

## Edmund S. Phelps and Modern Macroeconomics

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It is not easy to summarize Ned Phelps's monumental contribution to economics. A first impression is likely to be of a vast array of original concepts and models: the "natural rate of unemployment" and the expectations-augmented Phillips curve (1967, 1968, 1971), the "island" parable of search unemployment (1968, 1969, 1970), "incentive/efficiency wages" (1968), optimal inflation targeting over time (1967, 1972, 1978), the consequences of staggered wage-setting for unemployment dynamics (1977, 1979) and for disinflation (1978), the "customer market" model of pricing (1970, 1994), the roles of education and technological diffusion in long-run growth (1966), "golden rules" for investment in physical capital (1961) and in research (1966), dynamic inconsistency in savings behavior (1968), statistical discrimination (1972), and "structuralist" models of endogenous variation in the natural rate of unemployment (1994).

Nearly all of these innovations have had a substantial impact, and some have been developed further by others in ways that have won considerable recognition. Thus the golden rule was further developed in the "overtaking principle" of Weizsäcker; the Phelps-Koopmans dynamic inefficiency theorem led to results by Cass (1972); the "island" parable was used in the celebrated rational-expectations business-cycle model of Lucas (1972) and in the analysis of equilibrium unemployment by Lucas and Prescott (1974); Phelps's conception of equilibrium unemployment was further developed by Stiglitz (1973); the model of staggered wage-setting was developed econometrically by Taylor (1979, 1980, 1993); the efficiency wage model was later extended to shirking by Calvo (1979) and Shapiro and Stiglitz (1984); the "customer market" model played a central role in the analysis of Okun (1981); the labor-market hysteresis hypothesis was tested by Blanchard and Summers (1985); the Nelson-Phelps view of role of education in technical progress has been an important theme of the recent Schumpeterian growth literature; the Phelps-Pollak time-inconsistent preferences have been built on by Laibson (1997) and others; the "Phelps problem" of optimal inflation planning has been extensively analyzed by authors including Taylor (1979) and Sargent (1999); the relation between population and technical progress relation is stressed in the recent work of Jones (1995) and others; the "structuralist" theory of an endogenous natural rate has been tested in econometric work by Blanchard, Bean, and others; and so on and on.

Yet we believe it is also possible to see Phelps's primary contribution as the unfolding of a *single* central project: *introducing imperfect information, with its associated market frictions, and imperfect knowledge, with its consequent complications, into macroeconomics*. This contribution has been of fundamental importance, not only to the development of macroeconomics over the past thirty-five

years, but to much of the most exciting work at the current research frontier, some of which is on display in this volume. True, Phelps was not the first economist to have attempted a break with the neoclassical paradigm of perfect information and knowledge. Among prewar theorists, Schumpeter, Knight, Keynes and Hayek each stressed themes of this sort, though their ideas were not accepted by all, and were certainly not assimilated into the core of mainstream economic theory. But it has been only since the 1960s and 1970s that it has begun to be possible to see how to revise the postulates of the neoclassical paradigm with regard to information and knowledge, while retaining a theory of comparable scope and power. Phelps has arguably been the pivotal figure in this new informational-expectational line of economic research; in particular, he was the first to stress the importance of reorganizing macroeconomic theory around issues of this kind, and to show how this could actually be done.

### **The “Phelps Program” in Macroeconomics**

Here we try to briefly summarize the main steps of what we perceive as Phelps’s unified *demarche*. In a first major effort, from the late 1960s, Phelps pioneered the first generation of models of unemployment and inflation based on micro-foundations, in which firms and employees have to make their current decisions before learning or inferring the average price, wage and employment decisions made by others. This was followed in the 1970s by work on models with staggered wage or price commitments, so that a firm’s effective expectational error could eventually become large even if there had originally been no misunderstanding of the firm’s environment. In a more radical effort made in the early 1980s, Phelps explored models in which each firm used a model to form its expectations, but did not assume that the expectations of others were based on the same model. Finally, his nonmonetary micro-macro models in the ’90s show that, even if we exclude both errors in expectations and delays in price adjustment, changes in the structure of the economy for exogenous reasons can generate large and fairly persistent shifts in the equilibrium path of unemployment. While these “structuralist” models stress the variation over time in the “natural rate” of unemployment, in the sense of a rate of unemployment that involves no expectational error, Phelps’s work continues to stress the *inefficiency* of the equilibrium unemployment rate, owing to pervasive information asymmetries. Let us now consider some of these steps in more detail.

#### *Incomplete Information, Expectations, and the Phillips Curve*

Phelps is perhaps best known for his contributions to the analysis of the effects of purely nominal disturbances, due for example to changes in monetary policy, upon real activity and employment. A perennial question in economic theory asks why an increase in the volume of nominal expenditure should result in a temporary increase in real activity, and not simply in a proportional increase in all money wages and prices, with no effect at all upon relative prices or any real quantities. In Phelps’s work, this is argued to result from the nature of wage and price-setting in a non-Walrasian world, where no “auctioneer” coordinates the

adjustment of wages and prices so as to instantaneously clear markets. Phelps (1970) offers the parable of an economy in which goods are produced on separate “islands,” each with its own labor market. Wages and employment decisions must be made on each island without an opportunity to observe what is being done on other islands. An increase in nominal expenditure across all of the islands due to loose monetary policy need not be immediately recognized as such on individual islands, and as a result wages and prices need not immediately adjust to the extent required to neutralize any effect upon the real quantities produced and consumed.

A crucial feature of Phelps’s analysis of decision-making in such a setting is the attention he gives to average *expectations* as a key state variable, in addition to such directly measurable variables (for an econometric modeler, after the fact) as the actual levels of wages and prices. In the models of Phelps (1967, 1968a), firms’ expectations of the level (or rate of change) of average wages and prices are critical determinants of their individual wage- and price-setting, and thus of employment and output. This is important, in that it allows Phelps to explain how real variables can be affected by changes in nominal quantities --- as was asserted in Keynes’ discussion of the “aggregate supply” schedule, and in the interpretation of econometric “Phillips curves” that had become popular in the 1960s --- without having to violate the crucial precept of rational decision theory according to which the absolute level of prices (as opposed to relative prices) should not affect people’s choices. His solution to the puzzle was to argue that the aggregate supply schedule or Phillips curve should actually be specified as a relation between employment (or output) and the difference between *actual and expected* levels (or rates of change) of wages and/or prices.

A key implication of Phelps’s analysis was the argument that while real effects of monetary disturbances could be important in the short run, they would have to be purely transitory. Subjective estimates of market conditions should not remain out of line with what actually occurs forever, and as a result both real activity and employment should return before long to their “natural” levels --- the equilibrium levels in the case of fulfilled expectations --- that depend solely upon real factors (Phelps, 1967). This *natural rate hypothesis* (also associated with Friedman, 1968) is surely one of the most important ideas in macroeconomics of the past fifty years; it has had profound consequences both for theory and for the practical conduct of monetary policy. Of course, Phelps’s conception of the “natural rate” implies neither that it is constant over time (and hence easily knowable with accuracy) nor that it should be regarded as in any way optimal; but its existence implies an important limit to what one can expect to achieve with monetary policy alone.

The recognition that inflation expectations are a crucial state variable has implied that banks must be more conscious of how their actions may shift expectations. Phelps (1972a) argues that monetary policy must as a result be conceived as an *intertemporal* planning problem, with policy at each time being judged partly on the basis of its effects upon the evolution of inflation expectations (modeled there in terms of a simple “adaptive expectations” rule) and hence the location of future short-run Phillips-curve tradeoffs. This sort of intertemporal

planning approach to monetary policy analysis is now at the heart of the approaches to policymaking now used by “inflation-targeting” central banks in particular. The problem of how optimizing monetary policy should take account of private-sector learning dynamics (including the problem of how best to model those dynamics) remains an important topic of current research.

### *Determinants of Equilibrium Unemployment*

Phelps’s concept of a “natural rate” of unemployment is important not only because of its emphasis upon the limits to the degree to which purely monetary disturbances can be expected to affect unemployment. It also directs attention to the *real* determinants of equilibrium unemployment, which have been an increasing focus of Phelps’s attention in recent years.

The real determinants of the “natural rate” are first addressed in Phelps (1968a). This model of expectational disequilibrium focuses on the labor market. Owing to the problem of employee turnover, a “wage-wage” spiral of unexpected and accelerating wage inflation is predicted to arise if the unemployment rate were to be maintained below its equilibrium path. Letting  $w_t$  denote the log of the average nominal wage, Phelps derives a wage-setting equation of the form

$$w_t = \log \psi( U_t, dN_t/dt ) + w_t^e$$

where  $\psi$  is a decreasing function of both the current level of unemployment,  $U_t$ , and the speed with which hiring is increasing employment  $N_t$ . A consequence of this relation is that, taking the labor force to be fixed, there is only one *steady* level of unemployment at which no expectational error will result, the rate at which

$$\psi( U^*, 0 ) = 1.$$

Phelps shows that this steady equilibrium unemployment rate should be positive in general. For a policy experiment of maintaining the unemployment rate at a sufficiently low level should cause workers to quit more readily, and that in turn would cause firms to attempt to outpay one another in order to protect their costly investment in their employees --- a state of unexpected wage inflation. The argument given here for equilibrium unemployment was an early example of what came to be known as *efficiency wage* models.

While this steady-state natural rate is a constant, Phelps’s work has from the beginning stressed dynamic elements in the determinants of the natural rate, and not just in the dynamics of temporary deviations from expectational equilibrium. The model just sketched actually implies that the natural rate should be time-varying. Equating  $w_t$  to  $w_t^e$  in the above relation yields a differential equation for the equilibrium unemployment rate *path* originating from the current unemployment rate, which changes only gradually with costly hiring and employee attrition and which

converges to the steady equilibrium rate. The paper also includes a relatively formal analysis of an individual firm's optimum rate of hiring under rising marginal hiring costs.

Phelps (1972a) further extends the analysis of dynamic aspects of natural-rate theory. This book introduces the idea of *hysteresis* in unemployment rate, according to which a drop in employment (perhaps originally due to expectational disequilibrium) might prove partially irreversible as a result of a loss in skills or morale. As noted earlier, this idea has stimulated a great deal of subsequent work, especially following the observed persistence of the increase in European unemployment rates in the 1980s.

### *“Customer Markets”*

A distinguishing feature of Phelps's research program was that it attempted to use simple, plausible *micro-economic* models of the firm, based on imperfections of competition and information, to explain widely observed macro-economic phenomena that were hard to reconcile with standard neoclassical theory. In the previous section, we showed how, beginning with an attempt to explain why nominal shocks to the economy had real effects, he at the same time developed a far more sophisticated understanding of the relationship between inflation and unemployment. Another long-standing puzzle has been the movement of markups over the business cycle. In Phelps and Winter (1970), he developed an explicit model of imperfectly competitive pricing behavior, in order to explain why prices need not fully reflect short-term fluctuations in marginal costs of supply.

In the Phelps-Winter model of “customer markets,” firms have substantial power to vary their prices in the short run (owing to imperfect knowledge of the distribution of currently available prices), but no long-run market power, as a price that is at all higher than that of other firms will eventually result in a complete loss of customers. There was a clear parallel between his earlier work in the labor market, where firms that paid too low a wage lost their workers, and this work in the product market, where firms that charged too high a price lost their customers. In a world with perfect information, of course, the trade-offs—and the complicated dynamic optimization to which it gives rise—would simply not occur. A firm that paid any less than its competitors or charged any more than its rivals would lose all of its workers or customers.

Imperfectly competitive models of price-setting are now commonplace in modern macroeconomic models, and the idea that business fluctuations involve variations in the relation between price and marginal cost is widely accepted as well, though there is now a plethora of models, with quite differing patterns of movements in mark-ups, perhaps reflecting differences in the markets in which the firms interact. (See, *e.g.*, Stiglitz, 1984, and Rotemberg and Woodford, 1999.) Even the specific model of dynamic markup variation developed by Phelps and Winter continues to be

used to be explain a variety of phenomena, and it is extensively used in the later models of equilibrium fluctuations in Phelps (1994).

*“New Keynesian” Models and Staggered Contracts*

The consequences of imperfect information became a central theme of the “New Classical macroeconomics” of the 1970s, as a consequence of the celebrated Lucas (1972) model of how business fluctuations result from monetary surprises. Lucas adopts the “island” setting suggested in Phelps (1970), but introduces the assumption of “rational expectations” --- the postulate that expectations of all agents are at each point in time given by Bayesian updating, starting from a prior that is consistent with the data generating process implied by the model, and conditioning upon all information that is observable on the individual agent’s “island”. This elegant development of the consequences of informational decentralization verified Phelps’s basic insight that monetary surprises could have temporary real effects in such a setting without any need for nominal rigidities, and also demonstrated the logic of the Phelps-Friedman “natural rate hypothesis”.

Nonetheless, the “New Classical macroeconomics” often stressed strong implications of this particular model that Phelps himself was reluctant to endorse. For example, it was argued that monetary policy could affect real activity *only* to the extent that it was purely random, and not a systematic response to aggregate conditions, and thus that monetary stabilization policy would be pointless. Phelps found this implausible, and led the development of a “New Keynesian macroeconomics” (though he did not himself introduce this term) in which monetary stabilization policy could mitigate the effects of real disturbances even under the assumption of rational expectations.

The key idea was the recognition that in reality, wages and prices are not continually readjusted. While Phelps’s early papers about the consequences of imperfect information had stressed the fact that this could give rise to real effects of monetary policy even in the absence of any such delays --- in the introduction to the “Phelps volume” (Phelps, 1970, p. 3) he states that the new theory “does not fundamentally require that price-setters economize on their decision time” --- he also always made it clear that in reality such delays existed. (On the page just cited, he states that “quarterly or annual reviews” of wages or prices “are frequently the rule,” rather than more frequent reviews.) In the third part of Phelps (1968a), he assumes “that wage negotiations are annual and are evenly staggered across firms over the year” (p. 698) and points out that, although the inflation rate may still jump in response to a monetary disturbance, the size of such a jump is reduced by the fact that existing wages are not immediately reconsidered.

In the mid-1970s, Phelps incorporated these insights into rational-expectations models of wage-setting, in collaboration with two younger colleagues at Columbia, John Taylor and Guillermo Calvo, showing that even if expectations were rational, a

negative shock to aggregate demand could generate a prolonged shortfall of output from the natural rate. The first of these papers (Phelps and Taylor, 1977) studied a simple setup in which a firm, though possessing rational expectations, has to decide its fall price by the start of the previous spring, and analogously its spring price – too soon to observe the events and outcomes of the spring season. Phelps (1978, 1979) examined the consequences of staggering of the timing of wage revisions across firms, and showed that such staggering could greatly increase the degree of persistence of the real effects of a monetary disturbance, allowing real effects to last longer than the time by which all wages would have been revised following the shock. Taylor (1979, 1993) then showed how this insight could be incorporated into econometric models of wage/price and output dynamics that incorporated rational expectations. Finally Calvo (1983) showed the consequences of modeling overlapping prices in a similar way. This particular model of price adjustment has since become the most common specification in “New Keynesian” analyses.

### *Imperfect Knowledge and Learning Dynamics*

While much of Phelps’s work since this period has made use of the assumption of rational expectations, he has also expressed frequent skepticism about the realism of assuming the degree of conformity between individual beliefs and the predictions of the economist’s model that this postulate presumes, especially when analyzing the short-run effects of disturbances. Phelps (1983) argued that fully “rational” expectations were especially unlikely in contexts where individuals’ optimal actions depend, not simply on their own beliefs about aggregate conditions, but also on their beliefs about *others’ beliefs*, and so on in an infinite hierarchy of “higher-order beliefs”. Phelps suggested that higher-order beliefs were especially unlikely to be quickly revised following a disturbance, given the difficulty of knowing how others might perceive what had just occurred, even if one’s own awareness of the current state were believed to be fairly precise. This provided a further reason for slow adjustment of wages and prices to a nominal disturbance, and hence for the real effects of monetary policy to be greater and longer-lasting than the “New Classical” models of the 1970s implied.

A conference that Phelps organized with Roman Frydman in 1981 (Frydman and Phelps, 1983) gave an important early impetus to work on explicit models of the way in which economic agents learn about the laws of motion of the variables that they need to forecast, and the consequences of such learning for macroeconomic dynamics. In the introduction to this volume, Frydman and Phelps argue forcefully that individual rationality alone provides no guarantee of the coordination of beliefs that is assumed in a rational-expectations equilibrium, and stress the need for a model of learning as an element of a convincing model of aggregate dynamics. By the 1990s, this point of view had been adopted even by leading proponents of the “New Classical macroeconomics” (*e.g.*, Sargent, 1993), and work on the macroeconomic consequences of learning dynamics is now at the forefront of current developments in macroeconomics.

### *Intertemporal General-Equilibrium Models of Unemployment*

In recent years, the central focus of Phelps's research has been understanding the causes of unemployment, especially relatively persistent increases in unemployment like that seen in much of the European Union since 1980. An interest in "long swings" in unemployment of this kind has led to a de-emphasis in the later work of the problem of expectational disequilibrium (or monetary factors more generally) that occupied Phelps's earliest work on labor markets. Instead, he has given increased attention to the real determinants of changes in the "natural rate" of unemployment, a topic which he considers, in his work from the 1990s, in the context of complete intertemporal general-equilibrium models. The "structuralist" viewpoint to which this work has led is expounded in great detail in Phelps (1994) in particular.

While the emphasis on non-monetary models, the effects of real disturbances (including "technology shocks"), general-equilibrium effects and the dynamics of capital accumulation are all features that Phelps's late work shares with the "real business-cycle theory" developed by Kydland and Prescott, Plosser and others in the 1980s, Phelps's "structuralist" approach differs from real business-cycle theory in important respects. Notably, while RBC models tend to assume a highly efficient system of frictionless competitive markets --- and often compute the implied equilibrium responses to shocks by solving a planning problem, in confidence that the equilibrium response should in fact be an optimal one --- Phelps's work has continued to stress the market frictions resulting from information imperfections. In particular, his models of unemployment assume that unemployment is involuntary and inefficient; an inefficient level of unemployment generally exists due to "efficiency wage" concerns of one type or another, such as the need to pay high wages to avoid an inefficient rate of turnover, as in Phelps (1968a). Many of his models also assume imperfectly competitive product markets, incorporating the dynamics of customer flow first assumed in Phelps and Winter (1970). Variation in the desired markup of prices over marginal cost then becomes a crucial element in the effects of various types of real disturbances on the equilibrium level of employment.

A central theme of much of Phelps's "structuralist" writing has been the importance of changes in the real rate of interest (and asset prices more generally, such as the level of stock prices) on the equilibrium unemployment rate; this is a key element in his analysis of how many kinds of real disturbances should ultimately affect unemployment, and it is an issue that comes into focus only in the kind of intertemporal general-equilibrium analysis that he develops. High real interest rates are argued to reduce equilibrium unemployment by discouraging investment-like activities of many kinds: investment in the retention of a larger work force (for example, by paying higher wages) on the part of firms that face costs of recruiting, or investment in a larger customer base by lowering current price markups, in addition

to investments that would increase the productivity of the firm's workforce. Phelps's interest in this theme goes back to his relatively early work (Phelps, 1972b) on the effects of the government's fiscal stance (and the central bank's balance sheet) on aggregate supply; here Phelps argued that equilibrium employment is reduced by government actions that push up the real interest rate and so reduce firms' labor demand at a given real wage, and also by actions that push up the wealth of the working-age population, and hence raise the real wage that workers demand. An important further development of the theme came in the work of Fitoussi and Phelps (1986, 1988), which set out a series of models in which an increase in the world real interest rate reduce firms' willingness to hire, to increase or maintain their stock of customers, or to add to their stock of fixed capital.

The full theory presented in *Structural Slumps: the Modern Equilibrium Theory of Unemployment, Interest and Assets* (Phelps, 1994) develops this theme more rigorously and in greater detail. The models presented there also consider a number of other important types of general-equilibrium effects. These include the consequences for unemployment of a secular accumulation of private wealth by nationals; of an increase in what Phelps calls the "social wealth" provided by public entitlement programs; of labour-intensive public expenditure and taxes, particularly payroll levies and the income tax, to the extent that it effectively fails to tax nonwage income. In subsequent work, Phelps and his collaborators have explored the effects of changes in demographic factors such as the distribution of educational attainments and age, and the effect of changes in expectations of *future* productivity developments, measured empirically by a noisy proxy, the level of stock prices. All of these factors can produce persistent swings in equilibrium employment at a given real wage; when combined with a theory of real wage rigidity due to efficiency wage considerations, Phelps shows how substantial variations over time in (inefficient) unemployment can be understood.

### *Education and Technological Change*

Another important part of Phelps's contributions to economics has been his work on models of long-run economic growth. It would take us too far from the main themes of this volume to attempt to survey all of Phelps's work on aspects of growth theory. But we do wish to draw particular attention to certain aspects of Phelps's work in growth theory in the 1960s that have proven to have been ahead of their time.

It is only recently, in particular with the Schumpeterian growth literature of the 1990s, that the profession has fully realized the importance of the paper of Nelson and Phelps (1966) on education and technical change. Departing from the view that education affects growth primarily through its effects on the rate of human capital accumulation, Nelson and Phelps describe growth as being determined by the consequences of the stock of human capital (or the education level) for a country's ability to innovate, or to adapt to more advanced technologies. Differences in growth

rates across countries then result primarily from differences in human capital stocks (rather than in rates of human capital accumulation) and thereby in countries' ability to achieve productivity gains. This approach predicts that the return to education is an increasing function of the rate of technological progress, and suggests that the average level of education in a country should be increased not only directly through education policy but also indirectly through research and development policy. The Nelson-Phelps approach relating educational skills to technical progress is particularly helpful in explaining the upsurge in wage inequality during the past twenty years. While it has been widely recognized that much of the increased inequality has come from increased returns to education, the increased returns to education have also increased the relative supply of skilled workers, which in turn has increased the pace of innovation, which in turn has increased the relative returns to the educated.

### **Phelpsian Themes in Contemporary Macroeconomic Debate**

The work that we have sketched above is worth recalling not only as an important stepping-stone in the development of current macroeconomic theory; it also continues, to an impressive degree, to provide the agenda for current work on the frontiers of macroeconomic theory. The papers collected in this volume, representing the proceedings of a conference in Ned Phelps's honor held at Columbia University on October 5-6, 2001, amply illustrate this. Here we briefly review the topics treated at the conference, and the ways in which they recall themes in Phelps's own work.

#### *Information, Wage-Price Dynamics, and Business Fluctuations*

Session I illustrates the continuing relevance to current work of a central theme of the conference that Phelps organized in 1969, the proceedings of which were published in Phelps *et al.* (1970), the famous "Phelps volume". This is the role of incomplete information in explaining the real effects of monetary disturbances. As noted above, a major strand of the "New Keynesian" literature has instead given primary attention to delays in the adjustment of wages and/or prices as a source of real effects of monetary policy. (And this development as well had its origins in work of Phelps's.) In recent years, sticky wages and prices in this sense have been incorporated into quite sophisticated intertemporal equilibrium models, and the consequences of this hypothesis for the optimal conduct of monetary policy have been explored in some detail.

But at least the simplest and most familiar versions of such optimizing models with sticky wages and prices have difficulty explaining certain aspects of observed wage-price dynamics. In particular, while the models allow for stickiness of the absolute *levels* of wages and prices, they tend to imply that the *rates of inflation* of both wages and goods prices should be determined largely by current and expected future conditions, rather than by the rate of inflation that may have prevailed in the

recent past. This prediction is difficult to reconcile with evidence of apparent inertia in the rate of inflation --- for example, with the fact that nominal disturbances appear to have their greatest effect upon the rate of inflation *after*, rather than before, they have their greatest effect upon real activity. (See the paper by Woodford in this volume for further discussion.)

The Calvo-Celasun-Kumhof, Mankiw-Reis and Woodford papers presented here all seek, in different ways, to provide explanations consistent with optimizing behavior for this apparent “inflation inertia”. While the models of wage and price dynamics offered in each case differ in their details, all three papers share the theme of explaining inflation inertia as being due *not* to any mechanical effect of past inflation as such on the determination of current inflation, but rather to the continuing effect of *past inflation expectations*. It is really expectations regarding the rate at which others’ prices are being increased (and hence the rate at which it is desirable to increase one’s own prices) that are inertial in these models; and the reason for this, essentially, is the imperfect information --- in particular, the incomplete knowledge of *the minds of others* --- that Phelps has always stressed.

In the Calvo-Celasun-Kumhof model, prices are assumed to be automatically increased at a rate that remains unchanged between the periodic occasions upon which both the level of one’s price and its planned rate of subsequent increase are reconsidered. Thus between these occasions for re-optimization, the rate of price increase continues to be based upon what was judged optimal at an earlier date, and thus upon inflation expectations *given the information available at that earlier time*. The role of delays in the diffusion of new information is made more explicit in the model of Mankiw and Reis, where wages are assumed to be optimal at any time *conditional upon the individual wage-setter’s current information*, but information is assumed to be updated only at random intervals. Incomplete information is also central to the model of Woodford, which assumes that all price-setters constantly receive new information about the current state of aggregate demand, but that private observations at any date are of *only finite precision* (owing to the allocation of only a finite “channel capacity” to the monitoring of such developments). Woodford’s analysis also emphasizes the role of higher-order expectations as a source of sluggish adjustment of the aggregate price level. Awareness of the imperfect precision of private observations implies recognition of the even *greater* imprecision of one’s knowledge of what *others* may be observing, so that each higher order of expectations are predicted to adjust even more slowly.

These papers are important contributions to the agenda that Phelps set out in this area over the past three decades. At the same time, they make clear that more work needs to be done. Firms make decisions concerning the *rules* they use and the *information* which they process. They can decide to revise prices more or less frequently. They can have decision rules that use currently available information, e.g. related to inventories or sales, and in which there is, accordingly, no lag—though the rules themselves may need to be updates as circumstances change. The modeling of the choice of rules requires one to take into account the risks associated with each.

Greenwald and Stiglitz [1991], for instance, have emphasized the greater risks associated with wage and price adjustments—because of the uncertainties associated with knowing the responses of one’s competitors—than in quantity adjustments, using wage and price setting models akin to those of Phelps.

### *Imperfect Knowledge, Expectations And Rationality*

Session II continues the exploration of important themes in Phelps’s work. The Frydman-Goldberg and Kurz *et al.* papers build on Phelps’s early insights concerning the role of imperfect knowledge in understanding macroeconomic dynamics. The Laibson *et al.* paper illustrates the remarkable vitality of Phelps’s seminal work on hyperbolic intertemporal preferences in explaining savings behavior, as well as many other economic phenomena involving intertemporal choice.

While the papers presented in Session I rely on various, mostly informational, frictions in their explanations of macroeconomic dynamics, they remain rooted in the rational expectations tradition. In contrast, the Frydman-Goldberg and Kurz *et al.* papers explore another recurring theme in Phelps’s work. These papers argue that recognition of *imperfect knowledge* as distinct from *incomplete information* appears to be important for understanding macroeconomic behavior. Consequently, in modeling individual expectations, the Frydman-Goldberg paper abandons the rigid connection between agents’ expectations and the economist’s structural model that has been the hallmark of the RE approach. While retaining many of the key features of the standard intertemporal equilibrium approach, the Kurz *et al.* paper also loosens the connection between expectations and the economist’s structural model. This non-REH approach, according expectations a less mechanical and more autonomous role, was already implicit in the Phelps *et al.* (1970) volume and was the central theme of the Frydman-Phelps (1983) conference volume. As summarized in the Introduction (p. 3) to the latter volume,

There was no presumption by these authors (Phelps *et al.*, 1970) that an outside investigator could accurately model individual expectations about the “world imagined” on each island. Because individual decisions cannot be derived from the formal maximization framework alone, models of individual market behavior have to remain “open” in the sense that individual behavior can be analyzed only with some additional assumptions concerning the formation of individual expectations.

The Frydman-Goldberg paper formulates an alternative model of individual expectations, dubbed *Imperfect Knowledge Expectations (IKE)*. In contrast to the usual presumption that departures from the REH are at best “boundedly rational,” the paper argues that IKE are consistent with the postulate of individual rationality in a world of imperfect knowledge. To compare the empirical implications of IKE with those of the RE approach, Frydman and Goldberg use IKE in a standard monetary model of the exchange rate, and show that the model offers

surprising promise in explaining hitherto anomalous aspects of the floating rate experience. In particular, the model provides an explanation of “long swings” in real and nominal exchange rates, and is consistent with the widespread, though often ignored, evidence concerning the temporal instability of parameters of empirical exchange rate and other macroeconomic models. Although shifts in policy lead to temporal instability of reduced forms under the REH as well (Lucas (1976)), Frydman and Goldberg suggest that it is difficult to reconcile the standard RE approach with the discontinuous and irregular nature of the temporal instability that appears to take place in the foreign exchange market. This points to the possibility that autonomous changes in expectations might be an important cause of coefficient instability. Since the autonomous nature of expectations introduces indeterminacy into the solution of the model, the Frydman-Goldberg paper analyzes time paths of endogenous variables under various *qualitative* assumptions concerning the updating of individual expectations and discusses some methodological problems arising in the analysis of models with imperfect knowledge expectations.

The Kurz *et al.* paper models the diversity of individual expectations using an approach dubbed *Rational Belief Equilibrium (RBE)*, and applies it to the analysis of the role of monetary policy. In the RBE described in this paper, real effects of monetary policy arise because agents are assumed to believe in such real effects. The RBE theory assumes that all individual agents form forecasts of the payoff-relevant variables for all future dates, and these forecasts are assumed to encompass all future structural changes in the economy. In contrast to the IKE framework, the RBE theory requires that agents’ forecasts are intertemporally correct on average, and that the higher moments of the distribution of individual forecasts at all future dates are equal to the empirical distribution of forecasted variables generated by the RB equilibrium of the model. This definition of rationality derives from an assumption that, despite the diversity and instability of individual beliefs as well as structural change in the economy allowed for by the theory, there is one overarching “joint system” of exogenous shocks and agents’ beliefs that is stationary (Kurz and Motolese (2001, p. 516)). This implies, in turn, that all moments of the *empirical distribution* of the (suitably transformed) data are constant. The RBE theory assumes that the temporal stability of the empirical distribution is common knowledge. It also makes use of all of the traditional assumptions required for the validity of dynamic optimization and standard equilibrium analysis. Since RB equilibria are inherently non-unique, an equilibrium is selected such that the moments generated by the simulated model are the same as the moments (assumed to be constant) of the observed macroeconomic time-series.

The seminal paper of Phelps and Pollak (1968) developed an intertemporal framework involving hyperbolic discounting and applied it to the study of intergenerational altruism. Over the last three decades, the Phelps-Pollak framework has been reinterpreted in a variety of contexts involving problems of self-control, *i.e.*, conflicts between our preferences regarding the long run and our short-run behavior. (For some examples of contributions to this large literature see Angeletos *et al.* (2001) and references therein.) In the macroeconomic context Angeletos *et al.*

conclude that “a model of consumption based on hyperbolic discount function consistently better approximates the data than a model based on an exponential discount function” (p.64). Moreover, a hyperbolic discounting framework can be used to explain the observed responses of consumption to the predictable changes in income, “matching well-documented empirical patterns of consumption-income comovement.”

The Laibson *et al.* paper uses this form of preferences to provide an explanation of the puzzling co-existence of relatively large voluntary retirement accumulations (suggesting low discount rates) with credit-card borrowing (suggesting high discount rates). Laibson *et al.* show that hyperbolic discounting offers a resolution to this puzzle. They formulate a model allowing consumers to accumulate highly illiquid assets (*e.g.*, retirement savings) and use high interest credit card borrowing prior to retirement. Laibson *et al.* show that the results of the simulation of a calibrated model incorporating hyperbolic discounting match up well with empirical evidence: the hyperbolic consumers save aggressively for retirement, primarily in the form of illiquid assets, while borrowing frequently on their credit cards.

#### *Determinants of Equilibrium Unemployment*

Phelps’s concern throughout the 1990s with the real determinants of equilibrium unemployment has been shared by a very active community of scholars, and considerable progress has been made in both the theoretical and empirical analysis of this issue. Much recent theoretical work on unemployment makes use of models of job search and random matching of workers with vacant jobs, which further develop the basic view of the labor market emphasized in Phelps’s work of the late 1960’s and in the papers of the “Phelps volume” (Phelps *et al.*, 1970). An example of current work with an especially close connection to the concerns of that conference is Mortensen’s contribution to this volume. In their contributions to the 1970 volume, both Phelps and Mortensen described labor markets in which individual employers have the power to determine their own wage policies, even though there are many competing firms, because of workers’ imperfect information about the wages available at other firms. The resulting search frictions make it possible for different firms to pay different wages, though the lower-wage firms will be subject to a higher rate of turnover. (We have discussed above the role of this idea in Phelps’s earliest explanation for the existence of a positive equilibrium unemployment rate.) The Mortensen paper here develops an explicit model of search frictions in which a non-degenerate wage distribution exists in equilibrium, with lower-productivity jobs paying lower wages and suffering higher turnover rates (and thus remaining smaller) as a result. It then goes on to test predictions of the model on data on wages and size of labor force for a panel of Danish firms. It argues that the data not only fit the theoretical model, but that they indicate a considerable degree of monopsony power in the Danish labor market.

A particular focus of both Phelps's recent work and other work in a similarly "structuralist" vein has been the important effects that labor market policies and regulatory policies can have on the equilibrium unemployment rate, which is far from being a constant of nature. The Pissarides paper in this volume, for example, analyzes the effects of the differing levels of start-up costs for new firms in different countries, as a result of complex legal requirements, bureaucratic delays, and so on. A theoretical model is presented in which the number of people who choose to run firms (and hence the size of these firms) is endogenous; higher start-up costs reduce the equilibrium number of firms and then, given search frictions in the labor market, result in a higher equilibrium unemployment rate. A comparison of measures of start-up costs across the various OECD countries suggests that this factor can explain a certain amount of the observed variation in employment and unemployment rates across countries.

Ljungqvist and Sargent similarly focus on the role of generous unemployment compensation systems in accounting for the intractability of European unemployment over the past two decades. An interesting twist of their argument is that it is not the unemployment benefits alone that guarantee a high equilibrium unemployment rate; after all, they note, unemployment benefits have been generous (in comparison to the U.S.) in much of western Europe throughout the postwar period, while Europe had *lower* unemployment than in the U.S. during the 1950s and '60s. Instead, they argue that the unfortunate consequence of the system is the way that the equilibrium unemployment rate *changes* in response to an increase in "economic turbulence". Through a detailed numerical analysis of an equilibrium model with job search, they show how an increase in economic turbulence, of a kind that they argue has in fact occurred since 1980 both in the U.S. and in Europe, can result in a large increase in the number of long-term unemployed workers in the case of a benefits system that allows unemployed workers to collect benefits for an unlimited time at a level tied to their past wage level (which may not be a wage they can realistically expect to earn again under changed economic conditions). In their stress on the role of labor-market institutions in determining not only the long-run average rate of unemployment, but also the way in which an economy's unemployment rate will be affected by shocks, their analysis is in the spirit of Phelps's "structuralist" perspective.

Heckman similarly considers the way in which institutions of the European welfare state have interacted with the increased turbulence of the world economy in the past twenty years to generate higher unemployment, with particular reference to the German experience. His wide-ranging review of current knowledge about the effects of labor and product-market regulations on equilibrium unemployment consider a wide range of factors, including minimum wages and employment protection legislation, as well as the unemployment insurance and company start-up costs stressed by the previous authors. Heckman also stresses the advantages of "decentralized unionism" over centralized wage bargaining in improving labor market flexibility in a way that favors productivity growth and hence ultimately faster growth in average real wages (at the price of some increase in wage inequality in the short run); he argues that what is crucial for adaptation to our new era of rapid change

is not getting rid of unions, but rather making unions responsive to local conditions. Finally, Heckman stresses the importance of policies to deal with the human costs of abrupt economic transitions, like that resulting from German unification, and discusses the ways in which this can be done without interfering unduly with the incentives of the young to acquire the skills that will allow them to use new technologies.

Finally, Nickell offers an econometric analysis of the degree to which variation in labor-market institutions across the OECD countries can account for the observed differences across these countries in the evolution of both real wages and unemployment rates. The paper focuses in particular on the changes in unemployment rates that have been observed since the 1960s, and the extent to which these can be explained by changes in labor market institutions, such as the level of unemployment benefits, the degree of trade union power, the degree of wage “flexibility”, and the level of taxes on labor income. While the papers in this session differ considerably in style and methodology, taken together they provide a fairly coherent view of an emerging consensus on the sources of “structural” unemployment of the kind so evidently at the root of the current European unemployment problem.

#### *Education, Technical Change, and Growth*

Session IV collects four contributions on growth, education, population, and vintage effects, that have been strongly influenced by Phelps’s work in growth theory, and in particular by the paper of Nelson and Phelps (1966) on education and technical change.

The Aghion-Howitt-Violante paper develops an explanation for the rise in wage inequality based on the idea that technological change is skill-biased, not only in the usual sense of enhancing educated workers' productivity in producing goods and services, but also in the sense of raising the reward to adaptability. This argument builds directly upon the idea of Nelson and Phelps (1966) that skills are not only an input to the production of goods and services, but also a factor in the creation and absorption of new technical knowledge. This Nelson-Phelps notion of human capital, as a measure of the degree to which labor is adaptable to new technologies, is useful in understanding the labor-market experience of the U.S. in the past three decades. The explanation suggested in this paper is that the arrival of a new “general purpose technology” and the implied rise in the demand for labor adaptable to the new technological platform produced a surge in the return to adaptability.

Acemoglu revisits the “induced innovation” literature of the 1960s, to which Phelps was a major contributor (Drandakis and Phelps, 1966). This literature offered the first systematic study of the determinants of technical change, and also the first investigation of the relationship between factor prices and technical change. Acemoglu presents a modern reformulation of this literature using tools developed by the endogenous growth literature, and uses this modern reformulation to shed light on

two recent debates: (1) why is technical change often skill biased, and why has it become more skill biased during recent decades? and (2) what is the role of human capital differences in accounting for income differences across countries? The contribution of the paper to these debates also reiterates some of the leading themes of Nelson and Phelps (1966).

All models of sustained growth are linear in some sense, and the growth literature can be read as the search for the appropriate linear differential equation. Linearity is a “crucial” assumption, in the sense used by Solow (1956), and it therefore seems reasonable to ask that this assumption have an intuitive and compelling justification. Jones’s paper proposes that such a justification can be found if the linearity is located in an endogenous fertility equation. It is a fact of nature that the law of motion for population is linear: people reproduce in proportion to their number. By itself, this linearity will not generate per-capita growth, but it is nevertheless the first key ingredient of such a model. The second key ingredient is increasing returns to scale. A justification for technological progress is the fundamental insight of the idea-based growth literature, according to this view. Endogenous fertility together with increasing returns generates endogenous growth. This link between population growth and per capita growth has a number of precursors. Phelps (1966a) and Phelps (1968b) are two papers that together represent one of the earliest appreciations of this link.

Does it matter whether productivity growth is embodied in new machines or whether it is disembodied and lifts the productivity of all equipment? Phelps (1962) argued that the composition of the sources of growth is irrelevant in the long run. Benhabib’s paper here reconsiders the relevance of embodied technological change, both for the long-run equilibrium and for short-run transition dynamics. In particular, it shows that the composition of embodied versus disembodied technical change does affect the elasticity of output with respect to savings, and therefore that it is relevant for analyzing the effects of policies like investment tax credits. More importantly, it shows that in the short run, the effect of embodied aggregate technology shocks, unlike disembodied ones, produce the hump-shaped impulse responses in output observed in the data. The model also delivers the prediction that investment booms are followed by investment busts, not because of expectational errors, but because of the vintage structure of production.

The papers collected here do not come close to representing the wide range of topics in economics on which Ned Phelps has made notable contributions. But they do, we believe, amply illustrate the continuing relevance of many of the insights first introduced in his work, and the continuing importance of the project that he proposed for macroeconomics some thirty years ago.

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