can be written as

$$\frac{1-k}{(r-g)\widehat{V}(\rho)} - 1. \tag{9}$$

From the integral formula for the NAV, $\hat{V}$ is decreasing in ρ_t, and $\hat{V}(0) = \frac{1}{r-g}$. This can be used to demonstrate that $\bar{\rho}$ increases with k and u. When $\sigma = \mu = 0$, so that ρ is constant, $\hat{V} = \frac{1}{r+\rho-g}$ and the CEF premium is given by $\frac{\rho(1-k)}{r-g} - k$. When $\rho = 0$, this is equivalent to results obtained by Ingersoll (1976), Gemmill and Thomas (2002) and Ross (2002a). If ρ is non-zero, the fund trades at a (constant) discount or premium, depending on whether $\frac{\rho}{r-g}$, the capitalized liquidity savings, is smaller or larger than $\frac{k}{1-k}$, the relative ownership of the manager in the fund's assets.[15] Thus, as noted earlier, the premium reflects a tradeoff

[15]The result for constant $\rho \neq 0$ was first obtained by Cherkes (2003).

between the liquidity benefits of organizing the fund versus the loss of ownership in the underlying asset.

With a constant liquidity premium the fund always trades at a discount or a premium. If it always trades at a discount, there is no a priori reason for organizing the fund. On the other hand, while CEFs usually trade at a discount relative to their NAV, they also frequently trade at a premium. From this, it is clear that an appropriate valuation model requires time variation in the fund's fundamentals.

If $\sigma \neq 0$, the CEF premium can vary in $[-k, u]$ and is equal to u at the time of IPO. Subsequent to the IPO the CEF premium decreases. The rate at which it falls to a discount, and its long-run behavior, crucially depend on the value of $\bar{\rho}$ and the details of the stochastic process for ρ_t^f (i.e., σ and μ). The following result helps in calculating some of the properties of the premium.

Theorem 3. *The process ρ_t is stationary if and only if $\gamma \equiv \frac{2\mu}{\sigma^2} - 1 > 0$. Moreover, if it is stationary, then the unconditional cumulative distribution function is given by,*

$$F(\rho) = \left(\frac{\rho}{\bar{\rho}}\right)^{\gamma}.$$

For all γ, the expected time, T, it takes for the liquidity premium to reach a level, $\rho_0 < \bar{\rho}$, after an IPO is

$$T(\rho_0) = \frac{2}{\gamma\sigma^2}\left(\ln\left(\frac{\rho_0}{\bar{\rho}}\right) - \frac{1 - \left(\frac{\rho_0}{\bar{\rho}}\right)^{-\gamma}}{\gamma}\right). \tag{10}$$

The expected value of any function of ρ_t, say $\psi(\rho_t)$, calculated at $t = 0$ when the IPO is assumed to take place, is

$$E[\psi(\rho_t) \mid \rho_{t=0} = \bar{\rho}] = \int_0^{\infty} \left(2\sqrt{2}\theta\, N\Big(\theta\sqrt{t} - v\sqrt{\frac{2}{t}}\Big)e^{-2\sqrt{2}\theta v} + \frac{2}{\sqrt{\pi t}}e^{-\left(\theta\sqrt{t} - v\sqrt{\frac{2}{t}}\right)^2/2}\right)\psi\big(\bar{\rho}e^{-\sigma\sqrt{2}v}\big)\, dv \tag{11}$$

where $\theta \equiv \frac{\gamma\sigma}{2}$ and $N(\cdot)$ is the standard normal cumulative distribution function.

Proof: See Appendix D.

If ρ_t is not stationary (i.e., $\gamma = 2\mu/\sigma^2 - 1 < 0$) then as $t \to \infty$ the liquidity premium almost surely tends to zero. Depending on the magnitude of μ and σ this might take a long time and ρ_t might find itself at $\bar{\rho}$ multiple times before drifting off towards zero. Intuitively, this represents a situation in which the illiquidity of an asset is a 'temporary' phenomenon and can be rationalized by the expectation that technological innovation will, in the long-run, reduce clearing costs.

From Equation (10) the half life of ρ_t from its value at IPO is given by $T_{\frac{1}{2}} \equiv \frac{1}{\sigma^2\gamma}\big((2^\gamma - 1)/\gamma - \ln 2\big)$. This quantity is increasing in γ and decreasing in σ. To gain some perspective, when $\gamma = 0$, $T_{\frac{1}{2}} \approx \frac{0.24}{\sigma^2}$ so a volatility of 50% or more is required to obtain a half-life shorter than a year. While this may seem high, it is empirically plausible. For instance, such 'high' volatility would allow for the liquidity premium to change from 4% to 2% in one year. In other words, the volatility of the liquidity premium might be high in relative terms while the overall *level* of the premium is always below a few percentage points (e.g., $\bar{\rho} = 6\%$).

The possibility that a CEF might fall from a premium to a discount in a period shorter than a year is often cited as a major challenge to any 'rational' economic theory. Equation (10) indicates that this by itself is *not* inconsistent with our tradeoff model. Within our framework, short reversions are possible if the liquidity premium is non-stationary and volatile relative to its level. The IPO of a CEF, even if $T_{\frac{1}{2}}$ is small, is justified by the high likelihood that the liquidity premium could be positive in the future.

Finally, we remark that Equation (11) is useful in calculating the expected CEF premium t years after the IPO: $E\big[\frac{P(\rho_t) - \text{NAV}(\rho_t)}{\text{NAV}(\rho_t)} \mid \rho_{t=0} = \bar{\rho}\big]$.

4.2 Benchmark Calibration

Theorems 1 and 2 give NAV and CEF values as functions of the underlying parameters. In this section, we calibrate the model, and show that, for each CEF sector, it can qualitatively generate a pattern of CEF behavior resembling what is observed in practice. To parameterize the model, one must specify $k, u, r - g, \gamma$ and σ.[16] Our approach is to select benchmark parameters and then study the comparative statics. In order to make comparison with often quoted CEF statistics, we map our model parameters to the CEF's expense ratio, payout ratio, and a measure of the expected duration of the premium from the inception of an IPO. Specifically, we make the identifications in Table 3.

The benchmark values correspond to the overall estimates from Table 2. Note that the values specified in the table completely pin down all five model parameters.[17] The median fund age in our data is seven years (measured from the IPO year – see Table 1). In calculating

[16]Given our assumption of zero correlation between C_t and ρ_t^f, the drift and volatility of the payout process, C_t, are not relevant.

[17]As it turns out, the solution is unique.

Variable	Symbol	Observed Statistic	Benchmark Value
Manager's share of dividends	k	$\frac{\text{expense ratio}}{(\text{ expense ratio + payout ratio})}$	0.173
Risk neutral interest rate less growth rate	$r - g = \frac{(1-k)C_t}{P_t}$	payout ratio	0.062
Underwriter's fee	u	underwriting costs	0.057
Reversion time to a discount	T_{disc} from (10)	reversion time to discount	0.97 yrs
Average premium	Calculated from (11)	average time-series of premia since fund inception	-0.04
Age of the fund		length of time-series	7

Table 3: **Parameter Identification**

an average premium for our data we therefore calculate

$$\text{average premium} = \frac{1}{7}\sum_{t=1}^{7} E\big[\frac{P(\rho_t) - \text{NAV}(\rho_t)}{\text{NAV}(\rho_t)} \mid \rho_{t=0} = \bar{\rho}\big]. \tag{12}$$

The implied values, $\gamma = -0.28$ and $\sigma = 1.24$ must be solved for numerically and simultaneously with $\bar{\rho} = 0.11$ (from Eqn. (7)). The value of ρ for which the premium is zero is calculated to be $\rho_0 = 0.03$. The volatility is high and corresponds to a half-life of approximately two months from IPO. A high volatility also allows for the possibility that the liquidity premium will be frequently high in the future. Figure 2 plots $P(\rho_t)/C_t$ and $\hat{V}(\rho_t) = \text{NAV}(\rho_t)/C_t$ against ρ_t. Figure 3 plots the premium, along with the manager's fee, as a fraction of the NAV. As expected, for low values of ρ, the CEF trades at a discount, but the discount disappears when ρ reaches 3%, and the fund trades at a premium for higher values of ρ. Figure 3 shows that our assumption of constant k does not seriously contradict the fact that management fees are usually set to be a fixed proportion of the NAV. Note that the calculated value of γ is negative, meaning that the liquidity premium, for the assets managed by a typical fund, is not stationary, and is expected to disappear almost surely over time. Figure 4 calculates the expected premium t-years subsequent to an IPO for a fund with the benchmark parameters. The figure also shows the 5% and 95% confidence intervals,

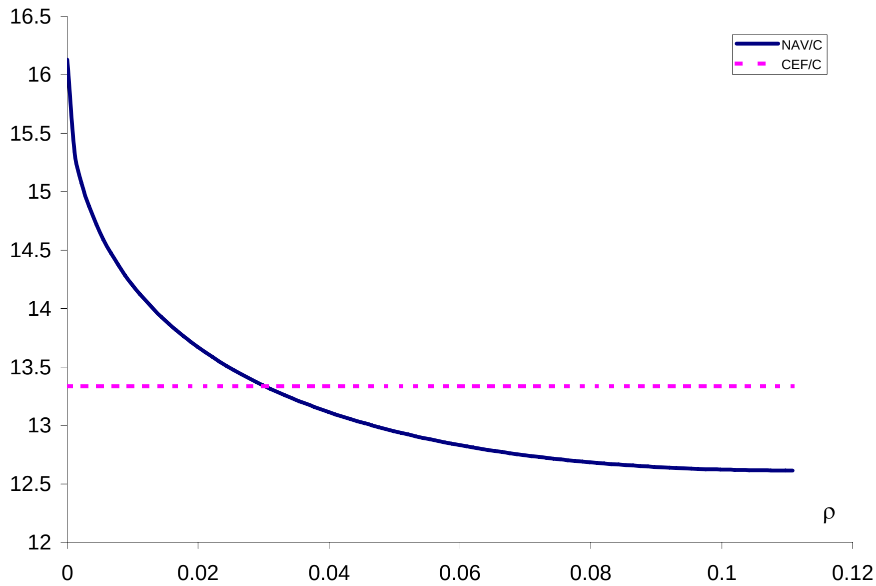

Figure 2: **NAV vs. CEF value**. The blue (solid) line shows the NAV (as a multiple of the current cash flow, C_t) for different values of the liquidity premium, ρ. The red (dashed) line shows the corresponding CEF value. All parameter values are equal to those given in Table 3.

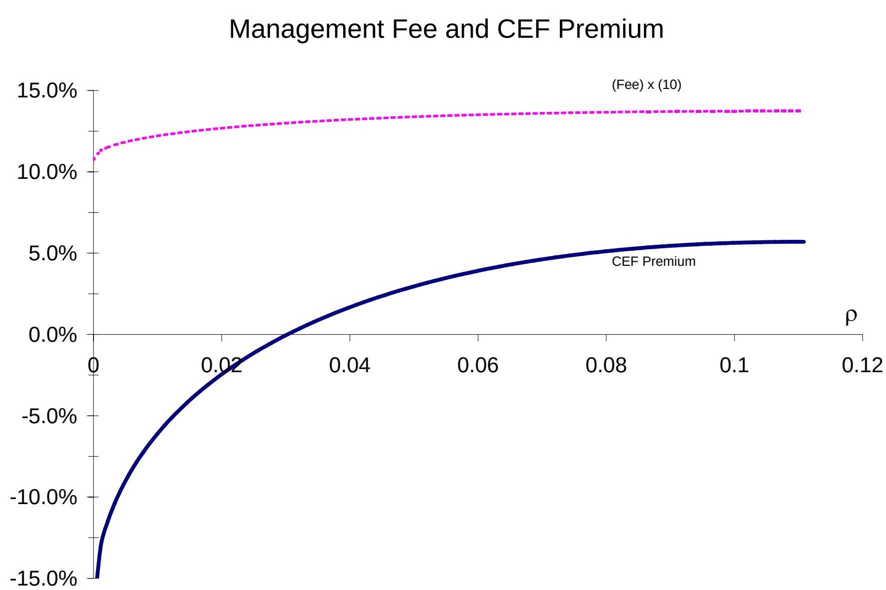

Figure 3: **CEF Premium/Discount vs. Liquidity Premium**. The graph shows the closed-end fund premium and the manager's fee (as a fraction of NAV) as a function of the liquidity premium, ρ. All parameter values are equal to those given in Table 3.

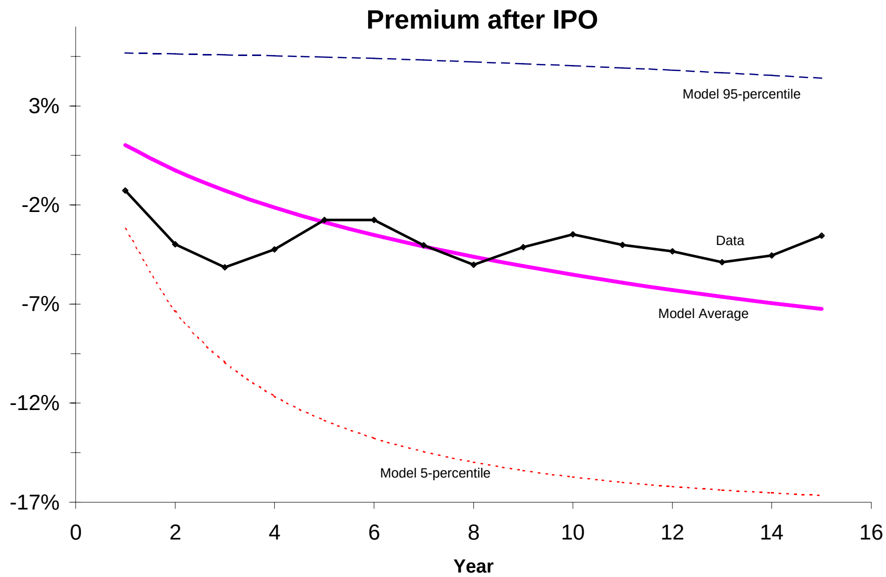

Figure 4: **Distribution of CEF premium after the IPO.** The graph shows the expected premium t-years subsequent to an IPO for a fund with the benchmark parameters. It also shows the 5% and 95% confidence intervals, and the average premium from the data.

indicating that even 15 years out there can be substantial variation in the premium. For comparison, we also plot the data average of the premium using all funds (e.g., for the year 2 point, we tabulate the second year premium for all funds that IPOed during our observation period, and average across the resulting series.) We emphasize that the model graph is fixed by the benchmark parameters in Table 3, and thus we have no extra degrees of freedom to force it to fit the data.

Table 4 shows the calibrated parameter values when the model is fit to the sector data in Table 2. A consistent message from the calibration exercise is that the required premium volatility must be high for the model to fit the stylized facts, and the underlying process for the liquidity process is non-stationary in the sense that eventually the premium disappears with probability one. The next section raises the possibility that these results might instead arise from the overpricing of CEF IPOs.

5 Empirical Analysis

In this section, we perform an in-depth empirical analysis, focusing in particular on differentiating between our liquidity explanation for the premium and the most popular alternative,

Parameter	Muni	Taxable FI	Dom. Equity	For. Equity	Other	Overall
a. Matched to data						
Payout ratio	0.059	0.088	0.051	0.019	0.074	0.062
Expense ratio	0.011	0.012	0.015	0.018	0.015	0.013
Underwriting costs	0.056	0.059	0.059	0.065	0.048	0.057
Average premium	-0.034	-0.026	-0.062	-0.079	-0.037	-0.041
Time to discount	1.014	1.009	0.792	1.079	0.742	0.975
Fund age	6	9	10	7	4	7
b. Calculated						
σ	1.160	2.880	1.740	0.360	1.000	1.240
μ	0.426	3.937	1.372	-0.004	0.227	0.556
γ	-0.367	-0.051	-0.094	-1.063	-0.547	-0.277
$\bar{\rho}$	0.102	0.165	0.147	0.091	0.111	0.111
ρ_0	0.029	0.008	0.030	0.061	0.044	0.030

Table 4: **Calibration of the model to the data**

the investor sentiment theory. This was first suggested by Zweig (1973), and modeled by DeLong et al. (1990) and Lee et al. (1991). One fundamental difference between the two explanations is that our liquidity-based theory provides a clear economic rationale for CEFs' existence—CEFs provide small investors with access to illiquid securities that would otherwise be prohibitively expensive—whereas in the sentiment model, the existence of CEFs makes investors *worse* off.[18]

A theory in which CEFs exist only to take advantage of an unsophisticated public would not have become widely accepted without substantial empirical support, yet much of the evidence cited in support of the sentiment model is equally consistent with our liquidity model. This is more than a coincidence. Consider again the model described in Section 4. In our exposition, we interpret ρ_t as the time-varying liquidity premium on the underlying securities, but we could alternatively interpret ρ_t as a measure of investor sentiment driving the degree of over- or underpricing of CEFs.[19] If exactly the same set of equations can describe premium behavior caused by either liquidity or investor sentiment, it follows that many empirical tests (including many of those most widely cited in the literature) will either

[18] As Lee et al. (1991) state (p. 84), "In this theory, then, there is no "efficiency" reason for the existence of closed-end funds. Like casinos and snake oil, closed-end funds are a device by which smart entrepreneurs take advantage of a less sophisticated public." Similarly, Weiss Hanley et al. (1996) (p. 130) conclude that "...the $1.3B in underwriting fees were an expensive tribute to the informational disadvantage (or irrationality) of small investors."

[19] We could also postulate a hybrid model, in which liquidity explains the existence of CEFs, but the time series dynamics of the premium/discount are primarily driven by investor sentiment. In this case, ρ_t would measure the difference between the liquidity and sentiment effects (we are grateful to the referee for this observation).

Paper	Sectors	Cross-Section	Time-Series	Supports Sentiment?	Supports Liquidity?
Brown and Cliff (2004)	DE		X	No	
Qiu and Welch (2006)	Index: FE+DE		X	No	
Lemmon and Portniaguina (2006)	DE		X	No	
Chan et al. (2005)	FE	X	X		Yes
Bonser-Neal et al. (1990)	FE	X	X		Yes
Manzler (2005)	DE	X			Yes
Datar (2001)	DE, Bonds	X	X		Yes

Table 5: **Existing Research on Determinants of the CEF premium.** In the sector column, Domestic Equity is abbreviated to DE, and Foreign Equity is abbreviated to FE.

reject or fail to reject *both* explanations, but cannot distinguish between them.

While both liquidity and sentiment can give rise to similar looking premium behavior, they differ in the underlying factors that drive the premium. If the sentiment story is correct, the premium should fluctuate with investor sentiment. If our liquidity explanation is correct, the premium should fluctuate with liquidity. One way to distinguish between the two models is therefore to test how much the premium is related to explicit measures of liquidity and sentiment.

Several recent papers test for a relation between the CEF premium and either sentiment measures or liquidity measures. Table 5 summarizes the results of this research, which has found little or no evidence that explicit sentiment measures are related to the premium, but has found some evidence that liquidity-related variables are important. Qiu and Welch (2006) conclude:

> "In light of our evidence, we believe [the closed-end fund premium] to be inadmissible as a reasonable proxy for investor sentiment."

While the results of this existing research are consistent, there is nevertheless a need for additional work. First, all of these studies test for liquidity effects or sentiment effects, but not both. If liquidity and sentiment are correlated with each other, omitting either variable could cause us to find a relation that does not really exist, or to find no relation when one does. Second, most of the studies analyze only a few sectors, and consider either cross-sectional or time-series effects, but not both. Third, the studies do not fully control for individual fund characteristics (e.g., leverage) before aggregating premia across funds. Compared with these prior studies, we analyze many more funds, of more different types, over a much longer time period, looking at both time-series and cross-sectional effects. We also incorporate many more possible explanatory factors into our analysis, including both systematic (market-wide and sector-specific) and fund-specific factors. Finally, unlike prior research, we simultaneously test for the effect of both liquidity and sentiment variables.

Variable Name	Description	Source	Predicted Coeff. Liquidity	Sentiment
a. Systematic:				
top_sent	U. Michigan Consumer Sentiment Index, top-third income households	http://www.sca.isr.umich.edu/	0	+
vix	S&P 100 volatility index	WRDS	+	–
liq_level2	Pástor and Stambaugh (2003) liquidity measure	WRDS	–	0
variable_component	Variable component of Sadka (2006) illiquidity measure	Ronnie Sadka	+	0
corpspread	Corporate bond spread (AAA corp. bond yield minus Treasuries)	Global Financial Data	+	0
taxDiff	Spread between the Green (1993) 7-yr muni implied tax rates and the marginal tax rate on dividends	Bloomberg and NBER	–	0
term	Term spread (20 year − 3 month rate)	Global Financial Data	+	0
b. Fund-Specific:				
prem	Premium on CEF	Bloomberg		
cmdm	Estimate of Roll (1984) trading cost	Joel Hasbrouck	–	0
gamma	Estimate of Pástor and Stambaugh (2003) reversal measure of liquidity	Joel Hasbrouck	–	0
lev	Fund's leverage, interpolated from quarterly data	S&P Capital IQ	+	+
exprat	Expense ratio	S&P Capital IQ	–	–
payout	Payout ratio (ordinary cash dividends)	CRSP	+	+

Table 6: **Variables.** This table describes the variables used in our empirical analysis in Sections 5.2 and 5.3, and shows the expected relation between each variable and the CEF premium under the liquidity model versus the sentiment model.

5.1 Variables

Table 6 describes the variables used in our analysis, along with the expected relation between each variable and the CEF premium under the liquidity model versus the sentiment model. Although our primary focus is on the systematic determinants of the CEF premium, we also consider the fund-specific variables described in Section 2, because these affect a CEF's premium in addition to the systematic variables. The variables liq_level2, variable_component, corpspread, and taxDiff, are measures of sector-specific liquidity, while top_sent and vix are sentiment measures. We also include the slope of the term structure (term), because, as we soon argue, it captures the liquidity benefits of CEF leverage. A few of the variables and predicted relations in Table 6 are worth commenting on.

U. Michigan consumer sentiment measure, top_sent The widely used University of Michigan household sentiment index is calculated from a regular survey of a large number of households regarding their financial situation and economic expectations (Ludvigson, 2004; Qiu and Welch, 2006; Lemmon and Portniaguina, 2006). This measure is closely related to other survey-based measures of investor sentiment (Qiu and Welch, 2006; Fisher and Statman, 2003), and has been shown to be related to investor economic activity (Acemoglu and Scott, 1994; Carroll et al., 1994; Bram and Ludvigson, 1998; Ludvigson, 2004). Most important, Lemmon and Portniaguina (2006) find that this measure predicts the returns on small stocks and stocks with low institutional ownership. This is consistent with Fisher and Statman (2003), who find that consumer confidence does not forecast S&P returns, but can predict returns on Nasdaq and small-cap stocks. Because CEFs are small stocks with low institutional ownership, the evidence supports the use of top_sent as a direct measure of the investor sentiment variable described by DeLong et al. (1990) and Lee et al. (1991). If the sentiment interpretation of the model is appropriate, the more optimistic investors are, the higher the CEF premium ought to be, so we should expect a positive relation between top_sent and the premium.

S&P 100 volatility index (vix) This is perhaps the most interesting variable, because the two models we are considering have competing implications for its relation with the premium. VIX is the CBOE's S&P 100 volatility index, calculated as a weighted average of Black-Scholes implied volatilities for CBOE-traded options on the S&P 100 Index.[20] It is often referred to as the market's "fear gauge" (see Whaley, 2000), and is widely used as a negative measure of investor sentiment. Under the sentiment model, a higher level of vix, meaning lower investor sentiment, should translate into a lower premium.

[20]Beginning on September 22, 2006, the index will switch to being calculated from S&P 500 options.

On the other hand, both inventory and information asymmetry models predict a positive relation between spreads and volatility (see, for example, Ho and Stoll, 1983; Admati and Pfleiderer, 1988; Foster and Viswanathan, 1990), and empirical evidence supports this prediction (see Stoll, 2000). Thus, under the liquidity model, higher market-wide volatility (i.e., vix) should mean lower liquidity for the underlying, and, if one controls for the liquidity of the CEF share, a *higher* premium on the CEF.

Sector-specific liquidity measures Both the Pástor and Stambaugh (2003) measure of aggregate liquidity, liq_level2, and the Sadka (2006) measure of aggregate illiquidity, variable_component, are priced liquidity factors. Consequently, one might expect the systematic liquidity of domestic equity, foreign equity, and the types of assets managed by 'Other' CEFs, to be correlated with these variables. As long as one controls for the trading costs of the CEF shares, the liquidity-based explanation predicts that the premium in the Domestic Equity, Foreign Equity, and Other sectors will decrease with liq_level2 and increase with variable_component.

Consistent with Longstaff et al. (2005), we use corpspread as a measure of systematic liquidity in the Taxable Fixed Income sector. Some funds classified as 'Other' manage preferred shares, thus we also include corpspread as a systematic liquidity factor when analyzing these funds.

Because of the tax status of municipal bonds, constructing a measure analogous to corpspread for the Muni sector is more involved. We use the Green (1993) formula and muni/treasury yields from Bloomberg to calculate the implied tax rate for a seven-year muni strip. The choice of a seven-year strip corresponds to the average duration of municipal bonds held by CEFs in 2000 (obtained from Morningstar). The federal marginal tax rate on dividend income, as posted by the NBER, is subtracted from the calculated muni-implied tax rate to form taxDiff. This variable represents a (negative) tax-adjusted yield spread on municipal bonds. Low realizations of taxDiff correspond to relatively high tax-adjusted yields on municipal bonds, implying lower liquidity, and consequently a higher CEF premium. A liquidity-based model therefore predicts a negative relation between taxDiff and the premium on Muni funds.

Expense Ratio and Payout Ratio Either increasing the payout ratio or lowering the expense ratio increases the share of the fund's cash flows that go to the investor rather than the manager. As a result, we expect the premium to be negatively related to the expense ratio, and positively related to the payout ratio in the liquidity model. While the types of sentiment model proposed by DeLong et al. (1990) and Lee et al. (1991) do not make predictions about the relation between fund-specific variables and the fund premium, interpreting ρ_t in our model as a sentiment variable clearly leads to the same predictions as would be obtained in the liquidity-based interpretation.

CEF trading costs In our liquidity model, the premium is driven by the relative liquidity of the CEF versus its underlying assets. The higher the CEF's trading costs, the lower its liquidity advantage relative to the underlying assets. Everything else being equal, we expect the premium to be negatively related to CEF trading costs. Moreover, we use this variable to control for the liquidity of the CEF shares.

Leverage While our model does not incorporate leverage effects, Table 2 indicates that CEFs make intensive use of leverage. It is therefore important in the empirical investigation to account for any possible effects leverage might have on the premium. To get a sense of how one might adjust the premium for leverage, consider an unlevered (all-equity) CEF that provides a premium of p_U on a unit of assets. An all-equity fund managing $1 + v$ assets is worth $(1 + v)(1 + p_U)$ to its shareholders. If the fund subsequently borrows v (risk-free and liquid) and distributes the proceeds to its shareholders, then the equity (NAV) of the fund falls to 1, while the value of the fund to the shareholders falls to $(1 + v)(1 + p_U) - v$. The levered premium is therefore

$$p_L = \big((1 + v)(1 + p_U) - v\big) - 1 = p_U(1 + v),$$

or, setting $L \equiv v/(1 + v)$ to be the leverage ratio,

$$p_U = (1 - L)p_L. \tag{13}$$

Because p_U does not depend on leverage, this means that we can control for the effect of leverage by placing $(1 - L)p_L$ on the left side of our regressions.

There are two possible adjustments that ought to be made to Eqn. (13). A manager might reduce her pay following the increase in leverage, in order to keep the compensation a fixed proportion of shareholder NAV. In other words, Eqn. (13) ought to be adjusted according to how the manager's pay is changed subsequent to a change in leverage.

Moreover, given that CEFs are able to hold a levered portfolio that would be more costly for their investors to hold, leverage ought to be viewed as a liquidity benefit supplied by a CEF. A model of CEFs based on the liquidity benefits provided to its investors, therefore, predicts a further adjustment, positively related to leverage, to the right side of Eqn. (13).

Table 7 shows summary statistics and correlations for the systematic variables. Interest-

Variable:	vix	top_sent	corpspread	taxDiff	term	variablecomp	liq_level2
a. Summary statistics							
mean	19.52	100.09	0.65	0.59	2.26	0.00019	-0.02422
sd	6.41	10.99	0.41	6.03	1.27	0.00468	0.06824
p50	18.97	100.70	0.54	0.69	2.05	0.00086	-0.01595
max	44.28	126.10	1.79	16.14	4.69	0.01102	0.20185
min	10.63	68.60	-0.13	-20.00	-0.25	-0.02081	-0.46154
N	188	240	240	177	240	240	228
b. Correlations							
vix	1.000						
top_sent	0.155	1.000					
corpspread	0.503	0.143	1.000				
taxDiff	-0.578	-0.055	-0.591	1.000			
term	-0.274	-0.447	-0.267	0.287	1.000		
variablecomp	-0.272	0.093	-0.111	0.316	0.000	1.000	
liq_level2	-0.345	-0.085	-0.079	0.226	-0.007	0.184	1.000

Table 7: Summary statistics and correlation matrix for systematic variables.

ingly, despite vix and the Michigan index both being commonly used measures of investor sentiment, the correlation between them is small (though positive). There is a sizeable correlation between vix and the two bond spread measures, as well as between the two bond spread measures. Both the Pástor and Stambaugh (2003) and Sadka (2006) liquidity measures are negatively correlated with vix, with the correlation between the two variables being small (though positive).

5.2 Determinants of the CEF premium

Our goal is to assess the effect on the CEF premium of systematic and fund-specific variables related to our model. We could regress all of the variables in Table 6 on each fund's unlevered premium individually, and report the average regression coefficients, but the fund-level noise would drown the effect of the systematic variables.[21] On the other hand, we could aggregate the unlevered premium and the independent variables across fund types, and then run the regression, but doing so removes the cross-sectional information in the firm-specific variables. Instead, we choose the following three-stage approach. Because the fund-specific factors may, themselves, be correlated with the systematic factors, the first stage of our analysis is to remove the systematic component of the fund-specific variables by regressing them against the systematic variables. In the second stage, the unlevered premium for each

[21] Comparing two sources of premium data, we found that they agreed on average, but that the discrepancy exhibited a standard deviation of 3%. This gives a sense of the noise present in individual CEF premium quotes.

fund, $\text{Prem}_L(1-L)$ (discussed above), is regressed against the residuals from the first stage regression, i.e., against the component of the fund-specific variables that is *not* related to the systematic variables. Among other things, the second stage regression controls for illiquidity of the CEF shares. In the third stage, the residuals from the second stage (i.e., the unlevered premia, stripped of fund-specific effects) are aggregated across sectors (to increase power in the time-series), and regressed on the systematic liquidity, sentiment, and macroeconomic variables described in Table 6.

Panel a. of Table 8 summarizes the aggregated t-statistics from the second-stage regressions; i.e., the average t-statistics times $\sqrt{N}$ where N is the number of funds. Consistent with the model, the premium is negatively related to the non-systematic expense ratio and positively related to the non-systematic payout ratio. The former is consistent with the findings of Gemmill and Thomas (2002) and Ross (2002a). The liquidity-based model also predicts a negative relation with non-systematic measures of the CEF share illiquidity (cmdm and gamma). This is essentially borne out (gamma is only marginally significant) and is also consistent with the findings of Datar (2001).

The unlevered premium is also cross-sectionally and positively related to the non-systematic leverage of the fund. In other words, it appears that the effect of leverage goes beyond the adjustment made in Eqn. (13). As discussed earlier, this is consistent with two possibilities: The sharing of the fund's income between the manager and shareholders improves in favor of the shareholders when the fund is levered. Alternatively, the market 'prices' the fact that it is less costly for the fund than for its clients (i.e., small investors) to hold a levered portfolio. To see which explanation better fits the data, we first calculate the growth in gross manager pay, and then regress this (with fixed effects) against the fund's change in leverage. We find that the coefficient on leverage is positive and highly significant, meaning that managers enjoy higher pay after an increase in leverage. The positive and significant impact of leverage on the unlevered premium documented in Table 8 is thus due to the liquidity benefits of leverage (which apparently overwhelm the increase in the share of payouts to the manager). We emphasize, once more, that the liquidity benefit of leverage is not generally provided by OEFs, whose use of leverage is highly restricted.

Overall, the second stage regression explains 72% of the variation in the unlevered premium. While a very large percentage, much of this is due to the large number of parameters being estimated.[22]

Results for the third stage are shown in panel b. of Table 8. These are broadly consistent with the predictions of the liquidity model, and inconsistent with those of the sentiment

[22] Running regressions using only (fund-specific) constants on the right hand side allows us to explain 49% of the variation in the premium.

model. The first variable to look at is vix, as both the liquidity and sentiment models have implications for the regression coefficient of this variable. In three of the four sectors where the coefficient is significant, the regression coefficient has the sign predicted by the liquidity model, and the opposite sign to that predicted by the sentiment model. Further evidence against the sentiment model is provided by the other sentiment measure, top_sent. The coefficient on this variable has the opposite sign from that predicted by the sentiment model in every instance in which it is significantly different from zero.

Looking at the sector-specific variables, the taxDiff variable has the sign predicted by the liquidity model and is highly significant, and the equity market liquidity variables have the correct signs when they are significant. However, the corporate bond spread coefficient has the wrong (though insignificant) sign for taxable FI funds, while its coefficient in the 'Other' CEF premium regression is both highly significant and contrary to our expectations.

If, as suggested by our analysis of the second-stage regression, fund leverage is a cost saving device for those investors who wish to have a levered portfolio, then one would expect these costs savings to increase when borrowing rates for institutions are relatively low.[23] Thus the term variable, which we believe proxies for the liquidity benefit of leverage, ought to be positively related to the systematic and unlevered portion of the premium. This is corroborated in Table 8, documenting a positive and significant coefficient for all but one of the term coefficients.

On balance, the results from the three-stage analysis provide evidence against the predictions of the sentiment model of Lee et al. (1991), confirming the negative results of Lemmon and Portniaguina (2006), Qiu and Welch (2006) and Brown and Cliff (2004). They do, however, provide some support for the liquidity model.

5.3 IPO Behavior

Our liquidity-based theory predicts that if the liquidity premium, ρ_t, is high enough that it makes sense for new funds to come into the market via an IPO, we should simultaneously see existing funds in the same sector trading at a premium (since the premium on new and existing funds is driven by the same factor). Thus, at the time of a fund's IPO, not only will it trade at a premium, but existing funds in the same sector will also trade above their average premium. A corollary is that IPOs should occur in waves specific to the sectors that are trading at an above-average premium. Evidence supporting these hypotheses is documented in Lee et al. (1991), and support for sector-specific clustering can be readily

[23]The CEF industry literature often touts the advantage of levering when the yield curve is steep. The regression coefficients remain highly significant and negative when the three-month treasury rate is substituted for term in our regressions.

Variable	Aggregate t-stat	N
lev	2.56	852
exprat	-4.39	852
payout	3.01	852
cmdm	-3.84	852
gamma	1.88	852
const	-20.45	852

a. Second stage: Fund-specific variables

	Muni	Taxable FI	Dom. Equity	For. Equity	Other
term	0.553 (3.24)	0.507 (3.14)	0.16 (0.72)	0.375 (1.99)	0.517 (3.19)
corpspread		-0.534 (-1.3)			-2.61 (-6.69)
vix	-0.04 (-1.44)	0.111 (4.43)	0.103 (2.78)	-0.1 (-3.18)	0.123 (4.42)
top_sent	0.022 (1.07)	-0.046 (-2.26)	-0.062 (-2.2)	0.007 (0.3)	-0.085 (-4.17)
variablecomponent			87.862 (1.41)	110.569 (2.1)	136.283 (3.11)
liq_level2			2.652 (0.93)	1.738 (0.72)	-2.71 (-1.31)
taxDiff	-0.123 (-3.44)				
Cons	-2.531 (-1.11)	1.849 (0.77)	3.949 (1.2)	0.873 (0.31)	6.714 (2.81)
Adj R2	0.109	0.3186	0.1386	0.2201	0.6003

b. Third stage: Systematic variables

Table 8: **Regression Results** This table show the results of a three stage regression of CEF premium against fund-specific and systematic explanatory factors. In the first stage (not shown), the systematic component of the fund-specific variables is removed by regressing them against the systematic variables. Panel b. shows the aggregate t-statistics from the second stage, in which the unlevered premium is regressed against the residuals from the first stage regression. Panel c. shows the results of the third stage, where the residuals from the second stage regressions are aggregated across sectors, and regressed on systematic liquidity-related and sentiment-related variables.

gleaned from Table 1. Note that the same predictions apply to a sentiment model only if one posits sector-specific sentiment.

As with the determinants of the premium above, we run a Tobit regression of the number of funds that IPO in each year from 1986–2004 against the variables that the two models suggest ought to explain the CEF premium. Table 9 reports the results of the regression, first without the premium on the right hand side, and then again with the premium on the right hand side. The results are weaker than those of the three-stage regressions presented earlier. There is a little more evidence for the sentiment story, although it is only conclusive for both sentiment measures in the case of domestic equity funds. Moreover, there is somewhat less evidence in favor of the liquidity story. The municipal bond taxDiff and the variable term still lend strong support to a liquidity-based model. Note that including the sector average premium in the regression adds relatively little to the regression's explanatory power (i.e., much of the time series effects of the sector premium are captured by the systematic variables).

5.4 Post-IPO Returns

In the model of Section 4, investors recognize the reflected process followed by the liquidity premium and expect the fund to fall to a discount over time. They invest nevertheless, because they still earn a fair expected return on all assets in the economy. In the sentiment model of Lee et al. (1991), new investors in the CEF earn below-market returns. We examine this by testing whether purchasing a CEF share *after*, say, one year following the fund's inception yields returns different than purchasing it *within* a year of inception. Our model predicts no difference between new and seasoned funds managing similar assets. Weiss (1989) found evidence of a negative post-IPO risk-adjusted return for CEFs, but she used only a small sample,[24] and measured returns relative to a market-wide index that might not reflect the actual holdings of CEFs. We investigate the same question using a larger sample and with a more appropriate index, by comparing the stock returns on 'young' CEFs with contemporaneous stock returns on 'seasoned' CEFs of the same type.

Details on how the age of a fund is calculated are provided in Appendix A. Each month and for each sector, we form a portfolio that contains only CEFs whose age exceeds 12 months, and another portfolio that contains only CEFs whose age does not exceed 12 months. The time-series average of the following month's profits from investing a dollar in the seasoned CEFs portfolio and shorting a dollar in the unseasoned CEFs portfolio are reported in Table 10. In other words, the table reports monthly excess returns to a strategy that is long

[24] She mainly considers 22 equity funds with IPOs between 1985 and 1987.

	Muni	Taxable FI	Dom. Equity	For. Equity	Other
term	1.274 (8.54)	0.419 (8.05)	0.269 (5.19)	-0.078 (-1.12)	0.351 (9.25)
corpspread		-0.335 (-1.82)			-0.459 (-3.65)
vix	0.000 (-0.02)	0.000 (0.03)	-0.077 (-5.18)	-0.066 (-4.13)	0.052 (6.41)
top_sent	-0.029 (-1.82)	0.001 (0.21)	0.031 (4.66)	-0.03 (-4.11)	0.002 (0.42)
variablecomponent			3.695 (0.22)	-27.814 (-1.31)	29.048 (2.74)
liq_level2			-1.244 (-1.17)	0.463 (0.32)	-0.262 (-0.4)
taxDiff	-0.22 (-7.65)				
Cons	1.095 (0.6)	-0.524 (-0.84)	-2.505 (-3.46)	4.343 (4.92)	-1.686 (-3.83)
Adj R2	0.2281	0.1944	0.2686	0.1366	0.3672

a. Without premium as regressor

	Muni	Taxable FI	Dom. Equity	For. Equity	Other
term	1.138 (7.81)	0.379 (5.77)	0.161 (2.37)	-0.079 (-1.19)	0.319 (8.48)
corpspread		-0.351 (-1.91)			-0.518 (-4.05)
vix	-0.002 (-0.09)	0.000 (-0.04)	-0.078 (-5.28)	-0.042 (-2.6)	0.052 (6.46)
top_sent	-0.011 (-0.68)	0.001 (0.24)	0.03 (4.75)	-0.026 (-3.78)	0.008 (2.08)
variablecomponent			-3.502 (-0.21)	-27.74 (-1.37)	28.058 (2.7)
liq_level2			-0.933 (-0.88)	0.664 (0.47)	0.031 (0.05)
taxDiff	-0.209 (-7.62)				
Cons	0.194 (0.11)	-0.368 (-0.58)	-1.909 (-2.53)	3.838 (4.57)	-2.183 (-4.8)
prem	0.201 (4.68)	0.02 (0.99)	0.048 (2.31)	0.044 (3.28)	0.039 (3.64)
Adj R2	0.2607	0.1965	0.2867	0.1661	0.4099

b.. With premium as regressor

Table 9: **Determinants of CEF IPOs.** Tobit regressions of the equally weighted six-month moving average of the number of IPOs each month against explanatory variables. Panel a. excludes the premium itself as an explanatory variable. Panel b. includes the premium.

seasoned funds versus a strategy that is long unseasoned funds.[25] We examine the effects of both equal and value weighting in the portfolio construction. We also examine the effect of unlevering the returns for funds that are levered.[26] The four columns in Table 10 correspond to equal vs. value-weighted profits, and levered vs. unlevered premia. Once we adjust the returns at the fund level for leverage, we find that evidence for underperformance of unseasoned funds only exists in two sectors: Muni and taxable fixed income. In particular, there is no evidence of underperformance in the much-studied domestic equity sector. Moreover, although statistically insignificant, there is evidence for economically significant *overperformance* of foreign equity unseasoned funds. The results are similar, though somewhat weaker, when unseasoned funds are defined to be two years or less from their IPO.

5.5 Other Tests

NAV vs. CEF returns—absolute In principle, one could distinguish between the liquidity and sentiment theories by looking at whether returns on NAV or CEFs are 'abnormal' when funds IPO. In the liquidity theory, CEF shares should always earn a fair rate of return, while NAV returns should be high at times of fund inception. In the sentiment theory, the NAV should always earn a fair rate of return, but the CEF shares should earn an abnormally low rate of return immediately following an IPO. To test this, we separately regressed sector stock returns and NAV returns on the number of IPOs, but found no significant relation in any of the sectors.

NAV vs. CEF returns—relative Another class of tests involves the *relative* returns on CEFS vs. the NAV. The liquidity theory predicts that NAV returns ought to be higher than CEF returns, whereas the sentiment theory does not make an unambiguous prediction for the unconditional average return difference.[27] As we remark in Footnote 11, the predictions of the liquidity model are somewhat corroborated by Table 2 in Wermers et al. (2005). Our data are also consistent with this, but not statistically significantly so.

6 Conclusions

This paper develops a rational, liquidity-based model of closed-end funds (CEFs) that provides a simple economic explanation for their existence: Since investors can sell their CEF

[25]Note that returns in the IPO month are excluded by construction.

[26]We assign a fund its average sector leverage in each reporting period that it is missing leverage data.

[27]Lee et al. (1991) point out that, if sentiment has a systematic component, rational arbitrageurs will demand a risk-premium, thereby causing CEFs, on average, to have higher expected returns than the NAV.

Sector		Value Weighted Raw	Value Weighted Unlevered	Equal Weighted Raw	Equal Weighted Unlevered
Muni	Monthly excess return	0.0042	0.0032	0.0051	0.0034
	t-stat.	4.44	3.73	5.17	4.01
	N	185	117	185	117
Taxable FI	Monthly excess return	0.0035	0.0032	0.0047	0.0038
	t-stat.	2.41	2.09	3.28	2.55
	N	204	123	204	123
Dom. Equity	Monthly excess return	0.012	0.0073	0.0138	0.0117
	t-stat.	2.63	0.98	3.04	1.54
	N	141	64	141	64
For. Equity	Monthly excess return	-0.0022	-0.0171	0.0057	-0.0121
	t-stat.	-0.38	-1.6	1	-1.13
	N	160	56	160	56
Other	Monthly excess return	-0.0009	-0.0007	-0.0006	0.0001
	t-stat.	-0.37	-0.27	-0.28	0.07
	N	150	78	150	78

Table 10: **Returns on new vs. seasoned CEFs.** This table reports average monthly excess returns on new (under one year old) vs. seasoned funds in our database.

shares without the underlying assets changing hands, there are cost savings to buying illiquid assets indirectly, via a CEF, rather than directly (or via an open-end fund). In our model, a CEF may trade at either a discount or a premium, depending on the size of the manager's fees relative to the liquidity benefits of the fund, and the model explains CEF IPO patterns and the behavior of the premium. Analysis of a comprehensive CEF data set from 1986–2005 provides support for both the underlying economic assumptions of the model and its predictions for IPO and premium behavior. Moreover, our analytical model can be calibrated to fit sector-specific CEF premium behavior. This includes the quick reversion from a premium at IPO to a discount. In our model, it is worthwhile to IPO a fund, even though the premium is expected to fall to a discount in one year, as long as the liquidity difference between the fund and its underlying is volatile enough to ensure a high probability that the fund will, at some point, trade at a premium again.[28]

The evidence documented in this paper suggests that, overall, the data do not support the predictions of a sentiment model, but do support both the liquidity tradeoffs underlying the model, and its predictions for the behavior of CEF premia and IPOs. Table 11 summarizes the evidence for the liquidity-based model, versus evidence consistent with various sentiment-type rationales. It appears that, if there is a puzzle associated with closed-end funds, it has to do with the under-performance of certain young funds (less than 12 months from their

[28]Our data set indicates that reversion to a discount takes an average of one year, significantly longer than the 120 days noted by Weiss (1989) in her much smaller data set.

Summary of evidence	Found in
a. Supportive of a liquidity-based model :	
The majority of closed-end funds specialize in illiquid securities such as municipal, corporate and international bonds while CEFs are, themselves, relatively liquid.	Tables 1 and 2
Other studies find little relation between the CEF premium and sentiment variables, while offering consistent empirical evidence for a relation between the premium and fund-specific or sector-specific liquidity measures.	Tables 5
A CEF's premium varies negatively with the CEF share illiquidity.	Table 8
Even after adjusting for leverage, the premium remains positively related to leverage, suggesting that the relatively unrestricted financial flexibility of CEFs is priced by the market.	Table 8
The CEF premium is related to systematic variables measuring the liquidity benefits provided by the fund, and the relation generally supports the prediction of a liquidity-based model. The evidence is weaker for IPOs.	Tables 6, 8, and 9
Aggregate sentiment related variables poorly explain the dynamics of the CEF premium. The evidence is slightly better for IPOs, although it is largely inconclusive.	Tables 6, 8, and 9
After adjusting for leverage, seasoned domestic equity, foreign equity, and 'other' funds do not significantly outperform or overperform unseasoned funds in the same sector.	Table 10
b. Supportive of a sentiment-based model:	
While CEFs IPO when other funds in the same sector trade at an above average premium, the prevailing sector premium is usually not as high as the IPO costs.	Table 2 and Figure 1
After adjusting for leverage, seasoned fixed income funds outperform unseasoned fixed income funds.	Table 10
c. Consistent with both models:	
The CEF premium is negatively related to the manager's fee and positively related to the fund's payout.	Tables 1 and 2
On average, CEFs trade at a discount to NAV and the average time to reversion is on the order of one year.	Tables 2 and 4

Table 11: Summary of empirical evidence.

IPO). The fact that the IPO cost for a fund is typically higher than the prevailing premium in the fund's sector, as well as the high volatility of liquidity premium required to calibrate the model to the data (see Table 11), appear to indicate that some CEFs may be overpriced when they IPO. It is worth documenting that the average IPO cost in our panel has decreased from about 7% to about 4.5%. Thus it may very well be the case, going forward, that the underperformance phenomenon will disappear.

If one suspects irrational and systematic overpricing of CEF IPOs (i.e., the possibility of issuers deliberately overpricing to take advantage of unsophisticated investors), then our model provides some guidance for policy. In particular, policy makers might consider that any regulations should be aimed at preserving the valuable liquidity services that CEFs provide small investors. In particular, we suggest the following:

1. It is commonly believed that the closed-end fund discount is a symptom of inefficiencies, and that reducing or eliminating the discount, such as by converting CEFs to ETFs, would also reduce or eliminate these inefficiencies.[29] In fact, even if there are inefficiencies, such as some IPOs being overpriced, attempting to address this by eliminating the discount would probably hurt all investors, since it could only be done by reducing the liquidity benefits provided by the CEF relative to its underlying assets.
2. If regulations are contemplated, it might make sense to restrict them to stipulations regarding the underlying assets of CEFs. Specifically, one could require CEFs to invest only in illiquid securities, and not in, say, diversified equity portfolios; in the latter case the overpricing problem would be mitigated by incorporating as an OEF or ETF, and the fund has no liquidity advantage to lose. While such stipulations rule out CEFs run by managers that claim special 'long-term' ability with liquid securities, the tradeoff might be worthwhile.
3. IPO overpricing could also be mitigated by allowing easier short-selling of CEFs at (or even before) their IPO.[30] The issuing underwriter, for instance, could be charged with the responsibility of taking the long side of short positions sought by market participants. This would permit more sophisticated investors who believed the IPO price was too high to act on that belief, putting downward pressure on the price charged by the issuer.

[29] See, for example, "New Fund Type Seeks SEC Approval", Wall Street Journal, April 26, 2005, p. C15.

[30] As Peavy (1990) discusses, CEF shares are not delivered by the underwriter for at least the first month during which the CEF stock trades in the secondary market. Thus, market participants cannot short during this period. Moreover, in order to effect "price support", the underwriters buy large numbers of shares in the secondary market in the months following the IPO. This does not create an inventory problem for the underwriters, because they are allowed to (and often do) place more shares at the IPO than are outstanding. Preventing this initial over-selling, and forcing the underwriters to take the long side of shorting demand just before, during, and/or just after an IPO, might help mitigate any overpricing at the IPO.

Finally, our explanation for the CEF discount is applicable to any situation in which bundling securities provides liquidity benefits to investors, such as REITs, ADRs and asset-backed securities. It also provides a potential explanation for the existence of conglomerates.

A Data Description

Our data are collected from a variety of sources. Not every data item is available for each fund-date combination.

CEF-level data From Bloomberg, we obtain monthly premium and NAV data on a survivorship bias-free sample of CEFs between January, 1986 and April, 2006.[31] Monthly data on returns, prices, number of shares outstanding, and cash dividend distributions are obtained from CRSP and matched to funds' ticker symbols. A CRSP stock is a CEF only if the second digit in the symbol's share code (shrcd) is a four or a five. Dividends are determined to be in cash if the first digit in their CRSP distribution code (distcd) is one and the second digit is less than five. We obtain quarterly SG&A and total assets data from funds' income statements and balance sheet, available through S&P Capital IQ (CEFs typically report their management fees under SG&A). We also compare these quarterly expenses with annual management fees available on a subsample of funds through Morningstar and generally find negligible discrepancy. The S&P Capital IQ data is only available from 1993 and on. We collect fund inception dates from SDC Platinum data (Thomson Financial) and from COMPUSTAT. The former is also our source for IPO costs. The fund prospectus objective is obtained from Morningstar and supplemented with descriptions from Lipper. Finally, we calculate 1993–2004 daily TAQ trades on a subset of funds.

Non-CEF data The sources for the non-CEF variables used in the study are summarized in Table 6. Summary statistics for monthly trading costs documented in Table 2 are calculated by dividing the annual level data (cmdmlevel) provided by Joel Hasbrouck by the monthly CRSP price. These trading costs compare well with estimates of TAQ bid-ask spreads calculated for a subsample of funds. The cmdm variable used in the three-stage regressions is calculated by dividing a fund's cmdmlevel by the average price of the fund for the year. Thus cmdm only varies annually. This is done so as to avoid a spurious regression relation between an individual fund's premium (which has price in the numerator) and the monthly trading costs.

Calculated variables A fund's payout ratio is calculated by dividing the monthly cash dividend by the sum of the cash dividend and the fund's NAV. A fund's quarterly expense ratio is calculate by dividing its SG&A by the total NAV (total NAV is NAV per share times the number of shares outstanding). A fund's quarterly leverage ratio is calculated by dividing

[31] We compare our premium and NAV data with a more limited sample available through COMPUSTAT and find that the average discrepancy is negligible but the standard deviation of the discrepancy is 3%.

the difference between total assets and total NAV by the total assets. For each fund, the quarterly expense ratio and leverage are interpolated to create a monthly time series. The IPO month for each fund is calculated to be the earlier date documented by Morningstar or COMPUSTAT (if a date is available from both sources). When analyzing the number of IPOs per year or per month (see Table 1, Figure 1, and the IPO Tobit regressions), we count the first month of trade on CRSP as the IPO month for funds without IPO data. On the other hand, when calculating the IPO month for the purpose of deducing the median fund age or the average time to discount, we only use funds for which Morningstar or COMPUSTAT IPO date data is available. A fund's age is calculated at each date based on the IPO month. The time to discount is determined by calculating the first month after the IPO month in which the premium is negative *and* is either also negative the following month or, if no data is available the following month, is below -2%. This is done to avoid noise in the calculation (see footnote 31). Moreover, if a fund never exhibits a discount, then the time to discount is taken to be the size of its time-series.

B Proof of Theorem 1

If $\rho_t \in (0, \bar{\rho})$, then regardless the value of x_t, there is only a single effective state variable – specifically, ρ_t. The differential equation satisfied by $\hat{V} \equiv \frac{\text{NAV}_t}{C_t}$ when $\rho_t \in (0, \bar{\rho})$ is given by

$$0 = \frac{\sigma^2 \rho^2}{2} \hat{V}_{\rho\rho} + \mu\rho\hat{V}_\rho - (\rho + r - g)\hat{V} + 1.$$

The homogeneous solution to this differential equation is

$$\alpha U_+(\rho) + \beta U_-(\rho)),$$

where

$$U_+(\rho) = \rho^{\frac{1}{2} - \frac{\mu}{\sigma^2}} I\Big(\sqrt{(1 - \frac{2\mu}{\sigma^2})^2 + 8\frac{r-g}{\sigma^2}}, \sqrt{\frac{8\rho}{\sigma^2}}\Big),$$

and

$$U_-(\rho) = \rho^{\frac{1}{2} - \frac{\mu}{\sigma^2}} K\Big(\sqrt{(1 - \frac{2\mu}{\sigma^2})^2 + 8\frac{r-g}{\sigma^2}}, \sqrt{\frac{8\rho}{\sigma^2}}\Big).$$

$I(\nu, y)$ and $K(\nu, y)$ are the modified Bessel functions of the first and second kind, respectively. U_+ increases, while U_- decreases, in its argument. Moreover, U_- is singular at the origin. The constants α and β are determined by the boundary conditions on the problem. The fact that the Wronskian, $W(K(\nu, y), I(\nu, y)) = \frac{1}{y}$, can be used to show that the Green's Function associated with the homogeneous differential equation is

$$G(\rho,\rho') = \begin{cases} \frac{4}{\sigma^2}U_+(\rho)\rho'^{\frac{2\mu}{\sigma^2}-2}U_-(\rho') & \rho \le \rho', \\ \frac{4}{\sigma^2}U_-(\rho)\rho'^{\frac{2\mu}{\sigma^2}-2}U_+(\rho') & \rho \ge \rho'. \end{cases}$$

A particular solution to the differential equation for $\hat{V}$ is therefore, $\int_0^{\bar{\rho}} G(\rho,\rho')d\rho'$:

$$\frac{4}{\sigma^2}U_+(\rho)\int_\rho^{\bar{\rho}} \rho'^{\frac{2\mu}{\sigma^2}-2}U_-(\rho')d\rho' + \frac{4}{\sigma^2}U_-(\rho)\int_0^{\rho} \rho'^{\frac{2\mu}{\sigma^2}-2}U_+(\rho')d\rho'.$$

One now adds a solution to the homogeneous differential equation which makes the sum satisfy appropriate boundary conditions. In other words the general solution in $\rho_t \in (0,\bar{\rho})$ is

$$\hat{V} = \frac{4}{\sigma^2}U_+(\rho)\Big(\alpha + \int_\rho^{\bar{\rho}} \rho'^{\frac{2\mu}{\sigma^2}-2}U_-(\rho')d\rho'\Big) + \frac{4}{\sigma^2}U_-(\rho)\Big(\beta + \int_0^{\rho} \rho'^{\frac{2\mu}{\sigma^2}-2}U_+(\rho')d\rho'\Big)$$

The following reflecting boundary conditions must be imposed in order to 'paste' the solutions in the regions together (see Dumas (1991)): $\hat{V}_\rho(0) = \hat{V}_\rho(\bar{\rho}) = 0$. Implementing these conditions gives the following, under the assumption that $\frac{\mu}{\sigma^2} \gg 1$:

$$\beta = 0, \qquad \alpha = -\frac{U'_-(\bar{\rho})}{U'_+(\bar{\rho})}\int_0^{\bar{\rho}} \rho'^{\frac{2\mu}{\sigma^2}-2}U_+(\rho')d\rho'$$

Substituting this, one gets

$$\hat{V}(\rho_t) = \frac{4}{\sigma^2}U_+(\rho_t)\Big(\int_\rho^{\bar{\rho}} \rho'^{\frac{2\mu}{\sigma^2}-2}U_-(\rho')d\rho' - \frac{U'_-(\bar{\rho})}{U'_+(\bar{\rho})}\int_0^{\bar{\rho}} \rho'^{\frac{2\mu}{\sigma^2}-2}U_+(\rho')d\rho'\Big) + \frac{4}{\sigma^2}U_-(\rho)\int_0^{\rho} \rho'^{\frac{2\mu}{\sigma^2}-2}U_+(\rho')d\rho'$$

□

C Proof of Theorem 2

First note that if $K \ge k$ then no CEF ever liquidates. Thus one only needs to worry about the entry of CEFs. Entry can only happen if the value of a managed fund exceeds $1+u$ times the value of its underlying assets. To show (8) describes an equilibrium process with $\bar{\rho}$ described in the Theorem, consider that (8) describes a reflected Brownian motion in $[0,\bar{\rho}]$. Taking this process as given, Theorem 1 gives the value of the underlying asset. $\hat{V}(\rho_t)$ is monotonically decreasing, and $\hat{V}(0) = \frac{1}{r-g}$. Moreover, from the asymptotic expansion of the

Bessel functions and their integral, $\hat{V}(\bar{\rho}) \to 0$ as $\bar{\rho} \to \infty$. Thus the equation

$$\frac{1-k}{r-g} = \hat{V}(\bar{\rho})(1+u)$$

has a unique solution if at least one of k and u is strictly positive.

Thus, if all stake holders take the process ρ_t as given, then CEF entry takes place only at $\rho_t = \bar{\rho}$. Moreover, at this value, firms are indifferent between entering and not entering. If all CEFs enter at $\rho_t = \bar{\rho}$ then $x_{t^+} = 1$ which is inconsistent with the posited process. On the other hand, if no CEF enters, then $\rho_t = \rho_t^f(1 - x_t)$ does not get reflected at $\rho_t = \bar{\rho}$. Thus a consistent equilibrium strategy must be mixed. To derive the equilibrium strategy, consider that $dx_t = \frac{1}{q'(x_t)} d\frac{\bar{\rho}}{s_t^f}$ is the increase in the amount of illiquid asset under CEF management. Given that there are $1 - x_t$ units of CEFs that could potentially enter, if each unit enters with probability $\bar{\rho}\frac{1}{1-x_t}\frac{1}{q'(x_t)}d\frac{1}{s_t}$, then the total amount of entry is $\bar{\rho}\frac{1}{q'(x_t)}d\frac{1}{s_t} = dx_t$, as required. Summarizing: ρ_t is an equilibrium supported by a mixed-strategy entry policy. □

In the text we remark that, in view of Assumption 6, the proportion of illiquid asset under CEF management can never decrease with time. We also remark that the model can be readily re-interpreted so as to do away with this peculiar feature. To see this, define

$$Q_t = \bar{\rho}\frac{y_t}{\max\{\bar{\rho}, \sup_{\tau \le t} \rho_t^f y_t\}}$$

where y_t is Brownian motion (as is ρ_t^f) and $\frac{d(\rho_t^f y_t)}{\rho_t^f y_t} = \mu\, dt + \sigma\, dW_t$. Then our results are the same if one writes $\rho_t = \rho_t^f Q_t$. Here, Q_t can be viewed as a monotonically increasing transform of the supply of the asset. Moreover, our original assumptions can be recovered by setting $y_t = 1$ for all t. Under this re-definition, the supply of illiquid asset no longer weakly decreases with time.

D Proof of Theorem 3

The probability density function for ρ_t, if it is stationary, can be derived from the Fokker-Planck equation:

$$\frac{\partial^2}{\partial\rho^2}\Big(\frac{\sigma^2\rho^2}{2}f(\rho)\Big) - \frac{\partial}{\partial\rho}\Big(\mu\rho f(\rho)\Big) = 0$$

The solution to this equation is $f(\rho) = \frac{A}{\rho} + B\rho^{2(\mu-\sigma^2)/\sigma^2}$. Since the cumulative distribution should vanish at $\rho = 0$ for a stationary process (i.e., recall 0 is an absorbing barrier), stationarity requires $2\mu > \sigma^2$. In addition, the integral of $f(\rho)$ between 0 and $\bar{\rho}$ is unity, so the solution is

$$f(\rho) = \frac{\gamma}{\rho}\Big(\frac{\rho}{\bar\rho}\Big)^{\gamma}.$$

where $\gamma = 2\mu/\sigma^2 - 1$. The cumulative distribution function, $F(\rho)$ follows from integrating $f(\rho)$.

To calculate the expected time to reversion from an IPO, consider the pricing of a perpetual barrier option that pays \$1 when the reflected process ρ_t falls below the level ρ_0 and assuming the interest rate is α. The value of such a security can be written as $W(\rho_t) = E_t[e^{-\alpha\tau}]$ where $\tau = \inf_{t\leq t'\leq\infty}\{t' \mid \rho_{t'} \leq \rho_0\}$ is a stochastic hitting time. The expected time that it takes for ρ_t to get to ρ_0 is defined as $T(\rho_t, \rho_0) \equiv -\frac{\partial W(\rho_t)}{\partial\alpha}|_{\alpha=0}$. To find this expression, we note that for $\rho_0 < x < \bar\rho$, $W(x)$ is a solution to the equation

$$\frac{\sigma^2 x^2}{2}\frac{\partial^2 W}{\partial x^2} + \mu x\frac{\partial W_t}{\partial x} - \alpha W_t = 0$$

with the value matching boundary conditions $W(\rho_0) = 1$ and the reflecting barrier condition $W'(\bar\rho) = 0$. The general solution is $W(x) = A_+x^{\gamma_+} + A_-x^{\gamma_-}$ where $\gamma_\pm = \big(-\gamma \pm \sqrt{\gamma^2 + 8\alpha/\sigma^2}\big)/2$. Note that for $\alpha > 0$, $\gamma_- < 0 < \gamma_+$. Imposing the boundary conditions and solving for $A_\pm$ gives

$$W(\rho_t) = \frac{\gamma_+\Big(\frac{\rho_t}{\bar\rho}\Big)^{\gamma_-} - \gamma_-\Big(\frac{\rho_t}{\bar\rho}\Big)^{\gamma_+}}{\gamma_+\Big(\frac{\rho_0}{\bar\rho}\Big)^{\gamma_-} - \gamma_-\Big(\frac{\rho_0}{\bar\rho}\Big)^{\gamma_+}}$$

To calculate the hitting time from $\rho_t = \bar\rho$, we differentiate $W(\rho_t)$ with respect to α and set $\alpha = 0$ and $\rho_t = \bar\rho$. After some manipulation one arrives at our expression for $T(\rho_0) = T(\bar\rho, \rho_0)$.

To work out the distribution of ρ_t a time t after the IPO, note that the the joint distribution density for the maximum and level (m and b, respectively) of a Brownian Motion process with drift θ is given by

$$\frac{2(2m-b)}{\sqrt{2\pi t^3}}\exp\Big(-\frac{(2m-b)^2}{2t} + \theta b - \frac{1}{2}\theta^2 t\Big)$$

where initially, $m_0 = 0 = b_0$, and $m > 0, b < m$.[32] Letting $\theta \equiv \frac{\mu}{\sigma} - \frac{\sigma}{2}$, the liquidity premium ρ_t can be written as $\rho_t = \bar\rho e^{\sigma(b_t - m_t)}$ (assuming the IPO took place at $t = 0$). Thus the expectation over any function of ρ_t given $t = 0$ information can be calculated by integrating over the distribution function. The expression in the theorem is calculated by making the change of variables $u = \frac{m+b}{\sqrt{2}}$ and $v = \frac{m-b}{\sqrt{2}}$ and computing the integral over u. □

[32]See Theorem 7.2.1 in Shreve (2004).

References

Acemoglu, D., and A. Scott, 1994, Consumer confidence and rational expectations: Are agents' beliefs consistent with the theory, *Economic Journal* 104, 1–19.

Admati, A. R., and P. Pfleiderer, 1988, A theory of intraday patterns: Volume and price variability, *Review of Financial Studies* 1, 3–40.

Almazan, A., K. C. Brown, M. Carlson, and D. A. Chapman, 2004, Why constrain your mutual fund manager?, *Journal of Financial Economics* 73, 289–321.

Amihud, Y., H. Mendelson, and L. H. Pedersen, 2005, Liquidity and asset prices, *Foundations and Trends in Finance* 1, 269–364.

Berk, J. B., and R. H. Stanton, 2006, Managerial ability, compensation, and the closed-end fund discount, Working paper, U.C. Berkeley, forthcoming, *Journal of Finance*.

Bonser-Neal, C., G. Bauer, R. Neal, and S. Wheatley, 1990, International investment restrictions and closed-end country fund prices, *Journal of Finance* 45, 523–547.

Bradley, M., A. Brav, I. Goldstein, and W. Jiang, 2005, Costly communication, shareholder activism, and limits to arbitrage, Working paper, Duke University.

Bram, J., and S. Ludvigson, 1998, Does consumer confidence forecast household expenditure? a sentiment index horse race, *FRBNY Economic Policy* 59–78.

Brown, G. W., and M. T. Cliff, 2004, Investor sentiment and the near-term stock market, *Journal of Empirical Finance* 11, 1–27.

Carroll, C. D., J. C. Fuhrer, and D. W. Wilcox, 1994, Does consumer sentiment forecast household spending? If so, why?, *American Economic Review* 84, 1397–1408.

Chan, J., R. Jain, and Y. Xia, 2005, Market segmentation, liquidity spillover, and closed-end country fund discounts, Working paper, University of Pennsylvania.

Chay, J.-B., and C. A. Trzcinka, 1999, Managerial performance and the cross-sectional pricing of closed-end funds, *Journal of Financial Economics* 52, 379–408.

Cherkes, M., 2003, A positive theory of closed-end funds as an investment vehicle, Working paper, Princeton University.

Chordia, T., A. Sarkar, and A. Subrahmanyam, 2005, Liquidity dynamics and cross-autocorrelations, Working paper, Emory University.

Chordia, T., 1996, The structure of mutual fund charges, *Journal of Financial Economics* 41, 3–39.

Datar, V., 2001, Impact of liquidity on premia/discounts in closed-end funds, *Quarterly Review of Economics and Finance* 41, 119–135.

Deli, D. N., and R. Varma, 2002, Closed-end vs. open-end: The choice of organizational form, *Journal of Corporate Finance* 8, 1–27.

DeLong, B., A. Shleifer, L. Summers, and R. Waldman, 1990, Noise trader risk in financial markets, *Journal of Political Economy* 98, 703–738.

DeMarzo, P., 2005, The pooling and tranching of securities: A model of informed intermediation, *Review of Financial Studies* 18, 1–35.

Diamond, D. W., and P. H. Dybvig, 1983, Bank runs, deposit insurance and liquidity, *Journal of Political Economy* 91, 401–419.

Dimson, E., and B. Hanke, 2004, The expected illiquidity premium: Evidence from equity index-linked bonds, *Review of Finance* 8, 19–47.

Dimson, E., and C. Minio-Paluello, 2002, *The Closed-End Fund Discount* (Association for Investment Management and Research, Charlottesville, Virginia).

Dixit, A., 1989, Entry and exit decisions under uncertainty, *Journal of Political Economy* 97, 620–638.

Duffie, D., N. Gârleanu, and L. H. Pedersen, 2005, Over-the-counter markets, *Econometrica* 73, 1815–1847.

Dumas, B., 1991, Super contact and related optimality conditions, *Journal of Economic Dynamics and Control* 15, 675–685.

Edelen, R., 1999, Investor flows and the assessed performance of open-end mutual funds, *Journal of Financial Economics* 53, 439–466.

Edwards, A. K., L. Harris, and M. S. Piwowar, 2006, Corporate bond market transparency and transaction costs, Working paper, Securities and Exchange Commission, forthcoming, *Journal of Finance*.

Eisfeldt, A. L., 2004, Endogenous liquidity in asset markets, *Journal of Finance* 59, 1–30.

Fama, E. F., and M. C. Jensen, 1983, Agency problems and residual claims, *Journal of Law and Economics* 26, 327–349.

Fisher, K. L., and M. Statman, 2003, Consumer confidence and stock returns, *Journal of Portfolio Management* 30, 115–127.

Foster, F. D., and S. Viswanathan, 1990, A theory of the interday variations in volume, variance, and trading costs in securities markets, *Review of Financial Studies* 3, 593–624.

Gastineau, G. L., 2001, Exchange-traded funds: An introduction, *Journal of Portfolio Management* 27, 88–96.

Gemmill, G., and D. C. Thomas, 2002, Noise trading, costly arbitrage, and asset prices: Evidence from closed-end funds, *Journal of Finance* 57, 2571–2594.

Glaeser, E. L., and H. D. Kallal, 1997, Thin markets, asymmetric information, and mortgage-backed securities, *Journal of Financial Intermediation* 6, 64–86.

Green, R. C., B. Hollifield, and N. Schürhoff, 2004, Financial intermediation and the costs of trading in an opaque market, Working paper, Carnegie Mellon.

Green, R. C., 1993, A simple model of the taxable and tax-exempt yield curves, *Review of Financial Studies* 6, 233–264.

Grenadier, S. R., 2002, Option exercise games: An application to the equilibrium investment strategies of firms, *Review of Financial Studies* 15, 691–721.

Harris, L. E., and M. S. Piwowar, 2006, Secondary trading costs in the municipal bond market, *Journal of Finance* 61, 1361–1397.

Ho, T. S. Y., and H. R. Stoll, 1983, The dynamics of dealer markets under competition, *Journal of Finance* 38, 1053–1074.

Ingersoll, J. E., Jr., 1976, A theoretical and empirical investigation of the dual purpose funds, *Journal of Financial Economics* 3, 83–123.

Lee, C. M. C., A. Shleifer, and R. H. Thaler, 1991, Investor sentiment and the closed-end fund puzzle, *Journal of Finance* 46, 76–110.

Lemmon, M., and E. Portniaguina, 2006, Consumer confidence and asset prices: Some empirical evidence, Working paper, University of Utah, forthcoming, *Review of Financial Studies*.

Levis, M., and D. Thomas, 1995, Investment trust IPOs: Issuing behavior and price performance. Evidence from the London Stock Exchange, *Journal of Banking and Finance* 19, 1437–1458.

Longstaff, F. A., S. Mithal, and E. Neis, 2005, Corporate yield spreads: Default risk or liquidity? New evidence from the credit default swap market, *Journal of Finance* 60, 2213–2253.

Longstaff, F. A., 2004, The flight-to-liquidity premium in U.S. Treasury bond prices, *Journal of Business* 77, 511–526.

Ludvigson, S. C., 2004, Consumer confidence and consumer spending, *Journal of Economic Perspectives* 18, 29–50.

Manzler, D., 2005, Liquidity, liquidity risk and the closed-end fund discount, Working paper, University of Cincinnati.

Nanda, V., M. P. Narayanan, and V. A. Warther, 2000, Liquidity, investment ability, and mutual fund structure, *Journal of Financial Economics* 57, 417–443.

O'Hara, M., 2004, Liquidity and financial market stability, Working paper, National Bank of Belgium.

Pástor, Ľ., and R. F. Stambaugh, 2003, Liquidity risk and expected stock returns, *Journal of Political Economy* 111, 642–685.

Peavy, J. W., III, 1990, Returns on initial public offerings of closed-end funds, *Review of Financial Studies* 3, 695–708.

Pontiff, J., 1996, Costly arbitrage: Evidence from closed-end funds, *Quarterly Journal of Economics* 111, 1135–1151.

Qiu, L., and I. Welch, 2006, Investor sentiment measures, Working paper, Brown University.

Roll, R., 1984, A simple implicit measure of the effective bid-ask spread in an efficient market, *Journal of Finance* 39, 1127–1139.

Ross, S. A., 2002a, Neoclassical finance, alternative finance and the closed-end fund puzzle, *European Financial Management* 8, 129–137.

Ross, S. A., 2002b, A neoclassical look at behavioral finance; closed-end funds, Princeton Lectures in Finance III.

Sadka, R., 2006, Momentum and post-earnings-announcement drift anomalies: The role of liquidity risk, *Journal of Financial Economics* 80, 309–349.

Sharpe, W. F., and H. B. Sosin, 1975, Closed-end investment companies in the United States: Risk and return, in B. Jacquillat, ed., *European Finance Association 1974 Proceedings*, 37–63 (North Holland, Amsterdam).

Shreve, S. E., 2004, *Stochastic Calculus for Finance II – Continuous-Time Models* (Springer, New York).

Spiegel, M., 1999, Closed-end fund discounts in a rational agent economy, Working paper, Yale University.

Stoll, H. R., 2000, Friction, *Journal of Finance* 55, 1479–1514.

Weiss Hanley, K., C. M. C. Lee, and P. J. Seguin, 1996, The marketing of closed-end fund IPOs: Evidence from transaction data, *Journal of Financial Intermediation* 5, 127–159.

Weiss, K., 1989, The post-offering price performance of closed-end funds, *Financial Management* Autumn, 57–67.

Wermers, R., Y. Wu, and J. Zechner, 2005, Portfolio performance, discount dynamics, and the turnover of closed-end fund managers, Working paper, University of Maryland.

Whaley, R. E., 2000, The investor fear gauge, *Journal of Portfolio Management* 26, 12–17.

Zweig, M. E., 1973, An investor expectations stock price predictive model using closed-end fund premiums, *Journal of Finance* 28, 67–87.