



MEASURING MARKET SENTIMENT IN HONG KONG'S STOCK MARKET

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Abstract

Market sentiment is increasingly seen as a key factor driving the movement of asset prices. This paper develops two indicators to measure investors' attitude towards risk in the Hong Kong stock market: a) a risk appetite index and b) an investment sentiment index. We find that although the risk appetite index based on the work of Gai and Vause (2006) is able to capture episodes of extreme optimism and pessimism between 1996 and 2006, it is volatile and in some cases gives spurious signals. Our results also show that the investment sentiment indicator, a sentiment measure derived by combining the current realised return and the expected short-term return of the stock market, has adequate power to predict the subsequent return of the stock market over a period of 6 to 12 months.

JEL Classification Numbers: G10, G12, G13

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Executive Summary:

- *Market sentiment is increasingly seen as a key factor driving the movement of asset prices. Thus it is important for central bankers to have a measure of investors' attitude towards risk. This study develops two indicators to measure the investors' attitudes towards risk in the Hong Kong stock market: a) a risk appetite index and b) an investor sentiment indicator.*
- *The risk appetite index is constructed by comparing the expectation from equity option prices and historical equity cash prices. This index is able to identify episodes of extreme optimism and pessimism between 1996 and 2006. In particular, it conforms well with asset price swings in the Asian financial crisis and the technology bubble period. However, this index is found to be volatile and thus in some cases gives spurious signals to regulators.*
- *The investment sentiment indicator is based on the current realised return as well as the expected short-term return of the stock market. The sentiment level given by the indicator has adequate power to predict the subsequent return of the stock market, especially over a period of six to twelve months.*
- *Both indicators give regulators a measure of investors' attitude towards risk. They should be part of the central bankers' surveillance framework for their on-going monitoring of the financial market.*

I. INTRODUCTION

Market practitioners often cite market sentiment as a key factor driving the movements in asset prices. For instance, the corrections in the Hong Kong equity market as well as the global equity markets in May 2006 were then mentioned as the repricing of risk by a decline in investors' risk appetite. Therefore, to monitor the swings in asset prices, a measure of investors' attitudes towards risk is important for central bankers. This study develops indicators which measure investors' attitudes towards risk in the Hong Kong equity market.

Despite its popular use in accounting for asset price movement, the concept of "risk appetite" appears to have different meanings in different contexts.² In recent years, a growing number of financial institutions and organisations have been developing measures to quantify risk appetite, ranging from the IMF's risk appetite indexes used for market surveillance (IMF 2003) to indexes developed by private financial institutions for understanding the sentiment of investors in financial markets.

Traditional studies on risk appetite have equated it with the Arrow-Pratt coefficient of risk aversion. Recently, Gai and Vause (2006) and Misina (2006) differentiate between these two concepts by arguing that while risk aversion is part of the intrinsic make-up of the investor and is a parameter that does not change markedly and frequently over time, risk appetite shifts periodically as investors respond to episodes of financial distress and macroeconomic uncertainties.

Most of the indexes on risk appetite, like the one developed in Gai and Vause (2006), have treated the risk appetite as a combination of attitudes and perceptions. Broadly speaking, these indexes can be categorised into two groups: a) an atheoretic index and b) a theory-based index. The atheoretic index combines market information on different types of risks (liquidity, credit and market risks) using statistical methods.³ While these atheoretic indexes capture a broad spectrum of financial market risks (such as bond spreads, implied volatilities and swap rates), they are often criticised because they are difficult to interpret and because of the ad hoc methodology they rely on to aggregate different financial risks.

The theory-based indexes, on the other hand, are based on economic or financial models (e.g., asset pricing models, Arrow-Pratte absolute risk aversion coefficient, etc.). These indexes have clear links with theories developed in economic or

² As discussed in Misina (2006), the phrase "risk appetite" has different interpretations in the literature. Examples of these include a) investor's risk aversion, b) demand for risky assets, and c) the quantity of risky assets demanded.

³ Examples of atheoretic indexes are JP Morgan Liquidity, Credit and Volatility Index, the UBS Investor Sentiment Index, and the Merrill Lynch Financial Stress Index.

financial studies, and they are thus easier to interpret the estimated numbers.⁴

As shown in Illing and Aaron (2005), many of the risk appetite indexes currently in use are able to capture market sentiment in some recent episodes. For example, these indexes are able to identify the 1998 Russian crisis as a period of low risk appetite and signal a high degree of risk appetite during the bull market in the US in 2003. Nonetheless, these indexes are volatile and, as a result, sometimes give multiple signals in a given period and apparently spurious signals during periods when no systematic events can be identified. This is not desirable as this fails to establish any link between the level of risk appetite and swings in asset prices.

The objective of this paper is to fill in this gap in the literature. It develops a sentiment indicator based on the risk appetite index recently proposed by Gai and Vause (2006) and tries to link this indicator with the future performance of the stock market. Using data from option prices, the risk appetite index proposed by Gai and Vause captures investors' expectation on the total expected return of holding the asset. Our indicator is different from this risk appetite index as we do not only focus on the expected total return but also extract the short-term investment sentiment by decomposing the expected total return into two components: the current realised return and the expected change from the current realised return.⁵ The expected change from the current realised return is a better measure of the short-term investment sentiment as this allows us to discover any sudden shift in sentiment from the current level. For example, if the current realised return is positive, its expected total return would still be positive even though the short-term sentiment shifts from positive to negative, as long as the shift is smaller than the current realised return. While the detection of this shift is important for gauging investor sentiment, focusing on the expected total return level only will miss it. In fact, both the current realised return and the expected change from it are important for the investment outlook and they are thus used as the key components in our indicator.

The construction of our investor sentiment indicator (ISI) for Hong Kong stock market is divided into two steps. First, we derive the risk appetite index based on the method proposed by Gai and Vause (2006). This step involves the estimation of forward looking risk neutral density (RND) function from option prices and statistical probability density function from historical cash prices. Second, we model the estimated risk appetite index as a linear system of total expected return. Using Kalman filter method, we derive the unobservable expected change from the current realised return of stock investors. Then we construct the investor sentiment indicator of the stock market from the above linear system based on both the current realised return and the expected change from the current realised return. The sentiment indicator is found to be a good indicator of future market movements.

⁴ Examples of theory-based indexes include Gai and Vause (2006), Tarashev et al. (2003), Kumar and Persaud (2002) and Goldman Sachs (2003).

⁵ The term "current realised return" refers to the return between time $t-1$ and t .

The remainder of the paper is organised as follows. The concept and methodology of the Gai and Vause index (GVI) will be discussed in Section II and the data used in this study will be described in Section III. The results of the estimated GVI for the Hong Kong stock market will be presented in Section IV. The estimated GVI will then be modelled by a state space model to get our ISI in Section V. Section VI examines the predictive power of the ISI and Section VII concludes.

II. RISK APPETITE INDEX (GAI AND VAUSE 2006)

The risk appetite index developed by Gai and Vause (2006) begins from the basic pricing equation in the asset pricing theory. For any asset in the market, its price (p_t) should be equal to the expected discounted values of its possible future payoffs over different states of world, i.e.,

$$p_t = E_t(m_{t+1}^s x_{t+1}^s) \quad (1)$$

where x_{t+1}^s denotes the pay-off of the asset in period $t+1$ at state s , and m_{t+1}^s denotes the stochastic discount factor at state s , which is also the marginal rate of substitution between the current and future consumption.⁶

Dividing both sides of equation (1) by the current price, we have:

$$1 = E_t(m_{t+1}^s R_{t+1}^s) \quad (2)$$

where R_{t+1}^s is the gross return at $t+1$ and state s . Since both m_{t+1}^s and R_{t+1}^s are random variables, equation (2) can be re-written as:

$$1 = E_t(m_{t+1}^s)E_t(R_{t+1}^s) + \text{cov}_t(m_{t+1}^s, R_{t+1}^s) \quad (3)$$

If an asset is completely risk-free, its returns do not vary over different states. In such a case, $\text{cov}_t(m_{t+1}^s, R_{t+1}^s) = 0$ and the gross risk-free return can be derived from equation (3) as:

$$R_{t+1}^f = 1 / E_t(m_{t+1}^s) \quad (4)$$

Substituting the risk free rate ($R_{t+1}^f = 1 / E_t(m_{t+1}^s)$) back into equation (3),

⁶ The payoffs include income (such as dividend payments) received over the horizon plus the future price of the asset.

we have:

$$E_t(R_{t+1}^s) - R_{t+1}^f = \underbrace{\frac{-\text{cov}_t(m_{t+1}^s, R_{t+1}^s)}{\text{var}_t(m_{t+1}^s)}}_{\beta_i} \underbrace{\text{var}_t(m_{t+1}^s) R_{t+1}^f}_{\lambda_t} \quad (5)$$

The left hand side of equation (5) is usually regarded as the expected risk premium of holding this asset. As shown in Gai and Vause (2006), the risk premium can be decomposed into the quantity of risk of asset i (β_i) and the unit price of risk (λ_t). Note that β_i is inherent in each asset i while λ_t is common across different assets. In Gai and Vause (2006), they define their risk appetite index as the inverse of λ_t to measure the investors' willingness to bear risk.⁷ So, the risk premium increases whenever the risk appetite decreases and vice versa.

The pricing formula in equation (2) involves the probabilities about various states of the world. In fact, assets can be priced by evaluating the expectation of discounted payoffs using investors' best guesses of the probabilities of different states of the world occurring. For N possible future states of the world, the expected discounted return of an asset can be written as the sum of discounted returns in each state, weighted by the investors' subjective probability of the state occurring, as follows:

$$1 = E_t(m_{t+1}^s R_{t+1}^s) = \sum_{s=1}^N m_{t+1}^s(s) R_{t+1}^s(s) f_{t+1}(s) \quad (6)$$

where $f_{t+1}(s)$ is the investor subjective probability. The subjective probability can be estimated by a statistical model using the historical data as it summarises the past behaviour of investors.

Alternatively, the asset can be priced by discounting payoffs by the risk-free rate and evaluating expectations using a set of risk-neutral probabilities. If the investor is risk neutral, then they are indifferent among the particular states of the world. In such a case, the covariance term in equation (3) is equal to zero. Then the asset pricing equation can be written as:

$$1 = E_t(m_{t+1}^s) E_t^*(R_{t+1}^s) = \sum_{s=1}^N \frac{1}{R_{t+1}^f} R_{t+1}^s(s) f_{t+1}^*(s) \quad (7)$$

where $f_{t+1}^*(s)$ is the risk-neutral probability. Note that in both equations (6) and (7), the

⁷ As shown in equation (5), the risk appetite reflects variation in the stochastic discount factor, which gives the marginal rate at which the investor is willing to substitute uncertain future consumption for the present consumption.

contingent return ($R_{t+1}^s(s)$) is scaled by a combination of discount factor and probability. As Cochrane (2005) pointed out, the scaling factors of the contingent return in each state in both equations (6) and (7) should be equal.⁸ In such a case, the risk-neutral probability can be transformed from the actual probability by the following equation:

$$\frac{1}{R_{t+1}^f} f_{t+1}^*(s) = m_{t+1}(s) f_{t+1}(s) \quad (8)$$

Rewriting equation (8) as the ratio of the two probabilities, we have:

$$\frac{f_{t+1}^*(s)}{f_{t+1}(s)} = m_{t+1}(s) R_{t+1}^f \quad (9)$$

Combining equations (5) and (9), the unit price of risk can then be derived as:

$$\lambda_t = \frac{1}{R_{t+1}^f} \text{var}\left(\frac{f_{t+1}^*(s)}{f_{t+1}(s)}\right) \quad (10)$$

As shown in equation (10), the measure of risk appetite (the unit price of risk) can be determined once the two probability density functions over future returns (f_{t+1} and f_{t+1}^*) are estimated. In this study, the risk neutral probability density function (RND) is estimated by option prices using the two lognormal mixture models, while the estimation of the subjective probability distribution is from a statistical method based on an asymmetric-GARCH model using historical return data. Details of these methods are given in the appendix.

III. Data

For the RND estimation, we use monthly Hang Seng Index (HSI) options data from January 1996 to December 2006. Spot month HSI options with strike price ranging from 600 points below the current level to 600 points above the current level are used to construct the density function.⁹ The risk free interest rate is approximated by the 1-month HIBOR.

⁸ See Chapter 3 of Cochrane (2005) for details.

⁹ As the strike price of HSI options is of an interval of 200 index points, there are altogether seven contracts to be considered for each RND estimation..

To estimate the GARCH model for an investor's subjective probability distribution, we use the monthly closing price of HSI from February 1986 to December 2006. In order to have monthly estimates of the variance and the mean of return, the estimation is based on rolling a 10-year subsample starting from the period of February 1986 to January 1996.¹⁰

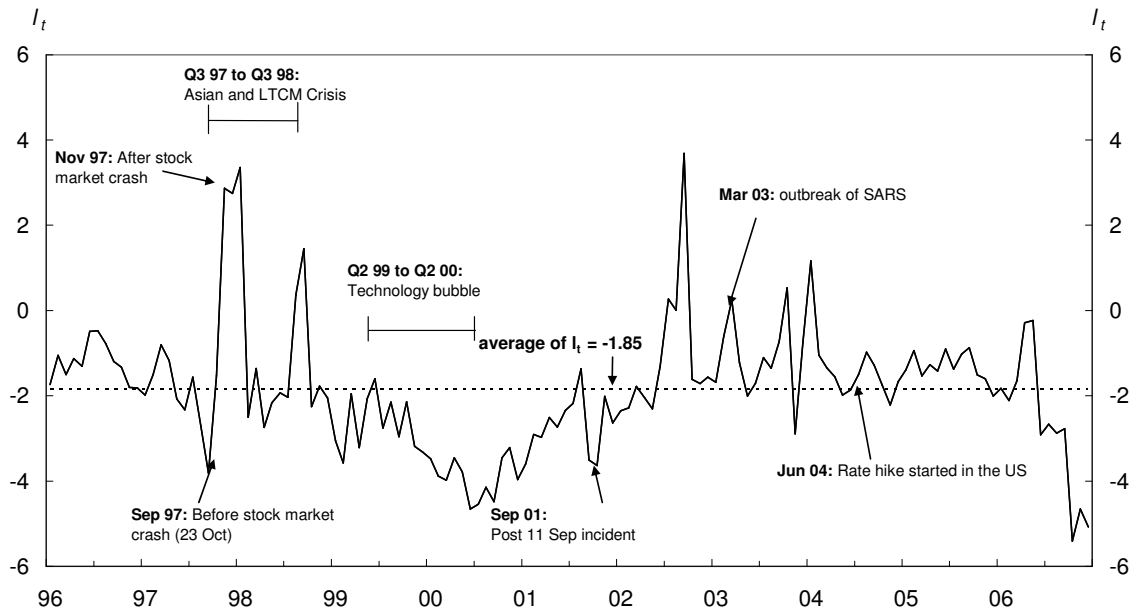
IV. Empirical Results of the Risk Appetite Measure

Chart 1 depicts the movement of the logarithm of the estimated price of risk of investors in the Hong Kong stock market from 1996 to December 2006. Low values of this variable can be interpreted as indicator of high risk appetite for investors. There are several instances that the indicator witnesses episodes of extreme investor optimism and pessimism during the study period. For example, the logarithm of λ_t was at a very low level at the end of September 1997, indicating that investors were very optimistic about the market just before the stock crash due to the speculative attack in October 1997. The indicator then rose sharply to an extremely pessimistic level in response to the crash, reflecting that the investor's risk appetite was at a very low level after the Asian financial crisis has started. At the peak of the dot.com era in 2000, the indicator was again at a very low level, signalling that the investor's appetite for risk was high prior to the burst of internet bubble. The September 11 incident in 2001 appeared to have negligible effects on the risk appetite of investors in the Hong Kong stock market. When SARS broke out in Q1 2003, the measure jumped up swiftly but very soon it returned to the pre-SARS level. The bull run in the stock market starting from the second half of 2006 also coincides with the optimism of investors, as reflected by the lowest level of the risk appetite indicator in two years.

Despite the apparent conformity of the indicator with the asset price swings in some episodes of extreme optimism and pessimism, the indicator, like other similar indexes in the literature, is volatile and thus sometimes gives multiple signals in a given period (for example in the Asian financial crisis in 1997-98) and spurious signals during periods when no systemic events can be identified.¹¹ This complicates the monitoring work as it fails to give clear warning signals if the link between these indicators and the future movement of the market is spurious. Given the growing interest in using risk sentiment to explain market swings, it would also be desirable for the authority to develop an alternative indicator as an additional tool for measuring the market appetite for risk.

¹⁰ In view of the possibly structural changes in the data, we use rolling samples in the estimation of the GARCH model.

¹¹ Spikes in mid-2002 and end-2003 are not clearly identified with any systematic events in Hong Kong.

Chart 1: Logarithm of the estimated price of risk of Investors in Hong Kong Stock Market

V. An Alternative Measure of Investor Risk Attitude

The high volatility in the risk appetite index is an undesirable feature if this measure is used for monitoring work. For example, the swing in the index in the 1997-98 Asian financial crisis is hard for policy makers to interpret and thus may lead to misjudgement if their policy response is based on this measure. Is it really the case that the investor's sentiment or the price of risk can shift so rapidly, even in a prolonged financial crisis such as the Asian crisis in 1990s? The answer to this question is not easy as investor sentiment is not directly observable. Moreover, the short-term expectation of changes in stock prices may or may not depend on the current market return. For example, in some cases, momentum trading may dominate the market sentiment and hence the short-term expected future changes in the stock price may follow the current market return. In other cases, when overshooting in a sharp correction is perceived, a rapid swing in the index is possible as the behaviour of bargain hunters will improve the short-term market sentiment.

The identification of the short-term expected changes in asset values is important for understanding the shift in investor sentiment and also in our alternative risk measure. To start with, we write the expected total return of an asset as a sum of two components: the current realised return of an asset at time t (r_t) and the expected but unobservable change in return from the current level (η_t). The distinction of r_t and η_t

is important in our specification as this allows us to separate the short-term sentiment from the change in the asset price. For example, when overshooting occurs in the sharp downturn market, η_t can be greater than zero even though the total expected return $(r_t + \eta_t)$ is negative.

To estimate the unobservable η_t , the Kalman filter method is applied with the risk appetite and the expected total return linked in a signal equation and the unobservable η_t as an autoregressive system in a state equation. Specifically, both the signal and state equations are expressed in the linear system as follows:

$$l_t = a + b(r_t + \eta_t) + cl_{t-1} + e_t \quad (11)$$

$$\eta_t = \rho\eta_{t-1} + \omega_t \quad (12)$$

where l_t is the logarithm of the price of risk at time t , r_t is the current realised return at time t , $(r_t + \eta_t)$ is the expected total return of the asset at time t , in which η_t is unobservable from an econometrician, a , b , c , and ρ are the coefficients to be estimated, e_t and ω_t are stationary random errors.

In this system, the signal equation implies that the risk appetite (represented by the logarithm of the price of risk) is related to a constant factor a , the expected total return and its autoregressive term. Also, the expected change in return from the current level follows the AR(1) process.¹² Note that if the expected total return of the asset increases, the investors will have a higher risk appetite or the logarithm of the price of risk (l_t) will be lower. In our specification, this implies that b should be negative.

Table 1 shows the estimates of these two equations. All the parameter estimates are consistent with the constraints and expectations implied by the specification. For example, the estimated coefficient b is negative, which agrees with what we expect from the relationship between the expected total return and the price of risk. The estimates of the autoregressive coefficients c and ρ are smaller than one, which satisfy the stationary condition.

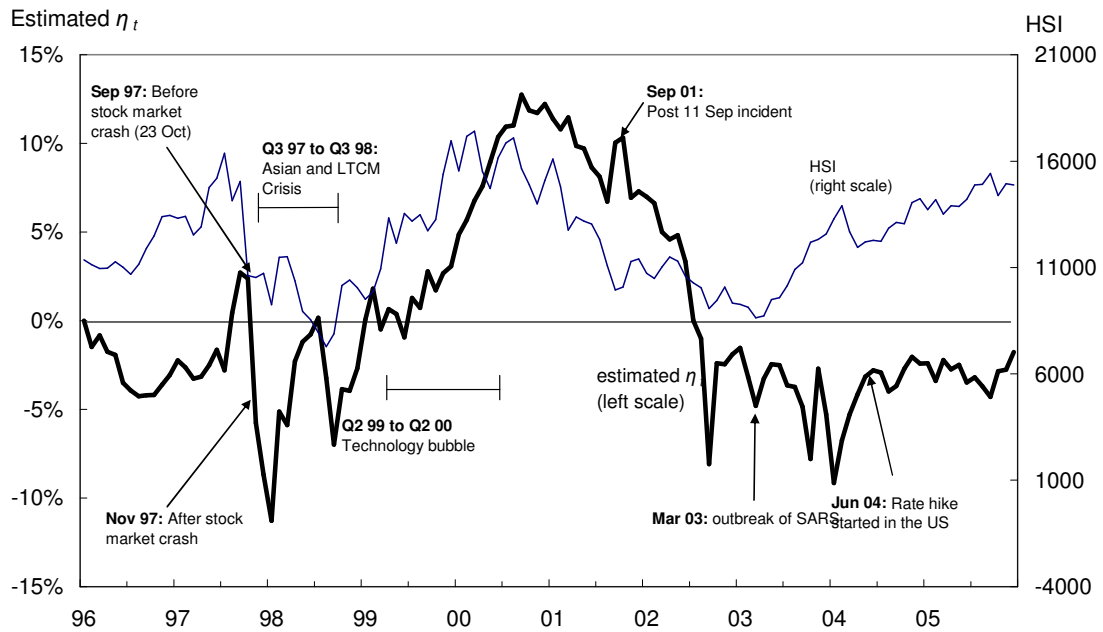
¹² We have tried different autoregressive processes, such as AR(1) with constant, AR(2) and AR(2) with constant. We found that the AR(1) process is the best in terms of Akaike information criterion and Schwartz Bayesian information criterion.

Table 1: State space model of l_t

	Coefficient Estimate	Standard error
a	-0.80*	0.25
b	-3.83*	1.20
c	0.54*	0.11
ρ	0.93*	0.10

Note: * denotes that the coefficient estimate is significant at the 5% level

The filtered expected change in return from the current realised return, η_t , is plotted in Chart 2 together with HSI. Prior to the Asian crisis in 1997, the short-term expected change in return from the current level turned from negative to positive. After October 1997, the short-term sentiment was in the doldrums as the expected return was always below the current realised return during the Asian crisis. The expected change in return moved into positive territory when the technology bubble started to build up in 1999. Then the estimated short-term return, η_t , stayed positive in 2000-01, reflecting that the market expected the short-term return would be above the current level despite the choppy movement in the stock index in this period. From mid-2002, the filtered expected change in return remained negative..

Chart 2: Estimated expected change in return from the current realised return (η_t)

It should be noted that as η_t represents the change in return from the current level, it is only part of the factors driving the investor sentiment. The sentiment is more driven by the expected total short-term return from investing in stocks. To reflect this, the current realised return (r_t) must be considered. In fact, we combine both η_t and r_t in constructing our investor's risk sentiment indicator. Specifically, the investor sentiment indicator (ISI) can be divided into four states as follows: (1) if the current realised return (r_t) is positive and the expected change (η_t) is also positive, then the sentiment is *high*, (2) if the current realised return (r_t) is negative and the expected change (η_t) is positive, then the sentiment is *recovering*, (3) if the current realised return (r_t) is positive and the expected change (η_t) is negative, then the sentiment is *deteriorating*, and (4) if both current realised return (r_t) and expected change (η_t) are negative, then the sentiment is *depressed*.

The idea behind this classification is outlined as follows: if the current market condition is good ($r_t > 0$) and investors believe that the good time will continue ($\eta_t > 0$), then the market sentiment is very optimistic as investors are more willing to take more risk. On the other hand, if the current condition is poor ($r_t < 0$) and the investors expect the poor condition to go on in the near future ($\eta_t < 0$), then the market sentiment is in a depressed mood and the investors are conservative in making investment decision. The cases in between these two conditions are the turning points, at which the market sentiment may switch to become pessimistic from a good mood ($\eta_t < 0$) or optimistic from a bad state ($\eta_t > 0$). Table 2 summarises these four sentiment states and the corresponding number of months in each state in our sample.

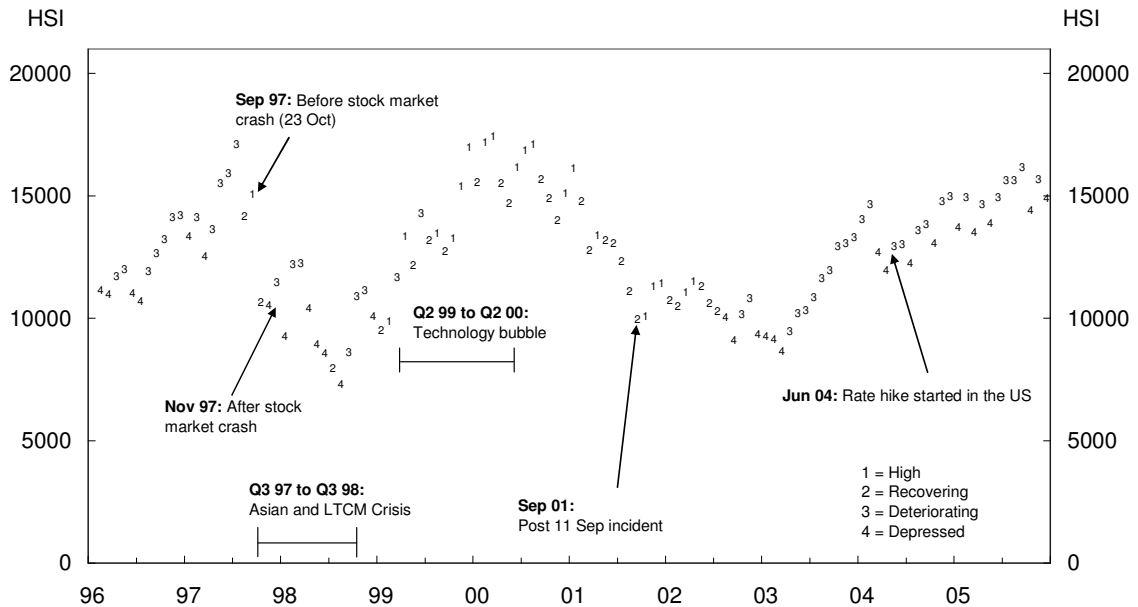
Table 2: Investor Sentiment Indicator of Investors in Hong Kong Stock Market

Sentiment	Conditions	Number of observations in the sample (months)
<i>High</i>	$r_t > 0$ and $\eta_t > 0$	25
<i>Recovering</i>	$r_t < 0$ and $\eta_t > 0$	25
<i>Deteriorating</i>	$r_t > 0$ and $\eta_t < 0$	51
<i>Depressed</i>	$r_t < 0$ and $\eta_t < 0$	30

Note: *Sample period: January 1996 to December 2006, with first observation excluded due to the lag term in the model

Chart 3 plots the HSI (denoted by the sentiment level of ISI) from 1996 to 2005. Prior to the stock market crash in October 1997, the market sentiment was high. Then the market sentiment was mostly at depressed and deteriorating modes during the Asian financial crisis. When the technology bubble built up in the stock market in 1999-2000, the investor sentiment was mostly high. The market became more conservative after the tech bubble burst. Although the Hang Seng Index stayed on the upward trend from about 12,000 to 16,000 between 2004 and end-2005, the market sentiment switched between depressed and deteriorating modes during the period, reflecting that the investors expected the market to fall in the near-term irrespective of the current performance of the stocks.

Chart 3: Hang Seng Index Movement with Market Sentiment Label



VI. Predictive power of the Investor Sentiment Indicator (ISI)

For the index to be a good tool for monitoring purposes, it should have some indication on the future market movement. To check this, we investigate the predictive power of the ISI by examining both the subsequent median and mean returns of the stock market signalled by the investor sentiment over a period of 1 to 12 months.

Table 3 gives the median return of the HSI for different sentiment levels over different time horizon. From the table, it is shown that when the market sentiment indicator is high or recovering ($\eta_t > 0$), the subsequent return is more likely to be negative in the following six to twelve months. On the other hand, if the market is generally pessimistic and at either a depressed or deteriorating mode ($\eta_t < 0$), then the returns in the following six to twelve months are more likely to be positive. These results suggest that short-term overshooting in stock prices tends to be common in Hong Kong.

Table 3: Median of subsequent return of the HSI of different sentiment levels

		Median return over n months (%)			
		$n = 1$	$n = 3$	$n = 6$	$n = 12$
Sentiment level	<i>High</i>	1.39%	-5.67%	-5.83% ^a	-17.67% ^a
	<i>Recovering</i>	-1.01%	1.69%	-5.64% ^a	-13.90% ^a
	<i>Deteriorating</i>	1.04%	3.53%	5.52% ^b	13.59% ^b
	<i>Depressed</i>	1.98%	4.43% ^b	9.04% ^b	19.07% ^b

Note:

- a: implies that the Wilcoxon signed rank test statistic significantly rejects the null at the 5% level, with H_0 : median = 0, H_1 : median < 0
- b: implies that the Wilcoxon signed rank test statistic significantly rejects the null at the 5% level, with H_0 : median = 0, H_1 : median > 0

The average subsequent return in the stock for different sentiment levels over different time horizon is given in Table 4. From the table, it is found that when the market sentiment indicator is high, the average subsequent twelve-month return in HSI is significantly negative. On the other hand, if the market is pessimistic and at either a depressed or deteriorating mode, then the average twelve-month return would be significantly positive.

Table 4: Average subsequent return of the HSI of different sentiment levels

		Average return over n months (%)			
		$n = 1$	$n = 3$	$n = 6$	$n = 12$
Sentiment level	<i>High</i>	-0.73% (2.09%)	-4.66% (3.04%)	-5.26% (3.68%)	-14.79%* (5.88%)
	<i>Recovering</i>	-0.72% (1.40%)	0.32% (3.28%)	-2.98% (3.35%)	-8.59% (5.28%)
	<i>Deteriorating</i>	1.38% (1.00%)	2.31% (1.81%)	3.14% (2.87%)	7.32%* (1.09%)
	<i>Depressed</i>	0.79% (1.21%)	3.49%* (2.06%)	9.70%* (2.21%)	21.13%* (4.07%)

Note:

1. Standard errors are shown in the parentheses.
2. * implies the average return is significantly different from zero at the 5% level.

VII. Concluding remarks

Market sentiment is increasingly important in explaining asset price movements. For monitoring swings in asset price, it is important for central bankers to have a measure of investors' attitude towards risk. This paper develops two indicators to measure the risk appetite of investors in the Hong Kong stock market. Based on the methodology of Gai and Vause (2006), we first estimate the risk appetite index or the price of risk measure of investors in the HSI. The index is found to be able to capture investor sentiment during some episodes of extreme optimism and pessimism during the period 1996-2006. However, this index is found to be volatile and thus in some cases gives spurious signals.

To address the need for an alternative index that has predictive power on the future return of stock market, this paper develops investment sentiment indicator based on two dimensions: a) the current realised return of the stock market and b) the expected short-term return from the current realised return, an unobservable but that we estimate using the Kalman filter method. Our results show that the investment sentiment indicator has a predictive power on the subsequent return of the stock market, especially over a period of 6 to 12 months.

Both the risk appetite index and the investment sentiment indicator give regulators some measures of investors' attitude towards risk as well as possible future

movement in the market. They should have a place in central bankers' surveillance framework for their on-going monitoring of the financial market.¹³

¹³ Similar risk appetite measures will be developed for different asset classes and different economies in the next step. These indexes will be useful for monitoring contagion risks across different asset types and the spillover effect of a financial crisis from one country to the other. Moreover, the correlation of these risk appetite indexes of different countries can be used as a measure of whether these financial markets are integrated or not.

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Appendix

The methods we used to find the option-implied risk neutral density (RND) of HSI and statistical density function are highlighted in this appendix.

A. *Finding the RND by fitting the two-lognormal mixture distribution*

The prices of European call and put options at time t can be written as the discounted sums of expected future payoffs:

$$c(X, \tau) = e^{-r\tau} \int_X^{\infty} f^*(S_T)(S_T - X) dS_T \quad (\text{A1})$$

$$p(X, \tau) = e^{-r\tau} \int_0^X f^*(S_T)(X - S_T) dS_T \quad (\text{A2})$$

where $c(X, \tau)$ and $p(X, \tau)$ are the call and put prices respectively. The option prices are functions of the strike price (X), the time to maturity (τ), the asset price at the expiry (S_T), the risk free interest rate (r) and the density function of the asset price as at expiry ($f^*(S_T)$). Assuming that the density function is a two-lognormal mixture, $f^*(S_T)$ at time t can be expressed as:

$$f(S_T) = \sum_{i=1}^2 \theta_i L(a_i, b_i; S_T) \quad (\text{A3})$$

where:

$$a_i = \ln S_t + (\mu_i - \frac{\sigma_i^2}{2})\tau \quad (\text{A4})$$

$$b_i = \sigma_i \sqrt{\tau} \quad (\text{A5})$$

$L(a_i, b_i; S_T)$ is the i -th lognormal density function with parameters a_i and b_i , θ_i is the weight of the i -th density in the mixture and the mixtures are summed to unity, μ_i and σ_i are the mean and volatility of asset return and volatility (in standard deviation) respectively. At any time t , five parameters ($a_1, b_1, a_2, b_2, \theta_1$) in the two lognormal density functions are estimated by solving the following minimization problem:

$$\underset{a_i, b_1, a_2, b_2, \theta_1}{Min} \left\{ \sum_{n=1}^N [c(X, \tau) - c_{obs}]^2 + \sum_{n=1}^N [p(X, \tau) - p_{obs}]^2 \right\} \quad (A6)$$

where N is the number of possible expiry asset price, c_{obs} and p_{obs} are the observed call and put prices at t respectively. By substituting the estimated parameters into (A3), the probability density at different prices can be calculated accordingly.¹⁴

B. Finding the statistical probability by the threshold GARCH model

The statistical probability is estimated by the threshold GARCH model of HSI return (r_t)¹⁵:

$$r_t = \beta + \varepsilon_t \quad (A7)$$

$$\sigma_t^2 = \phi_1 + \phi_2 \varepsilon_{t-1}^2 + \phi_3 \varepsilon_{t-1}^2 D_{t-1} + \phi_4 \sigma_{t-1}^2 \quad (A8)$$

$$D_t = 1 \text{ if } \varepsilon_t < 0 \text{ and } 0 \text{ otherwise} \quad (A9)$$

where r_t is the return of the HSI at t , σ_t is the volatility of the return which follows the threshold GARCH (1,1) model.

To estimate the risk appetite index at time t , we need to obtain the forecast of statistical probability as at $t+1$. For this purpose, we first estimate the GARCH model by the data up to time t . The expected return and variance of return as at $t+1$ can then be forecasted by (A7) and (A8). Plugging these forecasts into the lognormal density function of asset price gives the statistical probability of the HSI.¹⁶

¹⁴ Note that L is the standard lognormal density function: $L_i = \frac{e^{-\frac{(\ln S_T - a_i)^2}{2b_i^2}}}{S_T b_i \sqrt{2\pi}}$

¹⁵ We have tried different specifications for GARCH model, such as AR(1) and AR(2) for the mean equation, GARCH(1,2) and GARCH(2,2) for the GARCH equation, and they make no or insignificant difference on the resulting density. So we chose the simplest one for the sake of convenience.

¹⁶ As the HSI is assumed to be lognormally distributed, its log-return should be normally distributed. Therefore the normally distributed GARCH-implied return and the corresponding variance can be directly plugged into the lognormal distribution function.