Chapter 21
DSGE Models in Central Banks: Progress and Prospects

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Abstract This chapter traces how dynamic stochastic general equilibrium (DSGE) models became a central tool for quantitative monetary-policy analysis in Central Banks. Their appeal grew out of the shortcomings of large-scale macroeconometric models, the Lucas and Sims critiques, and the gradual shift from real-business-cycle theory to the New Keynesian framework. The chapter reviews the medium-scale DSGE model that became standard in policy institutions, as well as extensions dealing with unemployment, open-economy transmission, financial frictions, and fiscal policy. It also discusses the practical machinery (solution, estimation, forecasting, and counterfactual analysis) through which these models are brought to the data and used in policy work. The final part turns to heterogeneous-agent New Keynesian models (HANK), where incomplete markets and distributional heterogeneity reshape the transmission of monetary and fiscal policy. The central claim is that DSGE models remain valuable less as definitive descriptions of the economy than as a disciplined way to connect theory, data, and policy experiments, while identifying where richer mechanisms are needed.[1]

21.1 Introduction

Dynamic stochastic general equilibrium (DSGE) models entered policy institutions because they promised to combine three elements that had long been difficult to hold together: explicit economic structure, empirical discipline, and a framework

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[1] The views expressed herein are those of the authors and do not necessarily represent those of the Banque de France or the Eurosystem.

for policy experiments. Tovar (2008) emphasizes that, by the late 2000s, Central Banks in both advanced and emerging economies had become increasingly interested in these models for policy analysis and forecasting. Their appeal was not that they replaced judgment or reduced-form evidence, but that they offered a coherent way to organize policy discussions, identify the sources of fluctuations, connect structural features of the economy to observed dynamics, and evaluate counterfactual policy paths. This last role is especially important for systematic policy changes, such as shifts in monetary-policy regimes, where randomized experiments are unavailable and purely historical or reduced-form comparisons leave open which relationships should be treated as policy-invariant (Christiano, Eichenbaum & Trabandt, 2018). Dotsey (2013) makes the same point from the perspective of monetary-policy practice: DSGE models are useful because they place households, firms, fiscal authorities, and Central Banks in a single general-equilibrium environment, where prices, wages, interest rates, and expectations jointly determine the aggregate equilibrium. This makes their forecasts, decompositions, and policy experiments interpretable in terms of economic mechanisms rather than only statistical correlations.

The transparency of DSGE models is part of their value for policy institutions. Christiano et al. (2018) argue that DSGE models are useful precisely because their assumptions, missing forces, and empirical tensions are explicit. That openness makes them easy to criticize, but it also makes criticism productive: model builders can respond by changing frictions, adding mechanisms, or confronting the model with additional microeconomic and institutional evidence. In this view, DSGE models are not mechanical substitutes for judgment; they are data-based laboratories that make policy judgment more disciplined and more accountable.

In that sense, the appeal of the approach is not merely institutional. Galí (2017) argues that, given the nature of macroeconomic fluctuations, it is natural for frontier macroeconomic models to be dynamic, stochastic, and general equilibrium: dynamic because central macroeconomic objects such as interest rates, investment, public debt, and expectations are intrinsically intertemporal; stochastic because observed fluctuations contain an unforecastable component; and general equilibrium because aggregate outcomes reflect the simultaneous interaction of households, firms, financial intermediaries, and policy institutions across several markets. This defense of the DSGE label, however, does not imply a defense of every particular DSGE model. It instead clarifies why criticism is most useful when directed at the specific assumptions, frictions, and empirical implications of individual models.

This institutional success also came with a narrative about progress. Sergi (2017) argues that central-bank presentations of DSGE models often describe them as the outcome of two cumulative forces: a theoretical consensus around microfoundations, rational expectations, and nominal rigidities, and a technical improvement in computation and econometric estimation.[2] That narrative provides a convenient way to organize the discussion, provided it is not read as a simple sequence in which each new class of models supersedes the last. What changed over time was the benchmark for a credible policy model: empirical fit was no longer sufficient without

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[2] See also Avouyi-Dovi, Fève and Matheron (2007) for a similar analysis.

structural interpretation; structural interpretation then had to support internally consistent counterfactuals; and recent work has placed more weight on distributional transmission and policy incidence. This broad reading is close to Galí (2017)'s assessment. The DSGE methodology can cover early real-business-cycle (RBC) models, medium-scale New Keynesian policy models, and newer frameworks with financial frictions, learning, or heterogeneity. At the same time, many applied models still inherit restrictive assumptions, notably the infinitely lived representative household and the stationarity and linearity imposed in standard solution and estimation methods. Those restrictions matter for Central Banks because they limit the analysis of distributional transmission, persistently low natural rates, asset-price bubbles, financial-crisis dynamics, and nonlinear adjustment after large shocks. The chapter therefore reads the DSGE tradition less as a single model class than as a sequence of responses to successive empirical and institutional problems: policy-invariance after the Lucas critique, inflation stabilization after the rational-expectations revolution, financial transmission after the global financial crisis, and distributional transmission in the recent HANK literature.

21.1.1 From Old-Fashioned Econometric Models to Microfounded DSGE Frameworks

This section traces the intellectual path that led from the large macroeconometric systems of the postwar period to the DSGE framework used in modern policy analysis. It first recalls the empirical strengths and theoretical weaknesses of large-scale Keynesian models, then reviews the Sims and Lucas critiques that exposed their identification and policy evaluation problems. It then turns to RBC models as the first operational microfounded benchmark, before explaining how New Keynesian DSGE models combined that discipline with nominal rigidities and a renewed role for stabilization policy.

21.1.1.1 The Era of Large-Scale Macroeconometric Models

Before the rational expectations revolution, macroeconomic policy analysis was dominated by large-scale macroeconometric models developed during the postwar period. These models, typified by the Federal Reserve Board-Massachusetts Institute of Technology-University of Pennsylvania (FRB-MIT-Penn, or FMP) model in the United States (Fair, 1984) and similar collections of equations in Europe, sought to capture the aggregate relationships among consumption, investment, output, and prices through empirically estimated behavioral equations. Their structure combined Keynesian demand management principles with statistical estimation techniques. Policymakers used them to simulate counterfactual scenarios and assess the effects of fiscal and monetary interventions under different assumptions.

The strength of these models lay in their empirical orientation and their capacity to fit observed data. However, their theoretical foundations were weak: they typically lacked explicit optimization behavior, consistent expectations, or general equilibrium discipline. Moreover, behavioral equations were estimated under the assumption that structural parameters were policy-invariant, an assumption later shown to be untenable. Despite these shortcomings, such models guided policy decisions throughout the 1960s and 1970s and formed the backbone of forecasting exercises in many Central Banks (see Fair, 1984).

In retrospect, what aged well was the ambition to build policy models that could be used routinely for forecasting, scenario analysis, and institutional communication. What aged less well was the reliance on reduced-form behavioral equations whose coefficients could not easily be interpreted as stable objects under changes in policy regimes.

21.1.1.2 The Sims Critique: Identification and Dynamic Specification

A first wave of criticism emerged from Sims (1980), who argued that traditional macroeconometric models suffered from ad hoc identification restrictions and failed to respect the statistical properties of dynamic systems. Sims proposed the use of Vector Autoregressions (VARs)[3] as an alternative, atheoretical framework for capturing dynamic correlations among macroeconomic variables. VARs treated all variables as endogenous and allowed data, rather than prior structural assumptions, to determine the dynamic relationships. For Central Banks, the VAR approach provided a transparent empirical benchmark for impulse response analysis and forecast evaluation. However, it lacked the structural interpretation necessary for policy design. As Sims (1982) later emphasized, VARs could describe but not explain macroeconomic fluctuations. This limitation became more evident once the Lucas critique highlighted the conceptual fragility of policy simulations based on reduced-form relationships.

21.1.1.3 The Lucas Critique and the Microfoundations Revolution

In his seminal paper, Lucas (1976) argued that the parameters of 1970's macroeconometric models were not structural but instead functions of the policy regime. When policymakers changed their behavior, agents' expectations would adjust, rendering previous empirical relationships invalid. Lucas formalized this argument in a simple expectations-augmented Phillips Curve framework, showing that policy evaluation based on historical regressions could lead to systematically misleading conclusions. The implication was radical: to evaluate policy systematically, economists needed models built on microeconomic foundations (i.e., models where behavior derived from the optimization of rational agents subject to constraints), and where expectations were consistent with the model's structure (rational expectations). This critique

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[3] For comprehensive details on business-cycle models, including VAR models, see (Rojas Bernal & Markevych, 2026); for broader background on time-series methods, see (Fuleky, 2026).

fundamentally reshaped macroeconomics (Lucas & Sargent, 1979), giving rise to the microfoundations revolution that culminated in the DSGE paradigm.

21.1.1.4 Real Business Cycle (RBC) Models: A Benchmark of the New Paradigm

The first operational realization of the new paradigm was the Real Business Cycle (RBC) model developed by Kydland and Prescott (1982) and Long and Plosser (1983). Building on Lucas and Rapping (1969), the RBC methodology posited that economic fluctuations could be explained by real shocks (especially technology shocks) propagated through intertemporal substitution in consumption and labor. Agents were rational, markets cleared continuously, and prices were fully flexible.

A simplified RBC setup can be summarized as follows. A representative household chooses consumption, labor, and next period's capital (savings) so as to maximize expected, discounted utility over time, balancing both the intratemporal arbitrage between consumption and leisure and the intertemporal arbitrage between consumption and saving. Output is produced by combining capital and labor through a neoclassical production function hit by a stochastic productivity shock. In this environment, the discount factor governs intertemporal trade-offs, labor-supply curvature pins down the Frisch elasticity, and the production technology determines capital's income share. Under perfect competition, wages and rental rates equal marginal products, and aggregate fluctuations emerge from the economy's optimal response to productivity shocks.

In contrast to previous models, RBC frameworks are internally consistent and forward-looking. One may argue that they are in essence more immune to the Lucas critique. Moreover, they offer an elegant narrative: fluctuations arise as optimal responses to real shocks under rational expectations. However, they fail to explain persistent deviations of output and employment from potential, nor (obviously) the observed sluggish dynamics of inflation and output. The empirical shortcomings of RBC models (highlighted by Cogley & Nason, 1995) motivated the incorporation of real frictions and nominal rigidities that would restore a role for stabilization policy.

Historically, RBC models were less the final destination than the proof of concept for a new modelling discipline: fully specified intertemporal equilibrium models could be computed, calibrated, and taken to data. Their flexible-price view of business cycles has aged less well for policy analysis, but their discipline on expectations, technology, and intertemporal choices became part of the DSGE toolkit.

21.1.1.5 From Real to New Keynesian DSGE Models

The transition from RBC to *New Keynesian* models represented a reconciliation between microfoundations and Keynesian stabilization policy. While retaining the optimizing behavior and general equilibrium consistency of RBC models, *New*

Keynesian frameworks introduced nominal rigidities— sticky prices and/or wages that generated short-run non-neutralities of monetary policy.

The Rotemberg and Woodford (1997) model provided the canonical *New Keynesian* setup with monopolistic competition and Calvo-style price rigidity.[4] The representative firm faces a downward-sloping demand curve, sets prices subject either to adjustment costs or to staggered repricing opportunities, and produces output with a technology in which labor is the only input, subject to exogenous productivity shocks.[5]

A first-order approximation around the steady state delivers two core behavioral blocks. On the pricing side, current inflation depends on expected future inflation, on real marginal-cost pressure captured by the output gap, and on exogenous cost-push disturbances. On the demand side, the output gap is forward-looking and decreases when the ex ante real policy rate rises relative to the natural real rate. In this representation, the key objects are the output gap, the nominal policy rate, the natural real interest rate, and markup or cost-push shocks. Together with a monetary-policy rule, typically of Taylor type, these relationships form the standard three-equation New Keynesian core used in modern monetary policy analysis.

The integration of DSGE modeling into central-bank practice occurred through the work of Smets and Wouters (2003, 2007). Building on Christiano, Eichenbaum and Evans (2005), their medium-scale DSGE model combined the theoretical structure of *New Keynesian* models with a rich set of frictions. Using Bayesian estimation techniques, they demonstrated that the model could fit postwar U.S. data as well as unrestricted VARs while preserving structural interpretability. The Smets-Wouters (SW) model's empirical success marked a turning point. It bridged the gap between theoretical rigor and empirical relevance, showing that DSGE models could serve both as structural laboratories for policy analysis and as quantitative tools for forecasting and scenario simulation. Central Banks rapidly adopted variants of this framework, including the New Area-Wide Model (NAWM) at the European Central Bank (ECB) (Christoffel, Coenen & Warne, 2008), the SIGMA model at the Federal Reserve (Erceg, Guerrieri & Gust, 2006), and the Terms-of-Trade Economic Model (ToTEM) at the Bank of Canada (Murchison & Rennison, 2006), among others.

By the mid-2000s, a broad consensus emerged around the *New Keynesian* DSGE framework as the 'core model' of modern macroeconomics and monetary policy (see Woodford, 2003; Galí, 2008). The resulting 'New Neoclassical Synthesis' unified the microfoundations of RBC models with the nominal and real rigidities of Keynesian analysis. Central Banks employed these models to study the transmission of monetary shocks, to estimate potential output, and to evaluate alternative policy rules. This was the moment at which DSGE models became operational central-bank tools rather than mainly academic laboratories. The features that aged well were the combination of nominal rigidities, policy rules, Bayesian estimation, and shock decomposition;

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[4] Price rigidities can also be modeled through quadratic price-adjustment costs in the spirit of Rotemberg (1982), or through nominal contracts as in Fisher (1977) and Taylor (1980).

[5] Important precursors include Hairault and Portier (1993), Yun (1996), and Kim (2000), which already embed nominal rigidities in dynamic general-equilibrium environments with capital accumulation, but do not yet model monetary policy through the now-standard explicit Taylor-type interest-rate rule.

the features that aged less well were the representative household, the limited role of financial balance sheets, and the near-exclusive focus on small fluctuations around a stable steady state.

Yet this consensus was soon challenged by new developments, calling for an improved model design. In particular, the global financial crisis of 2008 revealed the inadequacy of models with frictionless financial markets to capture financial instability and the widening of interest rate spreads. These shortcomings motivated extensions incorporating financial frictions (e.g., Carlstrom & Fuerst, 1997; Bernanke, Gertler & Gilchrist, 1999; Christiano, Motto & Rostagno, 2014) and the rise of Heterogeneous-Agent New Keynesian (HANK) models, which reintroduced distributional mechanisms into the DSGE framework.

21.1.1.6 Chapter Scope and Organization

This chapter studies how DSGE models became a central framework for economic policy analysis in Central Banks and other institutions, and how their role has changed as the field moved from representative-agent New Keynesian models to heterogeneous-agent environments. The focus is deliberately practical: the chapter emphasizes the mechanisms, empirical implementation, and policy exercises that make DSGE models useful for organizing data, interpreting shocks, and evaluating counterfactual policy paths.

The chapter is organized as follows. Section 21.2 presents the canonical medium-scale New Keynesian DSGE framework used in Central Banks, together with selected extensions, particularly relevant for Central Banks, that add unemployment, open-economy, financial frictions, and fiscal policy to the core framework. It also reviews the solution and estimation methods that turn these models into quantitative tools. Section 21.3 explains how estimated DSGE models are used for dynamic analysis, forecasting, counterfactual experiments, and policy applications such as disinflation, unconventional monetary policy, and natural-rate measurement. Section 21.4 turns to HANK models, showing how incomplete markets and household heterogeneity modify transmission mechanisms, revive the Keynesian-cross logic in a structural setting, and broaden the set of policy questions that DSGE models can address. Section 21.5 concludes.

21.2 The Canonical New Keynesian DSGE Model for Central Banks

This section provides the technical backbone used in the remainder of the chapter. It first presents the medium-scale New Keynesian benchmark in the Smets-Wouters tradition, then reviews extensions that became central for policy institutions (labor-market slack, open-economy transmission, financial frictions, and fiscal interactions). It then turns to the operational implementation of these models: solution methods, from log-linear to nonlinear approaches, and estimation strategies, from limited-information methods to likelihood-based Bayesian procedures.

21.2.1 Medium-Scale DSGE Models

While the canonical three-equation model is analytically tractable, it abstracts from many empirically relevant frictions. Building on Christiano et al. (2005), Smets and Wouters (2003, 2007) introduce a richer environment designed to reconcile structural discipline with the persistence and comovement observed in postwar macro data. This medium-scale agenda was further developed by Justiniano, Primiceri and Tambalotti (2010, 2013), which provide complementary quantitative evidence on shock transmission and policy trade-offs in estimated New Keynesian frameworks.

Households

On the demand side, *habit persistence* in consumption increases the intertemporal complementarity in consumption decisions, thus imparting extra persistence, which helps generate hump-shaped responses of spending to monetary and demand shocks. Investment is governed by *dynamic adjustment costs*, so households optimally smooth investment over time because changing the growth rate of investment is costly; this friction reproduces the gradual response of investment seen in the data. The model also allows *variable capital utilization*, which gives agents an intensive margin of capital services in the short run and improves the joint fit of output, labor, and inflation dynamics by dampening the response of real marginal costs to macroeconomic shocks.

Firms and Labor Market

As in the canonical New Keynesian model, production is undertaken by monopolistic firms. They combine capital and labor through a neoclassical production function and possibly face fixed production costs. Price setting is subject to nominal rigidity. A key medium-scale contribution is the introduction of *sticky wages*. Nominal wage rigidities play a crucial role in improving the model's empirical fit. In addition, both price and wage rigidities are combined with *partial indexation* to past inflation. Relative to a purely forward-looking *New Keynesian* block, this delivers more realistic inertia in price and wage inflation and helps match the delayed, persistent pass-through of shocks. Wage stickiness is especially important for labor-market dynamics: it slows real wage adjustment and improves the empirical behavior of hours worked and marginal costs.

Monetary Policy

The Central Bank follows an interest-rate rule with *interest-rate smoothing*, reacting to inflation and real activity. Smoothing is not merely a statistical add-on: it captures observed policy gradualism and is crucial for matching the persistence of short rates and the transmission of policy shocks.

Shock Structure and Empirical Role

Smets-Wouters combines standard four real shocks (technology, risk-premium, investment-specific, government spending) with three nominal disturbances (price-markup, wage-markup, and monetary policy shocks). This richer shock structure is essential for historical decompositions and policy counterfactuals in Central Banks, because it separates demand, supply, and cost-push sources of fluctuations within a single coherent model.

In practice, the model is estimated in a Bayesian state-space framework, as we detail below. Its success comes from this combination: enough frictions to fit the data, but still sufficiently structured to support welfare analysis, forecasting, and policy simulation. As such, this class of DSGE models imposes economic structure on the data and helps clarify the transmission mechanisms through which policy affects output, inflation, and other macroeconomic aggregates.

21.2.2 Extensions Relevant for Central Banks

The Smets-Wouters framework gave Central Banks a workable core model for monetary-policy analysis, but its benchmark version was too narrow for many of the questions that later became central. It had no explicit unemployment rate, treated the economy largely as closed, left financial intermediation in the background, and gave fiscal policy only a limited role. Much of the subsequent DSGE literature can be read as an attempt to keep the discipline of the medium-scale model while opening it to these margins: labor-market slack, external transmission, financial frictions, and fiscal-monetary interactions.

21.2.2.1 Unemployment

Galí, Smets and Wouters (2012) start from a simple gap in standard New Keynesian DSGE models, including Smets and Wouters (2007): the models track the output gap and total hours, but they do not distinguish employment from hours per worker and therefore have no unemployment rate. After the 2008 financial crisis, that omission became hard to ignore. Central Banks needed an estimated model in which unemployment could move together with output, inflation, wages, and policy rates.

The extension also speaks directly to Chari, Kehoe and McGrattan (2009), who argued that estimated *New Keynesian* models were still weak policy tools, notably because their shock structure did not cleanly distinguish wage cost-push (wage-markup) disturbances from labor-supply shocks.

Their model enriches the Smets-Wouters framework by introducing, along the lines of Galí (2011), a heterogeneous labor supply with an endogenous participation rate, so that unemployment arises as the gap between the labor supply desired at the prevailing wage and actual employment. This formulation preserves the log-linear tractability of the model and allows Bayesian estimation on U.S. data, while adding observed unemployment to the vector of variables used to identify the structural shocks. The model can thus decompose unemployment fluctuations into contributions from demand, technology, monetary-policy and, above all, labor-supply (or *wage-markup*) shocks.

Two results emerge. First, adding unemployment as an observable sharpens the identification of *wage-markup* shocks, reducing their estimated volatility and clarifying their role in wage and price inflation. Second, labor-supply and demand shocks account for most medium-run unemployment fluctuations, whereas monetary-policy and technology shocks play only a minor role; in particular, the sharp rise in unemployment during the Great Recession is attributed primarily to demand shocks.

21.2.2.2 Open-Economy *New Keynesian* DSGE Models

Modern Central Banks operate in open economies, where exchange rates and external shocks matter. Open-economy *New Keynesian* models accordingly augment the canonical closed-economy block with foreign demand, trade linkages, and exchange-rate pass-through. A typical open-economy Phillips curve states that domestic inflation depends on expected future inflation, domestic slack, imported inflation, and a cost-push shock, with the imported-inflation term scaled by the degree of exchange-rate pass-through to import prices. Extensions of the Smets-Wouters framework have followed three broad routes, depending on the Central Bank's institutional setting.

A first strand treats the domestic economy as a small open economy taking world prices and interest rates as given. Building on Galí and Monacelli (2005), Adolfson, Laséen, Lindé and Villani (2007) estimate an SW-style model with incomplete exchange-rate pass-through for Sweden-the backbone of the Riksbank's RAMSES model-while Lubik and Schorfheide (2007) use a similar setup to ask whether Central Banks in small open economies respond to exchange-rate movements beyond their indirect effect on inflation and activity.

A second strand abandons the small-open-economy approximation in favor of two-country structures in which both blocks are fully specified and linked through trade and financial flows: Rabanal and Tuesta (2010), for instance, estimate such a model on euro area and U.S. data to account jointly for the real exchange rate and the international business cycle.

A third strand, of particular relevance for the Eurosystem, considers monetary unions in which member countries share a common currency and policy rate but differ in their cyclical positions. For example, the Euro Area and Global Economy (EAGLE) model of Gomes, Jacquinot and Pisani (2012) was developed within the Eurosystem to analyze macroeconomic interdependence across euro-area countries and the rest of the world under a single monetary policy. Similarly, the International Monetary Fund (IMF) developed the Global Integrated Monetary and Fiscal Model (Kumhof, Laxton, Muir & Mursula, 2010), a multi-region DSGE designed for the joint analysis of monetary and fiscal policy and cross-border spillovers.

21.2.2.3 Financial Frictions

In the baseline New Keynesian DSGE, financial markets are frictionless: firms borrow at the risk-free rate, and balance sheets play no allocative role. This assumption is convenient but counterfactual, as it rules out any transmission channel through credit spreads, leverage or intermediary net worth, and thus leaves the model silent on the episodes in which these variables are most informative. Introducing financial frictions restores a role for the financial sector in shock propagation and complicates the implementation of monetary policy by giving the Central Bank a second set of margins (spreads, leverage, risk premia) to monitor alongside inflation and the output gap.

The seminal contributions are Carlstrom and Fuerst (1997) and Bernanke et al. (1999). Both embed a costly-state-verification problem à la Townsend into an otherwise standard business-cycle model: entrepreneurs finance capital purchases with a mix of internal net worth and external debt, and the cost of external finance rises with leverage. The resulting *financial accelerator* amplifies and propagates shocks, because a fall in asset prices erodes net worth, raises the external-finance premium, and further depresses investment. For monetary policy, this mechanism implies that interest-rate changes transmit not only through the intertemporal consumption margin, but also through balance sheets and credit spreads, so that identical policy rates can have very different effects depending on the state of borrower net worth.

Gertler and Kiyotaki (2010) and Gertler and Karadi (2011) shift the friction from non-financial borrowers to financial intermediaries themselves. Banks face a moral-hazard constraint that ties their lending capacity to their own net worth, so that shocks to bank equity-not just to firm collateral-disrupt credit supply. This reformulation proved central to interpreting the 2007-2009 crisis: the collapse was not driven by a standard productivity or monetary shock, but by an impairment of intermediary balance sheets that widened spreads, tightened credit, and contracted activity even as policy rates were cut to zero. It also provides a natural laboratory for unconventional policies: once private intermediation is constrained, central-bank asset purchases and direct credit provision substitute for impaired intermediaries and relax the constraint, which rationalizes large-scale asset purchases and, more tentatively, the analysis of unconventional instruments more broadly.

21.2.2.4 Fiscal Policy

Fiscal policy enters *New Keynesian* DSGE models through the aggregate resource constraint, which states that output is allocated to private consumption, private investment, and government consumption, and through a government budget identity linking debt, taxes, and spending.

The financial crisis put fiscal policy on the forefront (e.g., American Recovery and Reinvestment Act in the US, Sarkozy's stimulus package in France).[6] Cogan, Cwik, Taylor and Wieland (2010) use the Smets-Wouters model to evaluate the 2009 U.S. stimulus and find government-spending multipliers well below unity-an order of magnitude smaller than the 'old Keynesian' numbers that informed the debate at the time. The mechanism is the standard *New Keynesian* one: forward-looking households anticipate future taxes and higher real rates, crowding out private consumption and investment. The exercise also exposes a more structural limitation: Smets-Wouters was estimated with only a residual treatment of the government sector (no distortionary taxes, no debt feedback, and a nearly unit-root spending process) so that the model is silent on precisely the transmission channels (anticipations of future taxes, debt dynamics, regime shifts) that drive fiscal multipliers, and its quantitative answers on stimulus are fragile for that reason.

Three subsequent contributions take this critique seriously. First, Leeper, Traum and Walker (2017) develop a medium-scale DSGE model with a fully specified fiscal block (distortionary labor, capital and consumption taxes, transfers, and a debt-stabilizing rule) and show that the reported dispersion of multiplier estimates collapses once one controls for the fiscal-monetary interactions, the financing assumption and the inclusion of non-Ricardian households.

Second, the influence of monetary policy on fiscal policy is particularly prominent at the zero lower bound. As shown by Christiano, Eichenbaum and Rebelo (2011), when the policy rate is stuck at zero, a positive government-spending shock no longer triggers an offsetting rise in the real interest rate, so that multipliers become substantially larger than in normal times-a result that reconciles the small *New Keynesian* multipliers of Cogan et al. (2010) with the much larger numbers invoked to justify stimulus during the 2008-2009 episode.

Third, Fève, Matheron and Sahuc (2013) make a complementary, more technical point: estimated government-spending multipliers obtained from DSGEs are biased when the econometrician treats the exogenous spending process as a first-order autoregressive (AR(1)) process while it is in fact anticipated (fiscal foresight) or responds systematically to debt. Ignoring these features delivers multipliers that are artificially low and unstable across samples.

Overall, once taxes are distortionary rather than lump-sum, they modify households' and firms' optimality conditions-intertemporal consumption, labor supply and investment margins-as in Leeper, Plante and Traum (2010), so that the fiscal instruments used to finance spending shape the propagation of fiscal shocks themselves.

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[6] See Coenen et al. (2012).

This literature uses estimated DSGE models to quantify fiscal multipliers and the interaction of tax and spending rules with the monetary regime.

21.2.3 Solving DSGE Models: Linear and Nonlinear Methods

DSGE models, whether canonical or medium-scale, involve dynamic stochastic systems derived from households' and firms' first-order conditions, together with feasibility constraints and market-clearing requirements. In general, these systems do not have an analytical solution, due to their nonlinearity, forward-looking structure, and size. Consequently, approximate solution methods are employed to obtain the equilibrium dynamics necessary for quantitative analysis.

21.2.3.1 Log-Linearization

Following Blanchard and Kahn (1980), the standard workhorse method in the DSGE literature is log-linearization around a deterministic steady state. The approach was pioneered for the stochastic growth model by King, Plosser and Rebelo (1988), who showed that the full equilibrium dynamics of a neoclassical business-cycle model could be characterized by a small linear system in percentage deviations from the balanced growth path, lending itself to transparent analytical and numerical manipulation (see Campbell, 1994). Practical recipes such as Uhlig (1999), Sims (2002), and Klein (2000) turned log-linearization into the routine first step of virtually every applied DSGE exercise, from textbook *New Keynesian* models to the medium-scale systems estimated at Central Banks.

Concretely, each endogenous state variable is rewritten as a deviation from its steady-state level, typically in log-deviation form, which at first order is equivalent to a percentage gap relative to steady state. This change of variables converts the original nonlinear equilibrium conditions into a linear expectational system in which current states, expected future states, and exogenous shocks are linked by coefficient matrices evaluated at the deterministic steady state. In that representation, the state vector collects the model's endogenous variables and the shock vector collects the exogenous disturbances. Because this is a first-order approximation, it is accurate for small fluctuations around steady state and is especially convenient for computing impulse response functions.

21.2.3.2 Higher-Order and Nonlinear Solutions

Log-linearization is convenient but certainty-equivalent: it preserves first-order dynamics and therefore misses any effect of risk on decisions and can become grossly inaccurate when shocks push the economy far from its deterministic steady state. A parallel literature, synthesized early on in Judd (1998), has developed higher-order and global solution methods to address these limitations.

Within this literature two families dominate. *Perturbation methods* extend the Taylor expansion beyond the first order. Early higher-order perturbation algorithms were developed by Collard and Juillard (2001b, 2001a), who showed that a second- or third-order Taylor expansion of the policy function around the deterministic steady state could be implemented systematically in forward-looking models and assessed its accuracy on asset-pricing applications. Schmitt-Grohé and Uribe (2004) then popularized a compact matrix formulation of the second-order perturbation, which preserves the tractability of log-linearization while restoring the risk-adjustment terms (precautionary savings, risk premia) that are absent under certainty equivalence, and opened the way to third-order methods routinely used to study stochastic volatility and rare-disaster dynamics (Fernández-Villaverde, Guerrón-Quintana & Rubio-Ramírez, 2015). *Projection methods* instead approximate the policy functions directly on a grid of state variables, via Chebyshev polynomials, splines or finite elements; they preserve full nonlinearity and handle occasionally binding constraints, at a much higher computational cost. Aruoba, Fernández-Villaverde and Rubio-Ramírez (2006) provide a systematic comparison of the two families and show that perturbation is usually sufficient for smooth medium-scale DSGEs, while projection becomes indispensable when nonlinearities are economically first-order. These methods are computationally more intensive but increasingly feasible with advances in numerical algorithms and computing power (Judd, 1998). A complementary branch, the parameterized expectations approach, replaces the unknown conditional expectations by flexible parametric functions fitted on simulated data (Den Haan & Marcet, 1990; Marcet & Lorenzoni, 1999).

21.2.4 Estimation Techniques

Once specified, DSGE models can be estimated to match observed macroeconomic data. Various estimation techniques are used in practice.

21.2.4.1 Generalized Method of Moments (GMM)

Introduced by Hansen (1982), GMM estimates the structural parameter vector by exploiting model-implied orthogonality conditions (typically Euler equations, first-order conditions, or other equilibrium restrictions).[7] In practice, one chooses parameters so that the empirical counterparts of those conditions are as close to zero as possible, using a quadratic criterion that weights each sample moment according to a positive-definite weighting matrix. Asymptotic efficiency is attained when that weighting matrix converges to the inverse of the long-run covariance matrix of

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[7] See Mátyás (1999) for a comprehensive treatment of GMM estimation.

the moments (Hansen & Singleton, 1982; Hansen, 1982). Two-step, iterated, and continuously updated variants (Hansen, Heaton & Yaron, 1996) are common, and finite-sample improvements have been extensively documented (Newey & West, 1987; Stock, Wright & Yogo, 2002).

In the early DSGE and RBC literature, GMM (and its limited-information cousins) was the workhorse for estimating preference and technology parameters from Euler equations (Hansen & Singleton, 1982; Christiano & Eichenbaum, 1992; Burnside, Eichenbaum & Rebelo, 1993; Fève & Langot, 1994), because it requires neither a full likelihood nor a complete solution of the model. Its use has waned in modern medium- and large-scale *New Keynesian* DSGE estimation, largely supplanted by Bayesian likelihood methods, due to weak-identification problems (Stock et al., 2002), sensitivity to the choice of instruments and weighting matrix, and the difficulty of imposing all cross-equation restrictions of a fully specified general-equilibrium model. It nonetheless remains a useful benchmark and a natural tool for single-equation estimation, as in the influential GMM estimates of forward-looking Taylor rules and New Keynesian Phillips curves (Clarida, Galí & Gertler, 2000; Galí & Gertler, 1999).

A closely related extension of GMM is *Minimum Distance Estimation* (MDE), often called impulse-response matching when the targets are dynamic responses to identified shocks. Rather than matching unconditional moments, parameters are chosen to minimize a weighted distance between empirical targets (typically impulse responses estimated from a structural vector autoregression, or SVAR) and the corresponding model-implied objects. As in GMM, estimation is based on a quadratic loss in the gap between data moments and model moments, with the weighting matrix governing efficiency and robustness trade-offs. This approach was popularized by Rotemberg and Woodford (1997) and Christiano et al. (2005) to discipline medium-scale New Keynesian models against monetary-policy shock responses, and is a natural bridge between SVAR-based identification and structural estimation (Hall, Inoue, Nason & Rossi, 2012). Like GMM it is robust to misspecification of features outside the targeted moments, but inherits sensitivity to the choice of weighting matrix and to weak-identification problems (Canova & Sala, 2009).

21.2.4.2 Maximum Likelihood and Bayesian Estimation

Likelihood-based methods exploit the fact that linearized DSGE models with Gaussian shocks yield a state-space representation, allowing for exact evaluation of the likelihood through the Kalman filter. Pioneering full-information maximum-likelihood (ML) estimations of an equilibrium business-cycle model are due to Christiano (1988) and Altuğ (1989). Closely related contributions include the ML estimation of stochastic growth models by McGrattan (1994) and Leeper and Sims (1994), and the maximum-likelihood study of nominal rigidities and monetary shocks by Kim (2000) and Ireland (2004). These early efforts also exposed the well-known pathologies of frequentist DSGE estimation (flat or multimodal likelihoods, parameters drifting to the boundary, and stochastic singularity when the number of shocks is smaller than the number of observables).

Bayesian techniques address many of these difficulties by combining the state-space likelihood with prior distributions on structural parameters through Bayes' rule: posterior beliefs are proportional to the product of the likelihood and the prior. Posterior simulation typically relies on Random-Walk Metropolis-Hastings or, more recently, Sequential Monte Carlo (E. Herbst & Schorfheide, 2014). The Bayesian DSGE program was launched by DeJong, Ingram and Whiteman (2000) and Schorfheide (2000), extended to medium-scale New Keynesian models by Smets and Wouters (2003, 2007), and is surveyed in Fernández-Villaverde (2010) and the canonical handbook treatment of An and Schorfheide (2007); see also E. P. Herbst and Schorfheide (2015) for a textbook synthesis. Bayesian methods now dominate empirical DSGE work because they discipline weak likelihoods through priors, accommodate large parameter spaces, deliver coherent probabilistic statements about shocks and policy counterfactuals, and integrate naturally with model comparison via marginal likelihoods.

21.2.4.3 Simulation-Based Methods

When the model lacks a closed-form likelihood (because the solution is nonlinear, the state space is high-dimensional, or some shocks are non-Gaussian) estimation often relies on simulation. The general principle is to replace intractable population objects (moments, likelihoods, score functions) by Monte Carlo averages computed from artificial data simulated at candidate parameter values (Gouriéroux & Monfort, 1996; Duffie & Singleton, 1993).

The earliest such strategy is the *Simulated Method of Moments* (SMM), introduced by McFadden (1989) and Pakes and Pollard (1989) and brought to time-series macroeconomics by Lee and Ingram (1991): the parameter vector is chosen so that a vector of empirical moments is matched, in a quadratic norm, by its simulated counterpart averaged over many artificial paths, with an efficiency loss that shrinks as the number of simulations increases. SMM remains the workhorse for complicated equilibrium models, notably heterogeneous-agent models, where the cross-sectional distribution makes likelihood evaluation prohibitive (Kaplan, Moll & Violante, 2018; Auclert, 2019).

A generalization is *indirect inference*, developed by Gouriéroux, Monfort and Renault (1993) and Smith (1993): the parameters of a tractable auxiliary model (typically a VAR or a reduced-form regression) are estimated on real and on simulated data, and structural parameters are chosen to minimize the distance between the two pseudo-true binding-function estimates. The approach is especially attractive when the auxiliary model summarizes salient dynamic features the structural model is required to reproduce. (See Gouriéroux et al., 1993, Smith, 1993, and Gallant & Tauchen, 1996 for theoretical expositions, and Dupaigne, Fève & Matheron, 2007 for a quantitative illustration in a DSGE setting).

For nonlinear, non-Gaussian state-space DSGE models, the likelihood itself can be approximated by sequential Monte Carlo (the particle filter) and embedded in a Bayesian Markov chain Monte Carlo (MCMC) sampler (Fernández-Villaverde &

Rubio-Ramírez, 2007; Andrieu, Doucet & Holenstein, 2010). This pseudo-marginal approach has opened the door to estimation of models with stochastic volatility, Epstein-Zin preferences, and occasionally binding constraints (Fernández-Villaverde & Guerrón-Quintana, 2021).

21.3 Quantitative Experiments in DSGE Models

This section moves from model construction to actual model use. It describes how Central Banks turn estimated DSGE structures into quantitative policy evidence: tracing shock transmission, decomposing historical fluctuations, building forecasts and scenarios, and evaluating policy counterfactuals under alternative objectives and constraints.

21.3.1 Dynamic Analyses

Canonical and medium-scale *New Keynesian* DSGE models provide a unified laboratory for Central Banks: once log-linearized and cast in state-space form, they deliver a coherent mapping from structural shocks to observed macroeconomic outcomes, and from policy rules to counterfactual paths. This makes DSGEs useful not only for interpretation (*which shocks drive fluctuations?*) but also for decision support (*which policy response stabilizes inflation and activity at lowest welfare cost?*).

This section is organized as follows. We first study dynamic propagation through impulse responses and forecast-error variance decomposition, turn to historical decomposition, then to model-based forecasting, and finally to policy simulations under alternative objectives and institutional mandates.[8]

21.3.1.1 Impulse Response Functions (IRFs) and Shock Decomposition

After log-linearization and solution of the rational-expectations system, the DSGE model can be written as a linear state-space system in which latent states evolve from their own lags and current structural shocks, while observables are linear combinations of those states around their steady-state levels. In this representation, one block of matrices governs state transition, one maps shocks into states, and one maps states into observables such as output growth, inflation, and policy rates, among many others.

For a one-standard-deviation innovation in a given structural shock, the horizon-specific impulse response of any observable is obtained by propagating that shock

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[8] For broader background on time-series methods, see (Fuleky, 2026); for a complementary discussion of business-cycle models, see (Rojas Bernal & Markevych, 2026).

through the transition and measurement mappings of the state-space system. IRFs summarize transmission channels over time (impact, peak, persistence, and overshooting), which is central to policy discussions in Central Banks. For example, consider an energy-price cost-push shock and take consumer price index (CPI) inflation as the target variable. The IRF profile indicates whether inflation reacts sharply on impact, when the maximum effect is reached, and how quickly it decays. These moments are directly relevant for policy calibration: a short-lived spike may call for partial accommodation, while a persistent response typically requires a stronger and more sustained monetary tightening to re-anchor inflation expectations.

The same state-space objects deliver forecast-error variance decompositions (FEVD): at any horizon, the contribution of each shock is the variance share obtained by comparing the cumulative forecast-error variance generated by that shock with the cumulative variance generated by all shocks jointly. Hence, IRFs describe *how* a given shock propagates, while FEVD quantifies *how much* each shock contributes to fluctuations.

21.3.1.2 Historical Shock Decomposition

Historical decomposition allocates realized fluctuations to sequences of identified structural shocks. Using smoothed shocks from the Kalman filter/smoother, one computes shock-specific latent state trajectories and their associated contributions to observables, then adds those contributions across shocks to recover total deviations from steady state. This decomposition is routinely used to distinguish, for each episode, the roles of demand, supply, monetary, fiscal, and financial shocks, and to connect model-based narratives to policy decisions.

21.3.1.3 Forecasting

In central-bank practice, forecasting with DSGE models starts from the estimated posterior distribution of parameters and latent states. Given the state-space law of motion, one projects latent states forward horizon by horizon and maps them into observables to obtain model-consistent projections for output, inflation, and policy rates at multiple horizons. Because parameters are uncertain, forecasting is typically conducted in density form: predictive distributions integrate forecast paths implied by each parameter draw over the posterior distribution of parameters, conditional on the information available at the forecast date.

Del Negro and Schorfheide (2004) show that forecast performance can be improved by embedding DSGE restrictions into a VAR prior (the DSGE-VAR), which allows controlled misspecification while preserving structural discipline. This approach is particularly useful when pure DSGE restrictions are too tight for short-run forecasting but a fully unrestricted VAR sacrifices policy interpretability.

Del Negro and Schorfheide (2013) provide a comprehensive assessment of DSGE-based forecasting in real time. Medium-scale DSGEs can deliver forecast accuracy comparable to benchmark time-series models for key macro variables, but their forecasting performance improves when the measurement system is fed with information that sits outside the core model, such as survey nowcasts, expected policy-rate paths, and long-run inflation expectations. This is also how they are usually used inside Central Banks. They rarely replace the rest of the forecasting apparatus; rather, they discipline part of it by forcing projections, economic narratives, and policy counterfactuals to be mutually consistent.

21.3.1.4 Policy Simulations

DSGE policy simulations are typically organized as a constrained optimal control problem in which the Central Bank minimizes a welfare-based loss subject to the model's equilibrium conditions. A standard approximation is an intertemporal quadratic loss that penalizes inflation fluctuations, activity-gap fluctuations, and, when desired, excessive changes in the policy rate to capture implementation frictions and gradualism. The linear-quadratic approach of Benigno and Woodford (2004) and the welfare foundations in Benigno and Woodford (2005) provide the analytical link between micro-founded utility and tractable policy objectives used in central-bank applications.

This framework naturally distinguishes *commitment* (Ramsey policy) from *discretion* (re-optimization each period). Under commitment, history dependence improves stabilization by shaping private-sector expectations, while discretion generally implies stabilization bias. Giannoni and Woodford (2005) show how optimal policy can be represented through implementable targeting criteria, clarifying the operational content of model-consistent optimal rules for Central Banks.

For practical policy design, Central Banks also compare alternative simple mandates. Debortoli, Kim, Lindé and Nunes (2019) show that a parsimonious loss function with a non-negligible (sometimes large) weight on real activity can approximate welfare well, supporting the quantitative relevance of the Federal Reserve System's dual mandate. In simulation exercises, these alternative objectives are mapped into counterfactual interest-rate paths and welfare outcomes after demand, supply, financial, or cost-push disturbances.

21.3.2 Applications for Central Banks

This section illustrates how Central Banks use estimated DSGE frameworks in concrete policy work. It first examines disinflation episodes to quantify short-run real costs and longer-run gains, then turns to unconventional monetary-policy tools when the policy rate is constrained, and finally discusses how structural models are used to infer latent policy benchmarks such as the natural real rate of interest.

21.3.2.1 Disinflation

Disinflation experiments are a natural laboratory for DSGE models in Central Banks: they combine a sharp, identifiable change in the monetary-policy regime with persistent output and labor-market adjustments, and they require the model to speak about the *cost* of reducing inflation (the sacrifice ratio) and/or the *welfare* gains from lower steady-state inflation. Two contributions are particularly representative of the way medium-scale *New Keynesian*-DSGE models have been used to address these questions: Fève, Matheron and Sahuc (2010) on the euro-area disinflation of the 1980s-90s, and Ascari and Ropele (2012) on the normative trade-off between the short-run costs and the long-run benefits of disinflation.

Fève et al. (2010) quantify the macroeconomic effects of the disinflation engineered by European Central Banks in the run-up to the euro. Their identification strategy illustrates methodological tools discussed earlier in this chapter. The authors first estimate a structural VAR on euro-area data[9] and identify a *disinflation shock* as a permanent downward shift in the central-bank inflation target, using long-run restrictions. The identified shock generates a persistent fall in inflation, a temporary but persistent decline in output, a gradual and permanent adjustment of the nominal rate. These are IRFs that the structural model is required to reproduce. The latter is a medium-scale *New Keynesian*-DSGE model (sticky prices and wages, partial indexation, habits, investment adjustment costs, Taylor-type rule, and noisy signals on the inflation target as a proxy for imperfect credibility), which they estimate by *matching* its model-implied impulse responses to those of the identified VAR, in the limited-information tradition of Rotemberg and Woodford (1997) and Christiano et al. (2005). The estimated model is finally put to work in two families of *counterfactual* experiments. First, they shut down a candidate propagation mechanism (e.g., nominal or real rigidities, monetary-policy gradualism) and re-estimate the remaining parameters to re-minimize the IRF-matching loss. Second, they impose the same perturbation while keeping all other parameters at benchmark values. Comparing IRFs, fit deterioration and sacrifice ratios across these two exercises identifies which mechanisms are essential and which can be offset by parameter re-adjustments. Their main finding is that a sizable fraction of the 1980s-90s decline in euro-area inflation is traceable to a credible reduction of the target, at a moderate but non-negligible sacrifice in activity.

Ascari and Ropele (2012) study the same class of experiment from a normative angle. Using a medium-scale *New Keynesian* model with trend inflation and price and wage indexation, they compute both the sacrifice ratio associated with a permanent reduction of the inflation target and the welfare gain from operating at a lower steady-state inflation rate. They show that the short-run output losses can be quantitatively large, but are outweighed (under plausible calibrations) by the welfare benefits of reduced price dispersion, lower nominal-wage distortions and less indexation-induced inertia, yielding a favorable *welfare-gain ratio*.

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[9] The sample starts in the 1980s and covers the countries that later joined the euro area. As such, the analysis proceeds as if a fictitious Central Bank had implemented the disinflation policy.

The two papers are complementary: Fève et al. (2010) is positive and data-driven (VAR identification, impulse-response matching, counterfactual history) while Ascari and Ropele (2012) is normative and quantitative-theoretic, taking trend inflation seriously in the log-linearization so that steady-state inflation shapes the slope of the Phillips curve and the welfare loss function.

These contributions illustrate the modeling and estimation methodologies described earlier. The underlying structure is the medium-scale *New Keynesian*-DSGE of Christiano et al. (2005) and Smets and Wouters (2003, 2007) (Section 21.2), with its combination of nominal rigidities, real frictions and an interest-rate rule with smoothing. The VAR-to-DSGE impulse-response matching step of Fève et al. (2010) connects directly to the identification literature reviewed in the GMM section, and the counterfactual exercise relies on the shock-decomposition tools introduced in the sections on IRFs, FEVD and historical decomposition; the welfare reading of Ascari and Ropele (2012) maps into the loss functions of Benigno and Woodford (2004, 2005) used in the section on policy simulations.

21.3.2.2 Analyzing Unconventional Monetary Policies and Quantitative Easing (QE)

Once the policy rate reached its effective lower bound (ELB) in the aftermath of the Great Recession and, later, during the euro-area sovereign-debt crisis, Central Banks turned to balance-sheet instruments, notably large-scale asset purchases (LSAPs) on the Federal Reserve side, long-term refinancing operations (LTROs) and asset purchase programs on the ECB side. Assessing these tools requires DSGE frameworks that go beyond the standard short-rate transmission channel and explicitly model the frictions through which balance-sheet policies can affect aggregate outcomes. Two contributions are emblematic of this literature: Chen, Cúrdia and Ferrero (2012) on the U.S. LSAPs and Cahn, Matheron and Sahuc (2017) on the ECB's LTROs.

Chen et al. (2012) study the macroeconomic effects of the Federal Reserve's second LSAP program (QE2, where QE stands for quantitative easing) using a medium-scale *New Keynesian*-DSGE model augmented with *segmented asset markets* in the tradition of Andrés, López-Salido and Nelson and of the preferred-habitat view. In their setup, a fraction of households can trade only long-term bonds while another fraction is restricted to short-term instruments; imperfect arbitrage between the two maturity segments generates a non-trivial term premium that the Central Bank can influence by purchasing long-duration securities. A LSAP shock is operationalized as an exogenous reduction in the supply of long-term bonds held by the public, which compresses the term premium, lowers long rates and stimulates investment, consumption and inflation. The model is estimated on U.S. data by Bayesian methods and used to generate counterfactual paths: the authors find that QE2-type purchases have quantitatively meaningful but moderate macroeconomic effects, concentrated on activity via the term-premium channel and conditional on the policy being perceived as persistent and on short rates remaining at the ELB.

Cahn et al. (2017) address the symmetric question on the euro-area side by assessing the macroeconomic contribution of the one-year LTROs conducted by the ECB throughout 2009. Their framework is a medium-scale *New Keynesian*-DSGE model with a *banking sector* in the spirit of Gertler and Kiyotaki (2010) and Gertler and Karadi (2011): banks finance long-term loans to non-financial firms with deposits and central-bank liquidity, are subject to endogenous leverage constraints driven by agency frictions, and transmit funding-cost shocks to the credit supply faced by the real economy. LTROs enter the model as a direct easing of banks' funding costs for a specified maturity, relaxing their balance-sheet constraint and lowering lending spreads. The distinctive methodological contribution, which the authors emphasize, lies in the econometric treatment of this unconventional instrument. Standard Bayesian estimation on a long sample would blur the LTRO effect into generic bank-funding shocks and miss the fact that the LTROs *were announced and anticipated*. More fundamentally, temporary activation of 6- and 12-month facilities implies that the model's state-space representation changes over time: each ECB announcement updates beliefs about facility maturity, allotment mode (fixed-rate full allotment, FRFA), and the expected unwind of liquidity operations. The authors therefore reconstruct the full announcement timeline and solve the model by backward induction under each announced policy path, which delivers time-varying transition matrices. Estimation then proceeds in a Bayesian framework using a time-varying state-space system, the Kalman filter, and Metropolis-Hastings simulation. Their counterfactual exercise shuts down nonstandard 6- and 12-month LTROs (and the associated FRFA regime) over 2008-09. Absent these measures, they estimate that average 2009 output, consumption, investment and the gross domestic product (GDP) deflator would have been lower by about 2.5%, 0.5%, 9.7% and 0.5%, respectively, while credit spreads would have been roughly 400 basis points higher, consistent with LTROs having prevented a severe credit crunch.

Taken together, the two papers illustrate how the medium-scale *New Keynesian*-DSGE apparatus introduced in Section 21.2 can be extended to analyze balance-sheet policies.

21.3.2.3 Estimating the Natural Rate of Interest

The natural (or efficient) rate of interest, defined as the real rate that would prevail in an economy without nominal rigidities and inefficient cost-push disturbances, has become a central input of monetary-policy analysis in advanced economies, especially since the post-crisis decline in equilibrium real rates has made the effective lower bound a recurring constraint. While semi-structural filters in the tradition of Laubach and Williams (2003) remain a workhorse at policy institutions, DSGE-based approaches provide a model-consistent alternative in which the natural rate is derived jointly with the other structural objects of the model and decomposed into its underlying shocks. Three contributions illustrate how medium-scale *New Keynesian*-DSGE models have been used to measure the natural real rate and to discuss its operational usefulness for policy: Cúrdia, Ferrero, Ng and Tambalotti (2015), Barsky, Justiniano and Melosi (2014) and Del Negro, Giannone, Giannoni and Tambalotti (2017). This nicely illustrates how DSGE models help identify non-observable latent variables crucial for monetary policy analysis.

Cúrdia et al. (2015) ask whether U.S. monetary policy has tracked the *efficient* real rate, defined as the real interest rate that would prevail in the model's counterfactual flexible-price, markup-shock-free allocation. Using a medium-scale *New Keynesian*-DSGE model estimated on U.S. data by Bayesian methods in the Smets-Wouters tradition, they recover the history of the efficient rate via the Kalman smoother applied to the estimated state-space system, and compare it to the path of the observed federal funds rate adjusted for inflation. Two results matter for Central Banks. First, over most of the Great Moderation, the actual real rate followed the efficient rate reasonably closely, suggesting that U.S. monetary policy was broadly consistent with the model's welfare-relevant benchmark. Second, in the aftermath of the Great Recession, the efficient rate fell sharply into negative territory while the observed real rate was pinned down by the effective lower bound (ELB), producing a large and persistent gap that rationalizes the recourse to unconventional instruments discussed in the previous section.

Barsky et al. (2014) deliver a cautionary companion message using essentially the same toolbox. They extract the natural rate from the Smets-Wouters model estimated on U.S. data and emphasize two features that condition its usefulness for policy. The natural rate is *highly volatile* at business-cycle frequencies and sensitive to the identification of structural shocks, in particular to the treatment of investment-specific technology and markup disturbances. Their conclusion is not that the natural-rate concept is meaningless, but that mechanical tracking of a single point estimate of the natural rate would be a poor guide for the policy rate, and that the operational value of the natural-rate estimate lies rather in its decomposition into economically interpretable shocks.

Del Negro et al. (2017) take a longer-run perspective and ask *why* the natural rate has trended down in advanced economies. They augment a DSGE model with an explicit *safety and liquidity premium* on U.S. Treasuries, using long time series on convenience yields (spreads between Treasuries and less-liquid, less-safe instruments) as additional observables. In their decomposition, the secular decline of the natural real rate reflects a combination of slower productivity growth, demographic shifts lowering the natural rate of growth, and a sustained increase in the convenience yield attached to safe and liquid assets (the latter captured as a shift in the preference for safe assets rather than as a pure equilibrium real-rate phenomenon). For Central Banks, the policy implication is that the low-natural-rate environment is unlikely to reverse quickly, so ELB episodes are likely to remain frequent, reinforcing the relevance of the unconventional instruments analyzed in Section 21.3.2.2.

21.4 HANK Models: A Structural Revisit of the Keynesian Cross

This section presents the heterogeneous-agent extension of the New Keynesian framework and explains why it may at some point become central for monetary and fiscal policy analysis. Once households differ in liquidity, income risk, and marginal propensities to consume (MPCs), aggregate stabilization and distributional incidence become part of the same mechanism. The section starts from the benchmark HANK structure, then turns to solution and estimation methods, before using policy experiments to show how redistribution, cash-flow exposure, and market incompleteness reshape the transmission of conventional and unconventional policies.

Seen from this historical perspective, HANK models do not abandon the DSGE program. They preserve its general-equilibrium and policy-counterfactual discipline, but redirect it toward questions that earlier representative-agent models were poorly equipped to answer: who bears shocks, whose consumption responds, and how redistribution shapes aggregate demand.

21.4.1 The Benchmark HANK Model

This section sets out the baseline HANK architecture used in the rest of the chapter. It first introduces the household and labor-market building blocks that generate heterogeneous MPCs and nominal transmission, then explains how aggregation through the cross-sectional distribution changes equilibrium dynamics, and finally links the full model to the intertemporal Keynesian-cross representation used for policy analysis.

21.4.1.1 Micro Foundations and Nominal Transmission

Building on Aiyagari (1994), Huggett (1993), and Krusell and Smith (1998), Heterogeneous-Agent New Keynesian (HANK) models relax the representative-household assumption by introducing incomplete markets and idiosyncratic labor-income risk into a standard *New Keynesian* environment with nominal rigidities. This matters quantitatively because households differ in wealth and exposure to income fluctuations, so they also differ in marginal propensities to consume; many are liquidity-constrained and react strongly to current disposable income. As a result, monetary and fiscal policies transmit not only through intertemporal substitution, but also through redistribution across households, in line with micro evidence documenting substantial consumption responses to income and transfers (Jappelli & Pistaferri, 2010; Parker, Souleles, Johnson & McClelland, 2013)[10] and with the mechanisms emphasized by Kaplan et al. (2018) and Auclert (2019).

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[10] Boehm, Fize and Jaravel (2025) provide a critical reassessment of this literature and report substantially smaller MPCs.

On the household side, the economy contains a continuum of ex-ante identical agents who become ex post heterogeneous due to idiosyncratic efficiency shocks. Households choose consumption and saving subject to an intertemporal budget identity and a borrowing limit, so self-insurance is partial and the distribution of assets and income becomes a core state variable. This is the key source of heterogeneous MPCs that amplifies the income channel of aggregate demand.

On the labor side, wages are set by unions for differentiated labor types under monopolistic competition. A standard aggregator maps those labor types into total labor services and implies type-specific labor demand that declines with relative wages. Nominal wage stickiness, introduced via staggered re-optimization or adjustment costs (often with partial indexation), then generates realistic wage and inflation inertia. Taken together, these ingredients allow HANK models to preserve structural discipline while reinstating distributional channels that are first-order for policy analysis, thus complementing the approach promoted by Smets and Wouters (2003, 2007).

21.4.1.2 Aggregation and Distributional Effects

Because the population is a continuum, aggregation is expressed using the cross-sectional distribution of households over individual states, typically assets and idiosyncratic labor efficiency. Aggregate variables are therefore population-weighted integrals over that distribution. Likewise, any object entering equilibrium (income, marginal utility, MPC, labor earnings) is a distribution-weighted integral, not an average over a finite number of 'types.' The law of motion for the distribution is induced by optimal household decisions and the Markov transition for idiosyncratic risk.

This distributional state is quantitatively central in HANK models. Changes in prices, wages, taxes, or interest rates reallocate income and wealth across households with heterogeneous MPCs. Aggregate demand then moves through both intertemporal substitution and redistribution channels. Relative to representative-agent *New Keynesian* models, this mechanism typically generates stronger and more persistent responses of output and consumption to monetary and fiscal disturbances.

21.4.1.3 Linking HANK to the Keynesian Cross

The usefulness of HANK models becomes clearest when we return to one of the most elementary objects of textbook macroeconomics, the Keynesian cross. In its static form, the Keynesian cross states that equilibrium output is the fixed point of a feedback loop in which aggregate demand depends on current income through a marginal propensity to consume out of disposable income, with investment and public spending treated as autonomous components. When the marginal propensity to consume is strictly between zero and one, the familiar Keynesian multiplier is equal to one divided by one minus that propensity, measuring how an autonomous demand impulse is amplified by induced consumption. Representative-agent *New Keynesian*-DSGE models, by contrast, anchor short-run consumption on the Euler equation, so current income drops out of the consumption function and the Keynesian-cross feedback disappears from the aggregate demand block: monetary and fiscal transmission operate essentially through intertemporal substitution and through wealth effects on the permanent income of a single representative household. HANK models reinstate the Keynesian-cross feedback within a fully specified intertemporal equilibrium framework. The key reason is the distribution of marginal propensities to consume induced by incomplete markets and borrowing constraints: a non-negligible mass of households is liquidity-constrained or near-constrained, and for those households current disposable income matters far more than the real interest rate. Aggregating the household problem over the cross-sectional distribution of household states then yields an aggregate consumption function in which current and recent disposable income enter with quantitatively large weights, and the *income-driven* component of aggregate demand becomes first-order, alongside the standard intertemporal-substitution component.

A useful way to make the link explicit is the *intertemporal Keynesian cross* of Auclert, Rognlie and Straub (2024). They show that, around a steady-state equilibrium, aggregate consumption in HANK economies admits a linear decomposition into two components: one driven by the path of aggregate disposable income, and one driven by the path of real interest rates. The associated intertemporal response matrices map an income or interest-rate impulse at one date into consumption responses at all future dates. In the representative-agent limit, the income-response matrix is close to the permanent-income benchmark and the income channel is largely muted. In empirically plausible HANK calibrations, the same matrix assigns large weight to contemporaneous income (households spend a substantial share of transfers on impact) and retains a slowly decaying influence of recent income on current consumption. The resulting dynamic fixed-point condition for output is the intertemporal counterpart of the static Keynesian cross, with the additional discipline that these response objects are derived from a fully specified household problem with idiosyncratic risk and constraints rather than postulated.

This decomposition also organizes the transmission of monetary policy shocks in HANK along the lines emphasized by Kaplan et al. (2018) and Auclert (2019). A change in the policy rate has a *direct* effect through intertemporal substitution by unconstrained households, captured by the interest-rate response matrix, and an *indirect*, general-equilibrium effect that operates by moving aggregate labor income, which then feeds back into consumption through the income-response matrix. In quantitatively realistic HANK calibrations, the indirect channel typically dominates, in line with the Keynesian-cross intuition: the bulk of the consumption response to a monetary shock comes from changes in disposable income of high-MPC households, not from their willingness to substitute consumption over time. Symmetric logic applies to fiscal disturbances: a transfer to constrained households is amplified by the income-response matrix in a way that the representative-agent benchmark mechanically misses.

For Central Banks, this rehabilitation of the Keynesian cross has two operational implications that motivate much of what follows. First, the size and shape of the income-response matrix (hence the strength of HANK transmission) depend on objects that can be disciplined by household-level micro data: the distribution of liquid wealth, intertemporal MPCs, and the response of consumption to transitory income shocks (Jappelli & Pistaferri, 2010; Parker et al., 2013; Boehm et al., 2025). Second, policy counterfactuals built on a representative-agent *New Keynesian* structure may significantly understate the short-run response of aggregate demand to redistributive policies and to monetary shocks that move labor income. The next sections turn to the numerical resolution and estimation of HANK models, and then to the policy experiments in which the intertemporal-Keynesian-cross logic translates into quantitative policy advice.

21.4.2 Resolution and Estimation

This section explains how HANK models are made operational for policy analysis. It contrasts recursive state-space methods with sequence-space approaches, then discusses how each strategy maps into estimation, historical decomposition, and forecasting workflows, highlighting the trade-off between computational speed, numerical accuracy, and empirical discipline.

21.4.2.1 Recursive Approaches

Solving and estimating a HANK model is, in essence, the problem of propagating a high-dimensional cross-sectional distribution forward in time jointly with aggregate quantities and prices, under rational expectations about aggregate shocks. Any practical algorithm must therefore take a stand on two dimensions: (i) how to represent the distribution numerically, and (ii) how to treat the dependence of individual decisions on the aggregate state. The class of *recursive approaches* tackles both within a standard state-space representation in which that distribution (or a finite-dimensional approximation of it) enters the vector of states, and in which aggregate dynamics are obtained either by simulation or by perturbation around a stationary equilibrium.

The historical benchmark is the simulation-based algorithm of Krusell and Smith (1998). They approximate the aggregate law of motion of the distribution by a small number of its moments (typically the mean of wealth) and postulate a forecasting rule in which households condition their policies on these moments rather than on the full distribution. A fixed point is found by iterating between (a) solving the household problem given a conjectured law of motion for the moments, and (b) simulating the economy to update that law of motion. The key conceptual result, *approximate aggregation*, is that the first moment is typically sufficient for accurate forecasting because concavity of the household policy functions dampens the contribution of higher-order moments. The method is robust and handles nonlinear aggregate dynamics, but it is computationally expensive, relies on simulation, and does not deliver a state-space representation amenable to Kalman filtering or Bayesian estimation. For central-bank applications, where IRFs, historical decomposition and likelihood-based estimation are routine, this is a serious limitation.

The modern recursive workhorse is the projection-plus-perturbation algorithm of Reiter (2009), which combines the two techniques along orthogonal dimensions. The idiosyncratic household problem is solved *globally* by projection. Policy functions over individual asset and efficiency states are computed at the stationary equilibrium, keeping all the nonlinearities induced by borrowing constraints, occasionally binding limits and non-Gaussian income processes. Aggregate dynamics, by contrast, are handled by *first-order perturbation* around the stationary equilibrium. The law of motion for the cross-sectional distribution is discretized on a finite grid, stacked with the aggregate endogenous variables and prices into a large but *linear* state-space system, and standard DSGE solution methods deliver the policy rules as a function of the discretized distribution and the aggregate shocks. This separation is powerful: it preserves the micro nonlinearities that matter for MPC heterogeneity while delivering a linear state-space representation that is fully compatible with the Kalman filter, impulse-response decompositions and Bayesian estimation. The main practical cost is the size of the state vector, since the discretized distribution may contain several thousand grid points.

A series of subsequent contributions has pushed the Reiter algorithm to empirically relevant scale. Winberry (2018) proposes a parametric approximation of the distribution (typically low-order polynomial families in the wealth distribution dimension) that reduces the size of the discretized state while preserving accuracy, and packages the method in a toolkit that integrates Dynare-style linearization and Bayesian estimation. Ahn, Kaplan, Moll, Winberry and Wolf (2018) develop a continuous-time counterpart in which the Kolmogorov forward equation for the cross-sectional distribution plays the role of the law of motion and in which a low-rank approximation of the Jacobian (via singular value decomposition or Krylov methods) dramatically compresses the state vector without loss of IRF accuracy. Bayer and Luetticke (2020) develop a complementary discrete-time implementation that uses a Discrete Cosine Transform and a copula-based separation of marginal distributions from their dependence structure to reduce dimensionality, with estimated HANK applications on euro-area and U.S. data.

Taken together, these recursive algorithms deliver three deliverables that matter for Central Banks. First, they provide IRFs and historical decompositions of aggregate variables that are directly comparable to those produced by representative-agent *New Keynesian*-DSGE models, and can therefore be plugged into existing policy-round pipelines. Second, they deliver linearized state-space representations of HANK economies that support Bayesian estimation on standard macroeconomic observables, so that posterior inference on structural parameters remains feasible even in models with several thousand latent states. Third, they preserve enough of the micro heterogeneity (MPC distributions, occasionally binding constraints, non-Gaussian income risk) to be disciplined jointly by macroeconomic and household-level data. The main remaining limitation of this family of methods is that it is anchored on a first-order approximation of the aggregate dynamics, which can be restrictive when the objects of interest are highly nonlinear (large shocks, state dependence, occasionally binding aggregate constraints such as the ELB). That limitation motivates the *sequence-space* and higher-order techniques discussed in the next section.

21.4.2.2 Sequence-Space Jacobians, Higher-Order Methods, and Estimation

The recursive methods of the previous section solve HANK models in *state space*. The cross-sectional distribution is a state, and policy functions are indexed by it. An alternative, mathematically equivalent at first order but operationally much more efficient, consists of working directly in *sequence space*, that is, in the space of time paths of aggregate variables. This is the core insight of Auclert, Bardóczy, Rognlie and Straub (2021), whose sequence-space Jacobian (SSJ) approach has become the reference computational tool for HANK estimation.

The starting point is the observation that, under a first-order perturbation around a stationary equilibrium, any HANK model reduces to a fixed-point equation on the path of aggregate quantities and prices. The household block, the firm block, the monetary and fiscal rules each map aggregate sequences into other aggregate sequences, and aggregate equilibrium is a set of paths such that the composed mapping is consistent. The key numerical object is the *sequence-space Jacobian* of each block: a matrix whose entry for each pair of dates gives the response of an aggregate output variable at one horizon to a shock to an aggregate input at another horizon. The Jacobians of the household block are nothing other than the intertemporal MPC matrices that appear in the intertemporal Keynesian cross, so the SSJ apparatus makes the decomposition introduced in Section 21.4.1.3 directly operational. Crucially, each block's Jacobian can be computed *independently* by a one-shot differentiation of the stationary equilibrium, without having to discretize the cross-sectional distribution as a state vector. The accuracy depends on the fineness of the idiosyncratic grids and on the truncation horizon for aggregate paths, but not on the dimensionality of the full distribution. IRFs for a medium-scale HANK are obtained in seconds, and the linear state-space representation that underlies Kalman filtering and Bayesian estimation is recovered at essentially the same cost as for a representative-agent DSGE. For central-bank applications, this is the step that makes HANK estimation routine rather than a one-off research exercise.

Bayer, Born and Luetticke (2024) illustrate how powerful the combination is in practice. They estimate a medium-scale HANK model with sticky prices and wages, investment adjustment costs, a government sector and an endogenous distribution of wealth on U.S. data, using a standard Bayesian likelihood built on the linearized SSJ representation. The resulting model delivers the full Smets-Wouters suite (IRFs, historical decompositions, forecast error variance decomposition) augmented with a decomposition of inequality dynamics, and fits the data comparably to the representative-agent benchmark while assigning meaningfully different roles to demand, supply and monetary disturbances. The exercise demonstrates two points that matter for policy. First, HANK models can be estimated on macroeconomic observables with the same Bayesian techniques already in use in Central Banks.

Second, the resulting posterior distributions over structural shocks and transmission mechanisms differ from those of the representative-agent benchmark in ways that are quantitatively relevant.

Both the SSJ and the Reiter families, however, rely on a *first-order* approximation of aggregate dynamics. This is innocuous for small shocks and smooth responses, but it is restrictive when the questions of interest involve genuine nonlinearities: precautionary savings that respond to aggregate-risk premia, state-dependent IRFs, occasionally binding aggregate constraints such as the ELB, and the feedback of time-varying aggregate uncertainty on the distribution itself. A second methodological strand therefore develops *higher-order* and fully nonlinear HANK solvers. Fernández-Villaverde, Hurtado and Nuño (2023) compute a continuous-time HANK with financial frictions using a global nonlinear scheme that solves the household Hamilton-Jacobi-Bellman (HJB) equation and the Kolmogorov forward equation for the distribution simultaneously with the aggregate equilibrium conditions, delivering nonlinear IRFs and state-dependent transmission. Bhandari, Bourany, Evans and Golosov (2023) develop a higher-order perturbation of incomplete-markets economies that preserves the distributional state and supports welfare-based policy analysis with precautionary effects. From the estimation side, higher orders are essential when one wants to let the data speak on *macroeconomic risk*. Stochastic volatility of aggregate shocks, risk premia, and the feedback from uncertainty to the wealth distribution enter aggregate dynamics only at second order or above, so quantifying their contribution to central-bank-relevant objects such as the natural rate or the equilibrium risk premium requires solving and estimating HANK models at higher order rather than linearized.

21.4.2.3 Key Takeaways for Central Banks

For Central Banks, the operational takeaway from this methodological literature is threefold. First, speed: SSJ-based estimation of HANK on standard macro observables is now feasible within the computational budget of a quarterly policy round, removing a long-standing barrier to the use of heterogeneous-agent models in policy analysis. Second, micro-macro consistency: the same linearized SSJ pipeline supports joint identification on macro time series and on micro moments (intertemporal MPCs, wealth distribution, consumption responses to transfers), so that the discipline emphasized in Section 21.4.1.3 translates into estimation practice. Third, nonlinearity when it matters: higher-order and global solvers extend the toolkit to questions (macro risk, uncertainty shocks, occasionally binding constraints) for which the first-order approximation is insufficient, and they do so within the same structural modeling framework rather than by stepping outside the HANK paradigm.

21.4.3 Policy Experiments in HANK Models

HANK models are especially useful when policy works through households that are not all exposed in the same way. A cut in the policy rate affects borrowers, savers, workers, and asset holders differently; a transfer has a different aggregate effect depending on whether it reaches households with high or low MPCs; and the impact of QE or forward guidance depends on who holds the relevant assets and how expectations feed into current cash flows. The section uses these examples to discuss conventional monetary policy, fiscal multipliers, and unconventional instruments.

21.4.3.1 Monetary Policy

In HANK models, the effects of a policy-rate change are decomposed into two channels. The first is the standard intertemporal-substitution channel, which mostly affects unconstrained households with positive liquid wealth. The second is an income-and-cash-flow channel, operating through labor income, debt-service positions, and portfolio exposures. Quantitatively, the second channel is often dominant, because the households with the highest MPCs are also those whose spending reacts most to changes in disposable income. This is the core reason why representative-agent *New Keynesian* models tend to understate short-run consumption and output effects of monetary disturbances (Kaplan et al., 2018; Auclert, 2019; Auclert et al., 2024).

21.4.3.2 Fiscal Policy

Fiscal experiments are where distributional structure matters most. Transfers targeted to liquidity-constrained households generate stronger aggregate-demand responses than uniform transfers, because they are directed toward agents with high MPCs. Government spending effects are also state dependent. When labor income risk is elevated and balance sheets are weak, the induced rise in household income can produce larger consumption spillovers than in representative-agent environments. Accordingly, HANK-based fiscal multipliers are typically more sensitive to program design, cyclical conditions, and financing assumptions than their representative-agent counterparts (Kaplan et al., 2018; Auclert, 2019).

Ferriere and Navarro (2025) provide a particularly direct quantification of this point. In a HANK model with heterogeneity in both MPCs and labor responses, they show that the distribution of tax financing is a first-order determinant of spending multipliers. Multipliers are substantially larger when the fiscal burden is shifted toward higher-income households, who are less responsive at the margin. Using long U.S. historical data, they also document that spending shocks were often accompanied by increases in tax progressivity, and they estimate progressivity-dependent multipliers that align with the model. For policy analysis, their result implies that ‘the multiplier’ is not a structural constant of spending alone. It is jointly determined by the composition of spending and by the cross-sectional tax adjustment used to finance it.

21.4.3.3 Unconventional Policy and Quantitative Easing (QE)

Two recent contributions sharpen the unconventional-policy message in heterogeneous-agent environments. Cui and Sterk (2021) study large-scale asset purchases in a HANK model with liquid and partially liquid wealth and sticky prices. Their key mechanism is a liquidity-composition effect: QE shifts household portfolios toward more liquid claims, and because the MPC out of liquid wealth is much higher than the MPC out of illiquid wealth, aggregate demand and inflation respond materially. In their estimated U.S. model, this channel implies that QE significantly cushioned the Great Recession, while also generating potentially adverse distributional side effects relative to conventional rate policy.

Hagedorn, Luo, Manovskii and Mitman (2019) focus on forward guidance in an incomplete-markets liquidity-trap setting and obtain the opposite quantitative conclusion: under empirically plausible rigidities and a realistic horizon for policy commitments, the macro effects of forward guidance are small. Their framework resolves the ‘forward-guidance puzzle’ of representative-agent *New Keynesian* models by showing that the required general-equilibrium redistribution and real-rate movements are too muted to generate large current output and employment effects.

21.4.4 Implications for Central Banks

This shift from representative-agent to heterogeneous-agent policy analysis has direct consequences for how Central Banks should interpret their stabilization mandate.

Three implications are especially relevant for Central Banks. First, optimal stabilization in heterogeneous-agent environments must take distribution aspects into consideration. Acharya, Challe and Dogra (2023) show that optimal monetary policy in HANK differs from the representative-agent benchmark because policy trades off price stability, activity stabilization, and consumption-inequality dynamics. Similarly, Challe (2020) shows that uninsured unemployment risk can call for systematically more accommodative policy than in complete-markets benchmarks. On the fiscal side, Le Grand and Ragot (2025) emphasize that optimal debt and tax adjustment in heterogeneous-agent economies depends on how financing instruments map into constrained households’ behavior.

Second, the monetary-fiscal mix cannot be assessed independently of distributional incidence. In representative-agent models, the standard classification of regimes relies on policy-rule coefficients and debt stabilization behavior (active/passive monetary and fiscal policy in the sense of Leeper (1991)). In HANK, this is no longer sufficient: monetary and fiscal shocks propagate through heterogeneous cash-flow and income exposures, and the aggregate response depends on who receives income gains and who bears tax adjustments (Kaplan et al., 2018; Auclert, 2019). In the intertemporal-Keynesian-cross framework, this dependence is explicit because output and inflation dynamics are pinned down jointly by policy rules and by distribution-dependent income-response objects (Auclert et al., 2024). The empirical importance of financing incidence is further documented by Ferriere and Navarro (2025), who show that spending multipliers vary strongly with tax progressivity. For policy institutions, the practical implication is that 'fiscal dominance' versus 'monetary dominance' must be assessed as a joint, estimated property of policy behavior and household distribution, rather than as a purely representative-agent taxonomy.

Third, determinacy and numerical solvability are now central operational constraints. For incomplete-markets models, Hagedorn (2023) provides a local determinacy criterion based on dimensionality reduction. The underlying winding-number logic traces back to Onatski (2006) in linear rational-expectations systems. Building on sequence-space methods, Auclert, Majic, Rognlie and Straub (2026) show how determinacy tests and large-scale model solution can be handled jointly in very high dimensions, a key practical step for policy institutions running multi-block HANK systems.

21.4.5 Limitations and Future Directions

Despite major methodological progress, several constraints still limit the routine use of HANK models in policy institutions, especially Central Banks.

- *Computation and scalability.* Even with SSJ and related dimensionality-reduction techniques, high-dimensional state spaces, rich shock structures, and nonlinear policy constraints remain computationally intensive in real-time policy environments.
- *Identification and data requirements.* Estimation requires joint discipline from macro time series and household-level moments (wealth distribution, MPCs, cash-flow exposure), and measurement choices can materially affect posterior transmission mechanisms.
- *Nonlinear risk and regime dependence.* Questions involving uncertainty shocks, occasionally binding constraints, and large policy interventions often require higher-order or global solution methods that are not yet as operationally standardized as linear pipelines.
- *Adding firm heterogeneity.* A key frontier is to complement household heterogeneity with heterogeneous firms and financial constraints, so that investment transmission and firm-level cash-flow channels are treated symmetrically with household consumption channels (Winberry, Auclert, Rognlie & Straub, 2025).
- *Broader policy architecture.* Integrating open-economy blocks, financial intermediation, and fiscal institutions in a single estimated framework remains an ongoing task for most Central Banks.

The medium-run research agenda is therefore not to replace current DSGE toolkits overnight, but to build hybrid policy platforms in which HANK blocks can be activated when distributional incidence is first-order while retaining the speed and transparency required for routine forecasting and policy rounds.

21.5 Conclusion

DSGE models became central to modern policy analysis because they offer a structured way to connect shocks, expectations, frictions, and policies within a single equilibrium framework. Their value lies in their ability to impose economic discipline on the data, to make counterfactual exercises internally consistent, and to translate policy questions into explicit transmission mechanisms. The move from large macroeconometric systems to microfounded DSGE models, and then to estimated medium-scale New Keynesian models, gave Central Banks a shared language for discussing economic policies.

The chapter has also emphasized that this language is still evolving. Representative-agent models remain useful because they are tractable, transparent, and operational in routine policy environments, but they miss distributional channels that are often first-order for monetary, fiscal, and balance-sheet policies. HANK models address this limitation by linking aggregate dynamics to household balance sheets, income risk, liquidity, and marginal propensities to consume. They therefore refine the interpretation of policy multipliers, forward guidance, QE, and the monetary-fiscal mix. The practical lesson is not that HANK should simply replace existing DSGE toolkits, but that policy institutions need a portfolio of models: fast representative-agent platforms for routine analysis, richer heterogeneous-agent blocks when incidence and redistribution are central, and disciplined empirical procedures to decide which mechanisms matter in a given episode.

The historical lesson is therefore selective rather than dismissive: the DSGE framework aged well as a language for disciplined counterfactual policy analysis, but particular modelling shortcuts aged unevenly as the policy questions moved from inflation stabilization to financial instability, the effective lower bound, and distributional transmission.

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