

**Toy Models, Structural Models and Empirically Detailed Models:
Finding a Modelling Strategy that is Fit for Purpose**

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1 Introduction

- Background
 - I edited an issue of *Oxford Review of Economic Policy* in 2018 on the future of macro as a discipline –
 - We asked of DSGE models: is the glass half empty or half full?
 - I edited a second issue on taking multiple equilibria seriously
 - I am now editing a third issue on the macroeconomics of structural change
- Then, last year, I heard striking criticisms of DSGE models by Joe Stiglitz at seminar in Oxford in 2023 when was visiting us for a month
 - What exactly was his criticism?
 - I will circulate a paper containing my response
- This talk takes my response further

Three ideas in the title of my paper

(i) Blanchard introduced idea of toy models in 2018 (PIIE; *OxREP*)

Some toy models – said Blanchard - only loosely based on theory.

- Allow for a quick first pass at some question, & present the essence of the answer from a more complex model or class of models.
- They may come before writing a more elaborate model,
- Or after, once the elaborate model has been worked out.
 - Blanchard's list of examples includes IS/LM, the Mundell-Fleming, the RBC model, and the New Keynesian model
- I think we need a new simple “toy model” to hold the whole subject together

(ii) Thinking about *structural change* requires non-linear toy model(s):

- Krugman's famous models of financial crisis
- Krugman's description of development as coordination problem

(iii) There is a task of communication and research management:

- Builders of toy models seek simple intuitive understanding
- Builders of detailed empirical models – aka as semi-structural models - seek a thorough understanding of data.
 - These two objectives do not necessarily point in the same direction

Hence: “Toy models, structural models & empirically detailed models”

My talk has four more parts

- Toy models in macroeconomics: some history of thought
 - The SENK toy model – my new simple toy
 - How to modify the SENK model to study structural economic change
 - How to manage conversations between people like me and people who carry out detailed empirical work, building semi structural models, and use them to give policy advice.
-
- I think that what I have to say has implications for how the Bank of England responds to the Bernanke Report
 - I will turn to this point in my conclusions

2 Toy models in macroeconomics: some history of thought

- The *General Theory (GT)* was a response to a core policy problem: unemployment
- Keynes's revolutionary idea was to go beyond Marshallian partial equilibrium
 - Keynesian multiplier is a *general equilibrium (GE)* concept
 - Low demand for *goods* leads to unemployment of *labour*
 - The IS/LM toy gave intuitive explanation of this GE idea
- What made the IS/LM toy so important was two things
 - it resolved the controversy between Keynes and the classics
 - It was necessary and sufficient for this task
 - It provided a toy model which became a benchmark platform on which research could be built:
 - everyone converged on this central unifying model.
- From 1936 to 1971 this benchmark model created a framework: it was basically the Keynesian multiplier + IS LM + Phillips curve
- The Klein Goldberger models were built on top of this framework
 - on top of a secure, agreed foundation

Some more history of thought

- But then by 1971 stagflation created a mess
 - Monetarism, Thatcherism, Great Moderation, Global Financial Crisis, Austerity, Covid, whatever.
- My claim: from 1971 there was again a core policy problem:
 - How to restore all of full employment, low inflation and growth
 - Remember this is 15 years after Solow-Swan model
- No longer a secure agreed foundation to replace IS/LM + Phillips curve
 - A jumble of ideas about unemployment inflation *and growth*
 - An intellectual mess – I grew up at this time!.
- The core intellectual response to this mess was the “forward-looking macroeconomics”: the rational expectations (RE) revolution
- But that revolution led to the creation of two different macro tribes
 - RBC – Kydland and Prescott believed that forward lookingness eliminated the need to think about stabilisation policy
 - The new Keynesian model - Clarida Gali and Gertler thought that one could put growth to one side

Yet more history of thought

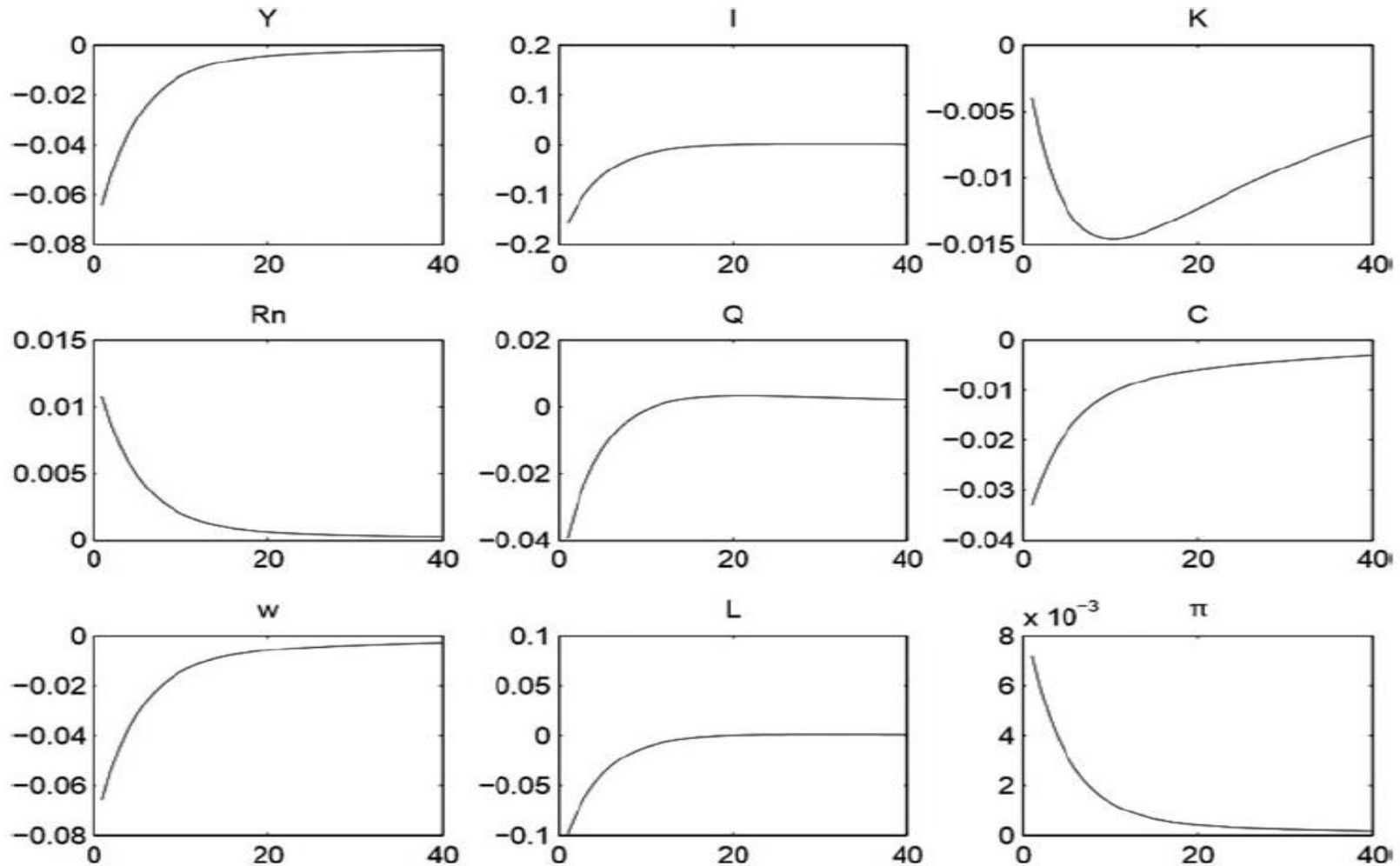
- I am proposing the SENK model – **S**imple **E**xtended **N**ew **K**eynesian DSGE model – as a framework
 - It is a simplified version of Smets and Wouters (2007) and Christiano Eichenbaum and Evans (2005)
 - It is a Ramsey growth model with *two* frictions
 - Nominal rigidities – & so *encompasses* the Clarida Gali and Gertler (CGG) short-run model
 - Adjustment costs of capital – which are necessary to enable a Ramsey model to encompass of SR analysis
- Many thanks to Warwick McKibbin, Tanya Kirsanova, and particularly Paul Luk, former student of mine now at the HKMA
 - Analytical details available in a paper I will distribute
- Paul and I call it the SENK model – Simple *E*xtended *N*ew Keynesian DSGE model because:
 - It is simple
 - It is “extended” because it extends the CGG model by embedding within longer–term analysis of a RBC kind
- Here are its components and here is how it works

3 The SENK toy model

3.1 Components and Behaviour

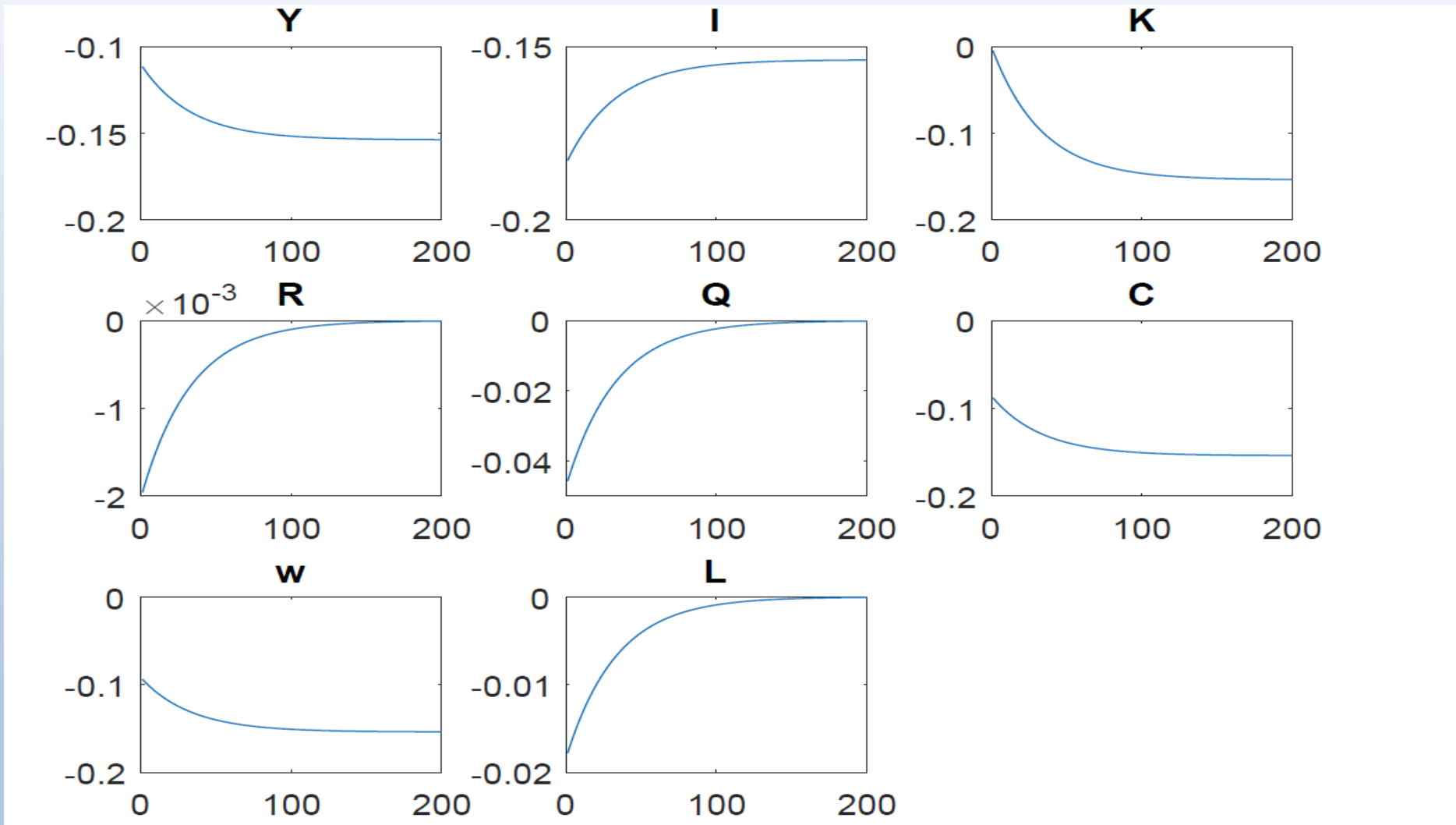
- (a) **Aggregate demand, $C + I$** , determines output. *An IS curve*
- (b) **Consumption C** depends on real interest rate and – at least in part – on expected future incomes and. Expectations matter.
- (c) **Investment, I** , depends on Tobin's Q & so on real interest rates & expected future profitability of capital, depending on what is required to equip the future stock of effective labour. Expectations matter.
- (d) **Aggregate supply Y** given by two-factor production function $Y = Af(K, L)$. K endogenous (but given at any point in time). A and L are exogenous.
- (e) **Inflation π adjusts *gradually*** to gap between aggregate demand (output) and aggregate supply, now & in the future. Expectations matter. The first friction *A Phillips curve* (Calvo fairy etc).
- (f) **The (real) interest rate R** : nominal interest rate set so that real interest rate R responds to inflation. *A Taylor rule*.
- (g) **Capital stock *adjusts gradually*** following investment. The second friction *The much slower dynamics of the underlying growth process* (RBC etc).

A 1% Cost push shock with a persistence of 0.8



Where Y is output, I is investment, K is the capital stock, R is the (real) interest rate, Q is Tobin's Q, C is consumption, w is the real wage, L is employment, and π is inflation

A Permanent Negative Shock of 10% to TFP (Total Factor Productivity)



Where Y is output, I is investment, K is the capital stock, R is the (real) interest rate, Q is Tobin's Q, C is consumption, w is the real wage, and L is employment

... simple toy to think about full employment, low inflation & growth

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3.2 How we got here and why we need the SENK model

Two different responses in the 80s and 90s to rational-expectations revolution

- CGG - forward-lookingness, nominal rigidities and no capital accumulation
 - Gali's textbook (2008, 2015) lives here
- RBC – forward-lookingness, capital accumulation and no nominal rigidities
 - Blanchard and Fischer (1989), Romer (1996), live here

So, unlike after *General Theory*, there was no central unifying model.

- No clear toy model became which became a benchmark platform on which to build detailed empirical models – semi structural models - on top of a secure, agreed toy model foundation

Smets and Wouters (1997) (SW) and Christiano Eichenbaum and Evans (1995) (CEE) provided the necessary integration of these approaches`

- These two models are necessary *and* sufficient for what has been needed to understand modern macro, ever since 1971

The SENK model is a toy version of SW and CEE & BC

- ISLM was a toy version of the *GT*: necessary & sufficient for the 30s.
- SENK model is toy version of SW & CEE: necessary & sufficient for now.

3.3 The SENK model & existing detailed empirical policy models

Models with SENK framework used for many years by policy makers & central banks.

- But producers of these models – and theorists - have not been good at explaining them
- James Meade's group used such a model in 1980s in initial work on inflation targeting
- Concerned to ensure that this policy did not involve crowding out private investment
- Thus we invented a SENK-type model and wrote it up in an impenetrable way!

Bank of England DSGE model has SENK-like structure, both BEQM & recent version

- Description of those models is cryptic: structure is also impenetrable

G Cubed model (McKibbin and Wilcoxon, used by many central banks) has this structure

- Twenty countries, four other regions, each with six sectors.
 - Each sector has capital accumulation subject to adjustment costs & nominal rigidities
- The two key frictions in the SENK model are central to the behaviour of world economy
 - Interest rate responses to different shocks in different countries ensure changes in *real* exchange rates, because of nominal rigidities
 - This ensure profitability of investment differs across countries
 - So investment occurs in different countries at different rates
 - As different rates of investment in different countries play out, this reallocates physical capital around the world, by means of current account surpluses and deficits

Moral – need a toy to think intuitively about actual models which are now used to study policies for promoting employment, low inflation & economic growth at same time

SENK model is a good way to understand the structure of these models

3.4 The SENK model & complex policy issues: “build back better”

- The new Labour government in Britain discussing how to “build back better”.
- A need to invest much more to rebuild its public infrastructure.
 - But there will need to be much additional private sector investment, which will only be forthcoming only if it appears that such investment will be rewarding. The SENK model analyses this.
 - The productivity of investment, and its profitability, which will depend on public investment in way which can be added to SENK model
- Whether investment will be financed will depend on the saving decisions of the private sector, which again the SENK model analyses.
 - Important here will be overlapping generations extension of the model to do with how much young people are prepared to save, given their expected needs for income and expenditure in their retirement.
- Intuitive analysis requires adding a public sector to the SENK model
 - It will be essential that public expenditure, incl. that on public infrastructure, does not crowd out the private sector investment.
- The SENK model – integrating SR and LR analysis is place to start.

3.5 The SENK model & complex policy issues: inflation

- Suppose that there is, for example, a shock such as the war in Ukraine.
 - Supply conditions for energy tighten & global price of energy rises temporarily
 - Also suppose that underlying rate of technical progress is low, population growth is slow, savings remain high, & global interest rates are low, as the before the war.
- The SENK model provides the equipment to discuss how and why the interest rate will rise in the short run and then go back to a low level in the longer run.
 - The initial responses will be very similar to those displayed in Figure 1 above.
- This argument underpinned actual policy discussions. (e.g. Blanchard May 2022)
 - Argued that after the initial inflationary blip interest rates would return to lower levels, because of the low rate of technical progress, the low rate of growth of population and a high level of savings.
 - Nine months later, the same approach was taken by the IMF in its WEO.
 - The work in the WEO was presented as a set of empirical findings
 - But it was – in effect - built on a SENK like underpinning (to which had been added an OLG analysis of savings)
- Can add public sector to SENK model and ask whether tax *cuts* and accumulation of public debt desirable to spread burden of adjustment over time
- The SENK model – which integrates SR and LR analysis - is place to start.

3.6 SENK model helps us understand China (and Europe, and the world)

- Martin Wolf on China (*Financial Times* October 15 2024)
 - Wolf effectively sets out Ramsey model for China and asks us to understand what is happening in China by using SENK model to think through what happens when population growth collapses – and indeed goes negative – and when rate of technical transfer from the advanced economies – i.e. from the US slows.
 - Outcome not unlike that shown in Figure 2 – the crucial point that Wolf made was about *consumption* needing to rise which is clear from this model
- And what is now happening in Europe (Draghi report)
 - Need for public sector investment in order to increase rate of return on private investment – this feature can be added to SENK model
- What has happened globally since the GFC
 - effect of zero lower bound - this feature can be added to SENK mode
- At every stage I am adding a feature to the simple to understand SENK toy model.

3.7. Using SENK model a platform for further analytical work

- Overlapping generations – necessary for understanding savings and interest rates
 - Introducing housing as alternative way to hold wealth
- Bernanke Gertler and Gilchrist on financial accelerator & financial crises –a SENK type model with a risk premium due to risk of bankruptcy amongst heterogenous firms
- Liquidity constraints – necessary for better understanding of financial crises and also of savings behaviour (HANK, TANK, etc) .
- Real wage resistance – necessary for understanding the effects of an inflation shock properly (Gali and Blanchard)
- Fiscal policy and government budget constraint (as discussed above).
- Modelling the transition to net zero (Shamik Dhar, forthcoming *OxREP*)

Initial intuition can be as simple as adding just four things to the basic structure:

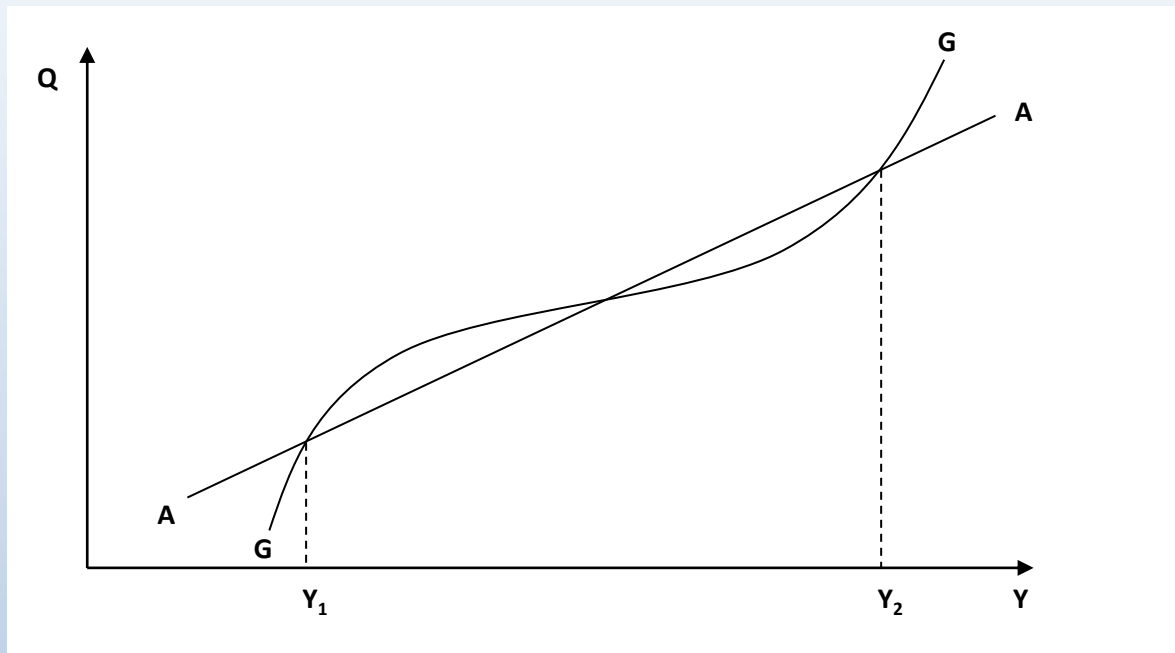
- (i) Adding link between output and *flow* of emissions
- (ii) Adding negative link between *stock* of emissions and the level of productivity
- (iii) Introducing the possibility of investing in emissions-reducing capital that enables the production of energy (electricity) without using fossil fuels
- (iv) Introducing choice between two types of goods, one of which uses fossil fuel energy and the other of which uses electricity without using fossil fuels and enabling choice by consumers, and investors, between these two types of goods

Aim is to study how these four things change the optimal growth path in a Ramsey model and understanding shorter-term transition to this optimal path

4 Generalising the SENK model to think about structural change

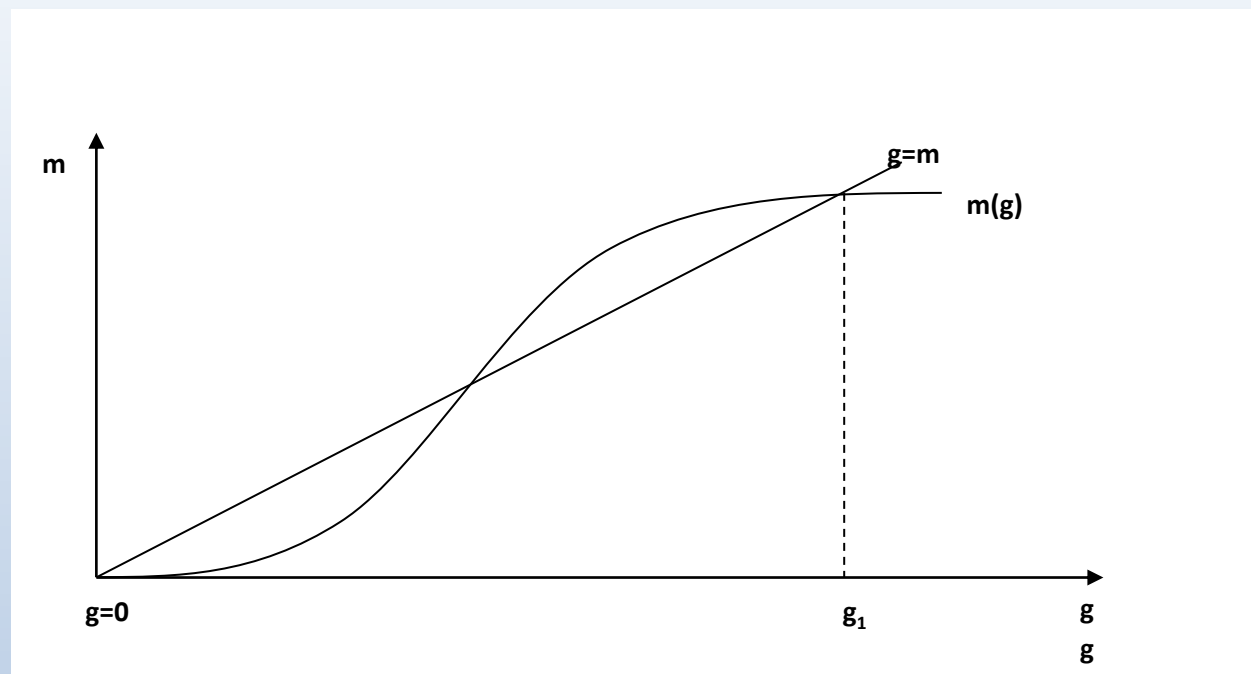
- Non-linear versions of the model are needed
 - To analyse *large economic downturns and structural change* need more than SENK model. Keynes wanted to show in his *General Theory* how *large* economy-wide disturbances – slumps and booms – can emerge from small shocks to savings and investment.
 - He achieved magnification by means of the Keynesian multiplier
 - This was an extraordinary achievement at the time, but is not now enough.
- Requires models with multiple eq. & move from good to bad eq.
 - Need to be able to identify where tipping points are likely to occur.
Examples
 - Collateral constraints on expenditure and transmission of shocks between banks
 - Endogenous technical change
 - Transition to zero emissions economy
- In all 3 cases, strategy is: start with SENK framework & add complexity

Adding endogenous financial collateral



- GDP might, over a range, move up or down in an explosive manner in response to changes in Tobin's Q , due to the operation of collateral constraints on consumers and investors.
- The GG schedule shows that high Q stimulates investment and consumption, which drives up GDP, Y , and that in turn drives up Q . This $Q \rightarrow Y \rightarrow Q$ process can be very strong.
- The AA schedule depicts asset market equilibrium. The monetary authority raises interest rates in response to the output gap which depresses Q . But as above $Y \uparrow \rightarrow Q \uparrow$
- There may be two stable equilibria: one with high Q and Y , and one with low Q and Y .
- Analysis can be added simply – in principle - to SENK model
 - Requires one to think about multiple equilibria and equilibrium selection in forward looking model

Adding endogenous technical change



- The $m(g)$ curve shows the rate of technical progress, m , as a function of the growth rate of economy, g , has S shape because tech progress embodied in new investment
- The second curve shows the growth rate of the economy g as a function of the rate of technical progress, m , and represents the long-run equilibrium growth path.
- Possibly two stable equilibria: one with high m and high g , and one with $m = g = 0$
- Analysis can be added – simply - to SENK model:
 - Requires one to add multiple equilibria and equilibrium-selection issues

Studying the transition to net zero

- With strategic complementarities stemming from peer effects in demand or technological spillovers, propagation and amplification mechanisms increase the effectiveness of climate policies.
- There can be multiple equilibria which means that policies are needed to shift the economy from a high-emissions to a low-emissions path.
 - Van der Ploeg and Venables (OxREP, forthcoming) develop a *static* analytical framework within which policies to achieve these tipping points are studied, looking at the extended role for tax and subsidy policies, at the process of change, and at policy under uncertainty.
 - They describe particular kinds of intervention which can be used to obtain more effective and more transformative climate policies.
 - Once the radical shift has taken place these policies can be withdrawn.
- But this is a dynamic intertemporal problem.
 - It will have implications for the Shamik Dhar paper on the transition to net zero which I have already described – there will be multiple equilibria and tipping points in the dynamic paths described in that paper.

There are deep issues to do with equilibrium selection

- See H. Peyton Young *Spontaneous Order* (OUP, September 2024)
- This book argues that equilibrium behaviors often coalesce from the interactions and experiences of many dispersed individuals acting with fragmentary knowledge of the world, rather than from the actions of fully rational agents with commonly held beliefs, as I have assumed until now.
- Book presents a unified - and rigorous - treatment of such 'bottom-up' evolutionary processes using stochastic dynamical systems theory.
- Framework illuminates how social norms and institutions evolve, how social and technical innovations spread in society, and how these processes depend on adaptive learning behavior by human subjects.
- As Peyton Young says in the abstract of the book, “the theory also has important applications to the design of distributed systems with many interacting components, such as information routing systems, mobile sensors, and wind farms”.
- And it is clearly relevant to getting an understanding of the three cases of multiple equilibria that I have just identified.

5 Putting toy models detailed empirical models together

5.1 The role of toy models in natural science

- In scientific modelling there has long been a tradition of toy models
 - Many details removed to enable concise explanation of mechanism
 - They are also be used as a description of the fuller model.
- Examples – thanks to Vijay Balasubramanian (!)
 - Model of magnets as “alignment” of internal mini-magnets
 - Early initial “stock-flow” model of neuron: superseded by Hodgkin & Huxley
 - Bohr model of atom as a solar system – superseded by Schrodinger
- Scientific modelling viewed by physicists as a three stage process:
 - (i) Toy model – as in above examples
 - (ii) “Effective model”: one based on reliable observations, explains data, & is used to make predictions, but lacks coherent understanding & explanation
 - (iii) “The theory”: an effective model with full causal explanation
 - e.g. standard model of particle physics –
 - but note this falls short of being complete – it cannot do gravity
- In macroeconomics we focus on the first two
 - Have little hope of the last (!)
 - And I have deliberately split toys into linear models and non-linear models

5.2 How to bring toy models and semi-structural models together?

- I have made four fundamental assumptions in the SENK toy model
 - Representative agent
 - Intertemporal optimisation of fully understood model
 - Participants have view that model is a correct representation of world
 - other than for the effect of unpredictable shocks.
 - There is a unique equilibrium to which the economy will tend.

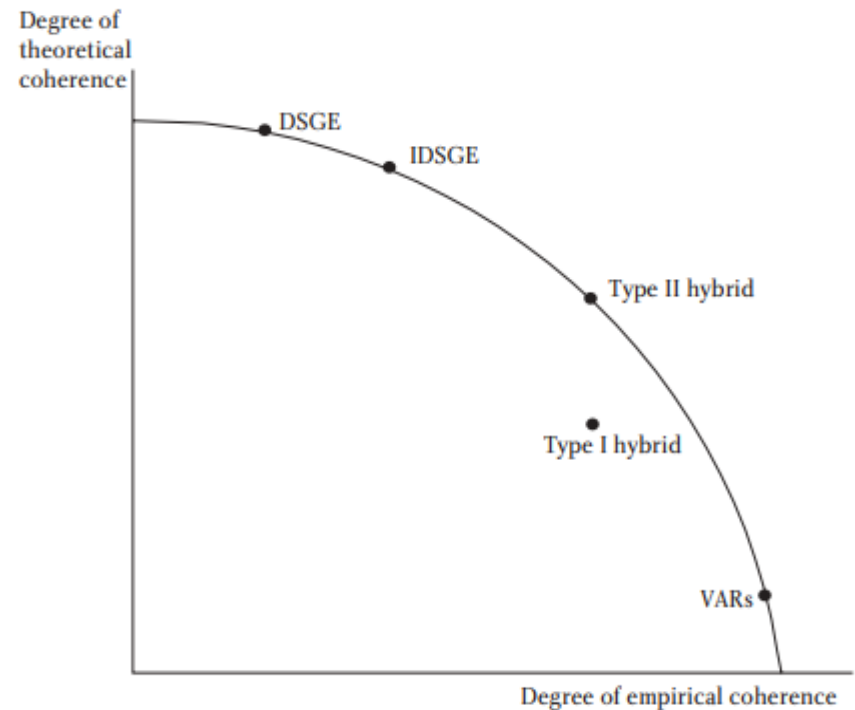
I have only abandoned last of these assumptions & only in a simple way.

 - Does this disable the insights that I have gained?
 - What next?
- Need to understand how to avoid confusing simple models with reality
 - Need to engage in proper conjectures and refutations with data rather than merely decorating a given paradigm with some numbers
- Making the right relaxations & making them work properly
 - Behavioural economics ideas are essential in these empirical investigations
 - This work will involve non-linearities & include looking for multiple equilibria
- Need to understand how to build hybrid models
 - Need to prevent theoretical underpinnings from constraining parameter estimation
 - Bernanke has criticised the way Bank of England has made these subtle judgements

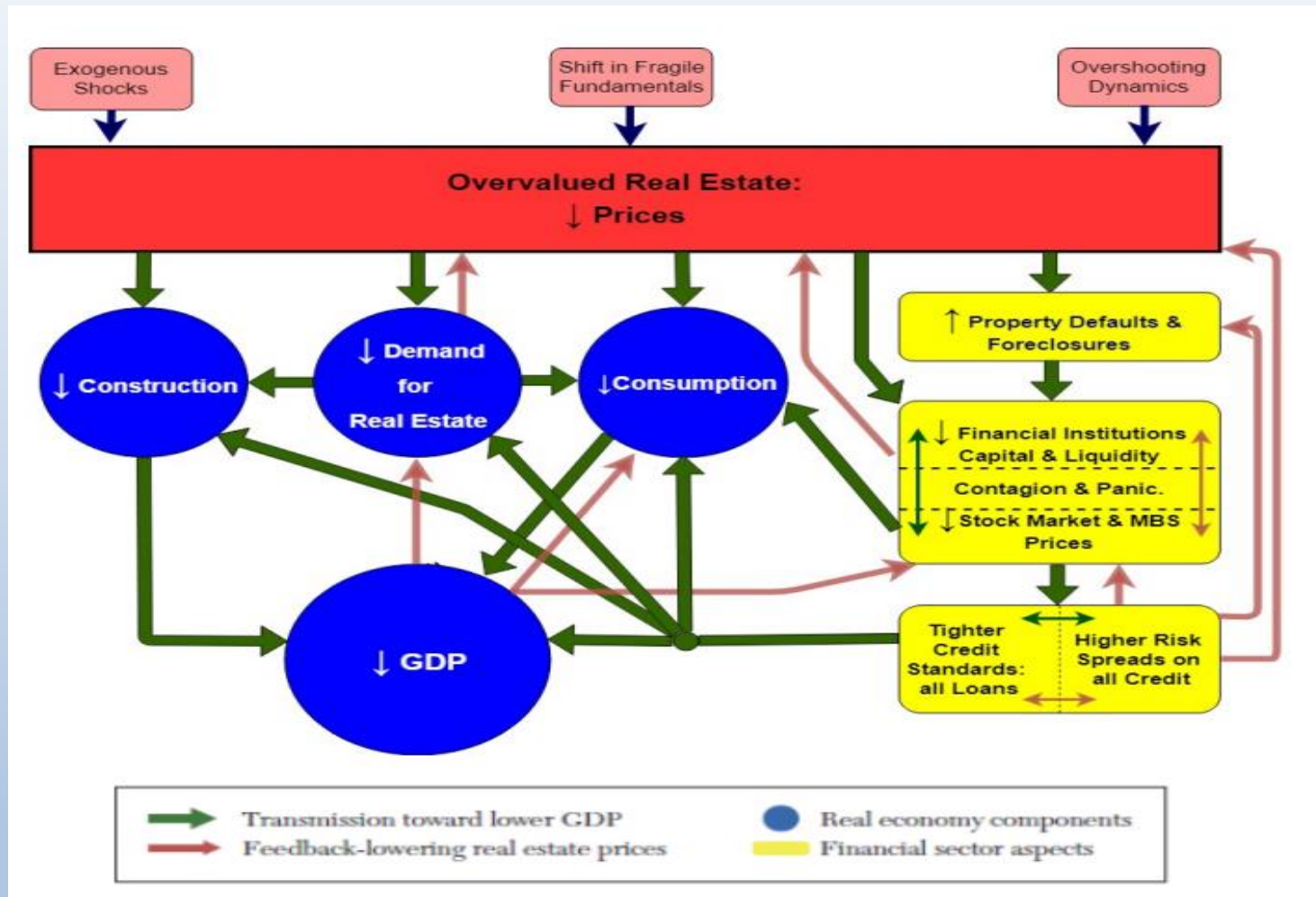
5.3 More on Bringing toy models & semi-structural models together

- A challenging issue here in the in the philosophy of social science
 - We economists are all instinctively utilitarians
 - Adrian Pagan discussed “bringing together” in a utilitarian manner for the BofE in a report in 2003
 - But the objectives may be incommensurable
 - Or they may be *thought to be* Incommensurable
- It may be the task of a research manager to find a way of finding where to choose on this tradeoff
- Three examples show how important but difficult this choice may be:
 - John Muellbauer
 - Doug Laxton
 - Laurence Kotlikoff

Figure 1
Trade-off between theoretical and empirical coherence for models



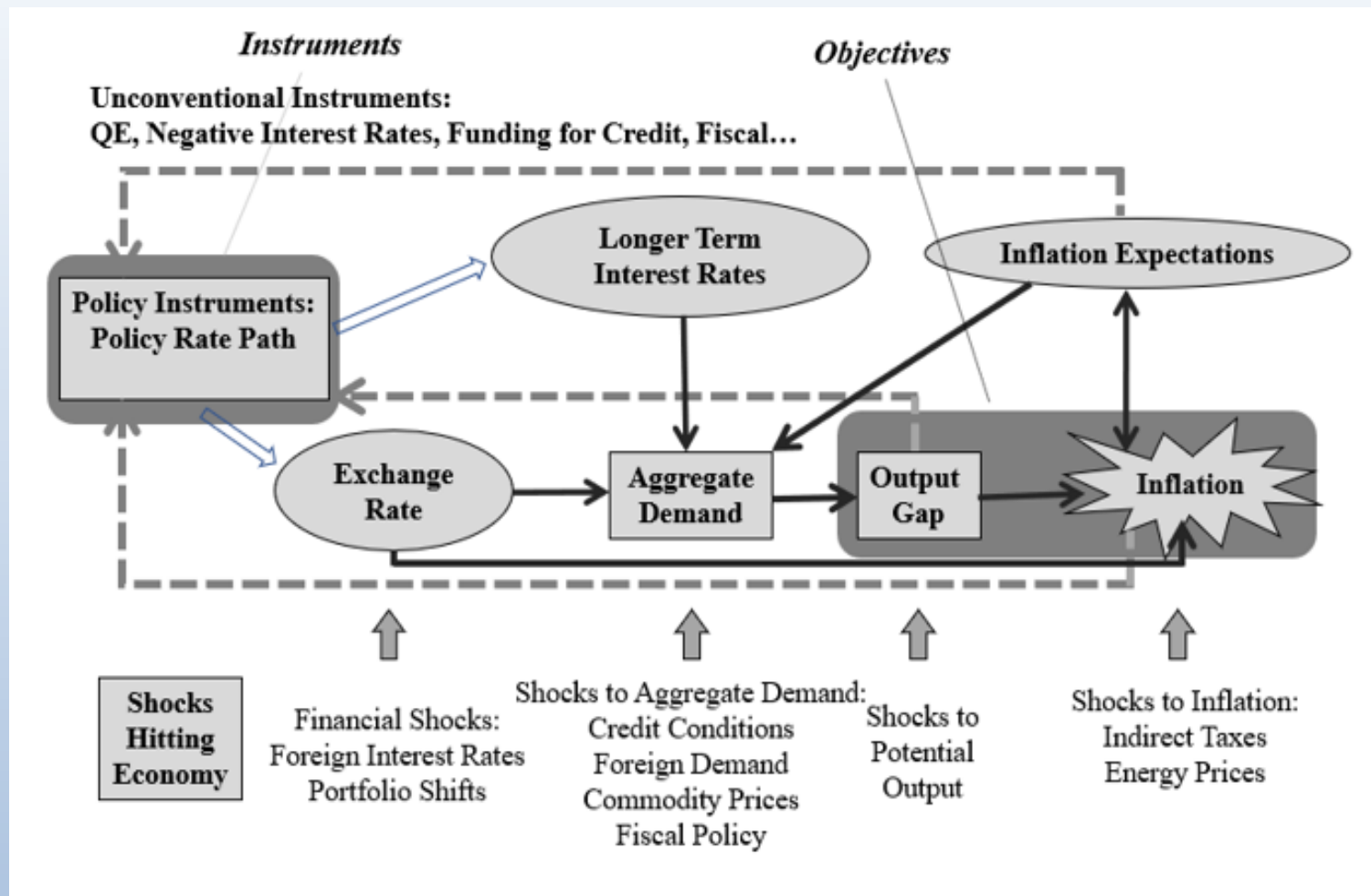
(i) The work of John Muellbauer on housing and the financial system



(i) Much "local detail" needs to be connected with a full macro model like the SENK model.

But JM very critical of its four fundamental assumptions !!!

(ii) The work of Doug Laxton on open economy macro and the FPAS



This open economy model needs to be connected with a model like the SENK model which understands the growth process and how short-run choices interact with policies for that longer term growth process

(iii) The work of Laurence Kotlikoff on global power in 2100



This work needs to be thought of as a set of overlapping Ramsey models - of 15 countries! - and then confronted with a SENK type model of kind which understands the kind of details analysed in the McKibbin Wilcoxon G-Cubed model.

6 Conclusion

- In this talk I have done three things
 - Presented you with a simple “toy model” to hold the subject of macro together which can be used to think about policies in relation to achieving full employment, managing inflation and promoting economic growth
 - Provided you with an understanding of how this toy model can help us to think about modelling structural economic change
 - Shown how use this toy model can help us understand and contribute to – the work of those who do detailed empirical work and build semi-structural models
- I think that what I have said has implications for how the Bank of England responds to the Bernanke report.
 - In a speech yesterday Clare Lombardelli (the new Deputy Governor for Monetary Policy at the BoE) gave an impressive description of what is being done *managerially* to respond to that report
 - But this is a task which will also require intellectual leadership .