Risk Management using Real-Time Financial and Business Conditions Indicators

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Outline

• Estimating real time business conditions indicators

• Relationship between business conditions indicator and equity indices

• Creating a systemic risk index

• Conclusions
Estimating a business conditions index for Australia

- Use a linear dynamic factor model in daily state-space form
- Handle mixed-frequency and stock/flow data for Australia from 1986-2013
- Construct an (unobservable) domestic business conditions index and an external conditions index for Australia that summarizes large amount of information
- Decompose the contributions of 9 observable variables to the indices over time
- Construct impulse responses for both states and observable variables
- Focus on the 2008 crisis and its aftermath
Related Literature

• Dynamic factor models with mixed frequency, US: Aruoba, Diebold and Scotti (2009, JBES), Mariano and Murasawa (2003, JAE)
• Leading and coincident indicators: Stock and Watson (1989)
• Dynamic factor model for macro, US: Bernanke et al (2005, QJE)
Nine observable series available at different frequencies (most from 01/01/1986 to 31/07/2013)

Internal-related variables:

- $y_{st}$ - Yield Slope (daily) | (10yr - 3m TB)
- $hr_{st}$ - Total hours worked (monthly)
- $bc_{t}$ - NAB Business confidence (quarterly) – from 30/09/1989
- $gdp_{t}$ - Real GDP (quarterly)
- $vac_{t}$ - Job vacancies (quarterly)
Considered Variables

External-related variables:

- \( \text{tot}_t \) - Terms of trade (quarterly)
- \( \text{twi}_t \) - Export-weighted real exchange rate (quarterly)
- \( \text{wgdp}_t \) - Export-weighted real world GDP (quarterly) - from 15/02/1988
- \( \text{ted}_t \) - TED spread (daily) | (3m LIBOR - US TB)

- Flow data: \( \text{hrs}_t \), \( \text{gdp}_t \), \( \text{wgdp}_t \)
- Stock data: \( \text{ys}_t \), \( \text{bc}_t \), \( \text{vac}_t \), \( \text{tot}_t \), \( \text{twi}_t \), \( \text{ted}_t \)
- Financial Data: \( \text{ys}_t \), \( \text{ted}_t \)
Model Setup (State Variables)

Model for daily (unobservable) domestic business conditions index $X^d$ and (unobservable) external conditions index $X^f$

\[
\begin{bmatrix}
X^d_t \\
C^d_{tM} \\
C^d_{tQ} \\
X^f_t \\
C^f_{tQ}
\end{bmatrix}
= 
\begin{bmatrix}
\rho_d & 0 & 0 & \phi & 0 \\
\rho_d & \theta^M_d & 0 & 0 & 0 \\
\rho_d & 0 & \theta^Q_d & 0 & 0 \\
0 & 0 & 0 & \rho_f & 0 \\
0 & 0 & 0 & \rho_f & \theta^Q_f
\end{bmatrix}
\begin{bmatrix}
X^d_{t-1} \\
C^d_{t-1} \\
C^d_{tQ} \\
X^f_{t-1} \\
C^f_{tQ}
\end{bmatrix}
+ 
\begin{bmatrix}
1 & 0 & 1 & 0 & 0 \\
0 & 1 & 0 & 1 & 0 \\
0 & 0 & 1 & 1 & 0 \\
\end{bmatrix}
\begin{bmatrix}
\epsilon^d_t \\
\epsilon^f_t
\end{bmatrix}
\]
Model Setup (Observable Variables)

\[
\begin{bmatrix}
    y_{st} \\
    h_{rs_t} \\
    b_{ct} \\
    v_{ac_t} \\
    g_{dp_t} \\
    t_{wi_t} \\
    t_{ot_t} \\
    w_{gdp_t} \\
    t_{ed_t}
\end{bmatrix}
= \begin{bmatrix}
    \gamma_{ys} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
    0 & \gamma_{hrs} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
    0 & 0 & \gamma_{bc} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
    0 & 0 & 0 & \gamma_{vac} & 0 & 0 & 0 & 0 & 0 & 0 \\
    0 & 0 & 0 & 0 & \gamma_{gdp} & 0 & 0 & 0 & 0 & 0 \\
    0 & 0 & 0 & 0 & 0 & \gamma_{twi} & 0 & 0 & 0 & 0 \\
    0 & 0 & 0 & 0 & 0 & 0 & \gamma_{tot} & 0 & 0 & 0 \\
    0 & 0 & 0 & 0 & 0 & 0 & 0 & \gamma_{wgdp} & 0 & 0 \\
    0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \gamma_{ted}
\end{bmatrix}
+ \begin{bmatrix}
    \beta_{ys} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
    0 & \beta_{hrs} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
    \beta_{bc} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
    \beta_{vac} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
    0 & 0 & \beta_{gdp} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
    \beta_{twi} & 0 & 0 & \beta_{f_{twi}} & 0 & 0 & 0 & 0 & 0 & 0 \\
    \beta_{tot} & 0 & 0 & \beta_{f_{tot}} & 0 & 0 & 0 & 0 & 0 & 0 \\
    0 & 0 & 0 & 0 & \beta_{wgdp} & 0 & 0 & 0 & 0 & 0 \\
    0 & 0 & 0 & 0 & 0 & \beta_{ted}
\end{bmatrix}
+ \begin{bmatrix}
    X^d_t \\
    C^d_{tM} \\
    C^d_Q \\
    X^f_t \\
    C^f_Q
\end{bmatrix}
+ \begin{bmatrix}
    \eta^y_{s_t} \\
    \eta^h_{rs_{t-1}} \\
    \eta^b_{bc_{t-1}} \\
    \eta^v_{vac_{t-1}} \\
    \eta^g_{gdp_{t-1}} \\
    \eta^t_{twi_{t-1}} \\
    \eta^t_{tot_{t-1}} \\
    \eta^w_{wgdp_{t-1}} \\
    \eta^t_{ted_{t-1}}
\end{bmatrix}
\]
Model Estimation

• Implementation of Kalman filter by minimizing prediction errors

• Challenge lies in the nature of the data:
  • not every series has data available in every daily period $t$
  • combination of stock and flow data

• Simplex method to find starting values for parameters

• Use quasi-Newton method for estimation
Estimated Domestic and External Index

[Graph showing the estimated domestic and external index from 1985 to 2011, with two lines representing domestic business condition index (solid) and external index (dashed).]
Individual Contributions of Observables

Domestic business condition index

ys

bc

gdp
Individual Contributions of Observables

- twi
- wgdp
- tot
- ted
Contributions of internal and external variables
Key Results for Derived Index

• The NAB business confidence measure plays a vital role in the estimated domestic business conditions index (leading indicator).
• Terms of trade plays a vital role in the external conditions index.
• Financial variables (the domestic yield spread and the external TED spread) only appear to play an important role in crisis episodes.
• Australia’s mild experience of the global financial crisis of 2008 mainly driven by the external index, which then fed into deteriorating business confidence.
• In 2013, the external index was positive and improving, yet the domestic index was languishing, which may be because of pessimism in business confidence.
Relationship of Business Condition Index with Equity Returns

• We investigate the relationship of the index with weekly and monthly returns of the AOI
• We examine contemporaneous relationship but also predictive relationship between changes in the derived BCI and AOI returns
• To examine contribution of index to risk management, we also consider possible non-linear relationship between changes in the index and equity returns using copula analysis
• Copulas allow for a more general specification of the dependence structure than correlation that can only measure linear dependence
Copulas (Definition)

Let \( X = (X_1, \ldots, X_n)' \) be a random vector of real-valued random variables whose dependence structure is completely described by the joint distribution function.

Each random variable \( X_i \) has a marginal distribution of \( F_i \) that is assumed to be continuous for simplicity.

Then the function \( C \) can be identified as a joint distribution function with standard uniform marginals — the copula of the random vector \( X \):

\[
F(x_1, \ldots, x_n) = P(X_1 < x_1, \ldots, X_n < x_n)
= P[F_1(X_1) < F_1(x_1), \ldots, F_n(X_n) < F_n(x_n)]
= C(F_1(x_1), \ldots, F_n(x_n)),
\]
Dependence Structure for Gaussian and Student-t Copula

Scatterplot of simulated dependence structure for Gaussian copula (left panel) and Student t copula with df=2 (right panel), $\tau=0.6$. 
Dependence Structure for Clayton and Gumbel Copula

Scatterplot of simulated dependence structure for Clayton (left panel) and Gumbel copula, $\tau=0.6$. 
BCI changes and AOI Returns

Scatterplot of AOI weekly returns in t+2 vs. weekly changes in BCI in t (left panel) and estimated Student t-copula (df=7) for dependence structure
Relationship of Business Condition Index with Equity Returns

• Student-t copula provides best fit to dependence structure between changes in BCI and AOI returns
• For weekly data contemporaneous correlations are close to zero but lagged BCI (t → t+2, t→ t+3) has some predictive power on AOI index returns (ρ>0.1)
• For monthly data, correlations for contemporaneous and t→t+1 relationship are significant (ρ>0.1)
• Indicates some symmetric tail dependence between changes and returns that cannot be modelled by linear correlation
• Substantial changes in index have some predictive power on forthcoming large AOI returns
Developing a Systemic Risk Indicator for Australia

• Aim: To develop a systemic index with early warning features that can be used for macro-prudential policy in Australia
• Systemic risk index can depend on estimated unobserved states for macroeconomic conditions index, financial conditions index, and other explanatory variables such as, e.g., volatility in the equity market
• Financial conditions index is derived using Moody’s EDF and ratings from 01/01/2000 – 31/12/2012
• A systemic index can be constructed for a region where no (or very few) systemic events have occurred.
Related Literature

• Bottom-up approaches measure the contribution of individual institutions to the systemic risk of the entire financial market in a region
  • CoVaR (Adrian and Brunnermeier, 2009); SRISK (Brownlees and Engle, 2010); VAR for VaR (White, Kim and Manganelli, 2010); Contribution to total capital shortfall (Acharya, 2010)
• Top-down approaches identify systemic risk by inferring factors relating to the whole financial system, potentially including macroeconomic variables
  • Principal Component Analysis (Billio et al, 2010); Network Analysis (Allen et al, 2010)
  • Systemic risk diagnostics and early warning indicators derived from macro and credit risk data (Schwaab et al, 2011)
Research Design

- Global macroeconomic factor model (4 regions, different frequency data)
- Global financial risk factor model (4 regions, 44 companies, EDF, ratings data)
- Systemic risk Poisson regression model (probabilities of systemic events)
Macroeconomic Factor Model

• Macroeconomic condition in each region is decomposed into a global component that is common to all regions $f_0$ and a regional specific component $f_i$

• Global factor follows the dynamics:

$$ f_{0,t+1} = \phi_0 f_{0,t} + \eta_{0,t} $$

• Transition of factor for region $i$ ($i=1,\ldots,4$):

$$ f_{i,t+1} = \phi_i f_{i,t} + \theta_i f_{0,t} + \eta_{i,t} $$

• Observation equation:

$$ y_t = \gamma y_{t-1} + Zf_t + \varepsilon_t $$
## Macroeconomic Variables

<table>
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<tr>
<th>Variables</th>
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<th>Quarterly</th>
<th>Annual</th>
<th>Stock/Flow</th>
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<td>ROW</td>
<td>Flow</td>
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<td>EU, US, ROW</td>
<td>AU</td>
<td></td>
<td>Flow</td>
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<td>Unemployment rate</td>
<td>AU, EU, US</td>
<td>ROW</td>
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<td>Stock</td>
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<td>Confidence index</td>
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<td>AU, ROW</td>
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<td>Stock</td>
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<td>Stock market return</td>
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<td>Flow</td>
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<td>Job vacancy</td>
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<td>EU, ROW</td>
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<td>Stock</td>
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<td>EU</td>
<td>Stock</td>
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<td>Term premium</td>
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<td></td>
<td></td>
<td>Stock</td>
</tr>
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</table>

Table 1: Variables used in macroeconomic model
Macroeconomic Factors
Financial Risk Model

Parsimonious groupings

- The largest 11 financial companies in each region \((i=1,..11)\)
- 4 regions: US, EU, AU, ROW \((r=1,..4)\)

Expected default freq:
(from Moodys EDF)

Rating level:

Unobserved factors:

\[
z_{i,r}(t) = \text{prob}(\text{value < debt})
\]

\[
A_{i,t} = 1, ..., 20
\]

\[
S(t) = \{S_a(t), S_r(t)\}
\]

\{Ratings, and region factors\}
## Rating frequency

<table>
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<tr>
<th>Rating</th>
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<th>Percent of Total Frequency</th>
<th>Cumulative Frequency Count</th>
<th>Cumulative Percent</th>
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<td>2498</td>
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<td>Baa3</td>
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<td>B1</td>
<td>156</td>
<td>0.65</td>
<td>23744</td>
<td>99.34</td>
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<td>B3</td>
<td>157</td>
<td>0.66</td>
<td>23901</td>
<td>100.00</td>
</tr>
</tbody>
</table>

*Table 3: Observations across ratings*
Model for Financial Risk Factors

\[
\log \frac{z_{i,t}}{1 - z_{i,t}} = a + A_{i,t} S_{a,t} + dS_{r,t} + v_{i,t}
\]

\[
S_{t+1} = \rho S_t + \eta_t
\]

\[
\eta_t \sim N(0, Q), \quad \rho, Q \text{ are diagonal.}
\]

Companies: \( i = 1, \ldots, 11 \)

Regions: \( r = 1, \ldots, 4 \)
Financial Risk Factors

ROW region factor

AUS region factor (relative to ROW)

EU region factor (relative to ROW)

USA region factor (relative to ROW)
Rating Factor
Systemically Relevant Events

• Default events of financial corporations are sourced from COMPUSTAT and Moody’s Corporate Default Risk Service

• We define a systemically relevant event as the default of a financial institution whose market capitalization is greater than (i) 0.01%; (ii) 0.002% of the total regional market capitalization of all financial institutions

• Based on this definition we obtain (i) 42; (ii) 82 events for all regions
Defaults in the Financial Sector and Systemically Relevant Events
Defaults in the Financial Sector and Systemically Relevant Events

• Largest company defaulted is: LEHMAN BROTHERS HOLDINGS INC

• Australian companies defaulted:
  AU000000RRT1, RECORD REALTY
  AU000000BAO2, BROOKFIELD AUSTR OPP FUND
Explaining Systemically Relevant Events

We create a simple model for explaining the number of systemically relevant events:

- Number of systemic events: \( y_t^s \)
- Common financial risk factor: \( f_{0,t}^f \)
- Regional financial risk factor: \( f_{r,t}^f \)
- Macroeconomic factor: \( f_t^m \)
- Stock market index volatility, estimated using an EWMA approach: \( X_t \)
Poisson Regression Model

Poisson regression assumes the response variable $y$ follows a Poisson distribution, and the logarithm of its expected value can be modelled by a linear combination of unknown parameters:

$$y_t^s \sim \text{Poisson}(\lambda_t^s)$$

$$\log \lambda_t^s = \gamma_0 + f_{0,t} \gamma_1 + f_{r,t} \gamma_2 + X_t \gamma_3 + f_t^m \gamma_4$$
Results for Poisson Regression (k=0.01%)

|       | Estimate | Std. Error | z value | Pr(>|z|) |
|-------|----------|------------|---------|----------|
| (Intercept) | 1.3234   | 1.5734     | 0.84    | 0.4003   |
| f0     | 0.7880   | 0.2219     | 3.55    | 0.0004   |
| fr     | 1.0168   | 0.3521     | 2.89    | 0.0039   |
| vol    | 119.5016 | 25.0235    | 4.78    | 0.0000   |
| fm     | 0.1047   | 0.0756     | 1.38    | 0.1661   |

Table 7: Poisson regression estimates, R-squared = 0.1941
Systemic Index – Europe (k=0.01%)
Systemic Index – Europe (k=0.002%)
Systemic Index – US (k=0.01%)
Systemic Index – US (k=0.002%)
Systemic Index – ROW (k=0.01%)
Systemic Index – Australia (k=0.01%)
Systemic Index – Australia (k=0.002%)
Concluding Comments

• We construct an unobservable domestic business conditions index and an external conditions index for Australia that summarizes large amount of information
• Addresses lack of parsimonious indicators for national or regional financial and business conditions in real-time
• Provides the first real-time business and systemic risk indicators for Australia summarizing large amount of information
• Identifies driving factors of risk in Australia’s economy financial markets including possible spill-over effects
• Derived index seems to have some predictive power on equity returns in financial markets (mainly for tail risks)
Concluding Comments

• We have used macroeconomic, financial risk and financial institutions’ default data to construct a systemic index.
• The method incorporates the probability of defaults of financial institutions as well as the size of financial institutions.
• A systemic index can be constructed for a region where no (or very few) systemic events have occurred.
• The index is consistent with observed systemic data, but number of systemically relevant events in Australia is lower than what is suggested by the created systemic risk indicator.
Concluding Comments

- Derived common and regional financial factors provide significant contributions to explaining systemic risk
- Volatility in regional markets is a significant factor for derived systemic risk indicators
- Derived macroeconomic condition index does not provide a significant contribution in the current model
Concluding Comments

- Forward-looking indicators for business conditions, financial and systemic risks will provide an efficient, low cost summary of information.
- Availability of this information in real-time is expected to provide economic benefits to policymakers and market participants.
- Indicators as result of this project will reduce the dimensionality of the information problem, and make it easier for market participants to better manage and hedge the many risks they face.
- Project will hopefully contribute to policy efforts to sustain financial stability in Australia and the region.
Thank you very much!
Impulse responses of domestic index

- $y_s$
- $bc$
- $gdp$
- $tot$
- $ted$
- $hrs$
- $vac$
- $twi$
- $wgdp$
Impulse responses of each observable on others and itself
### Appendix List of financial institutions

<table>
<thead>
<tr>
<th>No</th>
<th>Name</th>
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<th>Region</th>
<th>Country</th>
<th>Mcap</th>
<th>Rank</th>
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<td>COMMONWEALTH BANK</td>
<td>AU000000CBA7</td>
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<td>AUS</td>
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<td>2</td>
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## Appendix List of financial institutions

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