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Birgit Uhlenbrock

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Deutsche Bundesbank, Wilhelm-Epstein-Strasse 14, 60431 Frankfurt am Main,
Postfach 10 06 02, 60006 Frankfurt am Main

Tel +49 69 9566-0
Telex within Germany 41227, telex from abroad 414431

Please address all orders in writing to: Deutsche Bundesbank,
Press and Public Relations Division, at the above address or via fax +49 69 9566-3077

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Financial Markets’ Appetite for Risk – and the Challenge of Assessing Its Evolution by Risk Appetite Indicators

Birgit Uhlenbrock*

Abstract

Assessments of investors’ risk appetite/aversion stance via indicators often yields results which seem unsatisfactory (see e.g. Illing and Aaron (2005)). Understanding how such indicators work therefore seems essential for further improvements. The present paper seeks to contribute to this evolution, focusing on the “Global Risk Appetite Index” (GRAI) class of indicators going back to Kumar and Persaud (2002). Looking at international stock indices during the subprime crisis in 2007, the plausibility of the GRAIs benefits from applying the rank correlation approach of Kumar and Persaud (2002) combined with a modified version of the factor-transformation extension proposed by Misina (2006).

Keywords: Risk appetite indicators, risk aversion indicators, asset pricing, financial markets.

JEL Classification: G11, G12, G15.

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*Address: Deutsche Bundesbank, Central Office, Markets Department, Wilhelm-Epstein-Strasse 14, 60431 Frankfurt am Main, Germany; E-mail: birgit.uhlenbrock@bundesbank.de.

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Non-technical summary

Changes in investors' general appetite for or aversion to risk are an important factor in any analysis of financial market developments and stability. To meet the need for quantification, a number of risk appetite/aversion indicators have been proposed in the literature. When comparing the results obtained with these indicators, however, they often differ in terms of implications (see Illing and Aaron (2005)). Then again, the indicators also tend to vary in important aspects, such as their underlying concept of investors' aggregate-level risk appetite. "Theory-based indicators" aim for a narrower concept, for instance, when they attempt to disentangle the effects of changes in overall risk appetite on the relative demand for risky assets from those due to changes in risk assessments. Since the indicators rely on modeling assumptions, the extent to which such a separation is feasible in empirical applications hinges on the degree to which those assumptions are violated. Other indicators instead simply focus on the combination of both effects as reflected in market data. They concentrate therefore on a broader notion of aggregate-level risk appetite. A further observation is that indicator results often also might not correspond well to obvious expectations regarding the likely risk appetite stance in financial markets during critical periods (see Illing and Aaron (2005)). This represents an even more obvious problem with respect to plausibility and usefulness. The present paper investigates the extent to which we can exploit a better understanding of how an indicator concept actually works for improvements. In this respect, we focus on the popular "Global Risk Appetite Index" (GRAI) class of theory-based indicators that can be traced back to Kumar and Persaud (2002).

These intuitive indicators are ultimately based on the modeling assumption that the valuation of a risky asset already reflects an assessment of its riskiness at a given point in time. Accordingly, the indicators assume that the observation of a significant relationship between valuation changes and lagged measures of perceived riskiness (approximated by, for instance, historical variances) for a given cross-section of risky assets is attributable to a change of investors' general risk appetite. However, when implementing such an indicator, the choice of which financial market segments to cover in terms of assets is just one of several decisions to be made. Here, we concentrate on the results obtained for two data sets: a set of international stock market indices and a merged set that includes bond indices in addition to the stock market indices. The paper then explores for each data set how the indicator results are shaped by the various implementation decisions. On this basis, we then select that combination of options along the dimensions of implementation decisions which we expect to lead to the overall best empirical performance of the resulting indicators with respect to certain plausibility and consistency criteria.

For the financial market turmoil period beginning in mid-2007, in particular the equity-only GRAIs strongly benefit from applying a combination of the Kumar and Persaud (2002) rank correlation approach and a modified version of the Misina (2006) factor-transformation extension. We also find

that the merged-set GRAIs are more closely correlated with the corresponding equity-only GRAIs than with the bond-only GRAIs. This is consistent with the notion of a special role for equity markets when evaluating the overall situation in financial markets.

The extent to which investor assessments of (derivative) assets' riskiness are likely to change over the valuation period matters not just in terms of internal consistency considerations but also for the interpretation of significant GRAI results. Intuitively, for a weak relationship between changes in the assessments of (derivative) assets' riskiness over a valuation period and beginning-of-period riskiness assessments, for instance, it seems more likely that a significant GRAI result which suggests a decline in investors' aggregate risk appetite will do so not only in a broader, but to some extent also in a narrower sense. In our analyses, the preferred rank-correlation GRAIs with the modified factor-transformation extension perform more favorably is this respect, too. Furthermore, in their case there is also some empirical support for the notion that what occurred in financial markets at the onset of the turmoil in mid-2007 was connected at least to some extent with a decline in general risk appetite in a narrower sense.

The two ready-to-implement indicators – one for stock markets alone, one for stock and bond markets combined – are, however, only one result of the present paper. Its most important result is the insight how heavily dependent the outcomes obtained for the chosen risk appetite indicator concept are on technical implementation decisions, though. It is absolutely necessary to take this into account when using such indicators in practice.

Nichttechnische Zusammenfassung

Veränderungen in der allgemeinen Bereitschaft von Investoren zur Risikoübernahme sind ein wichtiger Faktor bei einer Analyse der Entwicklungen und der Stabilitätslage in Finanzmärkten. Angesichts der sich daraus ergebenden Notwendigkeit zur Quantifizierung wurden in der Literatur eine Reihe von Risikoappetit- bzw. Risikoaversionsindikatoren vorgeschlagen. Vergleicht man jedoch die Ergebnisse, die die Indikatoren liefern, so unterscheiden sie sich häufig in Bezug auf die Schlussfolgerungen (siehe Illing und Aaron (2005)). Allerdings ist zu berücksichtigen, dass die Indikatoren vielfach auch in wichtigen Aspekten differieren. Dazu gehört die zugrunde liegende Abgrenzung der Risikoübernahmebereitschaft bzw. des ‚Risikoappetits' von Investoren auf aggregierter Ebene. So genannte theoriebasierte Indikatoren zielen zum Beispiel auf eine eher engere Definition. Sie versuchen, die aus Veränderungen in der Risikoübernahmebereitschaft resultierenden Effekte auf die relative Nachfrage nach risikobehafteten Assets von den Effekten, die aus veränderten Einschätzungen der Risikograde der Assets resultieren, zu trennen. Dazu greifen sie auf Modellannahmen zurück. In welchem Ausmaß eine solche Trennung in empirischen Implementierungen erreicht werden kann, hängt davon ab, inwieweit die jeweiligen Modellannahmen verletzt sind. Andere Indikatoren konzentrieren sich stattdessen einfach auf die in Marktdaten reflektierte Kombination beider Effekte. Von daher liegt ihnen ein eher breiter angelegtes Konzept von Risikoappetit zugrunde. Eine weitere Beobachtung ist, dass Indikatorergebnisse häufig auch nicht zu dem passen, was in Bezug auf die Risikoneigung in kritischen Finanzmarktperioden offensichtlich zu erwarten wäre (siehe Illing und Aaron (2005)). Dies ist in Bezug auf Plausibilität und Nützlichkeit ein noch offensichtlicheres Problem. Die vorliegende Arbeit untersucht, inwieweit sich ein besseres Verständnis dafür, wie ein Indikator konkret funktioniert, für Verbesserungen nutzen lässt. Diesbezüglich konzentrieren wir uns auf die beliebte, auf Kumar und Persaud (2002) zurückgehende so genannte Global Risk Appetite Index (GRAI) Klasse von theoriebasierten Indikatoren.

Diese intuitiven Indikatoren basieren letztlich auf der Annahme, dass die Bewertung eines risikobehafteten Assets die zu dem entsprechenden Zeitpunkt vorliegende Einschätzung seines Risikogrades bereits reflektiert. Darauf aufbauend unterstellen die Indikatoren, dass für eine Gruppe risikobehafteter Assets die Beobachtung einer signifikanten Querschnittsbeziehung zwischen ihren jeweiligen aktuellen Bewertungsänderungen und früheren Einschätzungen ihrer Risikograde (approximiert zum Beispiel mit Hilfe von historischen Varianzen) auf eine Veränderung des allgemeinen Risikoappetits von Investoren zurückzuführen ist. Abgesehen davon, welche Finanzmarktsegmente durch entsprechende Assets abgedeckt werden, sind bei der Implementierung von solchen Indikatoren allerdings noch eine Reihe weiterer Entscheidungen zu treffen. Bei der Konstruktion der Indikatoren konzentrieren wir uns dabei auf zwei Datensätze: zuerst allein auf eine Gruppe internationaler Aktienmarktindizes, dann auf eine erweiterte Datenbasis, die neben den Aktienindizes auch Bondindizes umfasst. Die Studie analysiert anschließend, wie die für einen gegebenen Datensatz erzielten Indikatorergebnisse von den verschiedenen, bei der Implementierung getroffenen Entscheidungen beeinflusst werden. Darauf aufbauend wird dann in Bezug auf die verschiedenen Entscheidungsdimensionen diejenige Kombination von Optionen gewählt, für die nach Maßgabe bestimmter Plausibilitäts- und Konsistenzkriterien bei den resultierenden Indikatoren die insgesamt besten empirischen Ergebnissen erwartet werden.

Für die Periode der Finanzmarktverspannungen ab Mitte 2007 zeigt sich dabei, dass insbesondere die Plausibilität der nur auf Basis der Aktienindizes abgeleiteten GRAIs von der Anwendung des Rangkorrelationsansatzes von Kumar und Persaud (2002) in Kombination mit einer modifizierten Version der von Misina (2006) vorgeschlagenen Faktortransformationserweiterung deutlich profitiert. Außerdem beobachten wir, dass die auf Basis des erweiterten Datensatzes ermittelten GRAIs höher mit den entsprechenden GRAIs korreliert sind, die allein auf der Teilmenge der Aktienindizes basieren, als mit jenen, die sich für die Teilmenge der Bondindizes ergeben. Dies passt zu der Vorstellung, dass die Aktienmärkte wahrscheinlich eine besondere Rolle spielen dürften, wenn es um eine Einschätzung der Gesamtlage an den Finanzmärkten geht.

Abgesehen von Überlegungen zur internen Konsistenz des Ansatzes spielt die Frage, in welchem Ausmaß sich die Einschätzungen der Investoren bezüglich der Risikograde von (abgeleiteten) Assets im Verlauf einer Periode verändern, für die Interpretation signifikanter GRAI-Ergebnisse eine Rolle. Rein intuitiv scheint es zum Beispiel bei einer schwachen Beziehung zwischen den Risikoeinschätzungen der Assets am Anfang und deren Veränderungen im Verlauf der Periode wahrscheinlicher, dass ein signifikantes GRAI-Ergebnis gegebenenfalls einen Rückgang in der Risikoübernahmebereitschaft von Investoren nicht nur in einem breiteren, sondern auch in einem engeren Sinne nahelegt. In dieser Hinsicht ergibt sich in unseren Analysen ebenfalls ein Vorteil für die präferierten GRAI-Implementierungen mit Rangkorrelationsansatz und modifizierter Faktortransformationserweiterung. In deren Fall lässt sich zudem eine gewisse empirische Unterstützung für die Annahme finden, dass das, was in den Finanzmärkten bei Ausbruch der Turbulenzen Mitte 2007 zu beobachten war, wenigstens teilweise mit einem Rückgang in der generellen Risikoübernahmebereitschaft im engeren Sinne verbunden war.

Die zwei direkt anwendbaren Indikatoren – einer für Aktienmärkte allein, einer für Aktienmärkte und Bondmärkte zusammen – sind allerdings nur ein Ergebnis der vorliegenden Arbeit. Das wohl wichtigste Ergebnis der Arbeit ist jedoch die Erkenntnis, wie stark die Resultate für das gewählte Risikoappetitindikatorkonzept von technischen Implementierungsentscheidungen abhängen. Es ist unbedingt notwendig, dies zu berücksichtigen, wenn solche Indikatoren in der Praxis angewandt werden.

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1. Introduction

When reading a market report on how stocks fared relative to government bonds over the short run, one will often find that changes in investors' general demand for risky assets relative to assets considered rather safe are not only attributed to changes in assets' perceived riskiness[1], but also to investors' average or aggregate attitude towards risk[2]. Such changes in investors' narrowly-defined appetite for/aversion to risk over time might not only affect the size of the compensation market participants require per unit of risk, but could also influence how markets react to shocks. Bad news in a market situation where investor risk appetite is already low is likely to result in a much larger re-pricing of risky assets than in periods where it is high. The dynamic stance of the risk appetite of market participants as a sentiment could thus serve as an important contributing factor in the transmission of shocks through the financial system. Furthermore, as it might itself be influenced by the situation in financial markets, it could work as a multiplier. Accordingly, taking into account the risk appetite/risk aversion of investors and its evolution has become an important element of assessing the condition and stability of financial markets.

A number of indicators have therefore been proposed in the literature for quantifying the evolution of investors' general risk appetite (for an overview see e.g. Illing and Aaron (2005)). Some of them are based on theoretical models, while others are more atheoretic or adhoc in the sense that they only aggregate the information contained in market data without relying on a theoretical framework. But the notion of risk appetite underlying these indicators is not necessarily identical. Under a narrow interpretation of risk appetite, one faces the difficulty of having to disentangle the effects of changes in investors' risk appetite on investors' relative demand for risky assets from those of changes in risk assessments. For this, one can try to rely on certain modeling assumptions when developing indicators. Alternatively, one may choose to circumvent the problem by simply focusing on the combined effects reflected in changes of the relative demand for risky assets. This leads to indicators for a more broadly-defined concept of risk appetite. Finally, in theory the stance of investors' general risk appetite is likely to affect all risky financial market segments. In terms of actual results, however, the fact that the various risk appetite indicators often vary in their coverage of financial market segments is another potential source of heterogeneity.

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[1] In a stochastic environment, a priori the total return on an initial investment will in general be uncertain and subject to various kinds of risk, such as e.g. market risk, liquidity risk, and default risk. Assuming that changes along such risk dimensions lead to an immediate re-pricing of assets in financial markets, in the following sections the asset (return) riskiness measure of interest will be based on variances respectively covariances of (relatively short-term) realized asset returns.

[2] Traditionally, models often assume that the fundamental degree of risk aversion of an individual investor is a characteristic parameter that remains constant. But this does not preclude a change at the aggregate (cross-section) level if e.g. investors are not all identical, but instead characterized by different individual degrees of aversion to risk and the composition of investors actively participating in the markets changes over time, see Kumar and Persaud (2002). Furthermore, the behavioral finance theory argues that the degree of risk aversion of an individual investor may also change over time depending on previous investment decisions' outcomes. Thus, a row of positive results might lead to overconfidence of an investor and lower aversion to taking on risk, while the opposite may happen after significant losses.

It is therefore maybe not altogether surprising that the different indicators do not always suggest a similar stance of investors' risk appetite. What is even more problematic, it might not always be one that coincides well with given priors around critical periods in financial markets (see e.g. Illing and Aaron (2005)). Such findings raise concern about the usefulness of applying risk appetite indicators in the first place. A better understanding of how individual indicators work thus seems clearly warranted and might offer ways of potential improvement down the road. The paper contributes to this evolution, concentrating on the "**G**lobal **R**isk **A**ppetite **I**ndex" (GRAI) class of indicators.

This indicator concept, developed originally by Kumar and Persaud (2002), rests on the assumption that at a given point in time the price of a risky asset will already reflect an assessment of its risk. The authors assume that a significant monotonic relationship between excess returns and past measures of perceived riskiness for a cross-section of risky assets should then only be observed if market participants' aggregate risk appetite has changed. Focusing on the foreign exchange market segment, Kumar and Persaud (2002) assess the significance of risk appetite changes using cross-sectional Spearman rank correlation coefficients between monthly or quarterly excess returns of assets and assets' past volatilities.[3] Wilmot, Mielczarski et al. (2004) and Deutsche Bundesbank (2005) instead assume linear relationships between excess returns and past riskiness. Furthermore, they apply a linear-regression indicator approach to data from not only one financial market segment at a time, but consider stock and bond markets together. To emphasize investors' aggregate risk aversion as the dual concept to risk appetite, finally Coudert and Gex (2006) choose to define their linear Global Risk Aversion Index as the negative of the cross-sectional linear correlation between excess returns of assets and past volatilities.[4]

Its intuitiveness and simplicity makes the GRAI class a popular choice among the theory-based risk appetite indicators. The ability to cover a larger cross-section of indices from several financial market segments in an integrated way is another attractive feature. One also has to keep in mind some caveats, though. Despite having a similar model in mind, (G)RAI indicator results in the end will also depend on certain specification and input choices. This concerns the choice between a merely monotonic or a more restrictive linear relation between assets' excess returns and measures of riskiness, the selection of assets/financial market segments, the length of the period over which to calculate the respective (excess) returns, and how to proxy for riskiness as perceived by investors. For the latter, a common practice in the literature is to rely on volatilities respectively variances of individual asset returns. However, in a portfolio context, this effectively amounts to assuming that

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[3] They applied their indicator to specific segments of financial markets, primarily the FX market, but also to the US stock market where they looked at a cross-section of US sector equity indices. For details, see Kumar and Persaud (2002), p. 414. To avoid any overlap of the period over which volatilities and returns were calculated, the volatilities were derived for a period of 250 business days prior to the excess return period.

[4] For their linear correlation-based index they used the abbreviation GRAI, while the negative corresponding cross-sectional regression coefficient was dubbed Risk Aversion Index (RAI). They applied the indicators to two sets of cross-sectional data (one of foreign exchange rates, and another of international stock indices) separately like Kumar and Persaud (2002), however, they used a lower frequency of monthly instead of daily data.

covariances between asset returns do not significantly contribute to the riskiness of assets[5]. Misina (2006) therefore suggests taking the full variance-covariance (VCV) matrix of asset returns into account in his extended factor-based rank-correlation risk appetite indicator, called RAI-MI. Since he wanted to compare results of his RAI-MI with the preferred indicator of Kumar and Persaud (2002), however, he focused on international FX markets in his paper.

The current paper broadens the investigation into the relative pros and cons of the Misina factor-extension, as well as the necessary other choices to be made when deriving a GRAI-type risk aversion indicator. However, we introduce an important additional restriction to the Misina (2006) factor extension, which leads to our modified version of the factor-extended rank-correlation Global Risk Aversion Index (F-GRAI).

The remainder of the paper is organized as follows. The next section contains a short presentation of the theoretical background to the GRAI class of risk appetite indicators. Section 3 then moves to the empirical analysis of the GRAIs as global risk aversion indicators, where in terms of financial market coverage we focus first on international stock markets and later on stock and bond markets combined. The recent stressful phase of financial market turmoil from mid-2007 onwards will serve as an important yardstick for evaluating the plausibility of results and how that is affected by the factor-extension as well as the other implementation decisions.[6] Finally, section 4 will summarize the main results.

2. Methodology: The GRAI Indicator – Theoretical Motivation and the Misina Critique

Apart from adding the assumption that "investors have the same, but changing risk appetite", Kumar and Persaud (2002) in principle rely on a simplified capital asset pricing model (CAPM)[7] for theoretically motivating their indicator's key hypotheses. These are that a rank correlation between a cross-section of asset price movements at time t and the assets' riskiness at t-m should be weak for a contemporary change in general risk, but that it should be strong for a change in the general appetite for risk. With some measure of volatility as a proxy of asset riskiness, they then used the rank correlation between asset excess returns and past volatilities from the beginning of the return period as their risk appetite indicator.

Under the usual assumptions of the CAPM, the expected return of a risky asset i in period t+1, $E(R_{t+1}^{i})$, in equilibrium should exceed the risk-free rate R_{t+1}^{f} by a risk premium (excess return)

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[5] In the portfolio context that might be used to motivate the GRAI class of indicators theoretically, asset returns' covariances will be zero in the case of independence, see also Coudert and Gex (2006).

[6] Of course, another interesting empirical question in terms of the usefulness of a risk appetite indicator might be to explore whether factors that are considered influential for the evolution of investors' risk appetite, like e.g. the degree of liquidity in financial markets, can be related to the dynamic evolution of investors' aggregate risk appetite over time. See e.g. also ECB (2007a).

[7] For details on their simplified version of a CAPM, see Kumar and Persaud (2002), p. 409ff. However, the CAPM model used in the following is closer to e.g. Coudert and Gex (2006).

equal to the representative investor's degree of risk-aversion ρ times the asset's systematic risk. Since the latter is determined by how the asset return co-varies with the return R^{M}_{t+1} of the market portfolio, this leads to the familiar equation:

$$(1) \qquad E(R^{i}_{t+1}) - R^{f}_{t+1} = \rho \operatorname{cov}(R^{i}_{t+1}, R^{M}_{t+1}) = \rho \cdot \sigma_{i,M} \,.$$

A portfolio return is the sum of the returns on the portfolio's individual assets times their given portfolio weights α_i, i.e. $R^{M}_{t+1} = \sum_i \alpha_i \cdot R^{i}_{t+1}$, with $\sum_i \alpha_i = 1$. The covariance $\sigma_{i,M}$ can thus be re-written as

$$(2) \qquad \sigma_{i,M} = \operatorname{cov}(R^{i}_{t+1}, R^{M}_{t+1}) = \alpha_i \cdot \sigma_i^2 + \sum_{j \neq i} \alpha_j \cdot \sigma_{ij} \text{ , with } \sigma_i^2 = \operatorname{var}(R^{i}_{t+1}) \text{ and } \sigma_{ij} = \operatorname{cov}(R^{i}_{t+1}, R^{j}_{t+1})$$

and substituted into (1) in order to obtain

$$(3) \qquad E(R^{ex}_{i}) = E(R^{ex}_{i,t+1}) = E(R^{i}_{t+1}) - R^{f}_{t+1} = \rho \cdot \sigma_{i,M} = \rho \cdot (\alpha_i \cdot \sigma_i^2 + \sum_{j \neq i} \alpha_j \cdot \sigma_{ij}) \,.$$

A change in expected excess returns can then arise from a change in risk aversion or a change in the riskiness of asset i stemming either from a change in its own return variance or changes in its covariances with the other asset returns in the portfolio:

$$(4) \qquad \begin{aligned} dE(R^{ex}_{i}) &= \frac{\partial E(R^{ex}_{i})}{\partial \rho} \cdot d\rho + \frac{\partial E(R^{ex}_{i})}{\partial \sigma_{i,M}} \cdot d\sigma_{i,M} \\ &= \frac{\partial E(R^{ex}_{i})}{\partial \rho} \cdot d\rho + \frac{\partial E(R^{ex}_{i})}{\partial \sigma_i^2} \cdot d\sigma_i^2 + \sum_{j \neq i} \frac{\partial E(R^{ex}_{i})}{\partial \sigma_{ij}} \cdot d\sigma_{ij} \end{aligned}$$

According to (4), an autonomous change in the degree of risk aversion ρ should thus lead to a change of asset excess returns in proportion to their riskiness $\sigma_{i,M}$,

$$(5) \qquad \frac{\partial E(R^{ex}_{i})}{\partial \rho} = \sigma_{i,M}, \forall i \,.$$

Within the model, a change in risk aversion should therefore be accompanied by a significant correlation between asset excess returns and their riskiness. However, for an empirically feasible GRAI indicator, observable proxies must be substituted for the quantities on both sides of (5). Changes in expected asset returns are thus replaced by short-term realized (i.e. ex-post) returns defined in terms of observed changes in log asset prices.[8] The practice of approximating asset return riskiness by own past volatilities respectively variances only, like in Kumar and Persaud (2002), may

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[8] Under the assumption that any re-pricing of assets to effect a change in risk premia takes place immediately at time t while expectations concerning future asset values remain unchanged, one obtains $d(E(R^{ex}_{i})) = -dP^{i}_{t}$. See e.g. also Coudert and Gex (2006).

lead to a different ranking of assets in terms of riskiness than if one considered the covariances with the market portfolio, though. As shown by equation (2), only for covariances between the individual asset returns equal to zero and asset weights either equally large or increasing with the asset return variances it would be guaranteed that both approaches lead to the same asset return riskiness rankings. Misina (2003) argues, however, that the independence of asset returns has a further benefit when applying the GRAI. For independent returns, a common shock to the riskiness of all assets can – with given weights – only occur through a simultaneous increase or decrease of all variances. In that case, a rank correlation effect between assets' excess returns and their past variances could a priori not be excluded, unless one assumed equally weighted portfolios (see Misina (2003), p. 15-16). However, when returns are not independent, also a change in the covariance between two asset returns could lead to a rank correlation effect – again unless assets were assumed to have equal weights (see Misina (2003), p. 13ff).

This shows that assumptions concerning the weights and the independence of asset returns are important for nesting the empirical GRAI approach of Kumar and Persaud (2002) within the theoretical portfolio context of a CAPM. When returns are not independent, Misina (2006) proposes as a pragmatic solution to use an eigenvalue/eigenvector decomposition of the variance-covariance (VCV) matrix of asset returns to transform the original GRAI rank correlation problem into one considering orthogonal factors and their past variances. Rewriting (1) respectively (3) in matrix notation,

$$(6) \qquad ER_{t+1}^{ex} = \rho \cdot \Sigma_R \cdot \alpha \quad \text{, with } ER_{t+1}^{ex} = \begin{bmatrix} E\left(R_{1,t+1}^{ex}\right) \\ E\left(R_{2,t+1}^{ex}\right) \\ \vdots \\ E\left(R_{n,t+1}^{ex}\right) \end{bmatrix}, \ \Sigma_R = \begin{bmatrix} \sigma_1^2 & \sigma_{12} & \cdots & \sigma_{1n} \\ \sigma_{21} & \sigma_2^2 & \cdots & \vdots \\ \vdots & \vdots & \ddots & \vdots \\ \sigma_{n1} & \cdots & \cdots & \sigma_n^2 \end{bmatrix}, \ \alpha = \begin{bmatrix} \alpha_1 \\ \alpha_2 \\ \vdots \\ \alpha_\text{n} \end{bmatrix},$$

the VCV matrix is decomposed into $\Sigma_R = B \cdot D \cdot B'$, with D the diagonal matrix of eigenvalues (ordered from largest to smallest, i.e. $D_{ii} \geq D_{jj} \forall 1 \geq i > j \geq n$) and B the matrix of the corresponding normalized eigenvectors (in columns). The inverse of B can then be used to obtain orthogonal factors from the asset returns at time t,

$$(7) \qquad R_t = B \cdot f_t \leftrightarrow f_t = B^{-1} \cdot R_t \quad \text{, with } R_t = \begin{bmatrix} R_{1,t} \\ R_{2,t} \\ \vdots \\ R_{n,t} \end{bmatrix}, \ f_t = \begin{bmatrix} f_{1,t} \\ f_{2,t} \\ \vdots \\ f_{n,t} \end{bmatrix}.$$

Misina (2006) argues that the factors can be interpreted as returns on derivative assets constructed from the range of original assets (see there, p. 9) and proposes to take the correlation between the ranks of the orthogonal factors and the ranks of their variances (i.e. the ranks of the already ordered diagonal elements of D) as an alternative to the Kumar and Persaud (2002) indicator.[9]

Unlike argued by Misina, however, the normalization of eigenvectors alone cannot guarantee to avoid problems of non-uniqueness as normalization only enforces the restriction that the sum of squared elements of an eigenvector must add to one (i.e. that the eigenvector will have unit length). This still leaves the problem that multiplying all elements of a normalized eigenvector by -1 will again result in a valid normalized eigenvector. Therefore, we will ensure fully unique eigenvectors in B by conducting a "normalization-plus". This imposes the additional restriction that the sum of the elements of each normalized eigenvector must be non-negative.[10]

The factor extension is not a perfect solution. Again it depends on the (now transformed) weights $\tilde{\alpha}$ whether the rankings of factors in terms of true riskiness might be different from the one obtained based on factor variances alone. The problem of potentially observing a correlation effect between the ranks of factors and the ranks of their (lagged) riskiness proxies which might in fact be unrelated to changes in risk aversion is also not fully eliminated.[11] Another empirically relevant aspect is that the orthogonality of derived factors will to some extent be violated as VCV matrices of asset returns change over time. Such caveats must be taken into account and one has to acknowledge the assumptions implicitly made when applying the factor-extended rank-correlation GRAI. In the end, though, the main question is the usefulness of the factor extension when actually applying the GRAI approach. This we will explore in the following empirical section.

3. Empirical Results

3.1. Data and Indicator Inputs

The first data set for which risk-appetite indicators are calculated consists of a selection of MSCI developed and emerging stock market indices (for details see table 1 in the appendix), with the secondary rate on 3-month US Treasury Bills used as a proxy for the risk-free rate. (End-of-) Wednesday observations of the data are chosen to calculate the risk-appetite indicators at a weekly fre-

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[9] One could formulate an equilibrium relationship corresponding to (1) between expected returns and riskiness for the factors, i.e. $E(f_{t+1})-R^f_{t+1}=\rho\cdot D\cdot B'\cdot\alpha=\rho\cdot D\cdot\tilde{\alpha}$. As argued by Misina (2006), due to an identical profile of (expected) risk over (expected) return, investors should be indifferent between holding a portfolio of original assets with weights α' or a corresponding portfolio of derivative assets with the weights $\alpha' B$. But the CAPM model for the factors as derivative assets is not identical to the one for the original assets, as one can see when pre-multiplying (6) by B^{-1} .

[10] This assumption is plausible also from a theoretical point of view: for the factor CAPM model (see footnote 9) with equally large positive elements in α this restriction guarantees that also the new weights $\tilde{\alpha}=B'\cdot\alpha$ will at least all be positive.

[11] The potential for a rank correlation effect after a common shock to the factor variances now depends on the asset weights in the original portfolio and the elements of B. Furthermore, even for a constant weight vector α with equal-sized elements for the original portfolio of assets, the weights in the CAPM formulated for the factors, $\tilde{\alpha}=B'\alpha$, are likely to be affected by changes of B, e.g. if the covariances between the original dependent asset returns change over time.

quency.[12] A second data set of Merrill Lynch indices (for details see table 3 in the appendix) covers the bond market segment. In addition to a US government bond index as a relatively safe asset it includes indices for investment-grade US corporate bonds of different sector/rating segments, high yield bonds, ABS, and non-investment grade emerging market bonds of different rating segments.

Implementing the GRAI with stock index data has the advantage that they refer to comparable and liquid instruments. Since the stock market is considered to provide aggregate information on the stance of the real economy, it is also likely to react to any major shock that affects the economy or more narrowly the financial system from the outside. Accordingly, equity markets typically play a prominent role when gauging the general risk appetite stance of investors.

Furthermore, despite the assumption that a change in investors' general risk appetite should lead to a re-pricing of risky assets across a number of market segments, there might also be some element of idiosyncrasy in the appetite for specific asset classes' risk at a given point in time. That is to say, one important empirical question is how informative the changes in risk appetite implied for one segment of financial markets are for the common or general risk appetite stance indicated when considering different financial market segments simultaneously. Given the implications of the subprime crisis in mid-2007, it therefore seems particularly interesting to compare the stock market GRAI with results for data sets covering only or in addition different bond indices. Combined data sets of stock and bond indices were also used in Wilmot, Mielczarski et al. (2004) and Deutsche Bundesbank (2005). However, they looked at cross-sectional linear regressions between asset excess returns and past risk measures. Thus, one focus of the present paper is to compare the results obtained under a more restrictive linear (RAI) approach with those from the less restrictive rank-correlation GRAI approach.

There exist arguments both for and against considering different asset classes together when it comes to developing risk appetite indicators. On the one hand, a larger cross-section of assets with different degrees of riskiness should, ceteris paribus, lead to an increase in efficiency.[13] On the other hand, assets from different asset classes will be subject to different kinds of risk. From an investor's point of view, these kinds of risk might be more or less important at different times. The recent subprime crisis, for instance, quickly put credit and liquidity risk aspects very high on investors' worry list. When applying the GRAI indicator to a broad cross-segment portfolio, a cross-sectional averaging effect might therefore lead to the loss of information on the risk stance towards

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[12] Daily data of the MSCI indices (all with the USD as the reference currency) were taken from MSCI/Bloomberg, while the data for treasury bill rates were downloaded from the FRED website of the Federal Reserve Bank of St. Louis (www.stlouisfed.org). Based on the 3m T-bill rate given in p.a., a proxy for a one-week risk-free rate can be calculated as $rf_t^{weekly} = \left(1 + \frac{r_t^{\text{3m-Tbill,p.a.}}}{100}\right)^{\frac{1}{52}} - 1$ assuming 52 weeks per year, see also Bollerslev, Engle et al. (1988). Proxies for the risk free rates corresponding to alternative return periods can be obtained accordingly.

more specific asset classes. Furthermore, the factorization already adds another level of complexity. Expanding the data set thus might be a greater challenge to the robustness of results in the F-GRAI case. The F-GRAI also has by construction a broader range of riskiness degrees covered, it exploits the information concerning the original assets' riskiness more efficiently.[14] In particular for the F-GRAI it might therefore a priori not be clear whether to prefer an integrated or disaggregated approach.

Apart from the choice of assets to be included in the data set, one has to make four additional central decisions to actually obtain a (G)RAI type risk appetite indicator empirically.

The first decision is how and over what length of period to calculate the (excess) returns of the assets. For the following empirical applications, the asset returns of interest are the log index changes. More precisely, the return on index i at time t is calculated as the difference between the log index values at time t and some previous time t-m, with the lag m corresponding to the chosen return period length. Excess returns are then derived by subtracting the risk-free rate for a corresponding period of length m at time t-m.

Price or valuation changes of opposite directions observed from day to day or even week to week may average out to some extent over time. On the other hand, the cumulative impact of a row of weekly changes in the same direction is more visible if returns are calculated over a longer period. The pattern of returns thus becomes smoother and more distinguishable for longer return periods (see also figure 1 in the appendix). Accordingly, quarterly returns or even 6-month returns are often preferred when implementing a (G)RAI type of risk appetite indicator, since a smoother GRAI seems easier to interpret (see e.g. also Coudert and Gex (2006) and Deutsche Bundesbank (2005)). Unless otherwise noted, we therefore focus on the (G)RAI results obtained for a longer return period of 12 weeks.

A second decision has to be made regarding how to proxy for assets' riskiness. This holds true even when deciding to use lagged asset return variances (i.e., variances calculated at time t-m) as proxies as in the empirical GRAI literature. Intuitively, a 12-week return period might suggest considering the lagged variances of 12-week asset/index returns as well. However, to calculate the variance of 12-week returns from non-overlapping observations, one would need at least 7-9 years of data (30-39 observations). While this is the statistically correct approach, once one allows for changing variances, one may question whether such a measure in which current developments can have only a minimal impact serves as a good proxy for an asset's riskiness as perceived by real-life investors. Therefore, the GRAI literature typically considers a much shorter window of asset return

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[13] Kumar and Persaud (2002), p. 413, suggest using as many asset returns and as long a history as possible in order to reduce the risk of a chance correlation between risks and returns.

[14] As argued in Wilmot, Mielczarski et al. (2004), their approach rests on the availability of a set of assets which differ sufficiently in terms of their degrees of riskiness. But via the factorization approach, one constructs derivative assets that

observations for calculating volatilities/variances. Kumar and Persaud (2002), for instance, use one year of daily data .

In the current situation, one thus might decide to use the variance of weekly returns calculated for a short window of 52 weeks, but appropriately scaled to match the return-period length, as an alternative. While for a long-term portfolio investor a long-term risk concept seems more relevant, over the shorter-term periods of the GRAI context the scaled proxy certainly holds a particular appeal, too.[15] Because a return over 12 weeks might be approximated by the sum of the 1-week returns over the respective 12 weeks, an alternative is to construct an approximate measure for the 12-week return variance via a temporal aggregation approach.[16] For estimating an approximate 12-week return VCV matrix at time t, this approach takes into account the covariances between weekly returns at different lag lengths in addition to the most recent and lagged estimates of the VCV matrix of weekly returns. The simple scaling of variances, on the other hand, focuses only on the most recent information regarding short-term asset return riskiness. A priori it is not clear which approach might be preferable in the current context. Hence we apply both the scaling and the temporal aggregation approach to the construction of asset return variances and covariances. For the construction of the GRAIs, the estimated variances and VCV matrices of asset returns are then appropriately lagged to avoid any overlap with the period over which the cross-section of asset excess returns is calculated.

As argued above, though, even when assuming equal portfolio weights for the different assets, the riskiness of asset returns does not only depend on asset returns' own variances, but also on their covariances. While Misina (2006) suggests deriving factors from dependent asset returns and an eigen decomposition of the asset return VCV matrix, the true VCV matrix is unknown and may even change over time. Accordingly, the historical VCV matrix calculated at time t-m is used as an appropriately lagged, but ex post necessarily imperfect estimate in the factorization step. This implies, however, that the factor portfolio returns actually realized for time t are no longer guaranteed to be independent by construction. However, one can still expect that the problem of dependence between returns is smaller with than without the factorization adjustment.

Based on the decomposition of the lagged asset return VCV matrix estimate $\Sigma_R = B \cdot D \cdot B'$ (with B the matrix of "normalized-plus" eigenvectors in columns), the factors corresponding to the observed original asset returns at time t are thus calculated as

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cover a much broader range of riskiness degrees (in terms of the difference between maximum and minimum riskiness) than the original range of assets.

[15] Furthermore, if changes in the implied or revealed risk appetite behavior of investors at least partly reflect the changes in the riskiness seen over a shorter period, longer-term measures of variances – while being less-variable proxies – might also not resolve the real identification issue of capturing the evolution of riskiness as perceived by the average investor concerned.

[16] See in this context e.g. also Brandt (2008), p. 16.

$$f_t = B^{-1} \cdot R_t \quad \text{, with } R_t = \begin{bmatrix} R_{1,t} \\ R_{2,t} \\ \vdots \\ R_{n,t} \end{bmatrix}, \; f_t = \begin{bmatrix} f_{1,t} \\ f_{2,t} \\ \vdots \\ f_{n,t} \end{bmatrix}.$$

As in Misina (2006), the correlation between the ranks of the factors and the ranks of their lagged variances (i.e. the respective diagonal elements of the matrix D) is then used for the factor-based GRAI indicator.

However, this step actually involves another decision, namely whether to calculate the risk appetite or aversion indicator assuming a linear or a monotonic relationship between the cross-section of asset excess returns at some time t and appropriately lagged past measures of their riskiness. The former corresponds to a linear cross-sectional correlation or regression approach, the latter to the Spearman rank correlation approach of Kumar and Persaud (2002) (see also Misina (2006), p. 5). In the following presentation of empirical results **GRAI** stands for a rank correlation indicator and RAI for the linear RAI indicator, either as a linear correlation (**RAI-C**) or linear regression version (**RAI-R**). The usage of asset excess returns or factor returns, if not otherwise noted, is indicated by adding a preceding **R-** or **F-** to the indicator abbreviation. To emphasize the dual concept of changes in risk aversion rather than risk appetite, the respective cross-sectional regression or correlation coefficient estimates are multiplied by -1 so that positive values correspond to increases in risk aversion (see Coudert and Gex (2006)). Our (G)RAIs therefore represent global risk aversion indicators.

Figure 2 in the appendix compares the variance proxies for the 12-week MSCI US and Indonesia index returns with those of the first factor(s) obtained for the corresponding setups.[17] Since the factor variances are obtained as the ordered eigenvalues of a VCV decomposition, the variance of factor 1 must always be larger than that of factor 2. This difference in magnitudes (together with the different scales of factor returns) has important implications when applying the linear regression/correlation RAI indicators instead of the rank-correlation GRAI approach to a cross-section of factors and their variances. For a linear F-RAI indicator, the values will often be almost identical to the negative of the first factor's ratio of excess returns to variance, as the first factor is dominating by construction and the linear model's results tend to be strongly affected by large outliers.[18] This suggests that a combination of the factorization extension together with the rank correlation approach of the GRAI might be more promising to obtain an indicator for assessing an average risk aversion stance of investors.

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[17] Note that the factors are not directly comparable coming from different factorizations under the two setups.

[18] Intuitively, the first factor represents the factor portfolio of underlying assets with the maximum variance. The larger the cross-section of risky assets across which one can aggregate in the risk dimension, the larger is this maximum factor variance likely to be relative to the minimum factor variance.

3.2. Equity-Only (G)RAI Results

Since both the original Kumar and Persaud (2002) and the factor-extended indicator proposed by Misina (2006) are of the rank-correlation type, it seems natural to focus in particular on the GRAIs in the following discussion of indicator results.

One reasonable assumption is that times of higher stress in financial markets are more likely to be associated with decreasing than increasing risk appetite at the aggregate level. This suggests that for a plausibility check of the indicator results one might want to look in particular at their behavior during such periods. Some periods of likely higher financial market stress are therefore highlighted in the indicator graphs in the appendix. The exact dating of these periods is given in table 2 of the appendix. For the most part it closely follows González-Hermosillo (2008). Apart from small adjustments due to the weekly frequency of the current analysis, only in two cases did it seem advisable to deviate from the choices made by González-Hermosillo (2008). The first deviation concerns the beginning of the stress episode following September 11, 2001, where for the purposes of this study the highlighted period starts on September 12, 2001.[19] Furthermore, the end date for the US subprime mortgage and ensuing liquidity squeeze episode was left open, since – as also noted by González-Hermosillo (2008) – the crisis was clearly still ongoing at the end of the sample period used for the following analysis (March 12, 2008). Of course, the non-statistical method of dating these periods implies that there is a certain degree of discretion involved, in particular in terms of choosing the pre-crisis part of the highlighted periods.[20] Furthermore, longer-term cyclical dynamics which overlay shorter-term dynamics in financial markets likely also contribute to the evolution of investors' general risk appetite.

In addition, some of the figures in the appendix also include horizontal lines corresponding to the critical values for a two-sided significance test of the rank correlation at a 5% significance level (for the critical values see Zar (1972)).

Overall, the graphs of the GRAI indicators for 12-week factor returns in figure 3 of the appendix appear more in line with priors concerning changes in risk appetite/aversion around critical periods than the results based on the original 12-week index returns. Despite the 12-week return periods, the GRAI patterns still retain a certain volatility. However, in all of the highlighted periods the F-GRAIs are either already in the positive domain or start a noticeable increase after the actual crisis event. At first sight the crisis episode of the Ford and GM downgrades (no. 8) appears to be different in this respect. The F-GRAIs drop immediately after the crisis event date given in González-Hermosillo (2008), namely March 16, 2005 when Moody's announced their intention of reviewing the credit rating of GM. However, the crisis episode actually was played out over a pro-

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[19] González-Hermosillo (2008), on the other hand, chose a later date for her analysis, as certain markets were closed for a few days.

[20] Alternatively, one may choose a more statistical approach of directly dating such crises. Coudert and Gex (2006) e.g. used the CMAX indicator of Patel and Sarkar (1998) for the dating of stock market crises.

tracted period and in different phases.[21] In fact, the problems of Ford and GM already started to become more and more obvious in late 2004.[22] The F-GRAIs seem better than the R-GRAIs at capturing this by moving from a significantly negative territory associated with still increasing risk appetite into a stance of eventually even increasing risk aversion. The initial increase is much more pronounced for the F-GRAI calculated from the lagged scaled VCV matrices of weekly returns than for the F-GRAI derived from temporally aggregated (co-)variances of asset returns, though.[23]

One potential explanation why the F-GRAIs might be more affected than the R-GRAIs by the choice of calculating the (co-)variances as either a very short-term risk measure or a risk measure for a medium-term period could be that for the F-GRAIs it does not only influence the risk rankings of assets. Due to the factorization of the corresponding VCV matrices it also has implications for the composition of the factors as portfolios of the underlying original assets. While the first factor is constructed to have a higher riskiness – read variance – than the other factors, in the first case it will be constructed to exhibit the highest short-term riskiness of all factors. In the second case, however, it will rank higher than the remaining factors in terms of medium-term risk. Thus, for the F-GRAIs the difference in the variance-covariance calculation translates into a different composition of the factors as derivative assets. This might lead to a slightly more dissimilar pattern for the F-GRAIs than for the R-GRAIs across the two methods of deriving riskiness proxies.[24]

While there is some similarity in the graphs of the indicators, the choice of factor returns instead of the original asset returns seems to have a clear impact on the results. One interesting period in this respect is early 1998, before the outbreak of the Russian crisis. Unlike the R-GRAIs, the F-GRAIs suggest at least a short period of significantly increasing risk appetite for early 1998, i.e. in the wake of the Asian financial crisis of 1997.[25] For the stock market downturn in 2002, the F-GRAIs – in contrast to the R-GRAIs – indicate significantly increasing risk aversion only at a later stage. This seems to fit in with the strongest stock market downturns occurring only in July and September of that year, though. Thirdly, after the crisis of the Ford and GM downgrades, only the F-GRAIs give a clearer suggestion of actually declining risk appetite after March 16, 2005.

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[21] With the GM earnings warning of March 16, 2005 and the subsequent further ratings revisions the crisis in the automotive sector reached of course another level. However, already on October 14, 2004, the losses from auto sales in the US and the resulting worsening of earnings prospects had made headlines, with the S&P rating for GM subsequently being lowered to the lowest investment-grade level. The crisis in the US automotive sector thus developed over a longer time. And it reached another level of intensity when on October 8, 2005, the automotive parts company Delphi Corp., a former GM daughter, filed for Chapter 11 bankruptcy protection.

[22] I.e., at the time the announcement for the review actually came, it might have not been such a shock for investors anymore and their general risk appetite, while previously affected, might by that time temporarily have had a brief recovery.

[23] Although in both cases the F-GRAIs still fall short of crossing the upper critical value bound. So even for the F-GRAI based on weekly return (co-)variances one is not able to reject the null hypothesis of insignificance at the corresponding significance level (5% for a two-sided, 2.5% for an one-sided test).

[24] For the period Jan. 5, 2000 to March 12, 2008, the correlation between the 12-week GRAI indicators across the two methods of calculating the (co-)variances is approx. 0.71 between the F-GRAIs and 0.93 between the R-GRAIs.

[25] The R-GRAIs, on the other hand, remain in the positive domain, and as they are significant in early 1998, this suggests an increasing risk aversion at that time.

When comparing their overall patterns, the R-GRAIs appear at times more volatile and prone to very sharp corrections than the F-GRAIs. Before the Turkey crisis of 2006, the R-GRAIs still gave a strong indication that investors' risk appetite was increasing. However, after the outbreak of the crisis the R-GRAIs again very significantly indicate a switch to increasing risk aversion. The F-GRAI changes take longer and are more muted, reaching a peak only towards the end of the highlighted period or even slightly later. Given the critical values, only for the F-GRAI based on temporally aggregated (co-)variances is the implied increase in risk aversion weakly significant. But actually, concerning the timing of the increasing risk aversion as suggested by the F-GRAIs, one might also want to note another cause for concern around that time. Beginning in summer 2006, problems in the US housing market were more frequently mentioned.

This brings the discussion to the evolution of the indicators during the most recent crisis, the US subprime mortgage and liquidity crisis of 2007 and 2008.[26] Given the level of stress observed in financial markets at that time, it seems strange that all through the summer of 2007 the equity-based R-GRAIs remain in the negative domain, thus giving no indication of an increasing risk aversion around that time. The F-GRAIs, on the other hand, clearly suggest a decline of investor risk appetite after the outbreak of the crisis, and even point at a significant increase in investors' general risk aversion stance around August/September 2007. This initial increase of the F-GRAI is even more pronounced and longer-lasting when based on temporally aggregated (co-)variances. In the latter case it was also matched by a stronger – and at the end of November/beginning of December 2007 briefly significant – decline of risk aversion. However, early and mid December 2007 brought a return to increasing risk aversion as far as the F-GRAIs are concerned. Also the R-GRAIs suggest a change to increasing risk aversion, but in their case the change appears less pronounced. From February 2008 onwards, the R-GRAIs tentatively suggest an increasing risk appetite again, while based on the F-GRAIs one arrives at the conclusion that investors' risk aversion was overall still increasing. Looking at the end of the estimation period (mid-March 2008), only for the R-GRAI and the F-GRAI derived from temporally aggregated (co-)variances it is possible to reject the hypothesis of zero rank correlation. However, while the F-GRAI would suggest significantly increasing risk aversion at that time, the R-GRAI suggests the opposite conclusion. In light of the markets' worries about Bear Stearns during that period, this does not seem very likely. Considering the magnitude of the recent crisis, the results for the equity-only F-GRAIs are more in line with intuition. The modified Misina extension for the GRAI thus seems empirically useful, as it delivers more plausible results for the sample of international stock market indices.

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[26] A more detailed view of this period is given in the third panel of figure 3, which covers only 2006 and later.

Robustness of GRAI Results to the Choice of Alternative Return Period Lengths

Figure 4 in the appendix compares the GRAIs for 12-week returns with results obtained for 4-week and 24-week returns in order to explore the sensitivity of results to the return period length.[27] The results clearly show that the averaging effect of longer return periods has both benefits and downsides. When comparing results for 24-week with those for 12-week return periods, it seems that the downsides outweigh the benefits for 24-week returns. This is not only visible in the behavior of the GRAI indicators during the latest crisis, but also to some extent after the 2006 crisis. While the 24-week return R-GRAIs at least suggest a significant increase of risk aversion sometime in the second half of 2006, the relatively long delay makes it somewhat difficult to see the direct connection to the crisis of 2006. Relative to the results for 24-week returns, the graphs of the 4-week return period GRAI indicators appear more plausible. However, they are also more prone to strong corrections from time to time. The averaging effect of longer return periods implies that one loses potentially relevant information on short-term temporary effects on the stance of investors' risk appetite changes. The GRAI indicators based on 12-week returns therefore reflect those changes only with a lag and/or in a much more muted fashion.

For the stress period starting in the summer of 2007, the results for a 12-week return period suggest a significant increase in investor risk aversion based on the F-GRAIs, but not for the R-GRAIs. For a 4-week return period, the F-GRAIs suggest that investor risk aversion has started to increase even slightly earlier (already during June 2007). However, the change after the crisis event appears less pronounced than for the 12-week return F-GRAIs. The 4-week return R-GRAIs, on the other hand, show a strong increase in indicator values after July 11, 2007. This indicates a shift to increasing risk aversion between early August and early September.[28] But the significantly negative values of the 4-week R-GRAIs from early-September until around mid- to late October 2007 suggests that the earlier period of increasing risk aversion was followed by a temporary correction period in which investor risk appetite started to increase again early on as well. Overall, the priors concerning the crisis effects on the confidence of investors are easier to reconcile with the graphs of the F-GRAIs than with the completely different scale of investor risk appetite recovery suggested by the 4-week return R-GRAIs. The tendency of sharp corrections for 4-week return GRAIs is also very visible after the 2006 crisis. While suggesting a significant increase in risk aversion right after the outbreak of the crisis, the 4-week R-GRAIs turn significantly negative even before the end of the highlighted stress period. Then, they temporarily shift back to being significantly positive again in September 2006. Balancing the trade-off between the information loss of longer and more vola-

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[27] A corresponding 6-month period was e.g. used in Wilmot, Mielczarski et al. (2004) and Deutsche Bundesbank (2005). However, a shorter period of 1 month instead of the preferred quarterly returns was also applied in Kumar and Persaud (2002), to demonstrate its effect on the indicator.

[28] With the 4-week return R-GRAIs even being above the critical value for a short period of time in between, which suggests a significant increase in risk aversion.

tile corrections with shorter return periods, 12-week return periods therefore appear to be a good compromise. In the following analyses they will be the preferred choice.

Comparison of GRAIs with (Linear) RAI Results (12-week Return Period Length)
If the relationship between excess returns and proxies for past riskiness is approximately linear and not only monotonic, then the rank correlation results should be similar to those of a linear correlation approach (see also Misina (2006)). On the other hand, for a merely monotonic relationship the rank transformation should reduce the influence of extremes on estimating an aggregate or average relationship.

The first factor clearly is an extreme case, as by construction it will always have the highest historical variance within the set of given factors. One might therefore expect that the distinction between the rank and simple linear correlation approach should matter in particular for the results obtained when using the factor extension. This is also demonstrated in figure 5 of the appendix. The more pronounced amplitudes of the RAI-C indicators relative to the GRAIs suggest that the corresponding cross-sectional monotonic relationships exhibit some degree of non-linearity. This holds true even for the original asset returns. However, the difference in amplitudes – and thus the degree of the implied non-linearity – is much larger for the factor returns.

While the correlation-based indicators have the benefit of naturally bounded outcomes, the linear regression RAI-R indicators seem more popular in the literature. But as the factor extension exacerbates the non-linearity problem, it leads to the obvious question to what extent factor-based RAI-R results might be driven by the first factor. Figure 6 in the appendix illustrates this problem. For the period of 2002 to 2007, the graph of the RAI-R indicator using factor returns almost exactly overlaps the graph of the negative of the return/variance ratio for the first factor alone. Accordingly, the large t-values for the factor-based RAI-R indicators should be read as a further indication of the problem of applying a linear approach to a cross-section of such factor returns. However, figure 6 also suggests that the indicator implied by the first factor alone might be another valuable risk appetite indicator – but with a different target group in mind. While the GRAI concentrates on the general or average risk appetite of investors overall, the risk appetite indicator implied by the first factor alone is concerned with the risk compensation for the derivative asset with highest risk. Thus, it may be regarded as informative concerning the risk appetite/aversion changes of a hypothetical marginal investor only investing in portfolios of the highest risk.

3.3. GRAIs – Extending the Coverage to Bond Market Segments

This section extends the coverage of financial market segments to bond markets, which are represented by a sample of Merrill Lynch bond and ABS indices (for details see table 3 in the appendix). Using a 12-week return period, figure 7 compares the results for the GRAIs obtained for three data sets. For easier comparison, the results for the previous set of international stock indices are included as a first case (**Equity**) in addition to the results for a second data set composed of corporate and ABS bond indices plus a US government bond index (**Bonds/USG**). Finally, the two sets are merged into a third set of international stock and bond indices (**Eq/Bonds/USG**). While figure 7 covers the period from 2000 onwards, figure 8 is a snapshot of the period starting in 2006. [29]

The graphs support the notion that investor risk appetite changes are at times different for the various market segments. However, the GRAIs for the merged set exhibit a greater degree of comovement with the GRAIs derived from the stock indices alone than with the respective bond-only indicators.[30] The highest degree of correspondence between the respective GRAIs for the merged and the bond set is obtained when using the factor extension combined with scaled 1-week return VCV matrices.[31] But as afore, the choice of how to calculate the respective (co-)variances has an overall larger impact on the F-GRAIs than on the R-GRAIs. This holds true for the bonds-only as well as the merged data set.[32]

Focusing on the respective GRAI results before and during the latest financial stress period in figure 8, one observes a strong increase of the bond-only R-GRAIs already in May 2007. Given the lack of a significant increase in the equity-set R-GRAIs around that time, this can be interpreted as risk aversion having increased in the bond market segment first. As this is the financial market segment immediately affected by the subprime mortgage crisis, this is plausible. However for equity and bond markets combined, the merged-set R-GRAI still suggests a significantly increasing risk appetite around July 11, 2007. After a short period of significantly increasing risk aversion around mid- to end of August 2007, it again implies a significantly increasing risk appetite at the merged-set level between October to mid-December 2007. However, considering the overall situation the earlier increase as well as the later less significant reduction of the merged-set F-GRAI altogether appear more in line with common intuition. The differences are less strong when one takes into account that the significant risk aversion changes implied by the merged-set R-GRAIs were to some degree balanced by significant changes of opposite sign after the outbreak of the latest crisis period. Nevertheless, overall the merged-set F-GRAIs are conservative in the sense that they less often suggest significant changes in investors' risk appetite in the first place.

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[29] Apart from the highlighted periods of financial market stress, the figures also include the critical values for a two-sided significance test of the rank correlation at a 5% significance level for a cross-section of n=46 (i.e., for the merged set of 24 international stock indices and 22 bond indices including the USG index). For the critical values see again Zar (1972).

[30] For scaled VCVs and 12-week return periods e.g., the correlation between equity-only and merged-set F-GRAIs (R-GRAIs) in the period of Jan. 5, 2000 to March 12, 2008 is roughly 0.72 (0.78) versus 0.55 (0.42) between bond-only and merged-set F-GRAIs (R-GRAIs).

[31] For 12-week return periods, the correlation between the equity/bond/USG and bond/USG-only F-GRAIs (R-GRAIs) in the period of Jan. 5, 2000 to March 12, 2008 is approx. 0.55 (0.42) under the scaling approach versus 0.28 (0.47) under the temporal aggregation approach to calculating VCVs.

[32] The correlation between 12-week return period F-GRAIs (R-GRAIs) obtained with the two methods of calculating VCV matrices for the period of Jan. 5, 2000 to March 12, 2008 is roughly 0.46 (0.98) for the bonds/USG set and 0.67 (almost 1) for the merged set.

The choice of indices always involves some discretion. Due to its size and in general high degree of liquidity, the US government bond market plays a special role for international financial markets[33]. The reference bond data set therefore includes only an index for the US Treasuries, but no government bond index for another major developed country. Hence figure 9 in the appendix compares the results obtained in the 2006 – 2008 period for merged sets slightly differing in terms of included government bond indices from developed countries.[34] These small modifications, however, have only a negligible impact on the respective GRAI results.

3.4. A Caveat – The GRAIs and the Role of Risk Ranking Stability

Apart from the plausibility of results, an important criterion for judging indicators is the validity of core assumptions on which they are based. When constructing the GRAI for time t, it is conditional on the ranking of assets in terms of their return riskiness at the beginning of the m-week return period, i.e. at time t-m. Thus, one implicitly makes the simplifying assumption that this initial risk ranking of assets remains relevant to investors throughout the return period.[35] However, investors may change their assessment of assets' riskiness during the weeks of the return period, and the risk rankings of assets so most likely change as well. While the assumption is therefore likely to be violated to some extent, large violations obviously pose a problem. This holds true even if one is only interested in a broader risk appetite/aversion interpretation of the GRAI.[36]

One might expect this problem to grow with the length of the return period. Furthermore, the factor extension of the GRAI adds another dimension of complexity. This is particularly relevant for larger cross-sections. Finally, also the use of the scaling or the temporal aggregation approach to calculating (co-)variances can matter. An analysis of the potential susceptibility of the different GRAI variants to large intra-period changes in risk rankings is thus warranted. It also seems useful as a further criterion by which to judge their relative merits.

For the equity-only and combined-set F-/R-GRAIs, figures 11 to 13 in the appendix depict the maximum and minimum changes of (factor) asset variance ranks over the respective return period at each point in time, as well as the respective max-min spread. As expected, a longer return period is accompanied by larger max-min spreads of risk ranking changes. Furthermore, as illustrated by figure 14, the method of obtaining VCV matrices via scaling overall leads to smaller max-min

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[33] US Treasuries are also often referred to as a kind of "safe haven" asset for international investors in stressful times.

[34] Considering the combinations of USD valued government bond indices for the US, UK, Canada, plus in a second step, also Germany, Australia, and Japan; however, the case of including no government bond index is also considered.

[35] Misina (2006) argued that any additional conclusion respectively interpretation whether the GRAI might reflect changes in investors' more narrowly defined fundamental degree of risk aversion was conditional on the likelihood of common shocks having occurred. As a proxy for the latter, he used the number of factors whose volatilities had changed in the same direction over the return period. The question of risk ranking stability considered here is of course related but still different, as it is concerned only with the question to what extent such changes of factor variances were so large as to have led to changes in (implied) risk rankings.

[36] The larger the extent to which the assumption seems violated, the more problematic it becomes to interpret the signals of significant GRAI values as indicating at least changes of a broadly-defined risk aversion stance of investors.

spreads of (derivative) asset risk rank changes than the temporal aggregation approach. This holds true in particular for the F-GRAI, but in general also for the R-GRAI. Accordingly, for the equity-only data set the F-GRAI has an advantage over the R-GRAI in terms of the risk ranking stability criterion, in particular when using scaled covariances and 12- respectively 24-week return periods. For the merged data set, the evidence of a risk ranking stability advantage of the F-GRAI over the R-GRAI is more mixed as results depend on the combination of return period length and approach to calculating (co-)variances. However, with respect to overall risk ranking stability, the combination of F-GRAI with scaled VCV matrices and longer return periods remains the preferred choice also for the merged equity-bond data set.[37]

3.5. A Correlation-Based Comparison with Alternative Indicators

The number of risk appetite indicators presented in the literature is ample evidence of the lack of consensus on how to best assess the evolution of investors' risk appetite respectively its changes. Nonetheless, under the assumption that the different indicators are all imperfect proxies for investors' risk appetite/aversion changes, a principal component analysis (PCA) could be used to recover a potential common component as the common information contained in the individual indicators. However, when performing a PCA for nine market- and five theory-based risk appetite indicators, the ECB (2007b) found that the first two principal components together were able to explain only about 56% of the overall variance of the indicators. They therefore concluded that "differences in methodologies and underlying data" represented too big a problem when trying to recover "a common component between several commonly followed [market-based and theory-based] indicators" which could "explain large proportions of their variance". Accordingly, they derived their common component risk appetite indicator only for the set of chosen market-based indicators.

It is thus important to better understand to what extent these apparent differences between theory-based and market-based indicators depend on decisions made when constructing the indicators. Accordingly, not only GRAIs but also corresponding RAI variants are included in the following comparison with four alternative market-based risk sentiment indicators. We follow the ECB (2007b) and exploit the dimension-reducing properties of a PCA on the set of alternatives, though. Table 4 in the appendix presents the correlation coefficients for each of the equity-only and merged-set (G)RAI variants and the first principal component of the four alternative market-based indicators,

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[37] Figure 15 in the appendix also investigates whether a significant value of the GRAI coincides with a significant rank correlation between the asset/factor return variance changes over the return period and the past (i.e. beginning-of-period) variances. If there is a significant rank correlation between past variances and in-period variance changes with the same sign as the significant GRAI, one cannot exclude the possibility that the GRAI results might only reflect an adjustment of relative demand for riskier assets in response to the changes in the risk dimension, but not necessarily changes in the risk appetite/aversion stance of investors in a narrower sense. On the other hand, in case of significance of both but of opposite sign, this could tentatively be interpreted as a signal for increasing investor appetite for risk. The results in figure 15 suggest that at times such interpretation problems could even be observed for the F-GRAIs. However, this is not the case at the beginning of the latest stress period, in particular when looking at equity markets, but also initially for the equity-bond data set. This further supports the notion that investor risk aversion itself increased during the initial stage.

with values of 0.45 or larger highlighted.[38] The results for the longer period of November 8, 2000 to March 12, 2008 can be summarized as follows:

- Comparing the correlation coefficients across the two methods of calculating the variance-covariance matrices, the differences are in general relatively small. The exception is the merged-set F-GRAI with 12-week return periods.
- Shortening return periods is usually accompanied by an increase in the correlation coefficients, ceteris paribus. Market-based alternative indicators are likely to be relatively volatile given the continuous adjustments to changing market conditions. Hence longer return periods might make it harder to capture this via the (G)RAI indicators. This is due to the implied smoothing effect. However, for the merged-set F-GRAI and the equity-only R-RAI-C the choice of a 12-week return period resulted in higher correlation coefficients than either 24- or 4-week return periods.
- For the most part, the factor-extended (G)RAIs exhibit a higher correlation with the first principal component of the alternative indicators than the corresponding (G)RAIs without the factor extension. For the merged equity-bond data set, however, such a correlation advantage is obtained only for the 24-week return F-GRAI. The difference between the correlation coefficients obtained for the merged-set 12-week return F-GRAI based on scaled VCV matrices and for the corresponding merged-set R-GRAI is negligible, though.

The second panel of table 4 explores the stability of results by focusing on the last five years of the sample period. The correlation coefficients obtained for the preferred combination of scaled VCV matrices and 12-week returns over this shorter recent period tend to be smaller. An exception is the corresponding merged-set F-GRAI. There we find a correlation advantage over the respective merged-set R-GRAI calculated with scaled (co-)variances and 12-week returns.

Overall, the correlation analysis therefore supports the conclusion that the gap between market-based and theory-based indicators can be considerably reduced when accounting for such specification effects in the construction of indicators. In particular for the last years, the F-GRAIs obtained with the preferred setup of scaled VCV matrices and 12-week return periods are not only more appealing from a theoretical point of view. They also exhibit a higher degree of co-movement with the common component of the market-based risk aversion indicators than the corresponding R-GRAIs.

However, across all GRAI variants the largest correlation coefficient is observed for the 4-week return merged-set R-GRAI without the factor extension. This implies that a correlation analysis is

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[38] The first principal component (explaining about 71% of the overall variance) was calculated for weekly (Wednesday) observations (going from April 1, 1998 to March 12, 2008) of the following four indicators: the Citi Macro Risk Index (Bloomberg Ticker: MRI CITI Index), the risk aversion indicator implied by the Morgan Stanley Global Risk Demand Index (Ticker: STGRDI Index), the Westpac Risk Aversion Index (Ticker: WRAIRISK Index), and the UBS G10 Carry Risk Index Plus (ULTAFXRI Index). Where necessary, values were multiplied by -1 to correspond to a risk aversion interpretation. Data for the original alternative indices were downloaded from Bloomberg.

illustrative but should not be a major criterion on which to base preferences concerning the specification of an indicator. The correlation between two series only measures their degree of co-movement. However, apart from the problem that by aggregating across several alternative indicators one still does not necessarily arrive at an ideal yardstick of investor risk appetite changes, other considerations are more important criteria, like the plausibility of results and underlying assumptions. As figure 16 shows, during the latest crisis period the 12-week return equity-only and merged-set F-GRAIs delivered more plausible results and so seem preferable to the 4-week return merged-set R-GRAI. The F-GRAIs are also more in line with the common component of the alternative market-based risk aversion indicators.

4. Summary and Conclusions

Changes in investors' risk appetite are more and more recognized as important factors when assessing financial markets stability. While this creates an obvious need for quantification, currently available risk appetite indicators are not satisfactory. Thus it is essential to gain a better understanding of how existing indicators actually work.

Focusing on the (G)RAI class of indicators, this study analyses how indicator results obtained for samples of stock indices respectively stock and bond indices combined are shaped by the various choices made when constructing such an indicator. Initial decisions include the choice of the length of return periods and how to proxy for the asset riskiness at the beginning of the return period. For the latter, we consider two options, namely using short-term asset risk measures based on scaling weekly return (co-)variances or longer-term risk measures derived via a temporal aggregation of weekly return (co-)variances over a few weeks. One also has to decide whether to assume a monotonic or a linear relationship between asset excess returns and appropriately lagged risk measures when deriving the risk aversion indicator. Furthermore, one has to choose whether to derive it as a correlation- or regression-based indicator. The Kumar and Persaud (2002) GRAI indicator we focus on is a rank-correlation indicator and thus based on the more general case of a monotonic relationship. Finally, when constructing a GRAI another decision concerns whether to account for a dependence between asset returns by applying a factor extension as proposed by Misina (2006). Aside from analyzing how all these decisions influence the indicator one ends up with, the main goal of this study is to find a combination of decisions that overall delivers the best empirical performance of the resulting risk aversion indicator in terms of certain plausibility and consistency criteria.

For comparability reasons, Misina (2006) applied his indicator to a similar FX data set as Kumar and Persaud (2002). One contribution of the current paper therefore consists of applying the factor-extended GRAI approach not only to individual financial market segments, but also to a large pooled data set covering equity and bond markets together. Furthermore, a spuriously different behavior of GRAIs from their factor-extended versions can arise as a consequence of the normalization of eigenvectors alone, unlike argued by Misina (2006), being insufficient for defining unique vectors. We therefore introduce a normalization-plus restriction for the factorization step to ensure the uniqueness of eigenvectors. This leads to our modified factor-extended rank-correlation F-GRAI as another major contribution of the present paper. Finally, we systematically investigate to what extent the factor extension in combination with the other construction choices leads to an improvement of the GRAI's empirical performance. Our most important guideline in this respect is the overall plausibility of the indicators with respect to the implied aggregate risk appetite changes during crisis times, in particular the recent period of financial market turmoil. However, another contribution of this paper is the development of additional consistency criteria for evaluating e.g. the relative attractiveness of F-GRAIs versus R-GRAIs. These criteria are based on violations of an important implicit assumption used in the construction of the GRAIs, namely intra-return period asset risk ranking stability.

Summing up the main empirical results, based on asset risk ranking stability considerations we prefer the use of scaled VCV matrices when constructing the weekly GRAI indicators for the equity-only and the merged equity and bond data sets. Furthermore, a return period length of 12 weeks appears to be a good compromise between the smoothness supplied by longer return periods and the loss of potentially important short-term information. Finally, for deriving an indicator for changes in average investor risk aversion the GRAI rank-correlation approach seems overall preferable to the linear correlation or regression RAI variants. This holds in particular when the factor extension is applied. Focusing more narrowly on the GRAIs obtained for the preferred combination of 12-week returns and scaled (co-)variances, in the equity-only case we find that the plausibility of results during the latest crisis strongly benefits from applying the rank correlation of Kumar and Persaud (2002) combined with our modified version of the Misina (2006) factor-transformation extension. For the larger cross-section of the merged set of bond and stock indices, on the other hand, also the GRAI without factor extension indicates a significant increase in investor risk aversion at least for some time in August 2007. However, although the larger cross-section is likely to pose a challenge due to the additional complexity of the factorization step, the merged-set factor-extended GRAI still fares quite well in terms of overall plausibility, too. Finally, over the period of March 2003 to March 2008, both the equity-only and the merged-set factor-extended GRAIs are also more highly correlated with the first principal component (PC) obtained for four market-based risk aversion indicators than the corresponding GRAIs without factor extension. This demonstrates the importance of taking into account indicator construction decisions as one way of potentially reducing the gap between market-based and theory-based indicators noted in ECB (2007b).

At the end of this paper, we thus have obtained two new feasible factor-extended GRAIs – one for stock markets alone, one for stock and bond markets combined – which seem very promising for financial stability supervision purposes and future empirical applications. However, that is only one major achievement of the paper. Most importantly, we have gained a much better understanding of the chosen risk appetite indicator concept, and we have seen how strongly the quality of indicator results depends on technical implementation decisions. It is therefore absolutely essential to take this into account when using such indicators in practice.

Appendix

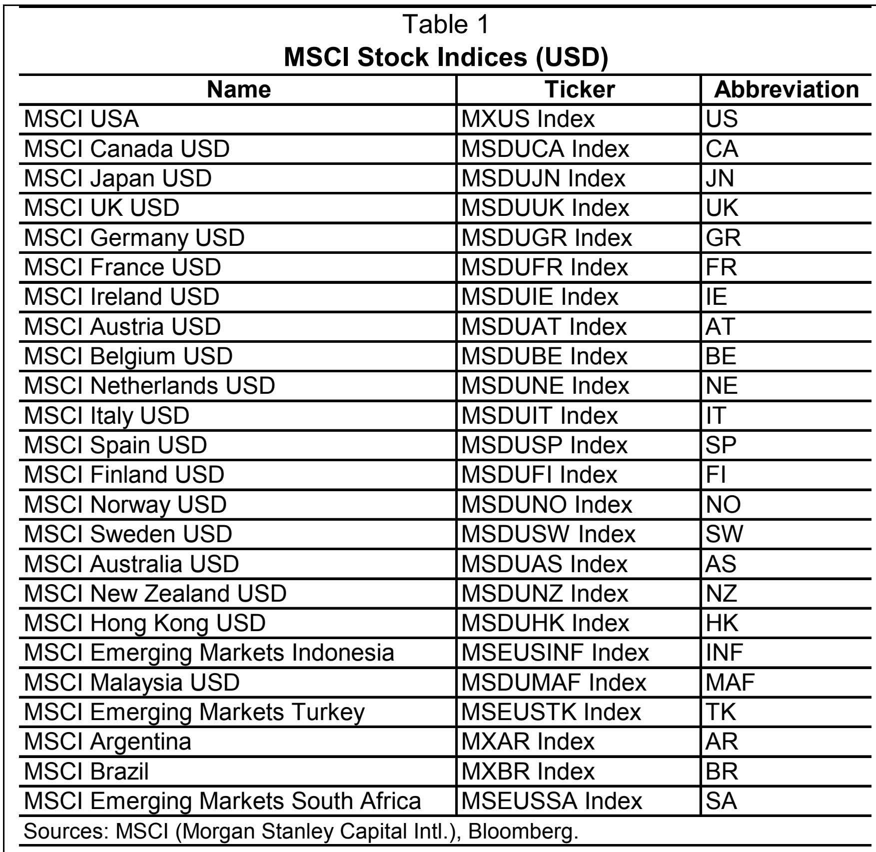


Table 1

MSCI Stock Indices (USD)

Name	Ticker	Abbreviation
MSCI USA	MXUS Index	US
MSCI Canada USD	MSDUCA Index	CA
MSCI Japan USD	MSDUJN Index	JN
MSCI UK USD	MSDUUK Index	UK
MSCI Germany USD	MSDUGR Index	GR
MSCI France USD	MSDUFR Index	FR
MSCI Ireland USD	MSDUIE Index	IE
MSCI Austria USD	MSDUAT Index	AT
MSCI Belgium USD	MSDUBE Index	BE
MSCI Netherlands USD	MSDUNE Index	NE
MSCI Italy USD	MSDUIT Index	IT
MSCI Spain USD	MSDUSP Index	SP
MSCI Finland USD	MSDUFI Index	FI
MSCI Norway USD	MSDUNO Index	NO
MSCI Sweden USD	MSDUSW Index	SW
MSCI Australia USD	MSDUAS Index	AS
MSCI New Zealand USD	MSDUNZ Index	NZ
MSCI Hong Kong USD	MSDUHK Index	HK
MSCI Emerging Markets Indonesia	MSEUSINF Index	INF
MSCI Malaysia USD	MSDUMAF Index	MAF
MSCI Emerging Markets Turkey	MSEUSTK Index	TK
MSCI Argentina	MXAR Index	AR
MSCI Brazil	MXBR Index	BR
MSCI Emerging Markets South Africa	MSEUSSA Index	SA

Sources: MSCI (Morgan Stanley Capital Intl.), Bloomberg.

Table 1: List of MSCI Stock Indices (USD)

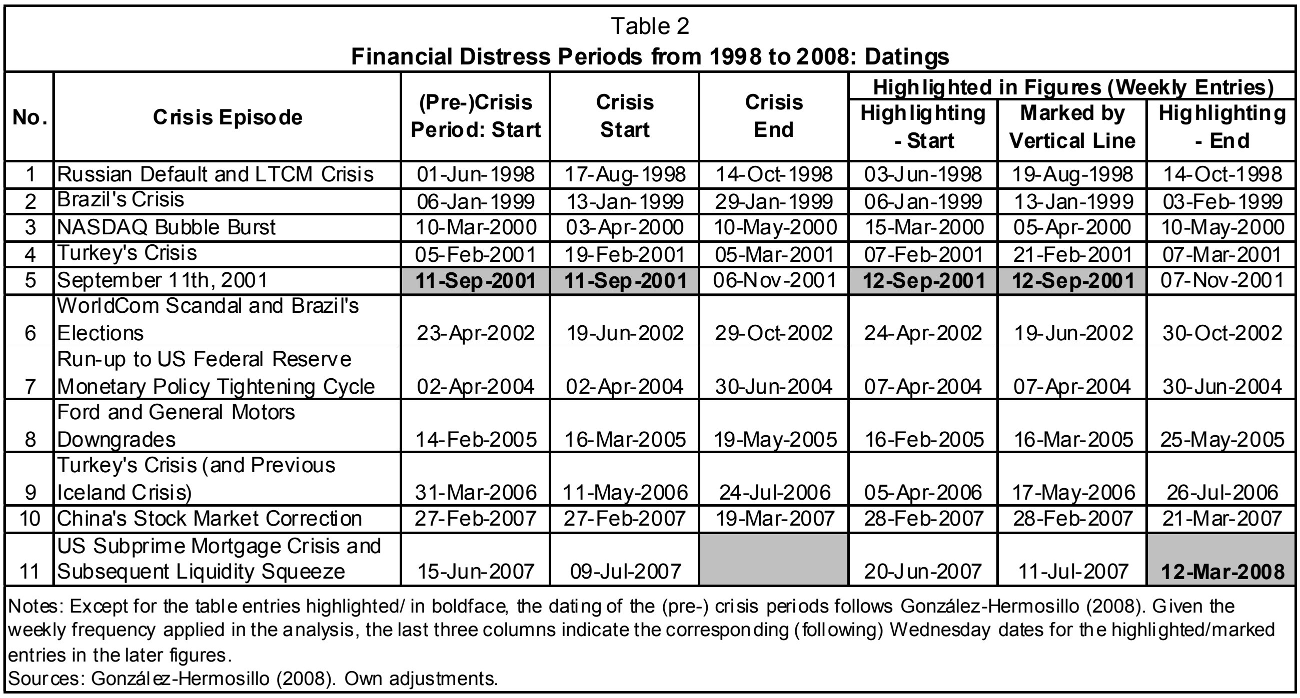


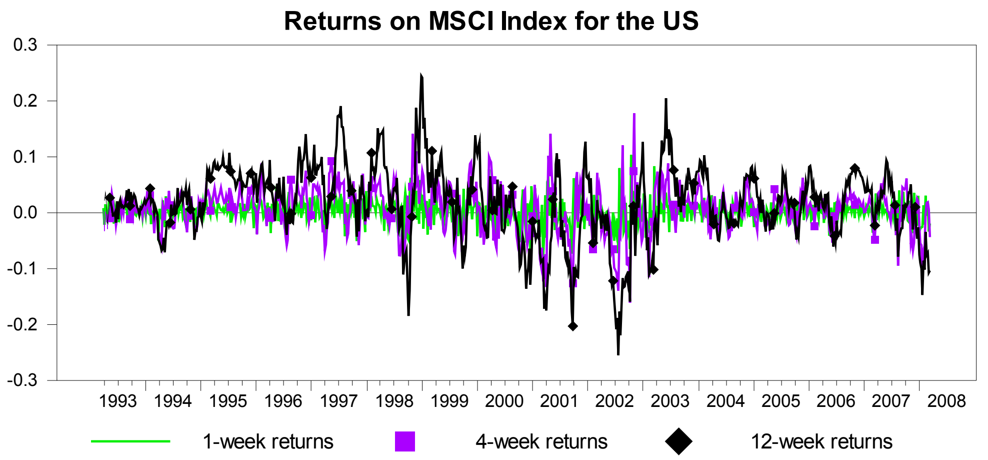
Table 2

Financial Distress Periods from 1998 to 2008: Datings

No.	**Crisis Episode**	**(Pre-)Crisis Period: Start**	**Crisis Start**	**Crisis End**	**Highlighted in Figures (Weekly Entries)**		
					Highlighting - Start	**Marked by Vertical Line**	**Highlighting - End**
1	Russian Default and LTCM Crisis	01-Jun-1998	17-Aug-1998	14-Oct-1998	03-Jun-1998	19-Aug-1998	14-Oct-1998
2	Brazil's Crisis	06-Jan-1999	13-Jan-1999	29-Jan-1999	06-Jan-1999	13-Jan-1999	03-Feb-1999
3	NASDAQ Bubble Burst	10-Mar-2000	03-Apr-2000	10-May-2000	15-Mar-2000	05-Apr-2000	10-May-2000
4	Turkey's Crisis	05-Feb-2001	19-Feb-2001	05-Mar-2001	07-Feb-2001	21-Feb-2001	07-Mar-2001
5	September 11th, 2001	**11-Sep-2001**	**11-Sep-2001**	06-Nov-2001	**12-Sep-2001**	**12-Sep-2001**	07-Nov-2001
6	WorldCom Scandal and Brazil's Elections	23-Apr-2002	19-Jun-2002	29-Oct-2002	24-Apr-2002	19-Jun-2002	30-Oct-2002
7	Run-up to US Federal Reserve Monetary Policy Tightening Cycle	02-Apr-2004	02-Apr-2004	30-Jun-2004	07-Apr-2004	07-Apr-2004	30-Jun-2004
8	Ford and General Motors Downgrades	14-Feb-2005	16-Mar-2005	19-May-2005	16-Feb-2005	16-Mar-2005	25-May-2005
9	Turkey's Crisis (and Previous Iceland Crisis)	31-Mar-2006	11-May-2006	24-Jul-2006	05-Apr-2006	17-May-2006	26-Jul-2006
10	China's Stock Market Correction	27-Feb-2007	27-Feb-2007	19-Mar-2007	28-Feb-2007	28-Feb-2007	21-Mar-2007
11	US Subprime Mortgage Crisis and Subsequent Liquidity Squeeze	15-Jun-2007	09-Jul-2007		20-Jun-2007	11-Jul-2007	**12-Mar-2008**

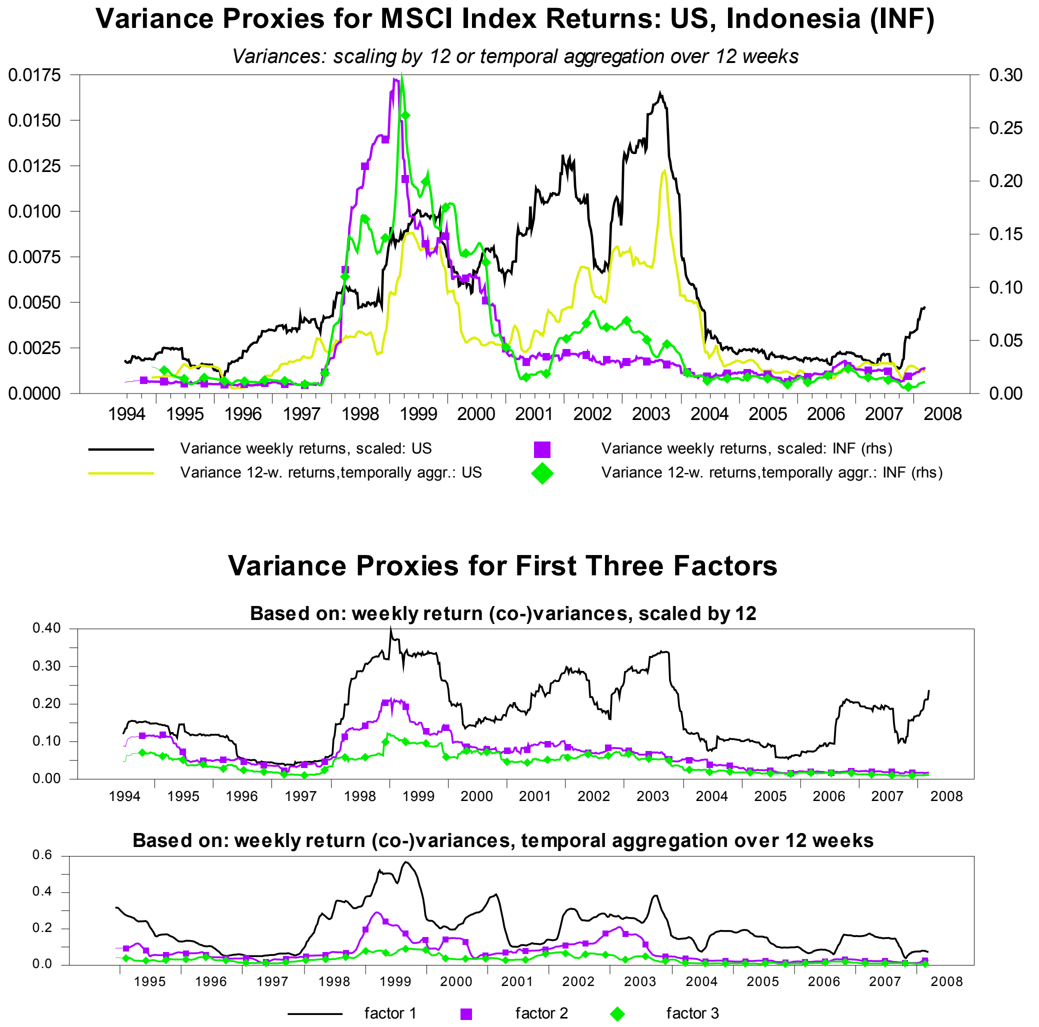
Notes: Except for the table entries highlighted/ in boldface, the dating of the (pre-) crisis periods follows González-Hermosillo (2008). Given the weekly frequency applied in the analysis, the last three columns indicate the corresponding (following) Wednesday dates for the highlighted/marked entries in the later figures.
Sources: González-Hermosillo (2008). Own adjustments.

Table 2: List of Special Events' Periods Highlighted in Figures



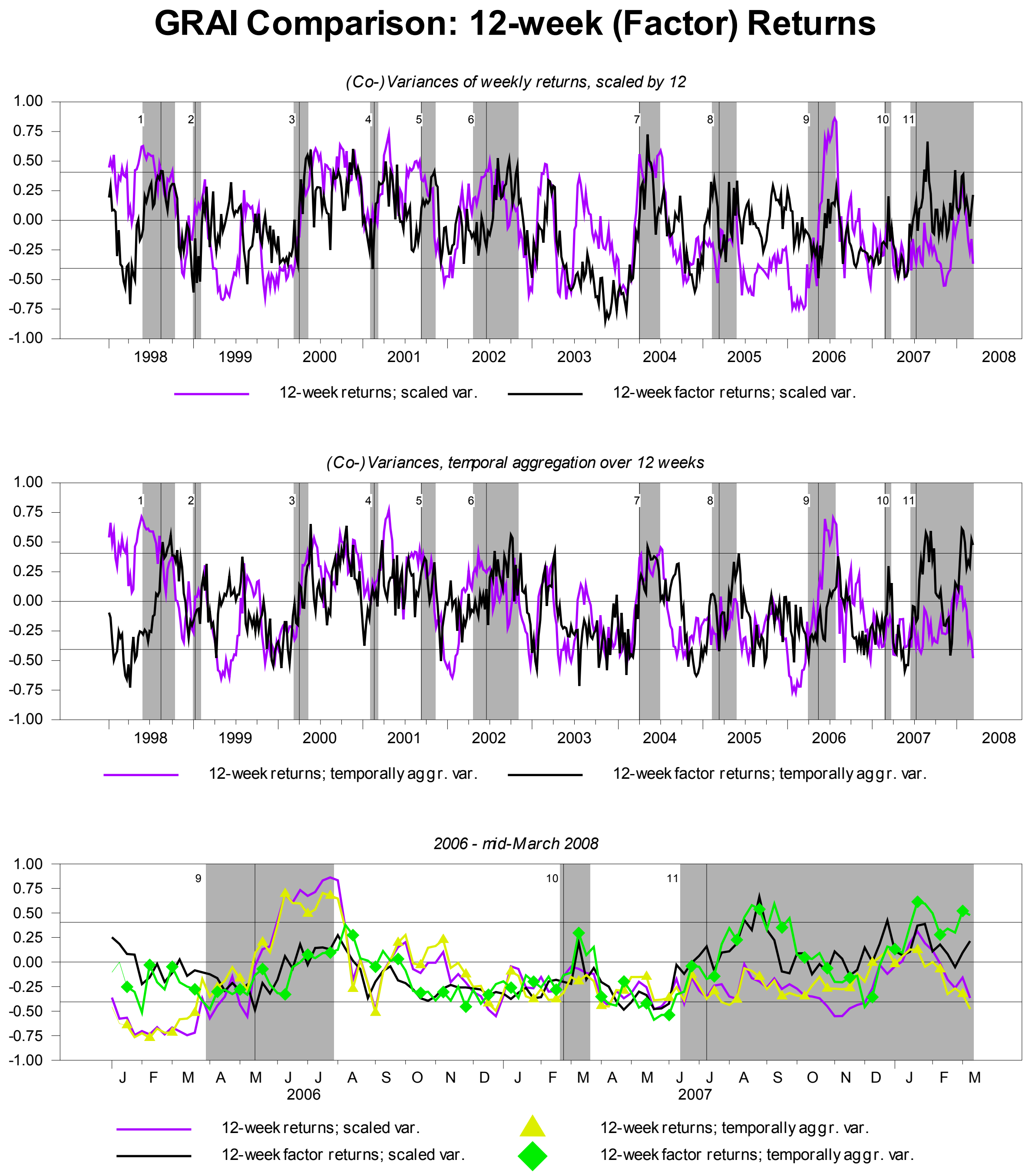
Sources: MSCI, Bloomberg. Own calculations.

Figure 1: Returns of MSCI Index for the US: Returns over 1, 4, and 12 weeks



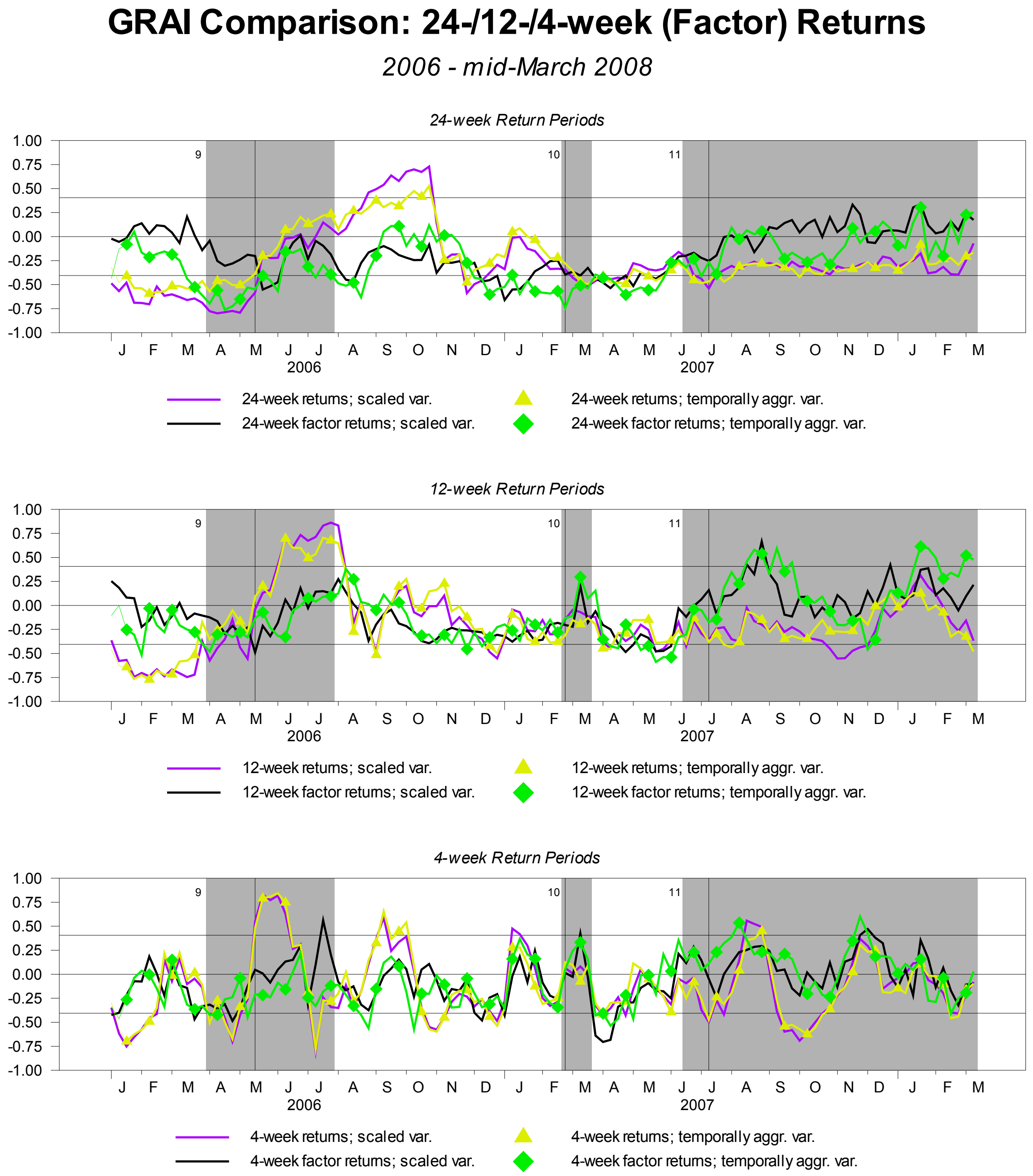
Sources: MSCI, Bloomberg. Own calculations.

Figure 2: Variance Proxies: MSCI Index Returns (US, Indonesia), First Three Factors



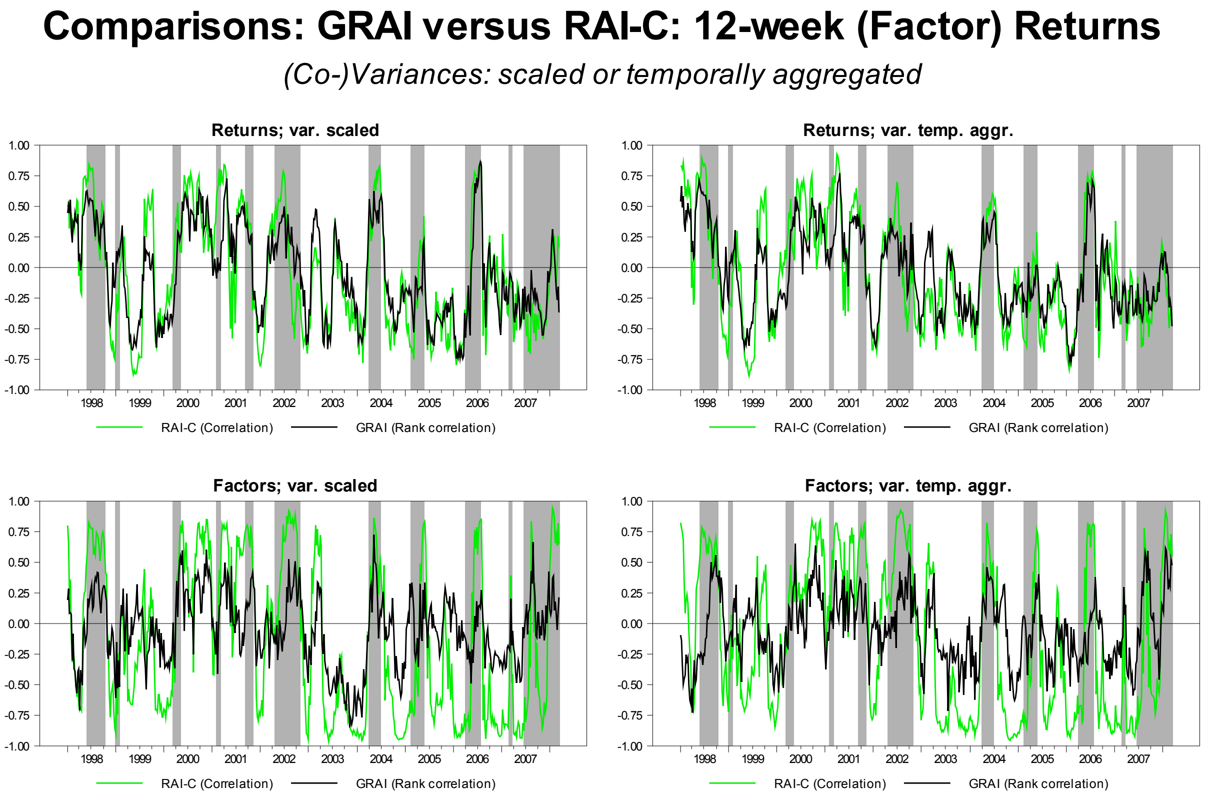
Sources: MSCI, Federal Reserve, Bloomberg. Own calculations.

Figure 3: GRAIs (12-week Return Periods): Equity-Only



Sources: MSCI, Federal Reserve, Bloomberg. Own calculations.

Figure 4: GRAIs (24-/12-/4-week Return Periods): Equity-Only – since 2006



Comparisons: GRAI versus RAI-C: 12-week (Factor) Returns

(Co-)Variances: scaled or temporally aggregated

Returns; var. scaled

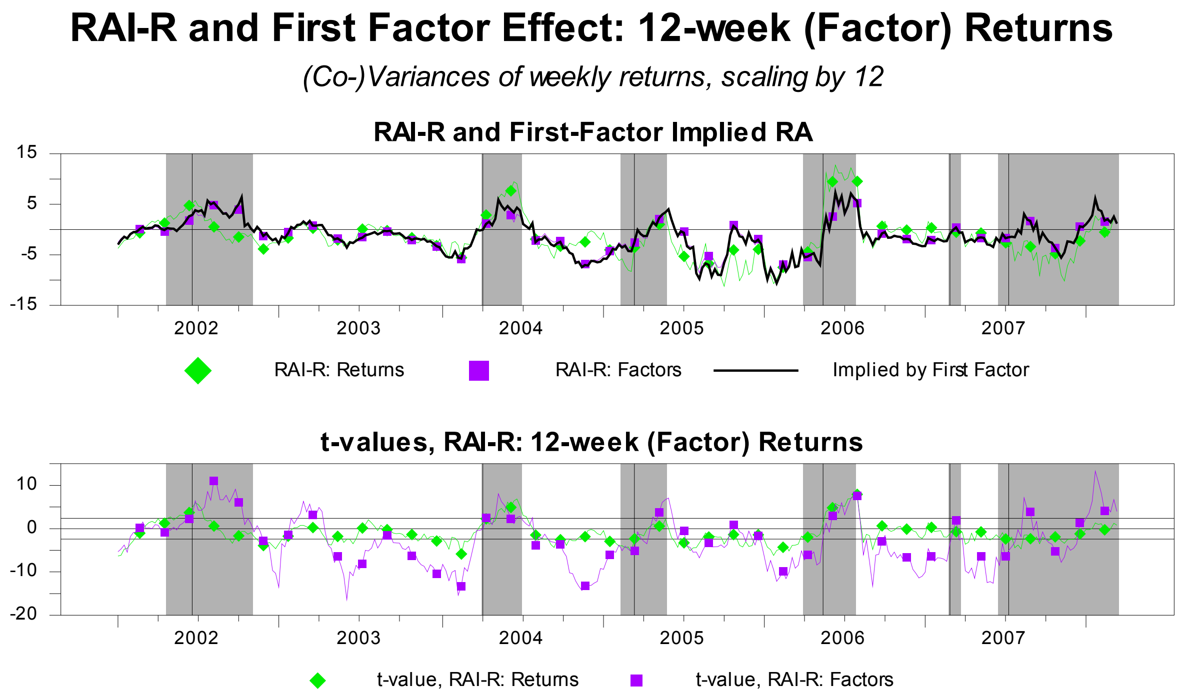
Returns; var. temp. aggr.

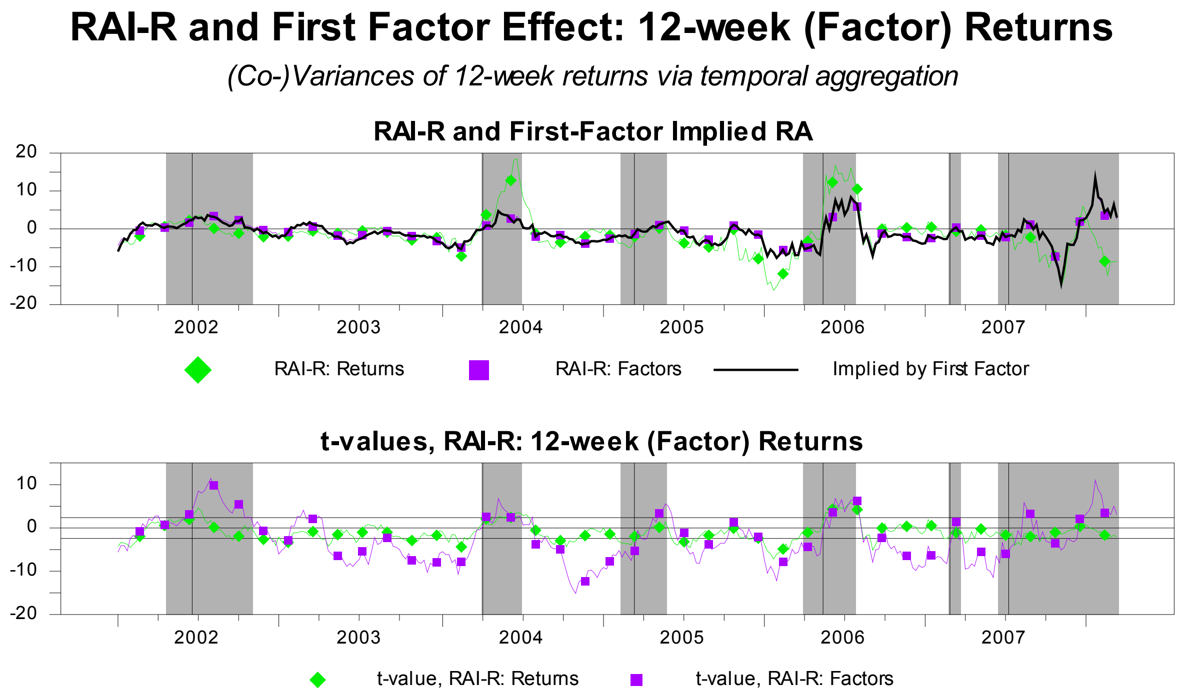
Factors; var. scaled

Factors; var. temp. aggr.

Sources: MSCI, Federal Reserve, Bloomberg. Own calculations.

Figure 5: GRAI versus RAI-C (12-week Return Periods): Equity-Only





Sources: MSCI, Federal Reserve, Bloomberg. Own calculations.

Figure 6: RAI-R vs. RA Implied by First Factor (12-week Return Periods): Equity-Only

Table 3

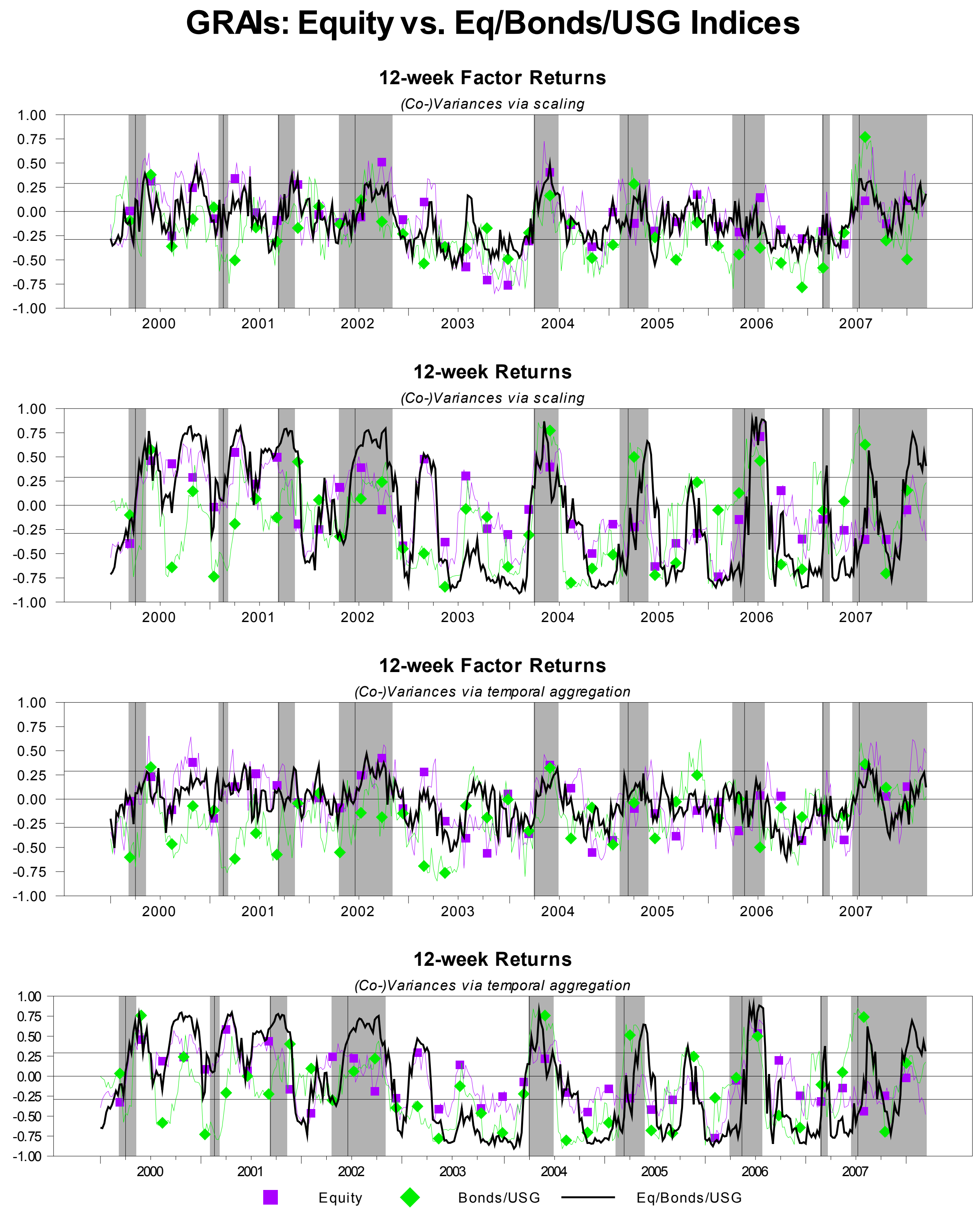
Table Merrill Lynch Indices

(TRR (Total Return) Indices, Val $USD)

Name	Ticker	Abbreviation
U.S. Treasuries, 7-10 years	G4O2	USG
Corporate Bonds, US Industrials, AA-AAA Rated	C6E0	USINDA
Corporate Bonds, US Industrials, BBB-A Rated	C6F0	USINDB
Corporate Bonds, US Utilities, AA-AAA Rated	C6H0	USUTILA
Corporate Bonds, US Utilities, BBB-A Rated	C6I0	USUTILB
Corporate Bonds, US Financials, AA-AAA Rated	C6K0	USFINA
Corporate Bonds, US Financials, BBB-A Rated	C6L0	USFINB
Corporate Bonds, US Banks, AA-AAA Rated	C6X0	USBKA
Corporate Bonds, US Banks, BBB-A Rated	C6Y0	USBKB
ABS, HEL (Home Equity Loans), AAA Rated	R0H1	ABSHEA
ABS, HEL (Home Equity Loans), BBB-AA Rated	R0H2	ABSHEB
ABS, Manufactured Housing, AAA Rated	R0M1	ABSMHA
ABS, Manufactured Housing, BBB-AA Rated	R0M2	ABSMHB
ABS, Automobiles, AAA Rated	R0U1	ABSAUA
ABS, Automobiles, BBB-AA Rated	R0U2	ABSAUB
ABS, Credit Cards, AAA Rated	R0C1	ABSCCA
ABS, Credit Cards, BBB-AA Rated	R0C2	ABSCCB
USD BB Rated EM Sovereigns	I1GV	EMSOVBB
USD B Rated EM Sovereigns	I2GV	EMSOVB
USD CCC and Lower Rated EM Sovereigns	I3GV	EMSOVCCC
US High Yield, BB-B Rated	H0A4	HYBB_B
US High Yield, CCC Rated and Lower	H0A3	HYCCC
Extended Lists: Also		
Canadian Governments, 7-10 years	G4C0	CAG
Japanese Governments, 7-10 years	G4Y0	JPNG
U.K.Gilts, 7-10 years	G4L0	UKG
German Federal Governments, 7-10 years	G4D0	BDG
Australian Government, 7-10 years	G4T0	ASG

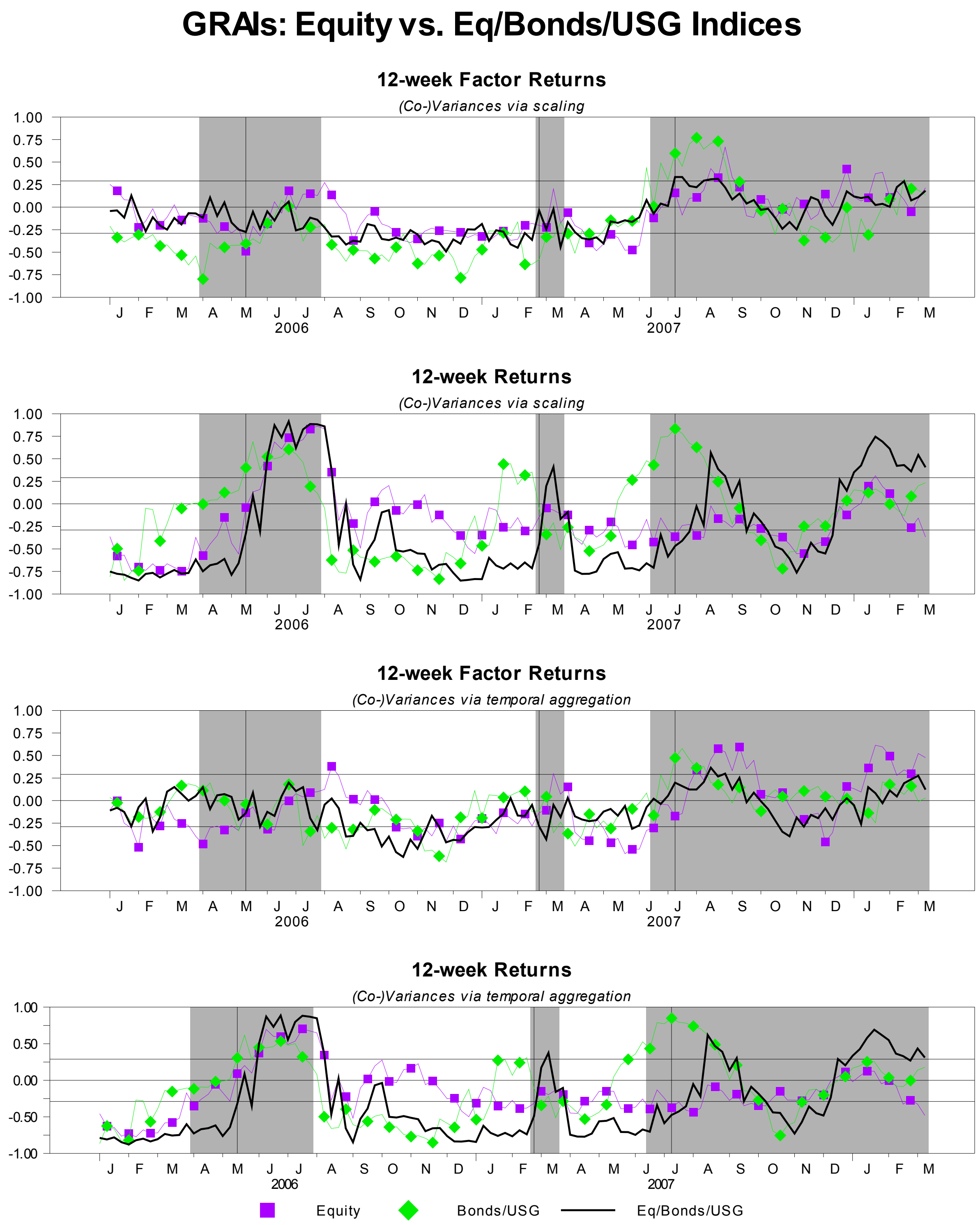
Sources: Merrill Lynch, Bloomberg.

Table 3: List of Merrill Lynch Indices



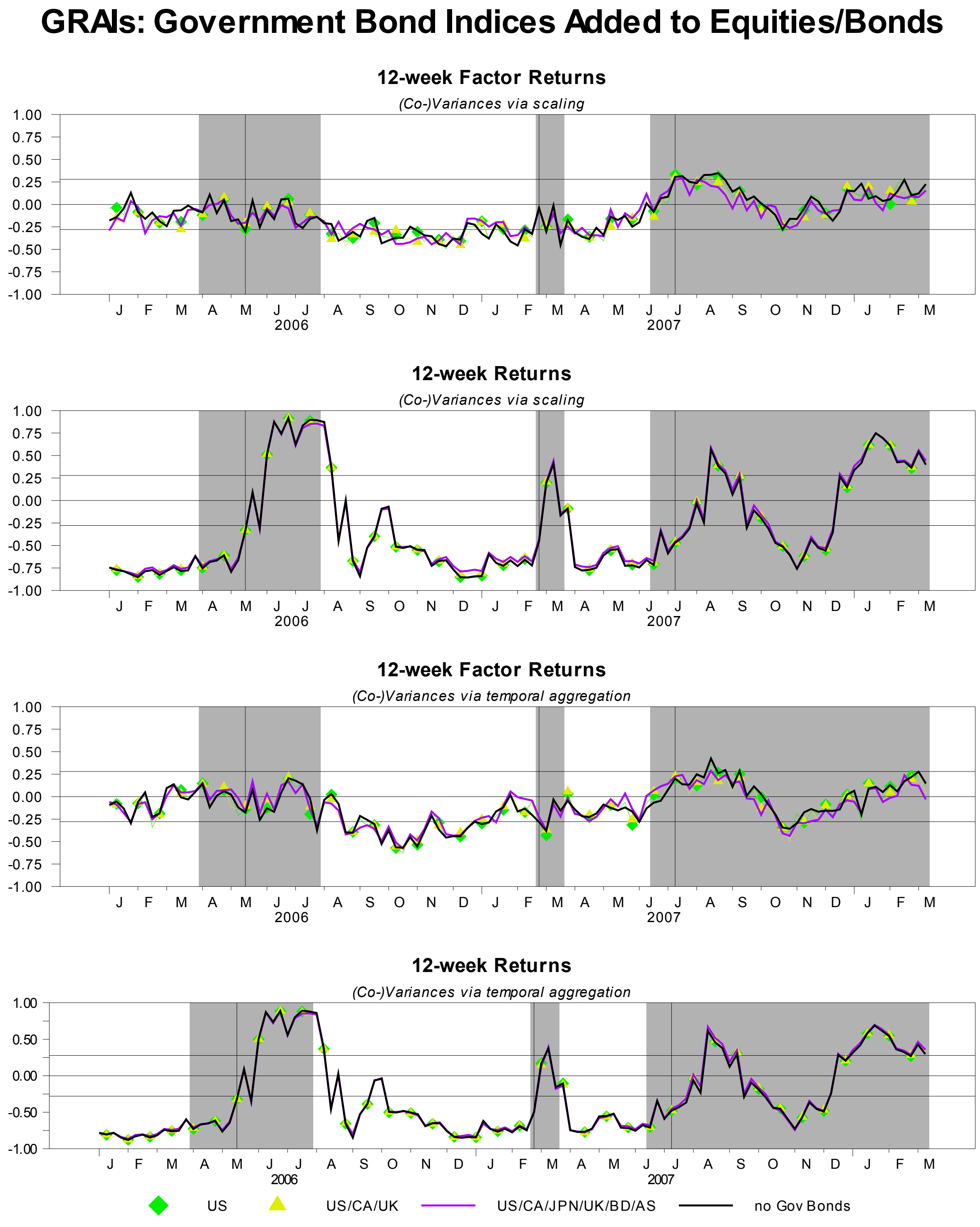
Sources: MSCI, Merrill Lynch, Federal Reserve, Bloomberg. Own calculations.

Figure 7: GRAIs (12-week Return Periods): Equity vs. Bond/US Government Bond Indices



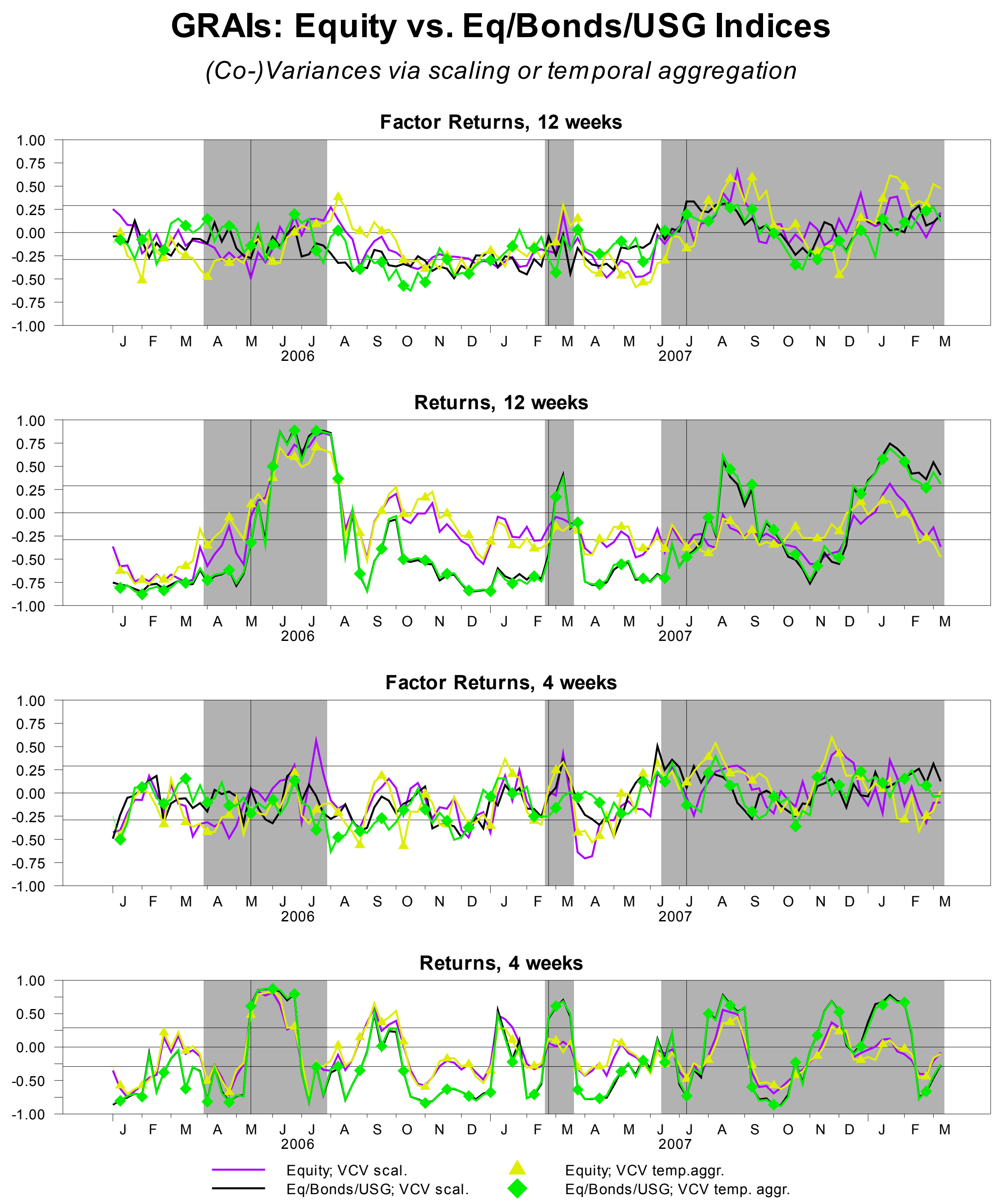
Sources: MSCI, Merrill Lynch, Federal Reserve, Bloomberg. Own calculations.

Figure 8: GRAIs (12-week Return Periods): Equity vs. Bond/US Government Bond Indices – since 2006



Sources: MSCI, Merrill Lynch, Federal Reserve, Bloomberg. Own calculations.

Figure 9: GRAIs (12-week Return Periods): Adding Government Bond Indices – since 2006

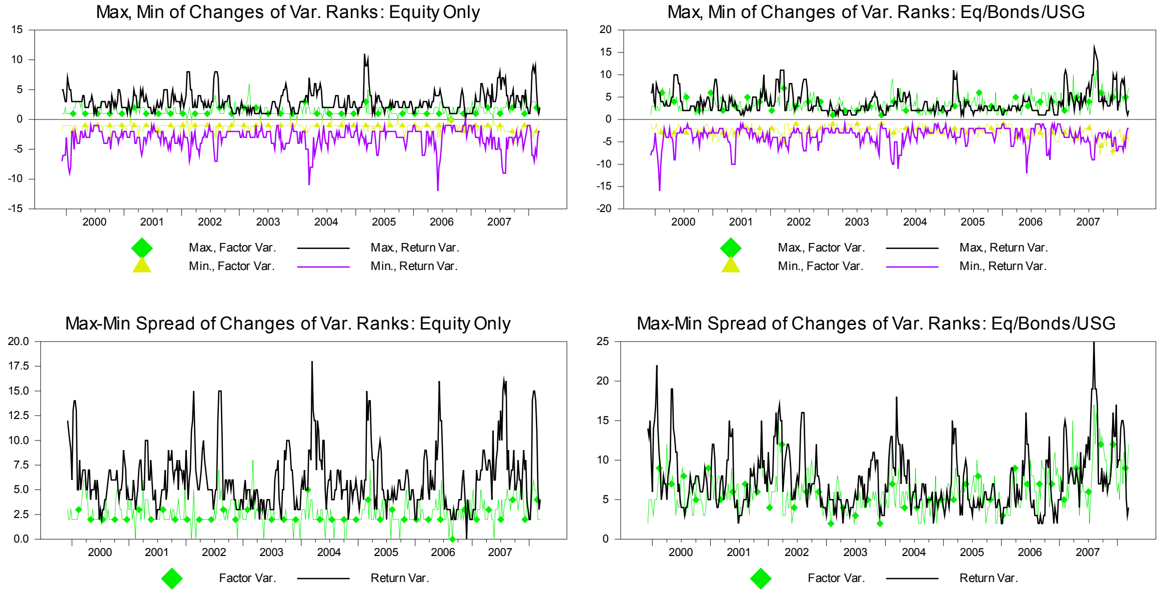


Sources: MSCI, Merrill Lynch, Federal Reserve, Bloomberg. Own calculations.

Figure 10: GRAIs (12-/4-week Return Periods): Equity vs. Equity/Bond/US Government Bond Indices

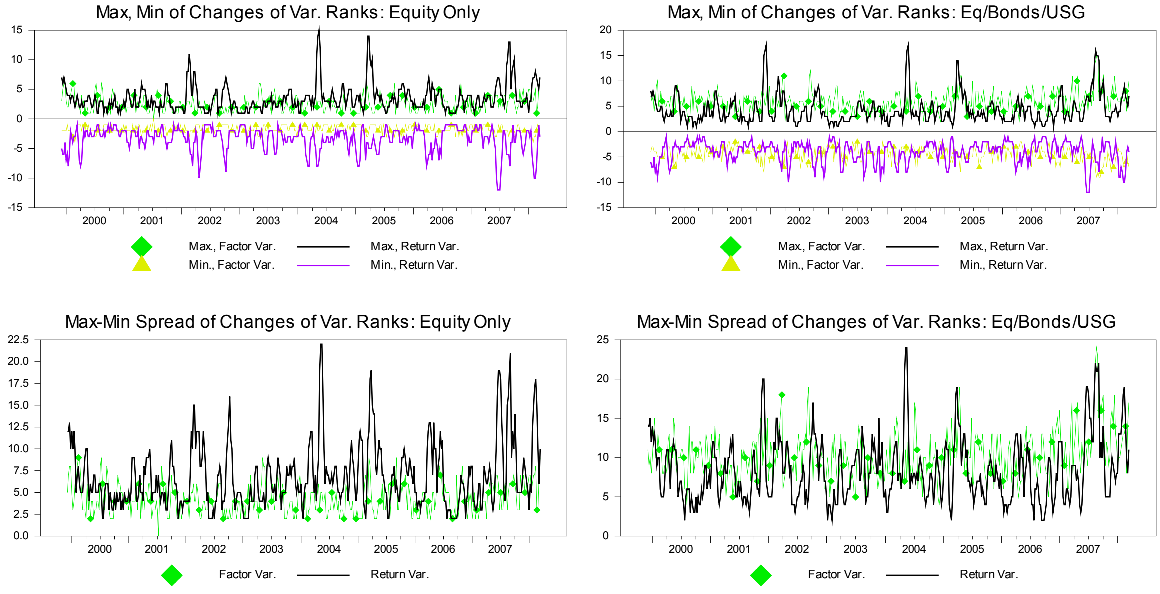
Change of Var. Ranks: F-GRAI and R-GRAI, 4-w. returns

Max, min, spread; (co-)variances via scaling



Change of Var. Ranks: F-GRAI and R-GRAI, 4-w. returns

Max, min, spread; (co-)variances via temporal aggregation

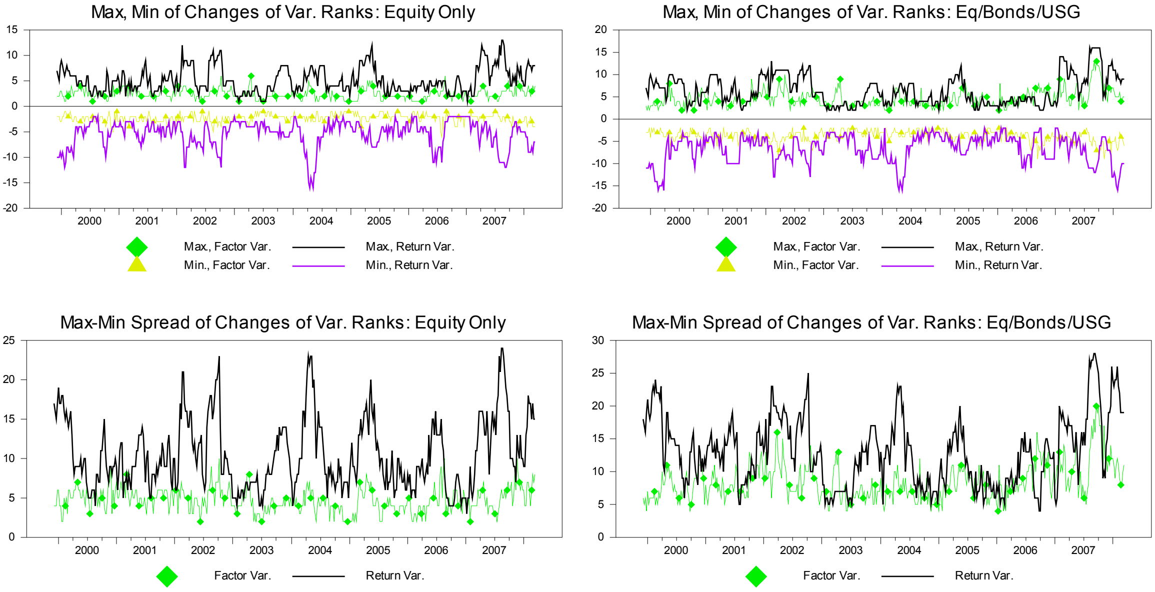


Sources: MSCI, Merrill Lynch, Federal Reserve, Bloomberg. Own calculations.

Figure 11: Max, Min, Spread: Change of Variance Ranks / GRAIs (4-week Return Periods)

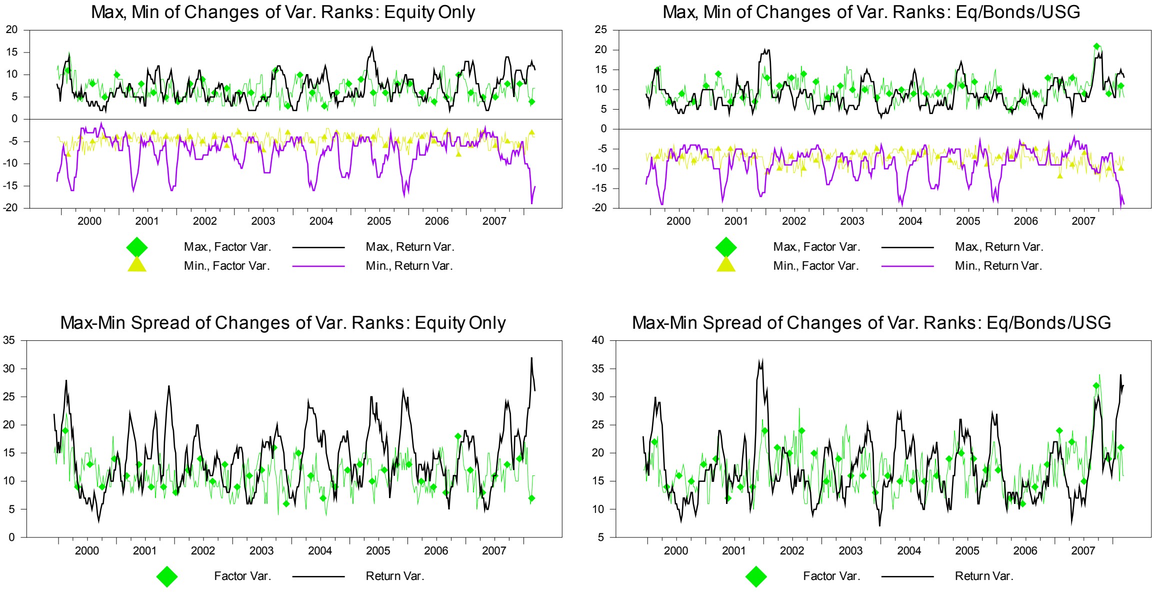
Change of Var. Ranks: F-GRAI and R-GRAI, 12-w. returns

Max, min, spread; (co-)variances via scaling



Change of Var. Ranks: F-GRAI and R-GRAI, 12-w. returns

Max, min, spread; (co-)variances via temporal aggregation

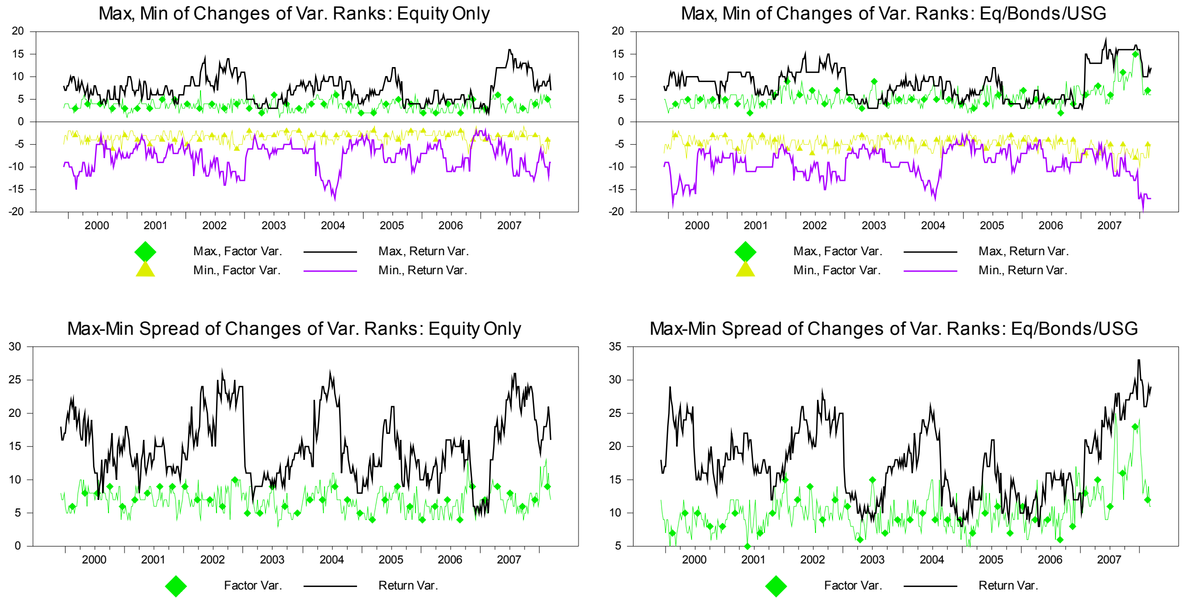


Sources: MSCI, Merrill Lynch, Federal Reserve, Bloomberg. Own calculations.

Figure 12: Max, Min, Spread: Change of Variance Ranks / GRAIs (12-week Return Periods)

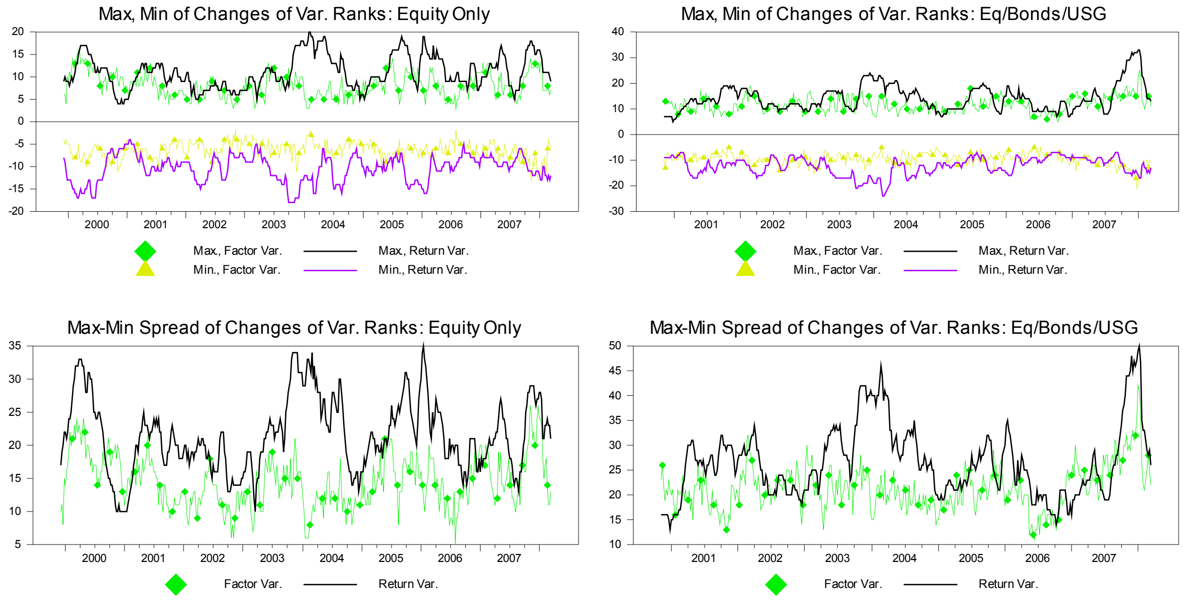
Change of Var. Ranks: F-GRAI and R-GRAI, 24-w. returns

Max, min, spread; (co-)variances via scaling



Change of Var. Ranks: F-GRAI and R-GRAI, 24-w. returns

Max, min, spread; (co-)variances via temporal aggregation

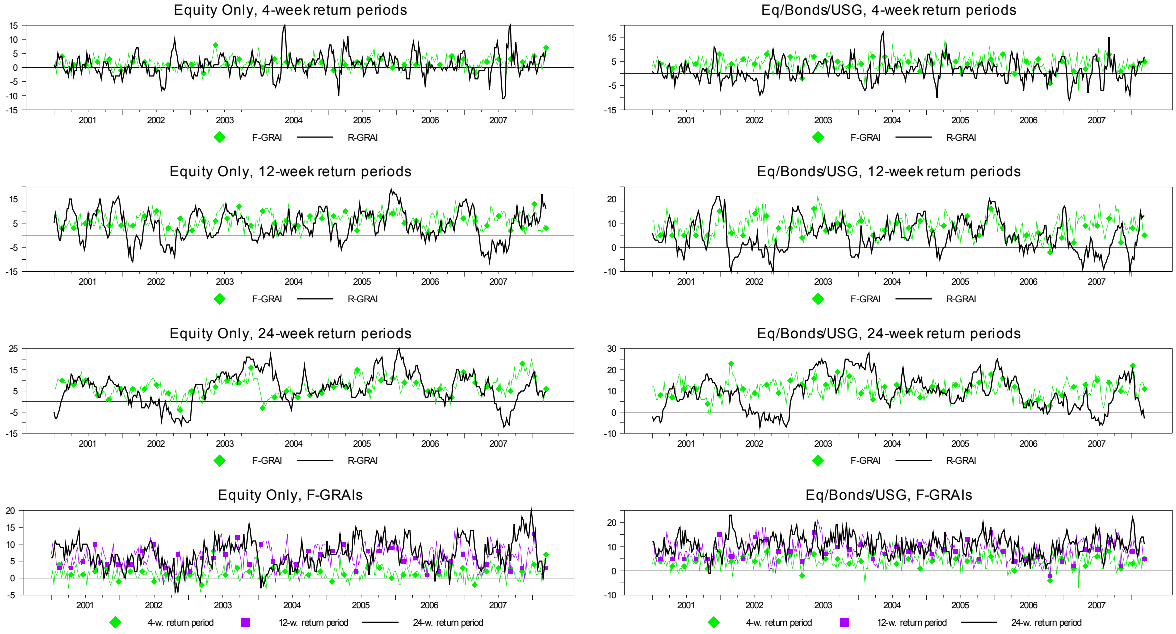


Sources: MSCI, Merrill Lynch, Federal Reserve, Bloomberg. Own calculations.

Figure 13: Max, Min, Spread: Change of Variance Ranks / GRAIs (24-week Return Periods)

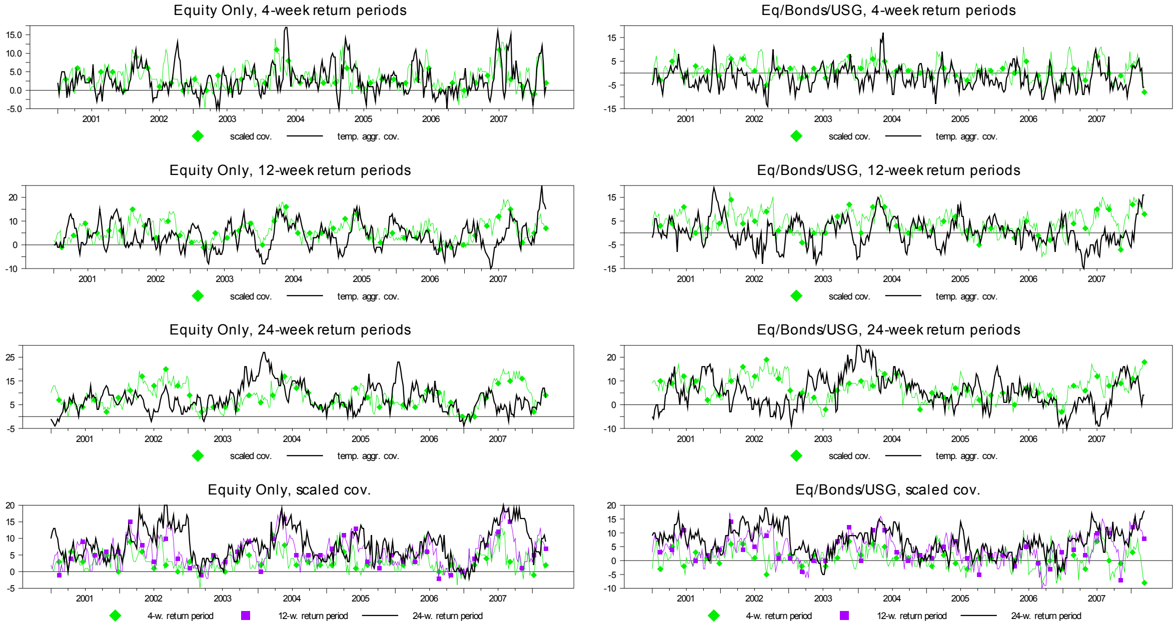
Risk Ranking Stability: Cov. Scaling vs. Temp. Aggregation

Diff. in Max-Min Spread of Changes in Var. Ranks for Cov. Temp. Aggr. vs. Scaling



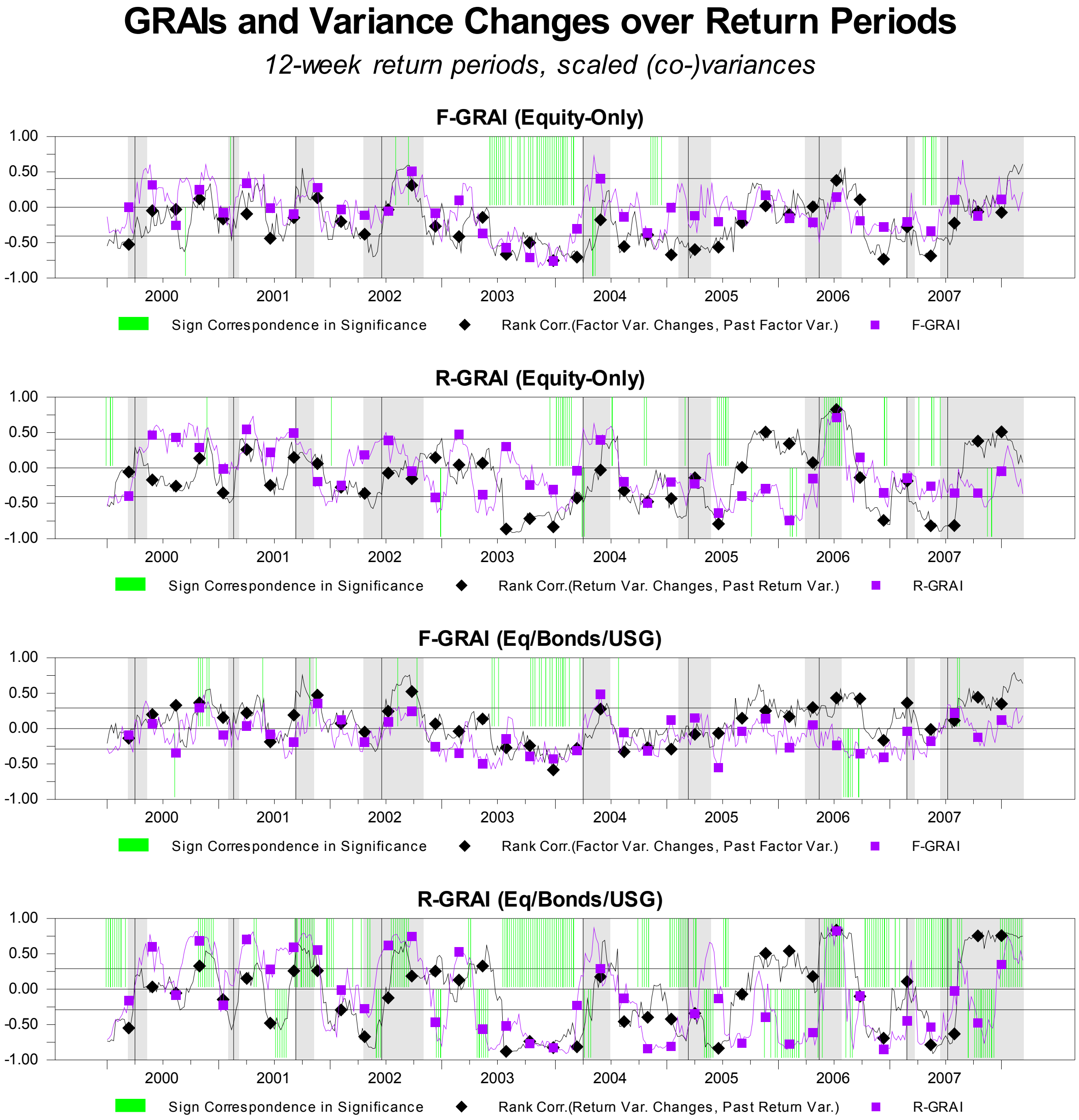
Risk Ranking Stability of F-GRAI vs. R-GRAI

Difference between R-GRAI and F-GRAI Max-Min Spread of Changes in Var. Ranks



Sources: MSCI, Merrill Lynch, Federal Reserve, Bloomberg. Own calculations.

Figure 14: Risk Ranking Stability Criterion and GRAIs



Notes: Critical values for two-sided significance test of rank correlation at 5% level (see Zar (1972)).
Sources: MSCI, Merrill Lynch, Federal Reserve, Bloomberg. Own calculations.

Figure 15: GRAIs and Variance Changes over Return Periods

Table 4

Correlations with First Principal Component of Four Market-Based Risk Aversion Indicators

	RAI-R	RAI-C	GRAI	RAI-R	RAI-C	GRAI
	scaled (co-)variances			temp. aggr. (co-)variances		
Period: Nov 08, 2000 - March 12, 2008						
for: 4-week return periods						
Stock Indices; Factor Returns	**0.541**	**0.575**	0.424	**0.529**	**0.580**	0.392
Stock & Bond Indices (+US GovB); Factor Returns	**0.556**	**0.592**	0.407	**0.538**	**0.593**	0.328
Stock Indices; Returns	0.249	0.246	0.340	0.212	0.228	0.312
Stock & Bond Indices (+US GovB); Returns	0.446	**0.472**	**0.600**	0.410	**0.464**	**0.603**
for: 12-week return periods						
Stock Indices; Factor Returns	0.436	**0.522**	0.408	0.395	**0.518**	0.410
Stock & Bond Indices (+US GovB); Factor Returns	**0.451**	**0.537**	**0.496**	0.416	**0.524**	0.360
Stock Indices; Returns	0.208	0.305	0.302	0.146	0.300	0.302
Stock & Bond Indices (+US GovB); Returns	0.352	0.439	**0.500**	0.299	0.443	**0.509**
for: 24-week return periods						
Stock Indices; Factor Returns	0.238	0.232	0.250	0.287	0.227	0.273
Stock & Bond Indices (+US GovB); Factor Returns	0.253	0.244	0.329	0.285	0.231	0.254
Stock Indices; Returns	0.023	0.145	0.114	0.095	0.183	0.086
Stock & Bond Indices (+US GovB); Returns	0.139	0.183	0.233	0.170	0.194	0.230
Shorter Period: March 12, 2003 - March 12, 2008						
for: 4-week return periods						
Stock Indices; Factor Returns	**0.520**	**0.590**	0.390	**0.517**	**0.597**	0.398
Stock & Bond Indices (+US GovB); Factor Returns	**0.534**	**0.607**	0.393	**0.526**	**0.612**	0.314
Stock Indices; Returns	0.258	0.278	0.314	0.207	0.245	0.279
Stock & Bond Indices (+US GovB); Returns	0.449	**0.508**	**0.595**	0.412	**0.488**	**0.598**
for: 12-week return periods						
Stock Indices; Factor Returns	0.366	**0.493**	0.403	0.343	**0.530**	0.384
Stock & Bond Indices (+US GovB); Factor Returns	0.388	**0.520**	**0.564**	0.378	**0.544**	0.361
Stock Indices; Returns	0.132	0.241	0.224	0.067	0.252	0.252
Stock & Bond Indices (+US GovB); Returns	0.289	0.397	**0.479**	0.242	0.422	**0.491**
for: 24-week return periods						
Stock Indices; Factor Returns	0.138	0.101	0.234	0.164	0.119	0.205
Stock & Bond Indices (+US GovB); Factor Returns	0.165	0.131	0.402	0.175	0.128	0.218
Stock Indices; Returns	-0.134	-0.070	-0.136	-0.065	0.018	-0.113
Stock & Bond Indices (+US GovB); Returns	-0.003	-0.003	0.125	0.022	0.038	0.146

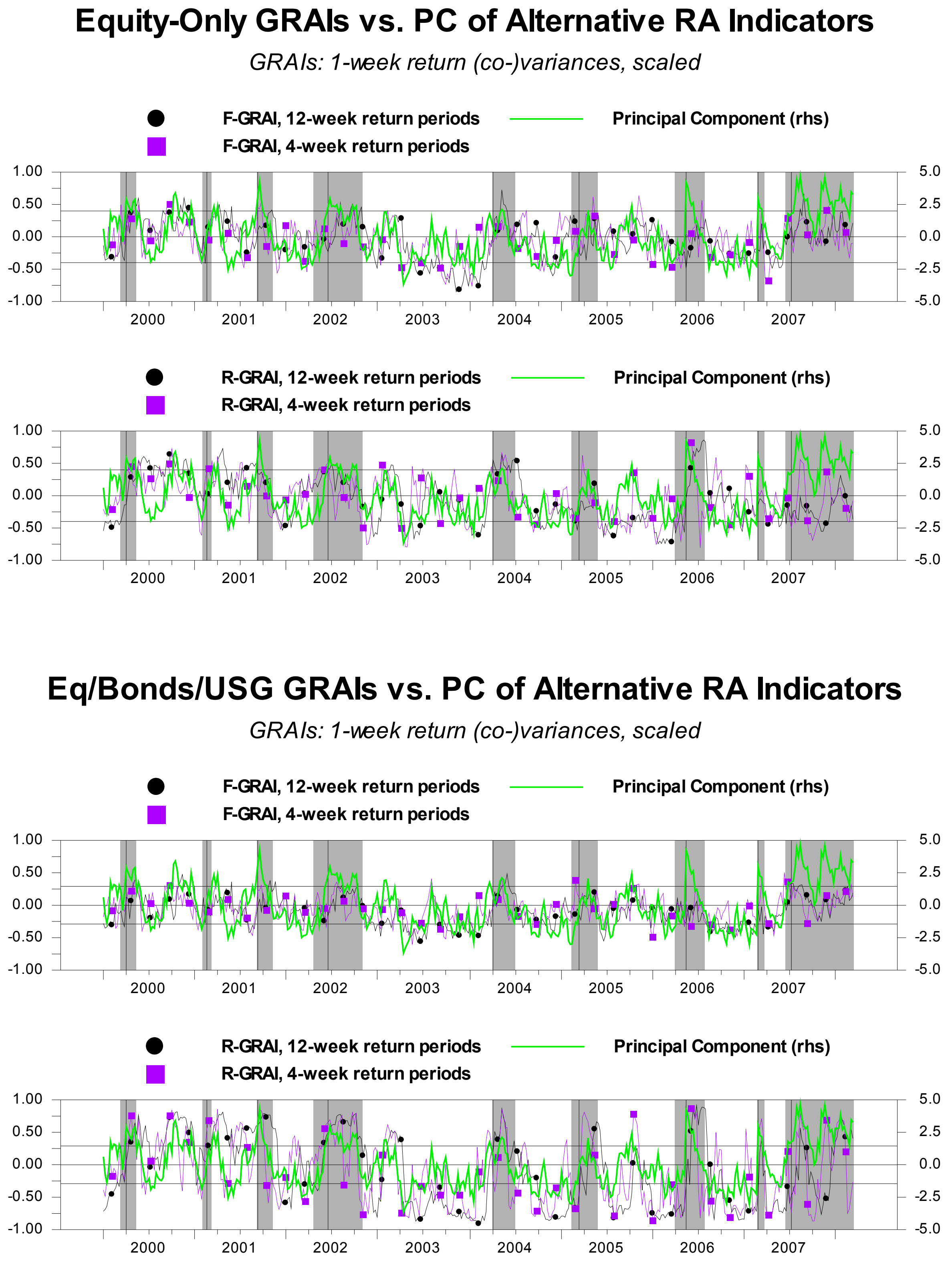
Correlation (April 1, 1998 to March 12,2008) between...

	RAI_MS	RAI_WP	RAI_UBS
RAI_MC	**0.482**	**0.562**	**0.648**
RAI_MS		**0.798**	**0.600**
RAI_WP			**0.557**

Notes: Principal component calculated for weekly (Wednesday) observations (April 1, 1998 to March 12, 2008) of the following four indicators: the Citi Macro Risk Index (RAI_MC), the risk aversion indicator implied by the Global Risk Demand Index (RAI_MS) of Morgan Stanley, the Westpac Risk Aversion Index (RAI_WP), and the UBS G10 Carry Risk Index Plus (RAI_UBS). Data for the indices were downloaded from Bloomberg. Where necessary, values were multiplied by -1 to correspond to a risk aversion interpretation. Correlations between (G)RAIs and principal component calculated for weekly (Wednesday) observations over the indicated periods. Correlation coefficients with absolute values larger than 0.45 highlighted/in boldface.

Sources: MSCI, Merrill Lynch, Federal Reserve, Citigroup Global Markets Inc., Morgan Stanley, Westpac Strategy Group, UBS, Bloomberg. Own calculations.

Table 4: Correlations of (G)RAIs with First Principal Component of Four Market-Based Risk Aversion Indicators



Sources: MSCI, Merrill Lynch, Federal Reserve, Citigroup Global Markets Inc., Morgan Stanley, Westpac Strategy Group, UBS, Bloomberg. Own calculations.

Figure 16: GRAIs vs. First Principal Component of Four Market-Based Risk Aversion Indicators

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