

Summary of “Types of Systemic Risk”: A Paper by Arthur Boman

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Abstract

I use an Arbitrage Pricing Theory factor model with systemic risk spillovers to distinguish between systematic and systemic risks. The model shows why systematic risk is so often mistaken as systemic risk, why systematic risk in the financial industry is important, and why it should be considered along with systemic risk in regulatory efforts. The model is then used to delineate and outline the various types of risk relevant to systemic crises. This vocabulary can facilitate communication and research in systemic risk. Finally, return distributions with humps in the left-hand tail and correlated tails are found to be the implication of interfirm systemic risk.

Note: This document is not for citation. This is a summary rather than a draft.

1 Introduction

This in-progress paper, “Types of Systemic Risk”, uses an Arbitrage Pricing Theory (A.P.T.) version of the model from my job market paper (started on page 27 and solved for arbitrage pricing with systemic risk from 28-31.) The model is simple by asset-pricing standards (this is as it should be; systemic risk work also strives to achieve other things), but the model adds a few things not in most systemic risk work - hence, it has potential to add to the exciting work being done on systemic risk and returns. The model yields a variety of valuable results. I am finishing a paper about these results. This is a summary of that paper.

2 Arbitrage Pricing Theory and Systemic Risk

Boman (2013b) is primarily about an endogenous sdf asset pricing model with interfirm systemic risk (*ISR*) or “spillovers” or “contagion”¹. The paper solves the model and finds implications for asset prices and capital allocation when there is the possibility of such systemic risk, whether it is from one financial firm to another, or from the financial industry to the real industry.

In the discussion section, that paper introduces a factor-model version of the model with *ISR*, solves the model’s basic pricing with factor model assumptions, and then solves arbitrage pricing with Arbitrage Pricing Theory (A.P.T.) assumptions (see Ross (1976)). No distributional assumptions are employed in the reference. Numerous applications are discussed but not pursued. A few of those suggested applications, and two others, are pursued in this paper.

One application of the model is using it to outline the types of systemic risk. The method of distinguishing these types of risks is to reference the A.P.T. factor model as applied to assets in the financial industry (for example, for financial firm i , in the absence of systemic risk, returns come from: $R_i = E(R_i) + b'_i g + \varepsilon_i$, $E(R_i) = b'_i \lambda$, $R_i = b'_i \lambda + b'_i g + \varepsilon_i$, where g is the vector of demeaned factors, b'_i is the transpose of the vector of firm i ’s factor loadings, and λ are the economy-wide risk premia for each of the factors). In the reference, with A.P.T. assumptions, arbitrage pricing is found, giving the results below. The arbitrage pricing results are used to help define types of systemic risk and other risks.

The pricing solution gives rigorously defined pricing, systematic risk, systemic risk, and firm-specific risk. It is used in Section 3 below to clarify and delineate the various types of systemic risk and systemically relevant risks. There are two differences between this pricing model and many prior return-generating specifications used in the systemic risk literature (even prior return specifications that include *SR* and *ISR*). First, the factor model is an asset-pricing model, rather than a return-generating specification. Any random variable specifying cash-flows by state can be

¹Stochastic spillovers across institutions can arise from direct contractual links and counterparty credit risk, or can occur indirectly through price effects and liquidity spirals, margin spirals, one firm holding credit-default swaps in another, or through many other means. Although these give rise to correlation in the returns of the affected firms, they are not *systematic* risk because they are causal, rather than both firms loading onto the same risk factors.

priced, resulting in returns. Secondly, the factor model contains *ISR* as a systemic risk², rather than adding non-Gaussian idiosyncratic or systematic terms as proxies for systemic risk, as is done in many systemic risk papers, notably Acharya et al. (2010). No distributional assumptions have been made in the factor model. The first application of the model maintains this, and the last two applications add distributional assumptions, but the types of risk are not defined by which distribution is added.

Defining stochastic return shocks $\hat{R}_i \equiv R_i - E(R_i)$ and $\hat{R}_j \equiv R_j - E(R_j)$:

$$\hat{R}_i = \underbrace{\underbrace{b'_i g}_{\text{systematic risk}} + \underbrace{\varepsilon_i}_{\text{idiosyncratic risk}}}_{\text{systemically important institution}}$$

$$\hat{R}_j = \underbrace{\underbrace{b'_j g}_{\text{systematic risk}} - \underbrace{f(R_i)}_{\text{systemic risk}} + \underbrace{\varepsilon_j}_{\text{firm-specific risk}}}_{\text{systemically impacted institution}} \quad (1)$$

and

$$R_i = b'_i \lambda + b'_i g + \varepsilon_i \quad R_j = E(R_j) + b'_j g - f(R_i) + \underbrace{\varepsilon_j}_{\text{firm-specific}} = \hat{b}'_j \lambda + \hat{b}'_j g + \underbrace{\eta_j}_{\text{idiosyncratic}}$$

To review one concept in the reference related to the pricing equations shown above, that will be important for our applications:

“Because R_i and g are correlated, but imperfectly so, the projection of the random variable $f(R_i)$ onto the priced factors is non-zero but of lower magnitude than $f(R_i)$. In other words, part of this risk is priced. Until now, firm-specific and idiosyncratic risks have been synonymous, but here we need to distinguish between them. I do not view this as an artifact of the model. If *ISR* exists, it imposes additional idiosyncratic risk. Part of firm j 's total idiosyncratic risk, η_j , comes from the firm-specific risk of firm i being transmitted to firm j via *ISR*, $\{[f(R_i) - f(R_i)_Y] - E[f(R_i) - f(R_i)_Y]\}$, and part comes from the firm-specific risk

²There are models, like corisk of Chan-Lau (2010), where the returns of one firm depend on another firm (not on its returns but on whether it is solvent), but they do not appear cleanly in an equation like this. The ones that do appear cleanly are usually systematic risk terms with fat tails as discussed below.

of j itself, ε_j . All three of these (η_j , $\{[f(R_i) - f(R_i)_Y] - E[f(R_i) - f(R_i)_Y]\}$, and ε_j) are diversifiable, mean-zero, and unpriced. It is already clear that if unimpacted returns are normal, and $f(\cdot)$ is anything but affine, then impacted returns will not be normal. It should also be clear that the returns of j are correlated with the idiosyncratic risk of i , another non-standard asset-pricing result.”

3 Application: *The Various Types of Systemic Risk*

There is a large literature that assumes the salient aspect of systemic risk is the possibility of a financial crisis, which impacts the real economy. This sub-section stands within that large literature. The assumption is that the financial system may have very poor performance one period, this will result in the intermediation capacity of the financial system failing, and this will result in a large negative externality on the real economy. Finally, as a proxy for the event that a financial crisis occurs, this large literature (and this section) use some threshold value for the returns of the financial industry as a whole. Any return realization for the industry which is below this threshold represents crisis and the resulting market failure and welfare loss.

In this view of things, regulators should care about anything that contributes to the chance of a crisis (the probability that the financial industry will have a return below the threshold), about the magnitude of the negative externality (per unit time) during crisis, and about the duration of crisis (see Ibragimov et al. (2011) for the importance of duration). As with the majority of this large literature, I do not model the magnitude or duration, but instead focus on the probability that the financial industry has an overall return below a constant threshold. I call this probability Overall Systemic Risk (*OSR*). One could think of *OSR* as the chance of a financial crisis occurring this year for example. Approximately following Acharya et al. (2010); Ibragimov et al. (2011) and many others, I define a *systemic financial crisis* as the event $\{\omega \in \Omega : R_I < \underline{R}\}$ and *overall systemic risk* (*OSR*) as $\mathbb{P}\{R_I < \underline{R}\}$, the chance of a financial crisis.

Wherever possible, I define terminology as it is already in use. In a few cases, terms are currently being used in the literature for more than one phenomenon per term, where it is not clear from

context how it is being used. Such a scenario makes it necessary to create a new term. In other cases, risks that are well established and known in the asset pricing literature are being referred to as systemic risk in the systemic risk literature. In such cases, it is not necessary to create a term or even address it directly. Outlining each type of risk allows specific terms to be used. I am not inventing any new types of systemic risks in this paper. One point that the model makes clear is that the difference between systemic and systematic risks is the difference between causality and correlation.

With the assumptions that the magnitude and duration of the crisis' externality are constants, the planner should, *ceteris paribus*, seek to minimize OSR ³. She would be concerned with anything that increases OSR - even if it does not represent a market failure or inefficiency in and of itself. The planner should also be concerned with anything that does represent a market failure and inefficiency in and of itself, even if it does not increase OSR . Finally, the planner would have two reasons to be concerned with any risk that increases OSR on the one hand, and is a market inefficiency in and of itself on the other.

The goal of this section is to identify and characterize, within this view of systemic risk, any risk or moral hazard that increases OSR , stands as a welfare-reducing market failure in and of itself, or both. The method of distinguishing these types of risks is to reference an A.P.T. model of the assets in the financial industry shown in equation (1) above.

For example, the firms in the financial industry having a lot of systematic risk (high beta's, or in this case, b 's) increases industry volatility and hence increases OSR . Even though the term "systemic risk" does not appear in the name of systematic risk, it could be considered to be a systemic risk only because it increases the chance of a financial crisis, i.e. it increases OSR .

Firms, even banks, increasing their loading on factors (factors such as the return of the market or the Fama-French factors, or any risk factor) is systematic risk, even though it increases their correlation and increases the chance of a financial crisis. The terms defined will also have use in

³Alternatively, several papers have a simple utility function that is dramatically impacted by a financial crisis. Maximizing this utility function is very similar to, and usually identical to, minimizing OSR .

other systemic risk literatures, such as the literature on contagion, but the paper should be viewed as living in the world described in the preceding paragraph. The terminology will not fit perfectly into all systemic risk literature, but will at least not conflict.

With the help of (1), the endogenous-sdf version of that model in the reference, and standard definitions of systematic risk, the types of risk that have systemic importance in this view of the world are:

1. Inter-industry systemic risk. This is the externality itself that comes from the financial industry and affects the real industry. It is causal.
2. Overall systemic risk (*OSR*). The probability of a financial crisis, of inter-industry systemic risk being realized.
3. Systematic risk in the financial industry. Systematic risk is risk within a firm return's that is both non-causal and correlated with the stochastic discount factor - and therefore undiversifiable. (Non-causal means there is nothing to model the fact that the amount of asset i 's systematic risk is caused by the returns of asset j . Also, non-causal means that there is nothing in the model representing i 's systematic risk as affecting other returns, the distribution of the factors, etc.) In a factor model, the amount of systematic risk in the financial industry is the overall magnitude of financial firms loading onto the systematic factors. The systematic factors do not need to be Gaussian. Systematic risk is only a problem in that it increases correlation of financial firms and industry variance and hence *OSR*.
4. Interfirm systemic risk. This is a spillover, a risk imposed one one institution by another, a contagion, or a stochastic externality. It is causal. This is welfare-reducing in and of itself if it is not somehow priced. It also increases correlation of financial firms and industry variance and hence *OSR*.
5. Systemic allocation risk. The prospect of systemic risk causes sub-optimal allocation, even worse than the allocation we would have if the market ignored the systemic risk. In other

words, not only does the market fail to take into account the systemic risk and adjust investment accordingly, the market actually reduces capital allocation efficiency when faced with systemic risk. As far as I know, this systemic risk was discovered (theoretically at least) in Boman (2013b).

6. Correlated factor risk, in the financial industry. For a given level of overall systematic risk, i.e. a given level of total loading on factors, there can be fairly even loading of the various firms onto the various risk factors – or the firms can all herd and load-up on the same factor. Neither of these is a problem by itself, the market achieves efficient allocation in the face of this. But it increases *OSR*, and so it is a problem when combined with the possibility inter-industry systemic risk.
7. Idiosyncratic risk. Idiosyncratic risk is risk within a firm return's that is both non-causal and uncorrelated with any priced risk, and usually uncorrelated with any other risk at all. In a factor model, it is risk that is uncorrelated with factors, and hence other assets. Idiosyncratic risk does not need to be Gaussian. It generally would not increase *OSR*, unless the firm was very large and/or the firm had a very large potential interfirm systemic externality.

As the literatures which contain systematic risk co-mingles with the literature containing systemic risk, we are naturally in a phase where confusion about the two may arise. There is sometimes confusion about item 4 being causal. In contrast, there is never confusion about item 1 being causal. There can sometimes be confusion about whether item 3 is still item 3 when the pdf is not Gaussian.

Finally, there are two moral hazards:

1. Risk-taking moral hazard. If managers know that their firm might get bailed-out to stop inter-industry systemic risk, then they may take on more risk, such as systematic risk. They might also engage in factor-herding to make sure their firm fails when others do, and hence when bailouts are happening.

2. Allocation moral hazard. As mentioned, just the potential of inter-industry or interfirm systemic risk distorts capital allocation and increases allocation to the systemically risky firm or industry. If the prospect exists that the risky firm might be bailed-out ex post, then it should seem obvious that investors will likely want to invest even more in this firm, increasing the magnitude and possibility of interfirm systemic risk further. A less intuitive result is that allocation moral hazard can exist even if the investors or managers of the risky firm are not allowed to benefit from the bailout, if the bailout is used only to reduce the systemic externality. As far as I know, this moral hazard was discovered (theoretically at least) in Boman (2013b).

With these definitions, we can characterize various types of risk, and what we should do about them:

Types of relevant risk:

<i>ISR</i>	Interfirm systemic risk
<i>SR</i>	Systematic risk
<i>IDIO</i>	Idiosyncratic risk
<i>OSR</i>	Overall systemic risk
<i>CFR</i>	Correlated factor risk
<i>IISR</i>	Inter-industry systemic risk

Actions:

A Regulate in theory because it is an unpriced externality itself. Additional issue if we believe that the firm is in an industry whose poor performance could hurt the real economy.

- B Should not regulate, even in theory, *unless* we believe that the firm is in an industry whose poor performance could hurt the real economy.
- C Same as B but contributes via two pathways to increase *OSR*, making it potentially more impactful.
- D Do not regulate.

List format:

[Phenomenon] – [Type(s) of Risk], [Appropriate Action]

- Counterparty risk – *ISR*, A
- Margin spiral risk – *ISR*, A
- One firm holding credit default swaps written on another – *ISR*, A
- Financial firms leveraging up – SR, B
- Many financial firms exposing themselves to one type of risk, such as real-estate prices – *CFR*, B
- A bank with *intra*-industry systemic importance taking on too much risk – SR, C**
- Hedge funds manipulating stock prices (See Ben-David et al. (2013)) - *ISR**, A
- Highly correlated financial firms with heavy loading on factors – *CFR*, B
- Banks in general taking on too much risk, or the banking industry taking on too much risk – SR, B
- Financial firms all with heavy loading on particular factors that have fat tails, causing high tail correlation – *CFR*, B

- Externalities that are only operative when the impacting firm is in distress, causing high tail correlation – *ISR*, A
 - Factors have fat tails, causing high tail correlation – SR, B
 - A financial firm faces tipping points in its own profitability making firm-specific risk with fat tails – *IDIO*, D
 - Contagion - *ISR*, *IISR*⁺, A
 - The two-way linkages between the banking sector and the macro-economy - *IISR*, A
 - A bank taking too much risk - SR and/or *IDIO*⁺⁺, B
 - Intermediation capacity of the system impaired – *IISR*, A
- * To the extent that actual economic losses occur
- ** The bank is adding its own increase of SR, which increase volatility and *OSR* of the financial industry. It is also increasing its own propensity to cause *ISR* by becoming riskier, which is a welfare loss in its own right, and increases volatility and *OSR* of the financial industry. Furthermore, because the increase in the propensity to cause *ISR* is coming from an increase in SR, the increase in propensity is to cause *ISR* in bad states of nature, when the industry could be near financial crisis. This is because SR is, by definition, pro-cyclical.
- + Or international systemic risk
- ++ The statement is not fully defined, but the idiosyncratic part does not matter.

4 Return Distributions

To derive implications for joint return densities in future work, further assumptions are needed. I proceed with distributional assumptions.

A3-O. Optional Assumption for certain applications. There are many assets. In the absence of systemic risk, their returns are normal. This nearly follows observation for most firms. Furthermore, the results of this model may explain the deviation that *is* observed.

A4-O. Optional Assumption for certain applications. Firm-specific risks are independent and normal. I follow the empirical asset pricing work on factor models, which often assumes normal, independently distributed return errors. We have every reason to imagine that firm-specific risk, being the sum of many random variables, is Gaussian, see for example Casella and Berger (2001) and the Central Limit Theorem.

A5-O. Optional Assumption for certain applications. $f(\cdot)$, being the interfirm externality, is weakly positive, equal to zero for all positive arguments, and decreasing.

We still have:

$$R_i = b'_i \lambda + b'_i g + \varepsilon_i \qquad R_j = b'_j \lambda + b'_j g - f(R_i) + \underbrace{\varepsilon_j}_{\text{firm-specific}} = \hat{b}'_j \lambda + \hat{b}'_j g + \underbrace{\eta_j}_{\text{idiosyncratic}}$$

Again, *ISR* imposes additional idiosyncratic risk on firm j . Part is transmitted firm-specific risk of i , and part comes from the firm-specific risk of j itself. However, $E(\eta_j) = 0$, η_j is, importantly, not Gaussian and not independent. The implication of including *ISR* is that R_j is also not Gaussian.

For the paper, I have derived several important things about the joint returns when a systemic externality is present. I will mention two results. The first is about non-Gaussian tails. For over a decade, technically sophisticated asset pricing work has been done with returns that have assumed fat tails to derive the implications for diversification, allocation, and prices. More recently, systemic risk work assumes fat left-hand tails.

I have shown that interfirm systemic risk *creates* a hump in the left-hand tail of the pdf of the impacted firm. Specifically, I have derived necessary and sufficient conditions such that there are places on the pdf of R that are well below $E(R)$, where the derivative of the pdf, df/dR , is less than zero. This implies a hump in the left-hand tail, akin to black swan return events. The necessary

and sufficient conditions are mild.

Secondly, discussion of tail correlation is common in the financial crisis literature. Most tail correlation measures have the characteristic that they increase with correlation, and do not disentangle how much tail correlation there is. For example, bivariate normal random variables have non-trivial values for tail correlation with these measures, and it increases in their covariance. This presents a challenge when trying to see if even a general form of systemic externality creates tail correlation.

I created the following definition for first order tail correlation: For an asset A , the inverse CDF $F_{R_A}^{-1}(\alpha)$ is the return level of R_A that leaves α portion of the pdf of R_A to the left of $F_{R_A}^{-1}(\alpha)$. $F_{R_A}^{-1}(1 - \alpha)$ is the return that leaves α portion of the pdf to the right. Assets A and B have “ α -level left-hand tail correlation” if $cov(R_A, R_B)$ conditional on both returns being in their α -tails ($\{cov(R_A, R_B) | R_A < F_{R_A}^{-1}(\alpha), R_B < F_{R_B}^{-1}(\alpha)\}$) is higher than $cov(R_A, R_B)$ conditional on both returns being in their right-hand α -tails. Assets A and B have “first order” left-hand tail correlation if they have α -level left-hand tail correlation $\forall \alpha \in (0, 0.5]$. Unlike tail correlation measures, it only exists if there is tail correlation over and above regular correlation. And with the definition, there must be a higher covariance of the left tails than right tails, regardless of where we define the point that the tail starts. It must be true for every such point.

I have found equivalent conditions for systemic risk to cause the involved assets or industries to have first order left-hand tail correlation if factors and unimpacted returns are Gaussian. Furthermore, when a systemically important firm impacts another firm, this causes the latter firm to have left-hand tail correlation with the market, but does not have this effect on the former. Most current definitions of a firm’s contribution to overall systemic risk are based on how likely the firm is to do poorly when the industry is doing poorly (tail correlation), thereby contributing to the crisis. If the firm being impacted by interfirm systemic risk is the one that develops the fat and correlated tails, then such a measure is punishing the effected firm, rather than the affecting firm. An exception is CoVaR, from Adrian and Brunnermeier (2011), which seeks to measure the spillover *from* the firm onto the industry. In Boman (2013a), I derive CoVaR directly in terms of the parameters of an

asset pricing model, using the A.P.T. model herein. There are two terms which sum to give CoVaR. One of them clearly captures spillovers from the firm onto the industry, in line with the intuition described by Adrian and Brunnermeier. However, the other term appears to be an unintended by-product, and an important one. It is potentially large, drowning out the first term. It also measures systematic risk (for example the firm's beta) rather than systemic, and it is decreasing in the firm's systematic risk.

These optional distributional assumptions have several other implications. One example is that the idiosyncratic risk of the impacting firm is correlated with the returns of the impacted firm, a potentially empirically useful result.

5 Empirical Potential

Finally, there are many possible empirical uses. In future work, using a data-smooth or other appropriate econometric technique to back out the form of the externality will yield an interesting paper if the results are compelling about the systemic risk. The results may validate one theory of the mechanism for the systemic externality above the others. It may show a compelling functional form of the systemic risk from the financial sector to the real economy. "Compelling" would be if realized systemic risk is near zero for positive returns of the financial industry and it is smoothly but rapidly increasing as the financial industry's returns drop - combined with a rather low and flat systemic spillover from the real industry to the financial. This could validate the common proxy that researchers often use for systemic crisis: that no crisis and no impacts occur for industry returns above some threshold and financial crisis occurs below that threshold, resulting in significant losses to the real economy. Alternatively, it could call this idea into question. This is the most likely piece that I would add to the paper being summarized.

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