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Intermediary Asset Pricing and the Financial Crisis

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Abstract

Intermediary asset pricing understands asset prices and risk premia through the lens of frictions in financial intermediation. Perhaps motivated by phenomena in the financial crisis, intermediary asset pricing has been one of the fastest-growing areas of research in finance. This article explains the theory behind intermediary asset pricing and, in particular, how it is different from other approaches to asset pricing. This article also covers selective empirical evidence in favor of intermediary asset pricing.

1. INTRODUCTION

This article aims to introduce the reader to the growing literature on intermediary asset pricing, which links movements in asset prices and risk premia to frictions in financial intermediation. In classical approaches to asset pricing, as presented in the well-known paper by Fama (1980), intermediaries satisfy the assumptions of the Modigliani–Miller theorem and are a veil. Asset prices reflect the tastes and shocks of households that may invest in asset markets through intermediaries but are the ultimate owners of all assets. However, the performance of many asset markets—e.g., prices of mortgage-backed securities, corporate bonds, and derivative securities—depends on the financial health of the intermediary sector, broadly defined to include traditional commercial banks as well as investment banks and hedge funds. The 2008 financial crisis and the 1998 hedge-fund crisis are two compelling data points in support of this claim. Phenomena in the 2008 crisis in particular have called the veil hypothesis into question and motivated the study of intermediary asset pricing.

This article clarifies the theoretical underpinnings of intermediary asset pricing. What does it take to break the veil hypothesis and justify an intermediary pricing kernel? It is commonplace to argue for intermediary asset pricing in certain markets by asserting that, because trade is dominated by intermediaries, these intermediaries must be marginal. But any asset holder not at a corner in his or her portfolio choice is marginal. So what is the content of intermediary asset pricing, and does intermediary asset pricing refute traditional consumption-based asset pricing? We provide answers to these questions in Section 2, which builds a simple intermediary asset pricing model.

Sections 3 and 4 review a small group of papers that are evidence in favor of intermediary asset pricing. The paper review is not exhaustive. Our purpose is to highlight different approaches to testing intermediary asset pricing theories and to discuss the advantages and drawbacks of these approaches.

This article is an introduction to intermediary asset pricing that can be understood by anyone who has completed the first year of graduate-level work in finance. It is not a comprehensive survey of the area. For a survey on asset market illiquidity and financial crises, see Amihud, Mendelson & Pedersen (2012). There are connections between intermediary frictions and macroeconomics that are important and interesting but omitted in this article. Brunnermeier, Eisenbach & Sannikov (2013) provide a survey of financial frictions and macroeconomic activity. Two influential papers that make the case for intermediary asset pricing are Allen's (2001) presidential address to the American Finance Association and Duffie's (2010) presidential address to the same body.

2. THEORY

The basic ingredients needed for a well-defined model of intermediary asset pricing are as follows. We have an intermediary sector and a household sector. The household sector, or some part of the sector, does not directly invest in some intermediated assets. Instead, it delegates investments in these assets to the intermediary sector. Contracting frictions in the intermediary mean that such delegation is not a veil. This leads to a pricing expression for the intermediated assets that depends on intermediary frictions and drives a wedge between the household and intermediary valuations of assets.

A central assumption is that there is limited participation by the households in a set of assets. This assumption implies that households are not marginal in pricing these assets. In other words, as we show more formally, their Euler equation does not apply to the pricing of intermediated assets, which opens the door to studying intermediary asset pricing. We can motivate this assumption in two ways. It may be that households lack the knowledge necessary to invest in complex assets (e.g., credit-card asset-backed securities) and hence delegate investments to intermediaries. This is the leading motivation in this article. But the assumption, albeit in a different form, may also apply in markets where households have some knowledge, such as the equity market. In these markets, many investors evaluate their consumption and portfolio holdings decisions only infrequently. If households rebalance in a coordinated fashion, say at the end of the tax year, then a standard representative-agent consumption capital asset pricing model (CAPM) may apply only on these infrequent dates [as documented by Jagannathan & Wang (2007), who show that a consumption CAPM holds for December–December equity returns] rather than on all dates. (For a model of infrequent portfolio choices, see also Abel, Eberly & Panageas 2013). In contrast, since intermediaries are marginal on all dates, intermediary pricing applies on all dates, and there is a wedge on some dates. The wedge may be higher at some times and for some assets. We clarify these points in the formal model.

As suggested by our motivation of limited participation by households in complex asset markets or of annual portfolio rebalancing by households, the intermediary asset pricing phenomena with which we are concerned may persist for many months, or even years. Household Euler equations may not apply for long periods of time. We are concerned not with the high-frequency asset price swings of market microstructure research, but with much lower-frequency phenomena. The empirical evidence in Section 3 illustrates this point.

2.1. Model

We consider a two-period ($t = 0, 1$) constant absolute risk aversion (CARA)-normal model with only one risky asset. In Section 2.7, we extend the model to the multiasset case. The risky asset pays out $\widetilde{D} \sim \mathcal{N}(\mu, \sigma^2)$ per share at date 1. The exogenous gross interest rate is $1 + r$. The aggregate supply of the risky asset is θ.

There is a unit mass of two classes of identical agents: intermediary managers (indicated by M) and households (indicated by H). Both agents have CARA preferences over their wealth at date 1. We denote the risk tolerance (the inverse of the coefficient of absolute risk aversion) of managers by ρ_{M} and the risk tolerance of households by ρ_{H}. Thus, agents maximize the objective

$$u_i(W_1^i) = -\exp\left\{-\frac{W_1^i}{\rho_i}\right\},$$

with $i \in \{\mathrm{H}, \mathrm{M}\}$ and W_1^i denoting the wealth at date 1.

By assumption, households cannot directly invest in the market for the risky asset at date 0. For example, the risky asset may be a credit-card asset-backed security, which requires specialized knowledge to value. Intermediary managers have the knowledge to invest in such an asset. This creates scope for intermediation. Households can give some of the wealth to intermediary managers, who invest in the risky asset on their behalf. In Section 2.7, we extend the model to include sophisticated households that are able to invest directly in the risky asset and bypass intermediaries.

2.2. Principal-Agent Problem

We assume that intermediation is not frictionless. Following He & Krishnamurthy (2012, 2013), we assume that households can contract with managers to invest on their behalf in the risky asset, but subject to a moral hazard friction. Frictions in intermediation are central to intermediary asset pricing and distinguish the approach from models with heterogeneous agents such as those of Dumas (1989) and Wang (1996), where agents differ in their risk aversion but otherwise trade in markets that are complete and frictionless. We discuss the difference further below.

An intermediary manager who manages the fund chooses a quantity of risky assets to buy, x_F, and makes a due diligence decision when making investments, $s \in \{0, 1\}$. If the manager chooses to shirk, setting $s = 0$, the intermediary return falls by Δ and the manager gains a private benefit of b. We can think of shirking as capturing actions such as trading inefficiently in a manner that reduces the fund's return. Throughout our analysis, we assume that parameters are such that it is optimal to write a contract that prevents shirking (i.e., shirking is socially costly). Households cannot directly observe the due diligence decision and must provide incentives to the manager to not shirk. We assume that households and managers sign an affine contract parameterized by (K, ϕ), where ϕ is the linear share of the return generated by the fund that is paid to the manager, and K is a management fee that is paid to the manager and is independent of the fund's return. In general, K will depend on the market protocols according to which households and managers form intermediaries. For example, in a search market, K will be affected by the bargaining powers of the parties, whereas in a Walrasian market, K will be based on the supply of intermediary managers. He & Krishnamurthy (2012, 2013) investigate these different cases. In our present CARA setting, the lack of a wealth effect implies that the fee K plays no role in asset demands and equilibrium prices. We therefore dispense with K, setting it to zero without loss of generality.

A manager with contract ϕ solves

$$\max_{x_F, s \in \{0,1\}} - \exp\left[-\frac{1}{\rho_M}\left(\phi\left\{x_F\left[\widetilde{D} - (1+r)p\right] - s\Delta\right\} + sb\right)\right],$$

which, since $\widetilde{D}$ is normally distributed, is equivalent to the following standard mean-variance optimization:

$$\max_{x_F, s \in \{0,1\}} \phi\left\{x_F[\mu - p(1+r)] - s\Delta\right\} - \frac{x_F^2\phi^2\sigma^2}{2\rho_M} + sb. \tag{1}$$

The first term is the expected excess return on purchasing x_F units of the risky asset and receiving a share ϕ of the expected return. The asset pays a mean dividend of μ and is purchased at price p. The one-period interest rate is $1 + r$. If the manager shirks, the fund's return falls by Δ. The second term is the penalty for risk, which is proportional to the variance of the payoff to the risky asset investment and is inversely proportional to ρ_M, the risk tolerance of the manager. These terms are all familiar from the textbook treatment of portfolio choice in the CARA-normal setting. The last term captures the manager's private benefit from shirking due to moral hazard.

2.3. Incentive Compatibility and Equity Capital Constraint

This section derives an equity capital constraint that arises from the incentive compatibility constraint in the above contracting problem. The manager's effective holdings of the risky asset when the manager chooses x_F and receives a share ϕ of the fund's return are

$$x_M = \phi x_F, \tag{2}$$

while the household's effective holdings are

$$x_H = x_F(1 - \phi). \tag{3}$$

We can interpret these effective holdings in terms of the financing of an intermediary. The manager and household set up an intermediary, each contributing a fraction of the intermediary's equity capital. For each ϕ dollars the manager puts in, the household-investor puts in $1 - \phi$ dollars; or, equivalently, for each one dollar the manager puts in, the household-investor puts in $(1 - \phi)/\phi$ dollars. The manager and investors share in the return generated by the intermediary in proportion to their ownership of the equity of the fund.

The incentive compatibility constraint to implement working ($s = 0$) in Equation 1 is

$$\phi\Delta \geq b \;\Rightarrow\; \phi \geq \frac{b}{\Delta}. \qquad 4.$$

In words, managers have to own a sufficiently large equity share of the intermediary to retain incentives not to shirk. Define

$$m \equiv \frac{1 - b/\Delta}{b/\Delta} = \frac{\Delta}{b} - 1.$$

Then m is the maximum amount of dollars of outside equity that investors are willing to purchase in an intermediary per dollar of equity that the manager purchases. If m is high (i.e., b is low, indicating a small agency friction), the manager can be incentivized with a small ϕ, i.e., with only a little skin in the game.

The above discussion implies that we can write the incentive compatibility constraint equivalently as an equity capital constraint,

$$\phi \geq \frac{1}{1+m}. \qquad 5.$$

From now on we refer to the primitive incentive compatibility constraint as an equity capital constraint.

2.4. Equilibrium Asset Price

We now derive equilibrium asset prices. It is useful to do so first in a frictionless economy to understand the effect of frictions. Suppose that households can fully participate in the risky asset market. Their demand for the risky asset is

$$x_{\mathrm{H}} = \rho_{\mathrm{H}} \frac{\mu - p(1+r)}{\sigma^2},$$

and market clearing requires that

$$x_{\mathrm{H}} + x_{\mathrm{M}} = \theta.$$

Solving, we find that

$$p = \frac{\mu}{1+r} - \left(\frac{1}{\rho_{\mathrm{H}} + \rho_{\mathrm{M}}} \times \frac{\theta\sigma^2}{1+r}\right). \qquad 6.$$

In our model with frictions, given the equity fraction ϕ to be determined endogenously shortly, the optimal portfolio solution x_{F} to the manager's problem in Equation 1 satisfies (recall Equation 2)

$$\phi x_{\mathrm{F}} = x_{\mathrm{M}} = \rho_{\mathrm{M}} \frac{\mu - p(1+r)}{\sigma^2}. \qquad 7.$$

Given this choice of x_{M}, the household's effective (i.e., via investment in the intermediary) holding of the risky asset is

$$x_{\mathrm{H}} = x_{\mathrm{F}}(1-\phi) = \frac{1-\phi}{\phi} \rho_{\mathrm{M}} \frac{\mu - p(1+r)}{\sigma^2}. \qquad 8.$$

The same market clearing condition implies

$$p = \frac{\mu}{1+r} - \left(\frac{\phi}{\rho_{\mathrm{M}}} \times \frac{\theta\sigma^2}{1+r}\right). \qquad 9.$$

Comparing Equation 9 with Equation 6, we see that the frictionless economy requires an equity share of

$$\phi = \frac{\rho_M}{\rho_M + \rho_H}. \qquad 10.$$

This is intuitive. In the frictionless benchmark, each agent owns the risky asset according to that agent's risk tolerance, with managers owning $\rho_M/(\rho_M + \rho_H)$ of the risky asset. In the equilibrium of the frictionless benchmark, both agents' risk tolerance parameters determine the asset price, as in Equation 6.

To understand the impact of frictions, suppose that ρ_M is low relative to ρ_H; in other words, managers are relatively risk averse. Then, with moral hazard, we see that the frictionless equity share may violate the equity constraint in Equation 5:

$$\phi = \frac{\rho_M}{\rho_M + \rho_H} \geq \frac{1}{1+m}.$$

That is, the frictionless risk allocation may not be achievable given the incentive compatibility constraint implied by the moral hazard friction. Rearranging, we say that when

$$m \geq \frac{\rho_H}{\rho_M}, \qquad 11.$$

intermediation is a veil. When this condition is violated, intermediation is not a veil and intermediary financing frictions affect asset prices. These results are summarized in the following proposition.

Proposition 1. *The equilibrium asset price, p, solves*

$$p = \begin{cases} \dfrac{\mu}{1+r} - \dfrac{\theta\sigma^2}{(1+r)\,(1+m)\rho_M} & \text{if } m = \dfrac{\Delta}{b} - 1 \leq \dfrac{\rho_H}{\rho_M}, \\ \dfrac{\mu}{1+r} - \dfrac{\theta\sigma^2}{(1+r)\,(\rho_M+\rho_H)} & \text{otherwise.} \end{cases} \qquad 12.$$

Here, the first term, $\mu/(1+r)$, is the expected value of the asset. The second term is the risk discount, which is proportional to the asset supply, θ, and the risk, σ^2. From the first line, we see that when m is small, intermediary frictions are tight and the risk discount is large and increasing in the intermediary frictions (i.e., falling m). From the second line, we see that when m is large enough, intermediary frictions do not affect prices.

2.5. Intermediation Shocks

In the world, shocks to intermediation may affect asset prices. Such shocks can be decreases in intermediary capital caused by losses; by investor withdrawals; or by increases in the complexity of intermediary investments, which worsen the moral hazard friction. There is considerable empirical evidence (which we review in Section 3) that such effects were present in the financial crisis. Indeed, the model implies that shocks to intermediation should especially affect asset prices during financial crises. To see this, take the case of an increase in moral hazard, corresponding to a decrease in m. During the crisis, given the complexity of the investment environment, it is likely that delegation became harder, increasing b and hence decreasing m. A decrease in m lowers the risk asset price p only if $m \leq \rho_H/\rho_M$, so that the equity constraint binds. When m is high (i.e., b is small), so that $m > \rho_H/\rho_M$, changes in m have no effect on p. This nonlinearity is a central feature of the intermediary asset pricing model of He & Krishnamurthy (2012, 2013).[1] Indeed, it is one clear distinction between the intermediary pricing model and the two-agent model of Dumas (1989). From Proposition 1, when m is very large (no frictions), we see that the asset price reflects the average risk tolerance of agents in the economy. In a two-agent model such as that of Dumas (1989), this average risk tolerance is a function of the relative wealth of the two agents in the economy, which is a slow-moving state variable. There is no notion of a constraint, so the mechanism linking relative wealth and asset returns works in the same manner throughout the state space, rather than particularly sharply in some parts of the state space. Thus, this approach does not lead to the nonlinearity that is evidently a feature of financial crises. Additionally, phenomena such as increases in moral hazard or complexity of assets play no role in such a model.

He & Krishnamurthy (2012, 2013) show that shocks to the manager's wealth, which can be interpreted as capital shocks, impact asset prices in a nonlinear fashion. Capital shocks have no role in the present analysis because agents have CARA utility and wealth effects are absent. In a model with constant relative risk aversion preferences, we will have such effects, and we can see how such effects work by considering a local approximation. The agent's absolute risk aversion, $1/\rho_{\mathrm{M}}$, is related to the coefficient of relative risk aversion, γ, via wealth:

$$\frac{1}{\rho_{\mathrm{M}}} = \frac{\gamma}{W_{\mathrm{M}}}.$$

A fall in W_{M} translates to a fall in ρ_{M}. Then from our analysis of the CARA model, such a change will lead the equilibrium asset price p to fall. While this wealth effect will be present both when intermediation is constrained and when it is not, the effect is larger when intermediation is constrained.

More formally, we can see the wealth effects as follows. When the equity constraint binds, the Sharpe ratio of the asset, denoted by SR, is given by

$$\mathrm{SR} = \frac{\mathbb{E}\left[(\widetilde{D}-p)/p\right]-r}{\mathrm{Std}\left[(\widetilde{D}-p)/p\right]} = \frac{\mu/p-1-r}{\sigma/p} = \frac{\mu-p(1+r)}{\sigma} = \frac{\theta\sigma}{(1+m)\rho_{\mathrm{M}}}.$$

In fact, we can relate the Sharpe ratio to the coefficient of relative risk aversion as follows:

$$\mathrm{SR} = \underbrace{\frac{1}{\rho_{\mathrm{M}}}}_{\substack{\text{Absolute}\\ \text{risk aversion}}} \times \underbrace{\frac{\theta\sigma}{1+m}}_{\substack{\text{Standard deviation}\\ \text{of dollar return}\\ \text{of } W_{1,\mathrm{M}}=\theta\widetilde{D}/(1+m)}} = \underbrace{\frac{1}{\rho_{\mathrm{M}}}W_{0,\mathrm{M}}}_{\substack{\text{Relative}\\ \text{risk aversion}}} \times \underbrace{\frac{\theta\sigma}{W_{0,\mathrm{I}}}}_{\substack{\text{Standard deviation}\\ \text{of percentage return}\\ \text{of } W_{1,\mathrm{I}}/W_{0,\mathrm{I}}}} = \frac{1}{\rho_{\mathrm{M}}}W_{0,\mathrm{M}} \times \frac{\sigma}{p}.$$

Here $W_{0,\mathrm{M}}$ represents the date-0 wealth of the manager, which is invested in the equity of the intermediary, and $W_{0,\mathrm{I}}$ is the date-0 total capital of the intermediary, which is equal to $W_{0,\mathrm{M}}(1+m)$ when the equity constraint binds. The date-0 capital of the intermediary is $W_{0,\mathrm{I}} = \theta p$, since the intermediary purchases all of the risky asset. The second equation clarifies that the price of risk is the coefficient of relative risk aversion of the marginal agent multiplied by the volatility of the marginal agent's wealth return.

[1]Models such as that of Allen & Gale (1994), which combine segmentation and cash-in-the-market pricing, deliver nonlinearity and have been useful frameworks to understand financial crises (see Allen & Gale 1998). But these models do not connect to the empirical asset pricing evidence that we discuss in Section 4. In particular, the evidence regards variation in the cross section of asset returns and ties such variation to an intermediary stochastic discount factor. Under the cash-in-the-market pricing model of Allen & Gale (1994), there is no variation in the cross section of expected returns across intermediated assets.

2.6. Regulatory Capital

In practice, financial intermediaries face regulatory capital constraints that may affect their demand for assets and impact asset prices. The effects of these constraints are similar to the wealth effects we have discussed. Whether or not they affect asset prices depends on financing frictions and whether intermediaries are a veil. The effects of shocks to capital are nonlinear and depend on whether or not capital constraints bind.[2]

To see these points, we extend our model. We have noted that the key incentive compatibility constraint (Equation 4) of the model can be interpreted in terms of the equity financing of an intermediary. The manager and household set up an intermediary by each contributing a fraction of the intermediary's capital. For each one dollar the manager puts in, the household investors put in at most $m = (1-\phi)/\phi$ dollars, so the manager's equity share ϕ never falls below $1/(1+m)$, as in Equation 5.

Suppose that a manager has wealth W_{M}, which the manager invests in an intermediary as equity. The total equity capital of the intermediary is E_{F}, subject to the equity constraint derived above,

$$E_{\mathrm{F}} \leq W_{\mathrm{M}}(1+m). \tag{13}$$

Suppose an intermediary purchases the risky asset and makes some commercial loans (indicated by L) to an unmodeled corporate sector. The portfolio is subject to the regulatory capital constraint

$$k_x p x_{\mathrm{F}} + k_{\mathrm{L}} x_{\mathrm{L}} \leq E_{\mathrm{F}}, \tag{14}$$

where k_x and k_{L} correspond to the capital charges on the risky asset and on loans in the spirit of Basel risk-based capital requirements.[3] Denote the Lagrange multiplier on Equation 14 by $\lambda_{\mathrm{RC}} \geq 0$.

Putting these two constraints in Equations 13 and 14 together, we have

$$\underbrace{k_x p x_{\mathrm{F}} + k_{\mathrm{L}} x_{\mathrm{L}} \leq E_{\mathrm{F}}}_{\substack{\text{Regulatory} \\ \text{capital constraint}}} \underbrace{\leq W_{\mathrm{M}}(1+m)}_{\substack{\text{Equity} \\ \text{capital constraint}}}. \tag{15}$$

Importantly, the capital requirement (the first inequality) binds only if the equity constraint (the second inequality) binds. In other words, $\lambda_{\mathrm{RC}} > 0$ only when $\phi = 1/(1+m)$, so that the equity constraint (Equation 5) binds. If the equity constraint remains slack, then intermediaries can raise equity capital from households to fund the investment in the risky asset, and households are willing to do so as long as the delegated investment in the risky asset is profitable. As a result, if the equity constraint is slack, no constraints will bind and we will again find that intermediation is a veil.[4]

The manager of the intermediary chooses holdings of the risky asset to maximize his objective subject to Equation 14. The optimization over x_{F} is

$$\max_{x_{\mathrm{F}}} x_{\mathrm{F}}[(\mu - p(1+r)] - \frac{\phi\sigma^2}{2\rho_{\mathrm{M}}} x_{\mathrm{F}}^2 - \lambda_{\mathrm{RC}} k_x x_{\mathrm{F}} p,$$

[2]It should be evident that the two-agent approach of Dumas (1989), for example, cannot speak to these regulatory capital effects. If an intermediary's regulatory capital constraint binds but intermediation is frictionless, so the Modigliani–Miller theorem applies, then the intermediary raises more equity capital and adjusts its capital structure so that the constraint is slack.

[3]One can think of the regulator as a principal, who, like the household, has a payoff that is tied to the manager's portfolio decisions. For example, the regulator may be concerned with a default externality and hence wants to limit intermediary risk and leverage. Then the regulatory constraint is also an incentive compatibility constraint on the manager that can be loosened if the manager has more equity capital.

[4]Note that if the equity capital constraint is slack, $E_F < W_m(1+m)$, then the optimal capital structure of the fund will have the manager choosing to invest in the equity of the fund and raising total equity of $E_F = w_m(1+\rho H/\rho_M)$. With this choice, the fund satisfies the regulatory capital constraint, the incentive compatibility constraint, and achieves the frictionless risk-sharing allocation.

where we are suppressing the optimization over x_L, as it plays a role in our analysis only via its influence on λ_{RC}. Recall that $\lambda_{RC} \geq 0$ is the Lagrange multiplier on the capital constraint (Equation 14), i.e., the return on equity of the intermediary. In purchasing a unit of the risky asset, if the constraint already binds, the intermediary needs to scale back a profitable loan to free up regulatory capital by $k_x x_F p$.

This optimization problem gives

$$\mu - p\,(1+r) - \frac{\phi\sigma^2}{\rho_M} x_F - \lambda_{RC} k_x p = 0 \;\Rightarrow\; x_F = \frac{\rho_M}{\phi\sigma^2}\left[\mu - p(1+r+\lambda_{RC}k_x)\right].$$

Imposing market clearing, we find the equilibrium price,

$$p = \frac{\mu}{1+r+\lambda_{RC}k_x} - \frac{\phi\sigma^2\theta}{(1+r+\lambda_{RC}k_x)\rho_M}, \qquad 16.$$

where $\phi = 1/(1+m)$ when Equation 5 binds and $\phi = \rho_H/(\rho_H + \rho_M)$ otherwise.

The supplementary leverage ratio (SLR) requirement, which is not risk based, corresponds to a requirement where k_x ($= k_L$) is constant and independent of asset characteristics. In this case, a tighter capital constraint (a higher λ_{RC}) amounts to an increase of the discount rate on the risky asset.

In the case of a risk-based capital requirement, k_x is proportional to risk, i.e., $k_x = k\sigma$ for some positive constant $k > 0$. For relatively small σ, the price expression allows for the approximation

$$p \approx (1 - \lambda_{RC}k\sigma)\left(\frac{\mu}{1+r} - \frac{\phi\sigma^2\theta}{(1+r)\rho_M}\right),$$

so that the equilibrium asset price reflects an additional compensation for risk.

We have shown that the equilibrium price is affected by the capital requirement ($\lambda_{RC} > 0$) only if the equity capital constraint binds. Moreover, as the Lagrange multiplier λ_{RC} on the regulatory capital constraint should increase with losses in equity capital E_F, the model extension with regulatory capital also implies nonlinear effects of shocks to capital on asset prices.

2.7. Multiple Assets and Households

We return to the basic model without the regulatory capital constraint and instead introduce a second asset into the model; it is straightforward to generalize to N assets. Asset $j \in \{1, 2\}$ has a date-1 risky payoff $\widetilde{D}_j \sim \mathcal{N}(\mu_j, \sigma_j^2)$. For simplicity, we assume that $\text{Cov}(\widetilde{D}_1, \widetilde{D}_2) = 0$. We assume that households can participate in asset market 2 but must go through intermediaries to invest in asset market 1. For example, asset market 1 is credit-card asset-backed securities and asset market 2 is the S&P 500 index. Mapping to our model, which puts underlying agency fictions at the asset level, another equivalent interpretation is that asset 1, potentially because of its sophisticated nature, has a relatively high agency friction b_1 (which gives rise to a low m_1), whereas there is much less (or zero) agency friction in asset 2 (and hence an arbitrary high m_2).

We also introduce a third class of agents, sophisticated households, who have CARA utility with risk tolerance ρ_S. We assume that these households can fully participate in all asset markets, but, unlike managers, they cannot set up intermediaries. Denote by x_i^j the demand for asset $j \in \{1, 2\}$ of agent $i \in \{H, S, M\}$.

In our CARA-normal framework, independent payoff distributions imply an independent demand system for each asset, and one can easily derive the equilibrium asset prices as presented in the following proposition. More importantly, the comparative statics results with respect to m, capital, and the nonlinear effects we have described continue to hold in the equilibrium with two assets.

Proposition 2. *Suppose that the intermediation constraint binds, i.e.,* $m_1 < \rho_H/\rho_M$; *then the asset market equilibrium is*

$$p_1 = \frac{\mu_1}{1+r} - \frac{\theta_1\sigma_1^2}{(1+r)[(1+m_1)\rho_M + \rho_S]}, \quad 17.$$

$$p_2 = \frac{\mu_2}{1+r} - \frac{\theta_2\sigma_2^2}{(1+r)(\rho_S + \rho_H + \rho_M)}. \quad 18.$$

The two-asset case illustrates one approach to testing intermediary asset pricing. Suppose that we have two similar assets, one of which is intermediated (asset 1) and one of which is not (asset 2), and we construct the spread $p_1 - p_2$. Suppose further that one can credibly identify a shock that increases intermediation frictions (a decrease in m_1 or ρ_M). Then the spread $p_1 - p_2$ should rise after this shock. This difference-in-difference strategy has been employed in a number of empirical papers documenting intermediary asset pricing effects in the crisis. We discuss some of these papers in Section 3.

2.8. Degree of Intermediation

We next describe how assets that are more intermediated will be affected by intermediary frictions. Suppose that the mass of the sophisticated households is S. We have derived price expressions for the case of $S = 1$, but it is straightforward to generalize the formulae. When the intermediary constraint binds, the risk premium on asset 1, which is denoted by $\Pi_1(m_1, \theta_1, S)$, is

$$\Pi_1(m_1, \theta_1, S) = \mu_1 - (1+r)p_1 = \frac{\theta_1\sigma_1^2}{(1+m_1)\rho_M + S\rho_S},$$

which depends on the agency parameter $m_1 = \Delta/b_1 - 1$. As noted, an increase in m_1 reduces the intermediation friction, which reduces the risk premium:

$$\frac{\partial\Pi_1(m_1, \theta_1, S)}{\partial m_1} = -\frac{\theta_1\sigma_1^2\rho_M}{[(1+m_1)\rho_M + S\rho_S]^2} < 0.$$

We highlight a further notion of comparative statics. Asset 1 is held by both intermediaries and sophisticated households. We say the asset is more intermediated if the share held by intermediaries is higher, and we vary S to illustrate the effect. A larger S means that more sophisticated households hold asset 1, which implies that intermediaries hold less of the asset. Then we have

$$\frac{\partial^2\Pi_1(m_1, \theta_1, S)}{\partial m_1 \partial S} = \frac{2\theta_1\sigma_1^2\rho_M\rho_S}{[(1+m_1)\rho_M + S\rho_S]^3} > 0.$$

As S rises (less intermediated asset), the sensitivity of the asset premium to the intermediation friction $\partial\Pi_1(m_1, \theta_1, S)/\partial m_1$, which is negative, is dampened.

As an example, both intermediaries and sophisticated households trade equities. But intermediaries are a more significant player in the equity options market than in the equity market. Thus, we would expect to see that a shock to intermediation would have a larger impact on equity options than equities. As the next section illustrates, this translates to a higher beta for equity options than equities, all else being equal.

2.9. Euler Equation Tests

We next show that one can use the first-order conditions of the agents to express the expected return on asset j in the standard $\lambda\beta_j$ form, where λ is the price of risk associated with a risk factor and β_j is the loading of asset j on the risk factor. A number of papers in the empirical literature construct an intermediary stochastic discount factor (SDF) and show that this factor successfully prices asset returns. Our analysis clarifies the manner in which these papers test intermediary asset pricing theory.

The intermediary managers are marginal investors in both asset 1 and asset 2, so that their Euler equations will hold for both assets. Managers hold $\rho_M\theta_1/[(1+m_1)\rho_M+\rho_S]$ shares of asset 1 and $\rho_M\theta_2/(\rho_S+\rho_H+\rho_M)$ shares of asset 2. The dollar variance of their wealth is (recall that both asset payoffs are uncorrelated):

$$\mathrm{Var}(\widetilde{W}_{1,M}) = \frac{\rho_M^2\theta_1^2\sigma_1^2}{[(1+m_1)\rho_M+\rho_S]^2} + \frac{\rho_M^2\theta_2^2\sigma_2^2}{(\rho_S+\rho_H+\rho_M)^2}.$$

The beta of each asset with respect to the manager's wealth is

$$\beta_1 = \frac{\mathrm{Cov}(\widetilde{W}_{1,M},\widetilde{D}_1)}{\mathrm{Var}(\widetilde{W}_{1,M})} = \frac{\dfrac{\rho_M\theta_1\sigma_1^2}{(1+m_1)\rho_M+\rho_S}}{\dfrac{\rho_M^2\theta_1^2\sigma_1^2}{[(1+m_1)\rho_M+\rho_S]^2} + \dfrac{\rho_M^2\theta_2^2\sigma_2^2}{(\rho_S+\rho_H+\rho_M)^2}},$$

$$\beta_2 = \frac{\mathrm{Cov}(\widetilde{W}_{1,M},\widetilde{D}_2)}{\mathrm{Var}(\widetilde{W}_{1,M})} = \frac{\dfrac{\rho_M\theta_2\sigma_2^2}{\rho_S+\rho_H+\rho_M}}{\dfrac{\rho_M^2\theta_1^2\sigma_1^2}{[(1+m_1)\rho_M+\rho_S]^2} + \dfrac{\rho_M^2\theta_2^2\sigma_2^2}{(\rho_S+\rho_H+\rho_M)^2}}.$$

We can then write the risk premium of asset 1 as

$$\begin{aligned}\mu_1-(1+r)\,p_1 &= \frac{\theta_1\sigma_1^2}{(1+m_1)\rho_M+\rho_S}\\ &= \underbrace{\underbrace{\frac{1}{\rho_M}}_{\substack{\text{Absolute}\\ \text{risk aversion}\\ \text{of managers}}}\underbrace{\left(\frac{\rho_M^2\theta_1^2\sigma_1^2}{[(1+m_1)\rho_M+\rho_S]^2}+\frac{\rho_M^2\theta_2^2\sigma_2^2}{(\rho_S+\rho_H+\rho_M)^2}\right)}_{\text{Variance of manager wealth}}}_{\lambda_M}\underbrace{\frac{\frac{\rho_M\theta_1\sigma_1^2}{(1+m_1)\rho_M+\rho_S}}{\frac{\rho_M^2\theta_1^2\sigma_1^2}{[(1+m_1)\rho_M+\rho_S]^2}+\frac{\rho_M^2\theta_2^2\sigma_2^2}{(\rho_S+\rho_H+\rho_M)^2}}}_{\beta_1^M}\end{aligned}$$

and the risk premium for asset 2 as

$$\begin{aligned}\mu_2-(1+r)p_2 &= \frac{\theta_2\sigma_2^2}{\rho_S+\rho_H+\rho_M}\\ &= \underbrace{\underbrace{\frac{1}{\rho_M}}_{\substack{\text{Absolute}\\ \text{risk aversion}\\ \text{of managers}}}\underbrace{\left(\frac{\rho_M^2\theta_1^2\sigma_1^2}{[(1+m_1)\rho_M+\rho_S]^2}+\frac{\rho_M^2\theta_2^2\sigma_2^2}{(\rho_S+\rho_H+\rho_M)^2}\right)}_{\text{Variance of manager wealth}}}_{\lambda_M}\underbrace{\frac{\frac{\rho_M\theta_2\sigma_2^2}{(\rho_S+\rho_H+\rho_M)}}{\frac{\rho_M^2\theta_1^2\sigma_1^2}{[(1+m_1)\rho_M+\rho_S]^2}+\frac{\rho_M^2\theta_2^2\sigma_2^2}{(\rho_S+\rho_H+\rho_M)^2}}}_{\beta_2^M}.\end{aligned}$$

These expressions are intuitive. The risk premium is proportional to the inverse of the risk tolerance of the manager ($1/\rho_M$), the variance of the manager's wealth, and the beta of asset j (β_j^M) with respect to the manager's wealth. That is, a CAPM holds, with the manager's wealth as the market factor and with the price of risk being denoted by λ_M in the above expressions.

What is the content of tests of an intermediary SDF? We see from these formulae that an intermediary SDF should price all assets. But this will be true whether or not intermediary constraints bind. The real bite of these tests is in β_1^{M} versus β_2^{M}. Comparing the numerators of the beta expressions, we see that a binding intermediary constraint increases β_1^{M} relative to β_2^{M}. That is, all else being equal, more intermediated assets should have a higher beta with respect to the intermediary factor than nonintermediated assets. These effects are increasing in the strength of intermediary frictions (i.e., as m_1 falls, β_1^{M} rises).

Next consider the pricing expressions for sophisticated households. These households trade both asset 1 and asset 2, and we should expect that a $\lambda\beta_j$ pricing formula similar to the intermediary one should apply in this case as well, but with sophisticated household wealth as the market factor. After some algebra, we find:

$$\mu_1-(1+r)p_1=\frac{\theta_1\sigma_1^2}{(1+m_1)\rho_{\mathrm{M}}+\rho_{\mathrm{S}}}$$

$$=\underbrace{\underbrace{\frac{1}{\rho_{\mathrm{S}}}}_{\substack{\text{Absolute risk}\\\text{aversion of}\\\text{sophisticated}\\\text{households}}}\underbrace{\frac{\rho_{\mathrm{S}}^2\theta_1^2\sigma_1^2}{[(1+m_1)\rho_{\mathrm{M}}+\rho_{\mathrm{S}}]^2}+\frac{\rho_{\mathrm{S}}^2\theta_2^2\sigma_2^2}{(\rho_{\mathrm{S}}+\rho_{\mathrm{H}}+\rho_{\mathrm{M}})^2}}_{\text{Variance of sophisticated household wealth}}}_{\lambda_{\mathrm{S}}}\underbrace{\frac{\frac{\rho_{\mathrm{S}}\theta_1\sigma_1^2}{(1+m_1)\rho_{\mathrm{M}}+\rho_{\mathrm{S}}}}{\frac{\rho_{\mathrm{S}}^2\theta_1^2\sigma_1^2}{[(1+m_1)\rho_{\mathrm{M}}+\rho_{\mathrm{S}}]^2}+\frac{\rho_{\mathrm{S}}^2\theta_2^2\sigma_2^2}{(\rho_{\mathrm{S}}+\rho_{\mathrm{H}}+\rho_{\mathrm{M}})^2}}}_{\beta_1^{\mathrm{S}}},$$

$$\mu_2-(1+r)p_2=\frac{\theta_2\sigma_2^2}{\rho_{\mathrm{S}}+\rho_{\mathrm{H}}+\rho_{\mathrm{M}}}$$

$$=\underbrace{\underbrace{\frac{1}{\rho_{\mathrm{S}}}}_{\substack{\text{Absolute risk}\\\text{aversion of}\\\text{sophisticated}\\\text{households}}}\underbrace{\frac{\rho_{\mathrm{S}}^2\theta_1^2\sigma_1^2}{[(1+m_1)\rho_{\mathrm{M}}+\rho_{\mathrm{S}}]^2}+\frac{\rho_{\mathrm{S}}^2\theta_2^2\sigma_2^2}{(\rho_{\mathrm{S}}+\rho_{\mathrm{H}}+\rho_{\mathrm{M}})^2}}_{\text{Variance of sophisticated household wealth}}}_{\lambda_{\mathrm{S}}}\underbrace{\frac{\frac{\rho_{\mathrm{S}}\theta_2\sigma_2^2}{\rho_{\mathrm{S}}+\rho_{\mathrm{H}}+\rho_{\mathrm{M}}}}{\frac{\rho_{\mathrm{S}}^2\theta_1^2\sigma_1^2}{[(1+m_1)\rho_{\mathrm{M}}+\rho_{\mathrm{S}}]^2}+\frac{\rho_{\mathrm{S}}^2\theta_2^2\sigma_2^2}{(\rho_{\mathrm{S}}+\rho_{\mathrm{H}}+\rho_{\mathrm{M}})^2}}}_{\beta_2^{\mathrm{S}}}.$$

The sophisticated households' wealth also successfully prices both assets, with a price of risk given by λ_{S} and loadings β_1^{S} and β_2^{S}.

Last, consider the households who delegate investments in asset 1 to the intermediary but invest in asset 2 directly. We have

$$\mu_1-(1+r)\,p_1=\frac{\theta_1\sigma_1^2}{(1+m_1)\rho_{\mathrm{M}}+\rho_{\mathrm{S}}}$$

$$>\underbrace{\underbrace{\frac{1}{\rho_{\mathrm{H}}}}_{\substack{\text{Absolute}\\\text{risk aversion}\\\text{of households}}}\underbrace{\frac{m_1^2\rho_{\mathrm{M}}^2\theta_1^2\sigma_1^2}{[(1+m_1)\rho_{\mathrm{M}}+\rho_{\mathrm{S}}]^2}+\frac{\rho_{\mathrm{H}}^2\theta_2^2\sigma_2^2}{(\rho_{\mathrm{S}}+\rho_{\mathrm{H}}+\rho_{\mathrm{M}})^2}}_{\text{Variance of households wealth}}}_{\lambda_{\mathrm{H}}}\underbrace{\frac{\frac{m_1\rho_{\mathrm{M}}\theta_1\sigma_1^2}{(1+m_1)\rho_{\mathrm{M}}+\rho_{\mathrm{S}}}}{\frac{m_1^2\rho_{\mathrm{M}}^2\theta_1^2\sigma_1^2}{[(1+m_1)\rho_{\mathrm{M}}+\rho_{\mathrm{S}}]^2}+\frac{\rho_{\mathrm{H}}^2\theta_2^2\sigma_2^2}{(\rho_{\mathrm{S}}+\rho_{\mathrm{H}}+\rho_{\mathrm{M}})^2}}}_{\beta_1^{\mathrm{H}}},$$

$$\mu_2-(1+r)p_2=\frac{\theta_2\sigma_2^2}{\rho_{\mathrm{S}}+\rho_{\mathrm{H}}+\rho_{\mathrm{M}}}$$

$$=\underbrace{\underbrace{\frac{1}{\rho_{\mathrm{H}}}}_{\substack{\text{Absolute}\\\text{risk aversion}\\\text{of households}}}\underbrace{\frac{m_1^2\rho_{\mathrm{M}}^2\theta_1^2\sigma_1^2}{[(1+m_1)\rho_{\mathrm{M}}+\rho_{\mathrm{S}}]^2}+\frac{\rho_{\mathrm{M}}^2\theta_2^2\sigma_2^2}{(\rho_{\mathrm{S}}+\rho_{\mathrm{H}}+\rho_{\mathrm{M}})^2}}_{\text{Variance of households wealth}}}_{\lambda_{\mathrm{H}}}\underbrace{\frac{\frac{\rho_{\mathrm{M}}\theta_2\sigma_2^2}{\rho_{\mathrm{S}}+\rho_{\mathrm{H}}+\rho_{\mathrm{M}}}}{\frac{m_1^2\rho_{\mathrm{M}}^2\theta_1^2\sigma_1^2}{[(1+m_1)\rho_{\mathrm{M}}+\rho_{\mathrm{S}}]^2}+\frac{\rho_{\mathrm{H}}^2\theta_2^2\sigma_2^2}{(\rho_{\mathrm{S}}+\rho_{\mathrm{H}}+\rho_{\mathrm{M}})^2}}}_{\beta_2^{\mathrm{H}}}.$$

These agents' wealth prices asset 2, but not asset 1. This is simply because their investments in asset 1 are constrained by the intermediary friction; i.e., households are not marginal in the asset 1 market. Indeed, the households' pricing expression for asset 1 is an inequality, reflecting the limited participation constraint.

The fact that the pricing expression for asset 1 is an inequality, while that of asset 2 holds with equality, offers a further prediction of intermediary asset pricing:

$$\frac{\beta_1^{\mathrm{M}}}{\beta_2^{\mathrm{M}}} > \frac{\beta_1^{\mathrm{H}}}{\beta_2^{\mathrm{H}}}. \quad 19.$$

Relative to the beta for asset 2, the intermediated asset will have a higher beta with respect to intermediary wealth than with respect to household wealth. Moreover, this differential should increase with intermediary frictions (lower m). These testable implications are developed and evaluated in a recent paper by Haddad & Muir (2017), who explore the dependence of the heterogeneous sensitivity across asset classes on households' direct participation costs.

Our analysis leads us to the following conclusions.

Proposition 3.

1. *An intermediary-based pricing factor will price the cross section of asset returns whether or not intermediaries are a veil. Empirical results demonstrating the success of an intermediary factor are a necessary but not sufficient condition for frictional intermediary-based asset pricing theories.*
2. *A sophisticated household–based pricing factor will price the cross section of asset returns whether or not there are intermediary frictions. Such frictions would only affect the betas.*
3. *A sufficient condition for rejecting intermediary-based asset pricing is that the Euler equations for the households that delegate their funds to the intermediary price the intermediated assets.*

This last point is key for SDF-type tests of intermediary asset pricing. Intermediary asset pricing requires that an intermediary SDF price returns and that the household SDF fail to price returns. Note that testing intermediary asset pricing involves a joint-hypothesis problem. We need to specify the SDF of the households, so that the test is a joint one of a household and an intermediary SDF.

3. EMPIRICALLY CONNECTING CAPITAL SHOCKS TO ASSET PRICE CHANGES

The financial crisis has provided data in support of intermediary asset pricing theories. During the crisis, intermediaries suffered losses to their capital. In terms of the model, m fell. The returns on assets that are commonly associated with intermediary trading rose. Krishnamurthy (2010) and Mitchell & Pulvino (2012) document these phenomena in several asset markets.

Figure 1 graphs option-adjusted spreads on Government National Mortgage Association (GNMA) mortgage-backed securities, which were at the heart of the financial crisis, over the period 2007–2009. Spreads rise in 2008, coinciding with intermediaries suffering losses to their capital. As the crisis abates in 2009 and as banks raise equity capital from the US government and public equity markets, the spreads fall.

Figure 2 shows an episode of dislocation in the convertible bond market in 2005. **Figure 2*a*** plots the quantity of assets of three types of financial intermediaries: convertible bond arbitrage hedge funds, multistrategy hedge funds, and convertible bond mutual funds. Convertible bond

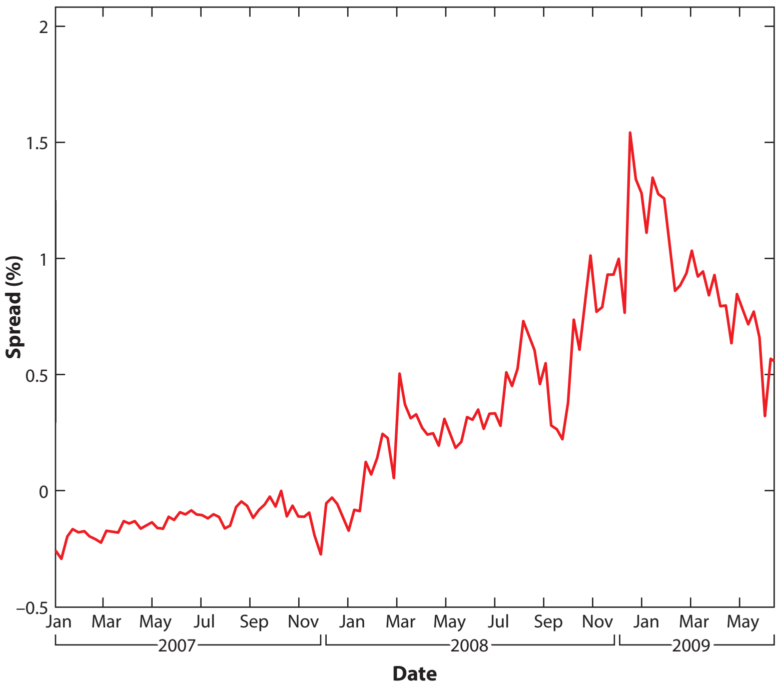

Figure 1

This figure graphs option-adjusted spreads on Government National Mortgage Association (GNMA) mortgage-backed securities relative to swap rates. The spreads are highest during the depths of the crisis in late 2008 and early 2009. Figure adapted from Krishnamurthy (2010) with permission.

arbitrage hedge funds specialize in purchasing convertible bonds, hedging out the equity risk, and capturing a return when such a hedged strategy is profitable. In 2004, there were withdrawals from these hedge funds that resulted in a substantial fall in the capital available for trading by these funds. Related funds, such as convertible bond mutual funds and multistrategy hedge funds, did not see similar redemptions. The capital reductions were matched by a reduction in prices of convertible bonds and an increase in returns on convertible bonds, as shown in **Figure 2*b***.

Figures 1 and **2** are good examples of the intermediary asset pricing phenomena with which this article is concerned. Disruptions in intermediation are associated with movements in the prices of intermediated asset classes. The price movements reverse over the course of months, not in the minutes or days that are the province of research in market microstructures. The phenomena reflect "slow-moving" intermediary capital, in the language of Duffie's (2010) presidential address to the American Finance Association.

However, **Figures 1** and **2** are not conclusive. Suppose intermediation were a veil and suppose a shock increased the risk premium that households demand for holding mortgage risk (or convertible bond risk). In this case, we would see a reduction in the prices of mortgage bonds (convertible bonds), losses to intermediaries specializing in these types of assets, and subsequently higher returns to these bonds. This type of problem is a challenge for many empirical studies of intermediary asset pricing. The rest of this section describes empirical experiments that solve this identification problem.

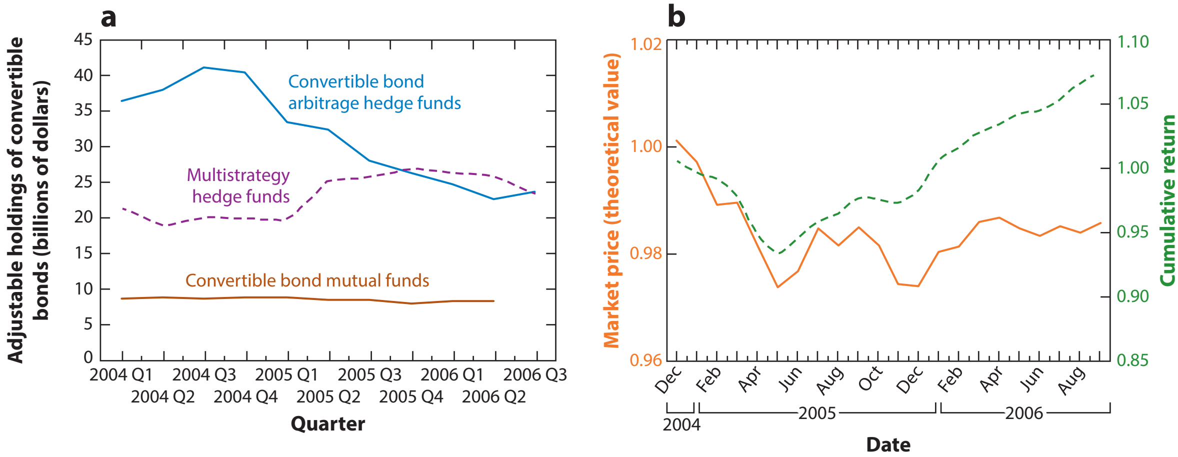

Figure 2

(*a*) Graph of the quantity of holdings of three types of bond intermediaries. (*b*) Graph of the returns on convertible bonds and of a model-based metric of price to fundamental value of convertible bonds. Figure adapted from Mitchell, Pedersen & Pulvino (2007) with permission.

3.1. Covered Interest Parity Deviation

The failure of covered interest parity (CIP) is one of the most glaring asset pricing anomalies in the crisis. Consider two trades.

- Trade A: Convert one US dollar into euros at time t at exchange rate S_t. Invest the funds in the euro market at a riskless interest rate i_t^{euro} for a term of one period to receive $S_t(1+i_t^{\text{euro}})$ euros at time $t+1$. Simultaneously purchase a forward contract at price F_t from a financial intermediary that converts F_t euros into one US dollar. By striking this forward, the payoff at time $t+1$ in dollars is
$$\frac{S_t}{F_t}(1+i_t^{\text{euro}}).$$
- Trade B: Invest in a one-period bond in US dollars at riskless interest rate i_t^{USD} to receive $1+i_t^{\text{USD}}$ at time $t+1$.

Trades A and B both invest one dollar at time t for a return at time $t+1$. Thus, we may expect that

$$\frac{S_t}{F_t}(1+i_t^{\text{euro}}) = 1+i_t^{\text{USD}}.$$

In fact, whereas this relation held almost exactly prior to 2008 [on the basis of the London Inter-Bank Offered Rate (LIBOR) values for the two interest rates], the pattern during the crisis and beyond has been that

$$\text{CIP}_t^{\text{deviation}} \equiv \frac{S_t}{F_t}(1+i_t^{\text{euro}}) - (1+i_t^{\text{USD}}) > 0. \qquad 20.$$

During the financial crisis, as Ivashina, Scharfstein & Stein (2015) document, many European borrowers lost access to US dollar short-term money market funding. They were unable to roll over dollar loans. One way they dealt with this dollar liquidity squeeze was to borrow euros and convert the euros into dollars while hedging the repayment in the forward market. That is, they took the opposite side of trade A.

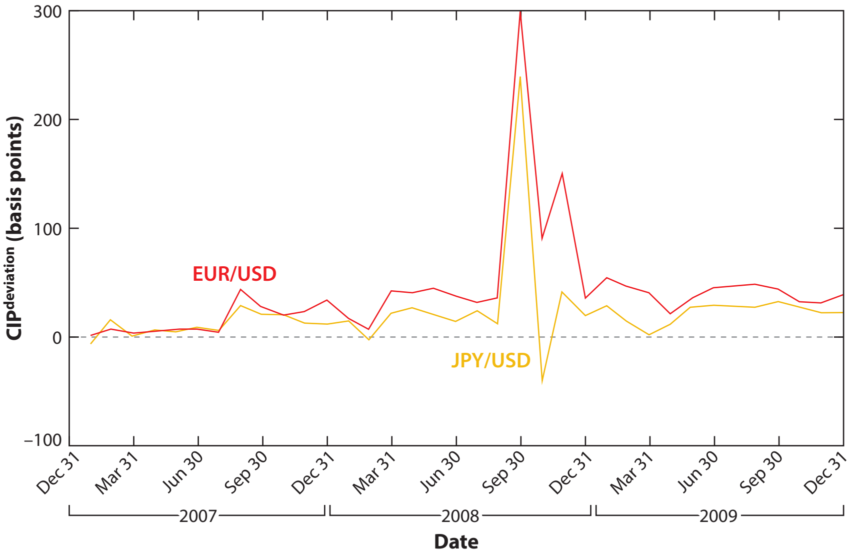

Figure 3

EUR/USD and JPY/USD 3-month LIBOR basis, end of month. $CIP^{deviation}$ (see Equation 20) for EUR/USD and JPY/USD are graphed from 2007 to 2009. The bases are positive and jump during the peak of the financial crisis. Data from Datastream and Federal Reserve Economic Data. Abbreviation: LIBOR, London Inter-Bank Offered Rate.

US banks typically took the other side and hence needed to absorb an increasing quantity of trade A. In terms of the model, the supply of asset A, θ_A, increased (or ρ_S increased). As a result, and given intermediation frictions, the return on trade A rose relative to the return on trade B as frictions worsened in the crisis. The pattern is evident in **Figure 3**, where we plot the CIP deviation (also referred to as the basis) for the euro relative to the US dollar and for the yen relative to the US dollar. Notice that the CIP deviations widen in late 2008 and reverse only after months, rather than days, as might be expected for a market microstructure friction.

We can understand these violations through the lens of intermediary asset pricing. The return to trade A corresponds to a more intermediated asset return than the return to trade B. This is a natural association because trade A involves a forward contract (i.e., the forward price F_t) that is written by a bank. Moreover, US households directly own trade B, which is riskless investments in US dollars, so their SDF prices trade B. But trade A offers a higher return than trade B, implying that their SDF does not price trade A. **Figure 1** is evidence of intermediary pricing because, as intermediation frictions worsened in the crisis, the relative return between trades A and B rose. If intermediation were frictionless, households would provide more capital to intermediaries to take advantage of the return spread and drive the spread to zero.

Du, Tepper & Verdelhan (2017) provide stronger evidence tying movements in CIP deviations to capital frictions in intermediation. They note that capital requirements on some banks are based on a snapshot of the banks' balance sheets at the end of each quarter. The banks thus face tighter capital requirements at the end of each quarter relative to days before and after. The authors show that the CIP deviation widens at the end of each quarter, consistent with this capital tightness. **Figure 4** graphs this pattern not for the USD/EUR but for the USD/JPY CIP deviation, which reflects the same economics. The graph is for the period 2014–2016, well after the financial crisis but still reflecting intermediation frictions. Not only does the CIP deviation jump at the end of

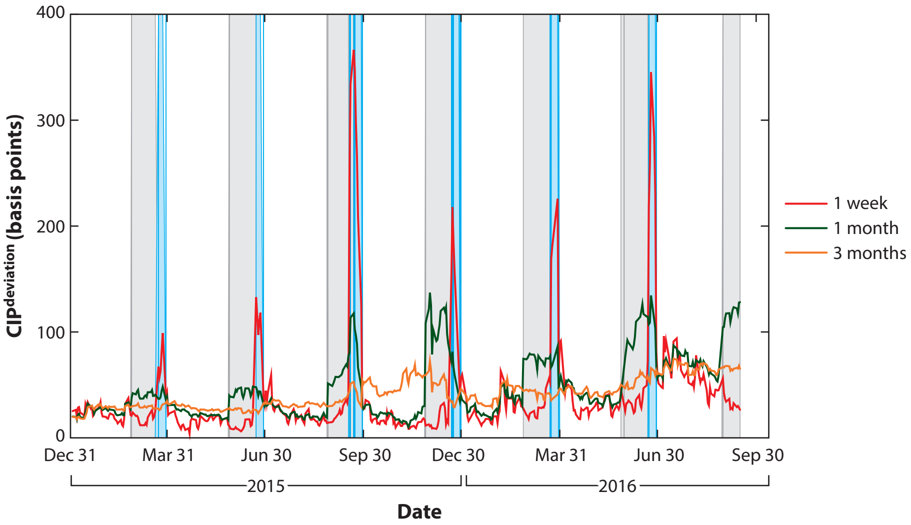

Figure 4

$CIP^{deviation}$ (see Equation 20) for JPY/USD is graphed for maturities of 1 week (*red curve*), 1 month (*green curve*), and 3 months (*orange curve*). Vertical blue lines coincide with ends of quarters. Figure adapted from Du, Tepper & Verdelhan (2017) with permission.

each quarter, but the jump is largest for the shortest-maturity (1-week) contract, as is suggested by theory, since this contract's term has the largest fraction of time ($\frac{1}{7}$) for which the capital constraint is tight. It is hard to reconcile these patterns with any theories involving household risk preferences, so the evidence for intermediary asset pricing is quite strong.

3.2. Insurance Markets

Some of the clearest evidence for capital effects in intermediary asset pricing comes from insurance markets. Froot & O'Connell (1999) study property and casualty insurance. They show that the price of such insurance is described by a cycle: A natural disaster results in reductions in the capital of insurers; the prices of new policies rise and the quantity of insurance sold falls; and, as capital builds up, prices fall and the quantity sold rises. This is compelling evidence of shifts in the supply of insurance induced by capital shocks because a nonintermediary asset pricing story would have to tie the cycle in insurance prices and quantities to a cycle in the probability of a natural disaster, which seems implausible.

Koijen & Yogo (2015) study life insurers and their pricing of long-term insurance policies during the financial crisis. They demonstrate a capital effect in the pricing of these policies, albeit in a counterintuitive manner. In contrast to the study of Froot & O'Connell (1999), where insurance premiums rise following an impairment of capital, Koijen & Yogo (2015) show that insurers sold policies at prices below actuarial fair value and that this gap was larger for insurers facing tighter capital constraints. They show that this behavior arises because sales of such insurance increases regulatory capital in the short run.

The evidence of Koijen & Yogo (2015) is consistent with the rest of the evidence for capital effects that we have discussed in this section and thus supports theories of intermediary asset pricing. It goes beyond the other evidence in two ways, which are worth highlighting.

First, the market for retail insurance allows the econometrician to observe different transaction prices for the same asset, sold by different insurance companies and purchased by different households. In the forward exchange rate market, we observe only one price, the "best" price for the forward contract. This means we can only learn how shocks to capital impact the aggregate supply curve for forwards, which involves studying a single time series of capital shocks and forward prices. In the retail setting, given search and attention frictions, each insurer has market power in selling contracts. Thus, we can learn about the supply curve for insurance at the insurer level, providing much more variation to study. Since the economics of capital effects remains the same, that is, capital shocks impact supply, the study has external validity beyond the retail insurance setting. For instance, Bao, O'Hara & Zhou (2018) document that the liquidity provision by dealers has been adversely affected by the regulatory tightening of the Volcker rule in the context of corporate bonds traded in the over-the-counter market.

Second, the rest of the studies we have described convincingly demonstrate a capital effect, but they stop short of quantifying the capital effect. Ultimately for model construction, it is necessary to know how a given reduction in capital impacts supply. Koijen & Yogo (2015) take a structural approach to estimation, allowing them to quantify the capital effect.

4. STOCHASTIC DISCOUNT FACTOR METHODOLOGY

In Section 3, we discussed evidence in favor of the prediction that shocks to intermediary capital or constraints will explain movements in the prices of intermediated assets. We now discuss a second empirical literature that investigates how intermediary variables explain the expected returns on intermediated assets. This literature constructs a factor that is posited as a proxy for the intermediary SDF and examines its pricing power for intermediated asset classes. It likewise constructs an SDF for the household sector, which, in a frictionless (veil) world, should also price these assets. The test of intermediary asset pricing relies on showing that the intermediary SDF can explain variation in asset returns while the household SDF cannot.

We focus on two papers in this literature: those of Gabaix, Krishnamurthy & Vigneron (2007) and He, Kelly & Manela (2017). As we explain, these papers are less well identified than the papers discussed in Section 3, but their approach is particularly well suited for quantifying models of intermediary asset pricing. In both papers, an intermediary price of risk is estimated that can serve as a target to match in quantitative intermediary asset pricing models.

4.1. Mortgage-Backed Securities Market

Gabaix, Krishnamurthy & Vigneron (2007) study the pricing of prepayment risk in mortgage-backed securities (MBS), providing evidence to support intermediary asset pricing models. MBS rise and fall in value on the basis of the exercise of homeowners' prepayment options. When a homeowner prepays a mortgage, the corresponding MBS is called back at par. Depending on the interest rate environment, unexpected prepayments can either hurt or benefit the MBS investor. For an MBS with a low coupon being traded in an environment where market interest rates are high, unexpected prepayments benefit the MBS investor. In the opposite case, where the coupon is higher than market interest rates, unexpected prepayments hurt the MBS investor. Gabaix, Krishnamurthy & Vigneron (2007) define prepayment risk as the risk of prepayment that is orthogonal to market interest rates (which investors are able to hedge out) and study the pricing of this prepayment risk.

Importantly for an investor who specializes in the MBS market and therefore holds a concentrated portfolio of MBS, prepayment risk represents a risk to the value of the portfolio. Gabaix, Krishnamurthy & Vigneron (2007) posit that financial intermediaries, such as mortgage funds, will hold such a concentrated portfolio and be exposed to prepayment risk. They derive an SDF for such investors and empirically demonstrate that this SDF prices the cross-sectional and time-series patterns in the spreads of MBS over Treasury bonds.

Gabaix, Krishnamurthy & Vigneron (2007) also provide evidence that a household SDF does not price prepayment risk. They note that for every MBS investor in a short position on a prepayment option, there is a homeowner in a long position on that prepayment option, and hence prepayments do not cause changes to aggregate wealth or the aggregate endowment. Thus, under a nonintermediary model, the pricing of prepayment risk should reflect the covariance of prepayment shocks with aggregate household wealth or consumption.

Gabaix, Krishnamurthy & Vigneron (2007) provide three principal empirical results. First, they show that in the cross section, MBS with more prepayment risk (i.e., securities that fall in value when prepayments are unexpectedly high) carry a higher spread than those with lower prepayment risk. That is, prepayment risk carries a positive risk premium. Second, the observed covariance between prepayment risk and either aggregate wealth or consumption implies a sign that is opposite that required to match the observed prices of prepayment risk. Prepayments are modestly procyclical, so MBS securities that fall in value when prepayment shocks are high should carry a negative risk premium rather than a positive risk premium. Last, they derive a proxy for the riskiness of the MBS market and show that the market price of prepayment risk comoves with this proxy.

Figure 5 presents the main result of Gabaix, Krishnamurthy & Vigneron (2007). For each month, the price of prepayment risk is estimated from the cross section of MBS spreads. That is,

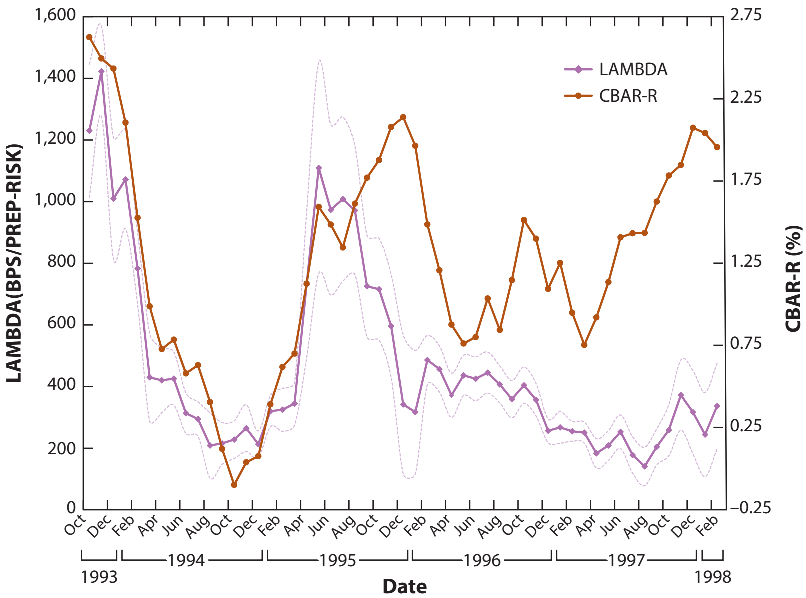

Figure 5

The estimated monthly market price of prepayment risk (LAMBDA) is plotted. The price of risk implied by intermediary asset pricing (CBAR-R, where CBAR is the average coupon outstanding in the mortgage-backed securities market and R is the 10-year constant-maturity Treasury interest rate) is plotted for comparison. Figure adapted from Gabaix, Krishnamurthy & Vigneron (2007) with permission.

the beta with respect to prepayment risk is estimated for each MBS, and the price of prepayment risk is then the spread compensation per unit of beta. **Figure 5** plots the time series of this price of prepayment risk. Theoretically, an investor in a long position on the entire portfolio of MBS will price prepayment risk depending on the investor's exposure to prepayment risk. If the market portfolio consists of MBS with higher coupons relative to the market interest rate, the unexpectedly faster prepayments result in larger losses to the investor. Thus, the investor's exposure to prepayment risk depends on the average coupon of the market portfolio of MBS relative to riskless interest rates (CBAR-R). **Figure 5** shows that the theoretical and estimated prices of prepayment risk move together. Regression analyses reported by Gabaix, Krishnamurthy & Vigneron (2007) confirm the pattern evident in **Figure 5**.

The empirical approach of Gabaix, Krishnamurthy & Vigneron (2007) is to construct a theoretically derived intermediary SDF and show that this SDF prices MBS prepayment risk while a household SDF does not price MBS risk. The approach is fruitful in this case because the object studied, prepayment risk, will carry opposite risk prices depending on the posited SDF. However, this statement rests on accurately measuring the household SDF. Gabaix, Krishnamurthy & Vigneron (2007) use household consumption and aggregate wealth data to assess the household SDF.

Finally, we note that Gabaix, Krishnamurthy & Vigneron (2007) study only a small sample that ends in 1998. In recent papers, Boyarchenko, Fuster & Lucca (2017) and Diep, Eisfeldt & Richardson (2017) consider a longer sample and larger cross section of MBS. Their results are also consistent with intermediary asset pricing in the MBS market.

4.2. Broker/Dealer Capital

He, Kelly & Manela (2017) propose an empirical measure of the SDF of financial intermediaries based on broker/dealers' capital ratio and explore its pricing power for seven asset classes: equities, US government and corporate bonds, foreign sovereign bonds, options, credit default swaps (CDS), commodities, and foreign exchange (FX). The approach of confronting intermediary asset pricing theory with a broad set of asset classes is in contrast with that of Gabaix, Krishnamurthy & Vigneron (2007), who focus only on the highly specialized MBS market. HKM build on the seminal work of Adrian, Etula & Muir (2014), who use broker/dealers' leverage rather than capital to measure the intermediary SDF. Adrian, Etula & Muir (2014) explore the pricing power of broker/dealers' leverage for equities and US government bonds, while He, Kelly & Manela (2017) expand the approach to include more intermediated asset classes.

4.2.1. Intermediary capital ratio. He, Kelly & Manela (2017) study primary dealers who serve as counterparties of the Federal Reserve Bank of New York in its implementation of monetary policy. These dealers are large and sophisticated financial institutions that operate in virtually the entire universe of capital markets and include the likes of Goldman Sachs, JP Morgan, and Deutsche Bank. It is natural to focus on these dealers because they are active (and hence are marginal investors) in many asset markets, just like the intermediaries of the model with multiple assets analyzed in Sections 2.7–2.9.

Following He & Krishnamurthy (2012, 2013) and Brunnermeier & Sannikov (2014), He, Kelly & Manela (2017) postulate that these dealers' equity capital ratio is the key determinant of the intermediary SDF. When an intermediary experiences a negative shock to its equity capital because of, say, unexpected losses in MBS, its risk-bearing capacity is impaired and its value from an extra dollar of equity capital rises. More specifically, He, Kelly & Manela (2017) construct the intermediary capital ratio, denoted by η_t, as the aggregate value of market equity divided by the

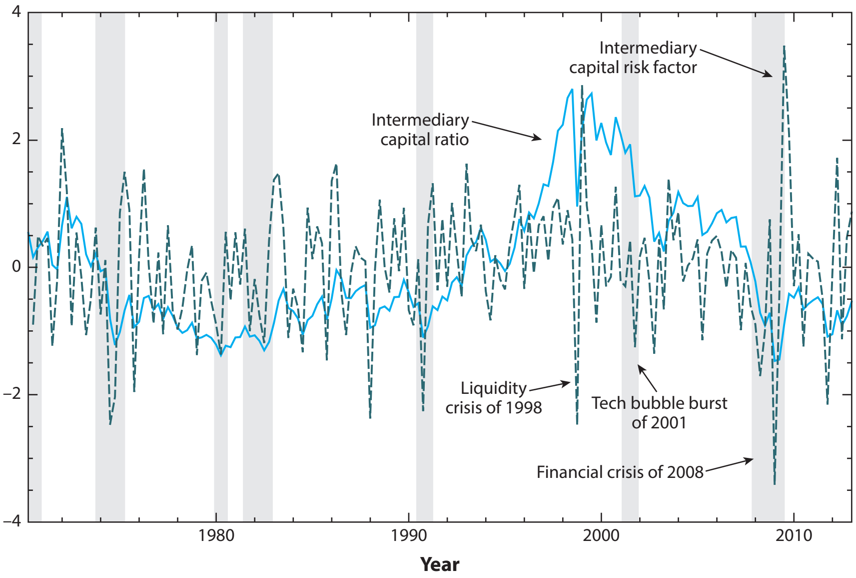

Figure 6

Graph of η_t (intermediary capital ratio) and η_t^{Δ} (intermediary capital risk factor, defined as percent innovations to η_t) over the period 1970 Q1–2012 Q4. NBER recessions are shown (*shaded areas*). Both time series are standardized to zero mean and unit variance. Figure adapted from He, Kelly & Manela (2017) with permission.

sum of the aggregate market equity and the aggregate book debt of the bank-holding companies of primary dealers active in quarter t:[5]

$$\eta_t = \frac{\sum_i \text{market equity}_{i,t}}{\sum_i(\text{market equity}_{i,t} + \text{book debt}_{i,t})}. \qquad 21.$$

In the language of the intertemporal CAPM (Merton 1973), the intermediary capital ratio η_t is a state variable that captures the soundness of the financial sector and hence matters for risk compensation, in addition to the aggregate market return R_t^W, which potentially captures other economy-wide shocks. Based on a parsimonious intertemporal CAPM–style two-factor structure consisting of the intermediary capital factor η_t^{Δ} (the percent innovation to η_t) and the stock market return R_t^W, He, Kelly & Manela (2017) empirically show that the intermediary capital factor has significant explanatory power for cross-sectional variation in expected returns in the seven asset classes studied.

Figure 6 graphs η_t and η_t^{Δ}, along with NBER recessions, over the period 1970 Q1–2012 Q4 reported on by He, Kelly & Manela (2017). There are several noteworthy observations regarding the relation between η_t^{Δ} and business cycle macroeconomic conditions. First, the most negative shock to intermediary capital occurred during the 2008 financial crisis, which coincided with the Great Recession. Second, and somewhat surprisingly, it is the liquidity crisis during the fall of

[5]Market values of equity arguably better reflect the financial distress of intermediaries. In the empirical corporate finance literature that studies the capital structure of nonfinancial firms (Leary & Roberts 2005), book values of debt are used to approximately measure unobserved market values of debt. The approximation is more accurate in our context of financial firms, as for banking institutions the majority of liabilities consist of safe short-term debt such as deposits, repurchase agreements, and trading liabilities, which are to a large extent collateralized and have market values equal to the face or book value.

1998 that witnessed the second-largest negative η_t^Δ, an episode that coincided with turmoil in the options market but little action in the broad stock market. Last, despite a significant stock market crash (the bursting of the tech bubble) during the 2001 recession, we observe only a relatively modest drop in η_t^Δ. These observations illustrate the difference between fundamental shocks (as reflected by R_t^W) and financial shocks (as reflected by η_t^Δ).[6]

4.2.2. Price of intermediary capital risk. As shown in Section 2.9, the standard risk–return relationship implies that any asset j with a β_j loading on the intermediary capital risk factor η_t^Δ should be compensated by an expected return of $\lambda_\eta \beta_j$ in equilibrium. Importantly, λ_η is independent of the asset class because the price of risk λ_η should only be specific to the characteristics of the investor for whom we measure the SDF. For instance, in the asset pricing model analyzed in Section 2.9, the price of risk is proportional to the relative risk aversion of marginal investors (either managers or sophisticated investors) and the variance of their return on wealth. Asset classes with different degrees of intermediation (say, equity versus CDS) might differ in their risk loadings to η_t^Δ, so that some asset classes are more sensitive to intermediary capital shocks, but this heterogeneity should be reflected in the asset β_j only.

He, Kelly & Manela (2017) test this prediction. They first perform cross-sectional asset pricing tests within each class separately, obtaining betas of each asset j in asset class k from time-series regressions and then running a cross-sectional regression of average excess portfolio returns on the estimated betas. This procedure allows them to estimate the asset class–specific risk prices λ_η^k for each asset class k.[7] Theory suggests that these risk prices λ_η^k should be positive and equal across asset classes, subject to estimation error. This is indeed what He, Kelly & Manela (2017) find. **Figure 7** plots intermediary risk prices from different asset classes with 95% confidence intervals. As shown, their test rejects the null of a 0% risk price in all classes but cannot reject the hypothesis that the estimated risk price is equal to 9% per quarter (the value found in the all-portfolios case, which pools all testing porfolios together) for any of the individual asset classes at the 5% significance level.

Theoretically, the prediction of equal risk prices relies on the following assumptions. First, the proposed equity capital ratio (Equation 21) represents the intermediaries' marginal value of wealth. Second, intermediaries are active traders in all asset markets (although not necessarily with large net positions). Also implicit in these assumptions is a degree of homogeneity in the pricing kernels of individual financial intermediaries. That all financial intermediaries are homogeneous is perhaps the most tenuous of these assumptions. Its failure could potentially explain the somewhat higher price of risk in options and FX (see **Figure 7**), for example, if intermediaries that specialize in trading these securities differ in substantial ways from other intermediaries (see, for example, Gârleanu, Panageas & Yu 2015).

4.2.3. Necessary and sufficient for intermediary asset pricing? Still, in light of Proposition 3 in Section 2.9, **Figure 7** showing that the intermediaries' SDF has explanatory power for a wide range of asset classes is necessary but not sufficient to demonstrate the core of intermediary asset pricing, i.e., that intermediaries are not a veil. To claim that, one needs to show that the households'

[6] Muir (2017) presents more comprehensive evidence from a large international panel on the differential impact of financial and real shocks for asset prices. He compares recessions involving financial crises (e.g., bank runs, bank closures) to nonfinancial recessions with similar declines in aggregate consumption and shows that the risk premia on stocks and corporate bonds rise substantially in the financial recessions relative to the nonfinancial recessions.

[7] Recall that we have emphasized nonlinearity; i.e., the price of risk is state dependent and may rise during severe economic downturns. This is illustrated in **Figure 5**. Under the assumption of constant asset beta, the unconditional estimate obtained by He, Kelly & Manela (2017) can be viewed as the average price of risk over time.

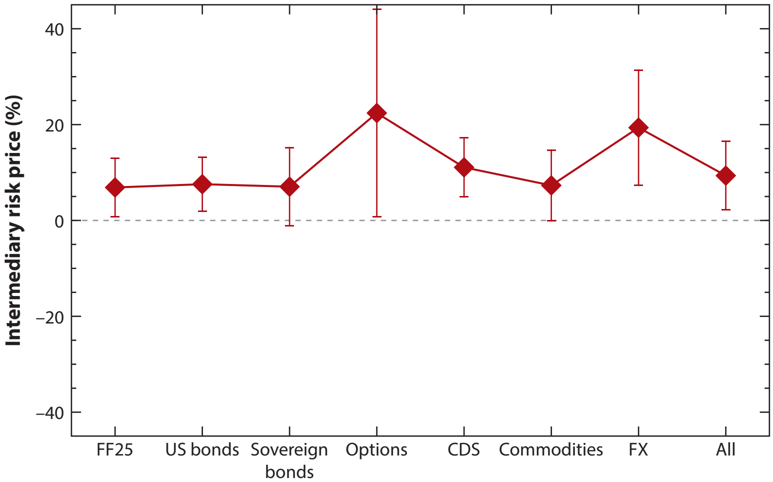

Figure 7

Intermediary risk prices from different asset classes are plotted with 95% confidence intervals. Figure adapted from He, Kelly & Manela (2017) with permission. Abbreviations: CDS, credit default swaps; FX, foreign exchange.

SDF fails. Although there exist some papers aiming to explain the time-series behavior of index options under the rare-disaster consumption-based asset pricing framework (e.g., Barro & Liao 2016), we are not aware of papers that successfully explain the cross section of expected returns for the nonequity asset classes considered by He, Kelly & Manela (2017) using an SDF constructed from household consumption data.

Another way of approaching the issues is to see which SDFs do not work in explaining returns. The model developed in Section 2 says that if all plausible SDFs work, then the intermediary is just a veil. He, Kelly & Manela (2017) present two sets of results to reject the veil hypothesis. First, they show that the well-known factors commonly used in the literature, including the five Fama–French factors, momentum, and liquidity (Pástor & Stambaugh 2003), perform poorly. If we interpret the earlier success of these factors as being due to their capturing of the SDF of households in the equity market, this result shows that their SDF fails to price the nonequity-heavy asset portfolios in He, Kelly & Manela (2017). Furthermore, He, Kelly & Manela (2017) postulate that within the broker/dealer sector, primary dealers, who are large and active in almost all asset markets, are the intermediaries of intermediary asset pricing models. The SDF of nonprimary dealers, who tend to be smaller, standalone, broker/dealers for the equity market but who trade little in derivatives markets, should not price the cross section of returns. He, Kelly & Manela (2017) repeat their main asset pricing test using the equity capital ratio constructed from nonprimary dealers. The SDF works for equity portfolios but not for other asset classes (He, Kelly & Manela 2017, table 7A). This result may imply that nonprimary dealers are a veil whose trades reflect the preferences and tastes of households. The fact that these other constructed factors fail to price the assets studied by He, Kelly & Manela (2017), whereas the equity–capital ratio of primary dealers does, is the strongest evidence that they present in favor of intermediary asset pricing.[8]

[8]Note that this evidence also differentiates intermediary asset pricing from heterogeneous agent frictionless models such as that of Dumas (1989). In that frictionless model, the pricing kernel of any agent should price all assets, and there is no particular reason why the SDF derived from primary dealers should perform better than that of any other.

5. SUMMARY AND CONCLUSION

We have explained both the theory behind intermediary asset pricing and some of the empirical approaches taken to testing the theory. There is now a large body of work in this area. On the theoretical side, the basic groundwork for intermediary asset pricing has been laid out. On the empirical side, there are a number of papers that have demonstrated intermediary asset pricing effects along the lines that we covered in Section 3. There is a smaller but growing body of literature that tries to construct an intermediary SDF.

We close with a short wish-list for future work in this area. For empirical work: What are the most salient financial frictions driving intermediary asset pricing? Which classes of intermediaries are most prominent for understanding asset prices? How much does heterogeneity within the intermediary sector matter? What is the relation between intermediary risk prices as measured from asset prices and macroeconomic activities, such as corporate and residential investment? For theoretical work: We need to construct tractable models to replicate the empirical findings both qualitatively and quantitatively. These models need to be embedded within a macroeconomic framework to elucidate links between the financial sector, asset prices, households, and the real sector. Finally, these models need to be quantitative in nature in order to evaluate policy counterfactuals that can guide financial regulation.

DISCLOSURE STATEMENT

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Contents

Indexes

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