Institution: University of Edinburgh

Unit of Assessment: 17 Business and Management Studies

Title of case study: Helping banks comply with a new regulation on provisions for default risk

Period when the underpinning research was undertaken: 2007-2020

Details of staff conducting the underpinning research from the submitting unit:

Name(s):	Role(s) (e.g. job title):	Period(s) employed by submitting HEI:
Jonathan Crook	Professor of Business Economics	1979-present
Tony Bellotti	Post-doctoral Research Fellow	2006-2010
Mindy Leow	Post-doctoral Research Fellow	2011-2014
Viani Djeundje	Research Fellow	2015-present

Period when the claimed impact occurred: 2014-2020

Is this case study continued from a case study submitted in 2014? Y

1. Summary of the impact

Changed regulations required that from January 2018 all banks in Europe (from 2017 in the US) have to predict, if default risk increases, the probability that a borrower will default in each month in the life of every such loan. This provided an opportunity to apply research carried out in the Credit Research Centre that related the probability of default in any particular month in the life of a loan to the macroeconomy. Banks used this methodology widely to meet the regulation and put aside appropriate amounts to cover for account default. This helped to protect the funds of depositors.

2. Underpinning research

A survival model uses data to predict the probability that an event will happen for the first time in the next time period. Until the work of Crook and colleagues they were typically used in medical and reliability applications. A credit risk survival model uses data to predict the probability that a borrower will default for the first time in the next month. These probabilities are often referred to as hazard rates. Predictions can be gained for every month in the life of an account subject to either a lagging structure or forecasts of the predictors.

Building on a 2009 paper by Bellotti and Crook (3.1) that showed that including macroeconomic variables into a credit scoring model in continuous time enhanced its accuracy and gave more information than conventional cross section models, Bellotti and Crook (3.2) showed how a discrete time survival model would be even more appropriate than a continuous time model to make such predictions. This is because loan repayment performance is almost always measured monthly by banks and financial institutions and gaining predictions is easier than in a continuous time model. The discrete time models also use an estimation methodology more familiar to statisticians in banks than continuous time models.

Bellotti and Crook showed how these models can be used for stress testing, that is deriving the empirical distribution of probabilities of default for a portfolio of loans if plausible but severe macroeconomic conditions hold. This is done by simulating values of the macroeconomic variables in the model from historical observed values. Crucial to this exercise is to preserve the correlation structure between the macroeconomic variables, otherwise implausible values are used. Bellotti and Crook (3.2 and 3.3) used two alternative methods of preserving this correlation structure. Leow and Crook (3.4) estimated survival

models of default before and after the financial crisis of 2008. They found that the parameters of survival models had changed. A change in parameters may be seen as the result of omitted variables. So they experimented to see if the inclusion of additional macroeconomic variables could make these models robust over the long run. Djeundje and Crook (3.5) developed the methodology to make the predictions more accurate by allowing the parameters of the model to change over time as the account ages.

Further research by Leow and Crook (3.6), again using survival models for credit risk, showed how to predict the probability that a retail credit account would move between any two states of delinquency (such as up to date to one payment behind or two payments behind to one payment behind), between any two periods in the life of a loan. To the best of our knowledge no lender had developed models that can do this.

3. References to the research

3.1 T. Bellotti and J. Crook (2009) Credit Scoring with macroeconomic variables using survival analysis. *Journal of the Operations Research Society*. 60 (12), 1699-1707. https://doi.org/10.1057/jors.2008.130

3.2 T. Bellotti and J. Crook (2013) Forecasting and Stress Testing Credit Card Default with Dynamic Models *International Journal of Forecasting*, 29(4), 563-574. https://doi.org/10.1016/j.ijforecast.2013.04.003

3.3 T. Bellotti and J. Crook (2014) Retail Credit Stress Testing Using A Discrete Hazard Model With Macroeconomic Factors. *Journal of the Operational Research Society*, vol 65, 340-350. https://doi.org/10.1057/jors.2013.91 .

3.4 M. Leow and J.Crook (2016) The Stability of Survival Model Parameter Estimates for predicting the probability of default: Empirical Evidence over the Credit Crisis. *European Jo of Operational Research*, 249(2), 457-464. http://dx.doi.org/10.1016/j.ejor.2014.09.005

3.5 V. Djeundje and J. Crook (2019) Dynamic survival models with time varying coefficients for credit risks. *European Journal of Operational Research* 275(1), 319-333. https://doi.org/10.1016/j.ejor.2018.11.029

3.6 M. Leow and J Crook (2014) Intensity Models and Transition Probabilities for Credit Card Loan Delinquencies. *European Journal of Operational Research*. 236(2), 685-694. doi.org/10.1016/j.ejor.2013.12.026

4. Details of the impact

A new standard, *IFRS9 Financial Instruments,* was introduced by the International Accounting Standards Board in 2014. It applies to every bank in Europe, Russia, Canada, South America, Australia and most of Africa (https://www.ifrs.org/use-around-the-world/use-of-ifrs-standards-by-jurisdiction/). In 2018 IFRS9 applied to over EUR2.223bn of consumer loans and receivables outstanding to the largest five UK banks alone. From January 2018 it requires each bank to predict the expected future losses from each loan if the risk associated with that loan's repayments changed after the loan had been granted. In the US a very similar requirement was introduced from December 2017 by the Financial Standards Board and applies to all US banks. The predictions will be of Current Expected Credit Losses (CECL). Both of these requirements are important because a proportion of the amount of cash received in each month by a bank is put aside as a "provision" to protect depositors and the bank in the event of loan default. So models for these losses are absolutely fundamental to the stability of the financial system and they affect the amount of capital that each bank must hold. These requirements posed major challenges to banks the vast majority of which had not modelled such concepts before 2014.

The research detailed above was disseminated to bank statisticians and consultants through our published papers, presentations at multiple conferences attended largely by practitioners, and at Innovation Forums we have organised with a multinational bank.

The research gave banks, other lenders and regulators a methodology to make these predictions. Therefore, it helped banks and lenders to protect those who saved with,

borrowed from, or bought equity in them from major losses. It also helped regulators ensure compliance.

To predict the expected losses from a loan a bank must weight each possible receipt value by the probability it is not received and do this for every month in the life of the loan. These probabilities must be made conditional on the factors that explain the increased risk, such as the state of the macroeconomy. The work of Crook et al showed exactly how to compute these predicted probabilities. The methodology expressed in these papers is therefore used widely by banks throughout the world.

As the Technical Director of 4 Most Europe, which has the largest number of credit risk modellers (130) in any consultancy in the UK, said in April 2018 [5.1]:

> "4most has supported around 20 banks in the UK and other regions to comply with IFRS9 requirements over the last 3 years. The work that the Edinburgh team has done to explore the use of discrete time Survival models and the linkages to economic drivers has been highly valuable in convincing banks that the approaches used are robust and compliant with requirements to be statistically valid."

He continues

> "Outside of our direct work we are aware that major consultancies (Deloitte, KPMG as examples) as well as other niche consultancies (Jaywing, Risk Dynamics - now part of McKinsey and Co) have also adopted similar approaches and are likely to have been influenced by these papers."

A letter from Jaywing [5.2] confirms this.

A letter from the Head of Risk Decision Analytics at RBS [5.3] also states that the modelling methodologies outlined in the above publications have been "especially useful in creating our own models to comply with the new International Accounting Standards Board IFRS9 regulation".

The CEO of Prescient Models LLC and Deep Future Analytics LLC (a consultancy with clients in the US and Europe) [5.4] wrote in September 2019:

> "On multiple occasions my consulting clients asked me specifically if we knew about the work by Profs. Crook and Bellotti and how they could apply that to their portfolios."

He continues

> "The best and some might argue the only way to comply with these rules with any accuracy is via some variation of survival analysis married with macroeconomic scenarios, again in line with research done at the Centre. Our companies now have 200+ CECL clients leveraging out multihorizon discrete time survival models which are a direct descendent of this earlier research"

Similarly a Managing Director of Moody's Analytics [5.5] states:

> "The analytics developed by the Centre helped firms such as Moody's Analytics develop credit risk models for the banking industry. They were especially useful in creating our models for provisions to comply with the new International Accounting Standards Board IFRS9 regulation…The multistate models' approach has inspired new lines of research within Moody's Analytics such as the analysis of recurrent events using discontinuous risk intervals"

He observes

"The results of this research have informed the development of our own methods and models to predict credit default and losses."

5. Sources to corroborate the impact

5.1. Technical Director, 4Most Europe testimonial
5.2. A manager, Jaywing testimonial
5.3. Head of Risk Decision Analytics, RBS testimonial
5.4. CEO, Prescient Models, USA, testimonial
5.5. Managing Director Moody's Analytics UK, testimonial