Institution: King's College London		
Unit of Assessment: 17 Business and Management Studies		
Title of case study: Developing New Forecasting Models at the Bank of England and the European Central Bank		
Period when the underpinning research was undertaken: 2015 – 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:**
George Kapetanios	Professor of Finance and Econometrics	From 01/09/2015
Period when the claimed impact occurred: 2015 – 2020		
Is this case study continued from a case study submitted in 2014? N		

1. Summary of the impact

Forecasting is a crucial activity at all central banks. It both informs policymakers on the direction of the economy when making decisions, and allows them to measure the effectiveness of their policies. Policymakers at central banks have relied on conventional time-varying econometric methods for their forecasting analyses. However, they have found them unwieldy, computationally demanding and misaligned with economic policy because they do not account for the ever-changing nature of economic data. To address these challenges, King's Business School researchers have partnered with analysts at the Bank of England and the European Central Bank to create an innovative time-varying estimation model that utilises rolling data. The new model has been successfully adopted by both banks, leading to more robust modelling efforts, improved policy analyses and strengthened analytical skills of their staff.

2. Underpinning research

The economy is in constant transformation: new technologies, products, jobs and businesses appear continuously, and new policies and institutional arrangements arise to accommodate them. As a result, the types of economic data and the methods needed to interrogate them change in fundamental ways. In this context of constant transformation, statistical analysis of the economy requires a more dynamic approach to data capture and demands improved statistical methods that can interpret rapid change in the characteristics of key economic variables such as averages and variances. Economists must address this fundamental feature of economic data, given that failure to do so could lead to catastrophic problems such as the inability to forecast efficiently. Most forecast failures in economics – and there have been many such instances, most notably the unexpected 2008 financial crisis – can (in part) be attributed to forecasting methodologies not adequately accounting for rapidly changing data.

The response has been to use models that can account for changes over time, referred to as 'time-varying models'. Conventional models of this sort involve some form of rolling averaging of the data. The problem, however, is that such models are insufficiently flexible to the effects of exogenous and random shocks. This makes them increasingly unsuitable to the current economic context, characterized by drastic and unpredictable changes wrought by events such as Brexit and the COVID-19 pandemic, for example.

Building on a close partnership with the Bank of England, King's researchers developed and refined an alternative 'time-varying model' that addresses the analytical and practical shortcomings of conventional models used by many central banks to forecast economic change. The new model requires minimal computational costs because it can be incorporated into existing systems [1].

In developing this new time-varying model, King's research has made significant contributions to knowledge: crucially, introducing a new model that allows for exogenous shocks to drive change, which was not possible using conventional models. In particular, the new model deploys non-

parametric estimation techniques instead of the conventional 'Bayesian statistics' [1,2,3]. The advantage is that non-parametric estimation techniques enable the incorporation of realistic assumptions about the sources of change in the economy. Specifically, they allow the change to have random elements and to be driven by sudden shocks. This enables, for example, the estimation of the degree to which financial shocks are transmitted to core variables of GDP and inflation [3], as well as the implications of a change in monetary policy [3,4]. The new model also provides inference (statistical testing and construction of confidence intervals) for forecasted estimates of output growth and inflation [2,5].

Perhaps the most important contribution of this research is the wide applicability and ease of use for the proposed class of methods. For example, in recent work, the method has been applied to big data [4] as well as machine learning models such as deep neural net (deep learning) models. Put simply, the method is adaptable because it is a refinement of rolling windows; as a result, it is easy to incorporate into most forms of modelling and, because it is possible to provide an underpinning for its desirable theoretical properties, it can be justifiably used widely.

3. References to the research

The research was published in top journals and went through strict peer-review processes: [2] is a top 5 journal in econometrics; [3] is a top 10 journal in finance.

[1] Chronopoulos, I., Kapetanios, G., & Petrova, K. (2019). Kernel-Based Volatility Generalised Least Squares. *Econometrics and Statistics*. DOI: 10.1016/j.ecosta.2019.11.001

[2] Giraitis, L., Kapetanios, G., Wetherilt, A., & Žikeš, F. (2016). Estimating the Dynamics and Persistence of Financial Networks, With Application to Sterling Money Market. *Journal of Applied Econometrics*, 31(1), 58–84. DOI: 10.1002/jae.2457

[3] Galvão, A. B., Giraitis, L., Kapetanios, G., Petrova, K. (2016). A Time-Varying DSGE Model With Financial Frictions. *Journal of Empirical Finance*, 38(1), 690–716. DOI: 10.1016/j.jempfin.2016.02.012

[4] Kapetanios, G., Masolo, R., Petrova, K., & Waldron, M. (2019). A Time-Varying Parameter Structural Model of the UK Economy. *Journal of Economic Dynamics and Control*, 106, 103705. DOI: 10.1016/j.jedc.2019.05.012

[5] Giraitis, L., Kapetanios, G., & Yates, T. (2018). Inference on Heteroskedastic Multivariate Time Varying Random Coefficient Models. Journal of Time Series Analysis, 39(2), 129–149. DOI: 10.1111/jtsa.12271

4. Details of the impact

Central banks are increasingly concerned about the effects of structural changes such as those caused by Brexit, new digital technologies, or COVID-19, on the validity of models used for economic policy making and forecasting. This concern spans all kinds of models: from statistical models mainly used for forecasting to structural economic models used for narrative analyses of the evolution of the UK and world economy. Researchers from King's Business School have collaborated with analysts at the Bank of England and the European Central Bank (ECB) to produce a new model that resolves the problems associated with 'time variation' in economic data [A]. The new model has been successfully adopted by the two central banks, improving their analytical capability and leading to more robust policy decisions.

Developing a new forecasting model for the Bank of England

Over the past 18 years, King's Business School Professor George Kapetanios has collaborated with the Bank of England on multiple projects, resulting in a profound impact on the work of several of its divisions. First and foremost, the modelling techniques co-developed by Kapetanios and colleagues at the Bank [4, A] have been formally implemented into the Bank's computational processes used in its forecasting platform. The recommended time-varying modelling techniques have been used by various teams to produce models and analyses that have informed the Bank's policy decisions, taken by members of the Monetary Policy Committee (MPC).

Francesca Monti, former Head of Modelling in the Monetary Analysis Directorate, explains that the new model co-developed by King's and Bank of England colleagues "*has been used to discuss*

various issues with the MPC, and particularly has been used to weigh in on the debate about the exchange rate pass-through, that is how exchange rate movements first affect import prices and then overall inflation, and how it has changed in time, with a rich structural model" [B]. King's research contribution to understanding how exchange rates feed into inflation has been particularly significant in light of the 2016 Brexit referendum, which has increased exchange rate volatility and is presumed to change the UK's trade relations in a permanent way.

Additionally, in September 2019, when uncertainty about the Brexit deal was rife, the Modelling Team at the Bank of England used the newly developed time-varying estimation techniques [2] to inform the MPC on the impact of macro-economic and financial uncertainty on the UK economy. Dr Monti explains that "*the model was able to disentangle the differential effects of the two types of uncertainty on key macroeconomic variables, such as GDP, inflation and other macroaggregates. It also gave very interesting insights on how the two types of uncertainty have affected the economy in different time periods*" [B].

The new model [4] also informed the speech given by Bank of England Chief Economist, Andrew Haldane, at the 2018 Federal Reserve Bank of Kansas City Economic Policy Symposium, Jackson Hole, Wyoming [C]. As the highest profile central banking conference in the world, the event brings together central bankers, financial market participants, government representatives, academics and news media to discuss long-term policy issues of mutual concern. In his speech on 'Market Power and Monetary Policy' Haldane specifically cited the King's research [4] when discussing the lower incidence of mark-up shocks. Using the King's finding that over the last few decades the estimate of mark-up shock volatility in the UK economy has decreased, the research contributed to the discussion of developments in product markets and monetary policy. This finding has, in particular, important implications for the variability of inflation and hence the MPC's ability to meet the inflation target. Ricardo Masolo, Research Manager of the Monetary Policy Outlook Division, explains that "*to the best of [his] knowledge no similar evidence was available for the UK"* prior to Kapetanios' model [D].

Improving the ECB's modelling efforts and policy analysis

King's research has also provided the ECB with useful tools for policy analysis, steering their internal policy work. This was enabled by Professor Kapetanios' formal involvement as a consultant and by his frequent presentations at the ECB, including at the ECB Workshop on Forecasting Techniques and at the Working Group on Econometric Modelling in 2018. Under his direct guidance, many internal tools were produced to support the ECB staff with their economic monitoring and forecasting efforts.

Gonzalo Camba-Mendez, Senior Lead Financial Risk Expert at ECB, confirms that "*the work of Kapetanios provided us with more efficient reduced-form models for forecasting, as well as with more robust tools to analyse the monetary policy transmission mechanism*" [E]. For the ECB, it was especially important to identify a more robust model because of the profound structural changes affecting the world economy, including those caused by globalisation, deregulation and the widespread use of information technologies, which have altered the transmission of monetary policy shocks. The new model [3] significantly helped the ECB adapt its economic estimates with respect to this changing environment. In fact, his contributions "*have been an important reference when setting up internal tools for the economic monitoring and forecasting of euro area macroeconomic developments. Many of those internal tools were developed under his direct guidance and leadership"* [E]. His recent work on modelling time-varying volatility [4] has also informed internal ECB tools to monitor and measure market risk.

The King's research collaboration has not only helped the ECB set up new policy tools, but also improved the analytical skills of the ECB staff. In fact, as reported by Camba-Mendez, *"Our cooperation with professor Kapetanios not only allowed us to quickly set-up tools for our regular economic and policy analysis, but has also been very important for strengthening the analytical skills of our ECB staff…his availability for some informal exchanges on his method has already provided us with very valuable information, and we very much look forward to future cooperation with Professor Kapetanios in this, as well as in many other areas of financial modelling where his expertise is very valuable to us*" [E].

5. Sources to corroborate the impact

[A] Petrova, K., Kapetanios, G., Masolo, R., & Waldron, M. (2017). A Time Varying Parameter Structural Model of the UK Economy', *Bank of England Staff Working Paper*, No 677.

[B] Testimonial from: Francesca Monti, former Head of Modelling in the Monetary Analysis Directorate at the Bank of England, 3rd December 2020

[C] Speech given by Andrew G Haldane, Chief Economist, Bank of England. Co-authors: Tommaso Aquilante, Shiv Chowla, Nikola Dacic, Riccardo Masolo, Patrick Schneider, Martin Seneca and Srdan Tatomir (24 August 2018). *Market Power and Monetary Policy.* At Federal Reserve Bank of Kansas City Economic Policy Symposium, Jackson Hole, Wyoming.

[D] Testimonial from: Ricardo Masolo, Research Manager of the Monetary Policy Outlook Division in the Monetary Analysis Directorate at the Bank of England, 8th February 2019

[E] Testimonial from: Gonzalo Camba-Mendez, European Central Bank, Directorate Risk Management, 5th April 2020