CHAPTER 4

The Frontier of Macroeconomic Modelling: Proceedings of the JRC-IEA Workshop 2017

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4.1 Introduction

The JRC-IEA Roundtable on Macroeconomic Modelling for R&D and Innovation was jointly organized by the DG Joint Research Centre (JRC) of the European Commission and the International Economic Association (IEA). The design and development of macroeconomic models addressed to study the impact of innovation policies is critical for the European Union, for which innovation policies are one of the highest priorities. The Roundtable aimed to discuss, in the framework of the recent development of the literature on economic growth and innovation, alternative modelling strategies for innovation and medium/long-term productivity and economic growth. The debate was organized having in mind the need for new ideas that may help the design of economic models addressed to evaluate the impact of innovation and related policies.

During the Roundtable, top researchers, including Philippe Aghion (Harvard), among others, presented some key new developments in the

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field of innovation and growth. The Roundtable aimed to better understand where the frontier of knowledge in the field of innovation and growth is to, and in a second stage, figure out the key elements a macro model designed to evaluate innovation policies should include. In particular, Ufuk Akcigit (Chicago) presented a survey on his views on the current academic research agenda on R&D and innovation. The session was closed by a panel composed mainly of practitioners, and a few academics, with the object of giving the perspective of those more directly involved in the evaluation of innovation policies or in the development of those models designed to evaluate these policies. A short summary of each contribution and my reading of the debate that followed are provided in Section 2. Section 3 discusses the proposed alternative lines of modelling that emerged from the Roundtable. It reflects the views of the author on a highly fruitful, sometimes controversial, debate that took place during the Roundtable.

4.2 Macroeconomic Modelling of Innovation

This section contains some of the lessons from the papers presented at the JRC-IEA Roundtable on Macroeconomic Modelling for R&D and Innovation.

- **Missing Growth from Creative Destruction** by Philippe Aghion, Antonin Bergeaud, Timo Boppart, Peter J. Klenow and Huiyu Li (Aghion et al., 2019).

  Statistical agencies aim to compute price indexes for representative baskets of constant quality products. However, in practice, some products disappear being displaced by better quality ones. The authors point out that, in these cases, statistical agencies typically impute inflation for disappearing products from the inflation for surviving products, when likely its inflation may be lower because of quality improvements embodied in the substituting product. As a result, creative destruction may result in overstated inflation and understated growth. The authors use a simple model to relate this missing growth to the frequency and size of various kinds of innovations. Using US Census data, they assess the magnitude of missing growth for all private non-farm businesses from 1983 to 2013. They find: (i) missing growth from imputation is substantial, between 0.5

and 1 percentage points per year; and (ii) almost all of the missing growth is due to creative destruction (as opposed to new varieties).

The paper points to a key issue on evaluating the macroeconomic impact of innovation policies: the critical problem of measuring real output and productivity in a world where technical progress is embodied in new, better quality versions of existing products. The measurement strategy suggested by the authors is model-based. However, statistical agencies are reluctant to explicitly use models to measure price changes and strongly prefer well-designed methods based on data collection, which depend much less on highly specific modelling assumptions. Of course, there is no measurement without theory. Hence, data collection and statistical methods used to aggregate individual data are both based on theory. However, the theory behind these methods is usually quite general and does not depend on specific functional forms and parameter values.

In the same direction, Broda and Weinstein (2006) suggest a different strategy, based on love-for-variety theories, to measure gains associated with new products. Contrary to Aghion et al. (2019)' s findings reported above, Broda and Weinstein (2006) conclude that the US missing growth from increasing the product variety is of around 1.2 yearly percentage points for the period 1972–2001. Indeed, this estimation strongly depends on some strong assumptions about the extent of utility gains coming from love-for-variety.

The measurement of productivity at the firm level raises also some important measurement problems. It is generally accepted now that productivity at the firm level has at least two components: product value (or demand shock) and technical efficiency (generally referred as TFPQ) whose estimation faces some important issues. Indeed, the propagation of productivity gains in a network, by reducing the cost of inputs of upstream firms, calls for a third dimension of productivity: the quality and price of production inputs.

The main lesson to retain from the Aghion et al. (2019) paper is that a careful analysis of the way GDP growth is measured in the data is needed to make a correct evaluation of innovation policies. This problem has to be seriously taken into account when comparing model simulations used to evaluate innovation policy with the data. If gains from innovation are not in the statistics, we will never find

them in the data and it will be difficult to find them in model's simulations.

- **The Dynamics of Development: Innovation and Reallocation** by Francisco Buera and Roberto Fattal-Jaef (Fattal Jaef & Buera, 2015).

  Buera and Fattal-Jaef study the aggregate and firm-level properties of the dynamics of economic development, by investigating the macro and micro features of successful growth take-offs in the data and find that, while every episode exhibits sustained growth in TFP and investment rates, there are substantial differences in the evolution of the firm size distribution between the experiences of post-communist economies and the rest of the successful take-offs. The pattern is that firms tend to get larger on average during a typical acceleration, while the average size of a firm is declining along a post-communist transition. To understand this behaviour, the authors provide a quantitative theory of transitions featuring endogenous innovation, entry and exit, and the dismantling of idiosyncratic distortions. They evaluate hypothetical reforms in which the rate of progress in the reversal of distortions is calibrated to the experiences of China and Chile, to find that the mechanisms in the model are able to capture the salient features that they document in the data. The approach may be relevant for economies undergoing a similar transition or catching-up.

- **Fewer but Better: Sudden Stops, Firm Entry, and Financial Selection** by Sina Ates and Felipe Saffie (Ates & Saffie, 2021).

  In a dynamic stochastic general equilibrium (DSGE) model with firm heterogeneity and innovation, Ates and Saffie incorporate endogenous technical change into a real business cycle small open economy framework to study the productivity costs of sudden stops. In this economy, productivity growth is determined by the entry of new firms and the decision by incumbent firms to expand. New firms are created after the implementation of business ideas, yet the quality of ideas is heterogeneous and good ideas are scarce. Selection of the most promising ideas gives rise to a trade-off between mass (quantity) and composition (quality) in the entrant cohort. Chilean plant-level data from the sudden stop triggered by the Russian sovereign default in 1998 confirm the main mechanism of the model, as firms born during the credit shortage are fewer, but better. The quantitative analysis shows that four years after the crisis, 12.5% of the output deviation from trend is due to permanent productivity

losses. Distortions in the entry margin account for 40% of the loss, and the remaining is due to distortions in the expansion decisions of incumbents.

Many of the elements suggested by Ates and Saffie (2021) in their DSGE model with heterogeneous innovative firms are of high value for the design of macro models addressed to evaluate innovation policy. Moreover, they also suggest a methodology that facilitates solving this family of models. Innovation policies are expected to have long-lasting effects that show up slowly during long transition periods. However, when evaluating the effects of policies, institutions cannot wait until all their effects have realized. Then, being able to characterize the transition from a balanced growth path to another is critical for policy evaluation. When equilibrium depends on the endogenous productivity distribution of heterogeneous firms and innovation makes firms' productivity endogenous, solving the dynamics of a general equilibrium model becomes a non-trivial object. Having this in mind, the methodology suggested by Ates and Saffie (2021) is consequently of first importance. Their theory features firm heterogeneity and innovation in a way that can be easily added to a DSGE model, to which standard algorithms may be applied to solve for transitional dynamics. On top of that, such an approach is likely to be useful to understand the differential effects of innovation policies during booms and recessions, since, during the latter, projects are likely to become more risky, thus they are being financed by the private market less likely.

- **Creative Destruction and Uncertainty** by Petr Sedlacek (Sedlacek, 2020).

  Sedlacek (2020) develops a dynamic stochastic general equilibrium model with heterogeneous innovative firms highly related to the literature on Schumpeterian creative destruction (Aghion and Howitt (1994), and Caballero and Mohammed (1996)) and documents how firm dynamics and firm-level uncertainty respond to technology shocks. He argues that even if there is agreement on the fact that uncertainty rises during recessions, it is less clear whether uncertainty causes downturns or vice versa. He shows that faster technology growth raises uncertainty through a growth option channel: firms face larger productivity gains if they innovate and relatively larger productivity losses if they do not. In addition, faster

growth spurs a process of creative destruction generating a temporary downturn and rendering uncertainty countercyclical. Estimates from structural VARs on the US data confirm the model's predictions. Growth explains 1/4 of the cyclical variation in uncertainty on average, and up to 2/3 around the dot-com bubble.

The contribution of Sedlacek (2020)'s paper is of the same nature as the Ates and Saffie (2021) paper and should be considered as a cornerstone approach to modelling innovation in a framework designed to evaluate innovation policies. The model can also be easily embodied into a DSGE model for whose solution standard algorithms can be used. The link between growth and business cycles with innovation uncertainty being the driver of both long-term growth and the business cycle, the model can be used to study the transitional dynamics of innovation policies.

- **How much Keynes and how much Schumpeter? An Estimated Macromodel of the US Economy** by Guido Cozzi, Beatrice Pataracchia, Philipp Pfeiffer and Marco Ratto (Cozzi et al., 2017).

  The macroeconomic experience of the last decade clearly shows that long-term growth and business cycle fluctuations need to be studied in the same framework. To analyse this issue, the authors embed a Schumpeterian growth model into an estimated medium-scale DSGE model. Results from a Bayesian estimation suggest that investment risk premia are a key driver of the slump following the Great Recession. Endogenous innovation dynamics amplify financial crises and help explain the slow recovery. Moreover, financial conditions also account for a substantial share of R&D investment dynamics. Cozzi et al. (2017) estimate for the US a DSGE model with Schumpeterian (semi-endogenous) growth. They document that the recent financial crisis seems to show a clear change in the pattern of GDP growth. Up to 2007, the US was clearly behaving as predicted by Neoclassical growth theory, with GDP systematically reverting towards the same trend. By contrast, after the financial crisis, GDP seems to have moved down to a lower trend. To match the data, Cozzi et al. (2017) suggest a semi-endogenous growth model that converges to the same balanced growth path, but only after a very long transition.
- **Innovation and Trade Policy in a Globalized World** by Ufuk Akcigit, Sina Ates and Giammario Impullitti (Akcigit et al., 2018).

Akcigit et al. (2018) assess the role of import tariffs and R&D subsidies as policy responses to foreign technological competition. To this end, they build a dynamic general equilibrium growth model where firm innovation shapes endogenously the dynamics of technology, and, therefore, market leadership and trade flows in a world with countries at different stages of development. The model accounts for competitive pressures exerted by both entrant and incumbent firms. Firms R&D decisions are driven by (i) the size of the market, (ii) the effort to escape international competition, (iii) domestic and international business stealing and (iv) technology spillovers. This theoretical investigation finds that, in a static context, globalization, proxied by reduced trade barriers, benefits domestic workers, while it has an ambiguous effect on business owners. In a dynamic context, globalization is shown to boost domestic innovation through an escape-competition effect. A calibrated version of the model reproduces the foreign technological catch-up the US experienced during the 1970s and early 1980s. Accounting for transitional dynamics, they show that foreign technological acceleration hurts US welfare in the short and medium run through business stealing, but generates long-run benefits via higher quality of imported goods and higher domestic innovation induced by the escape-competition effect. The model suggests that the introduction of the Research and Experimentation Tax Credit in 1981 proves to be an effective policy response to foreign competition, generating substantial welfare gains in the long run. A counterfactual exercise shows that increasing trade barriers, as an alternative policy response, produce gains only in the very short run, leading to large losses in the medium and long run. Protectionist measures generate large dynamic losses from trade, distorting the impact of openness on innovation incentives and productivity growth. Finally, the counterfactual exercise shows that less government intervention is needed when trade barriers are reduced as a result of globalization.

4.3 Modelling the Macroeconomic Effects of Innovation Policies

The JRC-IEA Roundtable between academics, policymakers and practitioners was animated by a lively discussion. Some of the more general

issues related to the modelling and impact assessment of European innovation policies will be presented in subsequent sections of the book. The remainder of this chapter will instead focus on more specific, albeit not less important, modelling issues:

- There is a well-known debate on the nature of economic growth in macroeconomics: *Is growth exogenous, endogenous or semi-endogenous?* Yet, no agreement has been reached, with empirical and theoretical arguments pointing in different directions. There is no doubt that relevant variables should be part of the analysis, with GDP and its growth rate being among the most important variables economists would like to understand. Hence, models of endogenous growth should be at the top of the agenda. However, the debate is not about the nature of growth (endogenous or not), but about the empirical pertinence of existing endogenous growth models.
- *Should predictions cover the short, medium or long run?* Of course, growth is about the long term, but innovation policies need to be regularly evaluated. In this sense, intermediary effects, those taking place during the transition from a balanced growth path to another, are critical for the evaluation of innovation policies.
- Since a model has to be understood as a lab for policy simulations, the fit of the model to the data is a fundamental criterion in model selection. In this regard, the large availability of microdata at present permits adding more *micro heterogeneity in macro models*.
- *Firm heterogeneity, the dynamics of firms (entry and exit) and innovation*. The last decade witnessed the emergence of a sizeable literature on the dynamics of heterogeneous firms, with most contributions assuming exogenous productivity processes. The Schumpeterian model is a model of innovation with heterogeneous firms, governed by entry and exit (creation and destruction). When innovation is at centre stage, the question that emerges is: what are the main differences between the Schumpeterian model and the Hopenhayn-Melitz model?[1] A new literature developed in recent years attempts to shed light in this respect.
- It is important to identify the *trade-offs between promoting excellence and/or promoting convergence*, which relates to the trade-offs

[1] The Hopenhayn-Melitz model refers to Hopenhayn (1992) and Melitz (2003)

between growth and inequality. At the national/regional level, European innovation policies may be addressed to give incentives to the most developed regions to deepen their innovation process or alternatively to promote the development of those regions that need to catch-up with the frontier technology.

R&D subsidies aimed to promote innovation and growth affect the variance of the productivity distribution across firms and regions. A better understanding of this effect is important to improve our comprehension of the distributive consequences of innovation policies.

Models must be able to clearly specify why excellence and convergence matter in order to quantitatively evaluate what is the right balance between them. This issue is highly connected to the related problem of inter-regional migration.

- It is important to analyse the differential behaviour of *small, medium and large firms*. The theory of firm dynamics is a good framework to study the dynamics of firm size.
- Should models distinguish between *innovation and adoption*? The success of an innovation policy depends not only on the number and degree of innovation of new technologies/ideas that it helps to create, but on the extent of their diffusion through a long process of adoption by others.

  This is related to the nature of technical progress: radical innovation and general-purpose technologies (GPT). Is innovation policy aimed at diffusing existing technological paradigms or, rather, at promoting the emergence of new ones? Should we, for example, invest in the diffusion of IT technologies or bid on the emergence of robotics?
- There is an important debate in the theoretical and empirical growth literature about the nature and extent of *technological spillovers*, in particular those related to trade. The impact of innovation policy and its regional effects critically depends on these spillovers.
- *Macro models must be disciplined by macro and micro data*. The decline of the endogenous growth literature in the first decade of the twenty-first century was due to the inability for the models belonging to this family to replicate by existing data. Its recent resurgence is attributable to the appropriate use of macro and microdata. In this sense, modelling microheterogeneity is important for macro

models in order to be able to capture the observed microeconomic data.

- As a general *modelling strategy*, one needs to first identify the policy-relevant question, second, investigate what the profession already knows (i.e, the relevant literature) as well as look for the available macro and microdata and, third, develop a model that is able to answer the policymakers' questions while fitting the data to the best degree possible. The overarching fundamental principle underlying this step-wise approach to modelling is that models are question and data dependent.
- In the process of identifying a good model, the dialogue between policy and economic analysts in policymaking institutions, on one hand, and academia, on the other, is crucial. This helps to identify and design the most appropriate models to answer the most relevant questions in the policy arena at a given point in time.
- Until now, the big absent in the innovation debate, primarily on the academic side but also on the policy debate, has been the *welfare and distributional consequences of innovation policy*. Creative destruction leads to new jobs often requiring new skills, but it also leads to job losses with associated distributional and welfare consequences, which may be unevenly distributed across sectors, regions and generations.
- A fundamental principle of Italian cooking is: *the least ingredients, the better*. One of the key questions that emerged during the workshop presentations was how one can implement this principle when modelling innovation policies aimed at very different objectives and likely operating through very different channels. This necessitates a thoughtful exchange between all the parties involved.

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