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Lawrence R. Klein: Macroeconomics, econometrics and economic policy[☆]

Ignazio Visco^{*}

Banca d'Italia, Via Nazionale 91, 00184 Rome, Italy

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1. Introduction

“Few, if any, research workers in the empirical field of economic science, have had so many successors and such a large impact . . .”. This was the conclusion of the press release in which the Royal Swedish Academy of Sciences motivated its decision to award the 1980 Nobel Prize in Economic Science to Lawrence Klein. Indeed, to this day, the way applied research is conducted, forecasts made and economic policy debated owes perhaps more to Klein than to any other economist.

An outstanding scholar and prolific writer, between 1943 and 2012 Klein authored over 350 articles and some twenty volumes, and also edited as many works. But Lawrence Klein was much more than this. In many ways his role can be likened to that of the master craftsman, whose workplace was a beehive of constant activity. His was a “workshop”, or rather several workshops, in which those who had the good fortune to take part ended up acquiring the “craft”, learning not only how to view the economic system using the instruments of theory, but also, and perhaps above all, how to create and utilize new quantitative tools for analysing its operation, to design forecasting scenarios and to derive practical indications for economic policy. Certainly,

[☆] This article draws upon the author’s introduction to the Italian collection of Lawrence Klein’s main contributions to macroeconomics, econometrics and economic policy (Klein, 2007).

^{*} Tel.: +39 06 4792 5505; fax: +39 06 4792 3060.

E-mail address: IGNAZIO.VISCO@bancaditalia.it

nowadays no one is surprised to find daily newspapers offering analyses and assessments referring to forecasts for GDP growth, household consumption, business investment, employment, inflation, interest rates, the money supply, international trade, exchange rates and all the other economic and financial variables that are as important for economic policy as they are for the decisions of households and firms. Yet this is a relatively recent phenomenon, and one in which Lawrence Klein was a protagonist: from his pioneering work in the 1940s and 1950s, to the great season of econometric models in the 1960s and 1970s, up to the more recent development of a new industry, present worldwide and fully exploiting the potential – for the organization of large data banks, the quantitative estimates of economic relationships with time-series and cross-section data, and the solution of systems of complex and nonlinear equations – of the computer revolution and technological progress, which has increasingly marked the last forty years.

An account of this will be given in the next section, which revisits the crucial steps in Klein's professional and scientific career. The five following sections will illustrate his main contributions to theoretical and applied economics. Special attention will first be devoted to his work on the relationship between microeconomic behaviour and macroeconomic relations. His interpretation and extension, theoretical and quantitative, of the contribution of Keynes (1936) in *The General Theory* and, specifically, the concept of effective demand will then be briefly reviewed. It will next be considered how, together with a systemic approach to determining aggregate demand, Klein also strongly emphasized the need to take account – when determining investment, prices and the costs of production – of the role of supply and the constraints on productive capacity in an economy. It will then be described how this systemic approach took on concrete form in the construction and use of econometric models, large ones in particular, for interpretation, forecasting and the assessment of alternative economic policies. Lastly, Klein's position on the determinants of fluctuations and of underlying economic trends will be illustrated.

Before going any further, however, it is worth remarking that if, as the Nobel Prize motivation observed, Klein's main contributions were to the construction and analysis of empirical economic models, his work on the theoretical principles and methods of econometrics was equally outstanding. For the most part this article cites essays in which Klein addressed, at the theoretical and applied level, the main questions about the functioning of economic systems. But Klein also had a leading role in the development of econometrics. It is to him that we owe several seminal textbooks, chief among them: *A Textbook of Econometrics* (Klein, 1953), his ground-breaking and lasting guide to the study of econometrics (thoroughly revised in 1974 after twenty years), with the main results on statistical theory uniquely accompanied with concrete examples of quantifying macro and microeconomic relations; *An Introduction to Econometrics* (Klein, 1962), mostly intended for readers less interested in the formal aspects of the subject but with enlightening chapters on the statistical analysis of demand, production and costs, and on the distribution of income and wealth; *Lectures in Econometrics* (Klein, 1983c), which examines the specification and solution of econometric models, for the analysis of their dynamic properties and the production of forecasts.

As regards his specific contributions to econometric theory, after his first 1943 *Econometrica* article on the identification of an investment function (Klein, 1943), it is worth recalling the interpretation of Henry Theil's two-stage least squares method of estimation as an efficient application of the instrumental variables method (Klein, 1955); the maximum likelihood estimation of distributed lags, in particular with reference to L.M. Koyck's geometric lag distribution (Dhrymes, Klein, & Steiglitz, 1970; Klein, 1958a); the application of Le Chatelier's principle, originally introduced by Paul Samuelson with reference to demand theory, to demonstrate the efficiency of system (or complete information) estimation of econometric models compared with that of single

equation estimation (in the *Festschrift* for Harold Hotelling: Klein, 1960a); the analysis of the effects of multicollinearity in the estimation of simultaneous equations, which are more severe in the case of system and limited-information estimates than for those obtained with ordinary least squares (Klein & Nakamura, 1962).

Finally, with reference to some of the main applications of econometric methods, we may recall the illustration, in the comment to a paper by Milton Friedman and Gary Becker (Klein, 1958b), of the relation between Friedman's econometric specification of permanent income and an extended Keynesian consumption function with a lagged dependent variable *à la* Koyck; the first maximum likelihood estimation of a nonlinear system of simultaneous equations (Klein, 1969); the use of stochastic simulations for the analysis of the dynamic properties of nonlinear econometric models (Howrey & Klein, 1972).

2. Lawrence Klein's professional career and the impact of his work¹

Born in Omaha, Nebraska, in 1920, Klein grew up during the Great Depression, which influenced his intellectual and professional career profoundly. He took courses in economics and mathematics at Berkeley before completing his studies at MIT, where in 1944 he was the first student to earn a Ph.D. in economics, with a dissertation that was later transformed into a book, *The Keynesian Revolution*, published to great acclaim in 1947 (Klein, 1947a). During this time Klein was strongly influenced by Paul Samuelson, his thesis advisor and only a few years his senior. While working on his doctoral thesis, which was essentially on economic theory, Klein also began to cultivate an interest in econometrics, making an important contribution (following up on the work of Haavelmo, 1943) to identification in simultaneous equation models (Klein, 1943). His thinking on Roosevelt's New Deal resulted in an essay on the cost of a "Beveridge plan" for the United States (Klein, 1944).

From 1944 to 1947 he was called to Chicago by Jacob Marschak as a member of the Cowles Commission, charged with the task of building a model of the American economy which, after Tinbergen's (1939) ground-breaking work, could be applied in the post-war period. Plainly, the construction of this model could not but be an equally pioneering task, given that econometrics was still evolving into an autonomous discipline, that the data on which to base the estimates were not easy to come by, even on an annual basis, and that, of course, the instruments for making the calculations were still basically mechanical, if not manual (computers did not start to be used until the mid-1950s). At the Cowles Commission in those years Marschak had put together a formidable team of researchers in the three areas from which econometrics originates: economics, statistics and mathematics. Among them were Theodore Anderson, Kenneth Arrow, Herman Chernoff, Trygve Haavelmo, Leonid Hurwicz, Tjalling Koopmans, Roy Leipnik, Don Patinkin, Herman Rubin and Herbert Simon,² each with his own lines of research, including the

¹ This section draws partly upon Klein's own account of his academic and professional career in a number of autobiographical essays. See, in particular, the one written in the occasion of the receipt of the Nobel Prize (Klein, 1981), Klein (1986) and Klein (1992a). See also Roberto Mariano's interview with Klein (Mariano, 1987), Bodkin, Klein, and Marwah (1991), the two collections of Klein's most important essays (Klein and Marquez, 1985; Marwah, 1997) and the two celebratory volumes (Adams and Hickman, 1983; Dutta, 1995), as well as the article written by Jim Ball at the time of the award of the Nobel Prize (Ball, 1981).

² Arrow, Haavelmo, Hurwicz, Koopmans and Simon would also become Nobel laureates in economics; Marschak would develop organization and information theory, Patinkin would make major contributions to micro and macroeconomic theory, while Anderson, Chernoff, Leipnik and Rubin would become leading scholars of mathematical statistics.

estimation of systems of simultaneous equations, especially important for Klein's project. The interaction among the team's members was intense, and there were frequent exchanges with other prestigious visitors at the centre, such as Abraham Wald and John Von Neumann.

In these years Klein not only completed the construction of his first series of econometric models (not published, however, until 1950; see Klein, 1950a), with a substantial personal investment in the production of quantitative estimates and the use of models for forecasting and economic policy analysis. He also rewrote and published his doctoral thesis and made important and original contributions to the theory of aggregation and index number methods. Moreover, as Klein himself observed (Klein, 1991a, p. 112) when recalling his work at the Cowles Commission: "There were two worlds of economics at Chicago then, 'us' and 'them', the former were the Cowles group, who were overwhelmingly New Deal democrats. . . . The latter were the stalwarts of the Chicago School, and we nearly always took polarized positions at general economics seminars on campus. Our intellectual opponents were Frank Knight, Henry Simons, Lloyd Mints, and at the end of this period, Milton Friedman." The disagreements bore on a series of points, from the mathematical approach to quantitative economics – about which Klein recalled in particular the reaction to Koopmans' (1947) critical review of Burns and Mitchell's (1946) work on measuring business cycles – to, above all, State intervention in the economy. Of course, the very idea of building and utilizing an econometric model in order to frame economic policy strategy was a major bone of contention.

In the summer of 1947, following a brief stay in Ottawa where he helped to build the first model of the Canadian economy, Klein left the Cowles Commission to spend the academic year in Europe, above all in Norway with Ragnar Frisch and Trygve Haavelmo; while there he met with other scholars including Herman Wold, Eric Lundberg, Erik Lindhal and Ragnar Bentzel in Sweden, Jan Tinbergen in the Netherlands, and Richard Stone in Britain. At Arthur Burns's personal invitation he then spent a year at the National Bureau of Economic Research, where he worked on the specification and estimation of investment and production functions.³ From 1949 to 1954 he moved to the University of Michigan, where he was associated with the Survey Research Center and produced a series of studies based on sample surveys of American households' budgets and expectations (a number of which written together with George Katona, John Lansing and James Morgan).

During this time, thanks to a grant from the Ford Foundation, he went back to constructing an econometric model. This model – developed with a team of researchers and in particular with Arthur Goldberger, his student and co-author of the volume describing their macroeconomic model of the United States (Klein & Goldberger, 1955) – was destined to become a point of reference and a source of inspiration for econometric modelling for years to come, and not only in the United States. An evident quantitative extension of the Keynesian framework, this was the first model to be used successfully to generate regular forecasts of US economic developments and to simulate a variety of fiscal scenarios, with attention to the differences between "impact", "interim" and "long-term" multipliers; its dynamic properties would also serve for important analyses, with simulations investigating the nature of US business cycles, distinguishing between deterministic cycles that reflect endogenous dynamics, and stochastic cycles that reflect the propagation of exogenous shocks.⁴ In the decades that followed the Klein–Goldberger model would be maintained and

³ Some of the results of this research can be found in his *Textbook of Econometrics* (1953). Of remarkable interest for the originality of the theoretical contribution is an unpublished study on the use of cross-section data in econometrics (Klein, 1949).

⁴ See in particular, Goldberger (1959) and Adelman and Adelman (1959).

developed by the University of Michigan, for much of this period thanks chiefly to the work of Daniel Suits.

In 1954 Klein left Michigan for the Institute of Statistics at Oxford,⁵ where he stayed until 1958, conducting a series of studies on saving based on the Institute's household survey data (similar to those of the Michigan Survey Research Center) and publishing articles on theoretical and applied econometrics, while also, with a research group including in particular his student James Ball, working on the construction of the first model of the British economy. The model was not particularly successful in terms of forecasting, owing to poor data quality, but it was remarkable for the attention paid, in determining prices and wages, to the specific features of the British labour market. In this project, at last, computers could be used in the estimation stage, though not yet for the solution of the model.

Klein returned to the United States in 1958 as Professor of Economics at the University of Pennsylvania, in the Department of Economics of which the Wharton School was then a part. In 1959 he was awarded the biannual John Bates Clark Medal for American economists under the age of forty having made a significant contribution to economic thought and knowledge, and in 1960 he became President of the Econometric Society. Klein's academic career as peripatetic professor now ended; he settled permanently at Penn. A new wanderlust, however, led him to take part in projects all around the world, mostly involving the construction of econometric models, but it was in the United States, where he had done his first work on models, that he made his name as the leading expert in this field, as well as one of the world's great econometricians. Klein combined his teaching with intensive scholarship, especially applied research; he took part in countless studies of the economies of other nations (Japan, for one, which he first visited in 1960, and whose first econometric model he co-authored in 1963–1964), and in 1959, with Michio Morishima and Shinichi Ichimura, he founded the *International Economic Review*.

Above all, however, in the course of the 1960s and 1970s Lawrence Klein was a leading protagonist in three major projects for the design and building of macroeconomic models. The first, funded by the Social Science Research Council, was a new large model of the US economy (later transferred to the Brookings Institution and named after it). With James Duesenberry initially as co-director, the project brought together, in the early 1960s, some thirty of America's leading economic scholars (including Albert Ando, E. Cary Brown, Frank De Leeuw, Phoebus Dhrymes, Robert Eisner, Gary Fromm, Franklin Fisher, Stephen Goldfeld, Charles Holt, Dale Jorgensen, Edwin Kuh, Charles Schulze, Daniel Suits and Paul Taubman). As the 1950s gave way to the 1960s, various models had begun to be applied to generate economic forecasts and policy scenarios. In addition to the University of Michigan model reworked by Suits (1962) and still estimated using annual data, mid-sized models estimated on quarterly data had been developed, patterned after Klein and Goldberger's project, by Duesenberry, Eckstein, and Fromm (1960), Liu (1963), and Klein (1964) himself.⁶ This model of Klein's in particular, which was the first to include variables relating to households' expectations and spending plans, was ultimately maintained, developed further and used regularly for forecasting and policy assessment by the Commerce Department's Office of Business Economics (which would later become the Bureau of Economic Analysis).

⁵ Because of his youthful association, probably more casual than ideological, with the US Communist Party, at the height of McCarthyism Klein was denied tenure and elected to move to Britain "for the peace and academic freedom of Oxford" (Klein, 1986, p. 28).

⁶ Together with Harold Barger, Klein had already constructed in the mid-1950s, essentially for methodological purposes, a small quarterly model (Klein & Barger, 1954). Another model for exploring the characteristics of US economic growth was built during that decade by Valavanis-Vail (1955).

All these models had essentially been the fruit of individual efforts or the product of small groups of researchers. The Brookings model, instead, instituted a new method of work, involving considerably larger groups, embracing economists who had worked in various fields, statisticians, mathematicians and, for the first time, computer scientists. The Brookings model was a hotbed of new ideas, applications, and innovations in methodology and calculation.⁷ Klein not only set the fundamental guidelines and coordinated the project but also contributed directly and indirectly to these developments. They resulted in an enormous advance in quantitative knowledge of the operation of the US economy, with great attention to institutional matters in various areas and markets, including money and financial markets, and general government. For the first time the demand-side determination of national income, in line with the national income and product accounts, was linked to a detailed input–output system of interdependent sectors.

Thanks to the great advances in computer applications, it was possible to quantify essentially nonlinear relations, which until then had had to be represented by linear approximations. New techniques were introduced for ordering equations to obtain a recursive structure of blocks, reducing interdependency to the minimum and permitting the application of limited-information estimators that could generate consistent estimates. New computation programs were developed for estimating the model's equations, and above all the team achieved an extraordinary advance in the solution of the entire model, with new algorithms perfected with the fundamental contributions of Robert Hall, Edwin Kuh, Morris Norman and Klein himself, based on iterative processes for solving appropriately ordered systems of equations – which even today remain the core of the simulation programs in econometric models. Finally, the use of computers made it possible to collect, update and systematically store all the data needed to estimate and simulate the model, originating the large data banks that are now available worldwide.

If the Brookings model was an enormous success in terms of the development and diffusion of empirical knowledge on the functioning of the economy and of econometric methods, the same cannot be said of a systematic use for forecasting and design of scenarios. In part this was due to its size (it eventually involved no fewer than 400 estimated equations) and the dimensions of the project (with a large number of scholars from many different universities, all with their own research interests). At the same time, it also reflected the success of other model-building projects by the same economists who had created the Brookings model. They answered a market demand for forecasts of economic and financial variables and business consulting, and in the end they revolutionized the state of research on econometric models and, above all, their utilization.

A totally new business thus arose. The models were no longer bound to their original makers but served as tools for companies specializing in forecasting on a commercial basis and in consulting for businesses, banks and governmental institutions. In the 1970s and 1980s two companies were the leaders in this field. One was Data Resources Incorporated (DRI), whose chief economist and a major shareholder was the Harvard professor Otto Eckstein. The other was the Wharton Econometric Forecasting Association (WEFA), owned by the University of Pennsylvania. WEFA, founded by Klein himself, represented the second major project of Klein's following his return to the United States. Both these forecasting companies, DRI in particular, were highly successful in providing not only forecasting but also data and consulting services on the use of databases and application software. Making the first use of time-sharing, they developed a number of models, short- and long-term, with special sectoral details, and formed the prototype for the impetuous

⁷ On the developments and applications of the model see [Duesenberry, Fromm, Klein, and Kuh \(1965\)](#), [Fromm and Taubman \(1968\)](#), [Duesenberry, Fromm, Klein, and Kuh \(1969\)](#), and [Fromm and Klein \(1975\)](#).

development of this type of service around the world. During the same period, under the direction of Franco Modigliani and Albert Ando, the construction of a model of the US economy exclusively for public use (by the Federal Reserve) and academic purposes got under way.⁸

The specification and development of these models, the refinement of econometric and statistical procedures and the design of new programs for calculation, simulation and database management saw the involvement over the years of young researchers, students at Harvard, MIT and Penn. These projects generated a good number of Ph.D. dissertations.

WEFA was formed in 1969 after several years of work on the construction and testing of the first Wharton model, which Klein fine-tuned together with Michael Evans, starting with the fusion of the model developed by Evans for his Ph.D. thesis at Brown with Klein's 1963 model for the Office of Business Economics. This first Wharton model was funded by several private corporations, which in return benefited from the consulting services of Klein and Evans. When WEFA began selling its services, and for as long as the Association was the property of the University of Pennsylvania,⁹ its earnings went chiefly to finance further econometric research work and fellowships for a good number of graduate students. Klein did not engage directly in commercial activity, however. He encouraged and contributed to the development of various Wharton models, the subject of a number of publications. He himself used the model for a series of original studies on such topics as the effects of fiscal and monetary policies, the use of subjective variables drawn from household and business surveys, the economic impact of demobilization as a result of the end of the Vietnam War, and more. He was interested above all in the dynamic properties of models and in improving their forecasting capability, including through the use of information external to the model. Klein always considered forecasting with the assistance of econometric models – the subject of a dense and concise essay drawn from the *Yrjö Jahnsson* lectures in Helsinki in 1969¹⁰ – to be the decisive test of the quality of one model's quantitative specification compared with others. In part for this purpose, in the early 1970s Klein and Fromm, with the sponsorship of the National Bureau of Economic Research and the National Science Foundation, organized a series of comparisons between up to eleven different models of the US economy, concluding with an overall assessment by Carl Christ.¹¹

The third of Lawrence Klein's major projects beginning at the end of the 1960s was another cooperative undertaking. As we have seen, in the course of the years he had taken part personally in the construction of econometric models for other countries, including Canada, the United Kingdom and Japan. He had also contributed decisively in the late 1960s to the development, at Penn. and in the WEFA framework, to the development of models for such Latin American countries as Mexico, Brazil and Argentina. Students of his in a good many countries in Europe, Asia, Africa and Latin America had begun building models of their own economies. In the mid-1960s he began working with UNCTAD on models of the less developed countries. This modelling effort was accompanied in many countries by the gathering of statistics and the development of systems of national income and product accounts.

⁸ See also Visco (2005).

⁹ In 1969 Evans left WEFA and founded, with the Chase Manhattan Bank, Chase Econometrics, which he left in the mid-1970s. WEFA in turn became a private company during that decade and in 1987 it merged with Chase Econometrics. Meanwhile, DRI had been acquired by McGraw-Hill. In 2001, finally, DRI and WEFA were merged into the worldwide forecasting and economic consulting firm Global Insight Inc.

¹⁰ The lectures were published in Klein (1971).

¹¹ See Fromm and Klein (1973) and the essays published in three volumes of the *International Economic Review*, 1974–1975, and collected in Klein and Burmeister (1991). This experiment would be repeated two decades later (see Klein, 1991b).

The time now seemed ripe for Klein to launch an even more ambitious project: the interlinking of the national economic models, so as to take account of their interdependency and the transmission of specific shocks from country to country: the LINK project, with initial funding from the Ford Foundation, the IMF and the National Science Foundation. The University of Pennsylvania was the locus of development of the algorithms needed to link, via trade tables, the models of different countries and areas (at first fewer than twenty, eventually about eighty, already in the 1970s embracing many developing countries and centrally planned economies, including the Soviet Union). Within a few years the LINK model was a reality, with regular meetings of the heads of the participating national models. For the most part these models were maintained, updated and used for national economic forecasting; for the most important missing countries and areas, simplified models were constructed directly in Philadelphia.

The LINK model, through the years, has served for many applications, from examining the effects of shocks, such as the oil crises, to assessing the consequences of lowering or removing tariff and non-tariff barriers to imports, from inquiring into the determinants of exchange rates to the coordination of fiscal and monetary policies.¹² Like the Brookings model, LINK also had a series of secondary effects. The most important was certainly helping to spread econometric modelling around the world, thanks to regular contacts among groups in different countries and rotating annual conferences in various countries. A second effect was to induce such institutions as the OECD, the IMF and the Federal Reserve to produce their own models of the world economy by linking together blocks consisting in models of single countries or areas, given that the exports of any country are equal to the sum of all the other countries' imports from that country, and that the worldwide sum of exports and imports is nil (save for statistical discrepancies that must be kept under control). A third effect, finally, was to intensify the pressure to produce national statistics where they were most defective in quality and in quantity or where they were simply non-existent, thus creating data banks such as the constantly updated public databases of the OECD and the IMF. In the course of the 1990s the coordination of the LINK model was shifted from Philadelphia to New York, where it is now maintained at the UN under the scientific direction of Peter Pauly, professor at the University of Toronto and a former colleague of Klein's in Philadelphia in the 1980s.

After heading the economic task force for Jimmy Carter's election campaign in 1976, Klein refused to join the new government team, choosing instead to continue his scholarly work, while collaborating with the Administration from his post at the university with analyses and consulting. In 1977 he became president of the American Economic Association. In 1980 he won the Nobel prize for economics. This award naturally produced a surge in invitations to conferences, round tables and other public events and to lecture at universities and research centres all around the world. Klein did not shrink from these requests, but nevertheless continued his intensive research activity. From 1982 to 2012 he authored or co-authored more than 150 articles, published various books of lectures in econometrics and edited a dozen collections of essays.

While maintaining unflagging interest in the LINK project, acting as consultant for the new companies into which WEFA had in the meantime been merged, and continuing to teach at Penn. until 1991 (when he became Benjamin Franklin Professor Emeritus of Economics), beginning in the early 1980s Klein focused especially on three lines of research. First, after serving as coordinator of the group of economists who established academic relations between the United States and China following the normalization of diplomatic relations between the two powers in

¹² On the LINK model, see among others Klein (1976), Ball (1973), Waelbroeck (1976) and Sawyer (1979).

1978 and organizing a series of symposiums on econometrics there, he dealt specifically with Chinese economic development, taking part personally in the construction and utilization of specific models. He then extended his research interest to other major Asian economies, notably India. A second field of research was the quantification of the effects of disarmament consequent to the end of the Cold War and the implosion of the Soviet Union. He produced several works on this topic, seeking to determine whether the hypothetical “peace dividend” had actually materialized, and if so its magnitude. Finally, with direct reference to econometrics as such, Klein continued to work to enhance forecasting capability, with special attention to high-frequency data (monthly and weekly) to improve the initial database for forecasting using models estimated with at least quarterly frequency.

3. Macroeconomics and aggregation

During his years at the Cowles Commission, as we have seen, Klein’s central project was to create a first econometric model of the whole US economy that could serve for forecasting and policy assessment. The theoretical foundations of the model were essentially Keynesian, and the equations therefore essentially macroeconomic. Nevertheless, as is clear from the appendix to *The Keynesian Revolution* (Klein, 1947a, pp. 189–213), in the mathematical derivation of the Keynesian system from the *General Theory*¹³ Klein made sure to offer microeconomic foundations to underpin the aggregate consumption, liquidity preference and investment functions, also borrowing the labour demand and supply functions from neoclassical economics.¹⁴ In designing the macroeconomic model, Klein kept the specification based on the hypothesis of rational behaviour of firms and households, observing that “the profit-maximizing [and utility-maximizing] equations of micro-economics hold in analogy for the macro-system if the aggregates of the latter system are *properly measured*” (Klein, 1947a, p. 199, emphasis added).

The term “properly measured,” for Klein, referred to a theory of aggregation on whose basis, starting from a state of microeconomic equilibrium and a corresponding expression in macroeconomic terms, the aggregates of the latter are obtained endogenously in such a way as to ensure full consistency between the two theoretical formulations. In two 1946 works of his (Klein, 1946a, 1946c), Klein showed that the necessary conditions for this to happen are quite restrictive and result in particular forms of the microeconomic functions. As Paul Samuelson observed in his contribution to a *Festschrift* for Klein (Samuelson, 1983), the necessary condition for deriving aggregate indices that produce consistency between micro and macro theoretical relations is that the elementary functions belong to the uniform homothetic class. Indeed, it is to this class which the Cobb–Douglas functions considered by Klein in his papers belong.

Major works on this theory of aggregation would follow, both highlighting the restrictiveness of these conditions and clearing up a series of questions that Klein had left open.¹⁵ The point

¹³ In the design of the Cowles Commission models, Klein was also attentive to the microeconomic foundations of the macroeconomic equations for specification and estimation; see Klein (1950a, chap. II).

¹⁴ As we shall see in Section 4, Klein considered the Keynesian assumption that labour supply was a function of nominal rather than real wages and concluded that this was not the reason why, in the theory of Keynes, the economy did not return automatically to a full-employment equilibrium.

¹⁵ Among the most celebrated of these contributions are Leontief (1947), Nataf (1948) and Gorman (1953). An acute analysis, bearing in particular on the acritical use of aggregate production functions in reference to the well-known “capital controversy” between the “two Cambridges”, was set out in works by Fisher (1993) and, most recently, Felipe and Fisher (2003).

here is not just Klein's originality but above all his attention to the microeconomic foundations of macroeconomics. A 1948 work co-authored with Herman Rubin (Klein & Rubin, 1947–1948) is an excellent example, one in which Klein sets the objective of obtaining from the marginal conditions of utility maximization, with demand functions that are linear in relative prices and income, a "true" index of the cost of living. In deriving the index, the authors introduced the "linear expenditure system," which would become a classic among demand systems and which was also independently derived by Stone (1954), with multiple empirical applications. As a matter of fact, the assumption of linear demand functions is highly restrictive, as Samuelson (1947–1948) noted immediately identifying the form of the underlying utility function, a result that Roy Geary (1949–1950) also reached on his own: it was again a Cobb–Douglas function, although this time shifted with respect to the starting point and taking as arguments the differences between consumers' demand for goods and the level of "necessities" consumed independently of income.

As Klein himself later noted (Klein, 1985, p. 13), in the course of the revision of *The Keynesian Revolution* – which benefited, after the original impulse from Samuelson, from intensive discussion with Haavelmo, Hurwicz, Marschak and Patinkin – and in the construction of his first model he faced another theoretical problem, this time connected with the dynamics of an economy, which gave rise to an article on stocks and flows in economics (Klein, 1950b). Here Klein formally showed that in specifying the relations of dynamic adjustment of the money market and in determining the interest rate, stock and flow analyses are not equivalent, above all in view of the stochastic nature of the model. This observation was pertinent to the debate between the Keynesian theory of liquidity preference and the classical theory of loanable funds, but Klein, while favouring the former, raised a quintessentially methodological problem, in contrast with an earlier note by Fellner and Somers (1949) that was intended as a response to Klein's observations on the matter, as presented in *The Keynesian Revolution*. In the ensuing debate, Fellner and Somers at first failed to grasp the significance of Klein's contribution, as they were interested mainly in defending their theoretical position. Karl Brunner instead, though sharing their theoretical view, properly understood the point that Klein was raising and accepted his conclusion on the difference in specification between the two theories and hence the need to take this carefully into account before conducting an empirical test (Brunner, 1950). Klein (1965) would come back to the question later, showing that the stock/flow problem can be properly understood only within the framework of a theory of the evolution of variables such as money or the capital stock outside of equilibrium.

In a paper prepared for a conference in honour of Don Patinkin in 1990, Klein (1993) returned to the relationship between micro and macroeconomics, concluding – against the view that was gaining currency, especially among US academics – that while microeconomic foundations were necessary, macroeconomics stands on its own as a separate subject and could not be fully derived from a Walrasian general equilibrium system. This was a particularly inspired essay, practically a manifesto of Klein's. He again dealt with the problem of aggregation, rejecting – against the established practice – the assumption of a representative agent, recalling his own proposal for endogenous aggregation while recognizing its restrictiveness, and contending that the proper approach to econometric specification was to integrate the microeconomic functions over the joint distribution function of the variables of interest. That is, Klein here transcends the concept of an analogy between micro and macro relations (under which it is the aggregates that must be constructed in such a way as to take account of variations in the distribution) and no longer maintains, as in his 1946 remarks on the theory of aggregation, that in practice the correlation between endogenously aggregated variables and the indices normally published is close enough as to make it possible to substitute the latter for the former (which is the assumption underlying

most of the equations estimated in macroeconomic models). It follows that attention must be paid not only to the means of these distributions (e.g. the national income account aggregates) but also to other moments of the functions: in the case of a demand function, say, the income elasticity will generally vary with the variation in the distribution of income. Works taking this condition expressly into account are those of the early 1980s by Dale Jorgensen, Lawrence Lau and Thomas Stoker.¹⁶

4. Keynesian economics and effective demand

Lawrence Klein acquired international fame with the publication of his doctoral thesis in 1947 as *The Keynesian Revolution*, anticipated in part in his celebrated article on theories of effective demand published the same year in the *Journal of Political Economy*. In that article Klein (1947b) compared the Keynesian theory of employment with the neoclassical theory and with an original formal interpretation of Marxian theory (in a number of respects seen as a precursor of some of Keynes's ideas). The article was important for the interpretation of Keynes and is often grouped with the classical works of Hicks (1937), Lange (1938) and Modigliani (1944) as part of the “neo-classical synthesis” of Keynesian theory, but it differs from them in some substantial respects. Klein himself called his own interpretation, more appropriately, a “neoclassical-Keynesian synthesis.”

Klein's thesis is that the essence of Keynes's contribution is his demonstration of the (logical) existence of an equilibrium without full employment; that is, that there is no guarantee that saving and investment are equal given a positive rate of interest, so that output and employment are determined on the demand side, with a labour supply curve consisting merely in “a set of virtual points that are never observed,” regardless of the flexibility or rigidity of prices and wages. In Modigliani's version, however, and in that of Hicks – who nevertheless saw Keynes's essential new contribution as his theory of liquidity preference and the liquidity trap, to which Klein but not, for instance, Tobin (1947), attached little empirical importance – flexible prices and wages produce full employment conditions as in general economic equilibrium theory.¹⁷ According to Modigliani, it is the rigidity of money wages which, in the “short” run, produces the kind of involuntary unemployment spotlighted by Keynes. For Klein, instead, this is a sufficient but not necessary condition for protracted underemployment. Specifically, Klein maintained that “the truly important ideas of Keynes, contrary to much of popular belief, are independent of any special assumptions about the labour market” (Klein, 1947b, p. 115).

¹⁶ Jorgenson, Lau, and Stoker (1980) and Stoker (1984).

¹⁷ In interpreting and extending the “model” underlying Keynes's *General Theory*, then, Klein gave little space to the balancing role of the interest rate and attached equally little importance to price and wage rigidity in preventing the return to full employment. Axel Leijonhufvud, in his critique of the “expenditure–income” interpretation and the reduction of Keynes to an IS-LM model rather than an inquiry into the possible reasons for the lack of a natural attraction to full-employment equilibrium, recalled Klein's reading and, like other “Keynesians,” criticized his attempt to correct or supplement Keynes so as to bring out the “real” contribution of the “Keynesian revolution,” namely the demonstration of the possibility of an underemployment equilibrium (Leijonhufvud, 1968, pp. 35, 184–185, 241, 316). While in the final analysis Klein's aim was to produce a formal scheme, quantifiable and of use to policymakers, his contribution on labour market dynamics was original and helpful in understanding his diffidence with respect to supply-side policies designed only to ensure the greatest possible flexibility in the operation of market forces (here, with some kinship with Leijonhufvud). As to the effectiveness of monetary policy, in the words of Klein: “Over the years . . . I have come to appreciate, more and more, the role of money and . . . I do believe now that money matters; it is not everything, but it does matter. That is perhaps the chief outcome of the debate between the monetarists and the rest of the economics profession” (Klein, 1992a, p. 188).

In fact, Klein suggests that it is not necessary, in order to obtain the result of involuntary unemployment, to posit on the supply side that workers suffer from “money illusion,” as Keynes himself apparently did. In general, even retaining the assumption of a neoclassically specified labour market, in the Keynesian framework one gets an underemployment equilibrium. But in this case another equation is needed to determine the absolute level of prices and wages (with the quantity of money essentially serving to determine the interest rate). Here, in an original contribution, Klein introduces a wage-determination function that takes the form of an equation for labour market adjustment (a collective bargaining equation), a function that consists essentially of an inverse relationship between the change in nominal wages and the rate of unemployment. In a word, this was an anticipation of what would eventually come to be known as the “Phillips curve,”¹⁸ with a dynamic representation that potentially contains money illusion and a static representation that, as Klein observes, has “the classical properties of homogeneity.”

If the adjustment equation were to be expressed in terms of real wages there would indeed be no role for money illusion also in the dynamic system, but Klein finds that such a hypothesis (a vertical Phillips curve, at least in the long run) lacks empirical support. This is further elaborated in a subsequent paper on the empirical foundations of Keynesian economics (Klein, 1954), where he presented a detailed quantitative version of his formulation of the Keynesian system; the explanatory variables in the wage adjustment equation are the rate of unemployment and the rate of inflation, the latter with an elasticity of less than one.¹⁹ The model set out in this article is also interesting as the first version of the celebrated Klein–Goldberger model and indicates that for Klein, as for Modigliani, the Keynesian macroeconomic system could be used to derive a general framework offering a reasonable, realistic approximation of the functioning of a modern capitalist economy like that of the United States.

An intriguing feature of this article, as of the one previously discussed, which also dealt with the issue at the theoretical level, is the empirical testing and strong rejection of Pigou’s hypothesis that consumption may react sufficiently strongly to changes in the real value of wealth to restore the (neoclassical) full-employment equilibrium. Finally, one cannot but emphasize the importance of Klein’s use of mathematics to formalize the Keynesian model. The formalization was not an end in itself, however, but instrumental, like the use of statistics, to deriving an empirical model as closely as possible approximating the performance of economies as observed in the real world. Mathematics, statistics and economic theory were combined to produce the studies in applied econometrics that constituted what Lawrence Klein himself called “the theme of my life’s professional work” (Klein, 1985, p. 17).

¹⁸ Klein considered this to be a structural equation, and on a number of occasions criticized the subsequent reading of the Phillips curve as a trade-off between inflation and unemployment, neoclassical and Keynesian interpretations alike. See Klein (1994), where he also notes that the form of the adjustment equation is similar to those of Lange (1944). Klein further observes that he was influenced, in the specification of the wage equation in the Cowles Commission model, by the equation estimated by Tinbergen in the League of Nations model, which however was formulated in static terms, with the wage level as a function of the level of output (itself assumed to be directly correlated with employment), the cost of living and a linear trend (Klein, 1985, p. 17).

¹⁹ This equation was already present in the model estimated during Klein’s work with the Cowles Commission, published (as Model III) in Klein (1950a), eight years prior to Bill Phillips’ famed article (Phillips, 1958). The inflation rate was included among the explanatory variables for the first time in Carl Christ’s revision of that model (Christ, 1951). See also Klein’s (1950c) comment on an essay by T.C. Schelling on the dynamics of price flexibility.

5. Supply side, capacity utilization and prices

In his 1959 doctoral dissertation, Albert Ando recognized Klein's pioneering work in building macroeconomic models but criticized his having made the level of employment in an economy totally dependent on aggregate demand (Ando, 1959, p. 1). In an article written the same year by Ando with Franco Modigliani, which in many respects laid the basis for what would have been the model produced jointly at MIT, Penn., and the Social Science Research Council (MPS), it is observed that "in the classical models, the major equilibrating device was the price mechanism . . . considered sufficiently effective to prevent significant and systematic departures from a situation in which all relevant markets are cleared," while in the business cycle and growth models derived from Keynesianism (Roy Harrod's model,²⁰ for one) "the price mechanism is conspicuously absent" (Ando & Modigliani, 1959, p. 501). In fact, a comparison of Modigliani's 1944 article with that of Klein in 1947 clearly shows the difference between their formulations of the Keynesian model. Where Modigliani held that the balancing role of prices, set on the supply side in the labour and product markets worked (although not in the short run, and probably too slowly) to bring aggregate demand back to a full-employment equilibrium, in Klein's set-up this mechanism is essentially absent. And it would long be lacking, at least up until the Wharton models, which certainly posit significant effects (though less powerful than in the MPS model) of real interest rates and relative prices on the components of aggregate demand.

However, this does not mean that in Klein's view supply did not matter, at least beyond the short term of Keynesian under-employment, when effective demand for goods and services results in a level of output lower than one would have with full utilization of resources. In his models and analyses, in fact, he displayed growing interest in the effects of the relations between the inputs and the outputs of the production process, in particular in determining production costs and output prices, as well as to the key role assigned, in this process, to capacity utilization. On these two questions Klein produced a substantial series of empirical works. These lines of empirical research, directed to achieving a better understanding of the functioning of the real economy, were based on noteworthy contributions to theory. Interestingly, both refer explicitly to imperfect competition as a major economic factor.

In Klein (1952–1953), he showed that, starting with sectoral Cobb–Douglas production functions, coefficients in Leontief's input–output tables can be derived that vary with changes in relative prices. This is an important result, among other things because in practice these coefficients are estimated in terms of value. The usual assumption of fixed coefficients (hence, that of a linear production function) is valid only if coefficients of a single input–output table are used to run simulations on different years from the one to which the table refers. If more than one table is considered, it is natural to suppose that coefficients vary not only owing to technical change but also because of changes in relative prices. In particular, as final demand varies, relative prices will also change, giving rise to substitution effects between the various production inputs.²¹

In Klein (1960b), he dealt with a second theoretical point, namely how to measure productive capacity and how to distinguish a purely technical from an economic concept of capacity. In this framework, differences between conditions of perfect competition and monopolistic competition are significant. Klein thus examined the basic question of aggregation, showing how it is possible to

²⁰ Harrod (1948).

²¹ This result was extended by Morishima (1956–1957), giving rise to an interesting exchange between Klein and Morishima in the *Review of Economic Studies*, where the two articles were originally published.

construct an index for the entire economy such that the sectoral components combine consistently. To this purpose, he explicitly used the system of equations defined in an input–output model and made use of an iterative procedure to highlight the need to take account of the effects of changes in any sector’s productive capacity on the other sectors, both directly and via the increase in investment required each time to overcome the capacity limits in upstream sectors.

With this formal contribution as point of departure, Klein devoted a good deal of attention to the actual measurement of productive capacity and its effective utilization, considering capacity constraints and sectoral bottlenecks as crucial elements in the interaction between effective demand, prices and aggregate supply. Recognizing how complex it is in practice to apply an iterative procedure within the framework of an essentially dynamic input–output system, Klein produced a series of works weighing alternative ways of constructing an aggregate index of productive capacity and its utilization. In an article written with Ross Preston (Klein & Preston, 1967), he generated aggregate measures starting from the estimation of sectoral production functions²² and later encouraged the use of linear programming to obtain capacity levels for specific industrial sectors.²³

Around the same time, together with Robert Summers, Klein constructed the well-known Wharton index of capacity utilization, which derives capacity levels by interpolating the output peaks of the various sectors (Klein & Summers, 1966) and makes use of estimates derived from sectoral production functions or linear programming applications to “correct” the index in extrapolation. The Wharton index quickly became one of the most successful tools for cyclical analysis (with numerous imitators internationally), a tool that is still widely used in the empirical analysis. Indeed this was the index that Klein employed in Klein and Long (1973) to infer a state of strong inflationary pressures in the autumn of 1973, a result that could not be generated by the qualitative McGraw-Hill index used at the time by the Federal Reserve.

The importance of supply factors in determining the level of national income and the final prices of consumer and investment goods and the role of demand in determining production inputs have been emphasized over the years not only in Klein’s theoretical analysis but above all in his applied research. The combination of a Keynesian demand model with a Leontief structure of intersectoral relations was first considered in the construction of the Brookings model. This was followed by a series of studies conducted within the framework of the Wharton models.²⁴ This was also the topic of Klein’s presidential address to the American Economic Association in December 1977, which underscored the limits of demand stabilization measures and the importance of structural policies, concluding: “It is my feeling that overall monetary and fiscal policy have been overworked [and that] a full supply-side analysis must be developed into which an elaborated IS-LM system of thought can be fully integrated” (Klein, 1978, pp. 6–7).

²² Klein’s interest in estimating production functions dates from his research for the NBER in the late 1940s (results were also presented in his *Textbook of Econometrics*). It continued over the years and this was also a field where new estimation procedures and new computer programs could be tested. While in Klein and Preston (1967) a Cobb–Douglas specification was used to estimate production function for all sectors, in a paper with Ronald Bodkin new software programs were used that allowed to derive nonlinear estimates of CES production functions (Bodkin and Klein, 1967). More recently, to analyze the relation between investment in infrastructure and productivity, Klein considered a particular specification that allows to take account of differing responses in the short and in the long run and of the nonlinear effects on the pace of technical progress produced by the level of infrastructure endowment and other variables (Duggal, Saltzman, & Klein, 1999).

²³ Malenbaum (1969) and Griffin (1971).

²⁴ See, in particular, Fisher, Klein, and Shinkai (1965), Preston (1972) and Klein (1983c, pp. 21–36).

Klein's approach to applied research is also noteworthy for the care displayed in the analysis of the data available and the particular attention to institutional matters. A remarkable example is the study on the determination of prices and wages in the UK economy conducted together with James Ball, written in 1957 but only published in 1959 after a series of discussions with Roy Harrod, the then editor of the *Economic Journal* (Ball & Klein, 1959). Written at the same time as Phillips' (1958) and another influential contribution by Dicks-Mireaux and Dow (1959), it is an application to the British economy of the ideas that Klein had already formulated with respect to price determination and adjustment mechanisms in the US labour market. In addition to the judicious use of statistical inference, what emerges is the steady effort to draw substantial quantitative implications from the estimates, beyond their statistical significance.²⁵ In this work the systemic approach, which is a steady characteristic of Klein's empirical work, is of special importance; an original feature is the consideration of "wage drift;" and it is also noteworthy the attention to checking for the presence of autocorrelation in the residuals, with one of the earliest systematic applications of the Durbin–Watson test, soon to become one of the most widely used tests in applied econometrics.

6. Econometric models, forecasting and economic policy

As the motivation for the Nobel Prize noted, Lawrence Klein was a true innovator in the construction of econometric models for forecasting and for the assessment of policy measures. With time, Klein's systemic approach became firmly established within the discipline, although not without significant critical observations, often enough anticipated and discussed in advance by Klein himself. These included Basmann's (1972) on the possibility of creating large quantitative models based on objective, falsifiable hypotheses; that of Lucas (1976) on the use of macroeconomic models to assess alternative policies without allowing for the possibility that the model's parameters vary with variations in policy; and the objections of Liu (1960) and Sims (1980) concerning the identification of the parameters of structural models.

Klein's reply to his critics consisted chiefly in showing that it was "possible" and useful to take a quantitative approach to build forecasting scenarios on the basis of which economic policy measures might be designed. Two essays (Klein, 1946b, 1947c) are celebrated instances of this task. They came immediately after the end of the war and made use of Klein's first Cowles Commission models. In essence, the articles contain much of the "art" required to draw from econometric models forecasts of the economy they are supposed to approximate. Klein explained why official forecasts had been wrong and showed that careful use of his own models could produce more accurate projections. These essays also describe the differences, both for forecasting and for policy-making, between structural, reduced-form and autoregressive macroeconomic models, decades ahead of the debate that would break out in the 1980s.

What really opened the path to the construction and application of other, more elaborate models, however, was Klein's successful forecasts, which contrasted with the failure not only of official predictions but also with those of most economists, in particular those who professed

²⁵ In fact, this is a constant feature of Klein's empirical work. Beyond his regular use of the most appropriate estimation methods and statistical inference procedures, which were themselves often innovative given data limitations, especially in time series, Klein's appears to give special attention to the substantial economic meaning of the estimates. In this regard, Deirdre McCloskey's comments on the "irrelevance" of statistical significance (McCloskey, 1996, chap. 2), interesting and partially convincing as they are, seem to me to be off the mark in accusing Klein of inducing applied economists to focus on statistical significance at the expense of economic substance.

to be Keynesians and had expected a severe recession in the immediate aftermath of the war. In the autumn of 1953, Klein used the model that he and Goldberger had just constructed to predict, rightly, against Colin Clark's widely accepted forecasts of sharp recession, that the end of the Korean conflict would see only a brief and modest contraction in economic activity.²⁶ Further successes would be notched up by the complex forecasting models of the 1960s and 1970s described above, in particular the Wharton model.

But Klein never used his forecasting models mechanically, merely solving for the future equations estimated on past data. Rather, he showed that if they are to generate forecasts or answer specific questions on the economy's reaction to some given shock, the models need to be supplemented with outside information and the special judgement of the people who use them. A good example is the article published on the occasion of the Yom Kippur war and the ensuing oil embargo in 1973 (Klein, 1974). Klein showed how to use information from outside the forecasting models (Wharton and LINK) to produce evaluations (which proved to be timely and quantitatively accurate) of an unprecedentedly large shock to the terms of trade that the models as specified and estimated could not take into account.

In an article co-authored with Vincent Su (Klein & Su, 1979), Klein used the LINK model of the world economy to shed light on questions in which economic interdependence is crucial. In particular, the authors quantified the negative impact on world trade and economic growth produced by protectionist measures, with their repercussions on the countries that resort to them as well as on those (in particular developing countries) that do not.

Klein's models were structural, in the sense that economic theory plays a relevant role in the specification of the equations. The approach, to repeat, was systemic; the models were composed of interdependent, possibly nonlinear equations and considerable attention was paid to institutional details. Over time, they tended to become ever more detailed. Apart from economic theory – at first, to be sure, heavily influenced by Keynes, but with increasing concern over the years for supply constraints and relative prices – Klein believed that special attention should be paid to the complexity of economic systems. He was thus in fundamental disagreement with economists who, in the name of “parsimony,” set the goal of constructing “a transparent, easily manageable, and elegant model”; and he also believed that the assumption of linearity, frequently adopted because “linear systems yield elegant closed-form results” does not attain a sufficient level of generality in economics as, in general, “economic life does not follow a linear model” (Klein, 1992a, p. 184).²⁷ In his view, only large and sufficiently disaggregated (by sector, product, agent, and geography) models, carefully specified on the basis of theoretical principles, accounting definitions and institutional constraints, can approximate the complexity of the real world closely enough to produce “good” forecasts.²⁸

This means not only that working groups for the construction and maintenance of econometric models are necessary – for the preparation of the data and the estimation and simulation software as well as for the theoretical specification – but also, in Klein's view, that theory itself must be seen as undergoing complex evolution. And although he appeared sceptical of developments such as the excessive reliance on “representative agents” with rational expectations, intertemporally

²⁶ See Klein and Goldberger (1954).

²⁷ He notes, in addition, that the revolutionary advances in electronics now make it possible, in estimating and solving models, to handle nonlinearities that were once intractable.

²⁸ On forecasting with econometric models and on the limits to accuracy in economic predictions, see Klein (1971). On the necessity for knowledge and information external to the model, to be used with “tender loving care,” see Howrey, Klein, and McCarthy (1974).

optimizing their objective functions in conditions of uncertainty, he became especially critical of the effects of doctrinal controversies on quantitative analysis. As he put it thirty years ago: “The real meaning of the *Keynesian Revolution* became clear when model comparisons of alternative systems – the classical, neoclassical, Keynesian, Marxian – were formulated side-by-side in mathematical equation systems. Model building took an unfortunate doctrinal turn at that time. Although I participated as fully as anyone else in that approach to model building, I have lately come to feel that a more rewarding approach that is neutral as far as doctrine is concerned will be through the accounting structure” (Klein, 1983c, p. 2). And one of his principal interests in the last years of his life has been how best to exploit data that are available practically in real time to improve models’ forecasting capability, putting them in the best possible starting conditions.²⁹

7. Growth and the business cycle

Most of Lawrence Klein’s work, as we have seen, dealt with the theory and practice of constructing and using econometric models for forecasting and macroeconomic policy. Nevertheless, he also raised fundamental questions on economic fluctuations and the underlying dynamics of an economy. We have already noted his attention to supply-side policies, which must ultimately serve to resolve structural problems, such as inadequate productivity growth, or problems deriving from demographic trends, energy and the environment, or over-regulation.³⁰ Klein dealt with these issues, in particular, in the course of his activity as economic adviser to Jimmy Carter. At the level of theoretical and applied analysis, however, Klein, unlike Frisch and Tinbergen, took Keynes’s short term as a point of departure. Yet in a number of essays he showed a clear interest in the causes of fluctuations in economic activity (in particular the role played by shocks and nonlinearities) and in what it fluctuates around – that is, long-run tendencies.

Klein and Kosobud (1961) sought to identify especially stable relationships, or systematic trends, in such variables as the saving rate, capital intensity, the functional distribution of income, and the velocity of circulation of money. The resulting fresco is fascinating, although more than formulating a “theory” of growth, Klein simply gave a consistent, quantitative description of long-run trends, determined mainly by the interaction between the rate of technical progress (separated from trends in productive factors, and hence neutral) and the tendency towards a reduction in the saving rate. He would come back to the theme of possible economic “laws,” extending his analysis to dwell on other regular patterns (such as Engel’s law, or the law of comparative advantages),

²⁹ To take account of data revisions and new data, including qualitative information, and to correct errors detected in parts of a model, the econometric forecasting industry began to adopt constant adjustments to single equations, so as to base forecasts on the most appropriate estimates of current values of the endogenous variables to extrapolate (see Klein and Young, 1980). Necessary as this is to the effective use of econometric models, an excessively “liberal” resort to the practice prompted criticism from a number of quarters, bearing on its subjective nature, lack of transparency and non-replicability (see, for one among many, Leamer, 1983). The recourse to extrapolation techniques of high-frequency indicators utilized in the production of official statistics was conceived of by Klein among other things for purposes of replicability of such exercises (see Klein and Sojo, 1989; Klein and Park, 1993; Klein and Özmucur, 2008) and for the increasingly common construction of “bridge models”, which have by now become an established complement to both traditional and new-generation models.

³⁰ See for instance the introductory chapter to Klein (1983b). Klein also later observed: “Supply-side economics has a great deal of meaning handed down from successive generations of economists, after 1776, but this interpretation of the supply side is far different from the simplistic and populist approaches through tax cuts” (Klein, 1992a, pp. 188–189).

concluding nevertheless that “generally speaking the Great Ratios are not stable enough to qualify as economic laws” (Klein, 1983a, p. 26).³¹

Quantitative inquiry into the causes of economic fluctuations was of course one of the main themes of Jan Tinbergen’s work for the League of Nations, which preceded Klein’s earliest models. Formally, the models were essentially linear finite difference systems of equations, which readily lent themselves to the analysis of cyclical properties. It therefore quickly became clear, simply from a look at the characteristic roots of these systems, whose absolute values were less than one, that in the absence of shocks these models could not generate cyclical variations equal in amplitude or duration to those actually observed. However, an original study by Adelman and Adelman (1959) showed that when subjected to random shocks the Klein–Goldberger model tended to generate regular economic cycles of about four years. Similar results were later obtained from stochastic simulations of other models, including the Wharton model (Klein, Saito, & Evans, 1972).

Klein accordingly asked two questions that are in some sense complementary. First, he wondered whether the business cycle might not be the product of nonlinearities, making it impossible to capture its characteristics by deterministic solutions of dynamic, but linear, models of the economy; second, whether it was not chiefly the product, as Frisch’s (1933) celebrated article suggested, of the propagation of repeated random impulses in a basically stable economic environment (possibly also through the working of exogenous variables, including the effects of economic policy measures). In the latter case, which the Adelmans studied, the point was to understand the conditions under which a succession of shocks could maintain cyclical fluctuations in variables whose essential tendency was to the rapid absorption of the effects.

Klein and Preston (1969) studied the question empirically, comparing deterministic and stochastic solutions of a nonlinear model of the business cycle such as the one proposed by Kaldor (1940) with cycles generated by the interaction between saving and investment decisions. This model has a limit cycle even in the absence of random shocks, as predicted by an “endogenous” business cycle theory. Exogenous shocks make it possible to stabilize the variance of the series simulated, while in a linear model, if the deterministic solution did not stabilize but instead followed a limit cycle of constant amplitude (that is, in the case of unit roots), in the stochastic case solutions would not have a bounded variance. The nonlinear model is thus capable of generating a limit cycle of constant amplitude and finite variance. But the nonlinearities introduced for this purpose do not appear adequately supported by the statistical evidence, at least in the case of the investment function.

Klein (1998) takes up the case of a dynamic linear system that is stable but capable of generating cyclical fluctuations of constant amplitude if disturbed by random shocks. The essay, written in 1995 for the hundredth anniversary of Ragnar Frisch’s birth, analyzes the “exogenous” theory of cycles that Frisch proposed. Klein shows that in general the model’s solution contains a moving sum of random errors, to which one can apply the well-known theorems of Slutsky (1937) and Yule (1927) on the accumulation of random shocks. However: “It is one thing to observe, as Yule and Slutsky did, that moving averages of random numbers tend to be oscillatory and to argue as Frisch and the Adelmans did that this must somehow be related to the solution of stochastic economic systems, but it remains to be shown more precisely just why this is relevant for interpretation of the solution form of the linear, stochastic, dynamic system. We are in need of a theorem on the existence of the stochastic cycle in economic systems” (Klein, 1983c, pp. 107–108). There is no

³¹ This was also, most likely, the reason for Klein’s scepticism over recent model construction methods based on “calibration” techniques (Klein, 1992c).

need to go into detail here. It suffices to note that this research project, set out by Klein in the 1970s, found a positive solution thanks to the theorems and analyses of his students, confirming the realistic nature of a Frisch-style exogenous theory of the business cycle, according to which a succession of random shocks, with expected value equal to zero, can produce an apparently regular cyclical pattern in the crucial variables of the economic system.³²

8. Conclusions

Beyond the specific contributions surveyed here, notable as they are both individually and as a whole, Lawrence Klein was decisive in getting the economics profession to shift resolutely to the use of quantitative analysis for forecasting, economic policy-making, and the empirical study of economic phenomena. Econometric modelling has come a long way in the seventy years since his earliest efforts with the Cowles Commission, following and at times anticipating developments in economic theory, fully exploiting and at times stimulating advances in information technology. Klein was not convinced of the value of all of these developments. Rational expectations with representative agents, new classical macroeconomics and real business cycle theory were not, in his view, theoretical constructs sufficiently able to take into account the complexity of the real world. At the same time macroeconomic methodologies that ask too little of a priori economic analysis, such as vector autoregression, or that underutilize the information contained in the data, like calibrated models, ran afoul of his belief, developed over the years, in the superiority of large models that can pay proper attention to accounting variables and institutional characteristics.

This is not the place for a thorough examination of the latest developments in econometric modelling or macroeconomic theory (which is now not only “micro-founded” but also often hard to distinguish from the theory of rational behaviour by individual agents under uncertainty). But on the role of economic theory, while it is impossible and senseless to describe Klein as a tireless defender of Keynesian economic stabilization policy,³³ he unquestionably did not agree with those who maintain that there is less and less need for government intervention in the economy. Specifically: “Philosophically, I do not believe that the market system, in even its purest form, provides adequate self-regulatory responses. The economy definitely needs guidance – even leadership – and it is up to professional economists to provide public policy makers with the right information to deliver such leadership. As for the methods of doing this, I see no alternative to the quantitative approach of econometrics, but I do realize that all policy issues are not quantitative and measurable. At times, subjective decisions must also be made” (Klein, 1992a, p. 186).

In any case, the categories that we use today in dealing with economic policy measures, whether minor or major, are very largely influenced by the work of Lawrence Klein. And while he may not have agreed with the philosophical foundations of the new “dynamic stochastic general equilibrium models”³⁴ widely used in the decade of the “great moderation”, there is no question that without his models it would have been impossible to impart any quantitative form at all to the latest theoretical paradigms. For that matter, it remains to be seen what empirical representation of the economy new models, included the refined versions of those that have been of little use in the years of the financial crisis and the “great recession”, will tend to produce, and how far

³² For these theories, see Otsuki (1971) and Yamamoto (1974). See also Klein’s extensive analysis in Klein (1983c, chap. 4) and, for a formal treatment, Klein (1973).

³³ “There is nothing in the Keynesian prescriptions to support highly unbalanced policies or excessive reliance on monetary policy to provide economic stabilization” (Klein, 1992b, p. 50).

³⁴ See Smets and Wouters (2003) and Christiano, Eichenbaum, and Evans (2005).

removed it will be from what we would now call “traditional” econometric models, which are still widely used, in one form or another, for economic forecasting.³⁵

A most fitting conclusion can be taken from the words used by Ball (1981, p. 92) in reviewing the fundamental contributions of Lawrence Klein that motivated his Nobel Prize: “It is appropriate to describe his work as pioneering. . . . He has attempted what others would not undertake. It is no mean achievement to have lifted, almost singlehandedly in the earlier years, the practice of large-scale econometric model building to a position of great value and respectability in the profession. In this sense, his work has been as much entrepreneurial as intellectual. . . . As a by-product of this, he set an example and a style which cannot simply be represented by any book, and which played a major role in integrating economic theory and applied analysis and in liberating applied economics from its rather dull image into the more exiting and active investigation of many contemporary problems. In this respect, his practical influence has been enormous.”

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³⁵ See Visco (2009, 2013).

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