Connectivity and Modulation as Behaviors in the Financial System

Richard Wyndbourne Kline
June 2008

Instability potentials in highly connected systems. Is high connectivity in the financial system desirable from the standpoint of stability? Is increased liquidity uniformly beneficial to markets or the financial system as a whole? Conventional wisdom at this time would answer yes to these related but not identical questions: highly connected capital and exchange markets should 'reduce inefficiencies,' bring liquid capital to where 'it is needed,' and 'level the playing field.' These outcomes are considered unequivocal positives for the system as a whole even if they can be problematic for some individual participants. Theoretical simulations of high connectivity systems together with related experience from systems design suggest the reverse: raising connectivity or undampening propagation in a system beyond modest levels in either case leads to high systemic asymmetry at best and pervasive systemic instability at worst.

What follows is a frankly theoretical discussion; the operationalization of a thought experiment, if you will, rather than a demonstrated analysis. This concerns the behavior of financial interaction networks as systems, and does not extend into issues of production or supply. The extent to which idealized simulations such as Kaufman's cited at the end can be translated to the financial system as a whole is far from clear. Formal trading markets at least do seem closely comparable, giving a context to the observations on connectivity which will be raised first. Several further hypotheses will be presented here regarding systemic modulation in the financial system which have yet to receive any formal study against economic data. Some of these issues have likely been much more thoroughly discussed in existing economic theory; others such as connectivity have been too little considered. Those readers with a low tolerance for theory may wish to skip to the **discussion** passages, or to the closing TAKEAWAY section.

A THEORETICAL FORMALIZATION

Self-modulation occurs in systems with throughput, nodes, and connectivity between those nodes. By self-modulation, I mean that such systems will change their internal organization in consequence of their own active process without any further discrete (deliberate) internal or external impetus. With regard to financial systems, a good deal of attention is paid to throughput, incomplete attention is paid to the nodes and to their number, and little attention is paid to connectivity beyond its gross existence.

Discussions of 'liquidity' for financial systems are largely focused on the volume and velocity of throughput. Consider, though, if throughput such as credit or commodity contracts enter the system but can't reach portions of it, instead pooling in only come parts of the system. Thus, volume and velocity can be impeded by lack of connectivity, or outright compartmentalization of the 'system.' Consider if throughput reaches many nodes, but they are different in composition. Say, some nodes are brokers looking to move throughput; some are retail purchasers looking to hold throughput; some may be end consumers looking to take throughput out of the system entirely; some may need currency conversions, others may need a hedge to acquire throughput, and so on. Thus, liquidity is also impeded by how similar or dissimilar the nodes in the system are. Consider finally whether there are a few (single digit) nodes or a very large (five digit or more) number of nodes. Impedance cannot be considered the same in both conditions even if systems of both number might easily permit high volume and velocity of throughput. From this perspective, 'liquidity' is a function of the systemic order as a whole, not simply of the relative abundance of units of throughput. The present conditions in the US capital markets as of May 08 illustrate the systemic rather than discrete nature of liquidity, where high volumes of throughput (tradable and reservable Treasuries) have been injected into the system but velocity remains low in part due to impaired connectivity between nodes (counterparty risks). This example indicates that if the movement of throughput does require a supply-demand gradient, the velocity of throughput is substantially a function of systemic order.

It is conceptually useful to formalize these relationships, both for this discussion and your own thought experiments. Take the following:

number = parameter space of 1 dimension N
connectivity = parameter space of 1 dimension K
nodal differentiation = a parameter space of 2 dimensions
    size S
    differentiation D
throughput = parameter space of 2+ dimensions
    volume L
    velocity V

The number of nodes can in fact be of fractional dimension, for example considering subsidiary firms of a holding company, different trading desks of a broker dealer, and so on. For the purposes of this discussion, nodes will be considered discrete, uniform, and of a nonzero positive number. Connectivity will here be considered as a simple on-off Boolean link between nodes; either they can pass throughput if terms match, or they can't. From the perspective of throughput, connectivity can be either one way or two way. From the standpoint of the system, this is less consequential in that the presence or absence of a connection alone will change the state of two nodes regardless of the direction of throughput. Whether an exchange node buys, sells, or facilitates in relation to you, their presence or absence affects your own state. Nodes can differ considerably in size; even more important, nodes can generate quite different basins of attraction in relation to other nodes and throughput. Consider the difference between an individual buying a mortgage and a sovereign wealth fund buying derivative swaps. Such scale differences matter a lot in relation to throughput and systemic order, but surprisingly little in relation to connectivity. The differentiation of nodes has a considerable impact upon systemic order independent of outright compartmentalization of the system. Low differentiation (high similarity) in effect lowers impedance in the system as a whole in that throughput does not have to 'translate' its order from node to node. High differentiation (low similarity) by contrast raises impedance. In this model, 'units of throughput' will be considered first as largely abstract and uniform; whether credit in a currency or tradable contracts, their conditions of price and term are considered as known values. In practice, throughput is more diverse, and such conditions will be considered briefly below under modulation. In formal trading exchanges as one example though, commonality of throughput is high and differentiation low, rendering conditions of connectivity more apparent.

A few very basic observations follow from this relationship schematic. A) Connectivity K and throughput volume L vary directly: more connections, more volume moves. This relationship breaks down at very high K however, as will be discussed. B) K and throughput velocity V have a more situational relationship. More connections may drain volume, lowering velocity; they may attract volume, focusing velocity locally though not necessarily raising velocity systemically; they may better match supply-demand gradients, raising overall velocity---but depleting volume. V thus depends upon *which* nodes are connected not just whether nodes are connected. C) By contrast, nodal differentiation D and throughput vary inversely: low differentiation (higher nodal similarity) will serve to raise throughput, and likely both in volume and velocity. D) As will be discussed below, increased connectivity K modulates the systemic standing of individual nodes in a sharply nonlinear fashion whether or not it varies the size S or differentiation D of individual nodes. And finally E) given the number of dimensions and the dissimilarity of the parameter spaces, it is probable that systems of this form will have internal attractors, and that they will be capable of nonlinear changes of state both locally and globally.

CONNECTIVITY AND SYSTEMIC ORGANIZATION

Setting aside issues of throughput for the moment, simulations of connectivity have been performed which suggest general principles for the interaction of connectivity K per node and differentiation D between nodes in large N systems of nodes. I take the following six points from Kaufman's text, although they have been validated in other work as well now. To summarize, consider a system with a large number of nodes N, low differentiation D per node, initially connectivity K=0 (i.e. no connectivity between nodes), and little or no existing background correlation between nodes. In those conditions, A) even very small increases in differentiation for an individual node lead to local correlations about its advantage, yielding a basin of attraction about that node. Given low systemic correlation, that basin of attraction can propagate to the entire system and subsequently lock that system about its own order, even if the advantage of the differentiated node is very small relative to others. Starting from the same uncorrelated state, if instead B) connectivity K per node increases but still remains low ($K \leq 2$), multiple nodes in the system will acquire local advantage gradients, yielding multiple basins of attraction even if no specific advantage is especially good. Because these basins are diverse, they are not fixed, but rather changes within and amongst them can periodically shift the overall order distribution in a system even while most of these local basins of attraction remain extant through such shifts.

As C) connectivity increases to $K > 2$, however, basins of order largely cease to remain stable. Indeed, as the number of local attractors increase with increases in K, the differences between them decline in a regression to the mean effect, which in turn lowers impedance to changes in the systemic order as a whole. Even if individual nodes remain as attractors, their local basins are increasingly in flux, and the system as a whole will not settle on an order distribution. In these conditions, a system is not so much unstable as working around a chaotic attractor. In the most extreme case D) where connectivity per node becomes very high, even $K \approx N-1$, very small further changes in connectivity K or differentiation D, even to a single node, can lead to complete and sharply nonlinear state changes, even to order resets for the entire system. Such systemic cascades, furthermore, can shift between states which have no correlation to each other, i.e. catastrophic global transformations. The reverse trajectory also holds such that E) in turbulent systemic conditions with high connectivity but low differentiation, lowering K per node down to the range of K=2 will precipitate an orthostrophic state change ordered basins of attraction normalize around individual advantageous nodes and coalesce system wide stability. Finally, a significant advantage of moderately connected systems is that F) the fluid state of their internal order makes them more adaptive to changes in background (extra-systemic) conditions, changing only some internal relationships as background order changes while retaining much of their existing systemic organization. Systems with very low K and hence little reactivity or very high K and hence excessive reactivity are in either case likely to experience a system reset in response to shifts in background conditions; that is, both extremes of K are transformative rather than adaptive states.

These simulations were performed for highly idealized conditions where abstract nodes had very little differentiation per node, i.e. low D but high N, in fact with D variation being a simple on-off Boolean condition. It can be inferred, if less precisely, that G) changes in differentiation D per node will also shift systemic order by modulating the propagation effects of connectivity K across the space of nodes. At low K levels, high differentiation disrupts well-defined basins of attraction so that systemic order will be more turbulent. In such a context, lowering D (increasing nodal similarity) lets connectivity burgeon local zones of stability as in the simulations; in some respects this increases stability. At high K, lowering differentiation may still increase local stability. However, if high K is sufficiently enhanced in this way systemic turbulence may result from K cascades. The key point is that the same function---lowering differentiation D---can have sharply different systemic outcomes depending upon concurrent connectivity levels (and potentially upon other contextual parameters). Some of these outcomes can be entirely unintended and distant due to order 'flows' via connectivity. Conversely, K) raising differentiation (decreasing similarity) between nodes in a system will, in effect, buffer connectivity-driven order even in the absence of outright compartmentalization of the system, although increased turbulence in throughput may also result.

Discussion of connectivity effects in the financial system. Connectivity behaviors in market and financial systems are numerous; only a few illustrations will be given here. A good example of a global attractor forming in an uncorrelated system is Amazon.com. Many e-commerce options initially existed with purchasing throughput uncorrelated to any one node. Amazon scaled though leverage, forming a deep attractive basin. Despite being completely wrong regarding inventory management initially---i.e. a suboptimal attractor---Amazon successfully propagated its order such that e-commerce in some forms is substantially locked and even more widely correlated to it. Sensitivity to initial conditions in uncorrelated systems is transitory, though: the system locks around a global attractor, as in the case of Amazon. Unlike online purchasing throughput, system spaces for trading exchanges such as commodities or futures have high existing background correlation; margins, contract terms, settlement durations, units of purchase, and so on. Also, exchange spaces have very high N (with nodes being participants), far higher than in early e-commerce. In these conditions, no one participant can correlate the exchange space to their own order at a comparable level, or grow to the same size relative to other participants. This illustrates that existing correlation in a system dampens propagation.

If one takes derivative swaps as a state space, differentiation is initially very high as the terms of each swap are highly specific. The execution, or for that matter the failure, of anyone contract should have negligible effect on the stability of that state space or the wider financial system. There are two trajectories which eliminate the buffer of high D, however. First, the more swaps that are written, the more likely that they correlate to common background conditions: throughput can get correlated in consequence even if the swaps aren't identical. For example, any one interest rate swap can be beneficial; enormous volumes of such swaps mean correlated impacts can occur at a given strike level which can be quite disproportionate to the impact of the interest rate itself. As an example, the impact of portfolio insurance (automated puts, often index driven) in the mid 80s led the declines in diverse positions to correlate in phase and momentum rather than diffuse over individual node-investor decisions with offsetting gains: everyone ended up betting the common background market momentum, ensuring accelerating loss through resonance phase-locking. Second, present derivative swaps are themselves typically hedged with offsetting positions, which in turn are hedged, which in turn . . . . In consequence, connectivity for any one swap is extraordinarily high. The K levels achieved make K cascades all too likely. Even if all positions in fact clear in a timely fashion, which is far from certain, very large amplitude swings in consequence of correlation are a significant risk. Any one swap desk may in principle offset their own positions, but systemic correlations up to and potentially including a reset cascade can be generated regardless.

This points to a further issue that hedges as a class of activity reduce D (enhance similarity) for the positions they are written against. Consider the derivative swaps just mentioned; in principle, they have widely varying terms and risk, making the trading of each contract a unique evaluation for buyer and seller. If a swap is hedged, in principle risk is 'contained' so that the degree of risk in any one position is convergent, leading risk to factor down or out of the trading calculus which then turns increasingly on price and duration. The swap is thus more 'liquid' or tradable---a major reason for the hedge---increasing throughput. Risk doesn't really disappear, though; it is exchanged for counterparty risk and increased connectivity which brings correlation risk. Increasing throughput volume L liquidity may be an admirable goal by itself. Achieving it by lowering differentiation here takes a moderate localized risk and transforms it into a low systemic risk, with any eventual localized losses sandbagged (buffered) by reserves replaced by small systemic degradation buffered if at all only by sheer large N of the system. Derivative swaps take the concept of externalizing losses to its logical conclusion. If, a few do it, that's a good bet; if many do it, that's a bad practice. Furthermore, since the risk is low and the system large, such shifts of risk can accumulate for quite some time before they are apparent unlike risk in the swap itself.

Reduced differentiation facilitates propagation generally, but what propagates may be rather different that what is intended or expected. Take the capital flows linked to mortgages in the US financial system. Time was, behavior relative to property contracts varied substantially in form in different parts of the system. Developers had a frankly speculative model of building housing into rising demand for payment on delivery on a per unit basis, and assessed demand accordingly. Mortgage issuers typically intended to hold the mortgages as a long-term payment investment, and evaluated their counterparties accordingly. Capital markets underwrote issuer debt and sometimes located investors as a fee-for-service, and assessed fee opportunities and the market for such paper accordingly. Nodal differentiation between levels was so high that these and other levels were in effect compartmentalized; stress in any one might inhibit but seldom threatened another level. Now, leaving the reasons aside most parties in this chain have moved to a fee-for-service model. Differentiation has decreased and connectivity increased between levels so that they have become highly correlated. Furthermore, since fee generation was a priority and demand assessment much less of one the incentive to pad prices at all levels was high, making price rises not only steeper but stickier by eliminating competition and countervailing pressures. Throughput---liquidity---of mortgages increased greatly but systemic stability plunged in the process.

A final example, regulation of mortgage originators in the US occurs at the state level, with differences amongst states. In some respects, it may be desirable to move to a single regulatory regime at the Federal level, and this has recently been proposed. However, lower differentiation means that the correlation of market response to regulatory regime increases. Should markets adapt to that regime---optimize, game, capture---they are likely to increase the amplitude of their swings unless the regulatory regime is notably *more* restrictive then existing ones. Lowering D requires that offsetting changes elsewhere in the system be made to avoid shifting the existing state of the system.

SYSTEMIC MODULATION

Throughput in a system---capital principally in the context of the financial system---can have many sources, with volume V and velocity L varying widely between nodes. Throughput can take different forms with different durations; in this discussion, throughput will be considered largely equivalent if it is priced in a common medium and transferable between nodes. Capital of similar form or moving in similar ways across a system of nodes-participants needn't be reshaped drastically transaction by transaction; rather, it can be disproportionately influenced by small changes to the system which raise or lower impedance to its movement. This is what is meant by modulation. Central bank interest rate setting is substantially a modulation effect. Central bank interest rate setting is substantially a modulation effect. A central bank 'signal' is small in relation to overall capital throughput, but even in the absence of legal compulsion that signal forms a value range around which transaction throughput is abundant and moves freely, while defining outlier value ranges where throughput moves poorly and accordingly is scarce.

Modulation can be externally caused, or derive from a single node or sub-system. However, it is possible for a system to self-modulate, particularly if it's throughput self-correlates. Separate from node and connectivity behavior, if many different kinds or terms of throughput move across nodes, any form which has lower resistance will move over more nodes; if its volume can scale, a larger share of throughput over a larger share of nodes is of the same form. If and as nodes are optimized to move a particular form of throughput, other forms or terms of throughput most nearly similar may see their velocity, volume, and distribution increase as well. By contrast, if particularly large basins of attraction optimize for a particular term or periodicity of throughput, by connectivity those fluctuations may structure resonance of throughput in connected nodes, especially if their basins of attraction are smaller. Such auto-correlative changes do not require overt external intervention, although in financial markets such throughput convergences are highly profitable if spotted or maximized so external intervention in throughput flows is high and probable.

While high K in a system implies organization via 'flows' of internal order, nodes throughout a system are not necessarily correlated amongst themselves, or at least not highly correlated. It is possible, though, that throughput across such a system can itself become sufficiently modulated as to yield a field effect. In particular, as nodal differentiation decreases, the action of throughput is increasingly similar regardless of where it passes through a system: the throughput in effect self-correlates even if nodes and local connectivities retain significant diversity. Field phenomena have low overall resistance to point-source propagation; that is, local and indeed small changes can uniformly shift the order of the whole. Marginal pricing in markets with good transparency strongly suggest a field order. Individual nodes may wish to diverge from a price point, but resistance from the rest of the market will be high; over any near duration, the field order will reduce the price discontinuity to the field order. The only alternative is for a node to break connectivity, that is not to transact throughput. This result, though, only drives convergence in the remaining throughput until and unless large N nodal share disconnect.

Assuming that throughput continues over a system which yields a field order, disproportionately small inputs can potentially focus (correlate over a duration) the throughput; this is signal source modulation. Again, large-large reasoning does not hold, especially for field phenomena: small value signals can reference many flows of throughput which they do not actually transact. The way in which specific nodes modulate overall throughput may be even more important than whether individual nodes or subsystems block or accept throughput altogether. For example, a market maker needn't handle any significantly large volume of capital throughput on an ongoing basis in its market so long as it bounds a range of throughput correlation (keeps volume or price centered over a preferred range). Field effects can be modeled by tensors, but their 'statistical logic' to use a broad term is distinct from that which follows from the kinds of statistical tools typically used for economic activity. In principle, throughput in a system is likely a tensor field, while the system it is mapped to if nodal may well itself be a scalar field. Moreover, fields can be modulated and even self-modulate; that is, they can globally reference their order state on a continuous basis. I cannot prove this conjecture, nor will I pursue it technically in any way, but the possibility suggests some intriguing explanatory metaphors for financial flows.

Moreover, fields induce flow. Set a price or a volume gradient for capital, and said capital will flow across a system, typically towards high capital density regions. Moreover, the gradient 'induces' illiquid or capital-like assets to shift toward liquid forms, or otherwise to shift their state. High nodal differentiation D impedes this process, and outright compartmentalization (say, currency conversion controls) restricts it. However, consider how the change in one currency value can still affect the valuation of another non-convertible currency via 'informal' or black market translation: This suggests field induction effects. Or consider certain classes of mortgage backed securities as of 08. When they circulated relatively freely as throughput with velocity V, they had a certain value. As their velocity declined, their value on the books of their holders has declined even without marginal price changes through open trading. Once completely immobile, their value is well less than previous face even without massive collateral destruction internally (yet, for some). To state this differently, a portion of their asset price is field induced. It went up with field induction from velocity V, and has declined as induction declined. One can see this arc as a 'psychological' one on the part of holders, surely in part rightly, but there is a 'superstition' element to such explanations too in that induction can't be seen so perceptions of 'mood' are created to explain 'gravity' which can't be seen. The invisible hand is the beck and grasp of a tensor field.

Lowering differentiation D between nodes likely accelerates throughput for the same connectivity K, which in turn enhances induction across the system. It is obvious to see how positive and negative feedback loops can develop in such conditions even if at first glance this seems counterintuitive. Reframing this hypothetical observation, either lowering D or increasing velocity V at least in a system probably *increases* rather than lowers feedback through the action of induction.

Finally, if throughput is sufficiently high in volume, velocity, or both, it can override, even mask, differences in nodes in the system. Few care about the size or distribution of a bank's collateral so long as large capital flows move in and out of their T1 router without constriction. We've seen this in the 'liquidity' amplified Securitization Crisis. In fact, even bank-like hedge funds without significant collateral perform exactly the same in the system at high throughput levels. When throughput volume or velocity drop, suddenly capital strength or term matching in a given node count greatly. The key point there is that overall system stability may vary considerably for different field states in the system, and that furthermore high V and high L throughput states make dysfunctional or non-nodal intermediaries function like nodes. System performance with high throughput will consistently give a misleading view of system stability. Correlation of throughput can by field induction carry flow behavior beyond the structural capacity of existing nodes.

One further issue is suggested if capital throughput in financial systems is considered in terms of field effects: capital concentrations may function as gravity wells. Without formalizing this notion mathematically in any way, capital densities are attractive systemically. They yield a field effect such that assets which are comparatively immobile in local contexts are induced to move when connected to the 'well' or gradient of systemic capital density. The more that capital aggregates in one place in the financial system, the more it tilts that system toward the central attractor in its gradient basin. In capital dense regions of the financial system, it takes greater capital volume to have an effect, but at the same time larger capital concentrations are accessible. There may be compression effects in terms of increased consumption of capital in high density nodes as well. . . . The analogy is far from perfect, but it is suggestive of systemic effects.

Discussion of systemic modulation effects in the financial system. Systemic modulation of capital throughput doubtless has positive influences, whether through field effects or by more typical positive and negative feedback which have been little discussed here. The salient 'positive' influence, and one well understood, is that systemic modulation can significantly increase 'liquidity.' This can be much a mixed blessing, however, because modulation in general and field effects in particular drive changes across a system by propagation so that increased 'liquidity' can yield more unintended consequences than intended ones. Something as large as the financial system may seem to have a lot of inertia, lack of central control, and diffusion-inducing fragmentation, conditions which should limit or at least buffer propagation transformations. However, field and modulation effects take place at a different level of system complexity where resistance to propagation may be far lower.

Take the example of collateralized debt in general, or collateralized mortgages specifically. As discussed above, bundling of mortgages and layering in monoline insurance or derivative swaps all served to lower differentiation, 'liquifying' these assets as throughput. If their value had remained constant, supply might have swamped demand, and lowered velocity via negative feedback. However, the movement of the assets as throughput increased their value, serving as an accelerator: the collateral appreciated in part by induction because it could easily be traded. Increased connectivity with decreased differentiation allowed demand (credit) to flow back down the channel from capital markets all the way to individual purchasers. Because this liquified capital had good velocity and was appreciating, it more easily jumped to distant nodes such as acquirers in Central Europe and East Asia. Regulatory nonfeasance left capital market demand increasingly unbuffered, while interest rate modulation lowered 'friction' thus raising throughput velocity V.

To read the mass media, the resulting price bubble was the result of uncontrollable consumer demand to borrow; consumers however were largely paying such high prices because they were induced by asset appreciation. The bubble more nearly looks to be the consequence of capital markets' uncontrolled willingness to lend because the resulting units of throughput were so liquid that they could be moved rapidly off of originators and underwriters books (for a fee). Only when lender demand exceeded borrower supply (income) did the system crashed into irregular brownouts, since shifted to rolling brownouts. 'Supply' and 'demand'---and who's using who---can look quite different when considered in the context of field effects. A general inference from this example is that unbuffered/undampened propagation in a system will generate asymmetries which exceed local node parameters to upside or downside. In this case, unbuffered capital market demand pulled in a surge in liquidity volume L flows, induced housing price rises far beyond income, and thus 'drew' value out of consume income flows faster than they could replenish it.

With regard to capital density in financial systems, there is a further issue. In the hypothesis above, such concentrations act as gravity wells, drawing throughput toward their own basins of attraction. Because connectivity in a system also allows 'order' to flow, such 'capital wells' may also propagate their own organizational order across the system; that is, they may drive other nodes and other localized stabilities to shape and act increasingly the same way. Such order flows are not necessarily either complete, linear, or stable; however, their net effect may be to drive differentiation D down, and increasingly to correlate it. The extent to which this might be considered a field induction is not clear, but if order flows principally through connectivity likely induction is a lesser influence. Nonetheless, systemic modulation is occurring, but via the medium of K rather than throughput.

The key point is that a basin of attraction in a system needn't directly control a large fraction of a system to modulate much or all of it so long as the system has few buffers to propagation effects. Indeed, the modulating node/basin and much of the rest of the system needn't even be directly connected. Thus dense capital wells in this hypothetical instance can drive system organization, velocity, and correlation by shifting system behavior gradually closer to their own order. Such outcomes are readily evident in previously uncorrelated systems, but they permeation of organization can happen even in highly complex systems, although the interaction order can be expected to be chaotic in such cases. Both velocity and correlation can be systemically destabilizing at high values, which suggests that **dense capital concentrations are inherently destabilizing for the systems in which they arise**. It should be noted here that the real agenda in globalization of financial services, in my view, was exactly to propagate the organization of the American-Anglo capital concentration, first in relation to previously uncorrelated emergent capital in peripheral economies and then by correlating throughput to enhance its own intermediation. Without detailing this general observation or this specific example, we are now experiencing amplitude swings from nodal resonances which would have been offsetting on a regional basis but are now increasingly on a global basis.

Increased connectivity and increased 'liquidity' are both seen as positives presently for a financial system in that they are presumed to make participation 'fairer.' Greater connectivity K is seen as leveling the playing field, so that individual nodes have greater access to capital, information, and a piece of the action. However, the principal effect of raising connectivity in systems with existing salient attractors is to boost the amplitude and propagation of those attractors: the rich get richer, to be blunt. This is the source of many Pareto distribution effects, where over time small volumes of nodes in a system monopolize large shares of the organization of the system. Moreover, the more that differentiation D is lowered (similarity increased) so that nodes behave the same way, the more skewed this connectivity effect will be. It is perhaps true that increased throughput, read 'liquidity,' in a low-K system will enhance individual nodes, or at least localized basins of attraction. However, increased throughput in a high-K or low-D system is more likely to amplify the basins of existing nodes, perhaps inducing field effects which exponentiate this process. It is not a coincidence that totalitarian political systems rigorously enforce uniformity, and make participation compulsory: power to the powerful is the systemic outcome, both in intention and in effect.

The systemic perspective here is that deliberate or self-organized increases in connectivity in a system will inherently draw throughput into a decreasing number of intermediaries without external intervention, with a further consequence of increased correlation of throughput. Such systems are not only 'unfair,' they are also **self-destabilizing** if they continue to self-enhance connectivity. This outcome may also result if systems self-correlate their throughput, although the inferences there are less clear. Perhaps the most effective way to disperse Pareto skews and 'increase fairness' in such systems without external intervention is to increase differentiation for the same levels of K and throughput, which will enhance niche behaviors. This is 'inefficient' but more stable: notice the direct relationship between those conditions. Speciation diversity through adaptive radiation is an example of stable systemic adaptivity; monoculture agribusiness is an example of destabilizing systemic adaptivity. (Call me a Luddite, but I prefer nature's way.)

THE TAKEWAY

In thinking about the preceding discussions, it is important not to reify (objectify) concepts such as throughput and connectivity; these terms are descriptions of behavior, not statements of entities. For a simple takeaway on the ideas here, the observations above are summarized in capsule as follows:

Organization in a system will self-generalize: order 'flows' across the nodes in a system inherently. Relatively stable organization will shift as differentiation D per node and connectivity K per node shift. Even if these changes are linear at the level of individual nodes, they are typically nonlinear at the level of the system, and may involve complete state changes with very short thresholds of transformation.

Correlation across a system tends to involve shifts in differentiation D and connectivity K; that is, correlation is substantially amongst nodes and their basins of attraction. Correlation is particularly important in studying how a system changes from internal state to internal state. Modulation across a system tends to involve shifts in throughput, both in velocity V and volume L, but also regarding self-correlation of throughput. Modulation is particularly important in studying how a system functions in and near to a particular state.

Differences between parts of a system create resistance to flows across a system, whether flows of order, of throughput, or both. Differences create 'inefficiencies,' but they also buffer propagation in a system. Specifically, differentiation D---the extent to which nodes in a system vary in size, composition, and function---buffers node to node flow. Connectivity K between nodes allows both order and throughput to circulate widely in a system. However, K is often agnostic as to the influences it allows to propagate, so that if changes in K may yield outcomes as intended they can yield and often do yield ones pervasive and unintended. Background correlation---the mapping of a system to its supporting context---often also serves as a buffer to propagation in a system since the background order is independent of and often resistant to modification by the order of an coordinated system. If the background order is itself highly correlated, though, it may function as a catalyst rather than as a buffer.

Systems with pervasive connectivity K amongst nodes have the advantage of being significantly adaptive to external changes. Raising connectivity for a system increases its overall adaptivity. However, this is accomplished at the expense of stable internal organization since high-K systems are very prone to system-wide changes: they are globally rather than locally adaptive. Global warming is a fair example of a global adaptation.

Lowering nodal differentiation D in a system increases 'efficiency' in that it lowers buffering of throughput and allows connectivity to propagate order changes in a system beyond local attractor basins. However, this may be at the expense of system stability as the effect may be the same as increasing connectivity K to levels where system organization becomes chaotic.

'Liquidity' in a system is a composite behavior. Not only does throughput vary in velocity V as well as in the 'headline number' of volume L, it may modify itself through self-correlation. Additionally, ‘liquidity’ is so affected by changes in both differentiation D and connectivity K in the underlying system that no valid perspective on liquidity can be formed independent of the latter factors.

There is the possibility that running throughput across a moderate connectivity K, low differentiation D system creates a field effect in the organizational state of the throughput itself. Statistical reasoning appropriate for field functions is seldom used in assessing throughput organization in the financial system, leading to misunderstanding of systemic conditions by observers.

Should attempts be made to modify a moderately connected, nodally comparable system, one can at a minimum: A) vary size of nodes, or B) vary differentiation (similarity) of nodes; damp or undampen connectivity by C) varying links per node, D) varying the scale of links, or E) severing links selectively; modulate throughput by F) varying velocity, G) varying volume input, H) impeding the range of throughput across a system, or I) impeding changes in throughput state.

In systems of this kind in general, and the financial system as a specific example, undampened propagation, massive correlation across nodes, or tight couplings between subsystems are all known to diminish systemic stability through cascade effects. Cascades can certainly be limited by outright compartmentalization such that portions of the system communicate through overtly controlled ‘gates.’ This is highly inefficient however, and moreover difficult to achieve in the case of the financial system which is highly fragmented into many nodes. Soft compartmentalization may be more effective. For one example, nodes can be restricted in their interaction with throughput. For another, connectivity can be modulated or restricted though this requires a broad perspective of the system as a whole. In a system of political economy, this is called ‘regulation.’

Throughput correlation may be beneficial, but it may also be destabilizing; the issues here are unclear. Hard limits on the volume of throughput are again inefficient, and moreover will be hard to enforce in the global financial system. Concentrations of throughput need to be closely monitored, but systemic connectivity must be considered in tandem due to its capacity to shift stress from system locations of obvious concentration. Modulation of throughput rather than outright barriers offers a high return of effect for a low investment of cause. For one example, dampening throughput velocity may offer a valuable buffer. In general, insulation will be useful with regard to throughput, but interventions which serve as ‘capacitors and resistors’ may have the largest potential value.

Further reading:

Stuart Kaufman. 1993. *The Origins of Order*.
Christopher Chase-Dunn and Andrew Hall. 1995. *Rise and Demise*.

[Kaufman’s text is dense but seminal in discussions of systemic connectivity, in this case amongst genes. Chase-Dunn and Hall consider core-periphery relations, a concept from political economy which has different implications from the perspective of systemic connectivity.]