UBS

Global Research

4 July 2016

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Q-Series

How can supply chains improve earnings visibility?

Equities

Global
Quantitative

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Supply chains matter

Supply chains and network effects are of increasing importance in the global economy. The recent investor focus on quality and ESG (environmental, social and governance) has brought unprecedented transparency to the supply chain and revealed a rich new data source for financial analysis.

Conquering network data is challenging

Network data requires a paradigm shift in its analysis as conventional techniques are woefully ill-equipped to handle relational data. While it might seem obvious how adjacent business relationships affect each other in isolation, it is far less obvious how to discern the bigger picture. Our investment thesis is simple: we believe equity markets react to supply chain developments in a piecemeal manner, which exposes mispricing opportunities that we can quantify with the right tools.

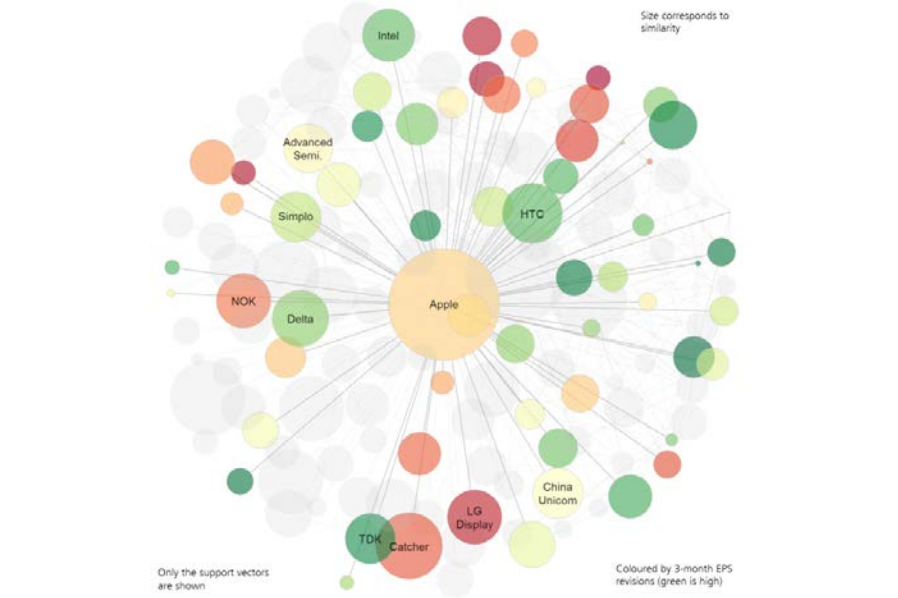
A new form of securities analysis is required

Fortunately, this is a very active area of academic research and commercial interest—network data is the foundation of the most successful technology companies today. We introduce a powerful new machine learning technique for understanding supply chain effects, in plain English and assuming no prior knowledge in the field.

The upside is significant—long and short mispriced opportunities

We then use this technique to predict the supply chain impact of earnings revisions and price momentum signals, and find this significantly improves performance in developed markets. These performance gains are steadily improving as the supply chain picture becomes increasingly transparent, and we see the largest performance gains in markets with the most competitive (i.e. unconcentrated) business environments. Our highest predicted earnings revisions are for Thermo Fisher Scientific and Home Depot; our lowest predictions are for CF Industries and Mitsubishi Materials.

Forming stock-level predictions



Source: FactSet, UBS

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Executive Summary

Supply chain effects matter

The Thailand floods in late-2011 rattled the global supply chain, reminding us how connected the world economy has become. From computer hard drives to automobiles, economic shudders were felt worldwide as this seemingly small, but critical cog seized in the Swiss watch that is global trade.

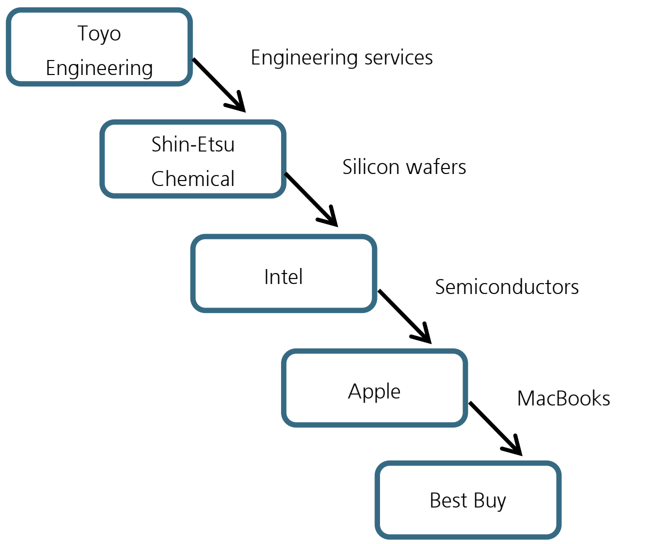
And they are becoming increasingly visible

Less than five years later, we observe an incomprehensible complexity growing in the global supply chain; a tangle of business relationships born of globalisation and perpetual technology drivers. Furthermore, the renewed investor focus on ESG and quality investing introduced unprecedented transparency to supply chains and revealed a rich new data source for financial analysis.

But network data analysis presents a new challenge

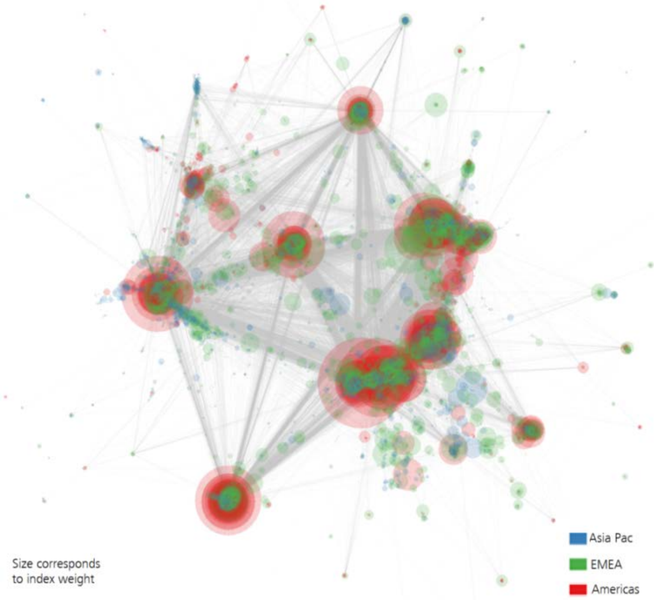
But there is no free lunch. Network data requires a paradigm shift in its analysis, as more conventional techniques are woefully ill-equipped to handle relational data.

Figure 1: A single thread…



Source: FactSet, UBS

Figure 2: …in a global tapestry



Source: FactSet, UBS

While implications for adjacent relationships seem obvious…

Intuitively, we expect that a big earnings surprise for Apple has implications for its suppliers like Intel, its customers like Best Buy, and its competitors like Samsung—but this simply does not fit into any conventional paradigm; these relationships span industries, geographies and size bands in a seemingly chaotic fashion.

…this overlooks the bigger picture

And while it might seem obvious how adjacent business relationships affect each other, it is far less obvious how to discern the bigger picture. This is a single thread in a global tapestry of business; a stitch coming undone seemingly far away from one company may manifest itself later on, as inventories run dry, accounts receivables balloon or cascading write-downs expose structural weaknesses.

Markets react in a piecemeal manner; machine learning gives us a new approach to this data

Our investment thesis is simple: equity markets take time to react to these business developments in a piecemeal manner, which exposes mispricing opportunities we can quantify with the right tools. Fortunately, network data is a very active area of research and commercial interest—in fact, such data is the foundation of the most successful technology companies today.

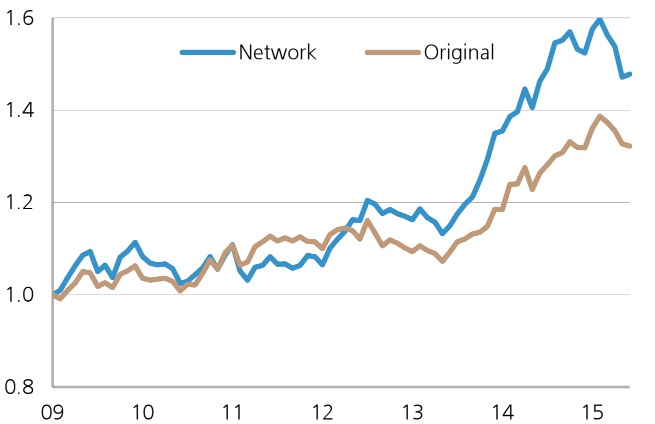
Following our earlier popular research on machine learning, our clients demanded more applications of these modern techniques to add to their investor toolkits for making sounder investment decisions. In this report, we introduce a cutting-edge machine learning technique in plain English, assuming no prior knowledge in the field. We then use this to analyse supply chain networks and better understand the interconnected nature of financial information.

Using a cutting-edge technique to analyse supply chain networks…

Borrowing a result from mathematical physics that describes how your morning coffee heats up the coffee mug, we describe how price and earnings momentum diffuses through the supply chain. Known as a "kernel support vector machine", this technique is a powerful tool in the investor's toolkit—and to our knowledge, our attempt here is the first application of it for supply chain networks.

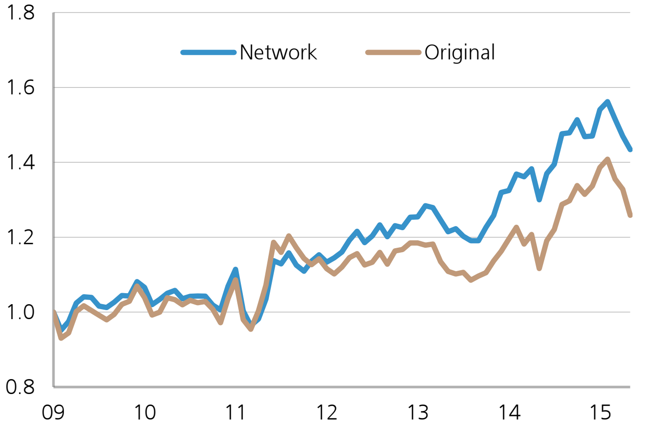
…we can better understand the interconnected nature of financial data

Figure 3: Earnings revisions (3M), MSCI World



Source: FactSet, IBES, MSCI, UBS

Figure 4: Momentum (12-1M), MSCI World



Source: FactSet, MSCI, UBS

We then use this technique to predict the supply chain impact of earnings revisions and price momentum signals, and find this significantly improves performance in developed markets. These performance gains are steadily improving as the supply chain picture becomes increasingly transparent, and we see strongest performance in markets with the most competitive (i.e. unconcentrated) business environments.

Enhancing our perspective on earnings and price momentum

The performance in emerging markets is unimpressive due to data limitations, but this is improving. Subsequent reports will draw further on the expertise of the UBS Evidence Lab to address these shortcomings.

Figure 5: MSCI World—Highest predicted revisions

Ticker	Name	Price (loc)	Rating	EPS Rev. 3M	Network
TMO UN	Thermo Fisher Scientific	149.23	Buy	2.52	0.97
HD UN	Home Depot, Inc.	129.62	Buy	1.32	0.93
JNJ UN	Johnson & Johnson	121.29	Buy	1.53	0.86
PM UN	Philip Morris Intl. Inc.	101.28	Neutral	2.07	0.80
HCA UN	HCA Holdings, Inc.	76.66	Buy	1.65	0.75
1803 JT	Shimizu Corp.	955	Buy	0.72	0.75
LPT UN	Liberty Property Trust	39.33	Neutral	1.66	0.75
NOC UN	Northrop Grumman Corp.	221.8	Neutral	1.34	0.74
UNH UN	UnitedHealth Group Corp.	140.86	Buy	1.59	0.71
NTRS UW	Northern Trust Corp.	65.23	Neutral	0.98	0.71

Source: FactSet, MSCI, IBES, UBS estimates

Figure 6: MSCI World—Lowest predicted revisions

Ticker	Name	Price (loc)	Rating	EPS Rev. 3M	Network
CF UN	CF Industries Holdings, Inc.	24.22	Neutral	-1.82	-1.03
5711 JT	Mitsubishi Materials Corp.	251	Neutral	-1.57	-0.79
MTB UN	M&T Bank Corp.	117.05	Neutral	-1.48	-0.72
AES UN	AES Corp.	12.33	Neutral	-1.65	-0.69
6506 JT	Yaskawa Electric Corp.	1306	Neutral	-2.19	-0.68
JNPR UN	Juniper Networks, Inc.	22.35	Neutral	-1.34	-0.58
AIG UN	American International Grp.	52.87	Neutral	-1.60	-0.56
ETL FP	Eutelsat Communications SA	17	Neutral	-1.53	-0.55
CNR CT	Canadian National Railway	76.29	Neutral	-1.28	-0.53
JM SP	Jardine Matheson Holdings	57.85	Sell	-2.45	-0.53

Source: FactSet, MSCI, IBES, UBS estimates

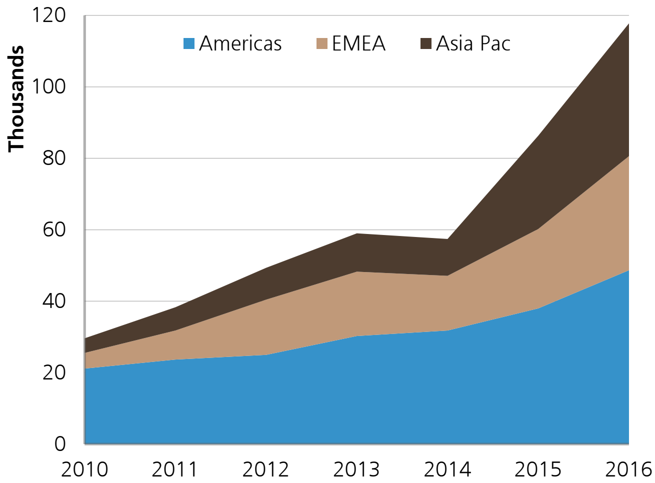
A new data source…

As quantitative analysts, we are continually looking for new data sources to help us understand and explain market effects. One such data set that has recently become available is the business supply chain database from FactSet.

Supply chain networks are an untapped source of information

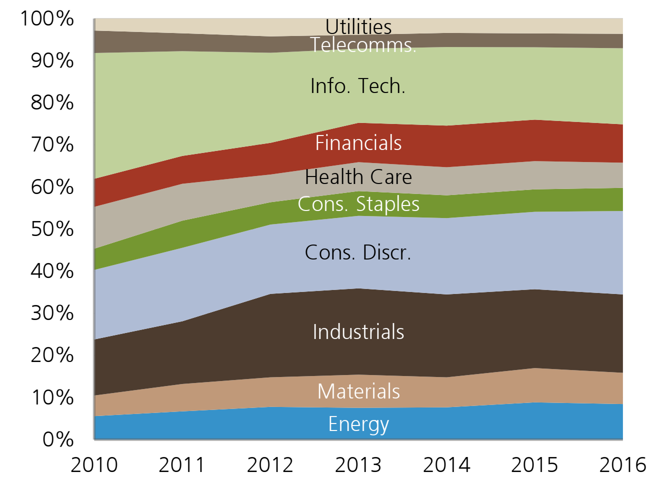
Essentially, this captures any supplier, customer and partner business relationships disclosed in financial statements, press reports, regulatory filings, and so on. In practice however, such a database is by its own nature always incomplete as supply chain information disclosure requirements are in their nascent stage.

Figure 7: Supplier linkages by region



Source: FactSet, UBS

Figure 8: Supply chain links by sector



Source: FactSet, UBS

For instance, in the US, Reg S-K states that companies that are publicly traded on a US-based exchange must disclose customers that account for 10% or more of revenue on an annual basis. However, this information is still limited as there is no requirement for their supplier counterparts. Furthermore, there is no particular economic rationale to the 10% threshold, and most companies do not have customers that represent more than 10% of revenue.

Some jurisdictions outside of the US follow similar guidelines, but it is generally just in good practice rather than an actual mandate. For instance, the IFRS proposes the disclosure of clients that represent 10% or more of revenue, but not explicitly named, and we still see instances of "Customer A", "Customer B", etc.

Investor focus on ESG means increasing supply chain transparency

While mandatory disclosure rules are lax and economic disincentives for companies to disclose this information remain (due to intellectual property concerns, for example), there are stronger catalysts for the increasing availability of this data:

- *Environmental*. Investors are increasingly focused on environmental impact and sustainable development as the implications of climate change unfold; indeed several large asset managers have divested their entire fossil fuel exposure.

- *Governance*. These concerns have renewed afresh in the wake of Dieselgate. As the scale and extent of this scandal unfolds, investors are demanding greater transparency to better understand the risks of their holdings.

- *Ethical.* The California Transparency in Supply Chains Act became law in 2012. Designed to prevent human trafficking and slave labour, it requires companies in California with annual revenue above US$100m to "disclose their efforts to eradicate slavery and human trafficking from their direct supply chains for tangible goods offered for sale." Apple is an example of one company that provides supplier lists as part of its compliance.

- *Sanction/compliance.* The so-called "conflict mineral" portion of the Dodd-Frank Act requires companies to affirm that any coltan, cassiterite, gold, or wolframite is not sourced from the Democratic Republic of the Congo or adjoining countries.

Currently, the only vendor that provides global supply chain relationship data in feed form is FactSet. Bloomberg has a trove of data in its SPLC function, but this is largely limited to the function itself, and a very restricted Excel API. Both datasets, however, are limited to the challenges mentioned above. So any attempt to build a comprehensive supply chain database must be augmented by primary research, which requires extensive exploration of alternative data sources and poses its own difficulties. For instance, filings in various places use multiple names relating to the same entity, use only marketing logos or use less formal names referring to a larger parent entity. Examples include "Foxconn" as Hon Hai Precision Industry; or the semiconductor distributor TTI, which is an operating subsidiary of Berkshire Hathaway.

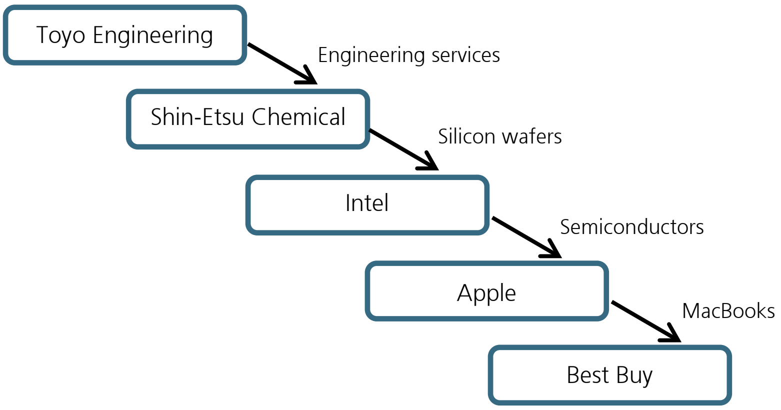
The UBS Evidence Lab platform is doing all this hard work for you. We have augmented structured data feeds with non-structured disclosed information and added the expertise of our sector analysts globally. We believe empowering our clients to navigate in a new era of supply chain “hyper-transparency” will be paramount as the complexity of the *visible* supply chain continues to increase—therefore, supply chain effects will become increasingly difficult to analyse and mispricing opportunities will increase accordingly.

…Presents a new problem…

Network data presents a new challenge for financial analysis, which traditional techniques are woefully ill-equipped to handle. For instance, consider a *tiny* part of Apple's supply chain shown in Figure 9. Toyo Engineering is building an ethylene plant for Shin-Etsu Chemical, which also supplies silicon wafers to Intel, which turns them into semiconductor chips used in Apple's MacBooks, which are supplied to Best Buy, which in turn supplies them to consumers.

The implications for adjacent business relationships seem obvious

Figure 9: A single thread in Apple's supply chain



Source: FactSet, UBS

Markets react to new information piecemeal; exposing mispricing opportunities

But the bigger picture is far more difficult to discern

While it might be obvious how adjacent business relationships affect each other in this example, it is far less obvious how to discern the bigger picture. This is a single thread in a global tapestry of business; a stitch coming undone seemingly far away from one company may manifest itself later on, as inventories run dry, accounts receivables balloon or cascading write-downs expose structural weaknesses.

Even so, Apple and Intel do not have a single direct relationship as Apple is both a client and supplier of Intel, at different levels. Economic linkages between these companies can also have varying correlation dynamics depending on the trigger. A drop in profit for Apple will have a different impact on Intel depending on whether the trigger of the decline came from the revenue side or the cost side of Apple's income statement. Furthermore, a one-off tax issue or a write-off for Apple could have different implications than a recurring long-term increase in labour costs.

We need a paradigm shift in data analysis

Despite these complications, our investment thesis remains simple; equity markets take time to react to these business developments in a piecemeal manner, which exposes mispricing opportunities we can quantify. This requires a paradigm shift in its analysis, as conventional techniques will yield meaningless results if they do not account for relational data.

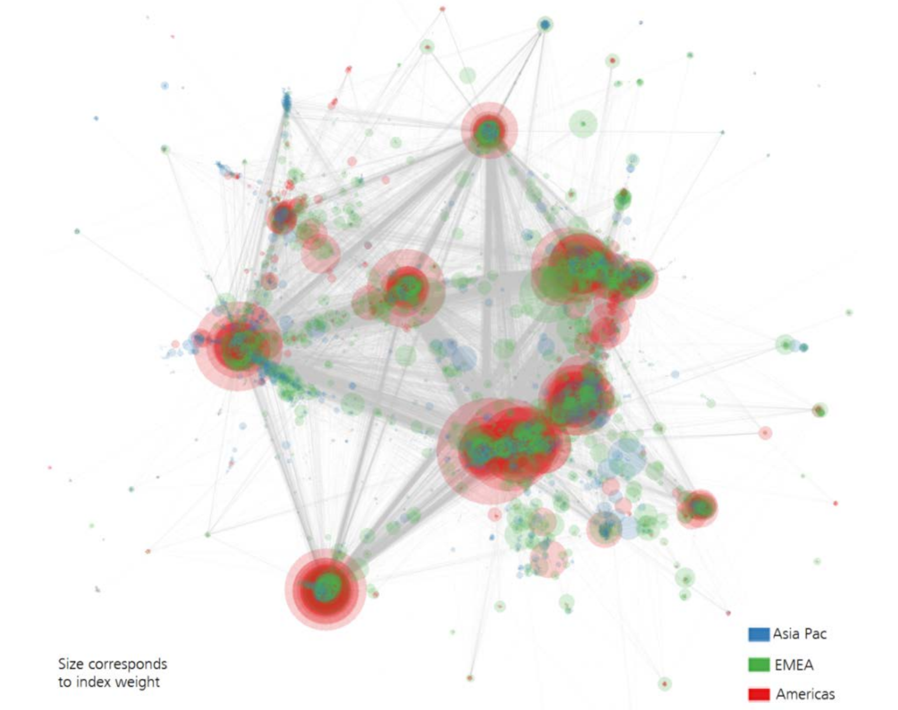
An explosion of interest in the analysis of such datasets

Fortunately, we are not alone in this quest. There has been an explosion of network datasets published over the last decade or so, e.g. in telecommunications, chemoinformatics, molecular biology and sociology. These have been accompanied by significant academic and commercial research interest in their analysis.

Network data is the cornerstone of the (second) tech revolution

In fact, many of the most successful tech companies beyond the tech-wreck have harnessed the power of such datasets to full effect. For instance, every Facebook interaction is scrutinised by marketing algorithms, Google distils meaning from the chaos of hyperlinks spanning the entire internet, while Amazon and Apple represent the paragon of supply chain logistics in their own right.

Figure 10: The global supply chain visualised—clear as mud



Source: FactSet, UBS

However, research remains fragmented and immature

However, network research is very much an emerging field. It is heavily fragmented and often the research conducted is not very "vertical". Rather it often addresses a small component of what might form a real-world problem. Network research can be lumped into four categories of interest:

There are many ways to plot network data

- **Network visualisation**. Usually the first step of exploring a new data set is visualising it. This field addresses the conventions, aesthetics and constraints to effectively convey information from a highly complex network structure. Aside from making pretty (but often unintelligible) charts, this is not useful to us.

A language for quantitatively describing networks is needed

- **Network characterisation**. We need a language for describing the network quantitatively, e.g. how can we *quantify* how "important" certain nodes are, or how "clustered" the network is? This probably comprises the majority of network research published, though it is arguably not the most fruitful; nor are the frequent, clumsy mashes of such techniques into financial applications.

So we can describe their evolution and infer meaning

- **Network modelling**. Equipped with this new language, we can now simulate networks grown from the same gene pool to determine the significance of our observations. Just as we might consider whether a correlation co-efficient of 10% is significant at face value, often a reference is useful to better understand these statistics; network models give us a framework for doing so.

Or model other processes affected by network interactions

- **Network processes**. Perhaps the network structure is not of primary interest and we are interested in modelling some underlying process that "sits on top" of the network, or flows through it. The challenge here is finding a technique versatile enough to model complex network effects, but robust enough to produce meaningful results.

In this report, our efforts are focused on network processes. We model the diffusion of earnings revisions and price momentum as they absorb into the supply chain, using a cutting-edge machine learning technique.

...Requiring a new solution

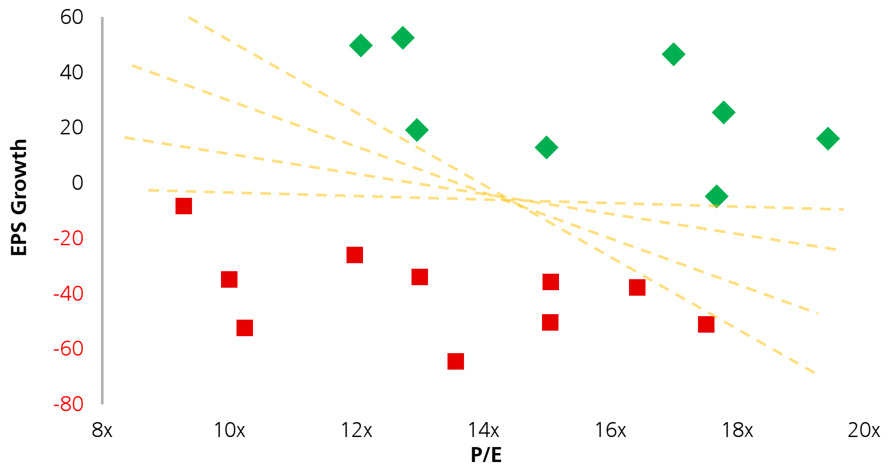
Support Vector Machines

Suppose we are trying to determine a relationship between valuation, growth and earnings surprises. Imagine then the simple illustrative example in Figure 11 below, in which companies "beating" estimates are marked with green diamonds and companies "missing" estimates are marked with red squares.

How can we "best" separate the beats from the misses?

So our task essentially boils down to how to "best" separate beats from misses. Unfortunately for us, there are an infinite number of solutions to this problem, all of which perfectly separate this data—meaning they all appear 100% accurate.

Figure 11: Which line "best" separates the beats from the misses?



Source: UBS

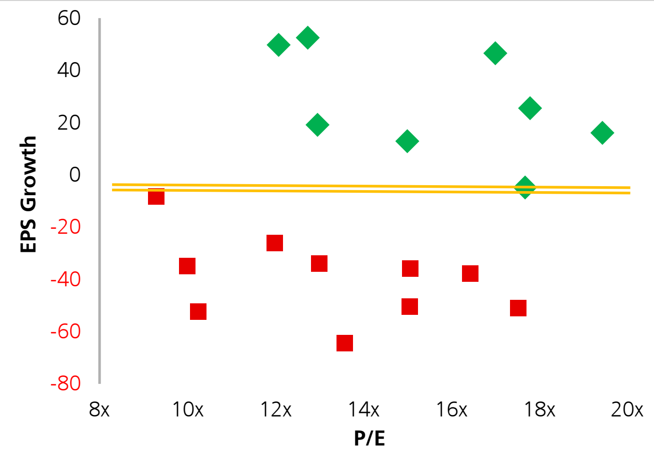
There are many ways of approaching this

For example, in our earlier research on using machine learning for stock selection (link), we explored a technique called random forests; these use individual decision trees that might "split" the data with a vertical or horizontal cut as in Figure 12.

Support vector machines find a more intuitive solution

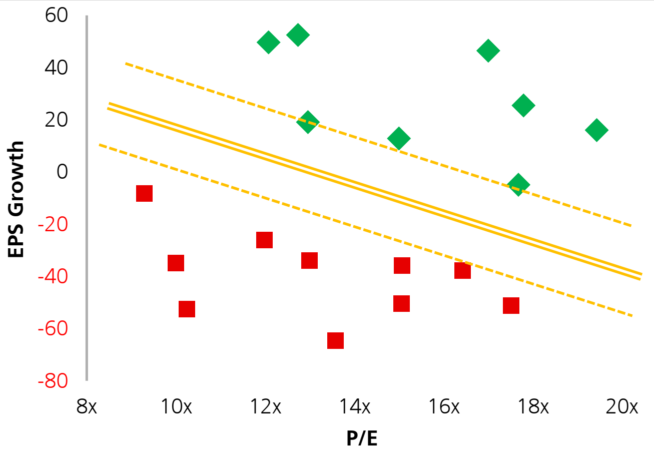
On the other hand, support vector machines (SVM) aim to separate the beats from misses by choosing the line with the widest gap (the *margin*) between the two groups (Figure 13). This perhaps more closely aligns with our intuition if we were to draw a line by hand—essentially this is the line furthest away from both groups.

Figure 12: Decision trees make horizontal or vertical splits



Source: UBS

Figure 13: SVMs split where the margin is maximised



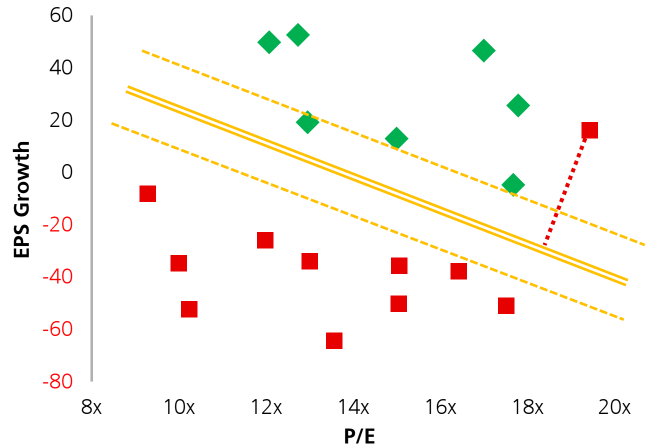
Source: UBS

Of course, in practice our problem has many more dimensions than just PE and EPS growth, so we generally cannot just spot a good solution visually and draw it. However, there is a unique solution to this problem that many free software packages can easily compute—though it cannot be solved in Excel.

Real-world financial data is noisy; we need to tolerate this

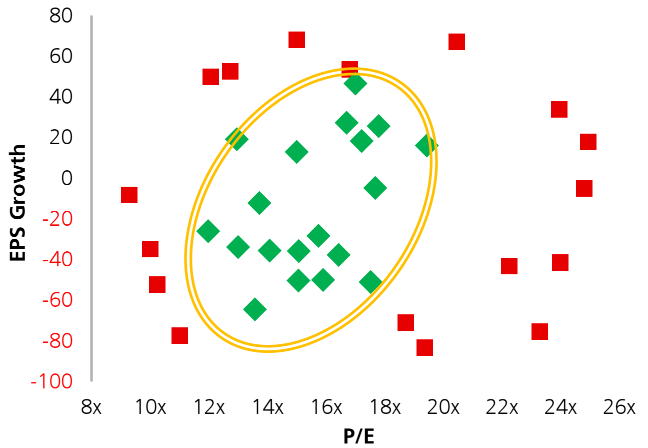
Let's get closer to reality… what if a straight line cannot separate the two groups? Financial data is often quite noisy and a single anomalous data point could render the solution infeasible. Therefore, we need to be more forgiving of noise and relax this hard constraint, by penalising data points on the wrong side of the "best line" (Figure 14).

Figure 14: We can tolerate noisy data…



Source: UBS

Figure 15: …and accommodate data structure



Source: UBS

Linear relationships are rare in practice, we need to be flexible

But how can we take advantage of any deeper structure in the data (Figure 15); what if the best line is just not linear? In practice, linear relationships are quite rare; very low or very high earnings growth might be symptomatic of poor earnings visibility, or very low valuations might indicate value traps, for example.

Or more to the point, what if the beats and misses are all interlinked via the supply chain? Perhaps a plummeting crude oil price sparks a cascade of downgrades from drillers to refiners, toolmakers, explorers and so on. There must be a connection between such events, but this does not fit into any existing data analysis paradigm.

Ideally, we could incorporate such domain knowledge into our solution, but how? For this, a kernel is often used.

Kernels

A kernel is just a function that transforms the original inputs so we can (hopefully) find a better fit afterwards. More precisely, it defines a similarity measure that encodes our prior knowledge of the problem, e.g. value traps, earnings visibility or supply chain linkages as above. To see how this works, let's take a quick step back.

A kernel just outputs similarities

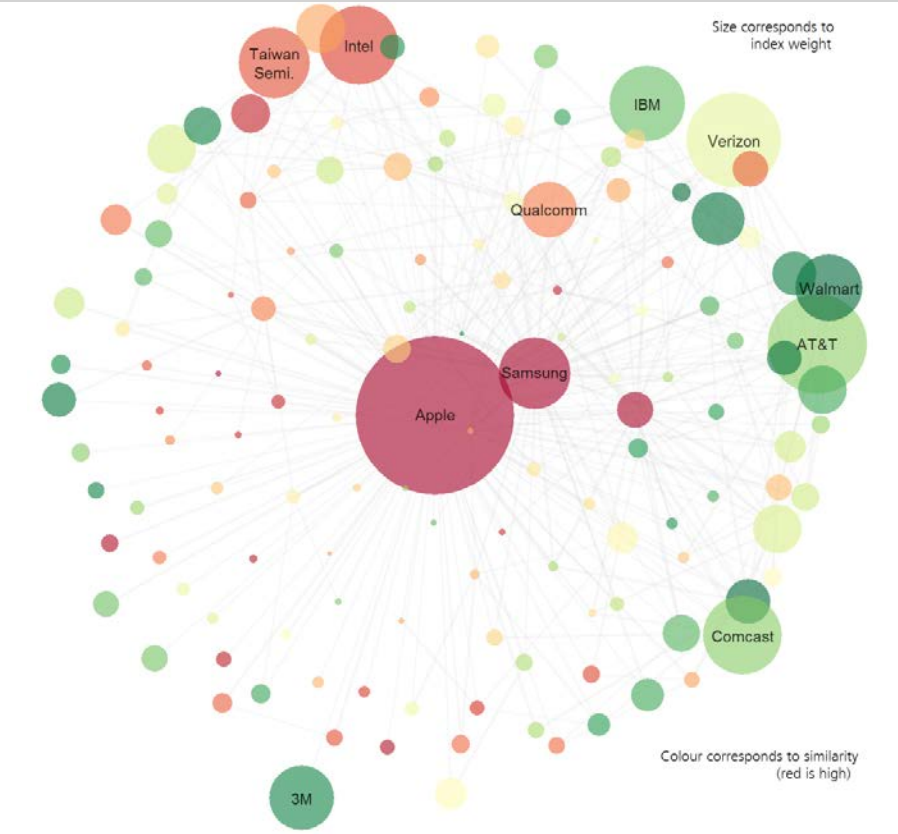
Essentially, all machine learning involves generalising a relationship to unseen data. In other words, it seeks an association between inputs and outputs we have seen and then extends it to unseen *but similar* inputs, to predict the unknown outputs.

Similarity defines how we identify structure in our data

So *predictions are always based on what we have seen in the past*; there is no magic involved. However, before we can predict supply chain effects, we first need to define what similarity means in a network. This is a subtle point—and one easily overlooked in a more conventional setting.

This is easily overlooked in a more conventional setting

Figure 16: A subset of Apple's immediate supply chain



Source: FactSet, UBS

Here, our definition of similarity should reflect the supply chain topology. We intuitively expect that a big earnings surprise for Apple has implications for its suppliers such as Hon Hai, its customers like Verizon, and its competitors like Samsung. Our choice of kernel, and by extension the similarities it produces, should reflect the correlated nature of information within this peer group.

But we have an intuitive grasp of what supply chain effects mean

We need not even define whether these are positive or negative implications—rather we can let the algorithm uncover their meaning. These similarities merely capture the "weights" by which information from one company is stacked up against others. Figure 16 shows merely a *subset* of Apple's *immediate* supply chain relationships; it is not difficult to imagine how this information can become unwieldy quickly.

In fact, this concept of similarity is completely distinct to the network data we are modelling; it is derived from the network topology itself, irrespective of whether we are looking at earnings revisions or momentum as they flow through it.

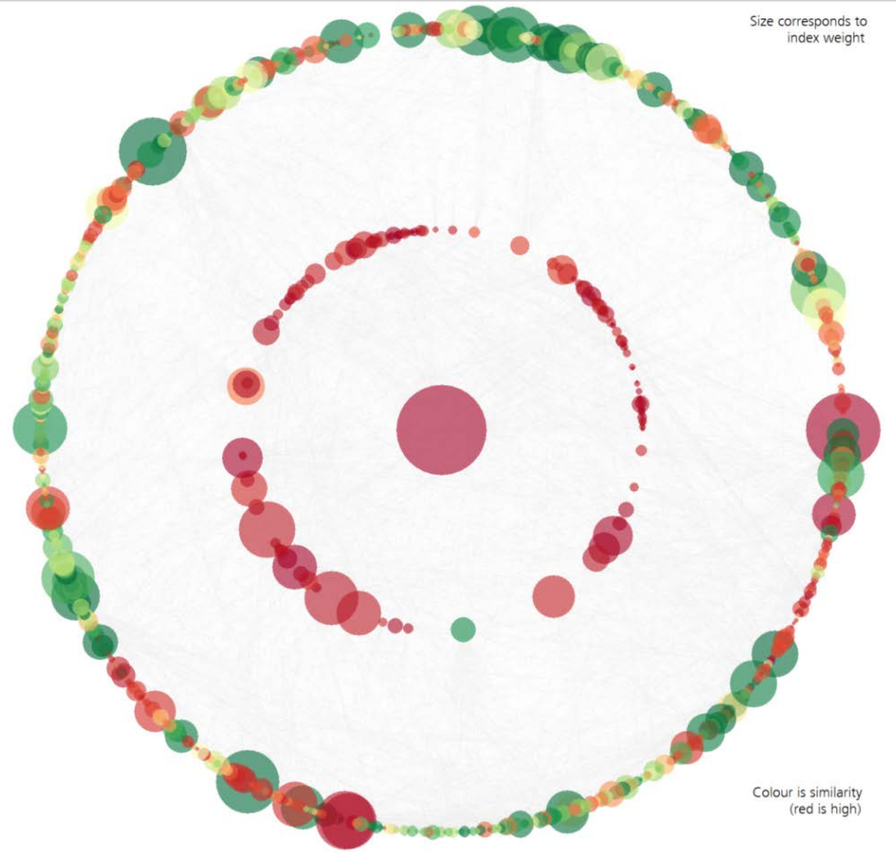
So how do we actually define similarity in the supply chain?

Essentially, the way we define similarity is to measure how information "pools" in the global supply chain, i.e. if we inject some information into the supply chain at company X, how does this diffuse through the network—how much will end up at company Y?

A result borrowed from physics; the same way heat diffuses over time

This might seem abstract, but in fact it borrows a result from mathematical physics; this is precisely the same manner in which heat is modelled as absorbing into a material, a solution known as the "heat kernel". We can now simply[1] plug this into the SVM machinery, yielding what is known as a kernel support vector machine.

Figure 17: Peeling back the layers—two degrees of separation from Apple



Source: FactSet, UBS

This models effects beyond the immediate supply chain relationships

Note that this technique models the effects extending far beyond the immediate supply chain peers. We suspect that the most prominent of these peers are monitored by investors and analysts already. Furthermore, immediate linkages have already been studied in a more conventional setting, e.g. Cohen & Frazzini (2008).

An important consideration in light of the data limitations

We also note that the majority of companies in this data set have a single supply chain peer (Figure 47 in Appendix), which is likely a limitation of the data capture method. So any results concluded from merely these immediate relationships are always limited to this narrow, localised perspective. Indeed Figure 17 suggests that significant linkages exist beyond these immediate supply chain relationships.

[1] Again we spare our casual readers the technical details until the Appendix.

Forming stock-level predictions

Like many aspects in economics, we also face the challenge of non-reproducibility. We cannot freeze the current information set and wait for the price discovery to converge—new information is released every day. Rather, we model an equilibrium state. As new information is introduced into the market and diffuses via the supply chain linkages, how does this affect the current state?

How do expectations change as new information is absorbed?

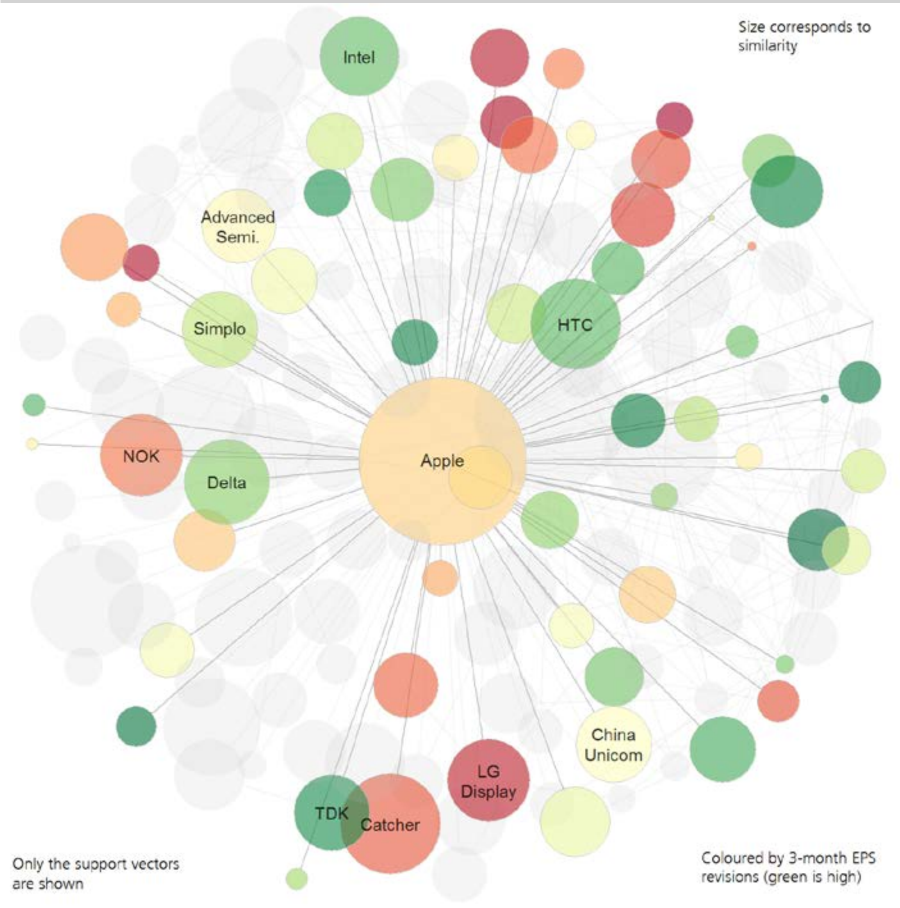
Our model estimates the relationship between recent information and subsequent implications using the similarities (kernel) of the supply chain and a support vector machine to define the functional form. The output is the stock-level characteristic of interest (e.g. earnings revisions), and the inputs are the similarities. In a nutshell, *recent, significant earnings revisions are used to predict subsequent implications via the supply chain linkages.*

Recent earnings revisions are used to predict revisions for supply chain linkages

Below we indicate how stock-level predictions are calculated for earnings revisions. In effect the SVM reduces all revisions to the most significant ones (these are called the support vectors). While a gross oversimplification, predictions can be thought of as a weighted average over these significant revisions and their corresponding similarities. This prediction forms our investment signal in the following results.

The SVM reduces the supply chain to the most significant companies

Figure 18: Forming stock-level predictions



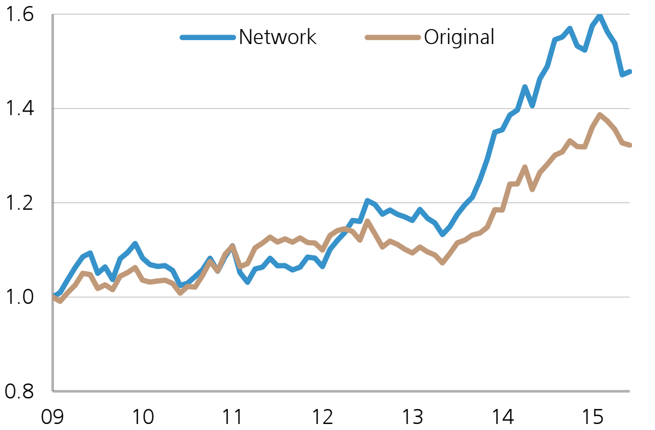
Source: FactSet, UBS

Figure 18 shows the same supply chain network for Apple as in Figure 16, but here only the support vectors are highlighted, the size corresponds to the supply chain similarity, and the colour corresponds to the actual earnings revisions.

Earnings diffusion

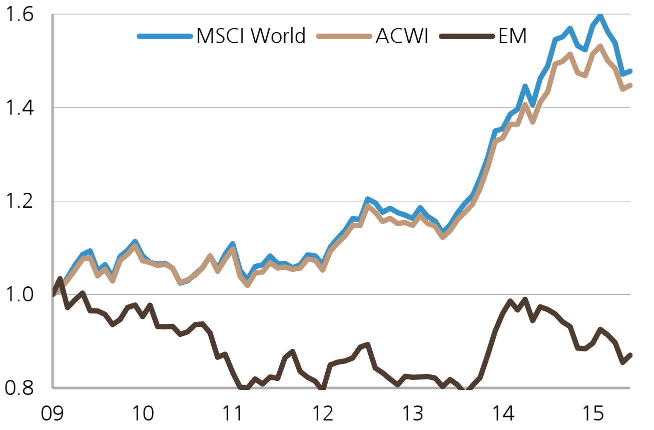
Using the approach outlined in the previous page, we predict the supply chain impact of recent earnings revisions[2] by discarding any estimates unchanged in 30 days. We then form portfolios directly from this predicted signal by going long the highest predicted revisions and short the lowest[3]. Below we show the performance of this strategy.

Figure 19: MSCI World, long-short network vs original



Source: FactSet, IBES, MSCI, UBS

Figure 20: Global markets, long-short network

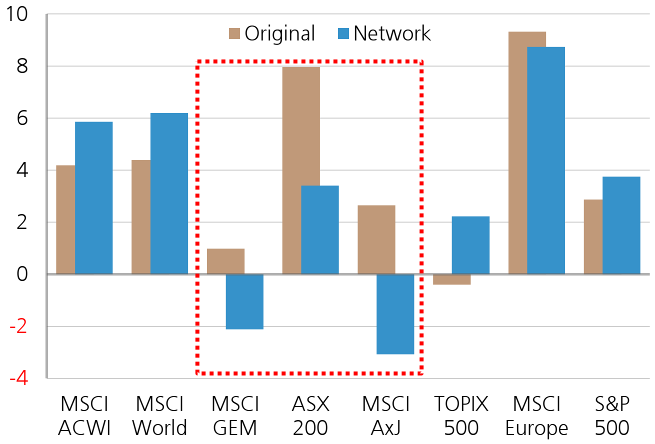


Source: FactSet, IBES, MSCI, UBS

We can clearly see a bifurcation in performance. Largely in developed markets, this provides a strong boost to original earnings revisions, with annual returns and hit rates materially improving (the hit rate is the percentage of time the strategy beat the benchmark). Note that all results use the entire global supply chain.

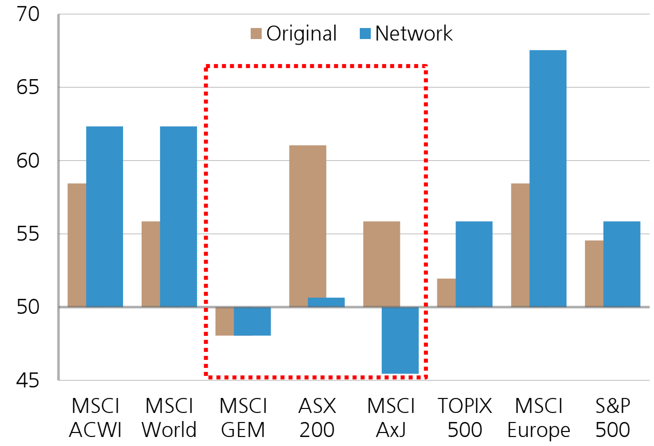
However, other markets show a drop in performance relative to the original signal over the same period—what happened? Asia Pacific in particular is suffering from a downturn in original earnings revisions efficacy over recent history, which was compounded by its limited history of supply chain data prior to then (Figure 7).

Figure 21: Annual returns by region



Source: FactSet, IBES, MSCI, UBS

Figure 22: Hit rates by region



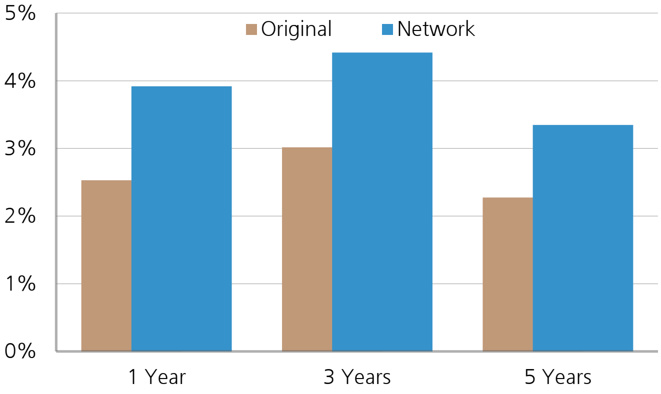
Source: FactSet, IBES, MSCI, UBS

[2] Earnings revisions are calculated as the three-month change in sell-side consensus earnings
[3] Monthly rebalanced long-short quintiles, market cap weighted and free-float adjusted, total returns shown in USD, from December 2009 to May 2016.

We often measure the predictive strength of a signal by its *information co-efficient* (IC); this is just the correlation between the signal and the subsequent stock return. In context of the data limitations identified earlier, we observe that the information coefficients are consistently improving on the original over recent history, not just in the developed markets, but Asia Pacific too (Figure 24).

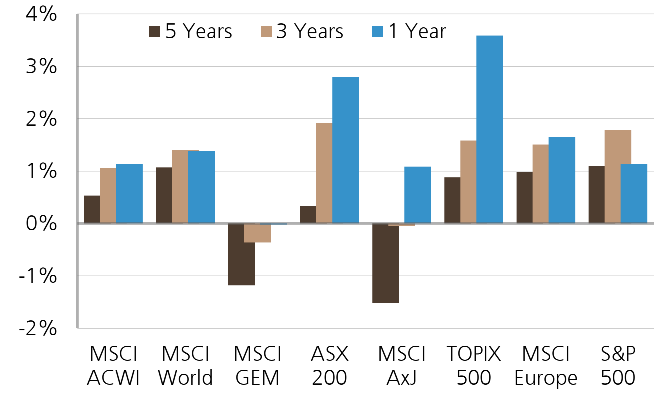
Asia Pacific has very little supply chain history, which is problematic for backtesting

Figure 23: MSCI World average rank IC



Source: FactSet, IBES, MSCI, UBS

Figure 24: Average rank IC, network less original

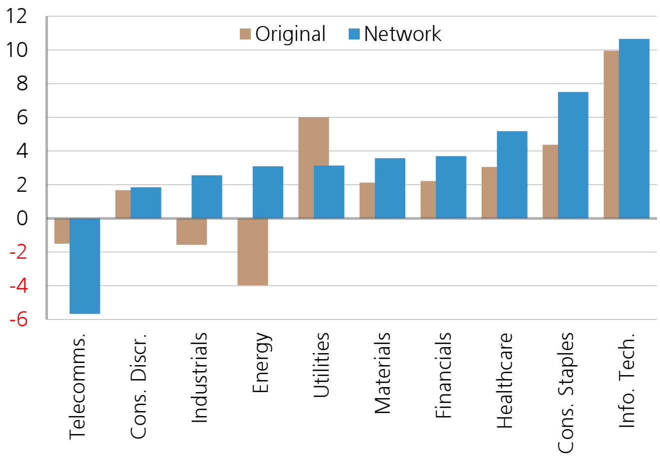


Source: FactSet, IBES, MSCI, UBS

Digging deeper into the factor performance within MSCI World, we can see a clear picture emerging. The supply chain seems to add most value in the energy sector and broadly across most manufacturing sectors; whereas the telecommunications and utilities sectors yield even worse performance than the original (Figure 26). This suggests that earnings revisions network effects in these sectors are not as predictive, or at least not as significant as the idiosyncratic effects.

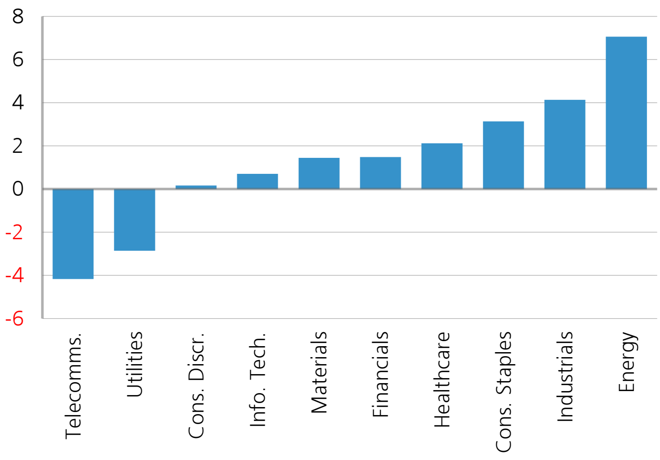
Network effects are not always as significant as the idiosyncratic effects

Figure 25: Annual returns by sector (MSCI World)



Source: FactSet, IBES, MSCI, UBS

Figure 26: Performance gains by sector (MSCI World)



Source: FactSet, IBES, MSCI, UBS

This is perhaps reasonable given the nature of the business environment in these industries; the utilities and telecommunications sectors are heavily regulated, which typically results in highly concentrated sectors. Our earlier report on size investing explored the relationships between small cap premiums and sector concentration; we found that large caps actually outperform small caps within these oligopolies.

For another perspective, we can use the network characterisation techniques briefly touched on earlier to better understand these results. A common statistic quoted in network literature is *centrality*, which is generally interpreted as the importance of an entity in the network.

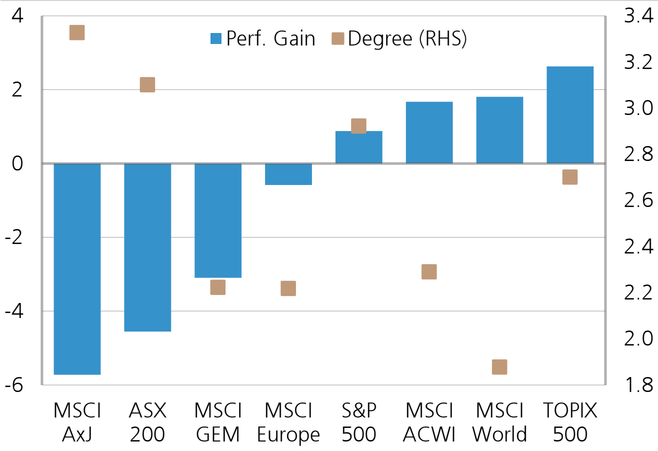
There are many ways of measuring this (arguably too many), but the simplest definition is the *degree*, which here is simply the number of supply chain linkages for each company. We compute the average degree per sector for the latest date available and actually observe that there is a weakly negative relationship between the performance gain (the difference in annual returns) on the original signal and the average degree—the less concentrated the market, the bigger the gain.

The less concentrated the market, the bigger the performance gain

If we now look at the coverage of the supply chain for each index (the total index weight we are able to map to estimates data), we can see another pattern emerge. The performance increase of the supply chain signal is correlated to the coverage of the market. Asia Pacific and the global emerging markets seemingly have more gaps than the developed markets, which contributes to the performance issues.

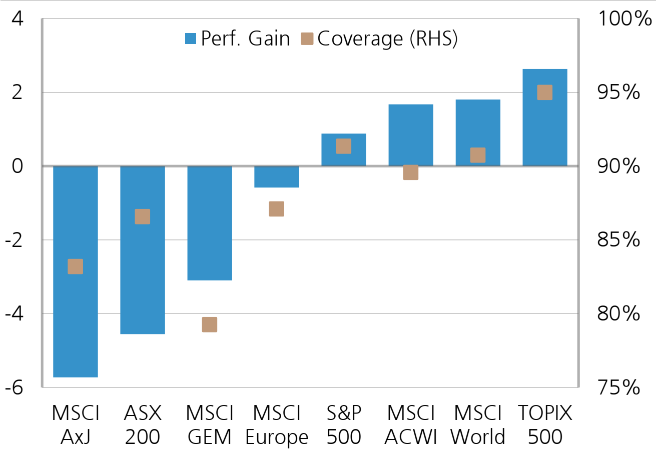
The more complete the supply chain picture, the bigger the performance gain

Figure 27: Performance gain versus average degree



Source: FactSet, IBES, MSCI, UBS

Figure 28: Performance gain versus coverage



Source: FactSet, IBES, MSCI, UBS

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Utilities are essentially vertically integrated, in that little of their industry has been outsourced. While they do buy raw materials like coal, wire and other capital items, this is quite distinct from the Apple supply chain example. So it is not surprising to see that supply chain effects are insignificant in these sectors.

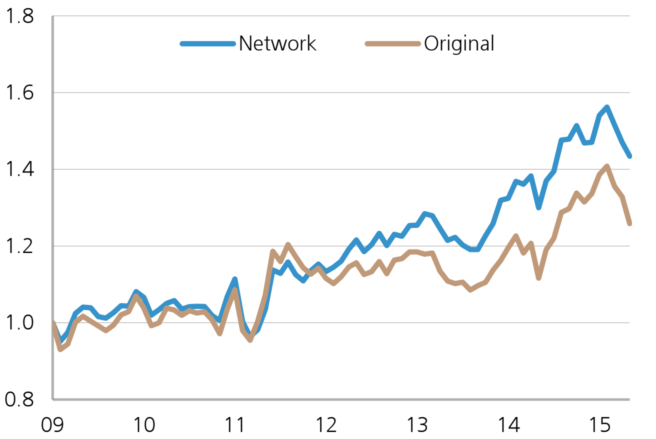
The significance of the supply chain within the energy sector is expected, given the availability period of the supply chain dataset. This was coincident with a period of falling oil prices, and so the energy service companies exposed to this were losing shareholder value accordingly.

Momentum diffusion

We now estimate the impact of price momentum diffusion along the supply chain using 12-1m momentum; this captures long-term momentum, but nets out short-term mean reversion. We can see a similar picture emerging—developed markets largely gain from this enhanced supply chain perspective, and emerging markets seem to perform poorly due to limited data availability and history.

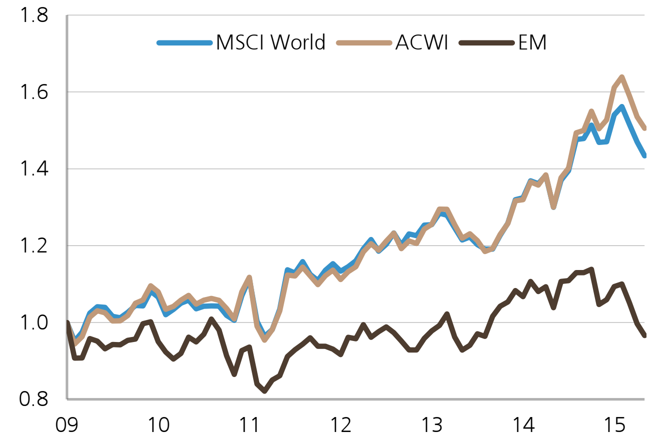
12-1m momentum captures long-term effects, net of short-term mean reversion

Figure 29: MSCI World, long-short network vs original



Source: FactSet, MSCI, UBS

Figure 30: Global markets, long-short network



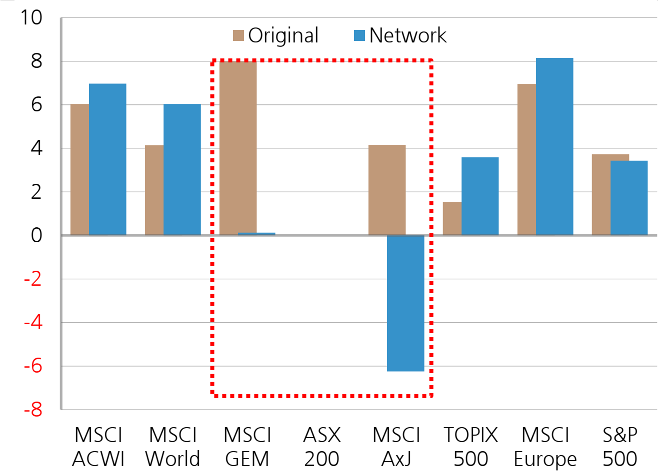
Source: FactSet, MSCI, UBS

MSCI Europe shows improvement; both annual returns and hit rates improve and even turnover is marginally reduced (Figure 46 in the Appendix). Japan also stands out, showing material gains to the historically underperforming momentum strategy, which has been steadily increasing over recent history.

However, Asia ex-Japan suffers again here from a paucity of supply chain data; recent market turmoil has resulted in several momentum upheavals and the supply chain prediction yields a poorer result compared to the original. We expect that as the supply chain picture becomes more complete in Asia (and market conditions hopefully stabilise), the gains here will become consistent with those of developed markets.

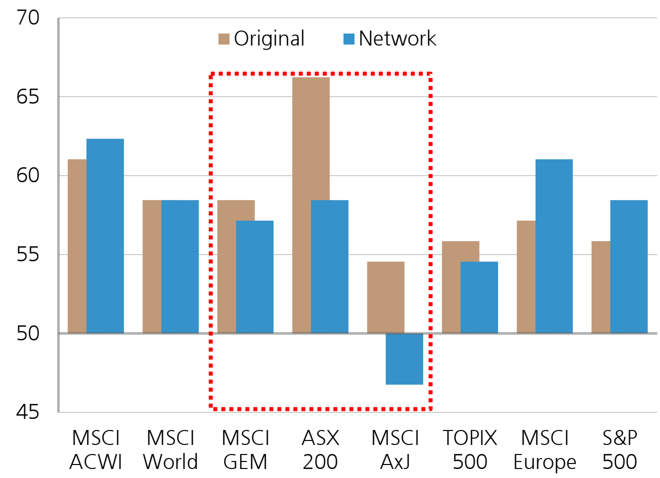
Asia ex-Japan suffers again from a paucity of supply chain data—though this is improving

Figure 31: Annual returns by region



Source: FactSet, MSCI, UBS

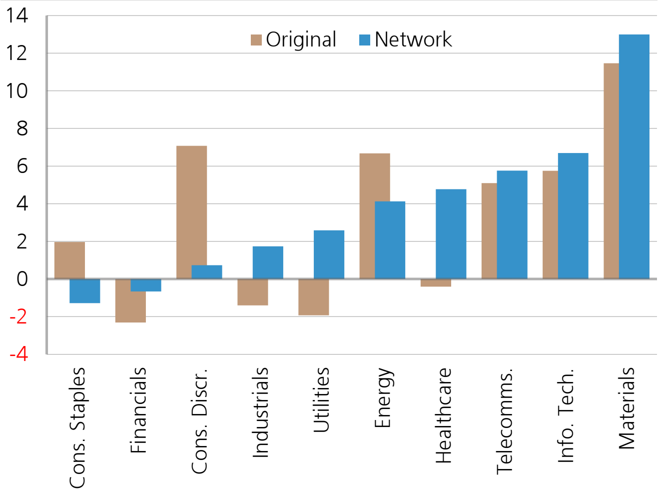
Figure 32: Hit rates by region



Source: FactSet, MSCI, UBS

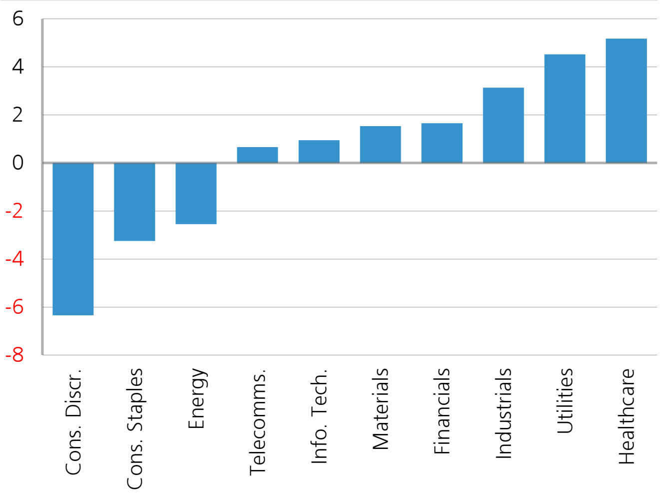
The sector performance gains are also more mixed here; sectors that benefit the most from the enhanced earnings revisions seem to gain marginal benefit from the momentum signal. Healthcare is surprisingly a leader despite disappointing results from the original momentum strategy.

Figure 33: Annual returns by sector (MSCI World)



Source: FactSet, MSCI, UBS

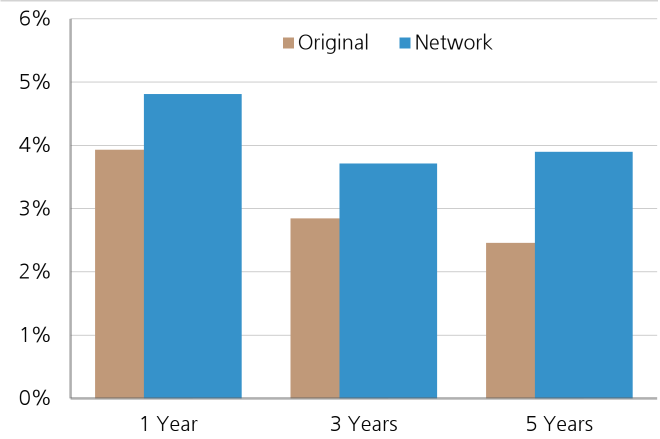
Figure 34: Performance gains by sector (MSCI World)



Source: FactSet, MSCI, UBS

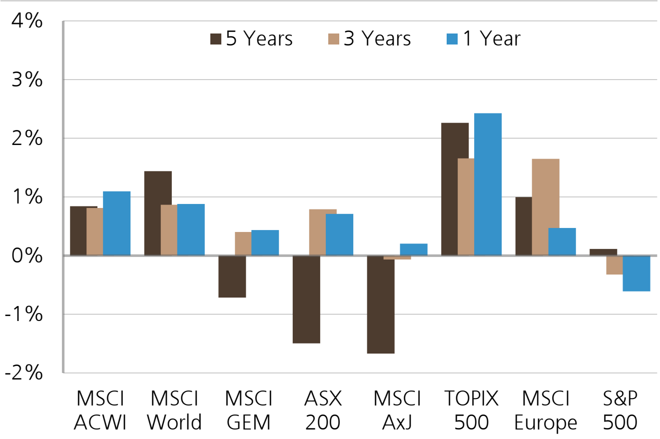
Generally, the performance gain of the supply chain momentum signal appears less convincing; while the information coefficients still show a long-term improvement across the global developed markets, this is just not as consistent globally. We identify some potential causes of this in the following page.

Figure 35: MSCI World average rank IC



Source: FactSet, MSCI, UBS

Figure 36: Network average rank IC, less original



Source: FactSet, MSCI, UBS

Our method essentially models the diffusion of data innovations originating from a subset of the network; thereby estimating the subsequent impact through supply chain linkages. By definition, long-term momentum does not reflect a novel piece of information being disseminated into the market, so much as a long-term trend, and one reflecting a latent exposure at that. Perhaps the expected diffusion of this information is mismatched with the prediction horizon (the rebalance frequency).

We might have a prediction horizon mismatch for long-term momentum…

Our method requires us to drop the directionality of the supply chain links (from supplier to customer), which might contribute to the middling performance here, although the earnings revisions consistently improved despite this. We discuss why this is necessary in the Appendix.

…or suffer from a lack of supply chain directionality

In our analysis above, we implicitly assumed that we have observed the "true" supply chain from the vendor. While a reasonable assumption, in light of the data collection limitations, we believe that this should be challenged. Drawing on both their extensive supply chain expertise and the resources of our global research analysts, the UBS Evidence Lab team has enhanced this database to address these limitations, which we will explore in subsequent reports.

…or the incomplete nature of the data set

Top and bottom stock picks

Below we show the top and bottom picks from our supply chain earnings revisions model for each region, filtered for UBS rating.

Figure 37: North America—top

Ticker	Name	Price (loc)	UBS Rating	EPS Rev. 3M	Network
TMO UN	Thermo Fisher Scientific Inc.	149.23	Buy	2.52	0.97
HD UN	Home Depot, Inc.	129.62	Buy	1.32	0.93
JNJ UN	Johnson & Johnson	121.29	Buy	1.53	0.86
PM UN	Philip Morris Intl. Inc.	101.28	Neutral	2.07	0.80
HCA UN	HCA Neutralings, Inc.	76.66	Buy	1.65	0.75
LPT UN	Liberty Property Trust	39.33	Neutral	1.66	0.75
NOC UN	Northrop Grumman Corp.	221.8	Neutral	1.34	0.74
UNH UN	UnitedHealth Group Inc.	140.86	Buy	1.59	0.71
NTRS UW	Northern Trust Corporation	65.23	Neutral	0.98	0.71
WMT UN	Wal-Mart Stores, Inc.	72.81	Neutral	1.04	0.69

Source: FactSet, UBS estimates

Figure 38: North America—bottom

Ticker	Name	Price (loc)	Rating	EPS Rev. 3M	Network
GPS UN	Gap, Inc.	21.4	Sell	-2.91	-0.32
RF UN	Regions Financial Corporation	8.36	Neutral	-0.22	-0.27
UA UN	Under Armour, Inc. Class A	40.43	Neutral	0.06	-0.20
CMG UN	Chipotle Mexican Grill, Inc.	393.91	Neutral	-2.11	-0.20
AEE UN	Ameren Corporation	53.75	Neutral	-1.64	-0.18
PSX UN	Phillips 66	79.78	Neutral	-0.93	-0.18
D UN	Dominion Resources, Inc.	77.86	Neutral	-0.53	-0.17
CMI UN	Cummins Inc.	112.92	Neutral	0.07	-0.17
WFC UN	Wells Fargo & Company	47.03	Sell	-1.18	-0.17
PCG UN	PG&E Corporation	64.03	Neutral	-0.03	-0.16

Source: FactSet, UBS estimates

Figure 39: Europe—top

Ticker	Name	Price (loc)	UBS Rating	EPS Rev. 3M	Network
ITRK LN	Intertek Group plc	3499	Buy	1.43	0.59
SVT LN	Severn Trent Plc	2429	Neutral	0.88	0.59
G1A GY	GEA Group Akt.	43.04	Neutral	0.90	0.52
DPW GY	Deutsche Post AG	25.4	Neutral	0.76	0.49
BNZL LN	Bunzl plc	2317	Neutral	1.40	0.48
ORK NO	Orkla ASA	74.6	Neutral	1.04	0.45
RRS LN	Randgold Resources Ltd	8775	Neutral	0.83	0.45
NESN VX	Nestle S.A.	76.05	Neutral	-0.17	0.45
RB/ LN	Reckitt Benckiser Grp plc	7545	Buy	1.41	0.44
HUSQB SS	Husqvarna AB Class B	63.65	Neutral	0.80	0.40

Source: FactSet, UBS estimates

Figure 40: Europe—bottom

Ticker	Name	Price (loc)	UBS Rating	EPS Rev. 3M	Network
ETL FP	Eutelsat Communications SA	17	Neutral	-1.53	-0.55
MUV2 GY	Munich Reinsurance Company	152.25	Neutral	-1.22	-0.47
SEBA SS	Skandinaviska Enskilda Banken	73.35	Neutral	-0.99	-0.45
MEO1V FH	Metso Oyj	21.63	Sell	-2.17	-0.42
BOSS GY	HUGO BOSS AG	50.21	Neutral	-1.74	-0.40
MFON LI	MegaFon PJSC	10.8	Sell	-1.44	-0.40
SPM IM	Saipem S.p.A.	0.3702	Neutral	-1.15	-0.40
GFC FP	Gecina SA	126.3	Neutral	-1.80	-0.38
LUX IM	Luxottica Group S.p.A.	44.61	Neutral	-1.90	-0.33
EVK GY	Evonik Industries AG	27.08	Neutral	-1.61	-0.32

Source: FactSet, UBS estimates

Figure 41: Asia Pacific—top

Ticker	Name	Price (loc)	UBS Rating	EPS Rev. 3M	Network
033780 KP	KT & G Corporation	134500	Neutral	1.04	0.77
1803 JT	Shimizu Corporation	954	Buy	0.72	0.75
1812 JT	Kajima Corporation	702	Buy	0.95	0.68
015760 KP	Korea Electric Power Corp.	58900	Buy	0.97	0.57
1802 JT	Obayashi Corporation	1085	Neutral	0.80	0.53
3283 JT	Nippon Prologis REIT, Inc.	250700	Neutral	-0.03	0.51
9020 JT	East Japan Railway Co.	9570	Neutral	0.40	0.48
1801 JT	Taisei Corporation	823	Neutral	1.22	0.48
2 HK	CLP Neutralings Limited	79.7	Neutral	0.76	0.47
005490 KP	POSCO	209000	Neutral	0.72	0.46

Source: FactSet, UBS estimates

Figure 42: Asia Pacific—bottom

Ticker	Name	Price (loc)	UBS Rating	EPS Rev. 3M	Network
9921 TT	Giant Manufacturing Co.	200.5	Neutral	-2.21	-1.45
5711 JT	Mitsubishi Materials Corp.	251	Neutral	-1.57	-0.79
5264 TT	Casetek Holdings Ltd.	116	Neutral	-1.49	-0.74
6506 JT	Yaskawa Electric Corp.	1306	Neutral	-2.19	-0.68
JM SP	Jardine Matheson Ltd	57.85	Sell	-2.45	-0.53
CTRP UW	Ctrip.com Intl. Ltd	41.13	Neutral	-2.25	-0.51
1880 HK	Belle International Ltd	4.57	Sell	-2.12	-0.50
4938 TT	Pegatron Corp.	71.6	Neutral	-2.19	-0.50
7203 JT	Toyota Motor Corp.	5137	Sell	-3.69	-0.49
ADRO IJ	PT Adaro Energy Tbk	885	Neutral	-1.23	-0.49

Source: FactSet, UBS estimates

Appendix

Graph basics

Graphs consist of vertices and edges. Vertices represent the "entities", which are connected by edges. Directed graphs make a distinction between the directions of this connection; undirected graphs do not. Weighted graphs assign values to these edges; often these correspond to capacity or size of the connection.

A common representation of a graph is given by its adjacency matrix A. If a graph has n vertices, then this is a $n \times n$ matrix. If an edge connects the vertex i to the vertex j (denoted $i \sim j$), then the corresponding matrix element A_{ij} is 1, otherwise it is 0. For an undirected graph, this matrix is of course, symmetric. This has a natural extension to weighted graphs, in which the matrix elements are given by the edge weight if it exists (and 0 otherwise), producing the weight matrix W.

The degree matrix D, is a $n \times n$ diagonal matrix whose diagonal elements are equal to the *degree* (the count of all inbound or outbound links in a directed network), of the corresponding vertices. In weighted networks, the diagonal elements are similarly defined as the sum over the (inbound or outbound) edge weights.

The graph Laplacian

The graph Laplacian $L = D - \mathrm{A}$ and its normalised counterpart $\mathcal{L} = D^{-1/2} L D^{-1/2}$ are fundamental objects in spectral graph theory (the study of the eigensystem of network objects); whose theory underpins much of the results here (Chung 1997).

The kernel matrix (also known as the Gram matrix) represents an inner product induced in a Hilbert space (the feature space). To satisfy the axioms of an inner product, this must be symmetric positive semi-definite: $\boldsymbol{f}^{\mathsf{T}} \mathrm{K} \boldsymbol{f} \geq 0, \forall \boldsymbol{f} \in \mathbb{R}^n$. This is essential to maintain the convexity of the SVM optimisation problem, ensuring that the (global) optimum can be found efficiently. Therefore, care must be taken when constructing "ad-hoc" similarity measures to ensure these conditions are met.

The weight matrix W could be considered as the "base similarity". It is not required to be positive semi-definite, however the Laplacian (and normalised Laplacian), are positive semi-definite as shown below, and so make a more suitable starting point:

$$\boldsymbol{f}^{\mathsf{T}} L \boldsymbol{f} = \langle \boldsymbol{f}, L\boldsymbol{f} \rangle = \tfrac{1}{2} \sum_{i \sim j} W_{ij} (f_i - f_j)^2 \geq 0 \text{ , } as\ W_{ij} \geq 0$$

Diffusion Kernels

Roughly speaking, the idea of the diffusion kernel is to evolve more complex global structures from the local structures naturally encoded in the Laplacian.

The graph Laplacian can be interpreted as an operator on a graph G, and a finite difference approximation to the familiar continuous Laplacian. In analogy with the heat equations from physics describing the diffusion of heat through a continuous media over time: $\frac{\partial}{\partial t} \psi = \mu \Delta \psi$, graph diffusion takes the form: $\frac{\boldsymbol{d}}{\boldsymbol{d}\gamma} K_\gamma = -\mathcal{L} K_\gamma$

As $\mathcal{L}$ is symmetric positive semi-definite, we are ensured a spectral decomposition $\{\boldsymbol{\phi}_i, \lambda_i\}$ and a solution to this is given by $K_\gamma = exp(-\gamma \mathcal{L}) = \sum \boldsymbol{\phi}_i \boldsymbol{\phi}_i^{\mathsf{T}} e^{-\gamma \lambda_i}$. From a spectral graph theory perspective, eigenvectors corresponding to small eigenvalues are smooth, capturing large clusters varying little between adjacent vertices; large eigenvalues correspond to "rugged" eigenvectors and are considered noise.

The regularisation link

Kernel methods can often be approached as an implicit representation of a high dimensional feature space as above, or from the perspective of regularisation and smoothing. Consider a smoothness functional $S(\boldsymbol{f}) = \frac{1}{2}\sum W_{ij}(f_i - f_j)^2$, sum over incident edges in G with some vertex process $\boldsymbol{f} \in \mathbb{R}^n$. Any sensible learning algorithm will try to classify correlated vertices (large W_{ij}) similarly where $f_i \approx f_j$, corresponding to small $S(\boldsymbol{f})$.

However from above $S(\boldsymbol{f}) = \langle \boldsymbol{f}, L\boldsymbol{f} \rangle$ so if $\{\boldsymbol{\phi}_i, \lambda_i\}$ denotes the eigensystem of L then $L = \sum \lambda_i \boldsymbol{\phi}_i \boldsymbol{\phi}_i^{\mathsf{T}}$ and since $\{\boldsymbol{\phi}_i\}$ forms a basis on $\mathbb{R}^n$ we can express any function as $\boldsymbol{f} = \sum \beta_i \boldsymbol{\phi}_i$, $\beta_i \in \mathbb{R}$ thus expressing our smoothness functional as shown below. This notion of smoothness again corresponds to emphasising smaller eigenvalues:

$$\langle \boldsymbol{f}, L\boldsymbol{f} \rangle = \boldsymbol{f}^{\mathsf{T}} L \boldsymbol{f} = \frac{1}{2}\sum_{i,j} W_{ij}(f_i - f_j)^2 = \sum_i \beta_i^2 \lambda_i$$

Smola and Kondor (2002) discuss a general principle for creating a semi-supervised kernel K from the normalised graph Laplacian via the introduction of regularisation functionals with their associated (positive semi-definite) matrices $P := r(\mathcal{L})$. The image of $\mathbb{R}^n$ under P with dot product $\langle \boldsymbol{f}, P\boldsymbol{f} \rangle := \langle \boldsymbol{f}, r(\mathcal{L})\boldsymbol{f} \rangle$ is then a Reproducing Kernel Hilbert Space with kernel $K = P^{-} = r^{-1}(\mathcal{L})$, and in contrast with the above:

$$\langle \boldsymbol{f}, r(\mathcal{L})\boldsymbol{f} \rangle = \left\langle \sum_i \beta_i \boldsymbol{\phi}_i, \sum_j r(\lambda_j) \boldsymbol{\phi}_j \boldsymbol{\phi}_j^{\mathsf{T}} \sum_l \beta_l \boldsymbol{\phi}_l \right\rangle = \sum_i \beta_i^2 \, r(\lambda_i)$$

The diffusion kernel corresponds to the regularisation functional $r_\sigma(\lambda_i) = e^{-\lambda_i \sigma^2/2}$

Induction versus transduction

In this report, we address a problem of transduction; completing the labelling of a partially-labelled dataset. In other words, we make predictions on a test set of data which is known *a priori*. Rather than learning a general function, as is the outcome of the common induction scenario, rather we just learn the set of labels (or values).

This is an important distinction and yet another subtlety of network data analysis. However, graph kernels are particularly well suited for this type of problem, as it provides a natural use for unlabelled data.

The supply chain data includes many thousands of small cap companies for which no analyst coverage is available, and private firms for which effectively no data is available at all. Currently fewer than 8,000 companies are covered by 5+ analysts in IBES, out of roughly 20,000 securities captured by the FactSet supply chain.

Rather than denying their presence in the global supply chain and throwing away this information, we can instead build the graph kernel using the full network. In this manner, their connection to the rest of the economy is retained and we can estimate information flow through the complete supply chain accordingly.

Furthermore, this gives us the flexibility to model the temporal aspect to information disclosure; analyst revisions might occur in "lumps" during earnings season, so the impact to analyst revisions of companies yet to announce and exposed via supply chain linkages can be meaningfully estimated.

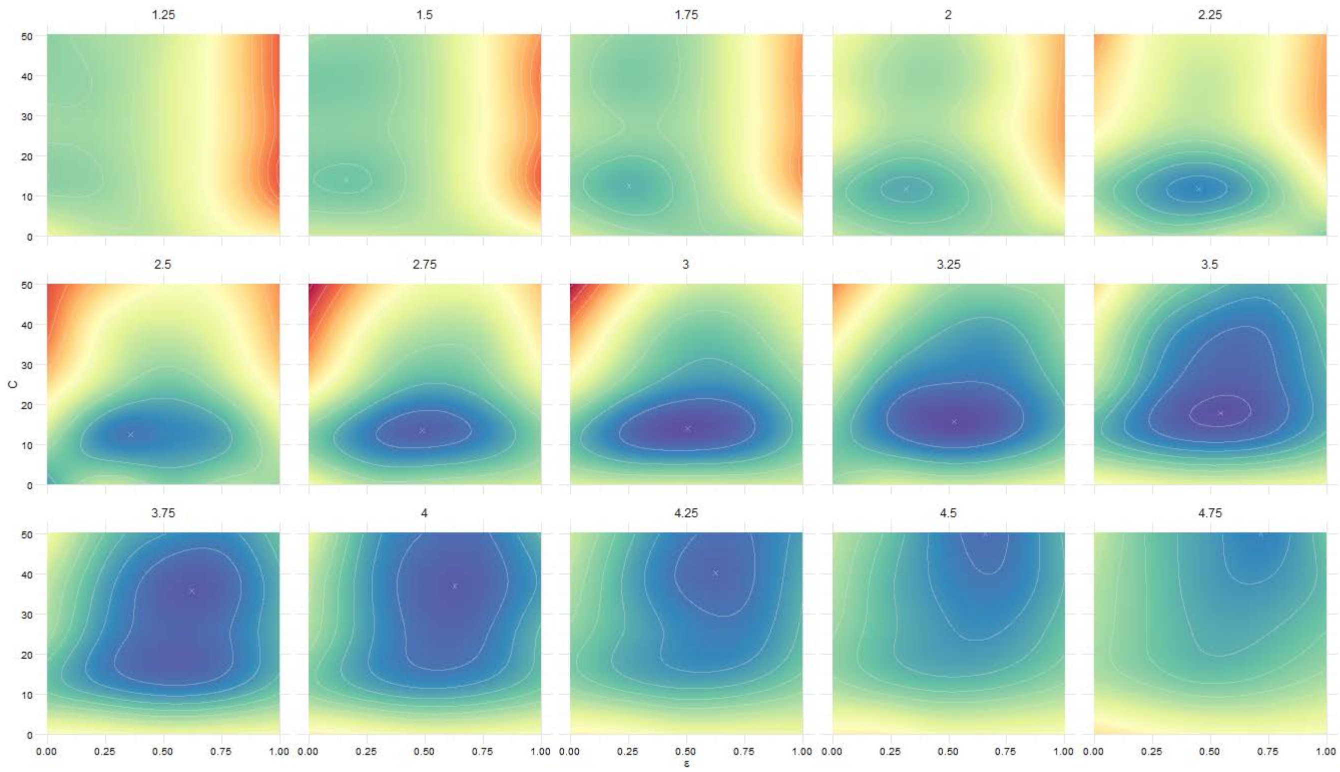
Tuning

The heat diffusion parameter (σ)

At high values this affects the regularisation by creating a "bland" kernel, in which the feature vectors effectively appear parallel, resulting in excessive generalisation. Conversely for small σ, the feature vectors will essentially all appear orthogonal and the kernel will look like the matching kernel, likely resulting in overfitting.

The computational cost of tuning this parameter is excessive, so we hardcode this to $\sigma = 3$, corresponding to a "well-defined" hyperparameter surface. While this is not ideal, this parameter could be interpreted as the prediction horizon instead; it merely defines a decay window by which we tune the other hyperparameters.

Figure 43: The effect of the diffusion parameter σ (3M EPS Revisions)



Source: FactSet, IBES, MSCI, UBS

The penalty "budget" of the support vector machine ($\boldsymbol{C}$)

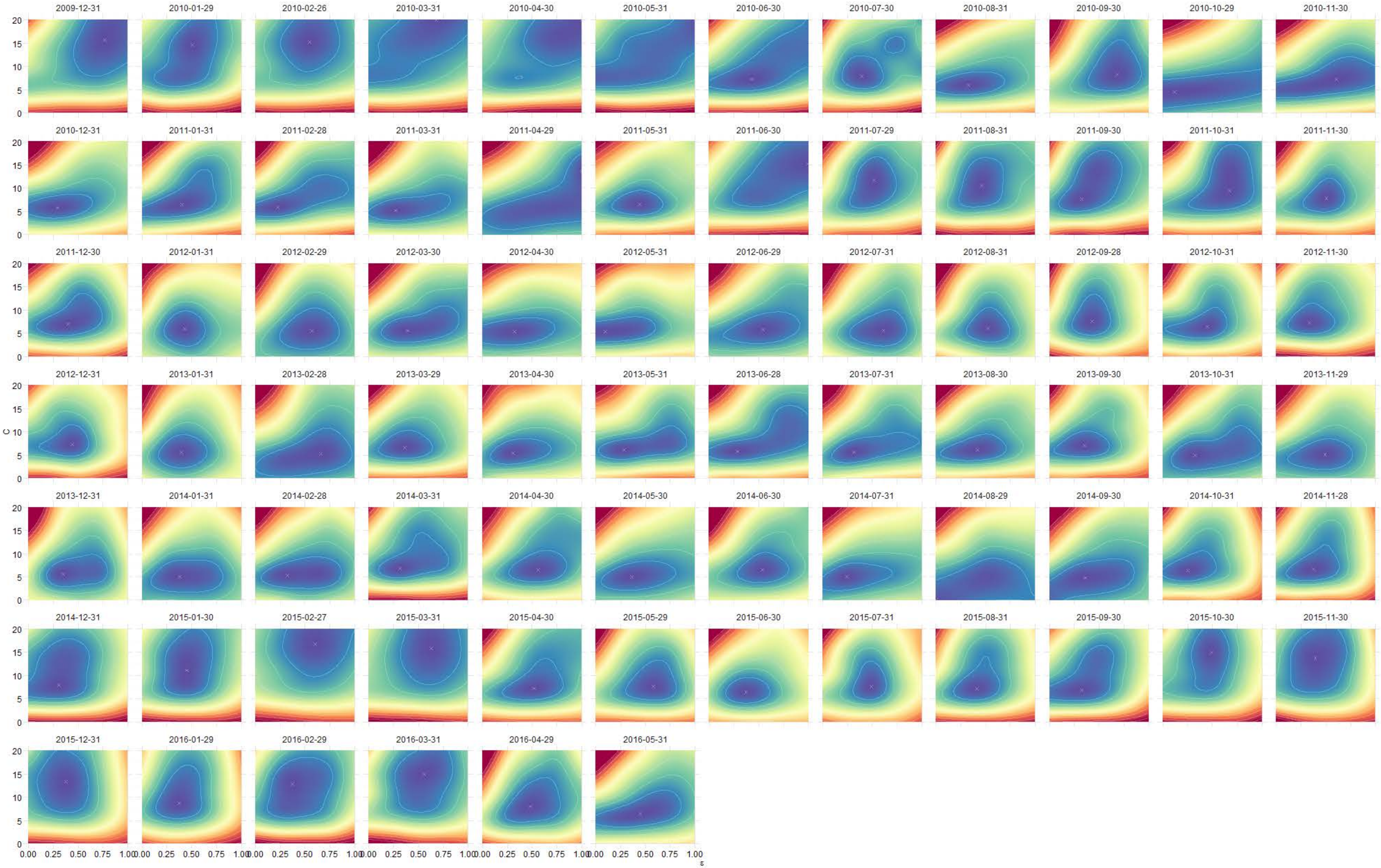
This defines a trade-off between training errors vs model complexity. A small value here effectively results in an unlimited "budget" for training errors. A very large value here means the decision function acts closer to that of the hard-margin SVM.

The regression loss parameter ($\boldsymbol{\varepsilon}$)

This parameter is used only in regression and corresponds to the intended accuracy of the decision function. This is often dependent on context, for example if we had prior knowledge of the input data which suggested that it was accurate to ±1%, or we are insensitive to outcomes of ±1%, these might make suitable candidates.

We have no such knowledge of best parameters for both C and ε, and so we tune these hyperparameters at each point in time using a simple grid search, choosing the co-ordinates that minimises the 10-fold cross validation error (Figure 44).

Figure 44: Hyperparameter surface of 3-month earnings revisions



Source: FactSet, IBES, MSCI, UBS

Figure 45: Summary statistics by region (3m EPS revisions, full period)

	Factor	Ann. Ret	Hit Rate	Sharpe	Drawdown	Turnover	Avg. IC
MSCI ACWI	Original	4.18	58.44	0.72	-6.96	25.41	2.49
	Network	*5.86*	*62.34*	*0.82*	*-7.66*	*26.41*	*2.85*
MSCI World	Original	4.39	55.84	0.71	-7.64	25.52	1.86
	Network	*6.20*	*62.34*	*0.82*	*-7.99*	*26.87*	*2.83*
MSCI GEM	Original	0.98	48.05	0.12	-18.04	25.31	3.35
	Network	*-2.11*	*48.05*	*-0.22*	*-23.96*	*33.06*	*1.22*
ASX 200	Original	7.96	61.04	0.65	-11.07	29.56	6.39
	Network	*3.41*	*50.65*	*0.22*	*-37.98*	*37.59*	*3.71*
MSCI AxJ	Original	2.65	55.84	0.29	-15.52	26.55	3.68
	Network	*-3.07*	*45.45*	*-0.29*	*-25.73*	*30.82*	*0.50*
TOPIX 500	Original	-0.40	51.95	-0.04	-14.18	29.31	-0.19
	Network	*2.23*	*55.84*	*0.23*	*-15.41*	*25.27*	*1.36*
MSCI Europe	Original	9.32	58.44	1.09	-6.79	28.61	4.67
	Network	*8.74*	*67.53*	*0.89*	*-10.46*	*30.70*	*5.28*
S&P 500	Original	2.87	54.55	0.40	-7.58	25.51	1.01
	Network	*3.75*	*55.84*	*0.49*	*-12.67*	*28.56*	*2.02*

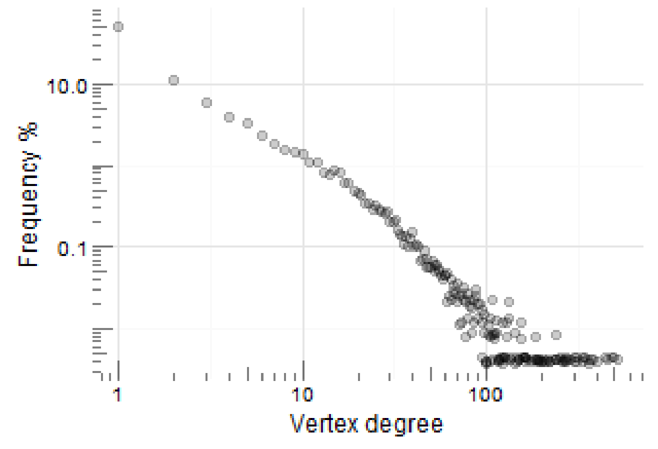
Source: FactSet, IBES, MSCI, UBS

Figure 46: Summary statistics by region (12-1m momentum, full period)

	Factor	Ann. Ret	Hit Rate	Sharpe	Drawdown	Turnover	Avg. IC
MSCI ACWI	Original	6.03	61.04	0.49	-12.94	23.12	3.47
	Network	*6.97*	*62.34*	*0.62*	*-14.66*	*19.43*	*3.71*
MSCI World	Original	4.15	58.44	0.34	-12.13	21.67	2.31
	Network	*6.03*	*58.44*	*0.57*	*-13.49*	*20.99*	*3.17*
MSCI GEM	Original	7.99	58.44	0.61	-13.11	21.88	4.18
	Network	*0.13*	*57.14*	*0.01*	*-18.61*	*27.91*	*3.09*
ASX 200	Original	16.76	66.23	1.04	-15.38	24.60	8.18
	Network	*9.94*	*58.44*	*0.70*	*-20.44*	*35.35*	*6.01*
MSCI AxJ	Original	4.16	54.55	0.32	-17.21	23.62	3.73
	Network	*-6.25*	*46.75*	*-0.52*	*-36.91*	*27.65*	*1.28*
TOPIX 500	Original	1.55	55.84	0.12	-17.20	22.79	1.02
	Network	*3.59*	*54.55*	*0.31*	*-19.11*	*23.30*	*3.14*
MSCI Europe	Original	6.95	57.14	0.47	-15.50	22.44	5.15
	Network	*8.15*	*61.04*	*0.65*	*-14.16*	*20.00*	*5.41*
S&P 500	Original	3.72	55.84	0.32	-11.86	20.04	2.20
	Network	*3.43*	*58.44*	*0.31*	*-17.08*	*21.62*	*1.96*

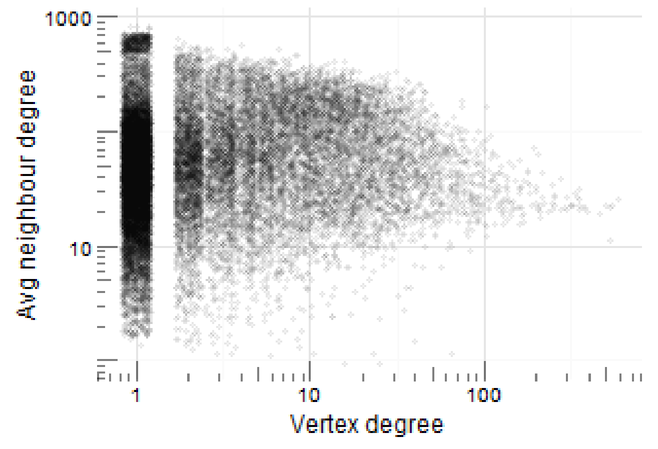
Source: FactSet, IBES, MSCI, UBS

Figure 47: Log-log degree distribution



Source: FactSet, UBS

Figure 48: Average neighbour degree



Source: FactSet, UBS

Further reading and references

Chung's book on spectral graph theory is essential reading. Schölkopf and Smola are the authorities on kernel learning; their book is widely regarded as the reference material on the subject. Diffusion kernels were introduced by Kondor, Imre and Lafferty, which was extended to general regularisation functionals by Smola and Kondor. Kolaczyk wrote an excellent introductory book on network analysis and another containing worked examples in R using the *igraph* package; both are highly recommended. MIT Press published an outstanding book on semi-supervised learning, which discusses transductive problems at length.

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