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The Japanese Economy in Crises: A Time Series Segmentation Study

Siew Ann Cheong

School of Physical and Mathematical Sciences, Nanyang Technological University

Robert Paulo Forna

University of Colorado at Boulder

Gladys Hui Ting Lee

School of Physical and Mathematical Sciences, Nanyang Technological University

Jun Liang Kok

School of Physical and Mathematical Sciences, Nanyang Technological University

Woei Shyr Yim

School of Physical and Mathematical Sciences, Nanyang Technological University

Danny Yuan Xu

Bard College, Annandale-on-Hudson

Yiting Zhang

School of Physical and Mathematical Sciences, Nanyang Technological University

Abstract We performed a comprehensive time series segmentation study on the 36 Nikkei Japanese industry indices from 1 January 1996 to 11 June 2010. From the temporal distributions of the clustered segments, we found that the Japanese economy never fully recovered from the extended 1997–2003 crisis, and responded to the most recent global financial crisis in five stages. Of these, the second and main stage affecting 21 industries lasted only 27 days, in contrast to the two-and-a-half-years across-the-board recovery from the 1997–2003 financial crisis. We constructed the minimum spanning trees (MSTs) to visualize the Pearson cross correlations between Japanese industries over five macroeconomic periods: (i) 1997–1999 (Asian Financial Crisis), (ii) 2000–2002 (Technology Bubble Crisis), (iii) 2003–2006 (economic growth), (iv) 2007–2008 (Subprime Crisis), and (v) 2008–2010 (Lehman Brothers Crisis). In these MSTs, the Chemicals and Electric Machinery industries are consistently hubs. Finally, we present evidence from the segment-to-segment MSTs for flights to quality within the Japanese stock market.

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Keywords Japanese industries; macroeconomic cycle; financial crisis; economic recovery; financial time series; segmentation; clustering; cross correlations; minimal spanning tree

Correspondence Siew Ann Cheong, Division of Physics and Applied Physics, School of Physical and Mathematical Sciences, Nanyang Technological University, 21 Nanyang Link, Singapore 637371, Republic of Singapore; e-mail: cheongsa@ntu.edu.sg

1 Introduction

Under the austere leadership of Junichiro Koizumi between 2001 and 2006, Japan emerged from the ‘lost decade’, ending a protracted period of recession and unimpressive economic growth since the asset bubble burst in 1986. Unfortunately, this long-awaited growth — and Japan’s ambitions to return to its heydays of the 1970s and 1980s, is almost immediately pitted against the most severe global financial crisis in recent history. A great slump in global investment and demand for Japanese exports in late 2008 sent Japan plunging back into recession. The rapid succession of five prime ministers in four years following Koizumi (see Table 1) most certainly does not help the cause of this only fully modernized country in Asia, which is also the third largest economy in the world.

Table 1: List of Japanese Prime Ministers since Junichiro Koizumi, the 56th Prime Minister of Japan, who led the country for three terms from April 2001 to September 2006. Shinzo Abe, who succeeded Junichiro Koizumi, resigned to take responsibility for his inability to extend the Japanese Self Defense Force’s anti-terrorism commitments overseas (The Japan Times, 13 Sep 2007). His successor, Yasuo Fukuda, resigned because of his inability to deal effectively with the financial crisis (The Economist, 1 Sep 2008), whereas Taro Aso, who followed him, led the Liberal Democratic Party (LDP) to a humiliating defeat in the September 2009 general elections (BBC News, 30 Aug 2009). The historic high unemployment rates at that time was cited as the cause of the LDP’s defeat. Yukio Hatoyama of the Democratic Party of Japan (DPJ) started his prime minister career with high approval rating, promising to end lavish spending on public works projects associated with the LDP, and to divert that money to tax cuts and subsidies for households. Hatoyama resigned in June 2010 because of a funding scandal, and also over the Okinawa row (BBC News, 2 Jun 2010), but it was clear to observers that the DPJ government was struggling to keep its economic promises.

| Name | Term of Office | Party | Remark |
|----------------|-------------------------|---------------------------|-------------------------------|
| Shinzo Abe | 26 Sep 2006–26 Sep 2007 | Liberal Democratic Party | resign |
| Yasuo Fukuda | 26 Sep 2007–24 Sep 2008 | Liberal Democratic Party | resign |
| Taro Aso | 24 Sep 2008–16 Sep 2009 | Liberal Democratic Party | defeated in elec- tions |
| Yukio Hatoyama | 16 Sep 2009–8 Jun 2010 | Democratic Party of Japan | resign |
| Naoto Kan | 8 Jun 2010–present | Democratic Party of Japan | |

On the surface, only the exits of Yasuo Fukuda and Taro Aso are tied to Japan’s economic performance. However, observers agree that under the leadership of Yukio Hatoyama, the DPJ had struggled with the country’s economic woes, and delivering its electoral promises. The current DPJ Prime Minister, Naoto Kan, who took office a little more than half a year ago, does not seem to be faring any better (Fox News, 14 Sep 2010). Certainly, there was no lack of effort on the part of Naoto Kan (Today, 15 January 2011). Are there perhaps deep structural problems with the Japanese economy that Japan’s leaders do not understand? Are these

structural problems preventing the country from responding more positively to all the stimulus measures that have been tried? Clearly, a time bomb is ticking away, with Japan's huge and growing deficit (Yoshino and Mizoguchi, 2010; Japan Economy News & Blog, 14 May 2010), coupled with its rapidly ageing population (Faruqee and Mühleisen, 2003; MacKellar, 2004). There is thus an urgent need to restart the Japanese economic engine.

To such a complex multifaceted problem there have been dissonant views. Reflecting on the 'lost decade', Iida and Matsumae (2009) argued that it is fundamentally misguided to rake up a huge deficit to finance public works, finance this deficit by issuing bonds, and hope that the public spending will revive the economy. Posen (1998), on the other hand, believe that austerity and government inaction are responsible for the 'lost decade', and argued for deficit spending by the government to drive spending and investment in the private sectors. In particular, he believe the Bank of Japan raised interest rates too late to arrest the asset bubble, and lowered interest rates too late to stimulate recovery. Performing a vector autoregression analysis, Bayoumi (2001) found the disruption of financial intermediation as a result of falling property prices to contribute most significantly to Japan's sluggish economic performance. On the other hand, after examining the Japanese economy for the 1990s, Hayashi and Prescott (2002) concluded that the 'lost decade' was not due to a breakdown in the financial system. Citing the lack of evidence for corporations large and small being shut out of profitable investment opportunities due to lack of access to capital markets, they argued instead that the main problem faced by Japan then and now is a low productivity growth rate. Amyx (2004) concurred in part, when she blamed in her book the institutional rigidity and social reluctance to embrace change for Japan's prolonged economic recession.

In contrast to the widely disparate opinions on what are the causes of Japan's economic woes, experts all agree on the need for reforms (Hoshi and Kashyap, 2004; Bigsten, 2005; Kurihara, 2007). In the depth of the 2007–2010 global financial crisis, the DPJ government led by Yukio Hayotama reversed Junichiro Koizumi's 2005 decision to privatize Japan Post, one of Japan's largest companies, and also the largest holder of personal savings in the world. This move have been criticized as a reform in the wrong direction (Wall Street Journal, 29 Oct 2009). To prevent an economic meltdown, the International Monetary Fund (IMF) urged Japan to increase its consumption taxes to combat rising public debts (Reuters, 14 Jul 2010). In Japan, such a move is of course tantamount to political suicide. In any case, there are also doubts on whether raising consumption taxes would be effective, given how reluctant Japanese consumers are to spend money, even after the Bank of Japan put in place a zero interest rate policy that makes saving an extremely unattractive option. Naturally, money is still flowing around in Japan. For the government to develop sound macroeconomic policies to unclog blocked

arteries, it is important to understand how money flows at all levels in the Japanese economy. In this paper, we hope to provide some insights on this problem.

Recently, we adapted a recursive entropic scheme to segment biological sequences, for use on high-frequency financial time series. Through segmenting the Dow Jones Industrial Average (DJIA) Index time series between January 1997 and August 2008, we found that the US economy went from a low-volatility growth phase into a high-volatility crisis phase twice during this period (Wong et al., 2009). The first crisis phase was from mid-1998 to mid-2003, triggered by the Asian Financial Crisis and sustained by the dotcom bubble bursting, whereas the second crisis phase started in mid-2007, apparently triggered by the February 2007 Chinese Correction, and leading on to the Subprime Crisis. When we extended this study to the cross section of ten Dow Jones US (DJUS) Economic Sector Indices, we found a slow one-and-a-half-year complete recovery from the 2000–2003 technology crisis and a rapid two-month descent into the Subprime Crisis (Lee et al., 25 Nov 2009). Comparing the sequence of seven closely-timed interest rate cuts by the Federal Reserve against the time series segment boundaries, we also found the first two cuts lowered market volatility across a broad spectrum of economic sectors, the next two cuts raised market volatility across an equally broad cross section of economic sectors, and then finally, the last three cuts to have no permanent effect on market volatilities.

Delving deeper into the cross section study, we computed the pairwise Pearson cross correlations between the ten DJUS economic sectors over the two crisis periods, the growth period between them, and also within time series segments of various volatilities (Zhang et al., 2011). Constructing the minimal spanning trees (MSTs) of these cross correlations, we found that the growth sectors such as industrials, consumer goods, and consumer services consistently form the core of the MSTs, whereas quality sectors such as basic materials, oil & gas, healthcare, and utilities frequently reside on the fringe of the MSTs. More importantly, we found that economic growth is robustly characterized by a star-like MST, whereas economic crisis is robustly characterized by a chain-like MST. In this paper, we perform a detailed time series segmentation and MST analysis on the 36 Nikkei 500 Japanese industry indices between 1 January 1996 to 11 June 2010, to better understand the dynamics of the Japanese economy, contrast it against the US macroeconomic dynamics, and perhaps offer policy-relevant insights.

Our paper is organized as follows. In Section 2, we will describe the data sets used, the statistical principles behind the recursive segmentation procedure and the grouping of time series segment into different volatility clusters, as well as how MSTs are constructed from the cross correlations. In Section 3, we will examine the temporal distributions of clustered segments of the 36 Nikkei industry indices. Here, we report our finding that the Japanese economy took two and a half years to recover from the 1997–2003 continuum of financial crises, but

only 27 days for 21 out of 36 industries to succumb to the Subprime Crisis. In Section 4, we construct the MSTs over the growth and crisis periods, to identify the core industries in the Japanese economy. Here, we report our finding that the Chemicals and Electric Machinery industries are consistently hubs in these MSTs, indicating that the overall mood in the Japanese economy is strongly dependent on the performance of these two industries. Measuring the diameter of these MSTs, we also find the MSTs to be growing more ‘open’ over the years. In Section 5, we analyze the MSTs of consecutive time series segments, and report signatures of flights to quality episodes within the Japanese stock market. Here we find that the Foods, Nonferrous Metals, and Railway/Bus industries to be the preferred quality industries. Finally, we conclude in Section 6.

2 Data and methods

2.1 Data

Tic-by-tic data of the 36 Nikkei Japanese industry indices (see Table 2) from 1 January 1996 to 11 June 2010 was downloaded from the Thomson-Reuters Tickhistory database (<https://tickhistory.thomsonreuters.com/>). Our main interest lies in the identification of macroeconomic phases, which should not be shorter than a day. Therefore we use only the half-hourly index values $\mathbf{X}_i = \{X_{i,1}, X_{i,2}, \dots, X_{i,t}, \dots, X_{i,N}\}$ for $N = 51,900$ half-hours, and $i = 1, \dots, 36$ are the industry indices shown in Table 2. We use this data frequency because it provides adequate statistics to identify segments as short as a day, but not shorter. Higher data frequencies are possible, since the indices are updated every minute during the trading hours, but we do not use these, because they will lead to short intraday segments which we are not interested in.

2.2 Segmentation

In the economics and finance literature, we find various methods to segment highly nonstationary financial time series into stationary segments called *regimes* or *trends*. Following the pioneering works by Goldfeld and Quandt (1973), and by Hamilton (1989), there is by now an enormous literature on detecting *structural breaks* or *change points* separating stationary segments. A few of these are based on the original Markov switching models (Kim and Nelson, 1999), but most are based on autoregressive models and unit-root tests (Bai, 1994, 1995; Chong, 1995; Loader, 1996; Bai, 1997; Lumsdaine and Papell, 1997; Bai and Perron, 1998; Lavielle and Moulines, 2000; Chong, 2001; Hansen, 2001; Zivot and Andrews, 2002; Bai and Perron, 2003; Perron and Zhu, 2005; Guo and Wohar, 2006; Carrion-i-Silvestre

Table 2: The 36 Nikkei 500 industry indices. Each index is a price-weighted average of stocks which are components of the Nikkei 500 index. The Nikkei 500 index was first calculated on January 4, 1972 with a value of 223.70, and its 500 component stocks are selected from the first section of the Tokyo Stock Exchange based on trading volume, trading value and market capitalization for the preceding three years. The makeup of the Nikkei 500 is reviewed yearly, and each year approximately 30 stocks are replaced. The present components, sorted according to industry, are listed in Appendix A.

| <i>i</i> | symbol | industry | <i>i</i> | symbol | industry |
|----------|--------|--------------------------|----------|--------|---------------------------|
| 1 | NAIR | Air Transport | 19 | NMNG | Mining |
| 2 | NAUT | Automotive | 20 | NNFR | Nonferrous Metals |
| 3 | NBKS | Banking | 21 | NOIL | Oil & Coal Products |
| 4 | NCHE | Chemicals | 22 | NPRC | Precision Instruments |
| 5 | NCMU | Communications | 23 | NREA | Real Estate |
| 6 | NCON | Construction | 24 | NRET | Retail |
| 7 | NELC | Electric Power | 25 | NRRL | Railway/Bus |
| 8 | NELI | Electric Machinery | 26 | NRUB | Rubber Products |
| 9 | NFIN | Other Financial Services | 27 | NSEA | Marine Transport |
| 10 | NFIS | Fisheries | 28 | NSEC | Securities |
| 11 | NFOD | Foods | 29 | NSPB | Shipbuilding |
| 12 | NGAS | Gas | 30 | NSTL | Steel Products |
| 13 | NGLS | Glass & Ceramics | 31 | NSVC | Services |
| 14 | NISU | Insurance | 32 | NTEQ | Other Transport Equipment |
| 15 | NLAN | Other Land Transport | 33 | NTEX | Textiles & Apparel |
| 16 | NMAC | Machinery | 34 | NTIM | Pulp & Paper |
| 17 | NMED | Pharmaceuticals | 35 | NTRA | Trading Companies |
| 18 | NMIS | Other Manufacturing | 36 | NWHO | Warehousing |

et al., 2009). This time series segmentation problem is also starting to attract the attention of econophysicists. Before our own works, Vaglica et al. (2008) broke the transaction histories of three highly liquid stocks on the Spanish stock market into directional segments to study trading strategies adopted in this market. Tóth et al. (2010) later segmented the time series of market orders on the London Stock Exchange, modeling each segment by a stationary Poisson process.

Because different indices have different benchmark values, it is more reasonable to compare their fractional changes. Instead of the half-hourly index time series $\mathbf{X}_i = \{X_{i,1}, \dots, X_{i,N}\}$, we consider the half-hourly log-index movement time series $\mathbf{x}_i = \{x_{i,1}, \dots, x_{i,t}, \dots, x_{i,n}\}$, where $x_{i,t} = \ln X_{i,t+1} - \ln X_{i,t}$ and $n = N - 1$. To determine the M_i stationary segments in a given time series \mathbf{x}_i , we typically assume a common statistical model for the log-index movements in all M_i segments. We know from the seminal work of Mantegna and Stanley (1995) that high-frequency index movements are best modeled by Lévy stable distributions. However, parameter estimation (Fama and Roll, 1971; Hill, 1975; Koutrouvelis, 1980, 1981; McCulloch, 1986; Zolotarev, 1986; Nolan, 1998, 2001) and probability

density calculation (Worsdale, 1975; Panton, 1992; McCulloch and Panton, 1997; Nolan, 1997, 1999) for Lévy stable distributions are computationally expensive, and not suited to the recursive scheme we employ to segment the time series. Our experience segmenting biological sequences tells us that statistically significant segment boundaries can be discovered by any segmentation procedure, whatever the assumed model. We therefore believe that the most statistically significant segment boundaries in financial time series would also be equally insensitive to choice of model. Indeed, in a limited study we have performed (Eng, Apr 2010), where we compare normally-distributed log-index movement segments against Lévy-stably-distributed log-index movement segments of the 2002–2003 DJIA half-hourly time series, we find that the strongest segment boundaries are in good agreement (no more than two days apart). With this reassurance, we chose to intentionally mis-specify the model, assuming that the log-index movements in segment m_i follow a stationary Gaussian process with mean μ_{i,m_i} and variance σ_{i,m_i}^2 . Unlike the Lévy stable distribution, the Gaussian parameters μ_{i,m_i} and σ_{i,m_i}^2 can be estimated very cheaply.

To find the unknown segment boundaries t_{i,m_i} separating segments m_i and $m_i + 1$, we use the recursive segmentation scheme introduced by Bernaola-Galván et al. (Bernaola-Galván et al., 1996; Román-Roldán et al., 1998). In this segmentation scheme, we check how likely it is for the point t in the time series $\mathbf{x} = (x_1, \dots, x_t, x_{t+1}, \dots, x_n)$ to be a segment boundary, by computing the likelihoods

$$L_1 = \prod_{s=1}^n \frac{1}{\sqrt{2\pi\sigma^2}} \exp \left[-\frac{(x_s - \mu)^2}{2\sigma^2} \right], \quad (1)$$

and

$$L_2(t) = \prod_{s=1}^t \frac{1}{\sqrt{2\pi\sigma_L^2}} \exp \left[-\frac{(x_s - \mu_L)^2}{2\sigma_L^2} \right] \prod_{s=t+1}^n \frac{1}{\sqrt{2\pi\sigma_R^2}} \exp \left[-\frac{(x_s - \mu_R)^2}{2\sigma_R^2} \right]. \quad (2)$$

Here, L_1 is the likelihood that \mathbf{x} is generated by a single Gaussian process with mean μ and variance σ^2 , whereas $L_2(t)$ is the likelihood that \mathbf{x} is generated by two statistically distinct processes: the left segment $\mathbf{x}_L = (x_1, \dots, x_t)$ by a Gaussian process with mean μ_L and variance σ_L^2 , and the right segment $\mathbf{x}_R = (x_{t+1}, \dots, x_n)$ by a Gaussian process with mean μ_R and variance σ_R^2 . Because the two additional parameters, the two-segment model always fits \mathbf{x} better than the one-segment model, i.e. $L_2(t) > L_1$. This improvement in fit can be measured using the Jensen-Shannon divergence (Lin, 1991)

$$\Delta(t) = \ln \frac{L_2(t)}{L_1} \geq 0, \quad (3)$$

which is the logarithm of the ratio of likelihoods. When we replace the Gaussian parameters $\mu, \mu_L, \mu_R, \sigma^2, \sigma_L^2, \sigma_R^2$ by their maximum likelihood estimates $\hat{\mu}, \hat{\mu}_L, \hat{\mu}_R$ and $\hat{\sigma}^2, \hat{\sigma}_L^2, \hat{\sigma}_R^2$, the Jensen-Shannon divergence $\Delta(t)$ simplifies to

$$\Delta(t) = n \ln \hat{\sigma} - t \ln \hat{\sigma}_L - (n - t) \ln \hat{\sigma}_R + \frac{1}{2} \geq 0. \quad (4)$$

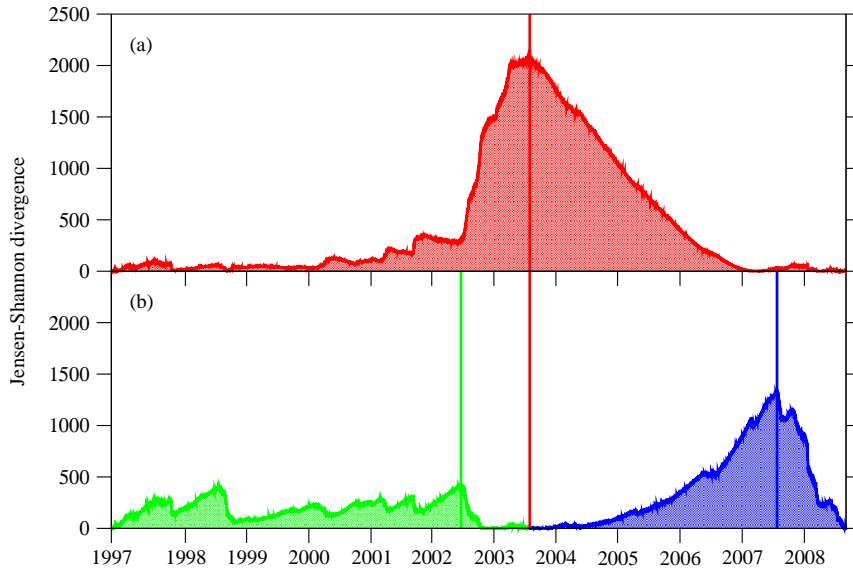


Figure 1: The Jensen-Shannon divergence spectrum for (a) the DJIA time series from Jan 1997 to Aug 2008 (red). This is a typical spectrum consisting of one very strong peak, in this example, at mid-2003. Also shown (b) are the Jensen-Shannon divergence spectra for the left segment (green, 1997 to mid-2003) and the right segment (blue, mid-2003 to Aug 2008) obtained at the second stage of the recursive segmentation. In this example, the two segments have divergence maxima at mid-2002 and mid-2007 respectively.

If we now examine the Jensen-Shannon divergence at all possible times t , we typically find a spectrum like that shown in the top of Fig. 1. This typical Jensen-Shannon divergence spectrum consists of one very strong peak at t^* , for which

$$\Delta^* = \Delta(t^*) = \max_t \Delta(t) \quad (5)$$

is maximized. This is therefore the optimum point to break the time series $\mathbf{x} = (x_1, \dots, x_n)$ into two statistically distinct segments $\mathbf{x}_L^* = (x_1, \dots, x_{t^*})$ and $\mathbf{x}_R^* = (x_{t^*+1}, \dots, x_n)$. This one-into-two segmentation is then applied recursively onto \mathbf{x}_L^* and \mathbf{x}_R^* to obtain shorter and shorter segments (see the bottom of Fig. 1, for example). When new segment boundaries are introduced, the positions of the old segment boundaries may no longer be optimal. Therefore, at each stage of the

recursive segmentation, we optimize the positions of all segment boundaries m within the time series subsequences bound by segment boundaries $m \pm 1$ (see Fig. 2, for example). We do this iteratively until all segment boundaries have converged onto their optimum positions (Cheong et al., 2009b).

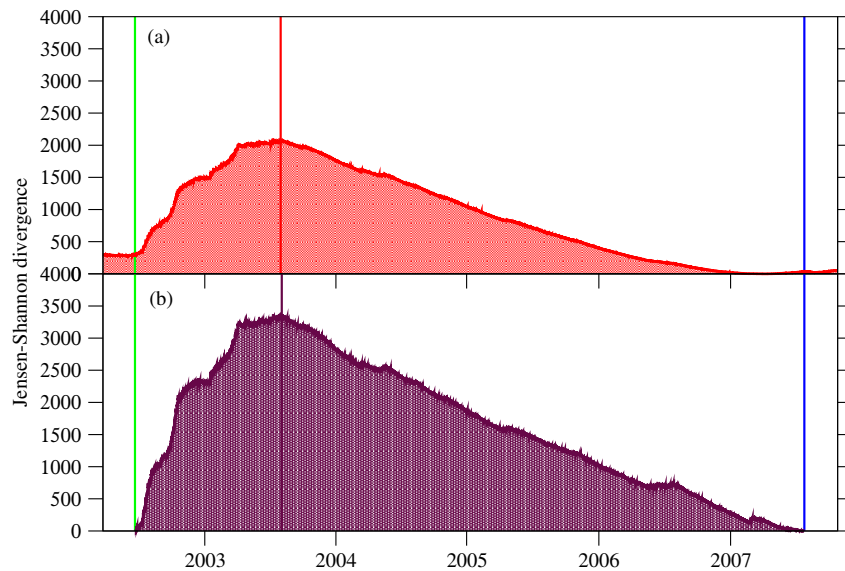


Figure 2: The Jensen-Shannon divergence $\Delta(t)$ of the Dow Jones Industrial Average time series computed in (a) the first stage of the recursive segmentation over the entire half-hourly time series from January 1997 to August 2008. The optimum segment boundary was identified to be at $t_1^* \approx$ mid-2003. After the second stage of the recursive segmentation, two new segment boundaries were discovered at $t_2^* \approx$ mid-2002 and $t_3^* \approx$ mid-2007. When $\Delta(t)$ was recomputed (b) over the interval (t_2^*, t_3^*) , the optimum position for t_1^* is now shifted slightly to $t_1'^*$.

As we continue to discover segment boundaries using the optimized recursive segmentation procedure, we will at some point exhaust all the statistically significant ones, and start to pick up those which are statistically insignificant. This is reflected in the Jensen-Shannon divergence of newly discovered segment boundaries becoming smaller and smaller in general. We must therefore terminate the recursive segmentation when all or nearly all the statistically significant segment boundaries have been found. In the literature, we find three ways to do this. In the first approach, the Jensen-Shannon divergences of new segment boundaries are tested for statistical significance against various χ^2 distributions with the appropriate degrees of freedom (Bernaola-Galván et al., 1996; Román-Roldán et al., 1998). When no new segment boundaries are more significant than the chosen confidence level p , the recursive segmentation terminates. In the second approach, new segment boundaries are accepted if the information criteria of the segmented time series exceeds the information criteria of the unsegmented time series (Li, 2001b,a). Here, the recursive segmentation terminates when further segmentation

does not produce a time series model that explain the data better. In the third approach, new segment boundaries are accepted if their Jensen-Shannon divergences are larger than the amplitudes of typical fluctuations in the Jensen-Shannon divergence spectra (Cheong et al., 2009b). Recursive segmentation stops when the signal-to-noise ratios $\Delta/\delta\Delta$ of all new segment boundaries fall below a chosen threshold value.

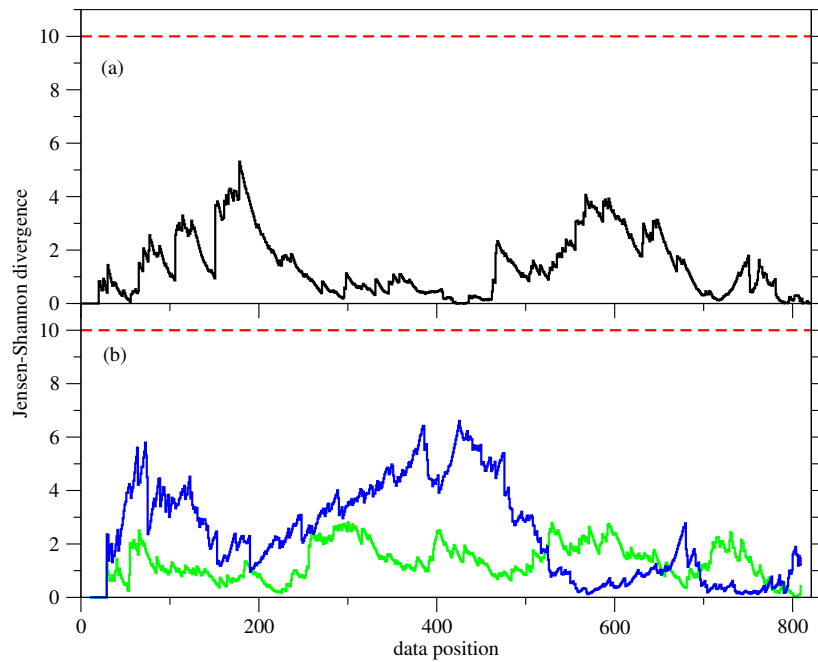


Figure 3: The Jensen-Shannon divergence $\Delta(t)$ of (a) a moderate-length (821 half hours, or equivalently, about 55 trading days) times series segment of the Dow Jones Industrial Average. Contrast this to (b), where $\Delta(t)$ is obtained from a 821-point time series generated by a stationary Gaussian process. In this example, the peak $\Delta_{\max} \approx 5.5$ at the data position of about 200 is only as strong as the typical divergence maximum obtained from a stationary Gaussian process of the same duration. We therefore do not introduce further segment boundaries.

To simplify the recursive segmentation, we adopted a conservative threshold of $\Delta_0 = 10$, i.e. recursive segmentation terminates when no new optimized segment boundaries with Jensen-Shannon divergence greater than a cutoff of $\Delta_0 = 10$ are found. We then examine the segments found by this simplified procedure. We find empirically that the short and medium terminal segments can no longer be further segmented. The long terminal segments, on the other hand, frequently have internal segment structures masked by their context (Cheong et al., 2009a). These we further segment, by progressively lowering the threshold $\Delta_0 \rightarrow \Delta'_0 < 10$ until a segment boundary with strength $\Delta > \Delta_0$ appears. Based on our previous

experiences (Wong et al., 2009; Lee et al., 25 Nov 2009; Zhang et al., 2011), this semi-automatic recursive segmentation produces acceptable results.

Table 3: Number of time series segments for the 36 Nikkei 500 industry indices.

| <i>i</i> | symbol | segments | <i>i</i> | symbol | segments |
|----------|--------|----------|----------|--------|----------|
| 1 | NAIR | 82 | 19 | NMNG | 116 |
| 2 | NAUT | 115 | 20 | NNFR | 123 |
| 3 | NBKS | 138 | 21 | NOIL | 94 |
| 4 | NCHE | 117 | 22 | NPRC | 104 |
| 5 | NCMU | 138 | 23 | NREA | 126 |
| 6 | NCON | 109 | 24 | NRET | 153 |
| 7 | NELC | 139 | 25 | NRRL | 142 |
| 8 | NELI | 147 | 26 | NRUB | 116 |
| 9 | NFIN | 125 | 27 | NSEA | 118 |
| 10 | NFIS | 105 | 28 | NSEC | 162 |
| 11 | NFOD | 113 | 29 | NSPB | 90 |
| 12 | NGAS | 60 | 30 | NSTL | 141 |
| 13 | NGLS | 124 | 31 | NSVC | 117 |
| 14 | NISU | 104 | 32 | NTEQ | 59 |
| 15 | NLAN | 98 | 33 | NTEX | 95 |
| 16 | NMAC | 124 | 34 | NTIM | 95 |
| 17 | NMED | 118 | 35 | NTRA | 130 |
| 18 | NMIS | 121 | 36 | NWHO | 86 |

2.3 Segment clustering

The number of time series segments obtained for each Nikkei 500 industry is shown in Table 3. The smallest number of time series segments is 59, for the Textiles & Apparel industry, and the largest number of time series segments is 162, for the Securities industry. Whatever the industry, successive segments are statistically distinct from each other. However, segments that are far apart can actually be statistically similar. Based on the standard macroeconomic classification of different market periods into four *phases* or *regimes*: (i) a growth phase; (ii) a contraction phase; (iii) a correction phase; and (iv) a crash phase, we also expect the numerous time series segments to be organized into roughly four *segment classes*. To determine these segment classes, we performed hierarchical agglomerative clustering of the segments within each Nikkei 500 industry independently (see Jain et al. (1999) for a review of the broad area of statistical clustering). We chose the complete linkage algorithm, favored by social scientists for producing compact and internally homogeneous clusters (Baker, 1972), because our goal is to discover macroeconomic phases with well-defined statistical properties. In contrast, the more popular single link algorithm (Sneath, 1957; Johnson, 1967), which is more

meaningful in the biological sciences because it corresponds more closely with the nature of evolutionary changes, tends to produce loose and elongated clusters (Baker, 1974).

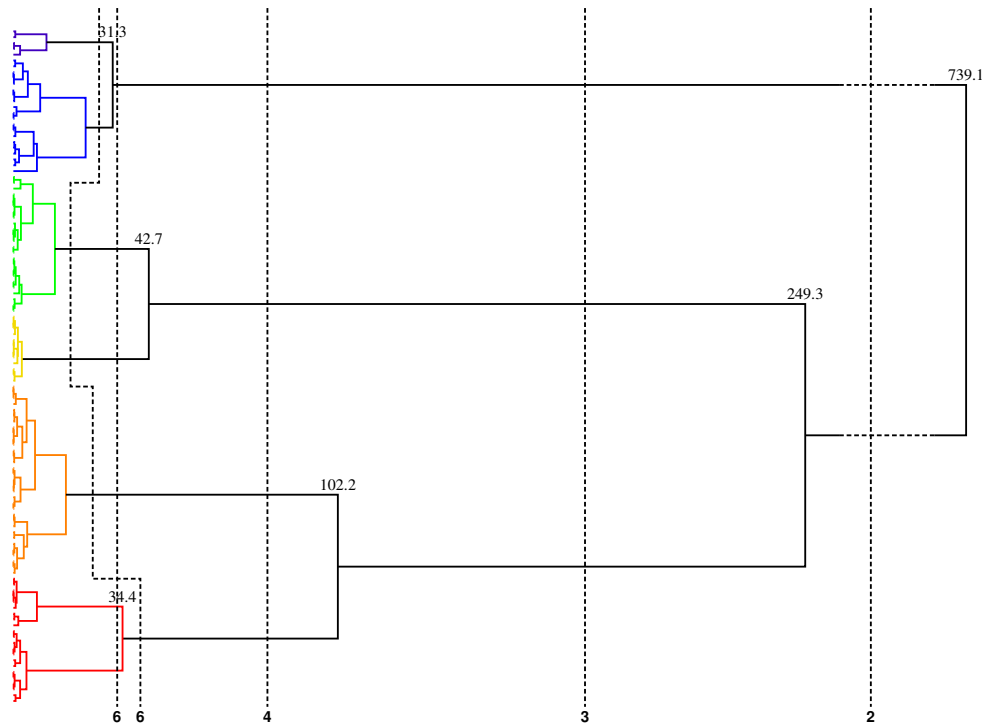


Figure 4: The complete-link hierarchical clustering dendrogram for the time series segments of the Dow Jones Industrial Average between January 1997 and August 2008. In this tree, we show the Jensen-Shannon divergence values at which the top branches diverge. If we choose a uniform threshold $249.3 < \Delta < 739.1$, we can identify two clusters. On the other hand, if we choose a uniform threshold $102.2 < \Delta < 249.3$, we will end up with three clusters. We can also identify six clusters, if we choose a uniform threshold $31.3 < \Delta < 34.4$. Alternatively, individualized thresholds can be selected to obtain the six robust clusters reported in Wong et al. (2009), which are colored in increasing order of market volatility as deep blue, blue, green, yellow, orange, and red.

Using the Jensen-Shannon divergences between segments as their statistical distances, we typically end up with a dendrogram like that shown in Fig. 4 for the Dow Jones Industrial Average. Different number of clusters can be identified by varying a uniform threshold. Fewer clusters means that we have a coarser description, whereas more clusters means that we have a finer description of the dynamics within the time series. Within this nested hierarchy of coarse-grained description of the Japanese macroeconomic dynamics, some descriptions are more useful than others because they are statistically more robust. In Fig. 4, for example, we see that a four-cluster description is more robust, because it extends over a larger range of uniform thresholds $42.7 < \Delta < 102.2$, whereas a five-cluster and

six-cluster descriptions are less robust, because they extend over smaller range of uniform thresholds $34.4 < \Delta < 42.7$ and $31.3 < \Delta < 34.4$, respectively. The four clusters can be loosely associated with the four macroeconomic phases known to economists.

Ultimately, different choices of robust clusters tell the same story with different contrasts, very much like red-tinted and blue-tinted versions of the same photograph. With this understanding in mind, we selected four to five clusters for each of the 36 Nikkei 500 industries. Depending on their average volatilities shown in Table 4, we color the time series segments of the five clusters blue, green, yellow, orange, and red to plot the *temporal distributions of clustered segments* for the 36 Japanese industries. The analyses presented in this paper are based on features identified from the temporal distributions of clustered segments for the 36 Nikkei 500 industry indices.

2.4 Corresponding segments

The most striking features found in the panel of temporal distributions are *corresponding segments* that appear in all or most of the indices. In the economics and finance literature, the consensus that arise from the study of *comovements* (Panton et al., 1976; Stockman and Tesar, 1995; Karolyi and Stulz, 1996; Croux et al., 2001; Forbes and Rigobon, 2002; Barberis et al., 2005; Baxter and Kouparitsas, 2005), *common jumps* (Barndorff-Nielsen and Shepard, 2006; Bollerslev et al., 2008; Jacod and Todorov, 2009), *common shocks* (Canova and Marrinan, 1998; Rigobon, 2003; Andrews, 2005), or *common breaks* (Bai et al., 1998; Carrion-i-Silvestre et al., 2005; Im et al., 2005; Bai, 2009; Bai and Carrion-i-Silvestre, 2009; Kim, 17 Oct 2009) is that the statistical significance of a change point is amplified by the cross section it occurs concurrently over.

In our study, the corresponding segments do not necessarily start at the same time. Our use of high-frequency data allows us to identify change points that are individually optimum for the 36 Nikkei 500 industry indices. For the same reason, our corresponding segments also do not end at the same time. Each corresponding segment therefore provides us with three independent parameters: (i) the starting time, (ii) the duration, and (iii) the Jensen-Shannon divergence value at the start of the corresponding segment. The starting times allow us to roughly map out the progress of volatility shocks, whereas the duration and Jensen-Shannon divergence tell us how strongly the shock impact the different industries in the Japanese economy.

To accommodate the different start and end times, segments in the Nikkei 500 industries are marked as corresponding segments if they (i) have similar volatilities (high and high, or low and low); or (ii) are flanked by volatility movements in the same directions (low-to-high and moderate-to-high, or high-to-low and moderate-

Table 4: Color scheme for the five volatility clusters, and the macroeconomic phases they correspond to: (i) blue (low volatility, growth), (ii) green (moderate volatility, correction), (iii) yellow (high volatility, crisis), (iv) orange (very high volatility, crisis), and (v) red (extremely high volatility, crash). The crisis phase, which consists of the high-volatility (yellow) and very-high-volatility (orange) clusters, is significantly longer than the economic contraction phase accepted by economists. In fact, economic contraction, as determined by successive quarters of contraction in the GDP, typically occurs at the end of a crisis phase. Also shown are the average standard deviation in each phase for the 36 Nikkei 500 industries.

| <i>volatility</i> | low | moderate | high | very high | extremely high |
|-------------------|----------|------------|----------|-----------|----------------|
| <i>color</i> | blue | green | yellow | orange | red |
| <i>phase</i> | growth | correction | crisis | | crash |
| NAIR | 0.003076 | 0.004810 | 0.007298 | 0.014102 | - |
| NAUT | 0.001897 | 0.003320 | 0.005405 | 0.008208 | 0.018155 |
| NBKS | 0.001619 | 0.002490 | 0.003930 | 0.007180 | 0.017130 |
| NCHE | 0.002267 | 0.003435 | 0.004619 | 0.007269 | 0.016209 |
| NCMU | 0.002468 | 0.003643 | 0.005877 | 0.009537 | 0.017001 |
| NCON | 0.002091 | 0.003201 | 0.004171 | 0.006756 | 0.015177 |
| NELC | 0.001194 | 0.002046 | 0.003509 | 0.006230 | 0.014315 |
| NELI | 0.002138 | 0.003524 | 0.005038 | 0.007979 | 0.015629 |
| NFIN | 0.002729 | 0.005090 | 0.007090 | 0.011174 | 0.028018 |
| NFIS | 0.001912 | 0.003815 | 0.006567 | 0.012460 | 0.028647 |
| NFOD | 0.001620 | 0.002680 | 0.003687 | 0.005215 | 0.009986 |
| NGAS | 0.002490 | 0.003694 | 0.005027 | 0.007378 | 0.016906 |
| NGLS | 0.002359 | 0.003845 | 0.005440 | 0.009608 | 0.022268 |
| NISU | 0.002864 | 0.004335 | 0.006487 | 0.014458 | - |
| NLAN | 0.002434 | 0.003489 | 0.004706 | 0.006529 | 0.016302 |
| NMAC | 0.002102 | 0.003545 | 0.005543 | 0.008346 | 0.017493 |
| NMED | 0.001855 | 0.002942 | 0.003914 | 0.007098 | 0.014396 |
| NMIS | 0.002002 | 0.002963 | 0.004201 | 0.007217 | 0.018282 |
| NMNG | 0.004580 | 0.007369 | 0.011228 | 0.022301 | - |
| NNFR | 0.001628 | 0.003456 | 0.005484 | 0.008297 | 0.017209 |
| NOIL | 0.002745 | 0.004461 | 0.006435 | 0.012054 | 0.023781 |
| NPRC | 0.002317 | 0.004005 | 0.005991 | 0.010417 | 0.020013 |
| NREA | 0.003226 | 0.004716 | 0.006432 | 0.011102 | 0.020469 |
| NRET | 0.002099 | 0.003547 | 0.005641 | 0.008193 | 0.013952 |
| NRRL | 0.001387 | 0.002583 | 0.003982 | 0.006202 | 0.011068 |
| NRUB | 0.002961 | 0.004065 | 0.005662 | 0.009723 | 0.019501 |
| NSEA | 0.004104 | 0.006678 | 0.010820 | 0.019426 | - |
| NSEC | 0.002294 | 0.003608 | 0.005474 | 0.008804 | 0.018534 |
| NSPB | 0.002998 | 0.005229 | 0.008543 | 0.014320 | 0.024994 |
| NSTL | 0.002709 | 0.004478 | 0.007228 | 0.014450 | - |
| NSVC | 0.001870 | 0.002692 | 0.003736 | 0.005765 | 0.011990 |
| NTEQ | 0.004331 | 0.006241 | 0.007555 | 0.009718 | 0.023070 |
| NTEX | 0.002045 | 0.003111 | 0.004462 | 0.007923 | 0.018235 |
| NTIM | 0.002452 | 0.003986 | 0.005250 | 0.006507 | 0.013207 |
| NTRA | 0.002439 | 0.003710 | 0.005263 | 0.007669 | 0.017821 |
| NWHO | 0.003358 | 0.005089 | 0.007388 | 0.012246 | 0.027377 |

to-low). These corresponding segments are identified visually, aided by the heat-map-like color scheme in the temporal distributions shown in Fig. 5.

2.5 Cross-correlations

Segmentation followed by segment clustering gives us a coarse-grained dynamical picture of the Japanese economy that is easy to understand and appreciate. However, in this process we also threw out a lot of useful time series information. Once we have a handle on the gross temporal evolution of the Japanese economy, we can recover the high-frequency time series information, by computing the normalized cross-correlation matrix C , whose matrix element

$$C_{ij} = \frac{\frac{1}{T-1} \sum_{t=1}^T (x_{it} - \bar{x}_i)(x_{jt} - \bar{x}_j)}{\sqrt{\frac{1}{T-1} \sum_{t=1}^T (x_{it} - \bar{x}_i)^2 \frac{1}{T-1} \sum_{t=1}^T (x_{jt} - \bar{x}_j)^2}} \quad (6)$$

is the zero-lag cross-correlation between Japanese industries i and j .

Cross-correlations between different stocks, and between different benchmark indices have been widely studied in the finance literature, in the bid to to understand the meltdown of global financial markets during the present financial crisis (Frank et al., August 2008; Lo, 2009; Tudor, 2009; Cheung et al., 2010; Münnix et al., 30 Jun 2010; Wong and Li, 2010). The econophysics community also pioneered a sophisticated method based on random matrix theory to decompose the cross correlations between different financial time series into a trivial noise part and a nontrivial signal part (Laloux et al., 1999; Plerou et al., 2002; Utsugi et al., 2004; Wilcox and Gebbie, 2004, 2007; Çukur et al., 2007; Kulkarni and Deo, 2007; Shen and Zheng, 2009). In all these studies, the cross-correlations were computed either over the entire data period, or over sliding windows. In this study, we calculate the cross-correlation matrix over three different time scales: (i) the entire duration of the time series, (ii) two-year intervals strictly within the growth and crisis macroeconomic phases, and (iii) over individual corresponding segments. As shown in Fig. 5, the interval chosen to compute cross correlations within a corresponding segment is such that it includes as little of the preceding and succeeding segments as possible.

2.6 Minimal spanning trees

For our cross correlations matrix of the 36 Nikkei 500 Japanese industries, there are 630 independent matrix elements. This is far too many for a human mind to process. To better understand what stories these cross correlation matrices are telling us, we can look at their simplified graphical representations constructed through correlations filtering (Matteo and Aste, 12 Dec 2005), or using community detection

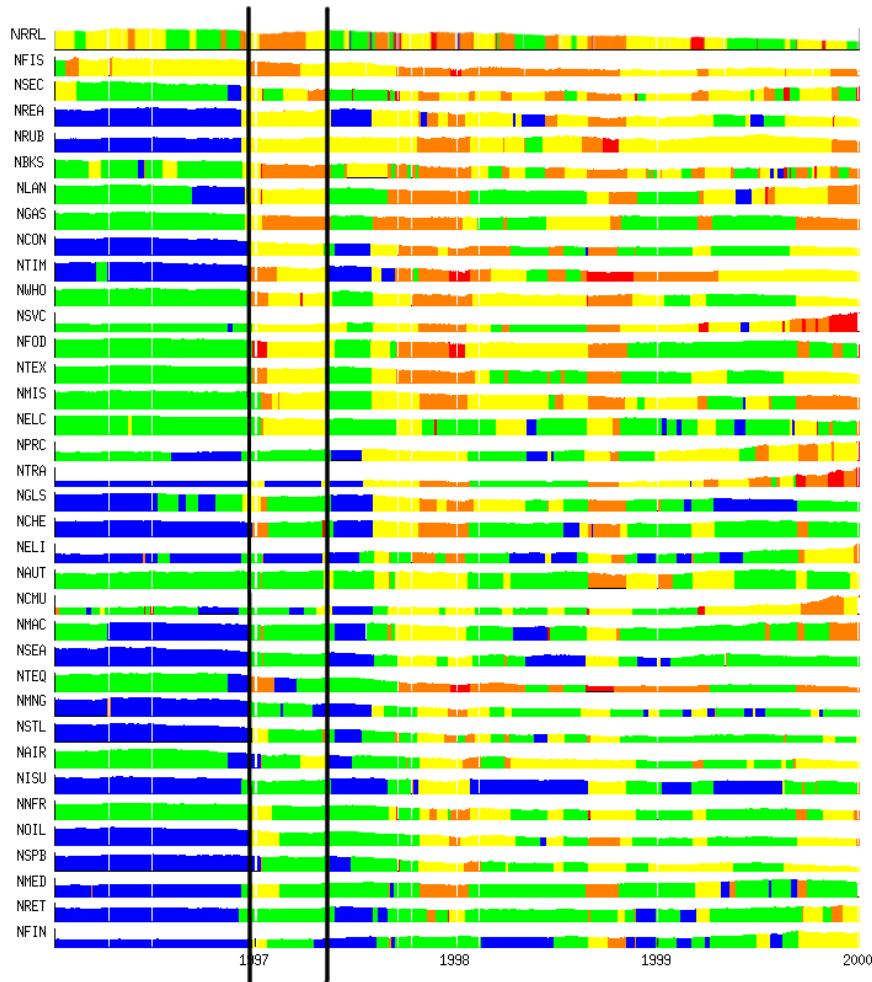


Figure 5: Temporal distributions of the 36 Nikkei 500 industry indices between 1996 and 2000. The corresponding segments in this plot are evident from their common color, or the color movements flanking them in different industries. As an example, we use the black vertical lines to mark a corresponding segment that started at the beginning of 1997, and ending roughly one third through 1997. Roughly half of the Japanese industries are in the high-volatility phase, whereas the remaining half are in the moderate-volatility phase. For the purpose of cross correlation computations, the interval marked by the black vertical lines are chosen such that it includes as little of the low/moderate-volatility phase preceding it, and as little of the low/moderate-volatility phase succeeding it as possible.

methods (Girvan and Newman, 2002; Newman, 2004; Duch and Arenas, 2005; Newman, 2006; Reichardt and Bornholdt, 2006; Lancichinetti and Fortunato, 2009; Fortunato, 2010) to develop a coarse grain description of the cross correlations within the Japanese economy. For this study, we do the former, and visualize the cross correlation matrices as *minimal spanning trees* (MSTs), whereby cycles are not admitted.

Kruskal (1956) first used the MST (also called *minimum spanning tree*) to simplify weighted graphs. The MST was later used by Gower and Ross (1969) to visualize cross correlations. Even though economists regularly deal with cross correlations, the MST visualization is not widely used (Hill, 1999, 2001). However, its application in econophysics took off right after Mantegna and coworkers showed that the MST is a robust caricature of the cross correlations matrix (Mantegna, 1999; Bonanno et al., 2000; Miccichè et al., 2003). The MST is now part of the basic tool suite for statistical analysis of financial market data (Bonanno et al., 2003; Jung et al., 2006; Brida and Risso, 2007; Borghesi et al., 2007; Brida and Risso, 2008; Eom et al., 2009; Brida and Risso, 2010). In particular, Onnela et al. (2003a,b,c), used MSTs extensively to study the dynamics of cross correlations during market crashes, while many others used clustering techniques based on the MST to discover different sectors in a stock market (Onnela et al., 2004; Bonanno et al., 2004; Boginski et al., 2005; Tumminello et al., 2007; Coelho et al., 2007b; Jung et al., 2008). At a higher level, the MST have been used to visualize how the interdependences of the European economies are evolving (Gligor and Ausloos, 2007; Gilmore et al., 2008), and how global markets are linked to each other (Miśkiewicz and Ausloos, 2006; Coelho et al., 2007a; Eryigit and Eryigit, 2009).

To construct the MST of a given cross-correlation matrix, we compute the statistical distance (Mantegna, 1999)

$$0 \leq d_{ij} = \sqrt{2(1 - C_{ij})} \leq 2 \quad (7)$$

between two financial time series i and j with correlation $-1 \leq C_{ij} \leq 1$. Following Kruskal's algorithm (Kruskal, 1956), we first draw a link connecting the time series pair (i_1, j_1) with the smallest distance $d_{i_1 j_1} = \min_{(i,j)} d_{ij}$. Following this, we draw a link connecting the pair (i_2, j_2) with the next smallest distance $d_{i_2 j_2} = \min_{(i,j) \neq (i_1, j_1)} d_{ij}$. We repeat this process with pairs (i_k, j_k) with increasingly larger distances $d_{i_k j_k}$. If no cycles are formed after drawing a link between i_k and j_k , the link is accepted. Otherwise, it is rejected. The whole process stops when all time series are incorporated into the spanning graph.

3 Growths and crises in the Japanese economy

The temporal distributions of all 36 Nikkei 500 Japanese industry indices are shown in Fig. 6, using the color map shown in Table 4. Here, low-volatility growth segments are colored blue, moderate-volatility correction segments are colored green, high-volatility and very-high-volatility crisis segments are colored yellow and orange respectively, and extremely-high-volatility segments are colored red. From Fig. 6, we see that there is only a short period of consistent growth in all Japanese industries in 2005. This suggests that the Japanese economy never fully recovered from the back-to-back Asian Financial and Technology Bubble Crises, before its growth was again derailed by the Subprime Crisis.

From this cross section of temporal distributions, there is a wealth of insights on the Japanese macroeconomic dynamics that we can extract (see Yim (Nov 2010) for details). For example, we know that the Japanese markets became more volatile right after the 9 September 1998 interest rate cut of 0.25% by the Bank of Japan, but did not react to the 12 February 1999 interest rate cut of 0.1% during the Asian Financial Crisis. In contrast, during the Subprime Crisis, the 0.2% rate cut on 31 October 2008 was not effective in calming the Japanese markets, but the 0.2% rate cut by the Japanese central bank on 19 December 2008 was more effective. Even then, only 12 out of 36 industries responded positively to the 19 December 2008 rate cut. Another example, based on the volatility movements at the end of 1996 and beginning of 1997, we see that the Asian Financial Crisis contagion spread across the entire Japanese economy in less than two months.

In this paper, we will focus on the 2005 near recovery of the Japanese economy, and the 2007 fall of the Japanese economy due to the Subprime Crisis. From Fig. 7, we see that NMNG (Mining) has a swath of blue growth segments that started the earliest, and NFIS (Fisheries) has the shortest swath of blue growth segments that started late. NSPB (Shipbuilding) has no blue growth segments between 2002 and 2005 at all. From Fig. 7 it is also clear that complete recovery in the Japanese economy took a long time. To put a number on this duration, we adopted the working definition of economic recovery as the start of sustained growth periods lasting longer than two months. With this operational definition, we could ‘date’ the start of economic recovery in each Nikkei 500 Japanese industry. As shown in Table 5, the Japanese economy took two years and two months to nearly completely recover from the back-to-back Asian Financial and Technology Bubble Crises, led by NMNG (Mining) and NELC (Electric Power). In contrast, the US economy took one and a half years to completely recover from the Technology Bubble Crisis, led by the Oil & Gas and Basic Materials sectors (Lee et al., 25 Nov 2009). While the time scales of complete economic recovery appear to be different, very similar industries led the recovery process.

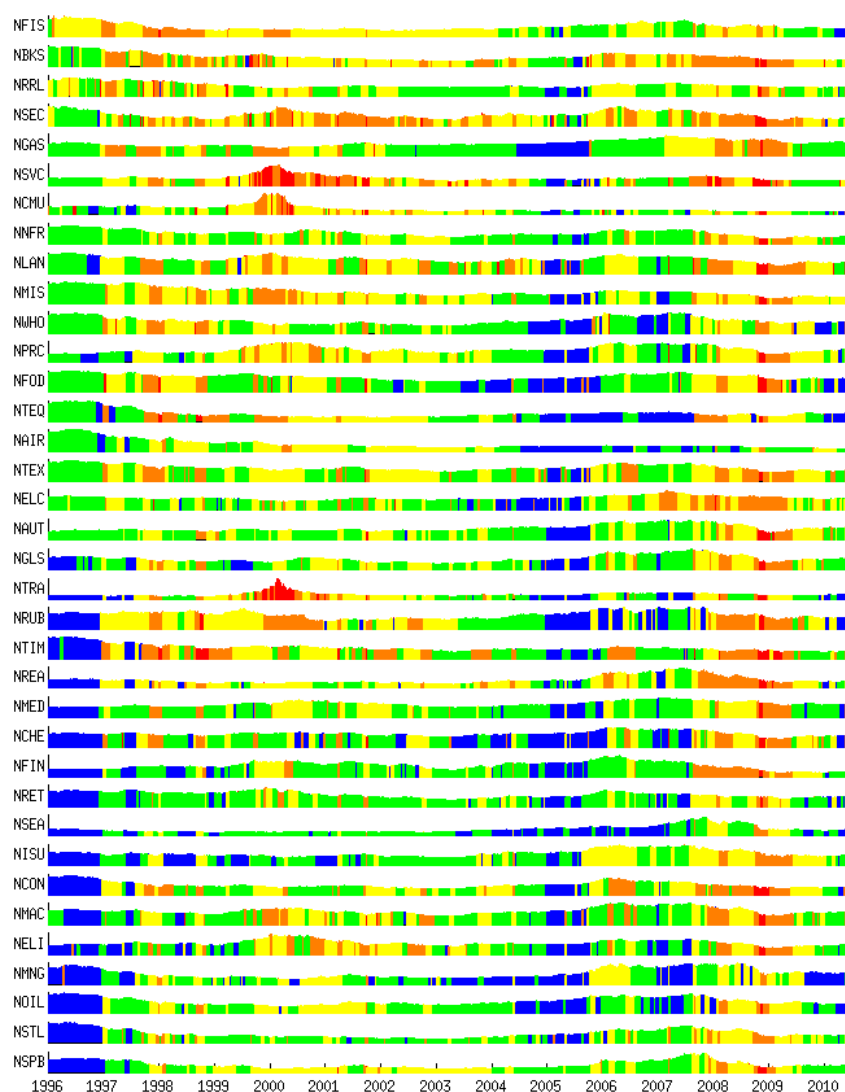


Figure 6: Temporal distributions of the 36 Nikkei 500 Japanese industry indices from 1 January 1996 to 11 June 2010. In this figure, the growth segments are colored blue, correction segments are colored green, crisis segments are colored yellow or orange, and crash segments are colored red.

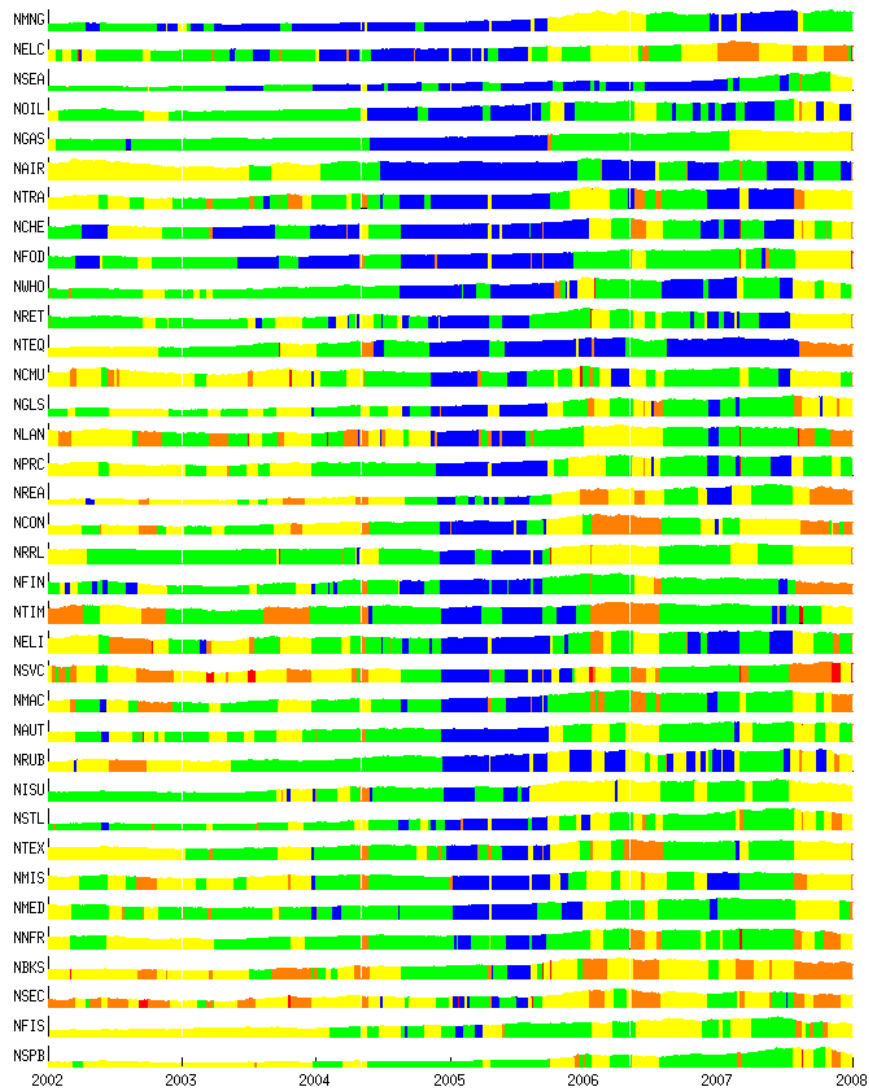


Figure 7: Temporal distributions of the 36 Nikkei 500 Japanese industry indices from January 2002 to December 2007. In this figure, the growth segments are colored blue, correction segments are colored green, crisis segments are colored yellow or orange, and crash segments are colored red.

Table 5: Start dates of economic recovery in the 36 Nikkei 500 Japanese industries, from the earliest to the latest. NSEC (Securities) and NFIS (Fisheries) are not included in this table, because their blue growth segments are shorter than two months. NSPB (Shipbuilding) is not included, because it has no blue growth segments at all.

| industries | start of recovery |
|------------------------------|-------------------|
| NMNG | 27 March 2003 |
| NSEA | 24 December 2003 |
| NELC | 8 January 2004 |
| NOIL | 21 May 2004 |
| NGAS | 25 May 2004 |
| NAIR | 21 June 2004 |
| NTRA, NWHO | 16 August 2004 |
| NCHE, NFOD | 19 August 2004 |
| NRET, NTEQ, NGLS | 5 November 2004 |
| NCMU | 8 November 2004 |
| NPRC | 22 November 2004 |
| NREA | 24 November 2004 |
| NLAN | 25 November 2004 |
| NCON, NRRL, NFIN | 2 December 2004 |
| NTIM, NELI, NSVC, NMAC, NAUT | 3 December 2004 |
| NRUB, NISU | 10 December 2004 |
| NSTL | 16 December 2004 |
| NTEX | 17 December 2004 |
| NMIS, NMED | 5 January 2005 |
| NNFR | 30 May 2005 |
| NBKS | 2 June 2005 |

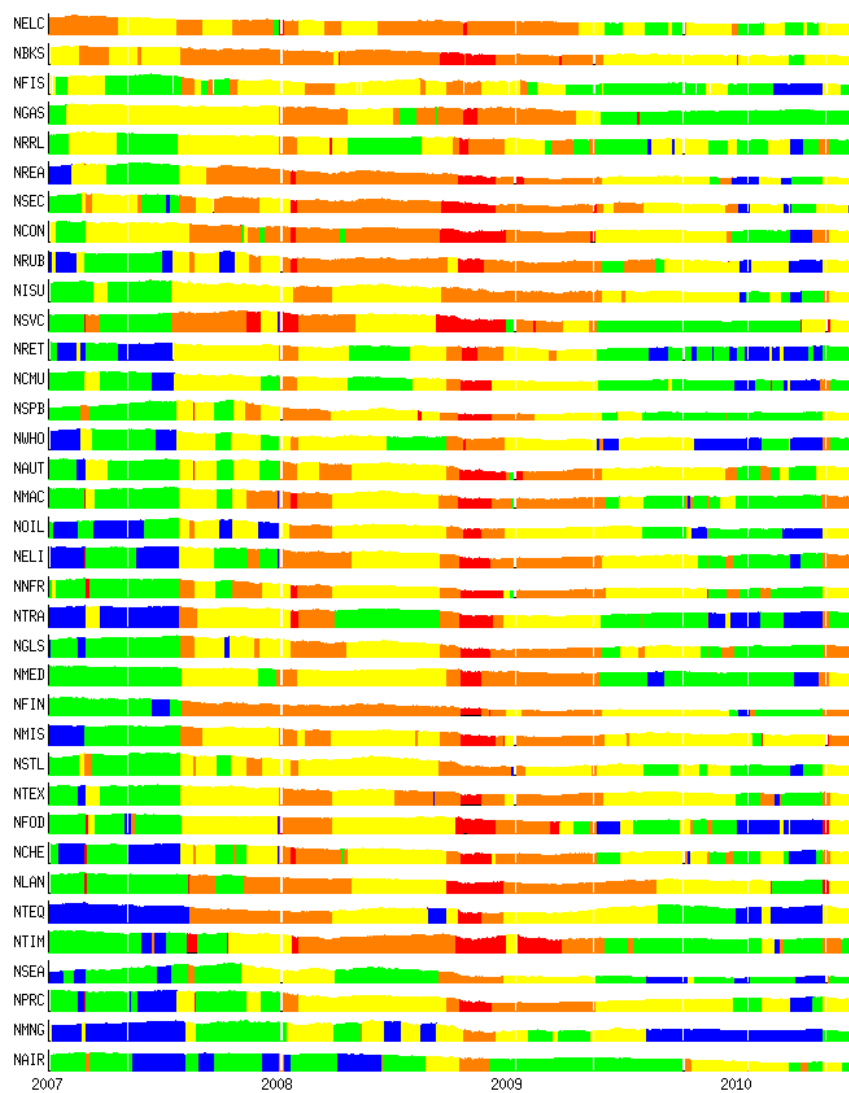


Figure 8: Temporal distributions of the 36 Nikkei 500 Japanese industry indices from January 2007 to June 2010. In this figure, the growth segments are colored blue, correction segments are colored green, crisis segments are colored yellow or orange, and crash segments are colored red.

Next, we look at how the Japanese economy succumbed to the Subprime Crisis. As we can see from the temporal distributions in Fig. 8, the Japanese economy fell in five stages (Table 6). Based on the timings, it appears that stage 1 is related to, but not simply a reaction to, the Chinese Correction of end February 2007. Stage 2, which affected 21 out of 36 Nikkei 500 industries, appears to be triggered by the start of the Subprime Crisis in US. The remaining stages involved one to two industries. If we measure the time elapse between NFIS (Fisheries) and NAIR (Air Transport), the financial crisis took one year and eight months to unfold in Japan. However, the most important time scale in Japan's response to the Subprime Crisis is that associated with stage 2. Here, the Subprime Crisis swept through NISU (Insurance), NSVC (Services), NRUB (Rubber Products) to NTEQ (Other Transport Equipment) in a mere 27 days. This is half the time it took for the US economy to fall from first to the last economic sector, with Consumer Goods (the sector homebuilders belong to) leading the pack. We find it bizzare for Rubber Products to be one of the three industries leading Japan's macroeconomic response to the crisis.

Finally, as late as June 2010, we see from Fig. 8 that most Japanese industries are still in the sustained crisis phase. However, NMNG (Mining), NWHO (Warehousing), NTRA (Trading Companies), and NRET (Retail) showed signs of early recovery from mid 2009 onwards. If the Japanese economy again takes two and a half years to completely recover, this will happen in the beginning of 2012.

4 Macroeconomic correlations between the Japanese industries

Based on the temporal distributions shown in Fig. 6, as well as popular accounts of the economic sagas that unfolded between 1996 and 2010, we selected five macroeconomic periods: (i) the Asian Financial Crisis (1997 to 1999); (ii) the Technology Bubble Crisis (2000 to 2002); (iii) economic growth (2003 to 2006); (iv) Subprime Crisis (2007 to 2008); and (v) Lehman Brothers Crisis (2008 to 2010) for more careful study. We calculated the cross correlations between the 36 Nikkei 500 Japanese industry indices over these five macroeconomic periods, and compared them against cross correlations over the entire 14-year period. The smallest, average, and largest cross correlations seen in these periods are shown in Table 7. As we can see from the averages and maxima, cross correlations have generally increased between the late 1990s and late 2000s.

We also examined the average cross correlations of each Nikkei 500 industry with the rest of the Japanese economy. As shown in Table 8, NAIR (Air Transport), NFIS (Fisheries), NGAS (Gas), and NMNG (Mining) are consistently weakly

Table 6: Start dates of Subprime Crisis in the 36 Nikkei 500 Japanese industries, from the earliest to the latest. NELC (Electric Power) and NBKS (Banks) are not included in this table, because the sustained crisis phase started in these industries around January 2006 and August 2006 respectively.

| industries | start of crisis |
|--|------------------|
| <i>stage 1</i> | |
| NFIS, NGAS | 30 January 2007 |
| NRRL | 31 January 2007 |
| NREA | 7 February 2007 |
| NSEC | 12 February 2007 |
| NCON | 27 February 2007 |
| <i>stage 2</i> | |
| NISU, NSVC, NRUB | 12 July 2007 |
| NRET | 16 July 2007 |
| NCMU | 17 July 2007 |
| NSPB | 19 July 2007 |
| NWHO | 20 July 2007 |
| NAUT, NMAC, NOIL, NELI, NNFR, NTRA | 24 July 2007 |
| NGLS | 25 July 2007 |
| NMED, NFIN, NMIS, NSTL, NTEX, NFOD, NCHE | 26 July 2007 |
| NLAN | 8 August 2007 |
| NTEQ | 9 August 2007 |
| <i>stage 3</i> | |
| NSEA | 3 October 2007 |
| NTIM | 8 October 2007 |
| <i>stage 4</i> | |
| NPRC | 3 January 2008 |
| NMNG | 10 January 2008 |
| <i>stage 5</i> | |
| NAIR | 13 August 2008 |

Table 7: Smallest, average, and largest cross correlations between the 36 Nikkei 500 Japanese industry indices over the entire 14-year period and the five macroeconomic periods. Also shown are the diameters for the MSTs of these five periods.

| period | minimum | average | maximum | MST diameter |
|--------------------------|---------|---------|---------|--------------|
| entire time series | 0.216 | 0.507 | 0.805 | 5 |
| Asian Financial Crisis | 0.234 | 0.485 | 0.767 | 5 |
| Technology Bubble Crisis | 0.115 | 0.509 | 0.836 | 10 |
| Growth | 0.126 | 0.498 | 0.819 | 9 |
| Subprime Crisis | 0.284 | 0.660 | 0.918 | 8 |
| Lehman Brothers Crisis | 0.259 | 0.630 | 0.919 | 8 |

correlated with the rest of the Japanese economy, whereas NCHE (Chemicals), NELI (Electrical Machinery), and NMAC (Machinery) are consistently strongly correlated with the rest of the Japanese economy. This suggests that NCHE, NELI, and NMAC play central roles, whereas NAIR, NFIS, NGAS, and NMNG play peripheral roles in the Japanese economy.

Indeed, when we plot the MSTs of the 36 Nikkei 500 Japanese industries over the entire time series and also over the five macroeconomic periods, as shown in Fig. 9, we see that NCHE (Chemicals) and NELI (Electrical Machinery) are hubs (highly connected nodes) in all the MSTs, while NMAC (Machinery) is a hub during the Lehman Brothers Crisis from 2008 to 2010. We also see that NGAS (Gas), NFIS (Fisheries), NMNG (Mining) and NAIR (Air Transport) are at the fringe of the MSTs. Looking more carefully, we see that the MSTs during the Technology Bubble, growth, Subprime and Lehman Brothers periods are more ‘open’ than that during the Asian Financial Crisis. We can make this comparison more quantitative by measuring the diameters of the MSTs, shown in Table 7. To put it simply, the diameter of a MST is the largest number of links that one has to traverse to get from one node to another.

While the MST does not give the full correlational relationships between the industries, financial contagion in general spreads faster on a ‘closer’ MST than on a more open MST. At the same time, positive sentiments also propagate faster on a ‘closer’ MST, making this a conducive environment for economic growth. In Zhang et al. (2011), we saw how the US economic MST huddled up during growth (to accelerate it), and opens up during crises (to slow down the spread of contagion). We believe this is the learned response of a mature economy. The Japanese economy, on the other hand, seems to have learnt the isolation response only after the Asian Financial Crisis, but not yet the coordinated response to enable growth.

5 Flight to quality in the Japanese stock market

In recent empirical studies, Connolly et al. (2005, 2007) studied return comovements of stocks in different countries, and the return comovements of stocks and bonds in the same country, to better understand the phenomenon of flight to quality. They are followed by Baur and Lucey (2009, 2010), who investigated the flight to quality between stocks, bonds, and gold. In these studies, the emphasis has been on the movement of money between different asset classes. However, the same flight to quality phenomenon can also happen within the stock market itself, where investors dump growth stocks in crisis times to buy quality stocks instead. In this section, we show evidence for such flights to quality within the Japanese

Table 8: The average cross correlations of the 36 Nikkei 500 industries with the rest of the Japanese economy over the macroeconomic periods. Within each period, the three industries with the lowest average cross correlations are colored cyan, whereas the three industries with the highest average cross correlations are colored yellow.

| industry | entire | 1997–1999 | 2000–2002 | 2003–2006 | 2007–2008 | 2008–2010 |
|----------|--------|-----------|-----------|-----------|-----------|-----------|
| NAIR | 0.348 | 0.373 | 0.349 | 0.359 | 0.505 | 0.381 |
| NAUT | 0.582 | 0.536 | 0.592 | 0.580 | 0.732 | 0.691 |
| NBKS | 0.591 | 0.563 | 0.596 | 0.585 | 0.718 | 0.702 |
| NCHE | 0.639 | 0.621 | 0.633 | 0.624 | 0.766 | 0.743 |
| NCMU | 0.492 | 0.406 | 0.517 | 0.527 | 0.675 | 0.652 |
| NCON | 0.582 | 0.572 | 0.570 | 0.558 | 0.708 | 0.694 |
| NELC | 0.387 | 0.387 | 0.374 | 0.363 | 0.525 | 0.480 |
| NELI | 0.601 | 0.533 | 0.625 | 0.613 | 0.765 | 0.737 |
| NFIN | 0.507 | 0.399 | 0.525 | 0.523 | 0.660 | 0.642 |
| NFIS | 0.348 | 0.428 | 0.265 | 0.278 | 0.453 | 0.420 |
| NFOD | 0.551 | 0.588 | 0.517 | 0.518 | 0.657 | 0.628 |
| NGAS | 0.347 | 0.372 | 0.339 | 0.305 | 0.494 | 0.433 |
| NGLS | 0.588 | 0.578 | 0.572 | 0.559 | 0.725 | 0.688 |
| NISU | 0.516 | 0.494 | 0.522 | 0.504 | 0.646 | 0.634 |
| NLAN | 0.497 | 0.467 | 0.474 | 0.456 | 0.680 | 0.639 |
| NMAC | 0.580 | 0.504 | 0.620 | 0.598 | 0.749 | 0.730 |
| NMED | 0.515 | 0.538 | 0.496 | 0.496 | 0.644 | 0.602 |
| NMIS | 0.536 | 0.491 | 0.555 | 0.535 | 0.715 | 0.671 |
| NMNG | 0.363 | 0.430 | 0.288 | 0.274 | 0.490 | 0.523 |
| NNFR | 0.607 | 0.587 | 0.616 | 0.594 | 0.744 | 0.713 |
| NOIL | 0.477 | 0.514 | 0.417 | 0.407 | 0.645 | 0.638 |
| NPRC | 0.530 | 0.443 | 0.541 | 0.537 | 0.720 | 0.699 |
| NREA | 0.535 | 0.524 | 0.521 | 0.510 | 0.668 | 0.644 |
| NRET | 0.521 | 0.487 | 0.590 | 0.572 | 0.668 | 0.618 |
| NRRL | 0.481 | 0.429 | 0.538 | 0.526 | 0.649 | 0.609 |
| NRUB | 0.472 | 0.438 | 0.468 | 0.454 | 0.663 | 0.640 |
| NSEA | 0.482 | 0.487 | 0.462 | 0.448 | 0.605 | 0.583 |
| NSEC | 0.557 | 0.481 | 0.597 | 0.583 | 0.706 | 0.679 |
| NSPB | 0.484 | 0.466 | 0.479 | 0.452 | 0.653 | 0.640 |
| NSTL | 0.546 | 0.527 | 0.538 | 0.526 | 0.684 | 0.675 |
| NSVC | 0.531 | 0.415 | 0.605 | 0.585 | 0.711 | 0.678 |
| NTEX | 0.583 | 0.561 | 0.573 | 0.566 | 0.736 | 0.698 |
| NTIM | 0.446 | 0.496 | 0.403 | 0.417 | 0.543 | 0.522 |
| NTEQ | 0.437 | 0.425 | 0.464 | 0.434 | 0.626 | 0.587 |
| NTRA | 0.506 | 0.436 | 0.613 | 0.598 | 0.738 | 0.717 |
| NWHO | 0.489 | 0.479 | 0.467 | 0.462 | 0.680 | 0.653 |

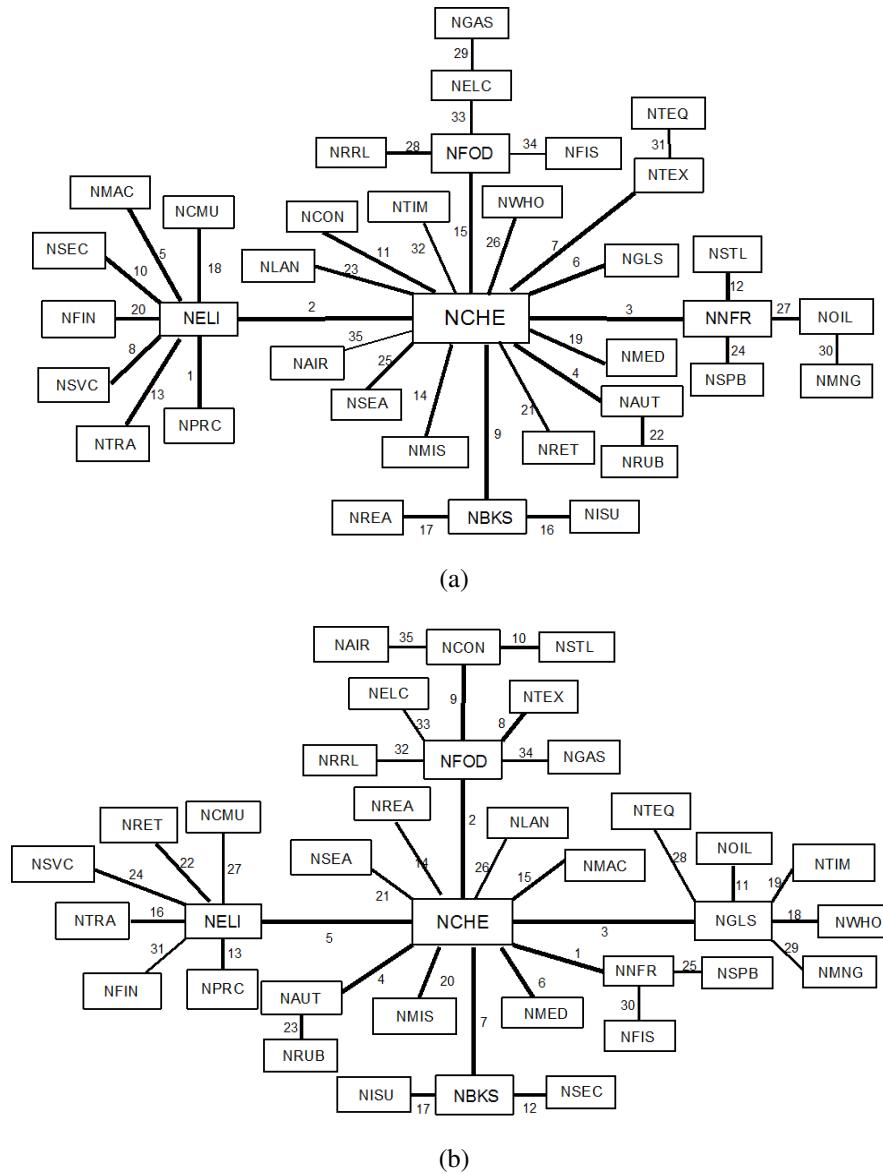
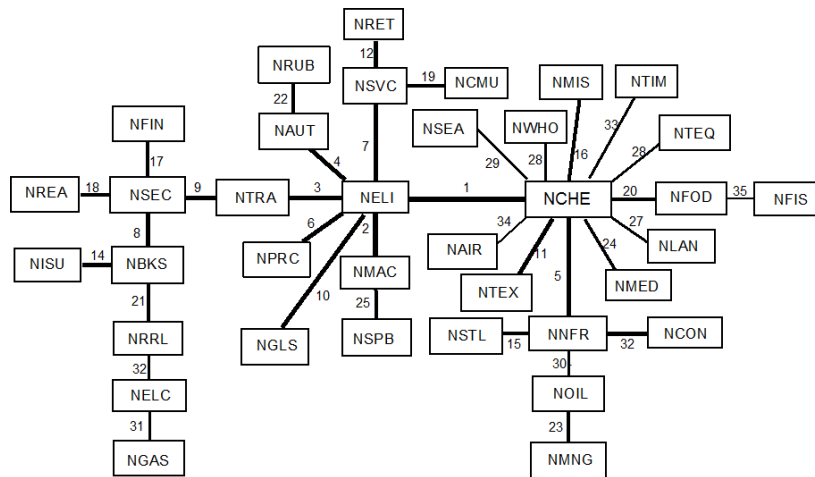
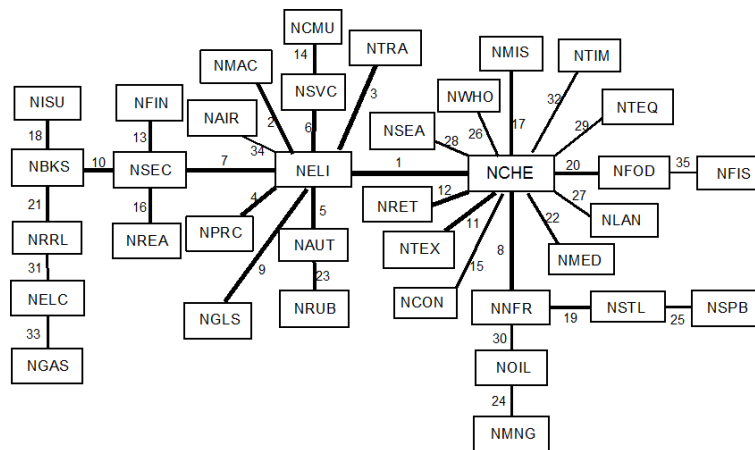


Figure 9: MSTs for the macroeconomic periods (a) January 1996 to June 2010, (b) 1997–1999, (c) 2000–2002, (d) 2003–2006, (e) 2007–2008, (f) 2008–2010. In this figure, the number beside each link indicates the order in which the link was added to the MST, whereas the thicknesses of the links indicate how strong the correlations are between industries. In (d), the industries NMNG, NSEA, NELC, NOIL, NGAS that recovered first from the 1997–2003 financial crisis are colored light blue. As we can see, they reside on the fringe of the MST. The industries NTIM, NELI, NSVC, NMAC, and NAUT colored yellow recovered on the same day. As we can see, NELI, NSVC, NMAC, and NAUT form a connected cluster on the MST. In (e), the industries NAUT, NMAC, NOIL, NELI, NNFR, and NTRA are colored yellow because they entered the Subprime Crisis on the same day. As we can see, they form a connected cluster on the MST.

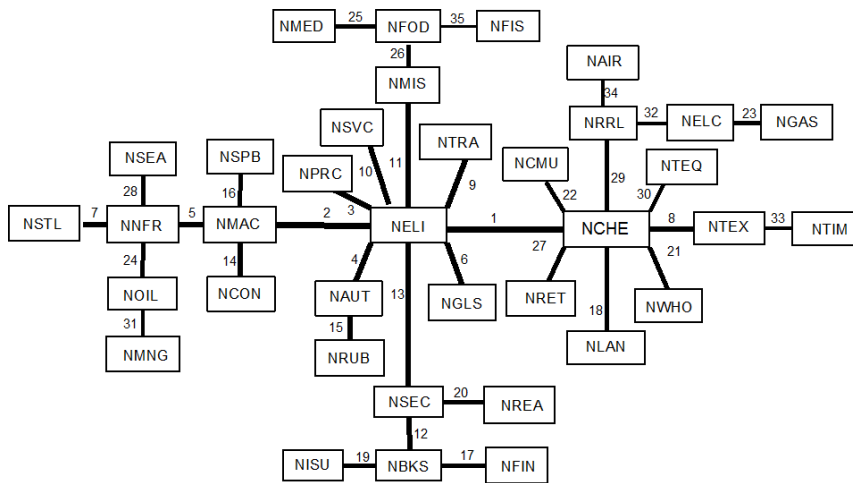


(c)

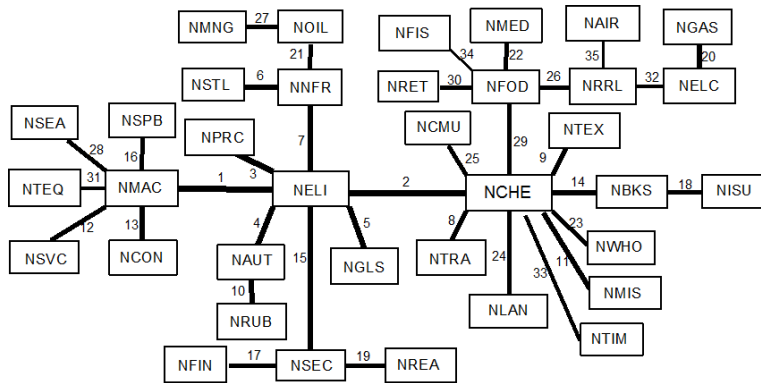


(d)

Figure 9: (continued)



(e)



(f)

Figure 9: (continued)

market, identifying the ‘growth’ industries investors exited from, and the ‘quality’ industries they then invested in.

In Fig. 10, we see that the period between January 2007 to June 2010 covering the Subprime and Lehman Brothers Crises can be divided into eight corresponding segments. The MSTs of these eight corresponding segments are shown in Fig. 11. In Fig. 11(a), Fig. 11(b), and Fig. 11(c), the hubs are (a) NELI (Electric Machinery) and NMAC (Machinery), (b) NCHE (Chemicals), NELI, and NBKS (Banks), and (c) NCHE, NELI, and NMAC respectively. These hubs can all be considered growth industries. In Fig. 11(d), apart from NELI and NMAC, we find that NNFR (Nonferrous Metals) and NRRL (Railway/Bus) are also hubs. The latter two industries are generally considered quality industries. Going from Fig. 11(c) to Fig. 11(d), we see that the most prominent change in the MST structure is the dissipation of the cluster of industries surrounding NCHE, and to a lesser extent, the dissipation of the cluster surrounding NMAC, and clusters growing around NNFR and NRRL. This tells us that the peripheral industries went from being most strongly correlated with NCHE and NMAC to being most strongly correlated with NNFR and NRRL. We believe this is a signature of money leaving the NCHE and NMAC industries, and entering the NNFR and NRRL industries, i.e. a flight to quality from NCHE/NMAC to NNFR/NRRL.

In Subprime5, which corresponds to the collapse of Lehman Brothers, one part of the MST became elongated, whereas the other part became very compact and centered around NELI, which became the only hub in the MST (see Fig. 11(e)). Comparing Fig. 11(e) and Fig. 11(f), we see that the cluster of industries around NELI very quickly dissipated and reformed around NCHE, NMAC, and surprisingly, NFOD (Foods), which is another industry perceived to be a quality industry. This partial migration of correlations to both growth and quality industries in going from Subprime5 to Subprime6, suggests that there are two fairly distinct groups of investors. The first group is optimistic, returning to the growth industries right after the Lehman Brothers collapse, whereas the second group is pessimistic, choosing to invest in a quality industry instead. Going through all eight MSTs, we see that the growth hubs are fairly robust and persistent, and recovers rapidly after short disappearances. The quality hubs, on the other hand, do not survive for very long. We take this to mean that Japanese investors are actually more optimistic than most people give them credit for. Why does the Japanese economy not grow then? We believe the growth industries are not harnessing enough of this positive energy that is coursing through the Japanese markets to realize their full potentials.

Before we conclude, let us mention that this flight-to-quality phenomenon is also observed for the Asian Financial Crisis period, which consists of seven corresponding segments spanning January 1996 to December 1999. Here, however, we find a different story. Although the growth (NCHE, NELI, NBKS) and quality (NFOD, NNFR, NGLS (Glass & Ceramics) instead of NRRL) hubs are by and large

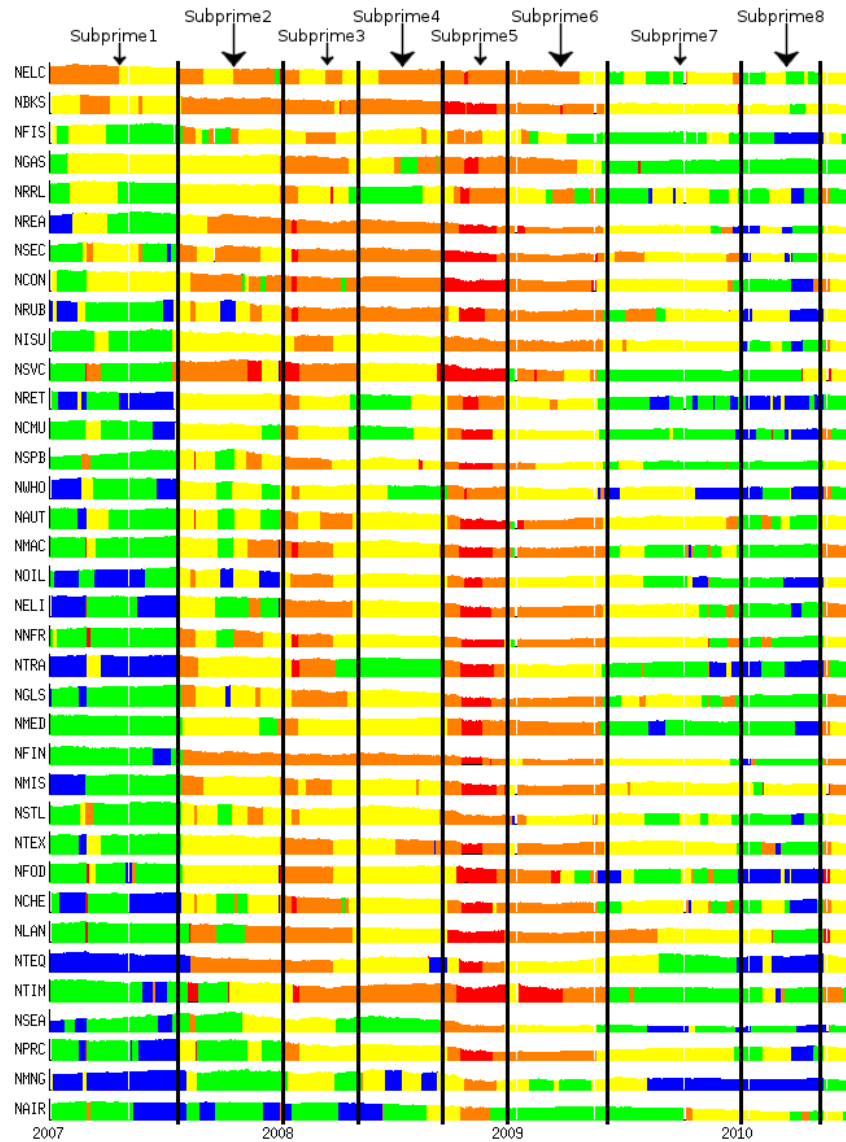


Figure 10: Temporal distributions of the 36 Nikkei 500 Japanese industry indices between January 2007 and June 2010. Within this period, we can identify eight corresponding segments, labeled ‘Subprime1’ to ‘Subprime8’.

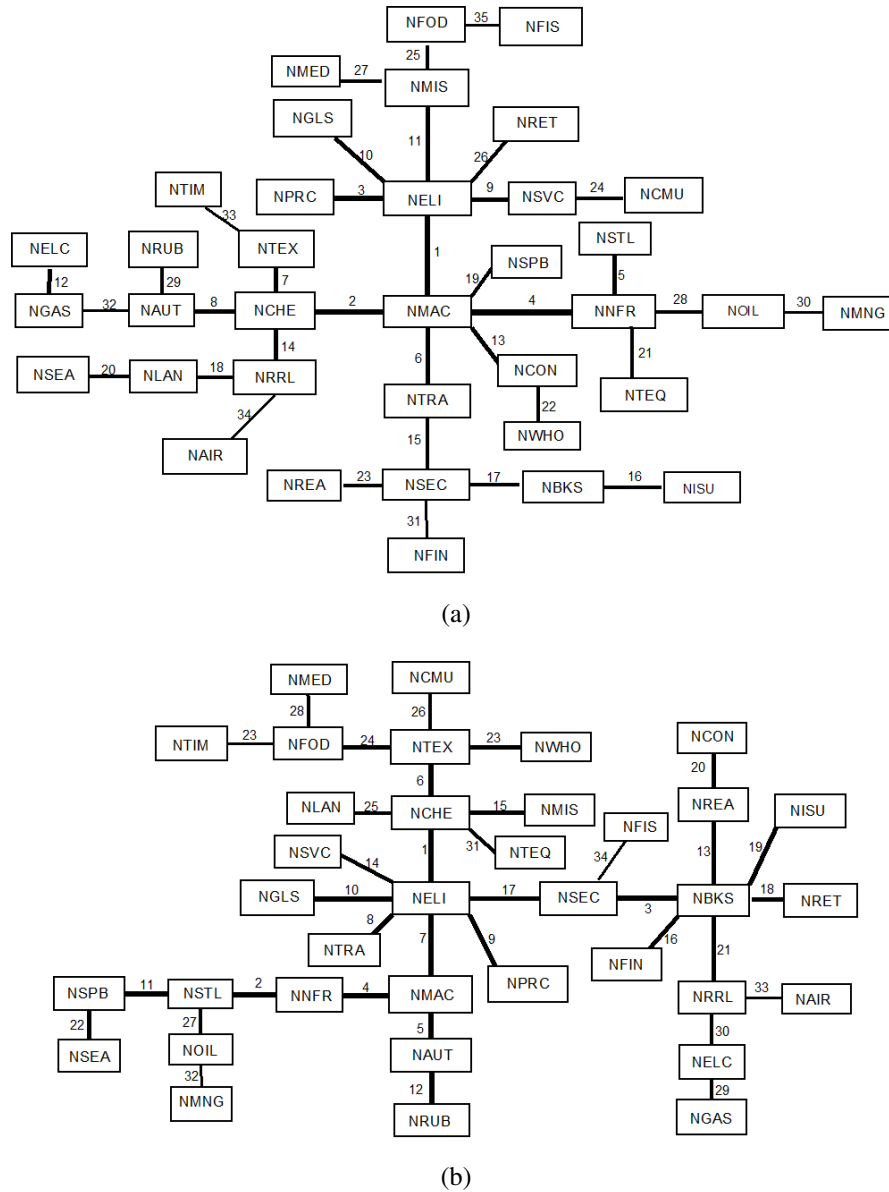
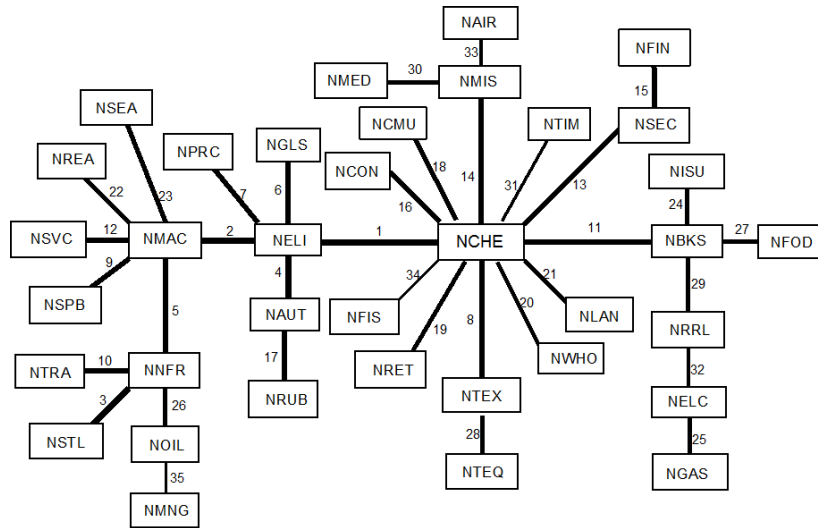
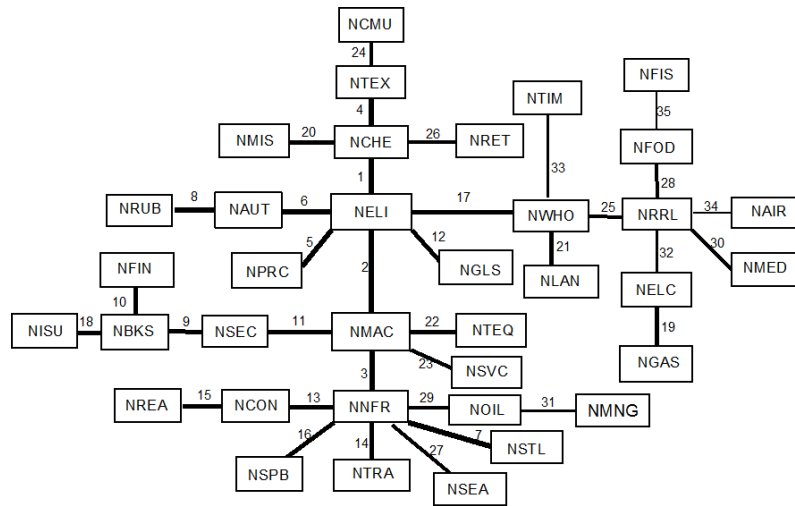


Figure 11: MSTs for the eight corresponding segments from (a) Subprime1 to (h) Subprime8. In this figure, the number beside each link indicates the order in which the link was added to the MST, whereas the thicknesses of the links indicate how strong the correlations are between industries.

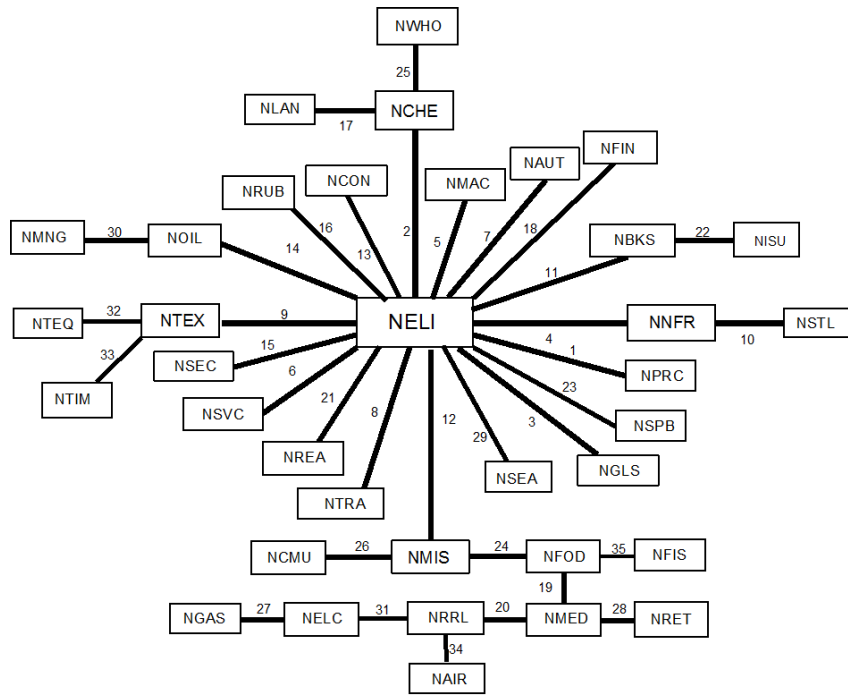


(c)

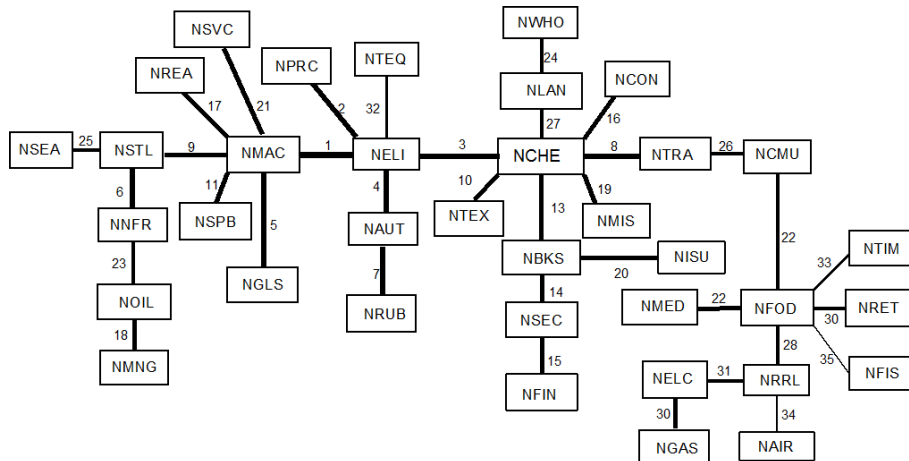


(d)

Figure 11: (continued)

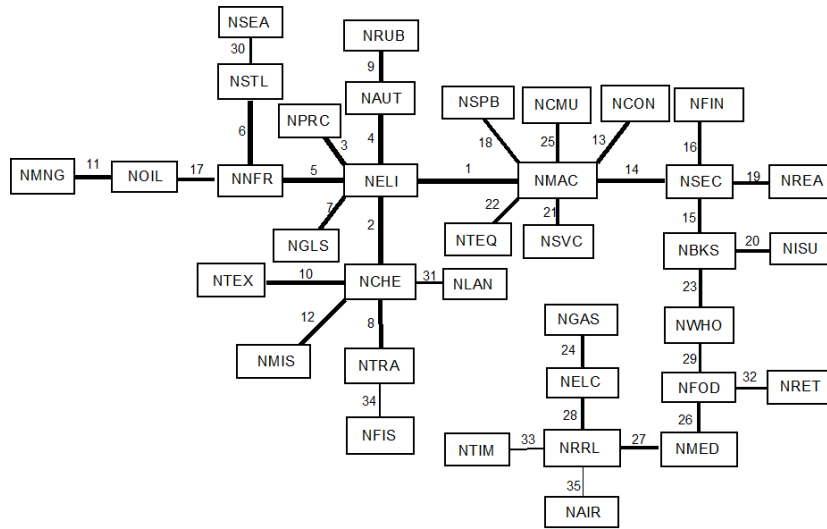


(e)

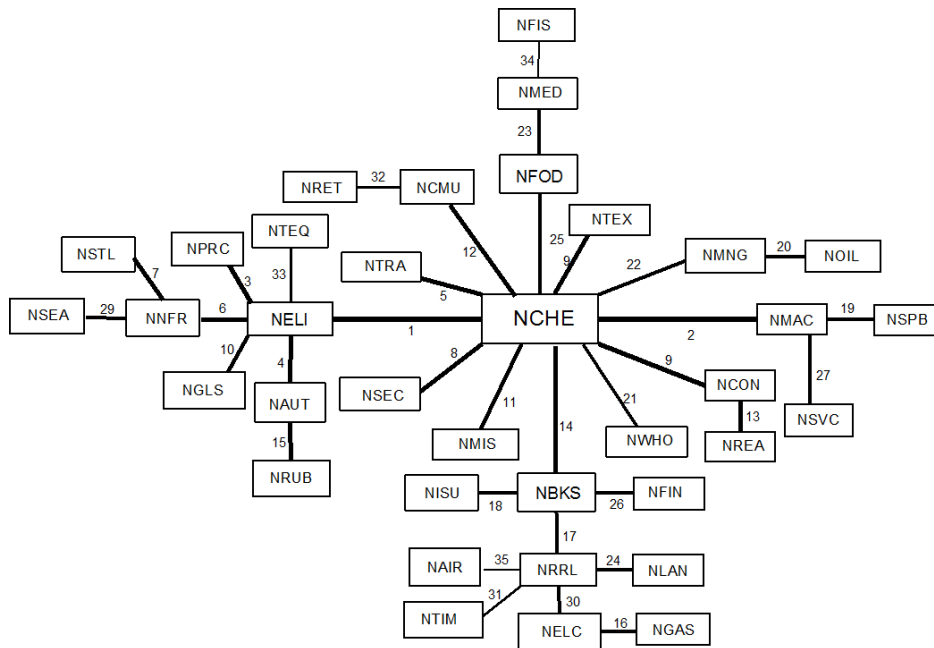


(f)

Figure 11: (continued)



(g)



(h)

Figure 11: (continued)

the same, the quality hubs (NFOD in particular) are longer-lived. This suggests that Japanese investors are more pessimistic during the Asian Financial Crisis than they are during the Subprime Crisis. This pessimistic outlook near the end of the last millenium might have contributed to Japan's slow economic recovery from the Technology Bubble Crisis.

6 Conclusions

To summarize, in this paper we segmented the time series of the 36 Nikkei 500 Japanese industry indices between January 1996 and June 2010, and then clustered the time series segments into four to five volatility clusters, each representing a distinct macroeconomic phase. By examining the temporal distributions of clustered segments, we found that the Japanese economy started recovering from the back-to-back Asian Financial and Technology Bubble Crises in the second quarter of 2003. Complete recovery of the Japanese economy, at the end of the second quarter of 2005, took well over two years. In contrast, 21 out of 36 Japanese industries succumbed to the Subprime Crisis in only 27 days starting 12 July 2007. To compare, we note from our previous work that the Subprime Crisis swept through all ten US economic sectors in two months, whereas complete economic recovery from the Technology Bubble Crisis took one-and-a-half years. We saw also that as late as June 2010, many Japanese industries were still in the sustained crisis phase, and argued that full recovery will take place in early 2012.

Next, we calculated the Pearson cross correlations between Japanese industries over five macroeconomic periods: (i) 1997–1999 (Asian Financial Crisis), (ii) 2000–2002 (Technology Bubble Crisis), (iii) 2003–2006 (economic growth), (iv) 2007–2008 (Subprime Crisis), and (v) 2008–2010 (Lehman Brothers Crisis), to compare against cross correlations calculated over the entire period of study. We found that cross correlations are in general increasing over the $14\frac{1}{2}$ years studied. To better understand these cross correlations, we constructed their associated MSTs, and found that the Chemicals and Electric Machinery industries consistently hubs. Based on their diameters, we also found the MSTs to be increasingly 'open' over the years. 'Closed' MSTs are conducive for economic growth but at the same time allows rapid propagation of financial contagion, whereas 'open' MSTs offers partial isolation from progressive crises. Comparing the macroeconomic MSTs of US and Japan, we saw the Japanese economy is still not as nimble as its US counterpart.

Finally, we analyzed the rearrangement dynamics of the segment-to-segment MSTs during the Subprime Crisis. We presented evidence showing how growth industries like the Chemicals, Electric Machinery, and Machinery can sometimes fall out of favor with investors, who flocked briefly to quality industries such as

Foods, Nonferrous Metals, and Railway/Bus. Comparing the lifetimes of flight to quality episodes within the Japanese stock market during the Asian Financial Crisis and the Subprime Crisis, we argued that investors were significantly more pessimistic during the former. We suggested that this outlook may have persisted through the Technology Bubble Crisis, culminating in Japan's late economic recovery.

Acknowledgements

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A Component stocks of the 36 Nikkei 500 industries

In this appendix, the lists of component stocks are taken from Nikkei's website, <http://e.nikkei.com/e/app/fr/market/constituents.aspx>, whereas the market capitalizations are obtained from Reuters, <http://www.reuters.com/>.

A.1 Air Transport

| Stock Code | Company Name | Market Capitalization (million JPY) |
|------------|----------------------------------|-------------------------------------|
| 9202 | All Nippon Airways Co., Ltd. | 643,864.62 |
| 9234 | Kokusai Kogyo Holdings Co., Ltd. | 13,240.51 |

A.2 Automotive

| Stock Code | Company Name | Market Capitalization (million JPY) |
|------------|-------------------------------|-------------------------------------|
| 7261 | Mazda Motor Corp. | 309,785.69 |
| 7211 | Mitsubishi Motors Corp. | 548,257.81 |
| 7240 | NOK Corp. | 227,677.20 |
| 7270 | Fuji Heavy Industries Ltd. | 429,010.50 |
| 3116 | Toyota Boshoku Corp. | 214,126.59 |
| 7202 | Isuzu Motors, Ltd. | 549,777.88 |
| 7248 | Calsonic Kansei Corp. | 84,704.91 |
| 7205 | Hino Motors, Ltd. | 222,362.80 |
| 7262 | Daihatsu Motor Co., Ltd. | 530,059.62 |
| 7251 | Keihin Corp. | 109,572.10 |
| 7222 | Nissan Shatai Co., Ltd. | 92,928.66 |
| 7242 | Kayaba Industry Co., Ltd. | 146,500.70 |
| 7201 | Nissan Motor Co., Ltd. | 3,187,104.00 |
| 7272 | Yamaha Motor Co., Ltd. | 462,379.81 |
| 7282 | Toyoda Gosei Co., Ltd. | 213,216.41 |
| 7269 | Suzuki Motor Corp. | 990,809.62 |
| 7276 | Koito Manufacturing Co., Ltd. | 198,735.80 |
| 7259 | Aisin Seiki Co., Ltd. | 789,728.00 |
| 7203 | Toyota Motor Corp. | 11,361,150.00 |
| 7312 | Takata Corp. | 187,696.00 |
| 7267 | Honda Motor Co., Ltd. | 5,506,743.00 |

A.3 Banks

| Stock Code | Company Name | Market Capitalization (million JPY) |
|------------|--|-------------------------------------|
| 8339 | The Tokyo Tomin Bank, Ltd. | 40,611.23 |
| 8415 | Kiyo Holdings, Inc. | 85,237.83 |
| 8303 | Shinsei Bank, Ltd. | 272,284.31 |
| 8366 | The Shiga Bank, Ltd. | 112,020.10 |
| 8404 | Mizuho Trust & Banking Co., Ltd. | 387,018.69 |
| 8328 | Sapporo Hokuyo Holdings, Inc. | 156,966.80 |
| 8411 | Mizuho Financial Group, Inc. | 3,236,671.00 |
| 8377 | Hokuhoku Financial Group, Inc. | 229,619.00 |
| 8333 | The Joyo Bank, Ltd. | 265,275.41 |
| 8379 | The Hiroshima Bank, Ltd. | 223,845.30 |
| 8356 | The Juroku Bank, Ltd. | 99,740.48 |
| 8334 | The Gunma Bank, Ltd. | 213,394.70 |
| 8308 | Resona Holdings, Inc. | 1,016,043.00 |
| 8304 | Aozora Bank, Ltd. | 298,676.69 |
| 8309 | Chuo Mitsui Trust Holdings, Inc. | 484,260.50 |
| 8327 | The Nishi-Nippon City Bank, Ltd. | 183,248.50 |
| 8332 | The Bank of Yokohama, Ltd. | 534,900.88 |
| 8359 | The Hachijuni Bank, Ltd. | 242,834.20 |
| 8341 | The 77 Bank, Ltd. | 151,778.41 |
| 8354 | Fukuoka Financial Group, Inc. | 275,983.59 |
| 8306 | Mitsubishi UFJ Financial Group, Inc. | 5,589,604.00 |
| 8336 | The Musashino Bank, Ltd. | 90,548.94 |
| 8544 | The Keiyo Bank, Ltd. | 121,286.80 |
| 8331 | The Chiba Bank, Ltd. | 421,790.41 |
| 8355 | The Shizuoka Bank, Ltd. | 457,666.19 |
| 8403 | The Sumitomo Trust and Banking Co., Ltd. | 721,980.38 |
| 8369 | The Bank of Kyoto, Ltd. | 266,200.81 |
| 8418 | Yamaguchi Financial Group, Inc. | 193,771.20 |
| 8385 | The Iyo Bank, Ltd. | 223,405.00 |
| 8382 | The Chugoku Bank, Ltd. | 212,307.80 |
| 8358 | Suruga Bank Ltd. | 183,020.70 |
| 8316 | Sumitomo Mitsui Financial Group, Inc. | 3,817,950.00 |

A.4 Chemicals

| Stock Code | Company Name | Market Capitalization (million JPY) |
|------------|-----------------------------------|-------------------------------------|
| 4912 | Lion Corp | 124,132.90 |
| 4045 | Toagosei Co Ltd | 109,292.90 |
| 4004 | Showa Denko K K | 239,538.09 |
| 4028 | Ishihara Sangyo Kaisha Ltd | 34,730.19 |
| 4043 | Tokuyama Corp | 141,617.09 |
| 4631 | DIC Corp | 165,487.00 |
| 4044 | Central Glass Co Ltd | 69,835.99 |
| 4208 | Ube Industries Ltd | 264,401.19 |
| 4183 | Mitsui Chemicals Inc | 284,121.59 |
| 4005 | Sumitomo Chemical Co Ltd | 667,144.81 |
| 4042 | Tosoh Corp | 172,533.50 |
| 4403 | NOF Corp | 68,814.11 |
| 4634 | Toyo Ink Mfg Co Ltd | 122,152.80 |
| 4204 | Sekisui Chemical Co Ltd | 342,587.09 |
| 4061 | Denki Kagaku Kogyo K K | 196,257.59 |
| 4023 | Kureha Corp | 68,676.52 |
| 4188 | Mitsubishi Chemical Holdings Corp | 715,486.88 |
| 4041 | Nippon Soda Co Ltd | 50,924.82 |
| 4202 | Daicel Chemical Industries Ltd | 178,457.00 |
| 4088 | Air Water Inc | 194,635.41 |
| 4118 | Kaneka Corp | 196,000.00 |
| 4203 | Sumitomo Bakelite Co Ltd | 129,109.60 |
| 4091 | Taiyo Nippon Sanso Corp | 264,832.00 |
| 4272 | Nippon Kayaku Co Ltd | 128,665.00 |
| 3407 | Asahi Kasei Corp | 770,036.38 |
| 4612 | Nippon Paint Co Ltd | 144,378.91 |
| 4613 | Kansai Paint Co Ltd | 194,653.00 |
| 4182 | Mitsubishi Gas Chemical Co Inc | 270,264.41 |
| 4401 | ADEKA Corp | 78,567.80 |
| 4911 | Shiseido Co Ltd | 595,200.00 |
| 4021 | Nissan Chemical Industries Ltd | 146,376.00 |
| 4452 | Kao Corp | 1,121,879.00 |
| 4205 | Zeon Corp | 173,810.30 |
| 3405 | Kuraray Co Ltd | 386,309.41 |
| 4114 | Nippon Shokubai Co Ltd | 199,916.00 |
| 4217 | Hitachi Chemical Co Ltd | 331,508.59 |
| 4185 | JSR Corp | 407,881.00 |
| 4901 | Fujifilm Holdings Corp | 1,296,342.00 |
| 4063 | Shin-Etsu Chemical Co Ltd | 1,728,427.00 |
| 6988 | Nitto Denko Corp | 741,948.50 |

A.5 Communications

| Stock Code | Company Name | Market Capitalization (million JPY) |
|------------|--|-------------------------------------|
| 9433 | KDDI Corp. | 2,372,469.00 |
| 9435 | Hikari Tsushin, Inc. | 97,969.05 |
| 9412 | SKY Perfect JSAT Holdings Inc. | 102,312.80 |
| 9401 | Tokyo Broadcasting System Holdings, Inc. | 181,294.09 |
| 9449 | GMO Internet Inc. | 37,601.29 |
| 9432 | Nippon Telegraph And Telephone Corp. | 5,417,985.00 |
| 9404 | Nippon Television Network Corp. | 301,838.09 |
| 9984 | Softbank Corp. | 40,805.88 |
| 9427 | Eaccess Ltd. | 159,828.00 |
| 4676 | Fuji Media Holdings, Inc. | 264,801.41 |
| 9437 | NTT Docomo, Inc. | 6,515,952.00 |
| 9613 | NTT Data Corp. | 686,383.50 |

A.6 Construction

| Stock Code | Company Name | Market Capitalization (million JPY) |
|------------|---------------------------------------|-------------------------------------|
| 1983 | Toshiba Plant Systems & Services Corp | 91,211.53 |
| 1951 | Kyowa Exeo Corp | 98,019.93 |
| 1820 | Nishimatsu Construction Co Ltd | 39,469.97 |
| 1802 | Obayashi Corp | 274,173.69 |
| 1808 | Haseko Corp | 97,758.18 |
| 1942 | Kanden Co Ltd | 103,260.00 |
| 1801 | Taisei Corp | 245,157.80 |
| 1812 | Kajima Corp | 263,270.69 |
| 1803 | Shimizu Corp | 302,789.59 |
| 1833 | Okumura Corp | 80,370.80 |
| 1860 | Toda Corp | 109,703.30 |
| 1721 | Comsys Holdings Corp | 120,723.70 |
| 1928 | Sekisui House, Ltd | 547,600.00 |
| 1925 | Daiwa House Industry Co Ltd | 646,715.81 |
| 1963 | JGC Corp | 508,002.81 |
| 1878 | Daito Trust Construction Co Ltd | 711,027.12 |

A.7 Electric Power

| Stock Code | Company Name | Market Capitalization (million JPY) |
|------------|--------------------------------------|-------------------------------------|
| 9508 | Kyushu Electric Power Co., Inc. | 832,192.81 |
| 9509 | Hokkaido Electric Power Co., Inc. | 361,044.50 |
| 9506 | Tohoku Electric Power Co., Inc. | 752,815.31 |
| 9504 | The Chugoku Electric Power Co., Inc. | 603,335.88 |
| 9505 | Hokuriku Electric Power Co. | 410,781.69 |
| 9503 | The Kansai Electric Power Co., Inc. | 1,828,652.00 |
| 9507 | Shikoku Electric Power Co., Inc. | 558,008.38 |
| 9513 | Electric Power Development Co., Ltd. | 429,416.41 |
| 9502 | Chubu Electric Power Co., Inc. | 1,487,196.00 |
| 9501 | The Tokyo Electric Power Co., Inc. | 1,118,484.00 |
| 9511 | The Okinawa Electric Power Co., Inc. | 67,119.69 |

A.8 Electric Machinery

| Stock Code | Company Name | Market Capitalization (million JPY) |
|------------|--|-------------------------------------|
| 7718 | Star Micronics Co Ltd | 44,194.78 |
| 6665 | Elpida Memory Inc | 217,949.59 |
| 6508 | Meidensha Corp | 70,340.05 |
| 6701 | NEC Corp | 445,409.31 |
| 6703 | Oki Electric Industry Co Ltd | 44,617.76 |
| 6764 | Sanyo Electric Co Ltd | 702,018.12 |
| 6796 | Clarion Co Ltd | 36,474.00 |
| 6479 | Minebea Co Ltd | 179,226.30 |
| 6773 | Pioneer Corp | 110,219.70 |
| 6707 | Sanken Electric Co Ltd | 56,596.13 |
| 6588 | Toshiba Tec Corp | 97,969.54 |
| 6674 | GS Yuasa Corp | 216,713.20 |
| 6925 | Ushio Inc. | 218,937.80 |
| 6502 | Toshiba Corp | 20,876.91 |
| 6504 | Fuji Electric Holdings Co Ltd | 188,860.70 |
| 6501 | Hitachi, Ltd | 1,852,706.00 |
| 6841 | Yokogawa Electric Corp | 164,129.59 |
| 7752 | Ricoh Co Ltd | 703,197.00 |
| 6756 | Hitachi Kokusai Electric Inc. | 67,972.93 |
| 6997 | Nippon Chemi-Con Corp | 48,859.78 |
| 6807 | Japan Aviation Electronics Industry, Ltd | 51,689.46 |
| 6503 | Mitsubishi Electric Corp | 2,061,314.00 |
| 6753 | Sharp Corp | 846,353.31 |
| 6632 | JVC Kenwood Holdings, Inc. | 50,179.07 |
| 6723 | Renesas Electronics Corp | 263,622.69 |
| 6976 | Taiyo Yuden Co Ltd | 123,252.50 |
| 7757 | Nidec Sankyo Corp | 109,313.60 |
| 6448 | Brother Industries, Ltd | 329,712.59 |

| Stock Code | Company Name | Market Capitalization (million JPY) |
|------------|-----------------------------------|-------------------------------------|
| 6702 | Fujitsu Ltd | 977,048.62 |
| 7735 | Dainippon Screen Mfg. Co Ltd | 210,290.80 |
| 6767 | Mitsumi Electric Co Ltd | 92,485.52 |
| 6770 | Alps Electric Co Ltd | 136,351.50 |
| 6752 | Panasonic Corp | 2,440,788.00 |
| 6952 | Casio Computer Co Ltd | 175,504.20 |
| 6967 | Shinko Electric Industries Co Ltd | 110,705.80 |
| 6991 | Panasonic Electric Works Co Ltd | 686,482.38 |
| 7751 | Canon Inc. | 4,721,523.00 |
| 6724 | Seiko Epson Corp | 251,570.09 |
| 6506 | Yaskawa Electric Corp | 246,780.59 |
| 6995 | Tokai Rika Co Ltd | 122,221.70 |
| 6923 | Stanley Electric Co Ltd | 237,736.70 |
| 6728 | Ulvac, Inc. | 85,237.70 |
| 6845 | Yamatake Corp | 148,654.80 |
| 6869 | Sysmex Corp | 284,563.31 |
| 6592 | Mabuchi Motor Co Ltd | 154,718.41 |
| 6902 | Denso Corp | 2,245,535.00 |
| 4062 | Ibiden Co Ltd | 379,716.00 |
| 6857 | Advantest Corp | 285,380.50 |
| 6758 | Sony Corp | 2,612,034.00 |
| 6965 | Hamamatsu Photonics K.K. | 268,885.59 |
| 6981 | Murata Manufacturing Co Ltd | 1,252,466.00 |
| 8035 | Tokyo Electron Ltd | 827,198.00 |
| 6586 | Makita Corp | 519,432.50 |
| 6963 | Rohm Co Ltd | 582,265.00 |
| 6762 | TDK Corp | 611,667.88 |
| 6806 | Hirose Electric Co Ltd | 351,382.09 |
| 6954 | Fanuc Ltd | 2,890,866.00 |
| 6971 | Kyocera Corp | 1,520,909.00 |
| 6727 | Wacom Co Ltd | 41,422.33 |
| 6861 | Keyence Corp | 1,130,363.00 |

A.9 Other Financial Services

| Stock Code | Company Name | Market Capitalization (million JPY) |
|------------|--|-------------------------------------|
| 8572 | Acom Co., Ltd. | 161,384.20 |
| 8515 | Aiful Corp. | 22,436.44 |
| 8258 | Cedyna Financial Corp. | 129,151.20 |
| 8511 | Japan Securities Finance Co., Ltd. | 50,785.40 |
| 8595 | Jafco Co., Ltd. | 100,017.60 |
| 8586 | Hitachi Capital Corp. | 129,570.00 |
| 8253 | Credit Saison Co., Ltd. | 241,634.50 |
| 8574 | Promise Co., Ltd. | 71,883.93 |
| 8570 | Aeon Credit Service Co., Ltd. | 174,390.30 |
| 8593 | Mitsubishi UFJ Lease & Finance Co., Ltd. | 285,771.09 |
| 8473 | SBI Holdings, Inc. | 198,238.50 |
| 8591 | Orix Corp. | 877,512.00 |

A.10 Fisheries

| Stock Code | Company Name | Market Capitalization (million JPY) |
|------------|-----------------------------|-------------------------------------|
| 1379 | Hokuto Corp | 62,247.85 |
| 1332 | Nippon Suisan Kaisha Ltd | 70,733.47 |
| 1334 | Maruha Nichiro Holdings Inc | 68,610.07 |

A.11 Foods

| Stock Code | Company Name | Market Capitalization (million JPY) |
|------------|-------------------------------|-------------------------------------|
| 2212 | Yamazaki Baking Co Ltd | 206,845.59 |
| 2809 | Kewpie Corp | 151,422.41 |
| 2002 | Nisshin Seifun Group Inc | 236,694.91 |
| 2871 | Nichirei Corp | 110,352.10 |
| 2503 | Kirin Holdings Co Ltd | 1,038,340.00 |
| 2501 | Sapporo Holdings Ltd | 122,525.10 |
| 2875 | Toyo Suisan Kaisha Ltd | 198,920.59 |
| 2810 | House Foods Corp | 142,318.30 |
| 2502 | Asahi Breweries Ltd | 694,429.31 |
| 2264 | Morinaga Milk Industry Co Ltd | 75,939.19 |
| 2531 | Takara Holdings Inc | 90,563.09 |
| 2602 | The Nisshin Oillio Group Ltd | 69,162.38 |
| 2801 | Kikkoman Corp | 164,309.30 |
| 2897 | Nissin Foods Holdings Co Ltd | 346,400.41 |
| 2593 | Ito En Ltd | 129,795.20 |
| 2802 | Ajinomoto Co Inc | 606,228.31 |
| 2579 | Coca-Cola West Co Ltd | 166,021.80 |
| 2282 | Nippon Meat Packers Inc | 227,074.70 |
| 2267 | Yakult Honsha Co Ltd | 365,013.69 |
| 2270 | Megmilk Snow Brand Co Ltd | 91,340.65 |
| 2269 | Meiji Holdings Co Ltd | 259,943.50 |
| 2914 | Japan Tobacco Inc | 3,140,000.00 |

A.12 Gas

| Stock Code | Company Name | Market Capitalization (million JPY) |
|------------|---------------------|-------------------------------------|
| 9532 | Osaka Gas Co., Ltd. | 699,316.31 |
| 9531 | Tokyo Gas Co., Ltd. | 1,017,309.00 |
| 9533 | Toho Gas Co., Ltd. | 235,594.09 |

A.13 Glass & Ceramics

| Stock Code | Company Name | Market Capitalization (million JPY) |
|------------|------------------------------|-------------------------------------|
| 5232 | Sumitomo Osaka Cement Co Ltd | 110,277.50 |
| 5233 | Taiheiyo Cement Corp | 149,197.20 |
| 5202 | Nippon Sheet Glass Co Ltd | 205,106.09 |
| 3110 | Nitto Boseki Co Ltd | 47,801.77 |
| 5302 | Nippon Carbon Co Ltd | 24,966.58 |
| 5214 | Nippon Electric Glass Co Ltd | 568,277.81 |
| 5301 | Tokai Carbon Co Ltd | 88,852.52 |
| 5332 | TOTO Ltd | 254,960.50 |
| 5201 | Asahi Glass Co Ltd | 1,232,987.00 |
| 5334 | NGK Spark Plug Co Ltd | 248,826.59 |
| 5310 | Toyo Tanso Co Ltd | 82,795.24 |
| 5333 | NGK Insulators Ltd | 472,584.31 |

A.14 Insurance

| Stock Code | Company Name | Market Capitalization (million JPY) |
|------------|--|-------------------------------------|
| 8763 | The Fuji Fire and Marine Insurance Co., Ltd. | 102,234.90 |
| 8630 | NKSJ Holdings, Inc. | 902,145.19 |
| 8795 | T&D Holdings, Inc. | 669,554.12 |
| 8766 | Tokio Marine Holdings, Inc. | 1,831,098.00 |
| 8725 | MS&AD Insurance Group Holdings, Inc. | 1,189,955.00 |
| 8729 | Sony Financial Holdings Inc. | 676,425.00 |

A.15 Other Land Transport

| Stock Code | Company Name | Market Capitalization (million JPY) |
|------------|---------------------------------|-------------------------------------|
| 9062 | Nippon Express Co., Ltd. | 332,499.69 |
| 9075 | Fukuyama Transporting Co., Ltd. | 110,704.20 |
| 9065 | Sankyu Inc. | 128,800.80 |
| 9076 | Seino Holdings Co., Ltd. | 123,984.80 |
| 9064 | Yamato Holdings Co., Ltd. | 588,342.50 |

A.16 Machinery

| Stock Code | Company Name | Market Capitalization (million JPY) |
|------------|---------------------------------------|-------------------------------------|
| 6367 | Daikin Industries Ltd | 730,146.88 |
| 7011 | Mitsubishi Heavy Industries Ltd | 1,228,008.00 |
| 6366 | Chiyoda Corp | 198,107.00 |
| 6310 | Iseki & Co Ltd | 42,522.24 |
| 6361 | Ebara Corp | 197,934.91 |
| 7004 | Hitachi Zosen Corp | 90,752.35 |
| 6330 | Toyo Engineering Corp | 59,958.48 |
| 6472 | NTN Corp | 197,544.00 |
| 6326 | Kubota Corp | 1,044,166.00 |
| 7013 | IHI Corp | 283,142.31 |
| 6474 | Nachi-Fujikoshi Corp | 103,913.70 |
| 6302 | Sumitomo Heavy Industries Ltd | 318,939.69 |
| 6395 | Tadano Ltd | 70,059.70 |
| 6371 | Tsubakimoto Chain Co | 79,433.89 |
| 6103 | Okuma Corp | 111,729.60 |
| 6436 | Amano Corp | 61,349.66 |
| 6104 | Toshiba Machine Co Ltd | 70,592.58 |
| 6581 | Hitachi Koki Co Ltd | 92,919.95 |
| 6471 | NSK Ltd | 373,208.50 |
| 6135 | Makino Milling Machine Co Ltd | 78,803.56 |
| 6349 | Komori Corp | 49,716.82 |
| 5631 | The Japan Steel Works Ltd | 236,622.00 |
| 6383 | Daifuku Co Ltd | 63,997.05 |
| 6473 | JTEKT Corp | 325,761.41 |
| 6113 | Amada Co Ltd | 263,277.41 |
| 6136 | OSG Corp | 111,522.50 |
| 6460 | Sega Sammy Holdings Inc | 394,818.31 |
| 6268 | Nabtesco Corp | 253,534.70 |
| 6417 | Sankyo Co Ltd | 424,061.09 |
| 6201 | Toyota Industries Corp | 792,770.31 |
| 6305 | Hitachi Construction Machinery Co Ltd | 440,985.81 |
| 6301 | Komatsu Ltd | 2,791,490.00 |
| 6370 | Kurita Water Industries Ltd | 310,619.81 |
| 6481 | THK Co Ltd | 271,194.09 |
| 6273 | SMC Corp | 11,599.56 |

A.17 Pharmaceuticals

| Stock Code | Company Name | Market Capitalization (million JPY) |
|------------|----------------------------------|-------------------------------------|
| 4535 | Taisho Pharmaceutical Co Ltd | 521,908.59 |
| 4506 | Dainippon Sumitomo Pharma Co Ltd | 284,100.69 |
| 4540 | Tsumura & Co | 176,150.70 |
| 4151 | Kyowa Hakko Kirin Co Ltd | 431,786.19 |
| 4521 | Kaken Pharmaceutical Co Ltd | 99,841.88 |
| 4530 | Hisamitsu Pharmaceutical Co Inc | 306,431.00 |
| 4508 | Mitsubishi Tanabe Pharma Corp | 743,317.31 |
| 4568 | Daiichi Sankyo Co Ltd | 1,135,127.00 |
| 4519 | Chugai Pharmaceutical Co Ltd | 783,560.31 |
| 4507 | Shionogi & Co Ltd | 485,972.41 |
| 4503 | Astellas Pharma Inc | 1,443,671.00 |
| 4523 | Eisai Co Ltd | 916,391.88 |
| 4502 | Takeda Pharmaceutical Co Ltd | 3,123,130.00 |

A.18 Other Manufacturing

| Stock Code | Company Name | Market Capitalization (million JPY) |
|------------|-------------------------------|-------------------------------------|
| 7936 | Asics Corp. | 212,960.59 |
| 7984 | Kokuyo Co., Ltd. | 79,691.59 |
| 7832 | Namco Bandai Holdings Inc. | 216,720.00 |
| 7951 | Yamaha Corp. | 172,598.09 |
| 7911 | Toppan Printing Co., Ltd. | 440,629.91 |
| 7912 | Dai Nippon Printing Co., Ltd. | 672,461.38 |
| 7966 | Lintec Corp. | 171,274.20 |
| 7915 | Nissha Printing Co., Ltd. | 75,244.28 |

A.19 Mining

| Stock Code | Company Name | Market Capitalization (million JPY) |
|------------|------------------------------------|-------------------------------------|
| 1518 | Mitsui Matsushima Co Ltd | 23,847.87 |
| 1662 | Japan Petroleum Exploration Co Ltd | 176,602.00 |
| 1605 | Inpex Corp | 1,735,998.00 |

A.20 Nonferrous Metals

| Stock Code | Company Name | Market Capitalization (million JPY) |
|------------|------------------------------------|-------------------------------------|
| 5929 | Sanwa Holdings Corp | 67,833.09 |
| 5715 | Furukawa Co Ltd | 33,569.82 |
| 5981 | Tokyo Rope Mfg Co Ltd | 45,713.76 |
| 5701 | Nippon Light Metal Co Ltd | 82,314.03 |
| 5812 | Hitachi Cable Ltd | 72,559.52 |
| 5711 | Mitsubishi Materials Corp | 365,540.91 |
| 5801 | Furukawa Electric Co Ltd | 221,187.50 |
| 5803 | Fujikura Ltd | 132,797.70 |
| 5938 | JS Group Corp | 646,457.12 |
| 5706 | Mitsui Mining and Smelting Co Ltd | 156,992.70 |
| 5714 | DOWA Holdings Co Ltd | 151,873.59 |
| 5707 | Toho Zinc Co Ltd | 50,945.71 |
| 5802 | Sumitomo Electric Industries Ltd | 876,510.38 |
| 5901 | Toyo Seikan Kaisha Ltd | 280,919.81 |
| 5991 | NHK Spring Co Ltd | 189,639.41 |
| 5727 | Toho Titanium Co Ltd | 122,392.60 |
| 5713 | Sumitomo Metal Mining Co Ltd | 840,452.50 |
| 3436 | SUMCO Corp | 388,431.91 |
| 5726 | Osaka Titanium Technologies Co Ltd | 198,720.00 |
| 5947 | Rinnai Corp | 298,190.50 |

A.21 Oil & Coal Products

| Stock Code | Company Name | Market Capitalization (million JPY) |
|------------|-------------------------|-------------------------------------|
| 5002 | Showa Shell Sekiyu K K | 300,726.59 |
| 5020 | JX Holdings Inc | 1,417,436.00 |
| 5007 | Cosmo Oil Co Ltd | 212,774.00 |
| 5012 | TonenGeneral Sekiyu K K | 561,790.88 |
| 5017 | AOC Holdings Inc | 45,424.71 |
| 5019 | Idemitsu Kosan Co Ltd | 388,400.00 |

A.22 Precision Instruments

| Stock Code | Company Name | Market Capitalization (million JPY) |
|------------|-------------------------------|-------------------------------------|
| 7701 | Shimadzu Corp. | 208,729.50 |
| 7762 | Citizen Holdings Co., Ltd. | 156,608.20 |
| 7731 | Nikon Corp. | 641,005.38 |
| 4902 | Konica Minolta Holdings, Inc. | 349,835.09 |
| 7733 | Olympus Corp. | 600,079.31 |
| 7741 | HOYA Corp. | 812,176.81 |
| 4543 | Terumo Corp. | 881,462.81 |
| 6146 | Disco Corp. | 182,263.70 |

A.23 Real Estate

| Stock Code | Company Name | Market Capitalization (million JPY) |
|------------|---|-------------------------------------|
| 8848 | Leopalace21 Corp. | 19,123.39 |
| 8803 | Heiwa Real Estate Co., Ltd. | 37,656.39 |
| 8840 | Daikyo Inc. | 52,104.52 |
| 8815 | Tokyu Land Corp. | 190,937.59 |
| 8804 | Tokyo Tatemono Co., Ltd. | 131,650.00 |
| 8801 | Mitsui Fudosan Co., Ltd. | 1,215,485.00 |
| 3231 | Nomura Real Estate Holdings, Inc. | 239,506.80 |
| 8830 | Sumitomo Realty & Development Co., Ltd. | 771,735.38 |
| 8802 | Mitsubishi Estate Co., Ltd. | 1,931,262.00 |
| 4666 | Park 24 Co., Ltd. | 119,161.70 |
| 8905 | Aeon Mall Co., Ltd. | 312,819.09 |
| 8933 | NTT Urban Development Corp. | 229,396.59 |

A.24 Retail

| Stock Code | Company Name | Market Capitalization (million JPY) |
|------------|---------------------------------|-------------------------------------|
| 3086 | J.Front Retailing Co., Ltd. | 175,349.91 |
| 8028 | FamilyMart Co., Ltd. | 302,817.69 |
| 8184 | Shimachu Co., Ltd. | 89,057.32 |
| 8242 | H2O Retailing Corp. | 113,500.70 |
| 8263 | The Daiei, Inc. | 36,166.27 |
| 8267 | Aeon Co., Ltd. | 740,412.81 |
| 8252 | Marui Group Co., Ltd. | 161,242.20 |
| 8233 | Takashimaya Co., Ltd. | 169,714.59 |
| 3050 | DCM Holdings Co., Ltd. | 68,511.63 |
| 2651 | Lawson, Inc. | 404,710.50 |
| 3099 | Isetan Mitsukoshi Holdings Ltd. | 282,555.69 |
| 8270 | Uny Co., Ltd. | 138,797.50 |
| 7532 | Don Quijote Co., Ltd. | 206,753.91 |
| 8273 | Izumi Co., Ltd. | 126,794.40 |
| 2730 | Edion Corp. | 74,705.60 |
| 3382 | Seven & i Holdings Co., Ltd. | 1,813,660.00 |
| 3337 | Circle K Sunkus Co., Ltd. | 106,694.80 |
| 2670 | ABC-Mart, Inc. | 219,332.70 |
| 7453 | Ryohin Keikaku Co., Ltd. | 89,007.26 |
| 9843 | Nitori Holdings Co., Ltd. | 402,841.09 |
| 8282 | K'S Holdings Corp. | 141,643.09 |
| 8227 | Shimamura Co., Ltd. | 248,426.50 |
| 9831 | Yamada Denki Co., Ltd. | 504,507.69 |
| 9983 | Fast Retailing Co., Ltd. | 1,083,012.00 |
| 2681 | Geo Corp. | 52,374.68 |

A.25 Railway/Bus

| Stock Code | Company Name | Market Capitalization (million JPY) |
|------------|-----------------------------------|-------------------------------------|
| 9021 | West Japan Railway Co. | 651,000.00 |
| 9001 | Tobu Railway Co., Ltd. | 350,626.31 |
| 9005 | Tokyu Corp. | 437,179.91 |
| 9048 | Nagoya Railroad Co., Ltd. | 199,238.20 |
| 9041 | Kintetsu Corp. | 470,558.19 |
| 9042 | Hankyu Hanshin Holdings, Inc. | 495,848.69 |
| 9008 | Keio Corp. | 316,877.81 |
| 9009 | Keisei Electric Railway Co., Ltd. | 160,342.41 |
| 9006 | Keikyu Corp. | 326,500.50 |
| 9007 | Odakyu Electric Railway Co., Ltd. | 518,107.81 |
| 9020 | East Japan Railway Co. | 1,836,000.00 |
| 9022 | Central Japan Railway Co. | 1,395,350.00 |

A.26 Rubber Products

| Stock Code | Company Name | Market Capitalization (million JPY) |
|------------|--------------------------------|-------------------------------------|
| 5105 | Toyo Tire & Rubber Co Ltd | 51,380.34 |
| 5110 | Sumitomo Rubber Industries Ltd | 222,797.50 |
| 5101 | The Yokohama Rubber Co Ltd | 137,039.30 |
| 5108 | Bridgestone Corp | 1,449,762.00 |

A.27 Marine Transport

| Stock Code | Company Name | Market Capitalization (million JPY) |
|------------|------------------------------|-------------------------------------|
| 9132 | Daiichi Chuo Kisen Kaisha | 41,904.32 |
| 9110 | NS United Kaiun Kaisha, Ltd. | 40,614.54 |
| 9101 | Nippon Yusen K.K | 549,278.00 |
| 9107 | Kawasaki Kisen Kaisha, Ltd. | 234,207.00 |
| 9104 | Mitsui O.S.K. Lines, Ltd. | 570,573.31 |

A.28 Securities

| Stock Code | Company Name | Market Capitalization (million JPY) |
|------------|---------------------------------------|-------------------------------------|
| 8698 | Monex Group, Inc. | 61,186.85 |
| 8607 | Mizuho Investors Securities Co., Ltd. | 96,123.91 |
| 8606 | Mizuho Securities Co., Ltd. | 367,631.69 |
| 8609 | Okasan Securities Group Inc. | 64,546.64 |
| 8616 | Tokai Tokyo Financial Holdings, Inc. | 79,393.79 |
| 8601 | Daiwa Securities Group Inc. | 642,022.00 |
| 8703 | kabu.com Securities Co., Ltd. | 53,134.43 |
| 8604 | Nomura Holdings, Inc. | 1,602,946.00 |
| 8628 | Matsui Securities Co., Ltd. | 121,976.90 |

A.29 Shipbuilding

| Stock Code | Company Name | Market Capitalization (million JPY) |
|------------|---|-------------------------------------|
| 7003 | Mitsui Engineering & Shipbuilding Co., Ltd. | 166,197.41 |
| 7007 | Sasebo Heavy Industries Co., Ltd. | 28,018.21 |
| 7012 | Kawasaki Heavy Industries, Ltd. | 586,362.19 |

A.30 Steel Products

| Stock Code | Company Name | Market Capitalization (million JPY) |
|------------|----------------------------------|-------------------------------------|
| 5410 | Godo Steel Ltd | 32,918.80 |
| 5405 | Sumitomo Metal Industries Ltd | 860,269.38 |
| 5479 | Nippon Metal Industry Co Ltd | 17,075.70 |
| 5480 | Nippon Yakin Kogyo Co Ltd | 21,571.36 |
| 5407 | Nisshin Steel Co Ltd | 166,081.50 |
| 5406 | Kobe Steel Ltd | 657,277.88 |
| 5401 | Nippon Steel Corp | 1,769,815.00 |
| 5481 | Sanyo Special Steel Co Ltd | 69,857.84 |
| 5423 | Tokyo Steel Manufacturing Co Ltd | 149,792.09 |
| 5541 | Pacific Metals Co Ltd | 119,420.10 |
| 5411 | JFE Holdings Inc | 1,452,532.00 |
| 5471 | Daido Steel Co Ltd | 190,305.59 |
| 5563 | Nippon Denko Co Ltd | 50,247.29 |
| 5486 | Hitachi Metals Ltd | 368,390.69 |
| 5444 | Yamato Kogyo Co Ltd | 185,676.00 |
| 5463 | Maruichi Steel Tube Ltd | 198,340.00 |

A.31 Services

| Stock Code | Company Name | Market Capitalization (million JPY) |
|------------|------------------------------------|-------------------------------------|
| 9681 | Tokyo Dome Corp. | 28,565.51 |
| 4756 | Culture Convenience Club Co., Ltd. | 115,353.70 |
| 8056 | Nihon Unisys, Ltd. | 57,792.68 |
| 3626 | IT Holdings Corp. | 70,231.28 |
| 4680 | Round One Corp. | 35,126.67 |
| 9737 | CSK Corp. | 33,992.73 |
| 9766 | Konami Corp. | 210,801.50 |
| 9697 | Capcom Co., Ltd. | 105,309.60 |
| 9684 | Square Enix Holdings Co., Ltd. | 163,941.59 |
| 9602 | Toho Co., Ltd. | 221,119.00 |
| 4716 | Oracle Corp. Japan | 433,402.41 |
| 4661 | Oriental Land Co., Ltd. | 560,992.12 |
| 4307 | Nomura Research Institute, Ltd. | 391,275.00 |
| 4739 | Itochu Techno-Solutions Corp. | 165,507.00 |
| 2327 | NS Solutions Corp. | 80,346.66 |
| 4544 | Miraca Holdings Inc. | 181,522.20 |
| 4324 | Dentsu Inc. | 571,668.12 |
| 9735 | Secom Co., Ltd. | 891,162.88 |
| 4704 | Trend Micro Inc. | 303,313.50 |
| 7974 | Nintendo Co., Ltd. | 3,153,552.00 |
| 2432 | DeNA Co., Ltd. | 455,403.91 |
| 4689 | Yahoo Japan Corp. | 1,771,467.00 |
| 4321 | Kenedix, Inc. | 39,454.22 |
| 3789 | So-net Entertainment Corp. | 72,700.56 |
| 3715 | Dwango Co., Ltd. | 38,531.00 |
| 2371 | Kakaku.com, Inc. | 132,334.41 |

A.32 Other Transport Equipment

| Stock Code | Company Name | Market Capitalization (million JPY) |
|------------|----------------------------|-------------------------------------|
| 7231 | Topy Industries, Ltd. | 49,840.45 |
| 7102 | Nippon Sharyo, Ltd. | 54,004.05 |
| 7224 | ShinMaywa Industries, Ltd. | 41,186.28 |

A.33 Textiles & Apparel

| Stock Code | Company Name | Market Capitalization (million JPY) |
|------------|-------------------------|-------------------------------------|
| 3103 | Unitika Ltd | 29,510.08 |
| 3107 | Daiwabo Holdings Co Ltd | 31,911.16 |
| 3101 | Toyobo Co Ltd | 105,968.10 |
| 3002 | Gunze Ltd | 62,980.55 |
| 3402 | Toray Industries Inc | 952,785.12 |
| 3591 | Wacoal Holdings Corp | 144,095.00 |
| 3401 | Teijin Ltd | 349,589.31 |
| 3105 | Nisshinbo Holdings Inc | 138,211.59 |

A.34 Pulp & Paper

| Stock Code | Company Name | Market Capitalization (million JPY) |
|------------|-----------------------------|-------------------------------------|
| 3864 | Mitsubishi Paper Mills Ltd | 29,462.25 |
| 3941 | Rengo Co Ltd | 141,220.20 |
| 3861 | Oji Paper Co Ltd | 402,336.31 |
| 3865 | Hokuetsu Kishu Paper Co Ltd | 90,401.97 |
| 3893 | Nippon Paper Group Inc | 206,584.91 |

A.35 Trading Companies

| Stock Code | Company Name | Market Capitalization (million JPY) |
|------------|-------------------------------------|-------------------------------------|
| 8113 | Unicharm Corp. | 629,112.12 |
| 8020 | Kanematsu Corp. | 34,222.58 |
| 2768 | Sojitz Corp. | 205,245.91 |
| 3315 | Nippon Coke & Engineering Co., Ltd. | 52,608.80 |
| 3332 | JFE Shoji Holdings, Inc. | 83,819.30 |
| 8078 | Hanwa Co., Ltd. | 77,680.39 |
| 8016 | Onward Holdings Co., Ltd. | 103,580.10 |
| 7459 | Medipal Holdings Corp. | 172,634.30 |
| 8060 | Canon Marketing Japan Inc. | 146,094.30 |
| 8002 | Marubeni Corp. | 1,027,123.00 |
| 8053 | Sumitomo Corp. | 1,479,463.00 |
| 8001 | Itochu Corp. | 1,366,175.00 |
| 9987 | Suzuken Co., Ltd. | 196,823.50 |
| 8015 | Toyota Tsusho Corp. | 454,608.59 |
| 9962 | Misumi Group Inc. | 176,076.00 |
| 8036 | Hitachi High-Technologies Corp. | 208,811.91 |
| 8058 | Mitsubishi Corp. | 3,922,156.00 |
| 8031 | Mitsui & Co., Ltd. | 2,721,781.00 |
| 2784 | Alfresa Holdings Corp. | 159,295.91 |

A.36 Warehousing

| Stock Code | Company Name | Market Capitalization (million JPY) |
|------------|----------------------------------|-------------------------------------|
| 9364 | Kamigumi Co., Ltd. | 192,316.30 |
| 9303 | The Sumitomo Warehouse Co., Ltd. | 77,198.88 |
| 9301 | Mitsubishi Logistics Corp. | 157,625.59 |

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