EARLY WARNING RISK SYSTEM

Forecasting Financial Stress

SEP 16
ABOUT US

CheckRisk is a trusted provider of risk services to over $70bn of risk assets globally. CheckRisk’s team of investment professionals has decades of combined experience within asset management, trading and qualitative/quantitative modelling disciplines. Our consulting services, risk models and commentaries provide a high level of value to any firm that is interested in having an independent view to aid decision making, formulating risk strategies, to put in place risk management systems or manage assets. Our work with the University of Bath, School of Management, and University of Bristol Systems Engineering Department means that investors wishing to understand risk have the backing of top level academic institutions and the pragmatic investment risk skills of CheckRisk’s team.

OUR APPROACH

Our approach to risk is innovative, forward-looking and multidimensional. We think of risk in the widest possible sense: from the macro global economy, down to the micro securities level, using both quantitative and qualitative analysis.

Legacy systems such as Value at Risk (VaR) are known to have failings and have not served the industry well. We aim to fill that gap.

Most investors spend their time chasing the thing they can’t control: returns. They spend little time thinking about the things they can control that make a difference: risk, cost and time.

The question CheckRisk is really trying to answer is: are you being paid to take risk?

Computers and new theories have transformed the way in which we can try and answer that question. We bring together the latest forward-looking methods and translate them into output that is easy to understand.

We recognise that there is no single ‘perfect’ approach and that there will always be a certain amount of irreducible uncertainty: this is why you need to use simulations and different techniques to build resilience. This offers us the best chance of achieving our objectives.

However, we should not leave it to computers alone. We believe that the future lies in combining their power with practitioner experience. Working closely with our clients, we have been successful in customizing our risk knowledge to provide specific client solutions.

The cross-fertilisation of the sciences and big data offers us new and exciting insights into how the world works. CheckRisk is at the leading edge of this new frontier.
OUR SERVICES

INVESTMENT RISK GOVERNANCE
We advise professional investors, boards and trustees on one of the most important and least understood risks: investment risk and its proper governance.

We do this by assisting our clients in reviewing their existing investment processes and looking for improvement in areas such as asset allocation, stress-testing and model validation.

RISK PRODUCTS
We help decision makers get a clearer picture on the global economy and financial markets with our risk products.

We have off-the-shelf products and fully customisable systems to suit individual needs.

Our cutting edge products are primarily focused on forecasting financial conditions and reflect the interconnected world we live in.

RISK MANAGEMENT CONSULTANCY
We provide bespoke, cost-efficient risk solutions to assist institutions in managing financial and operational risk.

We partner with our clients to help them deliver specific projects for internal, commercial or marketing purposes.

Our experience and modelling skills are useful in different parts of an organisation and across industries.

STRUCTURED PRODUCTS
CheckRisk creates bespoke structured products for institutional clients. These provide a diversified alternative to traditional asset classes, especially in an environment of low interest rates.

We adopt a multi-strategy approach and seek to create the best possible product. We also provide full ongoing after sales support.
Early warning systems have been brought about through a desire to try and avoid the mistakes of the past.

The first attempts were made by policymakers, seeking to identify an oncoming recession by monitoring vulnerabilities building across the financial system.

It is a difficult task, but the aim is worthwhile both from a societal and from an investor standpoint.

The models that were first created were comparatively simple. They did not have many time series to represent the financial system, and they were unable to overcome how the markets have changed over time. For example, with the advent of CDS markets. They therefore used only the most established markets with the longest history.

In doing so, however, these models lack the flexibility to deal with the reality of how the world has changed. They therefore tend to be coincident models that offer little predictive power.

The CheckRisk Early Warning Risk System (CREWS) employs cutting edge statistical and computational finance techniques to put forward a superior solution.

"We take hundreds of variables and turn them into one accurate risk signal"
SEE RISKS BUILDING IN FINANCIAL MARKETS

The CheckRisk Early Warning Risk System (CREWS) helps risk managers to identify and communicate emerging systemic risks.

These risks are broken down so that they can be seen in different parts of the financial system and across regions.

The high level indices we produce are rich with information and offer a clearer forward-looking picture that can be missed with the huge number of data points that are released each month. Alerts and reporting can be set with CheckRisk so that our clients are kept up to date as events unfold.

The charts and dashboards are visually powerful and can be understood by anyone in an organisation.

CheckRisk provides the most accurate read on financial conditions available in the open market.

KEY FEATURES

- Identify emerging systemic risks in different regions with statistical confidence
- Communicate risks in a visual language that is easily understood by quants and senior managers alike
- Receive high level information, or explore the detail. See the rates of change. Set the alerts and explanatory reporting from CheckRisk
- Use the output to develop predictive stress scenarios that CheckRisk can integrate with your portfolio and risk management systems
- CheckRisk Financial Stress Indices filter signals from noise from hundreds of indicators, dealing with mixed frequency data and asymmetric start and end dates

WHO IS IT FOR?

- Pension Funds
- Asset Managers
- Hedge Funds
- Wealth Managers
- Regulators
- Banks
- Insurers
THE PRODUCT

1

CREWS

If you buy the CheckRisk Early Warning System (CREWS) you will receive:

• A monthly report
• A quarterly report
• Share in any model improvements
• Ability to set e-mail alerts

The monthly report is a brief synopsis of events, and informs the reader of any material changes in the underlying indices and regions. You will receive this by email in PDF format.

The quarterly report goes into much more depth, both in terms of data and narrative. Not only do we seek to explain the changes in risk across regions in a quantitative way, but we also apply our subjective opinion.

We are constantly researching ways of improving what we do. We will automatically update our models and share the improvements with you. We are also open to feedback as to how we can improve our service.

The regions covered in CREWS are the US, Europe, China and Japan.

Please contact us if you would like to set specific alerts and we will email you if there are any breaches between reporting cycles.

Cost: £40,000 per annum

2

CREWS+

Many of our clients involved in investment management and trading require a more sophisticated approach. For this reason, we have expanded the standard CREWS and have created CREWS+.

If you purchase the enhanced CheckRisk Early Warning System (CREWS+) you will receive the standard service, but also with the ability to fully customize our models to your objectives.

The standard CREWS is a mixture of financial market, survey and macroeconomic variables. This is sufficient for a large proportion of our clients. However, if you have a specific requirement e.g. to forecast 3m volatility - this requires ongoing calibration.

You may be interested in creating trading strategies based off our models.

We will share the model testing statistics with you on an ongoing basis, to aid your quantitative teams. We can also collaborate on the most suitable delivery method for you e.g. API, business intelligence etc.

We can also add further countries or regions to the standard list in CREWS.

The cost is therefore dependent on the complexity of your needs. Please contact us to discuss a quote.

Cost: POA
EXPLAINING THE RISK SIGNALS

The methodology of our early warning risk indicators weaves together both macroeconomic and financial market data of mixed frequency (e.g. weekly, monthly etc.) from across the financial system. It is able to deal with missing data, asymmetric start and end dates and clustering to provide an up to date signal rich with information. The models are run on a dynamic basis and are recalibrated as information changes.

The next (time) period forecast of conditions is based off a form of vector auto-regression model, and is therefore purely statistical.

The CheckRisk Financial Stress Indices currently provide the most accurate picture on financial conditions available in the market (to our knowledge).

The charts can be used by an investment committee to understand the investment landscape at a given moment in time. The standard models are designed to forecast financial stress accurately up to one year away.

We would recommend that the signals need to be supported by macroeconomic knowledge, other risk models and expert interpretation to extract their highest value.

They are not intended to replace a standard DSGE model at forecasting real GDP, neither are they designed to fully explain short-term investment returns, although as we can show, they do a good job of both. Economists and risk teams may be more interested in the CheckRisk Nowcast models, and the CheckRisk Network Risk System as a complementary approach.

Understanding the differences between our models and the ones used by central banks may provide interesting insight. The results are purely statistical. We have placed no judgment in the traffic light system, but do so in the narrative that accompanies the report.

Headline indicators contain between 100-120 sub-indices, with approximately 30-40 time-series in each category: risk, credit and leverage.

**RISK**

Contains many instruments, spreads and indices pertinent to signs of distress/risk aversion in the plumbing of the financial system, including preference for liquidity or diminished liquidity. These come from many different markets including: rates, repo, credit, equity, FX, options, swaps. This index tends to give the most accurate short-term readings.

**CREDIT**

The ‘credit’ risk category not only refers to decreasing credit provision, but also that of deteriorating credit quality in different parts of the financial system.

It tends to have an intermediate lead time on the economy.

If this index turns up, then credit is deteriorating and it is a warning sign.

**LEVERAGE**

The ‘leverage’ risk category aims to quantify by how much debt is building up in different parts of the financial system: from the central bank, the government; to companies, banks, financial institutions and households.

Understanding how extended that has become is the most important early leading indicator of GDP growth and financial stress.

**OVERALL**

This indicator is a composite from all three other indicators.

It represents the optimal signal at a high level from the 100-120 individual time-series.

The signal is recalibrated on a dynamic basis to improve efficiency and to reflect the changes in the financial system.
HOW DOES IT WORK?

In order to get an accurate read on financial conditions and stress, it is important to throw the net as wide as possible to capture what is happening in a country’s financial system. This means gathering data from the central bank, government corporations and households. It also means covering all of the major markets and asset classes in a country. We also use some survey data that applies to expectations for a given asset class.

This usually boils down to a universe of between 100-120 time-series that represent the financial system.

Financial market data tends to be faster moving and is collected weekly, whereas, a lot of macroeconomic variables are released monthly or quarterly.

We use sophisticated filtering techniques to deal with asymmetric start and end dates. This means that we can ensure that we can include time series which have stopped and include newer members. Not only is this practical, but it reflects how the financial system has evolved over time.

In our research, we look for new time series that may be additive to the model. We test these and have made incremental improvements.

Within each risk category, there are some indicators which are more important than others and they are weighted accordingly. Due to the variation in data in both frequency and richness across regions, the underlying time series do vary from region to region. Several of the underlying indices within a given risk category in a country are themselves built from bottom-up financial statements often containing hundreds of companies.

The work has been built on numerous academic studies into financial indicators, systemic risk and their interaction with asset classes, the business cycle and the macroeconomy. We are fortunate to have a relationship with the University of Bath and Andreas Krause, Professor of Quantitative Finance, who is recognised as a leading authority on systemic risk & financial network theory. He has provided us with constructive advice in relation to this product.

The main innovation of the indicators is in using a dynamic modelling approach that uses supervised machine learning to optimise the signal and prediction as new information becomes present.

We also apply the most successful aspects of the methodologies in the business cycle and systemic risk literature to global regions where these do not currently exist (aside from the US).
The CheckRisk Early Warning Risk System (CREWS) model makes predictions based on evidence in the presence of uncertainty. We employ a supervised machine learning algorithm to identify patterns in the data. The model learns from the observations. When exposed to more observations, the model improves its predictive performance.

Specifically, a supervised learning algorithm takes a known set of input data and known responses to that data (output), and trains a model to generate predictions in response to new data.

For example, suppose we want to predict an economic recession in the US within a year. We have a set of data that contains previous recessions, included in the Risk, Credit and Leverage groups. We also know whether the previous conditions led to recessions within a year of their measurement. So, the problem is combining all of the data into a model that can predict whether the current financial conditions will lead to a recession within a year.

CREWS uses the following algorithms to classify and build forecasts about economic and market conditions:

- Discriminant Analysis
- K Nearest Neighbours
- Naive Bayes
- Support Vector Machines
- Decision Trees
- Neural Network

We use a supervised machine learning algorithm that learns from its observations to improve predictive performance.

<table>
<thead>
<tr>
<th>Recession Prediction Accuracy</th>
<th>One Month</th>
<th>Three Months</th>
<th>Six Months</th>
<th>One Year</th>
<th>Two Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naive Bayes Classifier</td>
<td>93.48%</td>
<td>95.59%</td>
<td>91.73%</td>
<td>93.65%</td>
<td>99.13%</td>
</tr>
<tr>
<td>Bagged Decision Tree</td>
<td>98.55%</td>
<td>100%</td>
<td>97.76%</td>
<td>97.66%</td>
<td>100%</td>
</tr>
<tr>
<td>Treebagger Using Sequential Feature Selection</td>
<td>98.55%</td>
<td>100%</td>
<td>94.12%</td>
<td>97.66%</td>
<td>100%</td>
</tr>
</tbody>
</table>
The results on the previous page are deduced from standard model validation techniques such as ROC (Receiver Operator Characteristic), Confusion Matrix and scatter plots.

The ROC test plots positive versus false positives and is used widely (especially in the medical industry) to assess how good your model is. There is a trade-off between the two, which we are looking to optimise.

The confusion matrix performs a kind of randomized sampling under different regimes, and gives a realistic assessment of both good, neutral and poor model performance.

The ROC plot above, shows how our early warning system is able to identify/forecast a recession two years ahead.

The confusion matrix gives our model using a neural network classification 99.2% accuracy.

The high level model is designed to detect financial stress and recession conditions. It is not specifically calibrated to explain market returns or volatility. However, we have performed tests in this area. These demonstrate that the CheckRisk Early Warning Risk System (CREWS) performs well on both counts.

“Risk test matrices show high accuracy”
PREDICTING RETURNS & VOLATILITY

To test the CREWS model ability to predict market returns and volatility for the US, we have used the S&P 500 stock index as a proxy. The grey areas show the NBER (National Bureau of Economic Research) recessions.

We classified the market into five regimes based on returns and volatility: Negative, Mild Negative, Neutral, Mild Positive and Positive. We then used the CREWS model to forecast future returns and volatility at different time periods.

Below is a table of performance under differing regimes from Jan 2000 to June 2016:

<table>
<thead>
<tr>
<th>Period</th>
<th>Monthly Returns</th>
<th>Monthly Volatility</th>
<th>1 Month Returns</th>
<th>1 Month Volatility</th>
<th>6 Month Returns</th>
<th>6 Month Volatility</th>
<th>12 Month Returns</th>
<th>12 Month Volatility</th>
<th>24 Month Returns</th>
<th>24 Month Volatility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max</td>
<td>20.95%</td>
<td>96.07%</td>
<td>11.89%</td>
<td>61.23%</td>
<td>39.70%</td>
<td>51.76%</td>
<td>51.90%</td>
<td>39.80%</td>
<td>63.82%</td>
<td>5.03%</td>
</tr>
<tr>
<td>Min</td>
<td>-33.87%</td>
<td>1.39%</td>
<td>-47.95%</td>
<td>5.20%</td>
<td>-59.77%</td>
<td>6.61%</td>
<td>-63.80%</td>
<td>8.53%</td>
<td>-71.92%</td>
<td>5.10%</td>
</tr>
<tr>
<td>Average</td>
<td>3.34%</td>
<td>15.65%</td>
<td>5.57%</td>
<td>16.16%</td>
<td>1.06%</td>
<td>14.17%</td>
<td>2.72%</td>
<td>6.11%</td>
<td>16.81%</td>
<td>16.88%</td>
</tr>
<tr>
<td>Range</td>
<td>34.61%</td>
<td>94.68%</td>
<td>75.04%</td>
<td>36.21%</td>
<td>95.46%</td>
<td>44.93%</td>
<td>118.93%</td>
<td>30.83%</td>
<td>137.04%</td>
<td>21.39%</td>
</tr>
<tr>
<td>25th percentile</td>
<td>2.53%</td>
<td>7.79%</td>
<td>-4.12%</td>
<td>9.91%</td>
<td>-6.69%</td>
<td>16.30%</td>
<td>33.67%</td>
<td>18.46%</td>
<td>20.33%</td>
<td>16.61%</td>
</tr>
<tr>
<td>40th percentile</td>
<td>-0.11%</td>
<td>10.12%</td>
<td>0.41%</td>
<td>11.97%</td>
<td>1.09%</td>
<td>11.99%</td>
<td>4.59%</td>
<td>12.37%</td>
<td>18.26%</td>
<td>11.51%</td>
</tr>
<tr>
<td>50th percentile</td>
<td>1.79%</td>
<td>14.02%</td>
<td>3.53%</td>
<td>15.11%</td>
<td>5.60%</td>
<td>16.32%</td>
<td>16.53%</td>
<td>17.32%</td>
<td>17.65%</td>
<td>17.46%</td>
</tr>
<tr>
<td>75th percentile</td>
<td>3.52%</td>
<td>20.50%</td>
<td>6.97%</td>
<td>20.34%</td>
<td>9.60%</td>
<td>26.62%</td>
<td>15.79%</td>
<td>21.47%</td>
<td>27.50%</td>
<td>21.49%</td>
</tr>
<tr>
<td>Regime 1</td>
<td>&lt; -7.93%</td>
<td>&lt; 7.33%</td>
<td>&lt; -4.26%</td>
<td>&lt; 7.91%</td>
<td>&lt; -9.09%</td>
<td>&lt; 10.3%</td>
<td>&lt; -13.17%</td>
<td>&lt; 20.46%</td>
<td>&lt; -29.33%</td>
<td>&lt; 16.51%</td>
</tr>
<tr>
<td>Regime 2</td>
<td>-2.5% - 0.11%</td>
<td>7.30% - 10.72%</td>
<td>-4.22% - 0.43%</td>
<td>9.31% - 11.97%</td>
<td>-5.46% - 1.70%</td>
<td>10.3% - 11.90%</td>
<td>-13.17% - 2.5%</td>
<td>14.24% - 22.33%</td>
<td>-20.33% - 10.24%</td>
<td>16.81% - 13.55%</td>
</tr>
<tr>
<td>Regime 3</td>
<td>-0.11% - 1.79%</td>
<td>10.72% - 14.56%</td>
<td>0.41% - 3.53%</td>
<td>11.97% - 15.31%</td>
<td>1.09% - 5.6%</td>
<td>11.99% - 16.32%</td>
<td>4.1% - 10.53%</td>
<td>12.37% - 17.12%</td>
<td>16.34% - 17.86%</td>
<td>13.51% - 17.48%</td>
</tr>
<tr>
<td>Regime 4</td>
<td>3.34% - 13.34%</td>
<td>14.05% - 20.5%</td>
<td>3.54% - 6.54%</td>
<td>15.31% - 20.34%</td>
<td>5.6% - 9.6%</td>
<td>16.12% - 20.62%</td>
<td>16.35% - 35.99%</td>
<td>17.32% - 31.49%</td>
<td>17.86% - 37.25%</td>
<td>17.48% - 21.99%</td>
</tr>
<tr>
<td>Regime 5</td>
<td>&gt; 5.52%</td>
<td>&gt; 26.3%</td>
<td>&gt; 6.97%</td>
<td>&gt; 20.54%</td>
<td>&gt; 9.6%</td>
<td>&gt; 20.42%</td>
<td>&gt; 15.76%</td>
<td>&gt; 21.47%</td>
<td>&gt; 27.50%</td>
<td>&gt; 21.49%</td>
</tr>
</tbody>
</table>
PREDICTING RETURNS & VOLATILITY

As you can see, the CREWS model performs exceptionally well at identifying recessions, but also does a good job of predicting returns and volatility despite not being specifically calibrated to do so.

For those clients who may be interested in focusing on returns and volatility, we are able to improve the scores significantly with the inclusion of additional factors, as well as sentiment and technical analysis indicators. Please enquire about our Risk Adjusted Asset Model (RAAM) if you are interested in a systematic approach to tactical asset allocation (TAA).

<table>
<thead>
<tr>
<th>Return Prediction Accuracy</th>
<th>One Month</th>
<th>Three Months</th>
<th>Six Months</th>
<th>One Year</th>
<th>Two Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naive Bayes Classifier</td>
<td>35.04%</td>
<td>44.44%</td>
<td>46.62%</td>
<td>50.00%</td>
<td>66.10%</td>
</tr>
<tr>
<td>Bagged Decision Tree</td>
<td>42.75%</td>
<td>57.35%</td>
<td>66.42%</td>
<td>75.78%</td>
<td>80.51%</td>
</tr>
<tr>
<td>Treebagger Using Sequential Feature Selection</td>
<td>45.65%</td>
<td>57.35%</td>
<td>67.91%</td>
<td>76.56%</td>
<td>82.76%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Volatility Prediction Accuracy</th>
<th>One Month</th>
<th>Three Months</th>
<th>Six Months</th>
<th>One Year</th>
<th>Two Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naive Bayes Classifier</td>
<td>34.06%</td>
<td>42.54%</td>
<td>54.48%</td>
<td>59.38%</td>
<td>65.81%</td>
</tr>
<tr>
<td>Bagged Decision Tree</td>
<td>34.06%</td>
<td>72.79%</td>
<td>79.85%</td>
<td>88.28%</td>
<td>92.37%</td>
</tr>
<tr>
<td>Treebagger Using Sequential Feature Selection</td>
<td>37.68%</td>
<td>72.79%</td>
<td>80.60%</td>
<td>89.06%</td>
<td>93.22%</td>
</tr>
</tbody>
</table>

Clients looking to understand the economic backdrop better, may be interested in our ‘nowcasting’ models. These give a highly accurate ‘real-time’ reading of economic activity and can forecast real GDP growth, also giving predictions of strong growth or recession. Please contact us for further details.
This document is provided to you on a confidential basis for your information and discussion only. It is not a solicitation or an offer to buy or sell any security or other financial instrument. Any information including facts, opinions or quotations, may be condensed or summarized and is expressed as of the date of writing. The information may change without notice and CheckRisk LLP (“CheckRisk”) is under no obligation to ensure that such updates are brought to your attention.

The price and value of investments mentioned and any income that might accrue could fall or rise or fluctuate. Past performance is not a guide to future performance. If an investment is denominated in a currency other than the base currency, changes in the rate of exchange may have an adverse effect on value, price or income. This document and any related recommendations or strategies may not be suitable for you; you should ensure that you fully understand the potential risks and rewards and independently determine that it is suitable for your given objectives, experience, financial resources and any other relevant circumstances. You should consult with such advisor(s) as you consider necessary to assist you in making these determinations. Nothing in this document constitutes investment, legal, accounting or tax advice, or a representation that any investment or strategy is suitable or appropriate to your individual circumstances, or otherwise constitutes a personal recommendation to you.

This document may relate to investments or services of an entity/person outside the UK, or to other matters which are not regulated by the FCA, or in respect of which the protections of the FCA for retail clients and/or the UK Financial Services Compensation Scheme may not be available. Further details as to where this may be the case are available on request in respect to this document. Certain information contained herein has been obtained from third party sources. While such information is believed to be reliable for the purposes used herein, no representations are made to the accuracy or completeness thereof and CheckRisk takes no responsibility for such information.

This document is intended only for the person to whom it is issued by CheckRisk. It may not be reproduced either in whole, or in part, without CheckRisk's written permission. The distribution of this document and the offer and sale of the investment in certain jurisdictions may be forbidden or restricted by law or regulation.

Investments may have no public market or only a restricted secondary market. Where a secondary market exists, it is not possible to predict the price at which investments will trade in the market or whether such market will be liquid or illiquid. As such investments will not be listed or traded on any exchange, pricing information may be more difficult to obtain and the liquidity of the investments may be adversely affected. A holder may be able to realise value prior to an investment’s maturity date only at a price in an available secondary market.

CheckRisk LLP is authorised and regulated by the Financial Conduct Authority (Firm reference number: 490575). The registered address of CheckRisk LLP is 4 Miles’s Buildings, George Street, Bath, BA1 2QS (Company number: OC338765).