

Understanding Financial Crises - a statistical perspective

M. R. Grasselli

Department of Mathematics and Statistics - McMaster University

September 10, 2016

- 1 Based mostly on the book *This time is different: eight centuries of financial folly* by Reinhart and Rogoff (2009).
- 2 Systematic search and compilation of all publicly available data mentioned in the book.
- 3 Independent reproduction of the main statistical findings described in the book, updated to 2013.
- 4 Implementation of the signals approach for early warning indicators for banking, currency, and stock market crisis.
- 5 Construction of aggregate indicators and application to long-term investment.

- 70 countries, 200 years.
- Fully downloaded and compiled:
 - inflation
 - GDP (real and nominal)
 - exports and imports
 - public debt
 - exchange rates
 - equity indices (46 countries)
- Datasets found and partially compiled:
 - public finances
 - national accounts
 - commodity prices
 - real estate

- 1 Thresholds (mark both start and duration)
 - Inflation crises: 20% per annum or higher. Median values were
 - 0.5% for 1500-1799
 - 0.7% for 1800-1913
 - 5.0% for 1914-2006
 - **Currency crises**: annual depreciation of 15% or more
 - **Debasement**: currency conversion rate of 5% or more
 - **Equity price crises**: n standard deviations below trend or C_{max}
- 2 Events
 - **Banking crises**: closure, merger, government assistance with or without runs (start only, duration is harder to measure)
 - **External debt crises**: default on government external debt obligations (start and duration)
 - **Domestic debt crises**: default on government debt under a country's own jurisdiction

- Choose a set of indicators for a given type of crisis based on theoretical considerations and/or historical evidence.
- Compute the relevant data transformation for each indicator for each country in the dataset (e.g year-to-year change).
- Obtain a histogram of transformed data for the entire period under consideration (e.g past 40 years) and select a country-specific threshold for each indicator.
- At each time step (e.g month), determine whether the change in the indicator is above the threshold (signal).
- Observe the occurrence of a crisis within the next forecast window (e.g 24 months).

The performance of each indicator will be evaluated using the following matrix:

	Crisis (within 24 months)	No crisis (within 24 months)
Signal was issued	<i>A</i>	<i>B</i>
No signal was issued	<i>C</i>	<i>D</i>

- *A* is the number of months in which the indicator issued a good signal.
- *B* is the number of months in which the indicator issued a bad signal or “noise”.
- *C* is the number of months in which the indicator failed to issue a signal.
- *D* is the number of months in which the indicator refrained from issuing a signal.

Lending Rate (France)

Understanding
Financial
Crises - a
statistical
perspective

M. R. Grasselli

This time is
different

The signals
approach

Methodology

Banking and
Currency Crises

Stock Market
Crisis

Aggregate
Indicators

Long-term
Investment

Conclusions

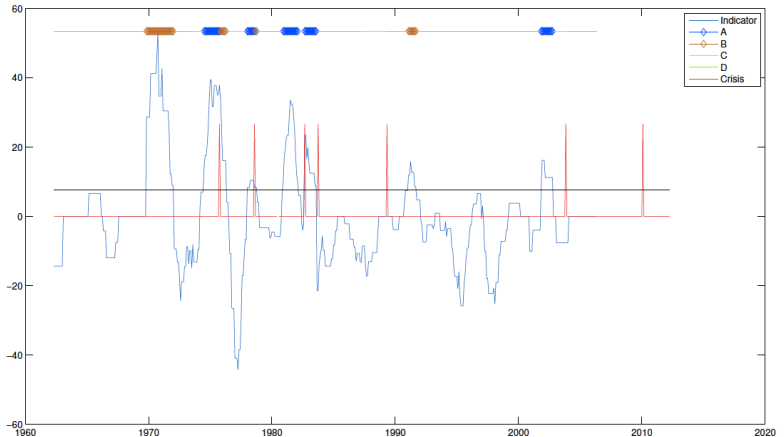


Figure: Visualization of an indicator for France

Current Account (Japan)

Understanding
Financial
Crises - a
statistical
perspective

M. R. Grasselli

This time is
different

The signals
approach

Methodology

Banking and
Currency Crises

Stock Market
Crisis

Aggregate
Indicators

Long-term
Investment

Conclusions

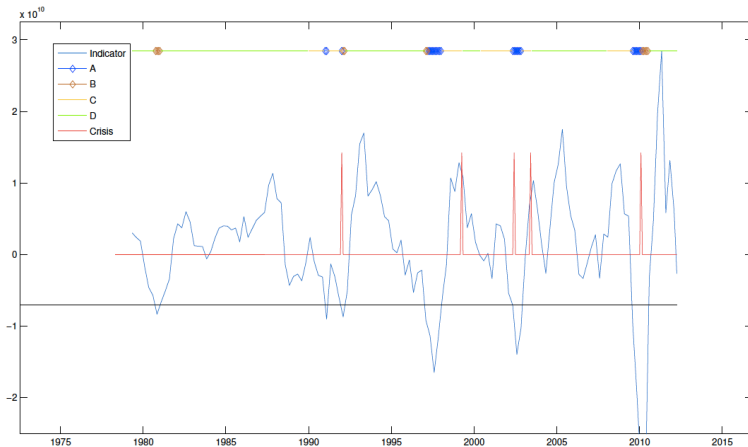


Figure: Visualization of an indicator for Japan

- The noise-to-signal ratio (NSR) is defined as follows:

$$\text{NSR} = \frac{B/(B + D)}{A/(A + C)}$$

- The percentage of crises detected (PCD) is the number of crises anticipated by a signal over all the crises considered.
- Persistence (PER) is the average number of signals issued by an indicator during the window preceding a crisis.
- The average lead time (ALT) measures the time between the first signal issued by an indicator and the occurrence of the corresponding crisis.

A good indicator should have a high PCD, ALT and PER and low NSR.

Currency Crisis with Annual Data

Understanding
Financial
Crises - a
statistical
perspective

M. R. Grasselli

This time is
different

The signals
approach

Methodology

Banking and
Currency Crises

Stock Market
Crisis

Aggregate
Indicators

Long-term
Investment

Conclusions

	NSR	%-ile	A/(A+C)	B/(B+D)	$P_{c s}$	$P_{c s} - P_c$
Reserves	0.38	11	0.17	0.07	0.5617	0.2346
M2/Reserves	0.55	90	0.14	0.08	0.4848	0.1423
Exchange Rate	0.56	10	0.14	0.08	0.4601	0.1375
Real Interest Rates	0.57	80	0.28	0.16	0.4918	0.1383
Terms of Trade	0.60	11	0.13	0.08	0.5208	0.1250
Output	0.66	20	0.26	0.17	0.4400	0.0991
Exports	0.71	20	0.26	0.18	0.4189	0.0809
Imports	1.05	82	0.18	0.19	0.3220	-0.0107
Lending/Deposit	1.96	90	0.06	0.11	0.2095	-0.1328

Table: Indicators for currency crises based on annual data for 70 countries from 1970 to 2010.

Banking Crises with Annual Data

Understanding
Financial
Crises - a
statistical
perspective

M. R. Grasselli

This time is
different

The signals
approach

Methodology

Banking and
Currency Crises

Stock Market
Crisis

Aggregate
Indicators

Long-term
Investment

Conclusions

	NSR	%-ile	A/(A+C)	B/(B+D)	$P_{c s}$	$P_{c s} - P_c$
Real Interest Rate	0.37	90	0.18	0.07	0.471	0.225
Output	0.48	20	0.16	0.08	0.383	0.155
Terms of Trade	0.53	10	0.15	0.08	0.462	0.149
Exports	0.60	14	0.21	0.13	0.303	0.096
M2/Reserves	0.71	90	0.13	0.09	0.271	0.062
Reserves	0.78	11	0.12	0.10	0.247	0.043
Exchange Rate	0.87	10	0.11	0.10	0.221	0.023
Imports	1.29	82	0.15	0.19	0.165	-0.039
Lending/Deposit	2.49	81	0.09	0.21	0.120	-0.134

Table: Indicators for banking crises based on annual data for 70 countries from 1970 to 2010.

Currency Crises with Monthly Data

Understanding
Financial
Crises - a
statistical
perspective

M. R. Grasselli

This time is
different

The signals
approach

Methodology

Banking and
Currency Crises

Stock Market
Crisis

Aggregate
Indicators

Long-term
Investment

Conclusions

	PCD	NSR	PER	ALT	Threshold
M2 by Reserves	0.78	0.44	6.75	14.96	84
Exports	0.85	0.47	4.11	15.58	10
International Reserves	0.71	0.47	4.05	11.14	10
Output	0.62	0.54	3.04	13.52	90
Domestic Credit by GDP	0.50	0.61	3.46	11.90	90
M2 multiplier	0.73	0.84	4.25	16.01	84
Real Interest Rate	0.26	0.92	1.95	13.52	90
Imports	0.43	1.26	2.08	17.21	90
Lending to Deposit Rate	0.28	1.52	1.73	13.85	80

Table: Indicators for currency crises based on monthly data for 22 countries from 1960 to 2010.

Banking Crises with Monthly Data

Understanding
Financial
Crises - a
statistical
perspective

M. R. Grasselli

This time is
different

The signals
approach

Methodology

Banking and
Currency Crises

Stock Market
Crisis

Aggregate
Indicators

Long-term
Investment

Conclusions

	PCD	NSR	Persist	ALT	Threshold
Real Interest Rate	0.49	0.60	7.05	18.56	80
M2 Multiplier	0.76	0.62	5.67	14.77	82
Exports	0.76	0.62	5.67	15.36	12
Domestic Credit y GDP	0.56	0.65	4.45	18.54	87
M2 by Reserves	0.59	0.84	4.12	15.33	85
Output	0.66	1.08	3.72	15.83	18
Imports	0.73	1.17	4.03	19.82	80
International Reserves	0.61	1.45	3.37	15.50	19
Lending to Deposit Date	0.34	1.89	1.52	20.21	80

Table: Indicators for banking crises based on monthly data for 22 countries from 1960 to 2010.

Let P_t be the price of an equity index and define:

$$\text{CMAX}_t = \frac{P_t}{\max(P_{t-W} \dots P_{t-1}, P_t)}$$

and

$$\text{Return} = \frac{P_t - P_{t-1}}{P_{t-1}}$$

We then define a crisis either as:

- 1.5 standard deviations below average CMAX
- 2 standard deviations below average CMAX
- 2 standard deviations below average Return

24 months window	NSR	PCD
Lending Rate	0.47	0.50
Current Account	0.53	0.51
M2 in US dollars	0.55	0.70
Deposit Rate	0.56	0.69
GDP Acceleration	0.60	0.90
Industrial Production	0.60	0.61
Industrial Production Acceleration	0.62	0.77

Table: Indicators for stock market crises based on monthly data for 46 countries from 1960 to 2012.

12 months window	NSR	PCD
Lending Rate	0.43	0.40
M2 in US dollars	0.43	0.62
Industrial Production	0.44	0.52
Imports	0.44	0.52
Industrial Production Acceleration	0.49	0.57
Exports	0.51	0.60
Current Account	0.53	0.39

Table: Indicators for stock market crises based on monthly data for 46 countries from 1960 to 2012.

24 months window	NSR	PCD
Lending Rate	0.53	0.49
GDP Acceleration	0.64	0.88
Current Account	0.66	0.52
M2 in US dollars	0.68	0.60
Exchange Rate US Acceleration	0.73	0.86
Current Account by GDP	0.76	0.51
Deposit Rate	0.77	0.58

Table: Indicators for stock market crises based on monthly data for 46 countries from 1960 to 2012.

12 months window	NSR	PCD
Lending Rate	0.41	0.37
GDP Acceleration	0.60	0.77
Current Account	0.61	0.41
Current Account by GDP	0.68	0.39
Deposit Rate	0.69	0.50
M2 (US) Acceleration	0.70	0.78
M2 in US dollars	0.70	0.45

Table: Indicators for stock market crises based on monthly data for 46 countries from 1960 to 2012.

Comparison between criteria and time windows

Understanding
Financial
Crises - a
statistical
perspective

M. R. Grasselli

This time is
different

The signals
approach

Methodology
Banking and
Currency Crises

Stock Market
Crisis

Aggregate
Indicators

Long-term
Investment

Conclusions

	24-months	12-months
C _{max} 2	(0.75,0.74)	(0.67,0.62)
C _{max} 1.5	(0.76,0.72)	(0.70,0.60)
returns	(0.82,0.69)	(0.77,0.58)

Table: Average NSR and PCD for the three different definition of crises and two different time windows. Bold face shows the best combination.

Motivation for an Aggregate Indicator

Understanding
Financial
Crises - a
statistical
perspective

M. R. Grasselli

This time is
different

The signals
approach

Methodology
Banking and
Currency Crises
Stock Market
Crisis

Aggregate
Indicators

Long-term
Investment

Conclusions

- Some indicators perform better than others.
- It would be interesting to build an *aggregate indicator* that tells how likely is that a crisis occurs in the following months.
- We do this by combining different indicators using their performance as relative weights.

Bringing weights and values together

Understanding
Financial
Crises - a
statistical
perspective

M. R. Grasselli

This time is
different

The signals
approach

Methodology
Banking and
Currency Crises
Stock Market
Crisis

Aggregate
Indicators

Long-term
Investment

Conclusions

- For a given type of crisis, first we assign a score from 0 to 10 to the average value of each performance measure (NSR, PCD, PER, ALT) for each country and each indicator.

- We then compute the weight in the i -th country for the k -th indicator as

$$w_{ik} = \frac{PCD_{ik} + NSR_{ik} + PER_{ik} + ALT_{ik}}{4}$$

- Next we assign a numerical value s_{kj} for the indicator k at time j based on its percentiles.
- Finally we compute the aggregate indicator (for this type of crisis) for country i at time t as

$$I_{it} = \sum_{k \in \mathbb{K}} w_{ik} s_{kt}$$

Aggregate Indicator for Stock Market Crisis in Chile

Understanding
Financial
Crises - a
statistical
perspective

M. R. Grasselli

This time is
different

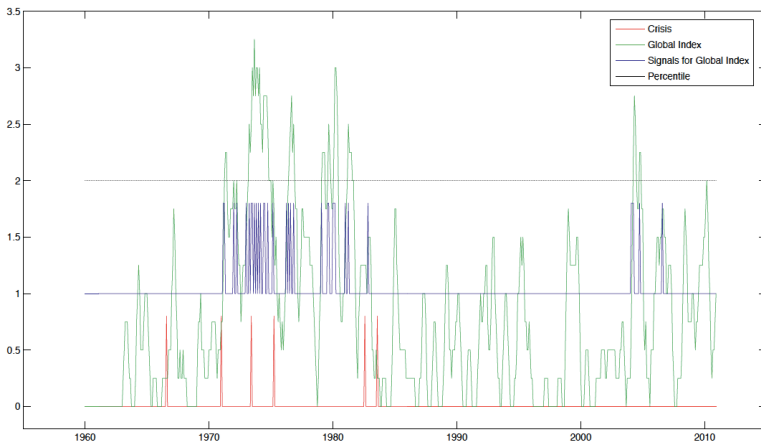
The signals
approach

Methodology
Banking and
Currency Crises
Stock Market
Crisis

Aggregate
Indicators

Long-term
Investment

Conclusions



Aggregate Indicator for Banking Crisis in France

Understanding
Financial
Crises - a
statistical
perspective

M. R. Grasselli

This time is
different

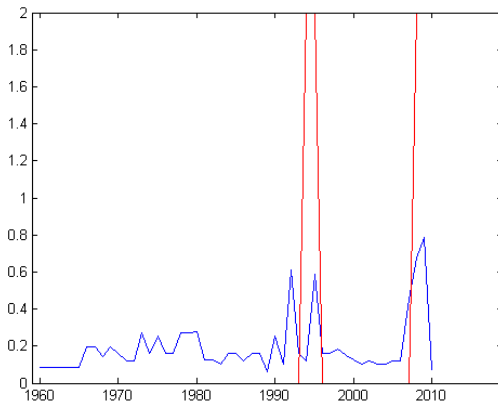
The signals
approach

Methodology
Banking and
Currency Crises
Stock Market
Crisis

Aggregate
Indicators

Long-term
Investment

Conclusions



- For each country considered, we focus on portfolio allocations with the following proportions:

$c(t) :=$ cash (3-months Tbills)

$b(t) :=$ bonds (10-year government bonds)

$e(t) :=$ equities

with $c(t) + b(t) + e(t) = 1$, $0 \leq c(t) \leq c_{max}$, $b(t) \geq 0$,
 $0 \leq e(t) \leq e_{max}$.

- For equities, we use CAC40 (France), FTSE100 (UK), S&P 500 (US) and MEXBOL (Mexico).

- We consider dynamic strategies of the form

$$\Delta c(t) = F_1 B(t) + F_2 C(t) + F_3 S(t)$$

$$\Delta e(t) = G_1 B(t) + G_2 C(t) + G_3 S(t)$$

where $B(t)$, $C(t)$, $S(t)$ are transformed (i.e weighted sums or filtered changes) of the aggregate indicators for banking, currency, and stock market crises.

- For simplicity we take $F_3 = G_1 = G_2 = 0$, $F_1 > 0$, $F_2 < 0$ and $G_3 = G < 0$.

Transformations on aggregate indicators

- For an aggregate indicator $I(t) := I_{it}^a$ for crisis a and country i , we first obtain a filtered series by applying a moving average with window k_1

$$\tilde{I}(t) = MA(k_1)\{I\}(t) = \frac{1}{k_1 + 1} \sum_{j=0}^{k_1} I(t - j)$$

- We then take the changes $\Delta\tilde{I}(t) = \tilde{I}(t) - \tilde{I}(t - 1)$ and their moving average $\tilde{\Delta}I(t) = MA(k_2)\{\Delta\tilde{I}\}(t)$.
- Next we take a weighted sum of past values for $\tilde{\Delta}I(t)$ (uniform between 9 and 18 months prior to t for banking and crises; peaked at 12 months prior to t for stock market crises).
- Finally we normalize by the maximum value over T .
- The results are denoted $B(t)$, $C(t)$ and $S(t)$.

Example of raw aggregate indicator and moving average

Understanding
Financial
Crises - a
statistical
perspective

M. R. Grasselli

This time is
different

The signals
approach

Long-term
Investment

Asset classes
and strategies

Transformed
indicators

Results

Conclusions

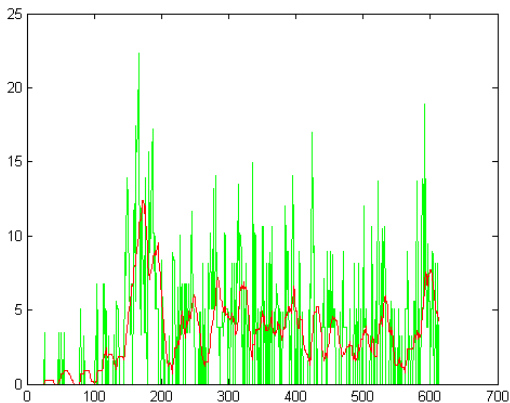


Figure: Raw aggregate indicator $I(t)$ (green) for stock market crisis in France and its moving average $\tilde{I}(t)$ (red).

Example of change in filtered indicator and moving average

Understanding
Financial
Crises - a
statistical
perspective

M. R. Grasselli

This time is
different

The signals
approach

Long-term
Investment

Asset classes
and strategies

Transformed
indicators

Results

Conclusions

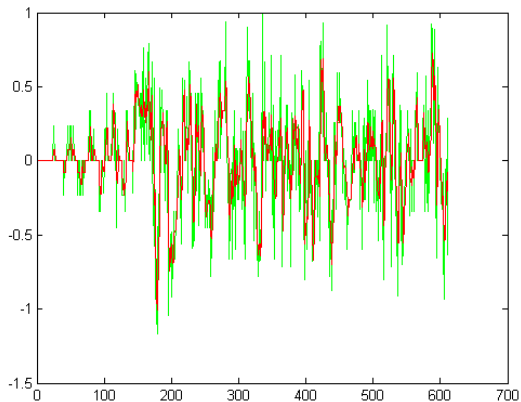


Figure: Change in filtered indicator $\Delta \tilde{I}(t)$ (green) for stock market crisis in France and its moving average $\tilde{\Delta}(t)$ (red).

Example of transformed indicators

Understanding
Financial
Crises - a
statistical
perspective

M. R. Grasselli

This time is
different

The signals
approach

Long-term
Investment

Asset classes
and strategies

Transformed
indicators

Results

Conclusions

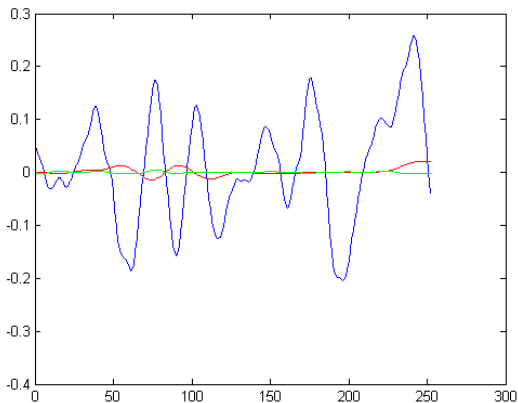


Figure: Transformed indicators for banking $B(t)$ (red), currency $C(t)$ (green), and stock market crisis $S(t)$ (blue) in France.

Using $c_{max} = 0.75$ and $e_{max} = 0.5$ we obtained the following parameters for optimal return from 1990 to 2013:

	Banking			Currency			Stock		
	k_1^b	k_2^b	F_1	k_1^c	k_2^c	F_2	k_1^s	k_2^s	G
France	22	5	1	1	1	-14	15	3	-0.4
UK	3	2	5	1	1	-27	23	11	-0.3
US	23	5	22	20	17	-30	24	2	-0.1
Mexico	22	20	19	23	20	-18	14	14	-0.5

Table: Parameters for different countries (note: T omitted).

Results France - in sample

Understanding
Financial
Crises - a
statistical
perspective

M. R. Grasselli

This time is
different

The signals
approach

Long-term
Investment

Asset classes
and strategies

Transformed
indicators

Results

Conclusions

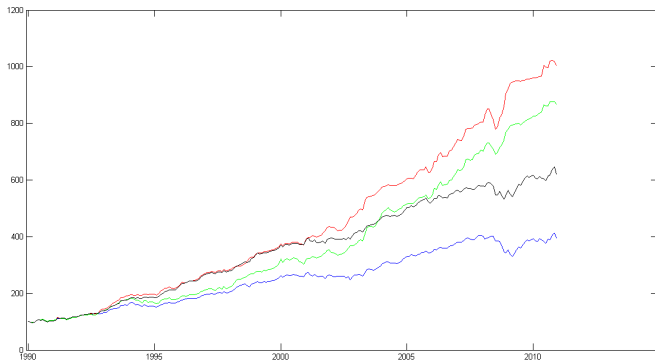


Figure: Portfolio value for full strategy (red), constant cash (green), constant equity (black), and benchmark (blue).

Results US - in sample

Understanding
Financial
Crises - a
statistical
perspective

M. R. Grasselli

This time is
different

The signals
approach

Long-term
Investment

Asset classes
and strategies
Transformed
indicators

Results

Conclusions

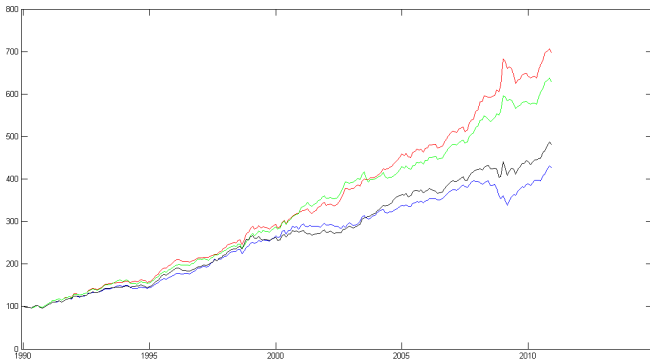


Figure: Portfolio value for full strategy (red), constant cash (green), constant equity (black), and benchmark (blue).

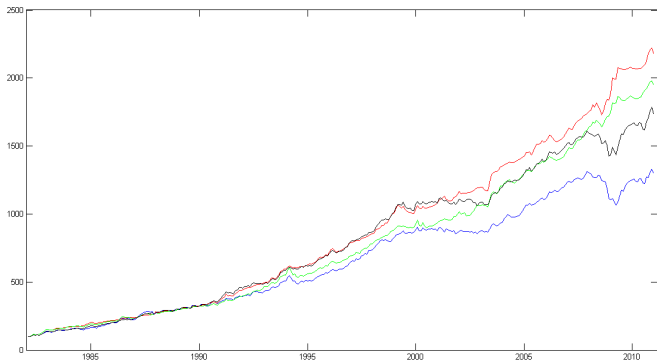


Figure: Portfolio value for full strategy (red), constant cash (green), constant equity (black), and benchmark (blue).

Results Mexico - in sample

Understanding
Financial
Crises - a
statistical
perspective

M. R. Grasselli

This time is
different

The signals
approach

Long-term
Investment

Asset classes
and strategies

Transformed
indicators

Results

Conclusions

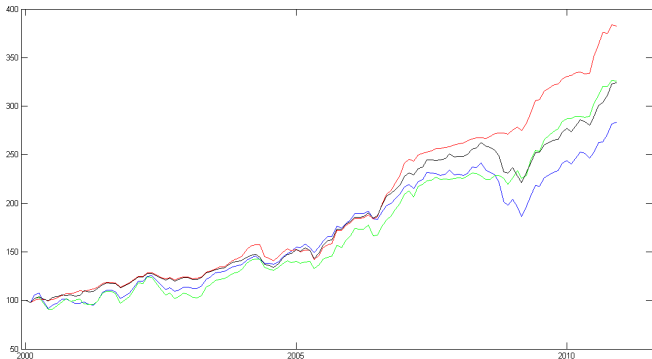


Figure: Portfolio value for full strategy (red), constant cash (green), constant equity (black), and benchmark (blue).

Summary of Results - in sample

Understanding
Financial
Crises - a
statistical
perspective

M. R. Grasselli

This time is
different

The signals
approach

Long-term
Investment

Asset classes
and strategies
Transformed
indicators

Results

Conclusions

	Benchmark	Full strategy
France	6.54%	10.99%
US	6.90%	9.25%
UK	8.85%	10.63%
Mexico	6.44%	12.18%

Table: Average annualized returns.

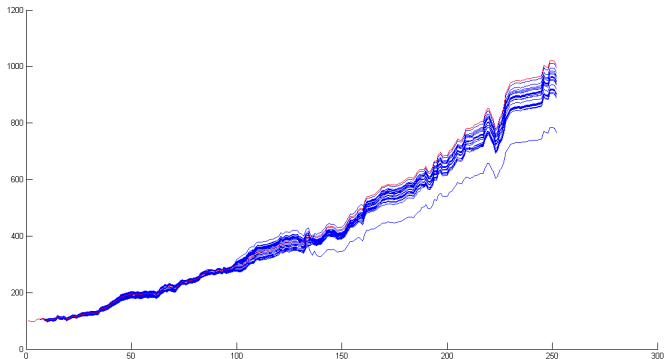


Figure: Perturbations (± 2 units) in moving average parameters for stock market indicator in France.

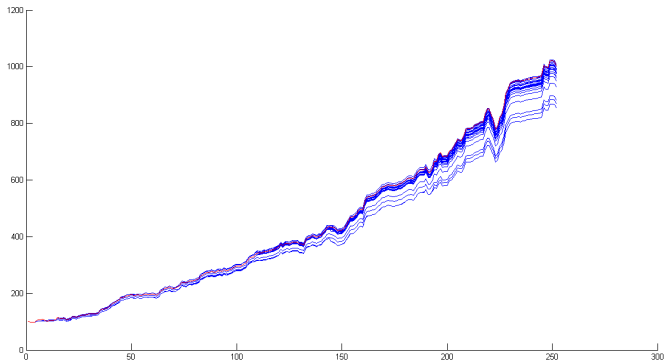


Figure: Perturbations (± 2 units) in moving average parameters for banking indicator in France.

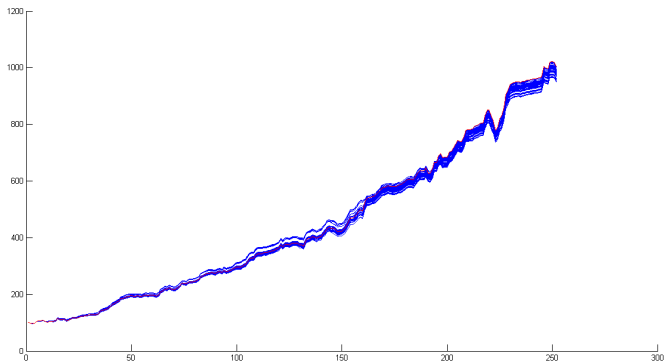


Figure: Perturbations in G and F_2 coefficients in France.

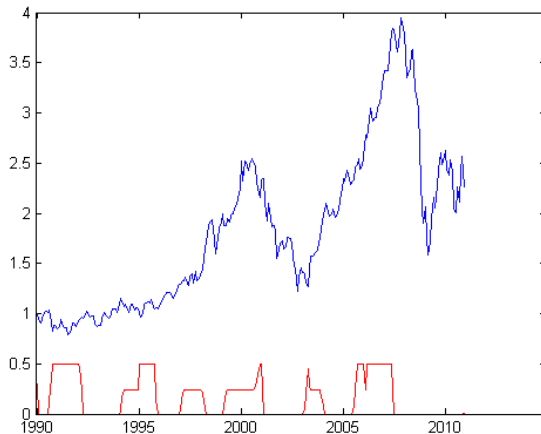


Figure: Stock market index and equity allocation in France.

Understanding
Financial
Crises - a
statistical
perspective

M. R. Grasselli

This time is
different

The signals
approach

Long-term
Investment

Asset classes
and strategies

Transformed
indicators

Results

Conclusions

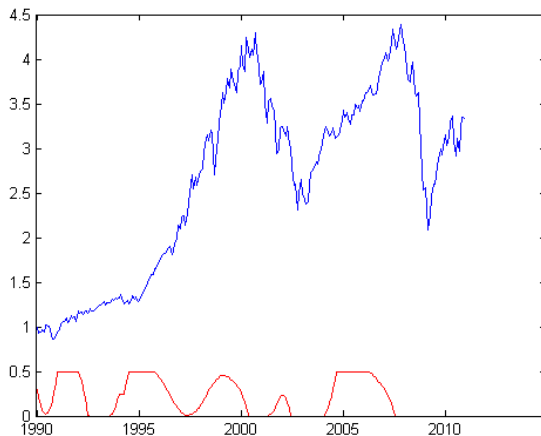


Figure: Stock market index and equity allocation in the US.

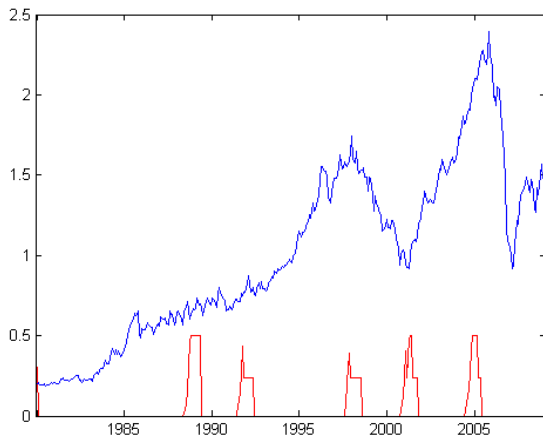


Figure: Stock market index and equity allocation in the UK.

Allocations Mexico

Understanding
Financial
Crises - a
statistical
perspective

M. R. Grasselli

This time is
different

The signals
approach

Long-term
Investment

Asset classes
and strategies

Transformed
indicators

Results

Conclusions

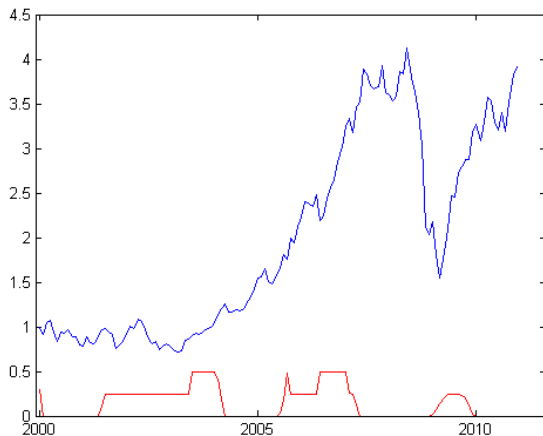


Figure: Stock market index and equity allocation in Mexico.

Results France - out of sample (2000-2011)

Understanding
Financial
Crises - a
statistical
perspective

M. R. Grasselli

This time is
different

The signals
approach

Long-term
Investment

Asset classes
and strategies
Transformed
indicators

Results

Conclusions



Figure: Portfolio value for full strategy (red) and benchmark (blue) using 1990-2000 as training period.

Results France - out of sample (2003-2011)

Understanding
Financial
Crises - a
statistical
perspective

M. R. Grasselli

This time is
different

The signals
approach

Long-term
Investment

Asset classes
and strategies
Transformed
indicators

Results

Conclusions

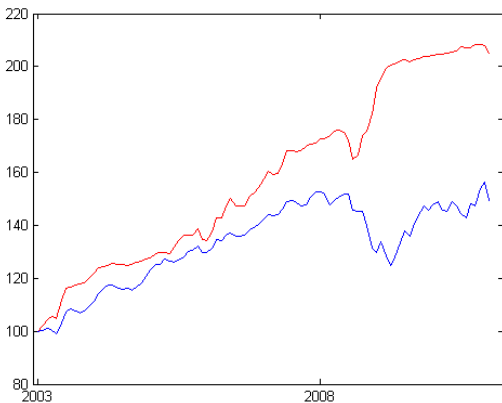


Figure: Portfolio value for full strategy (red) and benchmark (blue) using 1995-2003 as training period.

Results US - out of sample (2000-2011)

Understanding
Financial
Crises - a
statistical
perspective

M. R. Grasselli

This time is
different

The signals
approach

Long-term
Investment

Asset classes
and strategies
Transformed
indicators

Results

Conclusions



Figure: Portfolio value for full strategy (red) and benchmark (blue) using 1990-2000 as training period.

Results UK - out of sample (2000-2011)

Understanding
Financial
Crises - a
statistical
perspective

M. R. Grasselli

This time is
different

The signals
approach

Long-term
Investment

Asset classes
and strategies

Transformed
indicators

Results

Conclusions

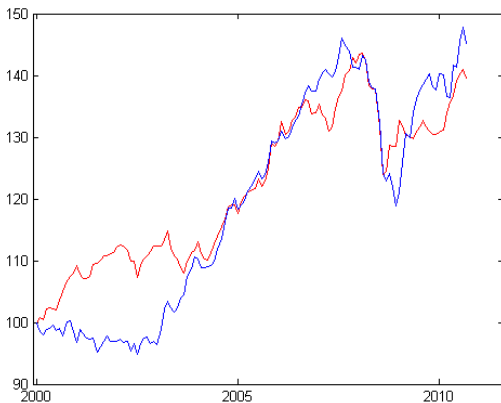


Figure: Portfolio value for full strategy (red) and benchmark (blue) using 1990-2000 as training period.

Summary of Results - out of sample

Understanding
Financial
Crises - a
statistical
perspective

M. R. Grasselli

This time is
different

The signals
approach

Long-term
Investment

Asset classes
and strategies
Transformed
indicators

Results

Conclusions

	Benchmark	Full strategy
France (2000-2011)	4.04%	5.64%
France (2003-2011)	4.98%	8.97%
US (2000-2011)	4.44%	5.54%
UK (2000-2011)	3.38%	3.05%

Table: Average annualized returns.

Allocations France - out of sample

Understanding
Financial
Crises - a
statistical
perspective

M. R. Grasselli

This time is
different

The signals
approach

Long-term
Investment

Asset classes
and strategies

Transformed
indicators

Results

Conclusions

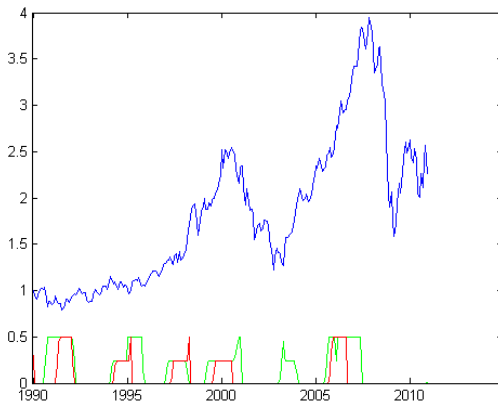


Figure: Stock market index and equity allocation in France for in-sample parameters (red) and out-of-sample parameters (green).

- Databases available on dropbox:
 - ① crises for 70 countries and 200 years.
 - ② annual indicators for banking and currency crises for 70 countries from 1970.
 - ③ monthly indicators for banking and currency crises for 22 countries from 1960.
 - ④ monthly indicators for stock market crises for 46 countries from 1960.
- Signals approach implemented on the databases above.
- Construction of aggregate indicators weighted by performance.
- Use of aggregate indicators in long-term investment strategies for select countries.

- Successful integration of macroeconomic signals in tactical allocation.
- In-sample backtesting of optimal strategy shows up to 5% increase in average annual returns in France.
- Out-of-sample testing shows that the strategy can achieve between 1.5% and 3% increase in average annual returns in France, depending on the choice of training period.
- Results for UK and US are less promising, probably due to higher degree of financialization.

- Establish best practices for calibration (optimal parameters, training period, etc) to improve robustness of the strategy.
- Extend tests to other countries.
- Extend model to incorporate multi-country investment.
- Incorporate market signals (volatility, price-to-earnings, etc) as indicators.