

Dynamic Stochastic General Equilibrium: macroeconomics at a dead end

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Abstract

The DSGE models are not only seriously flawed. They seem eminently irreparable. Their early versions started with over-simplistic assumptions and produced irrelevant conclusions. The later benchmark versions inherited the simplistic core on which ad hoc ‘frictions’ were grafted. These versions proved spectacularly useless. The most recent versions promise to make amends by allowing for agent heterogeneity and more attentive treatment of the financial aspects of micro-behaviour. But this promise cannot be squared with the basic ideas underlying the approach: general equilibrium and super-rational behaviour (including formation of expectations) attributed to so-called ‘representative individuals’.

The derivation, specification and estimation of computable DSGE models involve a great deal of pure arbitrariness while their identification remains problematic.

A science of micro-founded macroeconomics may be impossible. But scientific macroeconomics not based on micro-foundations may be possible. Newton’s laws of movements of solid bodies belongs to science without being derived from models of behaviour of elementary particles.

Keywords: micro-foundations, RBC, DSGE, natural interest rate, smell test

JEL: E17, E40, E30

“Economic theory is always and inevitably too simple; that cannot be helped. But it is all the more important to keep pointing out foolishness whenever it appears. Especially when it comes to matters as important as macroeconomics, a mainstream economist like me insists that every proposition must pass the smell test: does this really make sense? I do not think that the currently popular DSGE models pass the smell test. They take it for granted that the whole economy can be thought about as if it were a single, consistent person or a dynasty carrying out a rationally designed, long-term plan, occasionally disturbed by unexpected shocks, but adapting to them in a rational, consistent way. I do not think that this picture passes the smell test. The protagonists of this idea make a claim to respectability by asserting that it is founded on what we know about microeconomic behaviour, but I think that this claim is generally phony”.

Robert Solow (2010, p. 12)

1 Introduction

The aim of this paper is to analyse critically the rationales of the basic assumptions behind Dynamic Stochastic General Equilibrium modelling. The question researched is whether the applied DSGE models are based on acceptable fundamentals. Of course some models, even if theoretically unfounded or based on heroic simplifications, can have a potential to address vital real-life macroeconomic problems adequately. On the other hand, one would expect the unfounded models, or models based on ad hoc assumptions and naïve simplifications, to be of no use in practice (which happened to be the case with the DSGE-based policies during and after the Great Recession).

The rise (and recent ‘crash’) of DSGE modelling must be seen in a longer-term historical context. The early 1990s marked the final (as it then seemed) triumph of a new economic policy paradigm. Neo-liberalism became the principle behind the economic and social practice. The TINA: There Is No Alternative maxim served to stress the inevitability of deregulation, liberalisation and privatisation and of ‘sound fiscal policies’ across the world.

Economic ‘science’ played a supportive role in the paradigm change. It is perhaps not a sheer coincidence that the rise of the neo-liberal policy went in tandem with the rise, and then a long era, of dominance of the ‘micro-founded’ equilibrium macroeconomics, which obligingly refuted the (‘old’) Keynesian ideas. The latter, stressing the possibility of protracted involuntary unemployment, the role of ‘animal spirits’, intrinsic uncertainty and the paramount significance of fiscal policies, had informed the practical economic policies during the golden era of capitalism (1950–1970). From the mid-1970s these ideas were being ‘laid to grave’ – first in theory and then in practice.¹

¹ ‘Stagflation’ (simultaneity of high inflation and high unemployment), claimed to have compromised the old-Keynesian ideas and thus the policy practice derived from those ideas, emerged under the impact of severe shocks to the prices for imported oil. Arguably, inflation had to jump due to steeply increasing costs of energy even if workers had not insisted on wage hikes compensating real wage losses (had they not, consumer demand would have contracted more strongly than it did). On the other hand, the irrevocable business investments had to fall under the enhanced uncertainty about the sustainability of the OPEC cartel – and thus the fundamental uncertainty about the kind of technologies (energy saving? or traditional?) the newly installed capacities should embody. As long as that uncertainty prevailed it was rational for the business sector to ‘wait and see’. Countering the ensuing stagnation/recession and rising unemployment may have required much higher public deficits than seemed acceptable at that time (the deficits considered acceptable in 2008–2009 were about twice as high, relative to GDP).

The first salvoes directed at the original Keynesian ideas were shot by the proponents of the New Classical Economics and Real Business Cycles theory. RBC, the early version of the Dynamic Stochastic General Equilibrium approach, constitutes also the 'core' of the approach. The basics of the RBC approach are introduced in Section 2, the way it is specified in Section 3 and the principles of its validation in Section 4. Section 5 dissects the benchmark 'New Keynesian' (NK) DSGE model, which – essentially – is an RBC model with some 'frictions' added. Section 6 reports on the uselessness of the NK DSGE models exposed by the Great Recession. Section 7 critically analyses the logic behind two key variables of NK DSGE models: the output gap and the natural interest rate. Section 8 points out to some more or less obvious omissions and simplifications of the approach and the futility of the attempts to correct them. Section 9 ponders, sceptically, the question whether a scientific micro-founded macroeconomics is at all possible. Section 10, devoted to the 'empirics' of the DSGE approach, comes to the conclusion that it does not pass the 'smell test'.

2 Dynamic Stochastic General Equilibrium models without 'frictions': RBC

The Real Business Cycle (RBC) theories which presided over the funeral of the 'old Keynesianism', were initiated for good by Kydland and Prescott (1982). But some essential ideas accepted by the RBC authors were earlier put forward by Lucas (1972, 1976). Lucas authored the principle that valid laws of macroeconomics – which deals with economy-wide aggregates – must only be derived from the study of the rules governing the behaviours of microeconomic 'agents' populating the national economies. Such studies were to produce 'deep' parameters, invariant to the circumstances (first of all invariant to government policies). However, the 'agents' considered by Lucas bore no similarity to any type of really existing individuals. Instead, they were assumed to be 'representative'. The representative agents are to correctly aggregate all real individuals.

It is then typically assumed that the 'representative' acts in a perfectly competitive environment, as portrayed in elementary textbooks in microeconomics. As in the world of Walras (or, in the more refined DSGE models, as in the world of Arrow-Debreu) the 'representative' maximises his welfare by sticking to the general equilibrium (while the general equilibrium arises due to the welfare-maximising decisions of the 'representative'). The general equilibrium is tacitly assumed to exist (and be unique as well as stable). It is implied that equilibrium for any period (be it a year, or a quarter of the year) is attained in one single moment. The existence of out-of-equilibrium states does not merit any consideration. This presumes the existence of an invisible 'Walrasian Auctioneer' securing an instantaneous equality of demand and supply for everything tradable. Moreover, the RBC models endow the 'representative' with the power to form 'rational expectations'. In an environment free of any quantifiable risk and unquantifiable uncertainty the 'representative' would have full and perfect knowledge of that environment – as portrayed by the model itself. His actions (and the ensuing equilibrium) would therefore embody the 'perfect foresight' consistent with the model. If, however, that environment is assumed to be subject to external stochastic 'shocks' (such as e.g. due to normal variations in the weather conditions) the 'representative' modelled takes this into account by means of 'rational expectations'. That is, he is assumed to know also the stochastic characteristics of future 'shocks' and, while making his decisions, does not err systematically on future shocks, which are unknown *ex ante*. When confronted with fundamental uncertainty rather than with a simple risk, the 'representative'

would be unable to form ‘rational expectations’. However, the environments with such non-stochastic ‘unknown unknowns’ are not considered in the RBC (and DSGE) models. Consequently, there is no place in these theories for a ‘representative’ disobeying the principle of ‘rational expectations’.

3 The RBC prototype specified

The key features of the RBC modelling methodology are preserved in the more recent Dynamic Stochastic General Equilibrium models. DSGE models tend to be much ‘richer’, also on account of making allowance for various ‘frictions’ and policy actions not considered under the RBC rubric. It is therefore useful to proceed sequentially and devote some space to introducing a few general features of the RBC approach before proceeding to the ‘modern’ DSGE. Extensive reviews of original RBC works can be found in Stadler (1994) and Plosser (1989).

A (proto) typical RBC model assumes that the ‘representative agent’ (be it a ‘household’ or a ‘firm’, or a ‘representative household’ in fact owning the ‘representative firm’) possesses some more specific qualities. First, he is assumed to be infinitely lived. Then, he is believed to form plans extending until the end of time. In doing so he maximises the value of his objective function, subject to the resource constraints. The mathematical form of the multi-period objective function under maximisation is given explicitly. Specifically, it is a discounted sum of the momentary (static) utility functions. The summation of the static utility functions extends into infinity (for this to make mathematical sense the discount factor – assumed to be time-invariant – must be smaller than 1, which is postulated to be the case). The static utility functions all have the same (time-invariant) form. As a rule, very simplistic forms of the static utility functions with the usual properties are preferred (e.g. additively separable Constant Relative Risk Aversion (CRRA) which in the extreme case assumes the Cobb-Douglas form). Primarily this facilitates the mathematical analysis of the model (and also safeguards the existence of the steady state for the solution the infinite-horizon dynamic maximisation in question). Each static utility function has two arguments: consumption (of a single aggregate good which is produced by the ‘representative firm’) and the amount of leisure optimally fixed by the ‘representative household’. The ‘representative household’s’ consumption is related to the hours of work spent (at the expense of hours of leisure) while producing the ‘representative firm’s’ output. The ‘representative firm’ employs all work-time supplied by the ‘representative household’ and its own capital stock. Output is produced using a conventional neoclassical production function (preferably a Cobb-Douglas again, as in Solow’s neoclassical growth model), with hours of work and the size of capital stock as arguments. It is assumed that the production function is subject to random ‘shocks’ altering its purely technical properties (i.e. the multifactor productivity parameter in the Solow growth model). The non-consumed part of output produced gets invested, hereby increasing the ‘representative firm’s’ future capital stock (hence also feasible output and consumption in the future). Each period current investment – made at the expense of current consumption – allows higher output and consumption later on. Essentially then, the ‘representative household’ maximises its infinite life-long satisfaction from the infinitely-long streams of consumption and leisure. While establishing its infinitely long plan the ‘representative household’ is assumed to know everything about itself (i.e. be aware of its own utility and its ‘firm’s’ production function). Moreover, the ‘household’ is assumed to be capable of doing the necessary mathematical calculations resulting in establishing the plan maximising the value of its infinite-

-horizon objective function while taking into account the fact that this plan must be compatible with equilibria for all future dates. Last, but not least, the whole planning exercise must 'rationally allow' for the distribution of the future stochastic shocks.

Under the above assumptions it is often possible to derive analytically the explicit formulae for the trajectories of output, consumption and investment – all extending into infinity.² These formulae take into account only the 'technical' parameters characterising the production function, the parameters describing the static utility functions and the discount factor featuring in the multi-period objective function and the occasional 'real shocks' perturbing the technical parameters (the multifactor productivity parameter in particular).

The RBC model rules out very many real-world phenomena – such as e.g. income inequality: the whole population is collapsed into a single 'representative household'. There cannot be any distinction between the employers and employees – the 'representative firm' appears to be run and actually owned by the 'household'. Finally, observe that involuntary unemployment cannot be captured here. All hours not allocated to leisure are spent at work. All hours unspent in production represent leisure freely chosen so as to maximise the infinite sum of utilities from consumption and leisure. Since the model does not consider the government, neither monetary nor fiscal policies can have any impact on model solutions. Money (and inflation) does not play any role at all. There is really no place for e.g. credit and debt (and any financial instruments): first because monetary variables are absent in the 'representative's' maximisation problem, second because with only one 'representative household' it would have to 'borrow from itself' which rather obviously does not make much sense. The unreality of the basic assumptions of the early RBC models seems all too obvious. Moreover, these models clearly failed to account for the major features of the actual performance of the US economy. A number of modifications were later grafted into the basic RBC model to address some of the model's deficiencies. For example, some modified variants can consider government (primarily as another source of disturbing 'shocks', e.g. in the form of government spending). But the inclusion of nominal variables (of inflation, prices, wages and of money in the first place) turns out to be hard to achieve while respecting the genuine 'intellectual' motivations behind RBC models. Of course, it may be possible to insert symbols, e.g. for 'bonds' into the resource constraints of the 'representative household'. But such 'symbolic decorations' play no role in determining model solutions and their revealed properties.

The assumptions behind the RBC models are strikingly remote from the realities (however 'stylised') of any monetary market economy. These models may perhaps fit the realities of a primitive economy populated by a mass of undifferentiated self-employed peasants or artisans (who may occasionally exchange – through barter – the surpluses of their own products). However, the RBC modelling has had the ambition to discover essential truths about the contemporary US economy. The major 'truth' usually broadcast by the RBC theorists is that steady growth in a competitive macro-economy does not need any government interference of any sort. It is only admitted that the external

² With less 'facile' utility or production functions and more elaborate additional complications introduced (e.g. concerning the nature of the stochastic shocks, and/or allowing for lags in formation of capital and its depreciation) the explicit formulae for model solutions may be too difficult to derive analytically. In such cases it is proposed to take linear approximations to the implicit formulae characterising the 'representative household's' plan (i.e. the first-order conditions for the optimum). Assuming that these linear approximations remain valid in the vicinity of the presumed steady state of the system (and in absence of stochastic shocks) one then could solve the resulting simplified system and derive the trajectories for the endogenous variables: hours of work, consumption and investment.

stochastic shocks to supply or productivity could perturb growth – and generate ‘real’ (as opposed to monetary or policy-induced) business cycles. The RBC authors purport that if left to themselves, these ‘real’ cycles would correct themselves rather quickly – due to the inherent tendency of competitive markets to clear. Moreover, it is suggested that the economic fluctuations are “optimal responses to uncertainty in the rate of technological change” (Prescott 1986, p. 21). The ultimate policy advice then is that “costly efforts at stabilization are likely to be counterproductive”.

Another major ‘insight’ derived from the RBC model is that a negative shock to productivity makes leisure momentarily more worth to the ‘household’ relative to the momentary income to be earned by working (and thus momentary consumption). The momentary loss of consumption would be made up in the future when the negative productivity shock dies out and higher productivity makes work/consumption more attractive relative to leisure again.

The affinity of the RBC main theoretical implication to the deregulatory practices and the neo-liberal tendencies of the 1980s and 1990s is quite obvious. The ‘insight’ on leisure taken by households optimally (and thus voluntarily), in response to unobservable productivity shocks, is to deny the existence of involuntary unemployment. An implication of this is that since the observed unemployment is voluntary (and optimal to the affected) macroeconomic policy must not do anything about it.

4 Validation of RBC models

The ‘empirics’ of the RBC models involves a practice often referred to as ‘calibration’. This practice is unorthodox, to say the least (that appellation applies to the later DSGE models ‘with nominal frictions’ as well). The essential parameters for the ‘representative’ utility and production functions are at best informed guesses (or ‘stylised facts’) made by model makers. Such guesses, once made, prove to be long-lived. They tend to be taken over by the consecutive generations of DSGE scholars and eventually acquire a status akin to the ‘constants’ derived in natural sciences (the phrase all too often encountered in the DSGE studies is that “the magnitudes of our calibrated parameters are broadly consistent with those used previously”). Sometimes the values of some parameters are claimed to agree with the findings of empirically oriented microeconomic research. Making use of the estimates derived from such research seems a dubious practice. In practice the estimates derived from any micro-econometric study, even if conducted impeccably from the econometric point of view, are almost always imprecise and, in addition, conditioned on more specific assumptions that are almost always debatable and always obviously inconsistent with the RBC premises: ubiquitous market clearing, rational expectations, no involuntary unemployment and absence of any nominal and financial variables.

The second part of the RBC empirics requires the simulation of unobservable stochastic shocks (e.g. to the multifactor productivity parameter), which, as the model makers assume, could affect the ‘representative’s’ optimum paths of the variables of interest. A computer-generated shock is then fed, together with the ‘guesstimated’ parameters, into the formulae (whether explicit or approximate) to produce a fictitious path of variables of interest under the specific shock. With a large number of simulated shocks, one gets a large number of such artificial paths of variables of interest. These paths are then subject to averaging and further statistical treatment. This involves the calculation of the growth rates implied (e.g. of output) and of their statistical moments (e.g. variances) or correlations

(e.g. between variously dated rates of growth of consumption, hours of work, etc.). The same procedure (averaging, calculation of moments) is executed for the available data for the real macro-economy. Should the averages and moments computed for the real economy resemble ('match') the averages and moments derived from the model-based simulations, a success is claimed: the micro-funded RBC model in question is paraded as a micro-founded, but supported by real data, theory of the macro-economy.

That the conclusions drawn from thus 'validated' RBC models must remain mute on real-world phenomena such as e.g. unemployment, inflation or recessions (which appear to be totally unrelated to any identifiable 'negative' technological shocks) did not seem to matter. For a few decades RBC theories remained dominant within mainstream macroeconomics.³

The inadequacy of these theories – and their practical uselessness for the actual conduct of macroeconomic policy – did not go entirely uncontested. This is evidenced by a relatively early analysis of the RBC theory due to Summers (1986). Summers concluded his 'sceptical comments' as follows: "... economists are much better at analyzing the optimal response of a single economic agent to changing conditions than they are at analyzing the equilibria that will result when diverse agents interact (Summers 1986, p. 26). This unfortunate truth helps to explain why macroeconomics has found the task of controlling, predicting, or even explaining economic fluctuations so difficult. Improvement in the track record of macroeconomics will require the development of theories that can explain why exchange sometimes works well and other times breaks down. Nothing could be more counterproductive in this regard than a lengthy professional detour into the analysis of stochastic Robinson Crusoes".

5 Benchmark 'New Keynesian' DSGE models

Keynes did not pay much attention to 'stickiness' of wages or prices as a factor behind the business cycles, and behind persistent depressions with high unemployment in particular. Nor did he view wage and price flexibility as necessarily desirable. Hahn and Solow (1995) provide a meticulous 'micro-founded' discussion of this issue. According to Hahn and Solow, Keynes's suggestion (in Chapter 19 of *The General Theory*) that too much flexibility might induce such drastic price fluctuations as to undermine the functions of money itself merits attention. Some amount of nominal wage stickiness could be necessary for avoiding the harmful effects of unlimited flexibility. Thus, the attainment of maximum efficiency (and full employment) promised by the removal of 'frictions' is not guaranteed. Apparently, it did not occur to Keynes that a moneyless economy – as imagined by Walras and his modern epigones – could be claimed to represent an ideal ('efficient') benchmark for real economies.

The approach originated by Mankiw and D. Romer (1991) revolves around the idea of micro-founded 'stickiness' of nominal variables (wage rates and prices) as a decisive factor behind the undesirable macroeconomic fluctuations. The name given to that type of approach is 'New Keynesian Theory'. This is a misnomer, or even fraud, given Keynes's own views on the importance of 'rigidity', of wages and prices, and on the 'rigorous' neoclassical (micro) economics in general.

In the late 1990s the fusion of 'New Keynesianism' and the RBC approach took place resulting in an explosive growth of research seeking to enrich the frictionless RBC models with additional

³ Four major contributors to the RBC theory (R. Lucas, F. Kydland, E. Prescott and T. Sargent) were awarded the Nobel Prize in Economics. But the list of Nobel Prize Laureates critical (often rather harshly) of the RBC (or its DSGE follow-ups) is longer. It includes R. Solow, J. Stiglitz, P. Krugman, C. Sims, E. Phelps, R. Schiller, G. Akerlof and P. Romer.

‘stickiness’ of various types.⁴ That has been the domain of the New Keynesian Dynamic Stochastic General Equilibrium (NK DSGE) models. In practice almost all DSGE models are nowadays ‘New Keynesian’ (i.e. they distinguish themselves by introducing stickiness of some variables, parameters or unobservable ‘shocks’). The ‘DSGE’ appellation does not create any misunderstanding and will be used consequently henceforth.

Generally, the underlying intention of the DSGE model makers is, as in the RBC theory, to build a quantitative macroeconomic model exclusively from bottom up – that is, from the explicitly modelled optimising behaviour of ‘micro agents’. In contrast to the RBC models there is a place here for ‘frictions’ and for monetary policy. The latter comes in the form of the officially announced, fixed, nominal short-term interest rate transmitted to the real economy.

The benchmark DSGE models (such as in Clarida, Galí, Gertler 1999) introduce the ‘natural’ values for both output and the real interest rate. The motivation for these ‘naturals’ tends to be simplistic – but hardly convincing: “... it remains true that one can define natural values for output and the real interest rate that would arise in equilibrium if these frictions were absent ... roughly speaking, they correspond to the values of output and the real interest rate that a frictionless RBC model would generate, given the assumed preferences and technology” (Galí, Gertler 2007, p. 27). The logic behind the presumed existence of the natural values for output and the real interest rate will be considered in some detail later on.

The DSGE workhorse model exploited during the years of exuberant complacency of its authors (the late 1990s and the first part of the 2000s)⁵ boils down to two equations (for aggregate supply and aggregate demand, respectively) of a very specific form. These equations are claimed to be derived from ‘micro-foundations’. The third equation ‘closing the model’ is added. This is alleged to represent the motives behind monetary policy making.

At the centre of the underlying micro-foundations there is again the immortal ‘representative household’ (it is often said that actually there is a continuum of households. This does not mean anything because they are treated as indistinguishable).⁶ The ‘representative’ is assumed to maximise the infinitely-long discounted sum of his static utility functions. The latter functions are of the same time-invariant form (mostly the simplistic Constant Relative Risk Aversion, CRRA) with two arguments: hours of work and consumption volume (both dated). In maximising its objective function, the ‘representative household’ is guided by rational expectations about likely future shocks and has perfect knowledge of micro-economy itself (though not necessarily about the equation guiding the monetary policy authority). In contrast to the original RBC, the ‘representative household’s’ budget constraints which restrict the static choices are now explicitly in nominal terms. Thus, the symbols for the monetary wage rate and for the price level (both dated) are introduced. Moreover the ‘household’ has now access to ‘bonds’ which are also nominally priced and are assumed to yield an interest. It is not clear who issues these ‘bonds’, on what conditions and for what purpose. Presumably, ‘bonds’ are to be issued by some households to be purchased by other households. Given the fact that there is only one single ‘representative household’ considered, this does not seem to make much sense. Is that

⁴ Paul Romer (2016) characterises the synthesis of RBC and New Keynesianism as follows: “To allow for the possibility that monetary policy could matter, empirical DSGE models put sticky-price lipstick on this RBC pig”.

⁵ Issue 4 (2007) of the *Journal of Economic Perspectives* contains, apart from the article by Galí and Gertler, texts by two other major contributors to the DSGE methodology: Woodford and Goodfriend. The whole JEP issue is a paean by the authors to ... themselves (later specific reference will be made to the article by Goodfriend).

⁶ The highly influential DSGE model by Smets and Wouters (2003) has, at its centre, a single household that is to be understood as ‘representative’ for all households over the entire euro area! There is neither Greek nor German ... at least in the DSGE Euroland.

household trading the ‘bonds’ with itself? This suspicion is supported by the fact that in the end ‘bonds’ do not play any role in the solutions to the model (which may also be the consequence of the fact the yield on the ‘bonds’ there equals the nominal interest rate administered by the monetary authority).⁷ Sometimes it is hinted that the baseline models assume perfect capital and insurance markets. This is misleading. In fact, these models ignore capital and insurance markets altogether (‘agents’ acting in insurance, capital and banking sectors must not – in the model – be different from the ‘representative household’ or one would have to introduce different types of ‘representatives’ coexisting and interacting with one another. With one ‘representative agent’ considered, it would have to simultaneously embody the insurance, banking, etc. businessman – in addition to being the employee and the owner of the representative productive firm! That was perhaps too much to openly admit in the first generation of DSGE models – but tends to be uncritically, if tacitly, accepted in the more recent ones). Eventually, ‘bonds’ appear to be a smoke screen rationalising the introduction of nominal variables. And, as openly admitted, money is introduced in the DSGE models solely as a unit of account in which the nominal variables are priced: “... while monetary policy is central in the model, money per se plays no role other than to provide a unit of account” (Galí, Gertler 2007, p. 30).

The description of the production sector in baseline DSGE models seems to be more intricate than in the RBC and comes in some variants. Generally, it goes without saying that at each date production takes place instantaneously – but as if in two stages – and involves two types of firms: the ‘representative competitive’ one(s) and the specialised monopolistic firms whose number is infinite. The single final good is to be produced by the ‘representative competitive firm’ whose job is to combine the intermediate inputs to be delivered by the monopolistic firms. From a ‘technological’ point of view the combination of inputs to be delivered by the monopolistic firms is governed by an analytically specified production function which accounts for the substitutability (assumed imperfect, but constant and invariable) of various inputs. A ‘dual’ formula is then valid for the overall price index which aggregates the prices of inputs to be delivered by the monopolists.

The monopolistic firms are assumed to be endowed with the conventional production functions, with work-hours as inputs. These production functions are all of the same form (i.e. they do not differ with respect to their parameters such as marginal productivities of work-hours) and are subject to precisely the same shocks. A shock affecting one monopolist’s production function must affect all monopolists’ production functions to the same degree. Moreover, the monopolists face a competitive labour market. It is assumed that there must be a single nominal wage rate for an hour of work supplied by the ‘representative household’ and employed by different monopolists. That single wage rate is, at the same time, to clear the ‘labour market’. More correctly, since no such market is actually considered, the wage rate must simply be such as to secure the equalisation of the ‘household’s’ optimum amount of hours of work with the aggregated optimum amounts of work-hours employed by the monopolistic firms (the representative competitive firm ‘packaging’ the inputs delivered by the monopolists is assumed to do without any work).

⁷ Alternatively, ‘bonds’ could perhaps be understood as debt issued by the public authority (e.g. the central bank). This interpretation creates more problems than it solves. Is the supply of such debt unlimited? What happens to the revenue earned by the public authority selling its ‘bonds’ to the ‘household’? Isn’t it automatically returned to the ‘household’? In any case interest on ‘bonds’ earned by the ‘household’ in one period must, along the equilibrium path, all be spent on the acquisition of bonds the next period. Thus, such ‘bonds’ cannot affect the path of real magnitudes (e.g. consumption). Moreover, unless the initial stock of such bonds is zero (or the nominal interest rate on these bonds equals zero indefinitely) the stock of bonds would have to keep rising – eventually to infinity.

Being monopolists, the suppliers of intermediate firms are assumed to have a say on the prices they charge and the quantity of their output. Should they all respond optimally, they would exploit the circumstances without any regard for anything else but the currently prevailing wage rates and the demand from their products signalled by the competitive ‘representative firm’. At this point comes the coup: it is postulated that at each date some monopolistic firms do indeed fix their prices and outputs at levels which are optimal for them. The remaining firms simply keep their prices unchanged, at the previous period’s levels, while their outputs are adjusted to the demand accordingly. Thus, their prices are ‘staggered’, resulting in the overall price index showing some ‘stickiness’. This is the so-called Calvo pricing. In other words, it is postulated that at each date the probability is fixed that any monopolistic firm is ‘conservative’ with respect to pricing of its output. Consequently, the probability that a firm as if re-optimises its price prior to the delivery of its product is also fixed. Although hardly compatible with ‘micro-foundations’ and otherwise rather problematic, the Calvo ‘trick’ has played a decisive role in introducing ‘stickiness’ into the DSGE models (other types of ‘stickiness’ may be invoked to capture the possibility of evolving ‘tastes’, ‘habit formation’ etc. Also, it is ubiquitously assumed that the unobservable ‘shocks’ (the perturbing ‘technology’ or the three equations of the canonical DSGE models, discussed below) contain an autoregressive component. As such, the autoregressive ‘shocks’ also make the model solutions look as if reflecting stickiness of some sort).

The rest of the canonical DSGE model building involves rather tedious, but otherwise fairly unproblematic algebraic manipulations. Because any profits (or losses) made by the monopolistic firms are returned to their owner, i.e. the ‘representative household’, the optimising planning takes into account the production side, as well as the ‘household’s’ own explicit objective function and the budget constraints. Thus, that planning is to guarantee equilibrium in all ‘markets’ implied (for labour, the final good, the intermediate inputs) and embodies the rational expectations principle. In effect all this boils down to solving a constrained dynamic, infinite-horizon programming problem à la Bellman. Given its structure the problem should satisfy the so-called transversality condition (which is to rule out the possibility of the objective function’s maximum being infinitely large). The satisfaction of this condition is usually simply postulated but not necessarily automatically guaranteed. In any case, one often proceeds taking the satisfaction of the transversality condition for granted and then defines the optimum by a series of first-order conditions (i.e. by equating the derivatives of the appropriate Lagrangian to zero).

By virtue of more specific assumptions concerning the form of the infinite-horizon objective function (the discounted sum of invariable static CRRA utility functions) and the assumed invariance of the basic parameters (such as the time discount factor featuring in the objective function, or the Calvo parameter) the resultant first-order conditions for the ‘household’s’ optimum are also time-invariant. Because these conditions are often too difficult to analyse explicitly, they are eventually simplified and presented in the form of log-linear equations claimed to be valid along the system’s presumed (non-stochastic) steady state.

There are two canonical equations in the benchmark DSGE model: the New Keynesian Phillips Curve (or the aggregate supply function) and the Dynamic IS⁸ Curve (or the aggregate demand function).

⁸ IS stands for ‘investment-saving’. This term is used even in the versions of the model which rule out investment in fixed assets. In these models all output produced is consumed momentarily (thus there are no savings). Galí (2008) develops a long succession of DSGE models featuring the IS equation – none of them allows for investment in fixed assets.

The NK Phillips Curve has the following form:

$$\pi_t = \beta E_t \pi_{t+1} + \kappa y_t$$

The Dynamic IS Curve has the following form:

$$y_t = E_t y_{t+1} - \sigma (i_t - E_t \pi_{t+1} - r_t^*)$$

In the above equations the t subscript dates consecutive periods, E_t is the (rational) expectation formed at date t , π_t is inflation in period t , y_t is the unobservable ‘output gap’ (the per cent difference between actual output and its natural level), i_t is the central bank’s nominal interest rate, r_t^* is the unobservable natural level of the real interest rate, β is the time-discount factor featuring in the ‘household’s’ objective function, σ is related to the (fixed) marginal utility of consumption (featuring in the static CRRA utility function), and κ is a well-defined constant ‘amalgamating’ all other fixed parameters (the Calvo parameter, the discount factor and the parameters related to the marginal utility of consumption and disutility of working in the static utility function).⁹

The third equation completing the model is to represent the central bank’s response to the observed inflation gap (i.e. the difference between the current and the targeted inflation rates) and the output gap, y_t . This equation is a variant of the ‘Taylor Rule’ (the rule was originally meant to be an approximate description of the FED’s actual decision making (Taylor 1993). Since the late 1990s in the DSGE models the Rule has gained the status of a universal principle behind central banks’ nominal interest rate fixing. In the DSGE models the Taylor Rule has the following form:¹⁰

$$i_t = \phi_\pi (\pi_t - \pi^*) + \phi_y y_t$$

where i_t is the central bank’s nominal interest rate, π^* denotes its inflation target (possibly set at 0), and the non-negative constants ϕ_π , ϕ_y measure its sensitivity to inflation deviating from the target (π^*) and the output gap deviating from its ‘natural’ level (y_t) respectively.

It is worth observing that the term $E_t y_{t+1}$ must be interpreted as the ‘household’s’ (rational) expectation formed in period t of the next period’s output gap. Thus, such a ‘household’ is endowed not only with a rational foresight concerning inflation, but also with the capacity to rationally assess the output gap (which is essentially unobservable).

The three above equations are meant to be deterministic. They are then complemented by adding the symbols for ‘stochastic shocks’ that are unobservable (ex ante as well as ex post). The standard practice is to add, to the right-hand side of each equation, a respective random component. Usually it is postulated that these are autoregressive AR(1) ones:

⁹ The constant substitution parameter for the monopolistic sector does not affect the magnitude of κ . Effectively, in the end its size does not matter for the canonical equations at all! The introduction of substitutability (and of the ‘monopolistic competition’) is ‘window dressing’. It serves the sole purpose of permitting the Calvo pricing to be ‘smuggled’ into a model with otherwise perfectly competitive features. Also, it creates the (ungrounded) impression that the model goes beyond the RBC models (with ‘perfect’ competition) by allowing for ‘imperfect’ competition.

¹⁰ Some authors postulate a more elaborate Taylor Rule equation adding the natural interest rate r^* to the right-hand side of it and/or propose to introduce interest rate ‘smoothing’ (i.e. adding a fraction of the previous period’s interest rate).

$$\varepsilon_{t,s} = \delta_s \varepsilon_{t-1,s} + \eta_{t,s}; \quad \varepsilon_{t,d} = \delta_d \varepsilon_{t-1,d} + \eta_{t,d}; \quad \delta_{t,i} = \delta_i \varepsilon_{t-1,i} + \eta_{t,i}$$

where $\varepsilon_{t,s}$, $\varepsilon_{t,d}$ and $\varepsilon_{t,i}$ are shocks to the aggregate supply, aggregate demand and the Taylor Rule equation respectively, $\eta_{t,s}$, $\eta_{t,d}$, $\eta_{t,i}$ are uncorrelated independent identically distributed unobservable random variables with zero means and unknown variances and δ_s , δ_d , δ_i are the unknown shock ‘persistence’ parameters.

All random components are unobservable (as are the natural interest rate and the output gap). The ‘symbolic’ model consisting of the three equations (with the AR(1) components added) is then specified numerically – with most parameters ‘calibrated’ (i.e. based on ‘informed’ guesses, or simply assumed or postulated) and some parameters somehow estimated – e.g. applying the Bayesian methods (with the ‘point-calibrated’ parameters fixed).

6 After the crash: “the unfortunate uselessness of most »state of the art« academic monetary economics” exposed

Once numerically specified, the benchmark model used to be paraded as a fully-fledged representation of macroeconomic reality. Around 2007 the DSGE benchmark model (and its derivative versions) had gained the status of ‘hard science’, capable of providing truths about macro economy and of guiding monetary policy recommendations infallibly. Fiscal policy, ignored in these models, was considered unimportant and uninteresting – at best a source of another shock disturbing the IS equation. That feeling of victory (over the old Keynesian pre-scientific superstitions) was clearly expressed by one of the founding fathers of the approach: “The worldwide progress in monetary policy is a great achievement that, especially when viewed from the perspective of 30 years ago, is a remarkable success story. Today, academics, central bank economists, and policymakers around the world work together on monetary policy as never before.” (Goodfriend 2007, p. 65).

The Bible is right: “Pride is before a crash and arrogance before the fall.” (Proverbs 16:18). Soon after the proud claims about the solid ‘scientific’ foundations of the macro policies ‘around the world’ the economy of the US (and of the rest of the world) crashed spectacularly. The events mercilessly exposed the inability of the then dominant DSGE models to provide an understanding of what was going on – and even more their incapacity to propose ways out of the crisis. Some more or less obvious oversimplifications and omissions, long suppressed in view of the triumphant self-confidence of the DSGE authors, at last became the targets of legitimate analysis, mostly critical. The ‘science of monetary policy’ (Clarida, Galí, Gertler 1999) proved to be ‘unfortunately useless’, and “may have set back by decades serious investigations of aggregate economic behaviour and economic policy-relevant understanding” (Buiters 2009).

The failure of the DSGE models to predict the crisis (and to suggest policies to deal with its protracted consequences) is only one strand of the widespread post-2008 criticism of the approach. The important thing to stress is that the failure was not due to exceptional exogenous circumstances: no external events could be held responsible for the crisis. On the contrary: for a long time prior to the outbreak of the crisis a consensus prevailed that market economies, guided by enlightened central bankers, were gliding smoothly along a steady state path with low inflation and low unemployment.

That was the ‘era of great moderation’. Deep recessions were believed to have been definitely a thing of the past. Evidently, the crisis was the result of internal (‘endogenous’) processes for a long time brewing under the tranquil surface of normality. But these processes in no way could have been reflected, simply because the DSGE models had no place for them. Models equating the national economy with a single household owning the production side cannot be hoped to represent reality – even if rational expectations, maximisation extending into infinity, necessary equilibrium, token money and some ‘frictions’ are crammed into it. Simply put, the benchmark DSGE models proved glaringly inadequate in the face of economic realities.

7 Measuring the non-measurable: the ‘natural’ output and the ‘natural’ interest rate

Since 2008 the criticisms of various aspects of the DSGE approach have proliferated. The status of the two ‘natural’ variables playing central roles in the DSGE models: the natural output level and the natural interest rate have so far escaped critical scrutiny. Before briefly commenting on the most obvious deficiencies of the approach it is important to reflect on the logic behind these two ‘naturals’.

The natural output level, defined as the output that would emerge in the flexible-price competitive equilibrium, may be calculated in a specified DSGE model assuming ‘frictions’ and shocks away. If the canonical equations are to be known to the ‘representative household’ (as is assumed under rational expectations) then that ‘representative’ may also know the model’s natural as well as actual output levels. The same applies to the natural interest rate: it is supposed to emerge under flexible-prices equilibrium and ideally could be calculated in the DSGE models by the ‘representative’ as well as the model maker (actually, the natural interest rate sometimes comes from the ‘outside’, as yet another ‘calibrated’ parameter). But neither natural output level nor the natural interest rate can be detected in any real-world data.¹¹ This has a grave consequence when it comes to the validation of the DSGE models – i.e. when the moments or trajectories (impulse response functions) of the model-derived output gaps are to be compared with the moments or trajectories of the actual output gaps. The latter are unknown – not only to the ‘representative’, but also to model makers. In practice the actual output gaps are calculated as residuals following the application of a filter (Hodrick-Prescott for instance) to the raw time series of actual outputs. This is a problematic routine, not only because the choice of the filter is always arbitrary. More importantly, output levels following the ‘filtered’ data cannot correspond to the output levels that would actually emerge should the real economy be miraculously returned to primitive barter conditions (no money, frictions, shocks etc.). Nobody can guess what would be left of the really existing contemporary economies sans money. Moreover, the residuals following the application of any ‘filter’ must be positive and negative in roughly equal proportions, suggesting the presence of alternating periods of positive and negative output gaps. The (unasked and unanswered) question is, how come the actual output observed could be higher (roughly half the time) than its presumably natural level?

¹¹ NAIRU, another notorious unobservable, belongs to an older version of the mainstream. Its status is now questioned (e.g. Blanchard 2018). In DSGE models there is no place for any unemployment at all (but only for a free, utility-maximising choice between work/consumption and leisure).

Despite its ghostly appearance the natural interest rate (r^*) also plays quite a prominent role in mainstream monetary theories – and, apparently, also for the practice of monetary policy making. The size of r^* is often claimed to be an essential reference point for monetary policy. The research departments at central banks busy themselves with attempts at ‘guesstimating’ its numerical values. Not long ago the concept of the natural interest rate was invoked while attempting to rationalise the anaemic recovery (‘secular stagnation’) following the Great Recession. Specifically, it is claimed that r^* must have turned negative (e.g. Summers 2014; ECB 2018) thus activating the ‘zero lower bound’ and hence becoming directly responsible for ‘secular stagnation’.

The leading methodology for the estimation of natural interest rates is based on the assumption that r^* must stand in a certain relation to the output gap.¹² A logical circularity of this approach would seem quite obvious. The natural output gap is not only unobservable itself, but also conceptually dependent on r^* (as in the IS curve above). Judging the magnitude of an unobservable variable (such as the natural interest rate) by reference to another unobservable variable (or collection of such variables) is obviously not a very sane approach: it cannot pass Solow’s ‘smell test’. However, the persistent attempts to ‘estimate’ an unobservable create the impression that even if evading observation, it somehow does exist and matters a lot. In fact, however, such an item may be pure fiction, a kind of economic unicorn – or an ‘object’ with mutually excluding features.

The concept of the ‘natural interest rate’ is due to Wicksell (1936(1898), p. 102). Wicksell’s original definition claimed that “There is a certain rate of interest on loans which is neutral in respect to commodity prices, and tends neither to raise nor to lower them. This is necessarily the same as the rate of interest which would be determined by supply and demand if no use were made of money and all lending were effected in the form of real capital goods ... It comes to much the same thing to describe it [the natural interest rate] as the current value of the natural rate of interest on capital”.

This definition presumes the existence of such an equilibrium rate. But what guarantees its existence (and/or its stability and uniqueness)? Another – and rather curious – aspect of the natural interest rate concept is its reference to inflation (‘raising or falling commodity prices’) under ‘counterfactual’ conditions (absence of money, frictions, shocks and other nuisance factors). However, under absence of money, the price level remains indeterminate – and so is inflation. Under a barter-exchange general equilibrium (assuming it exists) only the relative prices are determinate. Prices of concrete goods can rise and fall – but only vs. one another! Besides, how can one interpret ‘lending in the form of real capital goods’? Would the repayment of such ‘real’ loans be also in terms of ‘real capital goods’? Would a piece of ‘leased-out’ machinery be returned to its original owner? And, in what units is the ‘natural rate of interest on capital’ measured in a moneyless economy?

Wicksell’s logical error (making reference to inflation or an interest rate on capital in a moneyless economy) has been left uncorrected by the self-professed ‘Neo-Wicksellians’. Woodford (2003, pp. 62–64) dodges the problem. On the one hand, it is claimed that the ‘price level in a cashless economy is in principle determinate’. But what is actually that price level when there is no money and ‘frictions’ of any sort are absent? Besides, in the one-good economy considered in the DSGE models there is no place for even relative price movements. Price level and inflation are indeterminate in the backup ‘frictionless’ RBC (and thus also DSGE) models, and so too is the ‘natural interest rate’ (eventually, things may look less dramatic as money is introduced after all – through the back door – as “central bank liability which may or may not have any physical existence”, Woodford 2003).

¹² Laubach and Williams (2003); Holston, Laubach and Williams (2017).

That the DSGE model assumptions are clearly unrealistic does not seem to trouble their proponents. What is being glossed over is the fact that while the models of perfectly competitive and moneyless economies can work excellently (in the introductory micro textbooks), the really existing developed market economies cannot be imagined to function – competitively or otherwise – without full-bodied money and financial transactions. The DSGE proponents seem equally insensitive to the fact their models all too often fail as forecasting tools. The standard apology offered (“all models are false”) is not convincing. Not all models (whether ‘false’ or not) base their key concepts on ill-defined, ambiguous and self-contradictory definitions which pre-empt any reference to reality.

8 Critiques and ‘repairs’

“After the global financial crisis, quantitative models used by central banks, as well as prevailing fashions in macroeconomic theory and the training of graduate students in economics, came in for heavy criticisms ...” (Hendry, Muellbauer 2018, p. 287).

The ‘representative household’ concept is the most obvious first target of numerous criticisms of the whole DSGE approach. Indeed, it is factually absurd in view of the economic heterogeneity of the really existing societies. Moreover, even if the society is reduced to a single ‘Robinson Crusoe’ endowed with the capacity to form rational expectations and super-human computational ability, there is absolutely no justification for attributing to him such things as e.g. an infinite life span and the maximisation of the summed up discounted static CRRA utility functions. Each such attribution is arbitrary. Why the separately additive CRRA utilities? Why not non-separable preferences such as e.g. reflected in the Almost Ideal Demand System (AIDS)? Why should the multi-period ‘maximand’ be a sum of static utilities – there are very many other non-additive forms that could be postulated. Why an infinite life span? Aren’t there alternative possibilities such as e.g. overlapping generations?¹³ Very similar questions may be asked about the features attributed to ‘representative firms’.

There is only one answer to all such questions: with less ‘usual’ attributes the constrained maximisation problem may be difficult to tackle, whereas with the ‘usual’ ones it has been easier to derive the customary DSGE expressions for aggregate demand and aggregate supply. Upon ‘empirical validation’ (on which later) it is then possible to use the numerically specified DSGE models (again mostly upon further problematic simplifications implicit in the derivation of linear approximations supposedly valid in some vicinity of the presumed steady state) to generate quantitative outcomes which, in the end, should provide ‘insights’ about the real economy. Of course, with alternative features attributed to the ‘Robinson Crusoe’, things may be more difficult to disentangle mathematically. However, the eventual ‘insights’ might prove radically different from those following the DSGE based on the usual assumptions facilitating computations.

The very specific (and restrictive) ‘representative’s’ attributes accepted in the benchmark DSGE model may be deemed consistent with the introductory microeconomics. In that sense these models are ‘micro founded’. But the claim that they represent a ‘micro-founded science’ is an abuse if only because the underlying collection of accepted attributes is purely arbitrary – one of very many equally admissible collections.

¹³ My suspicion is that the infinite time horizon assumption, together with rational expectations and the invariance of static utility functions, may be necessary to ensure the dynamic consistency of ‘optimal plans’.

The singleness of the ‘representative’ is the original sin engendering many very grave consequences. With the single ‘representative’ the benchmark DSGE models are mute on distribution and inequality issues which must be essential for capturing aggregate consumption and investment (e.g. via the systematic differences in saving propensities and investment motives across various social groups). Also, this construct pre-empted any nontrivial representation of finance and money. There was no place for non-token financial transactions, including borrowing or household debt (to itself?). These transactions cannot be treated adequately (or at all) if only because money is reduced to serve solely as a ‘unit of account’ and information is assumed to be perfect and costless (as implicit in the rational expectations assumption). Information – which in reality is imperfect, costly, often asymmetric or even subject to purposeful manipulation – is crucial for the functioning of the financial side of any mature real economy at the ‘micro level’. But all these ‘troubling’ aspects of information had no admittance into DSGE. Most of what is genuinely important is thus ignored. Ubiquitous non-market clearance (credit rationing) is left out (Stiglitz 2018) – together with the alternating manias and panics endogenously arising in the really existing financial markets (Minsky 1986; De Grauwe, Macchiarelli 2015). Illiquidity and insolvency do not exist and thus cannot play any role, etc. Without a multitude of diverse ‘agents’, and a serious treatment of information and finance, the DSGE models offered a version of Hamlet – sans Prince.¹⁴

Critiques of omissions and (over)simplifications of the approach may be construed as useful preludes to a positive ‘repairs’ programme. As stated by Blanchard (2016, p. 21): “I see the current DSGE models as seriously flawed, but they are eminently improvable and central to the future of macroeconomics”. Indeed, a huge number of ‘improved’ DSGE models have already entered the stage. These new-generation DSGE models are approvingly reviewed by e.g. Christiano, Eichenbaum, Trabandt (2018), Reis (2018) and Lindé (2018).

The ‘improved’ models introduce a multitude of detailed changes. Essentially these changes do not touch the key matters. These are changes that ‘keep essential things the same’. The idea is retained of ‘equilibrium’ instantaneously arising from the interactions of self-interested optimising ‘agents’ (claimed to be in plural now), which continue to be endowed with expectations (‘rational’ no doubt). Also, the new DSGE models promise to allow for the ‘heterogeneity of agents’.

In practice the treatment of heterogeneity proposed so far is unsatisfactory, to say the least. Things start with the introduction of distinct ‘individuals’ (even a continuum of individuals), each identified by ‘a subscript’. Each of them is a maximiser of the sum of discounted period utilities (or profits), as in the ‘unrepaired’ core DSGE. Then the set of optimality conditions is derived, as if separately, for each of them. Finally, it comes to aggregating these conditions, the purpose being the formulation of the aggregate supply and demand functions (the IS and Phillips Curve). At this moment it appears that the ‘individuals’ utility and/or production functions are essentially all the same “so they all behave the same [...] we therefore omit subscripts ...” (Michaillet, Saez 2018, pp. 22–24).

In effect the ‘repaired’ DSGE models often ‘fake’ heterogeneity. This is not their authors’ fault. Rather, this testifies to the inherent difficulty of capturing agent heterogeneity in a model that is

¹⁴ The implicit assumption that a single individual utility-optimiser can represent the multitude of utility maximisers is hardly compatible with the alleged microeconomic pedigree of the RBC/DSGE models. As it is (or should be) well known from advanced microeconomics (Sonnenschein 1972; Mantel 1974) there is no necessary correspondence between the utility (and production) functions for the aggregates (or averaging) of individuals and the utility (and production) functions resulting from the aggregation of such functions attributed to individuals (see also Kirman 1992; Hansen, Heckman 1996).

‘micro-founded’, safeguards equilibrium and is computable at the same time. Such ‘inauthentic’ heterogeneity can be detected in many recent models promising to tackle the issue. For example, Iacovello and Neri (2010) distinguish ‘patient’ and ‘impatient’ households. Both are characterised by the CRRA utility functions – with different discount factors (‘betas’) and different consumption habit parameters. The ‘patient’ households accumulate capital (and housing) – the impatient ones do not. Despite these parametric differences the resulting Phillips Curve for the steady-state representation of the model depends only on the parameters for the ‘patient’ households. The ‘impatient’ ones effectively vanish (from the model): only the ‘patient’ count. We are back in a homogeneous framework.

The model by Eggertsson, Mehrotra and Robbins (2019) introduces finitely-lived household cohorts distinguished by age (i.e. by the stage in the life-cycle) – and by the ability to provide/accept loans (according to life-cycle stage). But otherwise the consecutive cohorts do not differ in their preferences. Moreover, they are linked together (by bequests). In actual fact, different cohorts constitute a single ‘dynasty’, little different from a single infinitely-lived ‘representative agent’.

The HANK (Heterogeneous Agent New Keynesian) model by Kaplan, Moll and Violante (2018) considers a continuum of households. However, they do not differ in preferences, but only in the initial (exogenous) financial assets’ endowments (and therefore in the ability to lend or borrow). Given these assumptions the resulting dynamics of the model is derived as in the simple representative-agent models. HANK models suggest that the distribution of assets, on which the traditional DSGE models are mute, may be very important (and the effects of fiscal policy as well). On both counts much the same has always been obvious to the students of the ‘old’ Keynesianism.

There are two reasons why it proves difficult to treat heterogeneity seriously in the DSGE framework. One is computational. With truly diverse ‘agents’ the model may well prove intractable mathematically (also ‘calibration and validation’ of the essential parameters, such as the discount factors, would be much more troublesome: the number of parameters to ‘calibrate’ – and estimate – would have to be suitably multiplied). But it seems more important that should one truly differentiate the groups of individuals, one would have to be specific about their expectations. The assumption of ‘rational’ (or model-consistent) expectations can be swallowed as long as there is a single ‘representative’ in the model. But it seems most heroic to postulate that truly different ‘agents’ all possess the same perfect knowledge of everything worth knowing. Wouldn’t each ‘agent’ also have to know the parameters or mathematical forms of the utility/production functions of all other ‘agents’? In particular, would his ‘rational expectations’ have to take into account the ‘expectations’ of others? Wouldn’t the ‘rational expectations’ be meaningless under such conditions, and would the individual ‘optimal plans’ be necessarily time-consistent? These are unpleasant questions making the introduction of genuine ‘heterogeneity’ into DSGE models problematic. True heterogeneity is hardly consistent with the ‘rational expectations’ and the ‘common knowledge’ assumption.

There have been attempts at dealing with the higher-order information imperfections (e.g. agents’ having to form expectations of others’ expectations) in DSGE models. One way or another, these attempts propose a vision of agents’ learning. But learning is a complex and often lengthy (multi-generational) process. It involves trials-and-errors, with one generation’s knowledge learned being possibly forgotten by its successors. Learning cannot be easily (and adequately) squeezed into the DSGE (or any other economic) models. For example, the recent paper by Angeletos, Collard and Dellas (2018) introduces autonomous variation in higher-order beliefs. But eventually these authors are interested in the solution of the DSGE (and RBC) models in which higher-order beliefs quickly converge to common

knowledge and allow the determination of the regular general equilibrium. The real-life outcome of variations in beliefs is likely to result not only in waves of optimism and pessimism (as shown by Angeletos and his co-authors), but, first of all, in varying degrees of labour market disequilibrium. This is absent there.

A huge number of recently ‘improved’ DSGE models also address various aspects of imperfectness of information in connection with the operation of the financial variables. The list of purely speculative ‘calibrated’ parameters needed for the specification of these models must be extended further, together with still more imaginary ‘financial market shocks’. There are good grounds to believe that these models suffer even more than their predecessors from the inevitable arbitrariness of specific assumptions while the empirical validation routines cannot pass the ‘smell test’ any more than the ‘old’ DSGE models (on which later). Finally, it must be noticed that as long as the parties to the financial market transactions are eventually collapsed into a single optimising ‘representative household’ the whole exercise must yield conclusions of problematic relevance and problematic internal consistency.¹⁵

9 Is a micro-founded macroeconomics possible?

Before commenting on the empirics of DSGE models it is useful to consider some more fundamental reservations about the whole approach, repaired as well as unrepaired.

The first reservation is about the concept of ‘general equilibrium’ – the necessary attribute of the approach. Microeconomics dealing with a Walrasian (or an Arrow-Debreu) economy consisting of optimising ‘agents’ revolves around the notion of ‘general equilibrium’ and its properties (such as e.g. Pareto-efficiency). How (and if at all) the actual economies (even if consisting of consistently optimising ‘agents’) land at a ‘general equilibrium’ does not trouble the DSGE proponents. It must be tacitly implied here that there is a divine ‘Walrasian Auctioneer’ acting in each period.¹⁶ The Auctioneer announces, in one go, the set of equilibrium prices which every ‘agent’ finds the best possible given the circumstances. Of course, in the micro practice things are never that simple. Circumstances (including prices and volumes to transact that are faced by individuals) are seldom ‘given’ and there is always an urge to try to exploit the available (or so perceived) possibilities (e.g. through ‘testing the market’, re-contracting, or defaulting on earlier contracts). This may carry the individuals, as well as the whole market, away from equilibrium rather than closer to it. Research focusing on equilibrium may yield definite and interesting conclusions – even if irrelevant for the real world. But the study of disequilibria can also deliver conclusions that are definite, interesting, illuminating – but relevant for practice. A micro-founded model assuming trading at disequilibrium – with some more or less persistent rationing emerging – may say more about the macro-economy than the models assuming that everything worth studying takes place in equilibrium. Malinvaud (1977) provided an example of such a micro-founded general disequilibrium theorising leading to genuinely insightful dynamic macro conclusions.

¹⁵ The new-generation DSGE models often introduce a variable called ‘money’. However, full-bodied money serving the usual purposes (also as medium of exchange and store of value) cannot be squared with the Walrasian (or Arrow-Debreu) barter framework. Full-bodied money is inherently a nominal macro variable (Ostroy, 1989). Inserting money (representing e.g. wealth) as yet another argument into the utility function cannot be rationalised the way ‘consumption’ and ‘leisure’ are.

¹⁶ In continuous-time DSGE models the equilibrium is preserved continuously. The ‘Auctioneer’ does his job restlessly in these models, not at discrete points of time.

Second, it is certainly correct to assume that well-defined economic interests should strongly motivate ‘real microeconomic agents’. But even if economic interests are well defined (which by no means must always be the case) the decisions to take can bear hardly predictable (and uninsurable) consequences. Decisions on transactions in ‘speculative instruments’ (in markets that are close to being perfectly competitive such as e.g. for foreign exchange, commodities or financial instruments) are often of that character. In effect the DSGE (or other conventional) modelling of behaviour of agents active in the inherently ‘imperfect knowledge’ markets is likely to deliver factually irrelevant results (Frydman, Goldberg 2011). Endowing individuals with the capacity to assess the probabilities for alternative outcomes of their actions (and the well-defined theoretical modes of behaviour under risk) is no good in the conditions of fundamental uncertainty. In conditions of uninsurable uncertainty – which is quite central to everyday human experience – there is little place for any well-defined optimisation and rational expectations.¹⁷ Besides, there are various non-economic factors jointly co-determining actual behaviours of the really existing ‘agents’: cognitive, psychological, institutional or even social. Social (as well as legal and institutional) norms (such as the idea of fairness prevailing in a concrete society) may affect e.g. the outcomes of wage-fixing processes, or the frequency of defaults on contracts, etc. The build-up of price bubbles may be hard to account for without reference to social psychology (e.g. ‘herd behaviour’, or ‘animal spirits’). Eventually, all these ‘behavioural’ factors may be more important when it comes to taking specific actions than the narrowly defined ‘economic’ ones. These are the lessons taught by the illustrious economics Nobel Prize laureates: H. Simon, D. Kahneman, R. Thaler, G. Akerlof, and R. Schiller. Reducing the ‘agents’ to one-dimensional robots predictably responding to purely economic stimuli may facilitate the building of computable models. But the solutions to these models may have very little in common with the performance of actual individuals populating real economies.

To sum up, any attempt (including RBC/DSGE modelling) to derive valid laws of macroeconomics from the study of ‘micro agents’ does not seem promising. Adequate representation of a ‘micro agent’ (and even more so a multitude of ‘micro agents’ interacting in a non-trivial way) in a workable model that can be reliably specified, is next to impossible. An adequate ‘micro-founded’ model would have to be nearly as complex as the micro reality itself. Any concrete ‘micro-founded’ model proposed may encompass all that is deemed relevant. But it would tend to be monstrously complex and effectively unworkable. In any case its empirical ‘validation’ would certainly fail the ‘smell test’.

Because the study of ‘micro foundations’, as understood by the DSGE model makers, cannot be trusted to deliver reliable results, the ensuing ‘micro-founded’ macroeconomics must be of little use. In particular, its ‘scientific’ status cannot be claimed.

Does it mean that macroeconomics cannot be a science at all? Not necessarily. Isaac Newton’s laws of motion, applicable to massive objects, “give an accurate account of nature” (Encyclopaedia Britannica). However, these laws do not apply to the sub-atomic particles of which any massive object in fact consists. But the formulation of Newton’s laws was not micro-founded. Newton did not have to study the laws governing the motions of elementary particles to derive the laws applicable to macro objects. Moreover, had he begun his enquiries from ‘bottom up’ (as the RBC/DSGE theorists demand

¹⁷ The rational expectations rule out non-stationarity of shocks that the ‘representative agents’ are supposed to take into account, and assume the invariance of their probability distributions (assumed to be known to the ‘representatives’). If the shocks are non-stationary (as is obviously the case when major structural changes occur – e.g. during ‘deep’ economic crises) the rational expectations assumption cannot be legitimately invoked to specify the DSGE models. DSGE models ignoring this fact are likely to ‘crash’ when applied during ‘structural change’ (Hendry, Mizon 2014).

from macroeconomists) – from ‘modelling’ the behaviour of the tiniest possible objects constituting the massive ones – he might have never discovered the laws of motion of the latter.

10 DSGE ‘empirics’: failing the smell test

The specification of any DSGE model – that is, fleshing it up with concrete numbers – starts with ‘calibration’ of some of its unknown parameters. ‘Calibration’ can be a ‘point-calibration’ whereby a specific value is assigned to a parameter, or ‘stochastic calibration’, whereby a parameter is considered a random variable with a well-defined probability distribution with known characteristics such as the mean value (the ‘Bayesian approach’ to estimation involves ‘stochastic calibration’). These are then prior distributions of the parameters in question. The decision why some parameters are ‘point-calibrated’ while others are not is, on the whole, fairly arbitrary. The same applies to the choice of probability distributions for the ‘stochastically calibrated’ (i.e. ‘Bayesian’) parameters.

‘Point calibration’ itself has no firm place in the traditional, acknowledged econometrics. No statistical procedure can be invoked to validate the values of ‘point-calibrated’ parameters. In the last instance such a ‘calibration’ is arbitrary. It is guided by the model makers’ fantasy, inherited conventions, the desired properties of the eventual model solutions or the required formal properties of the model (such as satisfaction of the transversality postulate). Any concrete deterministic model can be empirically validated *ex post* – simply by comparing its solutions or forecasts with observable reality. But the DSGE models are not deterministic – they are stochastic. It is not only assumed that some ‘calibrated’ parameters (which are in part stochastic) may be perturbed by random ‘shocks’. In addition, it is also implied that the model forecasts may not (and need not) be simply falsified *ex post* through a direct confrontation with reality. The key factor making DSGE models non-falsifiable is the fact that the ‘shocks’ introduced are purely imaginary: they cannot be observed either *ex ante* or *ex post*.¹⁸

The earlier RBC approaches allowed a single ‘stochastic shock’ perturbing ‘technology’ in their models. The benchmark DSGE models – and their more recent ‘repaired’ versions – are far less ascetic. The standard number of imaginary stochastic shocks allowed to perturb various ‘calibrated’ parameters of these models seems to be about 10 at present.¹⁹

Despite being imaginary, the ‘shocks’ are subject to a ‘calibration’ as well. The ‘calibration’ of each ‘shock’ requires two arbitrary decisions: on its probability distribution, and on its relevant characteristic (such as e.g. mean or standard deviation). The ‘shock calibration’ thus produces another set of stochastic ‘priors’.

The model specified with the ‘calibrated’ parameters is then ‘bombarded’ with a large number of simulated ‘shocks’ (each conforming to its prior distribution). In effect a large number of artificial – fictional – data is generated. These are then taken seriously and used for the estimation of the posterior values of the characteristics (the mean values, or variances) of the prior distributions for the ‘shocks’ and the ‘stochastically calibrated’ parameters. The model with the ‘point-calibrated’ and ‘stochastically

¹⁸ A model relating yield per acre of corn to various deterministic factors and the *ex ante* unknown random rainfall is stochastic. However, this model can be validated *ex post*, when the rainfall is already subject to measurement.

¹⁹ As counted by Stiglitz (2018, p. 71), the iconic model by Smets and Wouters (2003) introduces a total of ten different ‘shocks’: two affecting supply, three affecting demand, three are cost-push ‘shocks’ and two are monetary policy ‘shocks’. The model by Bielecki, Brzoza-Brzezina and Kolasa (2018) is slightly less sophisticated, counting only nine different ‘shocks’.

re-calibrated' parameters can then be used e.g. for the calculation of moments (averages, cross-correlations) of the implied variables of interest (e.g. inflation, consumption, etc.). Next, these moments can be compared ('matched') with the moments calculated with actual data. A 'match' judged good is to prove the model's adequacy (to Korinek (2017) the practice of 'matching moments' is irrelevant – it 'misses the point'). For the 'stochastically calibrated' parameters the validation boils down to comparing the prior (assumed) parameter distribution with the posterior (simulated) one. It is essential that neither of these distributions can normally be confronted with 'reality'.

The amount of arbitrariness going into the specification of the model is one aspect making the whole exercise problematic. The model's dependence on imaginary unobservable stochastic 'shocks' is another. In the last instance the economic reality, as portrayed by the model, appears to be the product of a series of phantom 'shocks' – unobservable, yet 'calculable'.

That identification, estimation and formal evaluation of DSGE models are fraught with serious problems has been widely acknowledged. These problems have been extensively described by e.g. Tovar (2008, pp. 8–15), Canova (2009), Canova and Sala (2009) (the latter recapitulated by Fagiolo and Roventini 2016, pp. 9–12): "Given the large number of non-linearities, DSGE models are hard to identify. Identification problems lead to biased and fragile estimates of some structural parameters and do not allow to rightly evaluate the significance of the estimated parameters applying standard asymptotic theories". Non-identifiability of the structural parameters must be quite common: "... unfortunately, the structural parameters governing DSGE models are not identified when the driving process behind the model follows an unrestricted VAR ..." (Reicher 2015, p. 412). Then, "DSGE models are very hard to estimate by standard maximum likelihood (ML) methods, because the ML estimator delivers biased and inconsistent results if the system is not a satisfying representation of the data. A strategy commonly employed when the DSGE model is estimated following the limited information approach consists in calibrating the parameters hard to identify and then estimating the others' [...] But this strategy works only if the calibrated parameters are set at their "true" values' [...] Bayesian methods apparently solve the estimation (and identification) problems [...] However, this choice is not harmless: if the likelihood function is flat [...] the shape of the posterior distribution resembles the one of the prior, reducing estimation to a more sophisticated calibration carried out on an interval instead on a point. Unfortunately, the likelihood functions produced by most DSGE models are quite flat. In this case, informal calibration is a more honest and internally consistent strategy..." (Canova 2009 quoted in Fagiolo and Roventini 2016, p. 10).

The final estimation yielding the posterior estimates for the 'stochastically calibrated' (under the Bayesian approach) parameters is in itself likely to be meaningless. It is often the case with the maximum likelihood estimation that the results tend to be very sensitive to the values for 'priors' fed in. A minor change in the magnitude of a specific value attributed to a seemingly unimportant parameter may result in radically different values for essential estimates. This creates certain 'flexibility': a clever model maker may derive any final 'results' he prefers by simply manipulating the priors (as indicated by Romer 2016).

11 Concluding remark

The DSGE models are not only seriously flawed. They are eminently irreparable. Their early versions started with over-simplistic assumptions and produced irrelevant conclusions that had nothing to do

with economic reality. The later benchmark versions inherited the simplistic assumptions on which ad hoc ‘frictions’ were grafted. These versions proved spectacularly useless, especially during and after the Great Recession. The most recent versions promise to make amends by allowing for agent heterogeneity and more attentive treatment of the financial aspects of micro-behaviour. But this promise cannot be squared with the basic ideas underlying the whole approach: general equilibrium and super-rational behaviour (including formation of expectations) attributed to ‘representative individuals’.

The derivation, specification and estimation of computable DSGE models involve a great deal of pure arbitrariness while their identification remains debatable. As such these models do not conform to the usual standards of econometrics, whereas the eventual results derived from DSGE may ‘match the moment but miss the point’.

A science of micro-founded macroeconomics may be impossible. That does not mean that scientific macroeconomics not based on micro-foundations must be impossible too. Isaac Newton’s laws of movements of solid bodies belongs to science without being derived from the models of behaviour of elementary (‘micro’) particles.

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Dynamiczne stochastyczne modele równowagi ogólnej: makroekonomia w ślepych zaułku

Streszczenie

Celem artykułu jest pogłębiona analiza podstawowych założeń teoretycznych i aplikacyjnych modelowania makroekonomicznego odwołującego się do metodologii DSGE (Dynamic Stochastic General Equilibrium). Dla realizacji tego celu badawczego uzasadnione było, po pierwsze, przypomnienie genezy tej metodologii, tj. teorii realnego cyklu koniunkturalnego (*real business cycle*). Po krytycznej ocenie teorii RBC, która oparta jest na arbitralnych założeniach upraszczających (redukujących gospodarkę do jednego „reprezentatywnego podmiotu mikroekonomicznego”), wykluczających najistotniejsze zjawiska ekonomiczne (np. pieniądź, rynek finansowy, efekty polityki fiskalnej, zjawisko bezrobocia), poddano szczegółowej analizie podstawowe składniki późniejszych wcieleń modeli RBC. Modele te są powszechnie określane jako neokeynesowskie (New Keynesian) modele DSGE. Analiza standardowych modeli DSGE dominujących w nauce makroekonomii aż do Wielkiej Recesji prowadzi do wniosku, że są one również oparte na bardzo kruchych podstawach teoretycznych. Ich struktura nie różni się istotnie od struktury uproszczonych modeli RBC. Innowacje sprowadzają się do uzupełnienia podstawowego modelu RBC arbitralnymi założeniami dodatkowymi, dotyczącymi np. struktury produkcji i stanowienia cen. Pogłębiona analiza tych założeń pozwala stwierdzić, że są one z reguły formalnymi „dekoracjami”, niemającymi związku z rzeczywistością gospodarczą (a nawet, że mają one co najwyżej luźny związek z rozwiązaniami tych modeli). Co więcej, analiza kluczowych „zmiennych” modeli DSGE („naturalnej stopy procentowej” oraz „produktu potencjalnego”) ujawnia ich fantomowy, fikcyjny charakter. Są to zmienne nieobserwowalne, ich definicje są co najmniej mętne (jeśli nie wewnątrznie sprzeczne), a ich związek z wielkościami rzeczywistymi co najmniej problematyczny. Nieokreślone (i nieobserwowalne) są również rozliczne „szoki stochastyczne” wprowadzane do modeli na zasadzie uznaniowej, mające jednakowoż współokreślać trajektorie zmiennych modelowanych.

Nie może dziwić fakt, że sztandarowe modele DSGE okazały się całkowicie bezużyteczne dla zrozumienia praktyki gospodarczej po 2008 r. Najnowsza generacja modeli DSGE obiecuje uwzględnienie niektórych zjawisk ignorowanych poprzednio – m.in. tematyki funkcjonowania pieniądza, rynków finansowych, zróżnicowania (heterogeniczności) podmiotów gospodarczych. Niestety, analiza wskazuje, że dotychczasowe próby urealnienia modeli DSGE nie mogą być uznane za udane. W istocie uwzględnienia rzeczywistej (a nie pozorowanej) heterogeniczności podmiotów gospodarczych, pieniądza i rynków finansowych nie da się pogodzić z podstawowymi paradygmatami metodologii DSGE – z założeniami o tym, iż gospodarka zawsze funkcjonuje w warunkach równowagi oraz że rynek da się przedstawić jako efekt funkcjonowania pojedynczego mitycznego podmiotu o ponadludzkich możliwościach prognostycznych i planistycznych.

Osobnym – ale również bardzo istotnym – aspektem modelowania DSGE jest to, że specyfikacja i estymacja modeli DSGE są skażone wielką ilością całkowicie arbitralnych założeń, podczas gdy sama identyfikacja tych modeli jest co najmniej problematyczna.

Ogólny wniosek, do którego dochodzi się w artykule, jest taki, że podejście DSGE nie rokuje nadziei na osiągnięcie wiedzy adekwatnej do rzeczywistości makroekonomicznej i przydatnej dla praktyki polityki makroekonomicznej.

Makroekonomia oparta na podstawach wywodzonych z wyidealizowanej, podręcznikowej mikroekonomii prawdopodobnie nigdy nie osiągnie statusu nauki. Nie oznacza to jednak, że makroekonomia nieoparta na naiwnej mikroekonomii nie może osiągnąć tego statusu. Prawa ruchu obiektów materialnych w skali makro należą do nauki. Ale prawa te nie zostały przecież wyprowadzone (przez Izaaka Newtona) ze spekulacji dotyczących zachowania się cząstek elementarnych.

Słowa kluczowe: realny cykl koniunkturalny (RBC), DSGE, naturalna stopa procentowa