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Michael Woodford's *Interest & Prices* after 20 years

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ABSTRACT

The present paper reflects about Michael Woodford's *Interest & Prices*, 20 years after its publication. After stressing the three most important achievements of that treatise, it is argued that Woodford pursued a different, and much less recognised, objective: promoting an approach to monetary policy involving an explicit commitment to a "history-dependent" policy rule. Possible reasons why neither prominent authors nor central banks have (thus far) endorsed that approach are investigated.

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1. Introduction

Two decades have elapsed since the publication of Michael Woodford's book, *Interest & Prices—Foundations of a Theory of Monetary Policy*.[1] This book was exceptional because of its mere existence—we live in times where theoretical contributions appear in articles rather than in books—not to mention its forbidding length. Despite its handicaps, it gained a large recognition. Its importance has been widely acknowledged as witnessed by the number of citations it drew.[2] The aim of the present paper is, accordingly, to provide an assessment of its impact on monetary economics and central banking. Hence, it should be read as an exercise into aspects of the recent history of monetary theory and policy.

When wondering what its main contributions were, three come to mind. The first is that *Interest & Prices* imposed the so-called "three-equation New Keynesian model"—involving the New Keynesian Phillips Curve, the Euler equation (sometimes referred to as the "intertemporal IS curve"), and a Taylor-type rule. This model now forms the core of the New Keynesian–DSGE paradigm, which currently dominates monetary economics.[3] The second is that Woodford's book imposed the concept of a "natural rate of interest," especially on economists working in central banks. This rate is perceived as a key variable behind the dynamics of inflation, and many attempts have been undertaken to measure it. The third is that *Interest & Prices* provided a

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[1] While published in 2003, the first chapters of the book started to circulate in 2000.
[2] According to Google Scholar (9 November 2025), the book has been cited 13.367 times.
[3] DSGE for Dynamic Stochastic General Equilibrium.

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general method for deriving a "utility-based" welfare criteria consistent with the models used to determine the optimal monetary policy. This method, developed along lines first laid down in the theory of public finance, has been widely adopted by researchers.[4]

This paper aims at giving a detailed account of those three contributions. However, we also want to dwell on a less recognised contribution of Woodford's book. Or, to put it differently, on a purpose that seems to have been dear to him when working on his book, yet failed to be taken up. When studying *Interest & Prices* and looking at Woodford's subsequent work on monetary theory, it turns out that he pursued a distinct objective: promoting an approach to monetary policy that involves an explicit commitment to a policy rule displaying a very large amount of inertia.[5] This approach relies on Woodford's belief that conducting monetary policy in a discretionary fashion would induce highly sub-optimal responses of the economy to exogenous disturbances. According to him, a commitment to a very inertial—or, in his terminology, to a strongly "history-dependent"—rule would considerably improve the trade-offs faced by central bankers between their different stabilisation goals. Woodford's approach also critically involves the formulation of "principles" that would help selecting the rule in a way that would overcome central bankers' reluctance to the very idea of commitment to a policy rule. To Woodford's possible frustration, his approach has received scant attention, and none of the major central banks has made the kind of commitment advocated in *Interest & Prices*.[6]

The paper is organised as follows. In Section 2, we stress the main differences between the three-equation New Keynesian model and the set of equations that was previously underlying the New Keynesian–DSGE paradigm, and point out the importance of Woodford's comparison of the respective dynamics induced by the "cashless economy" and a standard monetary one. In Section 3, it is argued that Woodford's systematic emphasis on the effects of the natural interest rate on inflation dynamics was very important to impose this concept. In Section 4, it is claimed that the general method developed for deriving utility-based welfare criteria strongly contributed to unifying the literature on optimal monetary policy. In Section 5, Woodford's rules-based approach to monetary policy is presented. In Section 6, we discuss possible reasons why prominent authors have not endorsed that approach, and why central banks have (thus far) avoided making the type of commitment associated with it. Section 7 concludes and briefly illustrates how, in the wake of the 2008 economic crisis, Woodford dealt with a crucial missing topic from *Interest & Prices*—namely financial stability.

[4] The integration of the analysis of monetary policy with the analysis of fiscal policy, building upon the theory of monetary policy put forward in Woodford's book, has been further developed by Benigno and Woodford (2003).

[5] The term "commitment" appears no less than 373 times in the book.

[6] For instance, in his review of *Interest & Prices*, Charles Goodhart only briefly mentions Chapter 8—where Woodford presents his approach and formulates the associated principles—and finds it "both mathematically and philosophically difficult" (Goodhart 2004, 196). Similarly, Edward Green (2005, 133) devotes only few lines to that chapter in his fourteen-page review.

2. Imposing a model

A significant achievement of *Interest & Prices* is certainly to have imposed the "three-equation New Keynesian model" within the New Keynesian–DSGE paradigm. This model—initially proposed by Woodford (1996), and estimated in a slightly different form by Rotemberg and Woodford (1997)—now lies at the core of most New Keynesian–DSGE models, whatever their size. It comprises the following equations. First, the so-called New Keynesian Phillips Curve, resulting from the assumption (suggested by Calvo 1983) that in every period, only a fraction of randomly selected firms (producing differentiated goods) are allowed to reset the price of the goods they sell:[7]

$$\pi_t = \beta \mathbb{E}_t \pi_{t+1} + \kappa (y_t - y_t^n), \tag{1}$$

where π_t denotes the rate of inflation between period t and period $t+1$, β the subjective discount factor, $\mathbb{E}_t$ the expectations operator conditional upon the information available in period t, κ a reduced-form parameter (depending, in particular, upon the fraction of firms resetting their selling price in a given period), y_t the actual level of real output in period t, and y_t^n the "natural" level of real output in period t (i.e., the level that would arise if prices were perfectly flexible).

Second, the Euler equation, resulting from the optimisation programme of the representative household (along with the assumption of market clearing in all goods markets):

$$y_t - y_t^n = \mathbb{E}_t y_{t+1} - \mathbb{E}_t y_{t+1}^n - \frac{1}{\sigma} \left(i_t - \mathbb{E}_t \pi_{t+1} - r_t^n \right), \tag{2}$$

where σ denotes the inverse of the intertemporal elasticity of substitution of consumption, i_t the nominal interest rate on one-period riskless bonds in period t, and r_t^n the "natural" rate of interest in period t (i.e., the real interest rate that would arise if prices were perfectly flexible).

Finally, a feedback monetary policy rule of the type advocated by John B. Taylor in various contributions (such as Taylor 1993, 1999b):[8]

$$i_t = \rho + \Phi_\pi \pi_t + \Phi_y (y_t - y_t^n) + \nu_t, \tag{3}$$

where $\rho \equiv -\log\beta$ denotes the discount rate, Φ_π and Φ_y coefficients chosen by the monetary authority, and ν_t an exogenous monetary policy shock.

Before the publication of *Interest & Prices*, the core of most New Keynesian models was instead composed of four equations: the New Keynesian Phillips Curve (equation 1), the Euler equation (equation 2), a money-demand equation, and a money-supply equation. This was notably the case of the very first New Keynesian models of Hairault and Portier (1993), Kimball (1995), King and Wolman (1996), and Yun (1996), as well as the more recent contributions of Chari, Kehoe, and McGrattan (2000), and Christiano, Eichenbaum, and Evans (2001).

[7] The following equations are log-linear approximations of the equilibrium conditions around a steady state with a constant inflation rate.

[8] Different forms of Taylor rules have been considered in the New Keynesian–DSGE literature. Here we use the form selected by Galí (2008, Chap. 3), which is now quite standard.

Beyond the number of equations, there are two crucial differences between these New Keynesian models and the version popularised by *Interest & Prices*.

The first difference relates to the instrument of monetary policy. In the three-equation New Keynesian model, this instrument is the nominal interest rate, i_t. By contrast, in the above-mentioned New Keynesian models, money supply is the instrument of monetary policy—the nominal interest rate being determined by the interplay (on the money market) of money supply and money demand.[9] Although the interest rate has long been considered the main instrument of monetary policy, most models devoted to monetary policy issues continued to attribute this role to the quantity of money. This was partly due to the result contained in the famous paper by Sargent and Wallace (1975). There, the authors pointed out that (in their IS-LM model augmented with a New Classical Phillips Curve) the direct control of the nominal interest rate by the monetary authority could lead to the indeterminacy of the price level.[10] In Chapters 2 and 4 of *Interest & Prices*, Woodford stresses that Sargent and Wallace's indeterminacy result stems from their assumption that i_t is set independently from the behaviour of the endogenous variables of the model, and that this result would not arise in the three-equation New Keynesian model provided some conditions on the coefficients Φ_π and Φ_y are satisfied.[11] He especially raises the importance of the (suitably defined) *Taylor principle*:[12] indeterminacy of the rational-expectations equilibrium would be avoided if (and only if) the coefficients Φ_π and Φ_y are such that a permanent increase in inflation induces a more than proportional cumulative response of i_t.

The second, and more substantial, difference relates to the role of money in the economy. In the *cashless economy* underlying the model developed by Woodford, money is a unit of account and a store of value (yielding a nominal return), but *not* a medium of exchange—there are no frictions in the exchange process that money can help to overcome. Hence, there is no well-defined demand for money balances, and the quantity of money appears nowhere in the equilibrium conditions of the household.[13] However, Woodford argues that in so far as the dynamics of the endogenous variables are concerned, and as long as the monetary authority manages to make the nominal interest rate behaves in the way described by equation (3), this absence of a

[9] It is worth noticing that the choice of the instrument of monetary policy was one of the main reasons why Woodford, in his book, called his framework "neo-Wicksellian" rather than "New Keynesian": "It is perhaps worth commenting on why I have chosen to call my framework "neo-Wicksellian," rather than calling it a "New Keynesian" approach […] Notably, I emphasize the use of a short-term nominal interest rate as the instrument of monetary policy and accordingly devote considerable attention to the connection between interest rates and aggregate demand, while the "new Keynesian" literature identified monetary policy with changes in the money supply" (Woodford 2006, 195–196).

[10] The New Classical Phillips Curve is associated with explanations of nominal "rigidities" based on incomplete (and dispersed) information—as exemplified by the "islands parable" suggested by Phelps (1970) and Lucas (1972).

[11] McCallum (1981) and Clarida et al. (2000) are important forerunners in this connection.

[12] Woodford coined this concept in Woodford (2001).

[13] Since there are no transactions frictions in the cashless economy, assets are only stores of value. A no-arbitrage condition implies that all the assets must yield the same nominal return (otherwise, the assets with lower returns would not be held). Assets are therefore perfect substitutes, and households are indifferent to the composition of their portfolio. Hence, even though there is a demand for assets as a whole (so as to implement intertemporal transfers of purchasing power), there is no well-defined demand for each asset—and, thus, no well-defined demand for money balances.

transaction role for money is innocuous. Indeed, he shows that the dynamics of π_t, $y_t - y_t^n$, and i_t, are the same for: i) the three-equation New Keynesian model; ii) a model comprising equation (1), equation (2), a money-demand function (resulting from the money-in-utility assumption), and the supply of money adjusted to clear the money market at the targeted interest rate given by equation (3).[14] The cashless economy can therefore "be viewed as a useful approximation" (62) of a more complex monetary economy, and makes it clear that it is possible to study the behaviour of the variables of central interest for monetary policy "without any reference to either the evolution of the money supply or the determinants of money demand" (109).[15,16,17]

The "anti-monetarist approach" (McCallum 2005, 19) underlying the three-equation New Keynesian model has been recently criticised by some "new monetarist" authors.[18] Williamson and Wright (2010a) notably argued that the absence of a meaningful role for money would significantly understate the welfare costs resulting from inflation. In the three-equation New Keynesian model, the costs of inflation only stem from the dispersion of prices induced by nominal price rigidities (themselves stemming from the Calvo lottery). According to Williamson and Wright, price dispersion would leave aside a substantial part of inflation costs. In particular, they showed that inflation can be very harmful in the Lagos and Wright (2005) model—which has become the frame of reference in the new monetarist literature—as a result of a large inflation tax on money balances.[19,20] New monetarist authors have also

[14] The Euler equation in the second model is also given by equation (2) because the utility function is assumed to be additively separable between consumption and real balances, so that no real-balance effect is involved. If, instead, the utility function is non-separable, the Euler equation is no longer given by equation (2) since it now involves a real-balance effect. Woodford nevertheless shows that for a quantitatively small real-balance effect, the dynamics of π_t, $y_t - y_t^n$, and i_t, are almost the same as in the three-equation New Keynesian model. McCallum (2001) did the same exercise (and obtained similar results) by confronting the dynamics of the endogenous variables in the three-equation New Keynesian model with those in a model where money allows to save resources used in conducting transactions (as in so-called "shopping-time models").

[15] Quotations without references come from *Interest & Prices*.

[16] Money demand which has proven to be highly unstable since the mid-1980s.

[17] It is worthy to note that the three-equation New Keynesian model is now at the core of New Keynesian–DSGE models developed by institutions which have always given pride of place to the quantity of money. It is notably the case at the European Central Bank, where the three-equation New Keynesian model is at the core of the New Area-Wide Model and the DKR model.

[18] "New monetarism"—a label coined by Williamson and Wright (2010a, 2001b)—is meant to encompass the body of work which, from the early 1970s, has tried to provide microfoundations to the use of money in general equilibrium models. In practice, authors who have defined themselves as new monetarists have essentially developed search models of money (whose pioneering contribution is Kiyotaki and Wright 1989), where money allows to overcome the absence of double coincidence of wants.

[19] The Lagos and Wright (2005) model is a search model of money where each period is divided into two subperiods. In one, agents interact in a decentralised market (DM) with search frictions in the matching process. In the other, they interact in a frictionless centralised market (CM) as in standard general equilibrium theory. In the DM, agents meet randomly and bilaterally, and trade differentiated goods. Fiat money is valued because it allows to overcome potential absence of double coincidence of wants. Moreover, in each match, agents bargain over the terms of trade—in particular, in single coincidence matches, they bargain over the number of units of goods and money exchanged. In the CM, agents trade a single type of goods and rebalance their money holdings in the perspective of the next DM meeting. The CM is introduced only for the sake of tractability: associated with the assumption of quasi-linear preferences (so that there is no wealth effect), agents choose to hold the same number of units of money at the closure of this market; hence, there is no need for the modeller to track an endogenous distribution of money holdings period after period.

[20] Lagos and Wright (2005) showed that the welfare costs of inflation critically depend on the bargaining power of buyers in (single coincidence) matches. When this parameter is equal to one—so that the buyer gets the total surplus associated with a match—the welfare costs of inflation are small. In this case, indeed, the Hosios

stressed that the cashless economy embodied in the three-equation New Keynesian model would make this latter ill-suited to study some important aspects associated with monetary policy. They consider that monetary policy (both conventional and unconventional) mainly affects the economy through its effects on the liquidity of both financial and goods markets—and not simply through interest rate adjustments. The unconventional quantitative measures (termed "Quantitative Easing") implemented in the wake of the 2008 financial crisis (in a context where nominal interest rates hit the Zero Lower Bound) have fostered the development of new monetarist models where the concept of liquidity plays a pivotal role in the transmission mechanism of monetary policy.[21]

Before turning to the second contribution of *Interest and Prices*, it is worth stressing that contrary to equations (1) and (2), the policy rule depicted by equation (3) was postulated and *not* derived from an optimisation programme solved by the central bank. As we shall see in Section 5, the policy rules advocated by Woodford would implement the optimal monetary policy and differ markedly from equation (3) by involving a substantial amount of inertia—taking the form, in particular, of a higher-than-one dependence of the current nominal interest rate on its lagged value. Hence, the three-equation New Keynesian model should be seen primarily as a frame of reference for positive, rather than normative, analysis.

3. Imposing a concept

The concept of *natural rate of interest* has a long history in monetary economics. Initially coined by Knut Wicksell in his own *Interest & Prices* (1898), this concept was extensively used by the Austrian and Stockholm schools of thought, as well as by John Maynard Keynes in the *Treatise on Money* (1930), before falling into oblivion. Partially resuscitated by Milton Friedman in his Presidential Address (1968)—in order to draw a parallel with the natural rate of unemployment—the natural rate of interest raised the attention of only historians of the field since then.

Woodford's book has resuscitated and imposed this concept, especially on central bank economists. The natural rate is now defined as the real interest rate that would emerge if all prices were perfectly flexible. According to Stanley Fischer (then Vice-Chairman of the U.S. Federal Reserve), since the publication of Woodford's treatise "Many Fed researchers […] have attempted to measure the natural rate of interest" (2016, 20). This concept would represent "The most direct impact of Woodford on

(1990) condition for efficiency is satisfied: the bargaining power of the buyer equals her/his contribution to the total surplus of the match (which is one, since without her/his money there would be no surplus in single coincidence matches), and the buyer chooses to hold the efficient amount of money balances when leaving the CM. Inflation reduces the real value of money balances, but since buyers had chosen to hold the efficient amount in the first place, the inflation tax is relatively harmless. In contrast, when the buyers' bargaining power is lower than one, buyers receive a fraction of the total surplus of a match which is lower than their contribution to this surplus. They therefore choose to hold an amount of money balances that is lower than the efficient one. Inflation is particularly harmful in this case, since it reduces the real value of money balances from a level which is already too low.

[21] An illustration of this development can be found in the last chapters of Nosal and Rocheteau (2017), and in the body of work reviewed by Lagos et al. (2017).

Fed thinking and analysis" (2016, 19).[22] Research on the natural interest rate and its variations has been particularly active during the last decade, for two main reasons. First, many central banks have been forced to reduce their short-run nominal interest rates to the Zero Lower Bound (hereafter ZLB) in the wake of the financial crisis, preventing them from being able to meet a temporary fall in the natural rate below zero. Secondly, there has been a renewed interest in the "secular stagnation" issue, and therefore in the possibility of a natural rate permanently below zero. The possibility of a (temporary) negative natural rate of interest was discussed only briefly by Woodford in his *Interest & Prices* (251–52). He would tackle the issue in his joint paper with Gauti Eggertsson (Eggertsson and Woodford 2003) and elsewhere.[23]

In the 1990s, some authors already raised the importance of the real interest rate that would arise in a flexible-price environment for the sake of policymaking. For instance, Goodfriend and King (1997) and Blinder (1998) both recommended what they called a *neutral monetary policy*. Under such a policy, "central bankers should manage a low-inflation targeting regime by making the short-term nominal rate mimic the real short rate that would be ground out by a well-specified RBC model" (Goodfriend and King 1997, 277).[24] However, it was only after the publication of *Interest & Prices* that economists really acknowledged the importance of the natural rate and started to investigate more closely its dynamics. Contrary to the above-mentioned authors, Woodford provided a systematic analysis of the role of the natural rate in the dynamics of inflation. In Chapter 4, he showed that in the three-equation New Keynesian model, inflation and the output gap ($y_t - y_t^n$) can be expressed as functions of the current and expected future "interest-rate gaps"—the differences between the natural rate and the actual real rate. In Chapter 5, he pointed out that this result holds for each new ingredient (namely predetermined expenditure and inflation, habit formation, price indexation, and endogenous accumulation of capital) added to this model. In each case, Woodford systematically stresses that, in order to stabilise inflation, the central bank should "track" the variations of the natural rate.[25,26]

[22] Similarly, according to Mankiw and Reis (2018), "Today and for many years now, Friedman has lost this argument to Woodford (2003), who convinced academics and central bankers to embrace the Wicksellian use of interest rates as the main policy tool and their deviation from natural rates as the key policy target" (90).

[23] The notion of a negative natural rate of interest may be found already in Wicksell (see Boianovsky 2017).

[24] Similarly, in the words of Blinder (1998), "if the real interest rate is below the neutral rate, aggregate demand will eventually exceed potential GDP, leading to higher inflation. Conversely, a real interest rate above neutral will ultimately be disinflationary" (33).

[25] The following quotations illustrate this systematic emphasis: "the key to inflation and output-gap stabilization continues to be the adjustment of interest rates so as to track the variations in the natural rate of interest" (328); "I thus obtain, once again, the same general result as in Chapter 4: Inflation and the output gap are both stabilized, to the greatest extent possible, by commitment to a Taylor rule in which the intercept term tracks variation in the natural rate of interest" (336); "the requirement of tracking variations in the natural rate of interest continues to be as important to the pursuit of price stability as in our analysis of the basic neo-Wicksellian model" (378).

[26] Even though Woodford warns that "keeping track of [the natural rate's] current value would be an important (and far from trivial) task of central bank staff" (287, brackets in the original) and that "one must recognize that in practice, perfect tracking of the current natural rate of interest is impossible, as real-time information about the natural rate is inevitably imprecise" (288), the book tends to downplay the information problem that central banks face when trying to track the natural rate. One year before the publication of *Interest & Prices*, Orphanides and Williams (2002) argued that imperfect observations of this rate should significantly affect the conduct of monetary policy. Interestingly, they found that such imperfect observations would make the optimal policy more inertial—and, consequently, push this policy in the direction advocated by Woodford (see Section 5 below).

Interestingly, we shall see in Section 5 that while remaining a key indicator for the conduct of monetary policy, the natural rate of interest is *not* involved in the rules advocated by Woodford.

4. Unifying the literature

Before the publication of *Interest & Prices*, two distinct branches existed in the literature on optimal monetary policy. The first branch used a theoretically grounded welfare criterion to determine the optimal policy but delivered conclusions far from conventional wisdom. The second branch had implications more appealing for the conduct of monetary policy, but the analysis relied on *ad hoc* welfare criteria. Woodford's book strongly contributed to unify them.

The first branch, following the theoretical framework laid out in Lucas and Stokey (1983), studied the joint determination of optimal fiscal and monetary policy. The government's problem usually consisted in financing an exogenous stream of public spending by choosing the least disruptive combination of inflation and distortionary taxes. In such analyses: i) perfect competition and flexible prices prevailed; ii) the welfare criterion was derived from the utility of the representative household; iii) the optimal rate of inflation was highly volatile in response to exogenous disturbances.[27] The second branch instead focused on optimal monetary policy, taking as given the behaviour of the fiscal authority. In this group of papers, exemplified by Clarida *et al.* (1999): i) firms were engaged in monopolistic competition and prices were sticky; ii) the welfare criterion was a postulated loss function typically assumed to depend on inflation and the output gap; iii) the optimal rate of inflation displayed much smaller responses to exogenous disturbances.

By deriving a "utility-based" welfare criterion in an environment of monopolistic competition and nominal rigidities, Woodford made a key contribution to the unification of these two branches. State-of-the-art procedure now computes the optimal monetary policy by using models with nominal rigidities and maximises a welfare criterion derived along the lines described in Chapter 6 of *Interest & Prices*.[28] Rotemberg and Woodford (1997) initially proposed such a criterion for a specific New Keynesian–DSGE model. However, it was only in his treatise that Woodford presented the derivation method in general terms, showing how to get the welfare criterion consistent with the model used to determine the optimal policy. Moreover, Woodford illustrated his general method by deriving the utility-based welfare criterion associated with each of the price-setting mechanisms investigated in Chapter 3, and with each extension of the three-equation New Keynesian model introduced in

[27] Acting as a lump-sum tax on financial wealth, unanticipated inflation enables the government to keep distortionary tax rates stable over the business cycle. This implication was notably stressed by Chari, Christiano, and Kehoe (1991), and Calvo and Guidotti (1993).

[28] The model used to compute the optimal monetary policy is not necessarily a New Keynesian–DSGE model. For example, Ball et al. (2005) derive the welfare criterion associated with their *sticky-information* DSGE model—rather than *sticky-price* DSGE model—according to the method set out in *Interest & Prices* (they notably call the subsection within which this criterion is derived "Woodford's approximation").

the first part of the book.[29] In Chapter 6, the welfare criterion is thus derived when some prices are predetermined one period in advance, when all prices are set according to the Calvo lottery (with and without partial indexation to past inflation), and when additional ingredients—such as predetermined expenditure, habit formation, transactions frictions, the ZLB on the nominal interest rate, sectoral asymmetries, and sticky nominal wages—are alternatively considered.[30] This led Carl Walsh, in his review of Woodford's treatise, to conclude that "Perhaps the most important contribution of Woodford's work is his successful integration of monetary policy analysis with welfare economics" (2005, 467).

5. Woodford's rule-based approach to monetary policy

While the foregoing contributions represent significant achievements, the main objective of Woodford in writing his treatise was elsewhere. In the introductory chapter, it is especially argued that the book's "most important goal is to provide a method that individual central banks can use in order to choose sensible systematic policies on the basis of their own research on the nature of the transmission mechanism in their respective economies" (58). Accordingly, the present section describes the rules-based approach to monetary policy developed by Woodford in the final two chapters of *Interest & Prices*. This approach involves an explicit commitment to a policy rule which would help implement the optimal responses of the economy to exogenous disturbances. It also involves the formulation of principles that such an "optimal" rule should satisfy to be adopted in practice.

In Chapter 7 (entitled "Gains from Commitment to a Policy Rule"), Woodford stresses the very reason why central banks should explicitly commit themselves to a policy rule. This relates to a then-new aspect of the rules-versus-discretion debate: when the decisions of private agents depend on their expectations of policy actions in future periods, and when central banks cannot stabilise all of their target variables simultaneously, discretionary monetary policy (which maximises social welfare on a period-by-period basis) implies worse stabilisation trade-offs than would the optimal monetary policy (which implements the state-contingent plan that maximises welfare intertemporally). This is the so-called "stabilisation bias" associated with discretionary policymaking.[31] This bias stems from the fact that discretion does not feature the kind of inertial dynamics that Woodford (1999a) termed *history dependence*: in order to improve the stabilisation trade-offs they face, central banks should make the economy keep on responding to exogenous disturbances many periods after the effects of these latter vanished.

Figure 1 illustrates this stabilisation bias and the role played by history dependence for the most basic New Keynesian framework. The economy is indeed assumed to be

[29] As shown by Woodford, however, a model with inefficient natural output and no subsidy usually does not admit a quadratic approximation for the welfare function. Moreover, as rightly pointed out by a referee, Woodford's assumption that the wedge between the two steady-state paths—the one with flexible prices and the one with nominal rigidities—is small and constant over time (in order to be able to discuss welfare losses), is more an article of belief than anything for which we have a shred of behavioural logic or even empirical evidence.

[30] The ZLB, however, is not considered in the first part of the book and appears only from Chapter 6.

[31] As will be emphasised in the next section, the stabilisation bias (identified independently by Clarida et al. 1999 and Woodford 1999a) should be distinguished from the standard "inflation bias"—which is the object of the seminal papers by Kydland and Prescott (1977) and Barro and Gordon (1983).

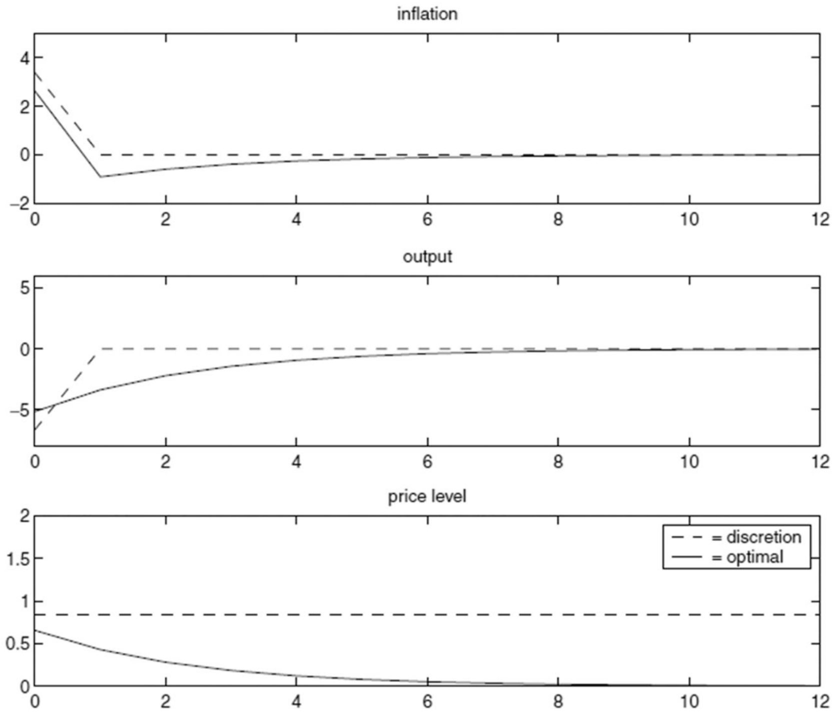

Figure 1. Optimal responses to a transitory cost-push shock compared with equilibrium responses under discretionary policy.[32]

represented by equations (1) and (2), except that a random-disturbance term u_t is added at the end of equation (1)—usually interpreted as a "cost-push" shock.[33] Equation (1) thus becomes:

$$\pi_t = \beta \mathbb{E}_t \pi_{t+1} + \kappa(y_t - y_t^n) + u_t, \qquad (4)$$

Moreover, the central bank is assumed to aim at minimising a quadratic loss function (which can be derived from the utility-based approach that was the object of the previous section) involving only inflation and output—whose target values are zero and y_t^n, respectively. Under discretion, the central bank is assumed to be re-optimising *each period*. The programme solved therefore involves the minimisation of the periodic loss function:[34]

$$\pi_t^2 + \lambda_y (y_t - y_t^n)^2, \qquad (5)$$

[32] Reproduced from *Interest & Prices* (494).

[33] It is worth emphasising that the New Classical Phillips Curve—which is the context in which Kydland and Prescott (1977) and Barro and Gordon (1983) study the inflation bias—does not induce a stabilisation bias. In this case, indeed, firms can adjust their selling price in every period, and thence need to estimate the state of the economy only in the *current* period (which they can observe only imperfectly).

[34] λ_y denotes the relative weight of output stabilisation with respect to inflation stabilisation.

subject to the constraints given by equations (2) and (4), *with expectational terms taken as given*.[35]

Under the optimal plan, the central bank is assumed to be optimising *once and for all*, and to be committing itself to simply implementing the decisions associated with the resulting plan thereafter. The programme solved therefore involves the minimisation of the intertemporal loss function:

$$\mathbb{E}_{t_0} \sum_{t=t_0}^{\infty} \beta^{t-t_0} [\pi_t^2 + \lambda_y (y_t - y_t^n)^2], \tag{6}$$

subject to equations (2) and (4).[36]

Figure 1 displays the responses of inflation and output under each policy regime when a one-period cost-push shock of value one hits the economy (i.e., $u_0 = 1$, $u_1 = u_2 = u_3 = 0$).[37,38] Before the shock takes place, inflation and output are assumed to be at their respective target values. Moreover, since the model does not feature endogenous persistence, both variables can be brought back to target in period one. It can be seen from Figure 1 that when the shock is occurring, inflation increases substantially more under discretion than under the optimal plan. At the same time, the fall in output is roughly similar under both policy regimes.[39] Hence, there is a stabilisation bias associated with discretion: discretion involves a less favourable trade-off between stabilising inflation and stabilising output than does the optimal plan. It can also be seen that, under discretion, inflation and output come back on target one period after the occurrence of the shock. This means that, under discretion, the effects of the shock on the economy last only as long as the shock itself. Under the optimal plan, by contrast, inflation and output keep on responding to the shock well after its effects vanished. This means that, under the optimal plan, the dynamics of the economy in a given period reflect the occurrence of shocks whose effects may be over for quite a long time. Hence, the optimal plan is—while discretion is not—"history dependent."

How does the history dependence displayed by the optimal plan improve the stabilisation trade-off faced by the central bank? Simply because by committing itself to

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[35] Private expectations are taken as given because the central bank, by re-optimising every period, internalises the fact that the private sector would ignore any announcement regarding future decisions.

[36] An economy represented by the same loss function but with equation (1) replacing equation (4)—i.e., in the absence of cost-push shocks—would involve no stabilisation trade-off (since both inflation and output can be fully stabilised simultaneously in response to the sole shocks on y_t^n) and, consequently, no stabilisation bias. Blanchard and Galí (2007) characterised such an economy as one in which a "divine coincidence" would be applying—in the sense that achieving complete stabilisation of one target variable automatically leads to the complete stabilisation of the other one. They showed that introducing some real imperfections (such as real wage rigidities) would break this unrealistic feature (and, therefore, reintroduce a stabilisation trade-off) without requiring ad-hoc cost-push shocks.

[37] Obviously, "period zero" in Figure 1 (the period when the shock occurs) has nothing to do with 'period t_0' (the period when the optimal plan was derived and the associated commitment was made).

[38] Galí (2008, Chap. 5) generalises the analysis to persistent cost-push shocks.

[39] Since y_t^n is not affected by shocks on u_t, variations in y_t reflect variations in $y_t - y_t^n$ and, accordingly, variations in welfare losses.

responding to shocks in an history-dependent fashion, the central bank is able to steer private-sector expectations in a way that furthers its stabilisation goals. In particular, a commitment to maintaining an inflation rate below zero for many periods induces negative expectations about future inflation when an inflationary cost-push shock hits the economy. According to equation (4), a negative value for $\mathbb{E}_0\pi_1$ partially offsets the effects of a positive value of u_0 on π_0. This reduces the fall in y_0 that the central bank should generate to stabilise π_0. Under discretion, by contrast, the public expects inflation (as well as output) to be brought back to its target as soon as the effects of the shock vanish. According to equation (4), a zero value for $\mathbb{E}_0\pi_1$ implies an higher increase in π_0 in response to the same increase in u_0. The central bank should therefore generate a larger fall in y_0 to stabilise π_0. In other words, a commitment to maintaining an inflation rate below its target many periods after the effects of the shock vanish presents the central bank with a better trade-off between stabilising inflation and stabilising output when the shock is occurring.[40]

The main conclusion emerging from this analysis is that discretionary monetary policy should be avoided because its lack of history dependence would induce larger fluctuations in the variables central banks aim at stabilising. At the same time, while a commitment to implementing the optimal state-contingent plan would be desirable, designing such a plan seems hardly possible in practice—not least because this would require central banks to know in advance all the possible realisations of shocks that could happen in the future. However, a well-known result from optimal control theory (especially stressed in economics by Holt 1962 and Chow 1970) is that, in the context of a quadratic loss function and linear constraints, the optimal policy can be expressed as a feedback *rule*—where the involved reaction to observed movements in endogenous variables would capture the effects of past and current disturbances. It is also well known from this literature that many different rules could implement the optimal policy.

Accordingly, the aim of Chapter 8 is to provide some *principles* that should help central banks to select one of these "optimal" rules for the conduct of monetary policy. In the introductory chapter, Woodford notably claims that formulating principles of this kind is actually the main objective of his book: "The primary task of this study is to provide principles that can be used in the design of such rules" (21). In his eyes, this task would even be the most critical one monetary theory should tackle at present time: "The central problem of the theory of monetary policy is to provide principles that can be used in selecting a desirable rule for setting a central bank's interest-rate operating target" (37).

In Chapter 8, Woodford proposes four principles that a policy rule—on top of being optimal (and, consequently, history-dependent)—should satisfy to be adopted in practice.

[40] It may not be obvious at first glance that welfare losses are lower under the optimal plan than under discretion. Indeed, the fact that inflation and output deviate from their respective target values for many periods under the former regime results in higher losses than under the latter regime—where both variables are on targets. However, total losses are actually lower under the optimal plan because of the quadratic nature of the loss function—which penalises heavily large deviations from targets. As a result, the lower losses associated with the optimal plan when the shock hits the economy more than offset the higher losses in subsequent periods.

First, the selected rule should guarantee the *uniqueness* of the equilibrium associated with the optimal policy. This principle would especially avoid the emergence of much less desirable outcomes (such as sunspot equilibria).[41]

Second, the selected rule should be *direct*, meaning that it should only involve target variables. This would help communicate the rule to the public, thereby fostering accountability and verifiability. A main implication of this principle is that the rule should involve the nominal interest rate—thus representing, in the terminology introduced by Lars E.O. Svenson in Svensson (1999), an "instrument rule"—only to the extent that this latter also belongs to the set of variables central banks aim at stabilising around a specific value.

Third, the rule should be selected from a *timeless perspective*. This means that when central banks compute the optimisation programme to derive the rule, they should behave as if this computation had been performed *far in the past* (i.e., assuming $t_0 \to -\infty$ when minimising equation (6)). Such a procedure would guarantee the *time invariance* of the selected rule—in the sense that if a similar computation were performed several periods later (with the same loss function and the same constraints), the same rule would arise.[42] This time invariance would help establish the credibility of the commitment to the rule. Moreover, the timeless perspective would enable central banks to revise the rule every time the model representing their respective economies is itself revised.[43] Hence, the timeless perspective would prevent central banks from being committed to a rule that is actually far from being optimal.

Fourth, the coefficients of the selected rule should be independent from the (assumed) statistical properties of the shocks that can hit the economy. This principle implies that the rule is *robustly optimal*: as long as the shocks enter the equations of the model additively (and that their size is bounded), the rule remains optimal even when the number of different shocks considered becomes extremely large (and is not necessarily finite).[44]

According to Woodford, the last two principles would allow avoiding "the sorts of rigidity that are often associated with commitment to a "rule" and that probably account for much of the resistance that central bankers often display toward the concept of a policy rule" (24). Hence, they would help selecting a rule that would represent "a policy commitment that a central bank could reasonably make" (521). The robustness involved in the fourth principle, in particular, would overcome "one of the most important practical objections to the idea of *commitment* to a policy rule" (548, italics in the original)—namely the belief widely held by central bankers (and most academics) that no rule could be effective under all circumstances.

[41] We have pointed out in Section 2 of the present paper that Chapters 2 and 4 of *Interest & Prices* provide a thorough analysis of the conditions ensuring determinacy/uniqueness of equilibrium.

[42] The extent to which the timeless perspective ensures that the selected rule is *time consistent* in the sense of Kydland and Prescott (1977) is the object of current work by one of the authors of the present paper.

[43] This would indeed be the case because the timeless perspective would prevent central banks from taking advantage of the fact that expectations of future policy are frozen at the time the new rule is derived. Accordingly, "A central bank might reconsider this question as often as it likes, without being led into the kind of suboptimal behavior that results from discretionary optimization" (pp. 23-24).

[44] This result is reminiscent of the 'certainty equivalence' principle put forward by Simon (1956) and Theil (1957) in the context of a similar linear-quadratic framework.

Two examples—both associated with the most basic New Keynesian framework involving equations (2) and (4)—can serve to illustrate the kind of rules that would result from the application of the foregoing principles. Let us first consider the environment that has been used to derive the optimal responses depicted in Figure 1. Equation (7) represents a rule that would not only emerge from the minimisation of equation (6) subject to equations (2) and (4), but would also meet Woodford's four principles:

$$\pi_t = -\frac{\lambda_y}{\kappa}(x_t - x_{t-1}), \tag{7}$$

where $x_t = y_t - y_t^n$ denotes the output gap in period t.

This rule implies that, in a given period, the central bank should adjust its instrument such that the inflation rate in this period equals a value determined by the rate of change of the output gap over that same period. Since it involves a particular relationship between target variables that the central bank should seek to bring about in every period (without any reference to the instrument of monetary policy), such a rule is (again in the terminology of Svensson 1999) an example of "specific targeting rule."

Let us now consider an economy still composed of equations (2) and (4), but with a central bank also concerned about stabilising the nominal interest rate around a specific level.[45] The welfare loss function is now given by equation (8):

$$\mathbb{E}_{t_0}\sum_{t=t_0}^{\infty}\beta^{t-t_0}\left[\pi_t^2 + \lambda_y\left(y_t - y_t^n\right)^2 + \lambda_i\left(i_t - i^*\right)^2\right], \tag{8}$$

Where i^* denotes the target level of the nominal interest rate, and λ_i the relative weight of interest-rate stabilisation (with respect to inflation stabilisation).

Equation (9) represents a rule that would arise from the minimisation of equation (8) subject to equations (2) and (4), and would at the same time meet Woodford's four principles:

$$i_t = (1-\rho_1)i^* + \rho_1 i_{t-1} + \rho_2(i_{t-1} - i_{t-2}) + \Phi_\pi \pi_t + \Phi_x \frac{(x_t - x_{t-1})}{4}, \tag{9}$$

with $\rho_1 = 1 + \frac{\kappa\sigma}{\beta} > 1,\ \rho_2 = \beta^{-1} > 1,\ \Phi_\pi = \frac{\kappa\sigma}{\lambda_i} > 0,\ \Phi_x = 4\sigma\frac{\lambda_y}{\lambda_i} > 0$

This rule implies that, in a given period, the nominal interest rate should increase with its level in the previous period, with its rate of change over the previous period, with the inflation rate in the current period, and with the rate of change of the output gap over the current period. Since it provides the central bank with a formula for setting the instrument of policy in each period, and since it requires adjusting the instrument in a given period with respect to the estimate of some variables for this period (which, in turn, depends on the value chosen for the instrument in that same period),

[45] Once again, the utility-based approach developed in Chapter 6 of *Interest & Prices* can provide microfoundations for such a loss function. In particular, interest-rate stability can emerge as a policy goal when a lower bound on the nominal interest rate is explicitly considered.

such a rule is an example of "implicit instrument rule."[46] Moreover, since it involves a higher-than-one coefficient of the current interest rate on its lagged value (i.e., $\rho_1 > 1$), this rule is also an example of what Woodford (1999b) called a "super-inertial" rule.

As briefly noted at the end of Section 3, the rules resulting from Woodford's approach make no reference to the natural rate of interest—to which Woodford gives pride of place in the positive analysis conducted in the first part of *Interest & Prices*. This stems from Woodford's second principle, according to which the selected rule should only involve variables that the central bank aims at stabilising. The natural rate remains, however, a key indicator for the practical implementation of these rules. Indeed, the dynamics of both inflation and the output gap critically depend on the variations in the natural rate. Moreover, both equations (7) and (9) imply that the central bank should react to the values of its target variables in the current period—values that the central bank is not able to observe when setting its instrument, and that it should consequently estimate. Thus, "tracking" the natural rate is crucial for correctly estimating the current values of inflation and the output gap, and thence for setting the instrument at a level that implements the selected rule.

In Chapter 8, Woodford also derives optimal rules that satisfy his four principles for all of the extensions of the basic New Keynesian framework developed in the first part of the book. For some extensions, the derived rules are not much different from (and, in a few instances, even identical to) either equation (7) or (9). Differences are more substantial for other extensions—and the derived rules become quite complicated when some of these extensions are combined. However, Woodford stresses that all these rules share a critical feature: they all involve a large amount of history dependence. Moreover, the strong history dependence underlying them tends to dominate their other (specification-dependent) features. This suggests that rules derived from simple versions of the New Keynesian framework would probably perform relatively well in more complex versions. In other words, the large amount of history dependence characterising optimal rules would make them relatively robust across specifications of the New Keynesian model.

Finally, it is worth emphasising that since the publication of *Interest & Prices*, Woodford has systematically pointed out the strong history dependence underlying the optimal rules derived from many other extensions of the New Keynesian framework. This has been especially the case when distortionary taxes were introduced (Benigno and Woodford 2003), under alternative fiscal regimes (Benigno and Woodford 2007), when expectations were only "near rational" (Adam and Woodford 2012), when "structural" inflation was accounted for (Woodford 2012a), when financial stability was assumed as an additional stabilisation goal for monetary policy

[46] By contrast, an 'explicit instrument rule' relates the instrument of policy in a given period only to predetermined and exogenous variables (which, by definition, are not affected by the value chosen for the instrument in that period). In Chapter 8, Woodford points out that an instrument rule satisfying all his principles can only be of the implicit type. Indeed, the optimal policy calls for starting responding to shocks in the period when they hit the economy (even if, due to the history dependence of the optimal policy, this response should be smoothed across periods). An explicit instrument rule can implement this contemporaneous response only if it involves the random terms associated with the shocks. However, this would not satisfy Woodford's second principle—namely that the selected rule should involve only target variables.

(Woodford 2012b), when credit market frictions were introduced (Cúrdia and Woodford 2016), or when a housing sector was considered (Adam and Woodford 2021).

6. Woodford's rules-based approach and the actual practice of monetary policy

Woodford's contributions to the analysis of optimal monetary policy have been very influential on economists working with New Keynesian models. On top of using Woodford's (and Rotemberg's) method to derive a utility-based welfare criterion (the subject of Section 4 above), these economists usually express the optimal monetary policy associated with their models by feedback rules that satisfy Woodford's "principles." Most of the time, indeed, these rules are derived from a timeless perspective (in accordance with Woodford's third principle), involve only target variables (in accordance with Woodford's second principle), and involve coefficients that are independent from the statistical properties of the shocks that hit the model economy (in accordance with Woodford's fourth principle). The optimal policy (and the rules that would implement it), however, is first and foremost considered as a theoretical benchmark against which to evaluate the actual policy and alternative policy proposals. None of the economists belonging to the New Keynesian tradition (to the best of our knowledge) has ever advocated the adoption of an optimal rule (even suitably designed along Woodford's principles) for the conduct of monetary policy. They instead promote proposals that are more general (and more abstract), and that usually involve a good deal of discretion. These proposals, in fact, very often belong to a policy framework termed "constrained discretion" by Ben Bernanke and Frederic Mishkin in Bernanke and Mishkin (1997). In a speech delivered in 2003, Bernanke describes constrained discretion as a "middle-ground" between rules and discretion where policymakers are allowed "considerable leeway in responding to economic shocks, financial disturbances, and other unforeseen developments. Importantly, however, this discretion of policymakers is constrained by a strong commitment to keeping inflation low and stable."

Furthermore, even authors (such as the signatories of the 2016 "Statement on Policy Rules Legislation") sympathetic to the idea of adopting a rule for the conduct of monetary policy usually do not recommend the highly history-dependent rules put forward by Woodford.[47] This may stem from the fact that, even though Woodford has suggested that such rules tend to perform relatively well across many different specifications of the (forward-looking) New Keynesian framework, it is now well known that they perform very badly when evaluated in models featuring

[47] Under the lead of Taylor, this "Statement" supported a legislation embedded in the "Monetary Policy Transparency and Accountability Act." This legislation was submitted by the Republican Party and passed the House of Representatives in November 2015 (but failed to pass the Senate). Based on the proposal initially made by Taylor (2011), it required the Fed to select a policy rule (the so-called 'directive rule') for the conduct of monetary policy, to compare the selected rule with the standard Taylor rule (the so-called 'reference rule'), and to subsequently explain any deviation from the selected rule. On top of Taylor, the "Statement" involved twenty-four signatories, among whom the Nobel Prize laureates Lars Peter Hansen, Robert Lucas, and Edward Prescott.

backward-looking behaviour. This lack of robustness regarding model uncertainty was notably stressed at the occasion of the National Bureau of Economic Research (NBER) conference on "Monetary Policy Rules" organised by Taylor in 1998, and whose proceedings were published in Taylor (1999a). There, on top of deriving the optimal policy rules from the different models they were using, participants (to whom Woodford belonged) were asked to simulate five simple instrument rules of the form:

$$i_t = \rho_1 i_{t-1} + \Phi_\pi \pi_t + \Phi_y (y_t - y_t^n), \tag{10}$$

The rules differed only in the values of the coefficients ρ_1, Φ_π, and Φ_y. One of these rules ("Rule V" in Taylor 1999b, 1999c) was super-inertial—featuring a value for ρ_1 equal to 1.3—and, consequently, strongly history dependent. It was the optimal rule (among the class depicted by equation (10)) for the purely forward-looking model of Rotemberg and Woodford (1999). A main finding was that this rule turned out to be unstable (i.e., generating infinite variances for most endogenous variables) in the purely backward-looking models of Ball (1999) and Rudebusch and Svensson (1999), as well as in the hybrid one of Batini and Haldane (1999). The instability of history-dependent rules in backward-looking models stems from the fact that the optimal policy is highly forward looking in these latter models—at odds with the inertia characterising history-dependent rules.[48] Thus, while robust across specifications of the New Keynesian model, these rules are not robust across alternative classes of macro models.[49]

Remember that a central aspect of Woodford's rules-based approach to monetary policy is the *explicit* commitment to a policy rule central banks should make to help implement the optimal responses of the economy to shocks. Again, the explicitness of the commitment stems from the history dependence underlying the optimal policy: the stabilisation trade-offs faced by central banks at the time shocks hit the economy are effectively improved only to the extent that private agents actually *expect* that monetary policy will be history dependent thereafter; an explicit commitment to conducting such a policy is therefore required in order to steer expectations in the right direction. Hence, it would be nonsensical to adopt a policy rule involving a large amount of history dependence without being explicitly committed to that rule. In the words of Woodford: "There is no point to a secret commitment to the future conduct of policy in accordance with a history-dependent rule while the private sector continues to believe that the central bank will act in a purely forward-looking fashion" (2004, 20).

Accordingly, whether central banks have tended to explicitly commit themselves to a history-dependent rule since the publication of *Interest & Prices* seems to be a relevant criterion for assessing the influence of Woodford's rules-based approach on

[48] Leitemo (2008) notably shows that the more backward-looking price setters are, the less inertial (i.e., history-dependent) monetary policy should be—and vice versa.

[49] In addition, it is also worth mentioning that Woodford's rules are not robust to another source of uncertainty—namely multiplicative uncertainty. It is indeed well-known from Brainard (1967) that the certainty equivalence principle underlying the 'robustly optimal' dimension of these rules does not hold when uncertainty is multiplicative rather than additive. This kind of uncertainty arises, in particular, when central banks can estimate only imperfectly the parameters of the models that would be used to derive their policy rules.

actual policymaking. For better or worse, none of the major central banks around the world has (thus far) made a commitment of this kind. While addressing such an issue can only be (at best) speculative, we believe there are two main explanations for this situation.

First, policy rules (history-dependent or not) do not fit easily into decision processes giving pride of place to the use of central-bank "judgement"—defined by Svensson (2005) as "information, knowledge, and views outside the scope of a particular model" (2). According to Mishkin, who was a member of the Board of Governors of the Fed between 2006 and 2008, "Monetary policy is as much an art as a science. Monetary policymakers look at a wide range of information in order to decide on the best course for monetary policy, and some of this information is not easily quantifiable […] Judgement, which in its nature is discretionary, is thus an essential element of monetary policy to stabilise inflation and output" (2017, 8). This would be an important reason why many central banks have adopted an approach to monetary policy termed "forecast targeting" by Svensson (2005)—an approach belonging to the "constrained discretion" framework mentioned above. In a speech delivered in 2004, Bernanke (then member of the Board of Governors of the Fed) describes this approach as follows: "Under a *forecast-based policy* regime, policymakers must predict how the economy is likely to respond in the medium term—say, over the next six to eight quarters—to alternative plans for monetary policy […] Under a forecast-based approach, for each policy plan under consideration, the policymakers and their staffs must make their best guess of how the economy is likely to evolve should that plan be implemented. They may also try to assess the likelihood of outcomes other than their principal scenario […] Taking both their baseline forecast and the various risks to that forecast into account, policymakers then choose the plan that seems most likely to produce the best results overall. Their current choice of interest rate corresponds to the first step in implementing the preferred plan" (italics in the original). Observing that "the Federal Reserve relies primarily on the forecast-based approach for making policy," Bernanke imputes this reliance to the fact that, while both forecast-based and rules-based approaches involve a commitment to the goals of monetary policy, "the forecast-based approach provides more guidance about how to incorporate judgement and special information into policymaking […]: Judgement or special information should affect policy choice to the extent that it affects the forecast or the risks to the forecast."[50]

Second, the gains from commitment to a policy rule emphasised by Woodford may be downplayed by central bankers. In particular, the quantitative significance of

[50] Svensson (2005) provides a similar account of, and a similar rational for, forecast targeting. Interestingly, while Svensson was initially quite sympathetic to using optimal targeting rules (such as equation (7)) for the practical implementation of what he called 'inflation-forecast targeting' in his 1997 seminal contribution, he gradually moved to the more general approach developed in Svensson (2005). There, it is argued that "Optimal targeting rules remain a practical way of representing optimal monetary policy in the small models usually applied for academic monetary policy analysis. However, for the larger and higher-dimensional operational macromodels used by many central banks in constructing projections, the optimal targeting rule becomes more complex and arguably less practical as a representation of optimal monetary policy" (2005, p. 6). The same argument (with the same wording) is made in the survey written for the second edition of the *Handbook of Monetary Economics* (Svensson 2010, p. 1264). Similarly, in his 2020 piece Svensson stresses that he is now considering "optimal targeting rules from more realistic models non-operational" (p. 75), and believes that "it is so far unrealistic to use optimal targeting rules as guides for practical monetary policy".

the stabilisation bias—which, according to Woodford, is the main reason why central banks should commit themselves to a (history-dependent) policy rule—is not at all clear. For instance, McCallum and Nelson (2004) found that the welfare gains from commitment to an optimal rule were quite sensitive to the values chosen for the parameters characterising the structural model and the (associated) loss function. For the basic New Keynesian case involving equations (2), (4), and (6), a commitment to the optimal rule represented by equation (7) would reduce welfare losses by 20% on average with respect to discretion, but this figure would fall to about 2% for some combinations of parameter values. Moreover, we have noticed above that the optimal policy becomes more forward looking when some backward-looking behaviour is introduced. This means that this policy converges to (and, in entirely backward-looking models, even corresponds to) discretion in such environment. Since the stabilisation bias is then made weaker, the gains from commitment to a rule implementing the optimal policy would be even lower. Hence the scepticism of some prominent authors, like Svensson, regarding the size—and even the sign—of these gains.[51]

Furthermore, the stabilisation bias has received much less attention than the standard "inflation bias"—which involves an inflation rate under discretion that is inefficiently high *on average*—identified by Kydland and Prescott (1977) in their pioneering contribution.[52] However, it is well-known that this latter bias can be avoided without abandoning discretionary policymaking—notably, as first suggested by Rogoff (1985), by appointing a central banker with stronger distaste for inflation than the representative agent (i.e., with a lower λ_y). Therefore, it may well be the case that central bankers believe that it is possible to overcome an important part of the inefficiencies associated with discretion without having to commit themselves to a policy rule. Moreover, in the paper where they (concomitantly with Woodford 1999a) identified the stabilisation bias, Clarida *et al.* (1999) pointed out that Rogoff's solution to the inflation bias would also considerably mitigate the stabilisation bias.[53] Hence, even the stabilisation bias could be avoided without abandoning discretion—and, accordingly, without requiring a commitment to a policy rule.[54]

Before concluding this paper, it is important to note that since they are underlying what is called "forward guidance," history-dependent policies have actually been conducted by many central banks in the wake of the Great Recession and the COVID-19

[51] In his 2003 paper, in particular, Svensson stressed that "discretionary optimization results in stabilization bias and a lack of history dependence. The practical and empirical importance of the inefficiency caused by discretionary optimization is not obvious, though. It is perfectly possible that, in realistic models with considerable inertia and strong backward-looking elements, this inefficiency is overwhelmed by benefits from both specifying clear objectives for monetary policy and allowing all relevant information and judgment to bear on monetary policy decisions" (p. 454).

[52] The inflation bias is therefore a steady-state result, whereas the stabilisation bias relates to dynamics. The inflation bias emerges when the central bank seeks to achieve a level of output that is above the natural one. Since the conditions leading to each bias are different, the inflation bias and the stabilisation bias work independently from each other. Hence, an economy can feature one without necessarily featuring the other. For instance, since the central bank was not trying to push output above its natural level (as can be seen from the loss functions depicted by equations (5), (6) and (8)), the economies considered in the previous section were *not* subject to the inflation bias—but nevertheless subject to the stabilisation one.

[53] See their Result 7, page 1680.

[54] Other authors (such as Jensen 2002, Walsh 2003, and Vestin 2006) have also stressed that the optimal responses to shocks can be replicated (or closely approximated), within the realms of discretionary policymaking, by suitable adjustments of the loss function retained.

pandemic. However, these policies have essentially taken the form of announcements of future actions aimed at mitigating the negative effects associated with the ZLB on the nominal interest rate. They were *not* part of a commitment to a policy rule involving both normal times and crisis conditions. In the first pages of his contribution to the 2012 Jackson Hole symposium, Woodford especially made it clear the gap between the forward guidance then practiced by most central banks and his own approach relying on a firm commitment to a rule: "In the case of forward guidance, it has been tempting for central bankers to believe that they can affect financial conditions simply by offering forecasts of likely future policy, while not really tying their hands with regard to future policy decisions. But instead, I shall argue that the most effective form of forward guidance involves advance commitment to definite criteria for future policy decisions" (Woodford 2012c, 187). Again, the commitment should be as explicit as possible: "In practice, the most logical way to make such commitment achievable and credible is by *publicly stating the commitment*, in a way that is sufficiently unambiguous to make it embarrassing for policymakers to simply ignore the existence of the commitment when making decisions at a later time" (191, italics in the original).[55]

7. Concluding remarks

This paper has argued that, despite significant achievements, Woodford's *Interest & Prices* has (so far) missed its target: to convince central bankers that they should explicitly commit themselves to history-dependent rules to help implement the optimal responses of the economy to exogenous disturbances. In the remainder of this concluding section, we will briefly investigate how Woodford, in the wake of the 2008 Global Financial Crisis, dealt with an important missing topic from his treatise—namely financial stability.

Throughout *Interest & Prices* "*complete financial markets*" (64, italics in the original) are assumed, in the sense that available financial assets completely span "the relevant uncertainty faced by households about future income, prices, taste shocks, and so on, so that each household faces a single intertemporal budget constraint." While assuring the transversality condition and model tractability, that assumption is behind the absence of commercial banks (and financial intermediaries in general) from the book. After the 2008 financial crisis, that became a handicap. Indeed, Woodford's 2003 macroeconomic model shared the missing financial intermediation with many other models then prevailing. In a series of papers (Cúrdia and Woodford 2016; Woodford 2010; 2012b), Woodford expanded his 2003 framework by adding financial intermediation to the original model.

The key to building a model integrating financial intermediation and credit frictions into macroeconomic analysis, from Woodford's perspective, is to consider an institutional feature of the American (and other) financial system. That is, the existence of a market-based financial system in which intermediaries fund themselves by selling securities (as did the Lehman Brothers) instead of collecting deposits subject

[55] The term 'commitment' is used on 106 instances in that contribution.

to reserve requirements. Multiple interest rates, and the spread between the interest rates available to savers and borrowers, are part of that setting. Moreover, the capital of intermediaries is turned into a main determinant of the supply of intermediation. The leverage ratio is deemed to be a negative function of the spread between the lending and deposit rates of commercial banks, which varies according to economic shocks. Financial stability becomes an additional goal of monetary policy in this new setting, although not incompatible with the other stabilisation goals.[56]

Interestingly, there are some parallels between Woodford's approach to financial intermediation in the wake of the 2008 crisis and Wicksell's (1908) interpretation of the American financial crisis of 1907—the historical event that most resembled the Great Recession of 2008-09. The immediate cause of the 1907 crisis was the failure of the third-largest trust company in New York, the Knickerbocker. The lower reserve requirements and looser regulation of trust companies led them to holding portfolios of riskier assets using collateralised loans. As discussed by Wicksell (see also Boianovsky 2011), American trust banks featured high leverage because of their operations as hedge funds, with relatively small capital. Hence, similarly to Woodford nearly a hundred years later, Wicksell expanded the scope of his monetary theory and policy framework to take account of financial instability and complex financial intermediation.[57]

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[56] For a comparison between Woodford's and other models of credit frictions, from the perspective of Axel Leijonhufvud (who introduced Woodford to Wicksellian economics), see Trautwein (2020, pp. 16-17).

[57] As rightly stressed by a referee, in spite of these similarities there are significant differences between the focus and thrust of Woodford's and Wicksell's respective arguments. Wicksell's article was essentially a plea for lending of last resort. He defined full elasticity of the loan supply at times of crisis as a basic requirement of sound banking. On the other hand, Woodford's introduction of time-varying spreads in interest rates available for savers and borrowers looks more like a minimal introduction of financial frictions into his earlier framework.

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