Network Science and Dynamical Systems Based Analysis of Firm Level Global Production Networks.

Internal supervisors:
- Bazil Sansom, *Maths and Economics*
- Robert MacKay, *Maths*

***Background*:** The economy is characterized by a complex – and increasingly highly globalised - production network, in which firms rely on each other for intermediate goods and services (as inputs for their own production) and for finance. This flow of outputs from suppliers to customers and the production process relies on the availability of finance and on the flow of payments from customers to their suppliers. Disruption to an important intermediate input may disrupt production downstream in the production process; withdrawal of bank-credit to a firm or subset of firms may propagate through the production-network; and there may be significant endogenous trade-credit dynamics within the production network (for trade credit to be stable, trade receivables need to be collected and trade creditors paid, acceleration/deceleration of either of these trade accounts by a firm or subset of firms may thus have knock-on effects that propagate through the supply chain based funding network); meanwhile credit-risk of one firm may spill over to its trade-creditors.

Production network structure/topology may play a key role in how these sorts of shocks propagate, thus shape the performance of both (i) individual firms; and (ii) the wider network (more or less aggregate outcomes). Conventional approaches in economics to understanding either firm level or aggregate risk and performance have not considered the role of network structure. Although this is an area of growing interest, there is little work from a dynamical systems perspective; and there are very few empirical studies of "real-life" supply networks - especially at the wider network level, which may include many thousands of firms. This lack of empirical work is not least due to the difficulties in acquiring large-scale empirical data sets. However recent data acquisition efforts seem to have opened up new opportunities. In particular Bloomberg supply chain data (some barriers to use even here overcome by tools we have built) presents a unique opportunity to explore: (i) an extensive firm level international production network; combined with (ii) rich detail on firm attributes. The combined study of both topological information and node level variables may allow for particularly rich analyses.

***MSc Project*:** There is scope to tailor to student interest and ideas. However the MSc project could explore topology of empirical firm level network and question of relationship between structure and node characteristics and between structure and dynamics. Strategies to be considered by and agreed with student, but strategies that could be taken include e.g: the student might use enumeration of motifs as a systematic approach to identify important local structures (opportunity to consider search space and efficient ways to explore it). Important motifs identified would represent 'archetypal' production structures (useful basis for further empirical and theoretical work); and also provide one approach to studying the overall network (based on exceptionality of motif frequencies); but the identification of motifs/sub-graphs combined with the rich node level data available from Bloomberg could further be used in order to study relationship between local structure and local dynamics. Other node level statistics might also be developed and studied based on economic theory. Analysis based on the global network could also be used not only to study global topology, but also to study the relationship between topology and firm level variables (e.g. is there a relationship between topology and capital structure? Cash flow volatility? Etc.). This could be theory driven, but the rich variable space available via Bloomberg could provide student an opportunity to take exploratory data driven approaches to studying relationship between topology and firm level variables. For a student more interested to pursue theoretical work, early identification of key motifs could provide a basis to develop small dynamic models of these motifs using e.g. a generalised modelling strategy (Gross & Feudel, 2006) (providing interesting extension of standard ODE modelling and local bifurcation analysis for student familiar with these methods).

***Prospect for follow-on PhD project*:**
This can be extended to a PhD in a number of ways depending on the interests of the student. Regarding methods both (i) methods for analysis of large empirical networks; and (ii) generalised modelling strategies for dynamic systems will provide useful tools for a very wide range of problems and applications. Thematically, manufacturing supply networks are complex dynamic networks that play a crucial role in the economy and are increasingly contested (think China-US trade-wars; HuaWei etc.) and rightly an area of growing interest and research. Nevertheless, there are so far only few studies that apply modern tools of network science and dynamical system theory to the analysis of these networks making it an area of considerable opportunity from a research perspective. Moreover the Bloomberg supply chain data the student will use provides a rich and highly underexploited resource and this presents plenty of opportunity. Themes and methods taken together are relevant to issues as diverse and significant as e.g. how to think about and monitor exposure and risk at firm or portfolio level; how to understand aggregate investment and output dynamics; how to understand cross-boarder monetary policy spillovers; how to understand the impact of international trade policies. For the interested student this work on production networks could also easily lead into work on financial networks where there are currently very significant policy issues and questions that would benefit from a complex network dynamics approach (e.g. financial market infrastructure following major reforms since the Global Financial Crisis (Marshall & Steigerwald, 2013)) where we also have projects and collaborations.

References

Gross, T., & Feudel, U. (2006). Generalized models as a universal approach to the analysis of nonlinear dynamical systems. *Physical Review E*, 15.

Marshall, D., & Steigerwald, R. (2013). The role of time-critical liquidity in financial markets, 30–46.