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Who is Anne P. Carter? She was born Anne Pitts on May 7 1925 in New York City. At a time when cars were sold without “accessories” such as headlights, trunks, mirrors, her father ran an automobile supply shop where he could sell, among other things, inventions of his own. Her mother devoted herself to the household and to her only child: “she wanted me to be happy, which, in her eyes, called for marriage to a man of means and status. Lacking the beauty and charm of a *femme fatale* one couldn’t count on making such a marriage and she deemed intellectual competence, essential as an alternative source of security” (Carter). According to the family legend, Anne Carter’s father, Jacob J. Pitts, invented the modern system of two-branch windshield wipers, allowing his wife to advise the driver in all kinds of weather.

Carter’s father was fascinated by technologies, and during summer holidays the family toured industrial plants! The very early years of Anne P. Carter are marked by a double trauma: first, the failure of her father’s business, because General Motors began to sell cars fully equipped, an innovation that ruined the family business; second, the threats of foreclosure of their home during the Great Depression of the 1930’s. The Pitts took out a mortgage and bought a house in October of 1929. Black Tuesday and the long depression led them and millions of other American households close to foreclosure several times. This extreme situation meant chronic unemployment for her father and forced her mother to go back to the market of labor. These economic pressures continued until the 1941 declaration of war.

In 1945 Carter completed her AB courses at Queens College in NYC where she studied with the economist Arthur Gayer and the philosopher Karl Hempel. She went on to graduate work at Harvard where she was taught by scholars like Joseph A. Schumpeter and Wassily W. Leontief. At that time women studied in the same Harvard classes and fulfilled the same academic requirements as men graduate students but were technically enrolled at Radcliffe¹. Harvard professors took the responsibility for placing their male graduates, but not their Radcliffe graduates, in appropriate academic jobs. In 1946 she married a classmate, Robert Grosse. The same year Carter began work on her PhD thesis at Harvard. However, as her husband got a teaching appointment in Maine (1946-1947), and then in New York City (1947-1949), Carter wrote her PhD thesis in *absentia*. During that period, she had a part-time teaching appointment at Bates College (Maine), and became Instructor in Economics at Brooklyn College (NYC) where she taught for two years while writing her thesis.

* Written for Robert W. Dimand, Mary Ann Dimand, and Evelyn L. Forget, editors, *A Biographical Dictionary of Women Economists*, Cheltenham, UK, and Northampton, MA: Edward Elgar Publishing, forthcoming. Reproduced by permission. The author gratefully acknowledges Anne P. Carter’s patience and generosity in answering questions during numerous interviews as well as countless email exchanges. Correspondence may be addressed to Amanar Akhabbar, Centre Walras-Pareto, University of Lausanne, amanar.akhabbar@unil.ch.

¹ See in this dictionary the biography of Margaret Gordon, representative of the generation that studied at Harvard before Carter. Gordon and Carter eventually never met.

Carter's thesis, *Production Functions and Cost Minimization in Basic Open Hearth Steelmaking*, focused on the interface between technology and the market mechanism. A first thesis project, proposed by Schumpeter on "Time in Economics" seemed too ambitious and she dropped it. Instead, she chose a topic that bridged her interests in methodology and in her early family focus on factory visits, supervised by Wassily Leontief and Edward S. Mason. Her PhD in economics was awarded by Radcliffe College of Harvard University in 1949.

In the spring of 1949, Robert Solow –who was Leontief's assistant at Harvard and one of Carter's classmates– suggested that Leontief would sponsor her in further research on the interface between technology and economics. She moved to Cambridge in the summer of 1949 to work more closely with Leontief's Harvard Economic Research Project (HERP), an institute dedicated to input-output studies and related issues. Leontief offered a year-round position not only to Carter but also to her husband. They accepted and stayed in Cambridge. Carter was shocked to find that although she was the prime object of the hiring decision, he offered her husband a higher salary. When she asked him why, Leontief said that he thought she would like it. She didn't, but one didn't quibble about such things in those days. Carter and Grosse divorced in 1950. The collective book published by the HERP in 1953 contained the works of Carter on "the technological structure of the cotton textile industry" (a study on the textile industry had been commissioned) and Robert Grosse's paper on capital coefficients for the input-output system.

Carter's professional career may be subdivided into two periods: 1950-1970, the "Harvard period", and from the 1970s onwards the "Brandeis period". We discuss separately Carter's role in the input-output community.

The Harvard period 1950-1970

Prior to 1966 there were no women in the economics faculty at Harvard. In 1966 Carter became the first assistant professor of the Harvard Economics Department but, while she was permitted to offer seminars on topics of her choice and to advise students, she was never given any teaching assignments. Before that, while a Research Fellow at Harvard (1951-1955), she lectured at Smith College (1951-1953) and at Wellesley College (1954-1955). In 1953, she married psychiatrist Franklin Carter, and in 1955 gave birth to her first child. The coming of Carter's child opened a part-time work period as she hesitated in going on in academic life. Leontief persuaded her to stay at HERP and offered her a very flexible arrangement. She accepted and gradually returned to full time research at the end of the 1950s. During the next decade she became one of the most eminent input-output specialists, the research director of HERP (1968-1972), and also gained the reputation of being Leontief's main "disciple".

In her work, Carter focused on technological innovation and structural change. For her part, Carter was primarily interested in the factors that influenced technical coefficients, those coefficients measuring the quantity of input (or capital) used to produce a unit of an output. While Leontief took changes of technical and capital coefficients in structural matrices to be given by engineers, during the 1950s and 1960s most of the work of Carter was dedicated to this issue.

Structural Change in the American Economy (1970)

In contrast to mainstream economists, Carter explored the hypothesis that changes in technical coefficients were not mainly the consequence of substitutions among factors but also the result of the technological structure of the economy. She developed the idea that an industry is not technologically homogeneous, i.e. that firms in the industry use different

technologies to produce the output. As a consequence, a technical coefficient does not define a unique technology but is composed of technologies of different “vintages” (Carter 1960). In her major book, *Structural Change in the American Economy* (1970), this idea was strengthened as the technological structure of each sector was described in terms of different technological layers with different weights. As a consequence, a change in the mix of technology vintages leads to changes in technical coefficients. Carter’s publications (1960, 1967, 1970) made use of linear programming to explain this process, and also provided detailed empirical studies of changes in technical coefficients. At that time Carter progressively gave up the microanalysis of production functions at the plant level to move to the sectoral level. However, because of her knowledge of theoretical and concrete issues of production at the plant level, Carter always offered a view that is all but naïve; and she always underlined the crudeness of data and, as a consequence, the weakness of economists’ concrete knowledge.

The 1970 study was based on comparisons of the technical coefficients of the US economy of 1939, 1947 and 1958. Even though it is difficult to draw general conclusions about technological change from a disaggregated structure of more than 70 sectors, some important conclusions can be summed up. First, what Carter called the “paradox” of her study: input-output structure changes slowly in an era noted for rapid technological advance. In this respect, two different shifts should be noted. Total intermediate output required to produce a fixed final demand remains fairly stable and even increases slightly while, over time, the economic system requires less and less labor and capital to produce a fixed final demand. Moreover, in contrast to the “golden age” proportional-growth assumption (see Phelps 1963), there are decisive changes in the relative importance of individual intermediate sectors within the total output. Indeed, sectors producing “general” commodities, like fuels, and particularly services like transportation, trade, communications, etc., grow, while materials processing industries, like metalworking, decrease in volume. Another point is that while input structures of industries are sensitive to relative prices –and thus substitutions explain part of structural change– it appeared that substitutions are of lesser importance compared with technological change. Technological change is modeled through a linear programming model of sectors defined as layers of technological vintages.

Carter’s 1970 book remains a must-read text on disaggregated growth accounting and technological change analysis. It also marked a turn in Carter’s career.

The Brandeis period

The 1970s are clearly a turn in the sense that Carter’s research interest are extended to energy and economic development issues, and that she left HERP and Harvard in 1971 to move to Brandeis University in Waltham, Massachusetts. The situation of women at Harvard was still not encouraging. In 1967 she was one of the first women to become assistant professor in the Faculty of Arts and Sciences at Harvard but she felt unwelcome. Hence, after two decades of ambiguous settlement at Harvard, Carter went to Brandeis University as visiting professor and accepted a full professorship in 1972. Leontief threatened to close the Project if she left, and indeed he did. Other events accelerated the end of HERP: Leontief approached the mandatory retirement age and received an attractive post-retirement offer at New York University; he was awarded the 1973 Nobel prize and his wife, a novelist, poet, and native New Yorker, welcomed a move to New York.

HERP was closed officially in 1973 and the HERP library and research materials were shipped to Brandeis. In contrast with Harvard’s “stifling constraints on women” (Carter), Brandeis offered many welcome opportunities. Carter’s career at Brandeis is dazzling:

between 1972 and 1979 she directed the Brandeis Economic Research Center; she became Fred C. Hecht Professor of Economics in 1976, served as dean of the Faculty from 1981 to 1986, chair of the Department of Economics between 1987 and 1993, and was Acting Dean of Arts and Sciences 1999-2000. Carter greatly developed the department of economics at Brandeis, and in this respect her work with Peter A. Petri was crucial (see Carter and Petri 1977, 1979, 1980, 1986, 1989).

The World Model (1977)

In 1974 UNO asked Leontief to initiate a study of the prospects of the world economy in the Club of Rome works and other studies of the limits-to-growth context. This was a time of high anxiety and concern about conflicts between free market and the environment. Along with the great promise of rapid industrialization came new concerns about the adequacy of resources and about environmental impact. Lacking a research organization to study the economic and environmental sustainability of the UN program at Harvard, he asked Carter, now at Brandeis, to help him. Committed to a full program of teaching and other academic responsibilities, she agreed to “help” on a limited basis. This project absorbed enormous energy and resources at Brandeis over several years, during which Leontief moved to his new position in New York. Fortunately Peter Petri, then a Harvard graduate student who had worked at HERP during his undergraduate years, agreed to work on this project with Carter at Brandeis. He later joined the Brandeis faculty and more recently became the founder and first dean of the Brandeis International Business School.

The broad theoretical basis of the study was the schematic “world model” Leontief presented in 1973 as his Nobel Prize conference. The development and the implementation of an operational world model were Carter and Petri’s work at Brandeis. The world model specified 15 regions, each with a 45-sector input-output structure. It dealt with environment, energy, growth, development and international income inequality and made decennial projections to the year 2000. One of the main findings of this study is that the UNO objectives of income equality among regions were not realistic. Indeed, even if the proposed growth objectives were to be achieved in poor and rich regions, the inequality ratios among those regions remain roughly the same at its 1970 value (12 to 1). Another important result is linked to the absence of any technological limitation to agricultural and industrial development in developing countries while strong (micro) institutional and (macro) financial brakes are at work. A third conclusion is that development would put the trade balance of developing countries under severe pressures and that enormous international financial aid would be required to offset balance-of-trade disequilibria. Concerning environment and energy, the study underlined that, if appropriate technologies were used, growth could be sustainable and that sufficient energy resources were available to fuel the projected levels of economic activity. Many conclusions of this study are still very relevant now, as Fontela (2004) underlined recently. However, during the 1970s, the effect of economic development on global warming had not yet emerged. This study is important not only because of the remarkable results displayed but also because it was a pioneering work in world models. Environmental world models, which are now a major feature of contemporary research, are an important field of study in the history of science (see Dahan 2007).

By the late 1970s the Brandeis material on the world model had been sent to New York where Leontief created a new research center at NYU. It is of interest to note that, while Leontief had never used an input-output model with changing technical coefficients, in his 1986 book on automation and workers, Leontief and Duchin finally chose to employ Carter’s coefficients defined as moving technological layers of different vintages. After the 1977 world model, Carter published new papers on energy, using the world model (1979 and 1981), but also came back to her favorite topic: innovation and technological change. While

Leontief used to say that Carter was the one who understood best his work, and despite the fact that she was one of the major experts in the field, she always felt free to use different techniques like econometrics (1960), linear programming models (1970) and rational choice models (1989). For instance, a 1989 paper examines the structure of the exchange of knowledge within the firm. Carter showed for instance “why barter is better suited to the exchange of ideas than to the exchange of conventional goods”. It is a point of major interest to understand the underlying motive of technological change. A series of articles dealing with innovation measurement has been published since 1990 (see 1990a, 1996b, 1996c, 2008).

A major character of the input-output community

From the late 1950s onwards, Carter was recognized as a prominent member of the input-output community. Carter is a reference specialist on input-output studies (see for instance 1972b, 1975, 1990b, 1991). With Andras Brody she organized and published numerous volumes of the International Input-Output Conferences (see Carter and Brody 1970a, 1970b, 1972a, and Carter 1976a). She also had a constant involvement in I/O policy making, for the American administration or other private and international organizations. See for instance Carter’s statement before the Sub-committee on International Economics of the Joint Economic Committee for Congress of the United States (1973 and 1977) about energy and employment matters, or her work for the OECD and her ongoing involvement with the Russell Sage Foundation. As an anecdote, *Business Week* noticed that Carter’s forecasts of inflation rate were the best forecast for 1977... Moreover, she wrote many papers on input-output economics for non economists audiences, but also on Leontief himself (1976b, 1989c, 2004). Her reflections on input-output analysis are always marked by her critical mind. She has pointed out that both input-output and mainstream economics fail to measure or take into account the “external” costs of technological change, the fixed and also the human capital losses imposed on those whose assets are rendered obsolete by innovation (1986).

The formation of an International Input-Output Association (IIOA) was proposed at the Eight Input-Output Conference, in Sapporo (Japan), and it was formed shortly thereafter. While Carter (and Leontief) felt ambivalent about the creation of the IIOA, largely because they saw I/O as a part of general economics and not as different discipline, Carter became the founding president of the IIOA in 1987 (to 1991). Recently, Carter observed that in contrast to other fields of economics, input-output economics is a women-friendly area despite the gender bias of American academics. Many of Leontief’s main co-authors and colleagues were women: Carter, Karen Polenske (president of the IIOA, 1997-2000), Faye Duchin (president of the IIOA, 2004-2006), Gabrielle Antille-Gaillard, etc., a fact that Carter analyzed with a deep insight (2005, 2007).

Currently, with her inimitable enthusiasm and Voltaire-like spirit, Carter goes on teaching, doing research and animating the I/O network. In January 2009, Anne Carter received, in San Francisco, the Carolyn Shaw Bell Prize from the American Economic Association. Since the age of 14 she also has been a cellist and an enthusiastic amateur chamber music player.

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