Computer Operators and Software Engineers at Data Resources Inc.: An Oral History (1969-1983)

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Abstract: Macroeconometric models went for profit in the 1960s. In Massachusetts, Data Resources Inc. (DRI) was established in 1968 by Otto Eckstein and Donald B. Marron. Together with the Wharton Econometric Forecasting Associates, founded by Lawrence Klein in 1969, and the Chase Econometrics, founded by Michael K. Evans in the same year, these companies had corporate and government clients and became the three giants in a thriving market in the 1970s. Using a wide academic network, DRI built its identity around three elements: a large database, a large computer infrastructure, and an in-house econometric software (the Econometric Programming System, EPS). DRI packaged them nicely through timesharing: its large-scale multi-frequency databases and the econometric software were accessible from remote telecommunications terminals that clients would dial in. The development and maintenance of economic databases, of the econometric software and of the models running in time-sharing computers required a host of technical computer experts: daily, computer operators would back up the economic data, the software source code, and everything in the computer; software engineers would design, develop, maintain, and test the computer software. In this paper we try to make some of the corporate practices of DRI visible through oral history, notably by interviewing Peter White, a computer operator then software engineer at DRI, and also a few other people who worked at DRI or at its competitors. By doing so, we offer some important and unprecedented insights into how the role of computers and softwares in the transformation of economics since the 1960s.

Keywords: history of macroeconomics, large-scale macroeconometric modeling, computerization of economics

Resumo: Modelos macroeconométricos se tornaram comercializados na década de 1960. Em Massachusetts, *Data Resources Inc.* (DRI) foi criada em 1968 por Otto Eckstein e Donald B. Marron. Juntamente com o *Wharton Econometric Forecasting Associates*, fundado por Lawrence Klein em 1969, e o *Chase Econometrics*, criado por Michael K. Evans no mesmo ano, estas três companhias tinham clientes do setor privado e de governos e se tornaram as três gigantes do ramo de consultoria econômica na década de 1970. Utilizando uma ampla rede acadêmica, DRI construiu sua identidade em torno de três elementos: uma grande base de dados, uma potente infraestrutura computacional, e um software econométrico por ela desenvolvida (o *Econometric Programming System*, EPS). DRI os vendia conjuntamente através da tecnologia de *timesharing*: a grande base de dados de frequências variadas e o software econométrico eram acessíveis aos clientes por terminais remotos ao computador central por linhas telefônicas. O desenvolvimento e manutenção da base de dados, do software econométrico e dos modelos em tecnologia *timesharing* exigia uma gama de técnicos em computadores: diariamente of operadores de computador faziam o backup da base de dados, do código fonte do software EPS, e tudo mais que estivesse no computador central; engenheiros de software desenvolviam, mantinham e testavam os softwares. Neste artigo tentamos analisar algumas das práticas corporativas da DRI através de uma história oral: entrevistamos Peter White, um operador de computador e posteriormente engenheiro de software na DRI, e algumas outras pessoas que ou trabalharam para DRI ou para suas concorrentes. Assim, oferecemos novas perspectivas sobre o papel dos computadores e softwares na transformação da ciência econômica desde a década de 1960.

Palavras-chave: história da macroeconomia, modelos macroecométricos de larga escala, computadores na transformação da economia

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1. Introduction

Macroeconometric models went for profit in the 1960s. After having been developed greatly since the original efforts of Jan Tinbergen (1936, 1937, 1939), in the 1960s such models connected academia, governmental agencies in different countries (mainly central banks), and now also consulting firms. In Massachusetts, Data Resources Inc. (DRI) was established in 1968 by Otto Eckstein (PhD Harvard 1955) and the financier Donald B. Marron. In Philadelphia, the Economics Research Unit was created within the economics department of the University of Pennsylvania in 1961 and started distributing the Wharton Quarterly Model. But it was in 1969 that the Wharton Econometric Forecasting Associates, Inc (WEFA) was incorporated by the Trustees of the University of Pennsylvania as a "not for profit" organization, and was led by Lawrence Klein (PhD MIT 1944). In the same year, Klein's colleague at the Wharton School and member of WEFA's Board of Directors, Michael K. Evans (PhD Brown 1964), broke up with WEFA and stroke a deal with Chase Manhattan Bank to create Chase Econometrics Forecasting Associates. These companies had corporate and government clients and became the three giants in a thriving market in the 1970s.

The main challenge of historicizing the modeling practices of private companies is access to archives or first-hand experience of those who worked for them. Serendipitously, in April 2021, when *Œconomia* circulated his call for papers "The Computerization of Economics," the editors of the special issue received a message from Peter White, who introduced himself as follows:

> *I worked at Data Resources Inc. in Lexington, MA, USA from 1972 to 1979. I was a software engineer, not an economist, though. And in 1972, I was a very junior one. By 1979 I was responsible for most of the infrastructure code in the EPS (Econometric Programming System) modeling Program that DRI produced, used, and licensed.* (Peter White, personal communication, 15/04/22)

Peter White's experience at Data Resources Inc. (DRI hereafter) proved of great interest, insofar as it would help documenting, based on a first-hand account, two relatively unknown and understudied aspects in the history of macroeconomics: the role of computers and softwares in 1970s, the thriving period of macroeconometric modeling in private companies, and how companies such as DRI shaped the development of macroeconomics. Our paper documents how these two aspects were connected, thanks mostly to Peter White's memories and on the recollections of other people involved, directly or indirectly, with DRI's activities: Robert Hall (PhD MIT 1967) Kevin McManus (BA University of Dayton 1976, MBA Boston College 1985), J. Phillip Cooper (PhD MIT 1972), and Jim Luke. The case of DRI illustrates how, within the industry of private macroeconomic consulting, the use of computers and softwares played a distinctive, driving role for the development and the dissemination, outside of academia, of macroeconomic knowledge and modeling practices. Moreover, macroeconometric modeling within corporation as DRI was far from being simply an "application" of macroeconometrics as developed in academia; it constituted, rather, a frontier for technical innovation in handling macroeconometric models and in spreading their use to businesses and government institutions.

Recent contributions to the history of macroeconomics have shifted the focus of investigation from theoretical debates within academia (as depicted notably in De Vroey, 2016) to the practice of macroeconomic modeling, particularly in policymaking institutions (see e.g. Boumans and Duarte, 2019).

This shift in focus has called attention to the "practice" of macroeconomics, to the interaction between economists and policymakers, and to the importance of policy routines (forecasting, economic scenarios, etc.) in determining modeling choices. In this literature, the materiality of practices (funding, availability of data, policy demands, etc.) is central: this also points, among other factors, toward a somehow important role of computers and softwares for macroeconomics. Indeed, computer tools have been often highlighted by historians of macroeconomics as creating both constraints and opportunities for the discipline (computational capacities, costs, possibility of simulation, handling more/different data, complexity/size of models, tractability issues, and so on). Though computer-related aspects are frequently mentioned by both macroeconomists and historians, they are rarely investigated in detail. This also results from the difficulties in finding suitable sources on computer-related practices, since macroeconomists often were, in their publications, quite elusive about computer-related details.

Given the scarcity of sources that historians of macroeconometrics face, relying on oral history offers a possibility to circumvent, at least partially, this difficulty. The first contribution of our paper is precisely to use oral history to "flesh-out" the concrete practice of the use of computers in macroeconomic modeling at DRI during the 1970s. Thanks to oral history, it is possible to "take a walk" through the computer room and observe the functioning of the computer infrastructure, the organization of work, the interaction between economists and other professional figures. At the end of this "tour," we better understand what kind of constraints and opportunities were created by computers and softwares for macroeconomics during this period.

Although DRI is a particular case of the practice of macroeconomics in the 1970s, it is a case that brings a novel element to the existing literature on the history of macroeconomics. While the role and place of macroeconomic knowledge in policymaking institutions has been documented, by now, for a large number of cases in the 1960s-1970s, much less is known about commercial models in the hype of what Smith (2003) called the "market for macroeconometric models."[1] Our paper, based on the case of DRI, documents some aspects of this industry, particularly one of the most distinctive aspects of the DRI business model: the development and commercialization of a broad economic database, of computing capacities, and of software facilitating econometric work for DRI customers.

In the first section of this article, we present the origins of DRI and contextualize its activities within the development of macroeconomics in the 1970s and the emergence of the industry of macroeconometric modeling. In the second section, we detail the functioning of computer infrastructure at DRI and how this supported economists (within and outside DRI) in their analytical work. The third section presents the development of the Econometric Programming System (EPS) by DRI and locates the design and functions of EPS with respect to other software of the time. Finally, in our concluding remarks, we highlight some historiographical challenges in writing about the role of computers in commercial companies.

[1] The literature on the history of models in policymaking institutions includes: for the Federal Reserve Board of Governors, see Brayton *et al.* (1997), Backhouse and Cherrier (2019), Rancan (2019; 2022), and Acosta and Cherrier (2021); for the Social Science Research Council, see Acosta and Pinzón-Fuchs (2019); for the Norwegian planning, Halsmayer (2017); for the Bank of Italy, Rancan (2020); and the several country studies in Bodkin, Klein and Marwah, 1991, chs. 6-12. This book also recounts the development of several macroeconometric models in the US (Brookings, the Bureau of Economic Analysis/US Department of Commerce model, Wharton, and others). See also Shenk (2016, ch. 5).

2. DRI and the Thriving Industry of Macroeconometrics

2.1. Wall Street, the Council of Economic Advisors, and Harvard: The Origins of DRI

DRI was established in 1968 by Otto E. Eckstein and Donald B. Marron. Both served as *de facto* co-chairs of DRI throughout the 1970s. Marron recounted in details the circumstances leading to the founding of DRI in a piece published at the occasion of Eckstein's death in March 1984 (Marron, 1984). Marron was a financier, who had built a career in Wall Street since the early 1950s. At the turn of the 1960s, he owned Mitchell Hutchins & Co, a company specialized in the analysis of financial markets.[2] At this time, Marron had the idea of creating a "consulting program" that would provide "portfolio managers" useful insights into macroeconomic conditions (Marron, 1984, 537). Marron further recalls: "I therefore put the following question to a number of my colleagues on Wall Street: 'Who is the best young economist you can think of to fill this role?' The most frequent reply was 'Otto Eckstein'" (Marron, 1984, 537).

Eckstein enjoyed such a well-established public reputation because of his role as a member of the Council of Economic Advisors in the years 1964-1966 (Arenson, 1984). Eckstein had also a prestigious academic career. A Princeton undergraduate in economics (1951), he completed his PhD in economics at Harvard (1955), and he became a Harvard Professor of economics. Eckstein's "outstanding reputation as an economist" made of him a "natural" candidate for entering the CEA (in replacement of John B. Lewis)—as President Johnson explained to Eckstein, on the phone, when offering him the job.[3] Eckstein's previous theoretical and empirical research on the determination of wages and prices (Eckstein and Wilson, 1962; 1964; Eckstein, 1964) led him, during his time at the CEA, to assume the responsibility for "wage-price guidepost policies" and for "developing some of the programs of the Great Society," which was a set of domestic programs launched by President Johnson in 1964-65 that included, among other things, the Civil Rights Act of 1964, the War on Poverty, and Medicare and Medicaid (Arenson, 1984).

After leaving CEA in 1966, Eckstein accepted Marron's invitation and the two started to develop a "consulting program," which took them across the US, meeting with various corporation executives. But:

> *traveling was a tedious and time-consuming way to impart information to our clients, and sometime in 1967 Otto suggested to me that perhaps we could use a computer instead.* (Marron, 1984, 537)

The original idea by Eckstein was for costumers to be able to access information through timesharing, a relatively new technology that allowed clients to "connect" their terminals to a computer over phone lines. The idea then blossomed in establishing a company, whose "product concept developed by Otto had four basic elements: the model itself, a large data base, a computer, and the software" (Marron, 1984, 537). Eckstein had been, more generally, interested in making the most recent econometric techniques

[2] During his life, Marron would have prominent executive roles well-beyond DRI, as for instance the chair of UBS Americas. After his death in 2019 the *New York Times* summarized his main achievements: "[Marron] led some of Wall Street's most powerful firms, played a shaping role in the expansion of the Museum of Modern Art in New York and delved into policy issues as a member of the Council on Foreign Relations and other organizations" (Padilla, 2019).

[3] Johnson conversation with Otto Eckstein on May 04, 1964. Lyndon B. Johnson Presidential Recordings, WH6405.02/3337, Miller Center, University of Virginia. Johnson was of course advised to appoint Eckstein by Walter Heller, then Chairman of CEA (Johnson Conversation with Walter Heller, on May 04, 1964, Lyndon B. Johnson Presidential Recordings, WH6405.02/3337, Miller Center, University of Virginia).

available to business and government for conducting their activities. His own experience had convinced him that economic analysis outside academia was not benefitting of the most recent advances in econometrics, especially when applied to macroeconomics:

> *After my most recent period of full -time government service in 1966, my views on the economy were sought by business and financial organizations. I quickly discovered that they made little use of macro economics or econometrics. The gap between macro and micro was unbridged. They typically ignored the overall situation. Econometrics, which always looked to me to be a very practical way to establish quantitative relationships, received little use and remained an academic plaything. I had already discovered in the government that even macro-decisions were made on the basis of very crude quantitative work, without the benefit of the thirty years of methodological development of econometrics.* (Eckstein to Galbraith, December 20th, 1972; in Collier, 2022).

For the purposes of its new consulting firm, Eckstein envisioned building his own macroeconometric model, instead of relying on an existing one. Eckstein had already been involved with the very beginnings of large-scale macroeconometric modeling in the US: with his Harvard colleague James Duesenberry (PhD University of Michigan 1948) and with Brookings' Gary Fromm, Eckstein had elaborated, in 1958, the first draft of what later became the SSRC/CES-Brookings model (Acosta and Pinzon-Fuchs, 2019, 538).[4] Thanks to his early involvement with the macroeconometric modeling community, Eckstein was able to ask other economists to contribute to the building of his model for DRI. Marron (1984, 537) cited as early contributors to the DRI models Fromm, Martin Feldstein, Lester Thurow, Dale Jorgenson, and Edward Green.[5]

For the data part of DRI business, Marron (1984, 537) emphasizes that Brooking's experience with collecting and handling large dataset was paramount in guiding Eckstein. This is no wonder: the procedures for collecting, homogenizing, storing, and exploiting a large dataset to be used for macroeconometric modeling (and beyond) was one key aspect of the SSRC/CES project in the early 1960s, which was then passed on to the Brookings Institution (Acosta and Pinzon-Fuchs, 2019). Two Brooking's economists (James Craig and John Ahlstrom) even joined DRI at its foundation, taking on the responsibility of the data part (Marron, 1984, 537).

All the economists consulted by Eckstein were offered shares of DRI as a compensation for their help:

> *I therefore proposed that we offer stock in the company to nearly all of the country's leading econometricians in exchange for commercial rights to their academic work. Otto questioned the wisdom of distributing stock to individuals who might contribute little to our company, but agreed that this was a small price to pay for technical assistance that might prove vital to the project. …*

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[4] The Social Science Research Council (SSRC) is an international, non-profit, independent organization founded in 1923 by the American Economic Association, the American Sociological Association, the American Political Science Association, and the American Statistical Association. By 1925, representatives from the American Anthropological Association, the American Historical Association, and the American Psychological Association joined the organization. Its aim is to generate new insight into pressing societal issues (https://www.ssrc.org/about-us/; accessed on July 1 2022). SSRC created the Committee on Economic Stability (CES) in 1959 "as a joint venture of economists in academia, think tanks, and government institutions that were interested in better understanding economic instability in postwar United States" (Acosta and Pinzón-Fuchs, 2019, 537).

[5] For a comprehensive lists of contributors to DRI models through the years see Eckstein *et al.* (1974, 595), and Eckstein (1980, xiii).

> *Therefore, we signed up most of the leading lights of econometrics, including Lawrence Klein, Martin Feldstein, Lester Thurow, Marc Nerlove, Dale Jorgenson, and Robert Hall.* (Marron, 1984, 538).

DRI relied mostly on 1 million dollars of venture capital, made possible by the contribution of First Security Company (a branch of First National Bank). After choosing the new company's name, Marron and Eckstein set sail.[6] DRI started operations in Summer of 1969, in its Lexington's headquarter, 10 miles (a 30-minute drive) from Harvard. Marron claims that this location was instrumental in the success of DRI, as it could both profit of the proximity of MIT/Harvard, as well as make possible for Eckstein to walk from his home to DRI offices at any time (he spent even weekends working at DRI according to Marron, 1984, 538). However, the double role of Eckstein and the relationship between Harvard University and DRI had been under scrutiny in 1972-1973: John K. Galbraith raised the issue of a potential conflict of interest, stirring an internal debate with Eckstein, Feldstein, Jorgenson, and Duesenberry (Collier, 2022). Later in 1973, the Harvard Economics Department ruled that "business connections between Economics professors and outside corporations do not interfere with hiring decisions and teaching practices." (*Harvard Crimson*, 20/03/1873, quoted in Collier, 2022).

2.2 DRI Activities and the DRI Macroeconometric Model

DRI activities were structured around different "groups" of economic analysis doing both sectoral and industry-level analysis and also a macroeconomic analysis based on the macroeconometric model. Kevin McManus, an economist working at DRI from 1976 to 1983, recalls that most groups would typically involve around 10 people, mainly economists, with 1 or 2 PhD graduates (McManus, interview). Each group would oversee data collecting and produce economic analysis for a specific sector of the US economy or a specific industry (McManus, interview).[7] McManus was for instance part of the "steel sector group", which would, for instance, collect and compile data on steel shipments (received from U.S. Steel), then use it to produce demand indicators for steel by end-industry, and finally estimating and forecasting demand for steel (McManus, interview). Other DRI groups would conduct similar activities for the paper industry, for the transportation industry, for the energy sector, for the agricultural sector, for banking and financial activities, for the housing sector, etc. The analyses of each group would feed into the work of the "National Forecasting Group", a larger group (around 30 people) in charge of DRI macroeconometric model. This was "the most prestigious" group within the company, since the model was conceived as the cornerstone of DRI's activities and reputation, but not necessarily brought the most clients to the company (McManus, interview).

The DRI quarterly model of the U.S. economy, developed throughout the 1970s, was representative of this class of large-scale macroeconometric models earlier advocated by Lawrence Klein (Klein and Goldberger, 1955) and then developed further by the joint effort of academics and policymaking institutions in the 1960s. Eckstein (1983, 3) explicitly claims this legacy for his own model, while he locates DRI model into a "second generation" of macroeconometric models, which would include models developed by SSRC/CES-Brookings, by MIT-Fed, and by Wharton (Eckstein 1983, 3-4).

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[6] Marron (1984, 538) explained that they chose DRI from a list of the names that were not already taken by competing firms.

[7] McManus recalled that an international macroeconomics group would also work on collecting data for other countries and producing an international forecast. DRI had also activities and clients outside the US, notably in Europe (with a European office set in West Germany, he mentioned). Due to a lack of sources on this aspect of DRI activities, we restrain our analysis to DRI US-based activities.

The original DRI model (1969-1972; presented in Eckstein *et al.*, 1974) went through substantial refurbishment after 1974.[8] The version of the model available at the end of the 1970s consisted of roughly 700 equations, of which 375 stochastic behavioral equations (Eckstein, 1983). The economy represented by the model is "disaggregated" into various blocks, each further disaggregated in further details, following what Hoover (2012) has identified as the "Klein" program of microfoundations.[9] DRI various "groups" were precisely in charge of this disaggregation. As Bodkin, Klein and Marwah (1991, p. 123) summarized, the model was "subdivided into seven model sectors: Final GNP Demands; Incomes; Financial; Supply, Capacity and Operating Rates; (Aggregate) Employment, Unemployment and the Labour Force; Prices, Wages and Productivity; and the Industry Sector. The three major sectors of the model, according to the equation counts, are the Industry Sector (at over half the model, with roughly 375 equations), Final GNP Demands (with roughly 130 equations), and the Financial Sector (with more than 100 equations)." The "demand" block of the DRI model consisted of 212 equations, a fairly similar level of sophistication to that of the "production" block, with 208 equations, and the "financial" block, with 193 equations.(Eckstein, 1983, Table 16). The disaggregation within blocks was conducted by differentiating industries, economic agents, institutions: for instance, the financial sector was featuring distinct representation of the flow of funds of commercial banks, of saving and loans associations, mutual saving banks, insurances, households, non-financial corporations, etc.

Like its kins from Brookings, the Fed Board, or WEFA and Chase Econometrics, the DRI model relied on a relatively heterogeneous theoretical foundation. Its overall structure was constructed very much in the mainstream Keynesianism of the time, but it also incorporated supply-side elements since at least the first oil crisis. In the model, price and wages adjust slowly and expectations were mostly adaptive (the expectation of a future variable is the weighted average of past realizations of that variable).

Not only the macroeconometric models of the 1960s were developed by teams of researchers connecting academia (typically as an inter-university effort) and governmental bodies, but also each one built on previous efforts and offered some novelties in comparison to the competitors. The SSRC/CES-Brookins model was developed in the 1960s by a team led by Klein and James Duesenberry with the ambition of building the most highly disaggregated model of the US economy (see Acosta and Pinzón-Fuchs 2019, and Bodkin, Klein and Marwah, 1991, pp.95-110). Although the model was terminated in 1972 (meaning it ceased active maintenance), its development brought several innovations that were further developed in other models, among which we focus on three. First, the large model (with non-linearities) was estimated with quarterly US data from 1949 to 1960 (a sample of approximately 60 observations) thanks to the splitting of the system of equations "into several interacting blocks" that were "ordered in a recursive chain" (Bodkin, Klein and Marwah, 1991, p. 101). Using the recursive estimation techniques just developed by Herman Wold (1954, 1960), Franklin Fisher (PhD Harvard 1960) showed that due to the block recursiveness of the Brookings model, each block could be consistently estimated by a system of single equation least square regressions (Fisher, 1965; see also Fisher, 1970; and the exposition in Bodkin, Klein and Marwah, 1991, pp. 101-103). Second, the application of the Brookings model to policy simulations was tested by "*ex post* forecasts for the period from the first quarter of 1961 to the fourth

[8] According to Eckstein, the model was rebuilt "after the oil shock", since "the behavior of the economy changed considerably in the mid-1970s and various aspects of supply and finance needed to be represented more explicitly" (Eckstein, 1983, xi).

[9] As Hoover (2012, p. 41) explains: "Empirical practice is paramount in Klein's view, and his approach to microfoundations does not suppose that we build up from secure micro-data, but that we start with the available data and a feasible macroeconomic model consisting of 'a smaller number of equations' and constantly work to disaggregate it and to elaborate in the direction of a complete Walrasian general-equilibrium model."

quarter of 1964" (Bodkin, Klein and Marwah, 1991, p. 103).[10] Third, the Brookings model advanced a computer simulation method that were used later on in several other models.[11]

The other key macroeconometric model developed in the 1960s under the leadership of Franco Modigliani and Albert Ando was the MPS model of the Fed Board. One of the key characteristics of this model was a "detailed financial sector which became a nuclear part" of the model, and which "grew out of the Brookings project" (Bodkin, Klein and Marwah, 1991, p. 108). This sector featured a detailed description of the monetary markets (with several different interest rates: on corporate bonds, commercial loans, municipal bonds, and mortgages), detailed links of these markets with the real sector, and various exogenous policy instruments.[12] Finally, the MPS model also relied on the technique of block simulations, and was heavily used in studies of stabilization policies in the US.

The Wharton model developed by Klein since 1963 would eventually build up on Brookings' and spliced the macroeconometric model with an inter-industry input-output model, yet initially being a much smaller model than Brookings', but quickly growing in size (the third version of the model, of 1972, had approximately 200 equations and 100 exogenous variables; Bodkin, Klein and Marwah, 1991, 126).

The DRI model of the US economy was a quarterly model (as the Brookings, MPS and Wharton models) re-estimated each year. It was larger than the MPS and Wharton models, and smaller than Brookings. With a detailed financial sector inspired in the MPS model, it was also organized in blocks of equations as the Brookings model. The DRI model's main characteristic, shared with the Wharton model, was the focus on *ex ante* forecasts that were released quarterly to DRI clients, and was an objective factor in establishing a "track record" by which credibility was established:

> *Because of the importance of the paying client to the development of the model, there has been an important emphasis on (ex ante) forecasting, but other aspects (such as the development of satellite or peripheral models by users of the basic model) have also received some attention.* (Bodkin, Klein and Marwah, 1991, 122).

The DRI model, building on previous models, mainly the Brookings model, found a niche with private, government-agent, and academic clients.[13] According to Bodkin, Klein and Marwah (1991, 119) the macroeconometric models in the 1960s became more complex and sophisticated due to five interrelated trends ("improvements in computer technology, the implementation of a team approach to econometric modelling, the development of an institutional framework largely independent of the originator(s) of the

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[10] See Bodkin, Klein and Marwah (1991, pp. 108-110) for other technical innovations from the Brookings model to the other macroeconometric models.

[11] This simulation techniques were so important that Klein (1975, 21) claimed that: "The procedures that are now routine in computer dynamic simulation at virtually every econometric center of the world stem from the research done between 1964 and 1969 at the Brookings model project. This is not to claim that simulation techniques would not have been developed, but they might not have developed in their present form, and it is virtually certain that they would have been seriously delayed but for the technological breakthroughs of the project."

[12] See Acosta and Rubin (2019) for an analysis of the banking sectors in several macroeconometric models of the 1960s, including the MPS.

[13] Robert Solow (1985, 81) wrote: ", I was a middle-aged DRI addict; I always looked forward to the monthly Review. Whenever I felt impelled to think about what is likely to happen in the near future, or what the differential effect of this or that policy change would be, I know my natural inclination was to start with the DRI forecast or the DRI estimate."

models, detailed and large-scale modelling, and increasing theoretical sophistication), that continued unabated in vigor in the 1970s, the latter decade witnessed "the rise of the econometrics consulting house as a commercial entity." And as the authors put it: "Perhaps the most successful econometric model ever built, from the point of view of the market test of the product, was the DRI Model of the US economy" (Bodkin, Klein and Marwah, 1991, 122).

2.3 DRI: From a Thriving Company to the Purchase by McGraw-Hill

Recent history of macroeconomics has provided strong evidence that large-scale macroeconometric modelling was still in an ascending phase of development all along the 1970s (Bodkin, Klein and Marwah, 1991; Boumans and Duarte, 2019). Conversely to what is sometime argued in contemporary "potted histories" of macroeconomics, neither the monetarist nor new classical macroeconomics had halted the development and use of these models, especially within policymaking institutions (see e.g. Goutsmedt *et al.*, 2019 on the resistances against the Lucas Critique).[14] The commercial success of DRI during the 1970s and early 1980s confirms once more the popularity of large-scale macroeconomic modelling during this period.

The "hype" of DRI was recounted in these terms by the *Chicago Tribune* (1985):

> *Young people flocked to work with Eckstein and Data Resources; economic forecasts were required reading from the White House to corporate board rooms. […] Throughout the 1970s, Data Resources reigned supreme in economics, extracting hefty fees from corporations that felt the need to know what Data Resources thought and were afraid to be caught without it.* (Chicago Tribune, 1985)

Corporate customers seem to make up a considerable part of the business (estimated by the *Chicago Tribune* at two thirds of the DRI revenues in the mid-1970):

> *Under time-sharing, a corporation paid Data Resources to plug into its big computer, which housed the Data Resources macro-economic model and massive amounts or raw data. Corporate economists would manipulate the data in the computer, throw in some of their own assumptions and make economic forecasts. Demand for time-sharing was so strong that Data Resources grew quickly from its 1969 start--to $3 million in sales in 1972, and to $72 million by 1982.* (Chicago Tribune, 1985)

To provide an illustrative example about the use of DRI services by corporate clients, we would rely on the recollections of Jim Luke, an economist who worked as Head of planning at Mead Corp. (1980-1984), a major paper company (Luke, interview).[15] Luke's role at Meade Corp. was to help planning production,

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[14] As mentioned by Goutsmedt *et al.* (2019), Eckstein was precisely one of those involved with pushing back against the Lucas Critique, on the ground of its weak empirical relevance (Eckstein, 1978). Eckstein, still in 1983, argues: "The basic rationale for continuing to use structural models in the face of the rational expectations criticism is this: changes in policy regime seem to have been among the minor sources of structural change of the economy and of forecasting error in the actual historical record" (Eckstein, 1983, xi-xii; see also *ibid.*, 40-46).

[15] Meade Corp. was, at the time, a Fortune 500 company, with headquarters in Dayton, Ohio, and dozens of regional branches and offices. Meade sold different qualities and types of paper, cardboard, but also printers and other services (such as an innovative "online" law library).

sales, and financing of the firm, typically through an annual 5-years rolling financial plan. This required forecasting the sales of different branches of the firm, at regional level, and by type of product. The planning process had proven difficult in the years preceding Luke's arrival; Luke recalls that he was brought to Mead to implement a more "scientific" approach to planning, based on econometrics.[16] DRI services were helpful in this task for at least two reasons. First, DRI provided his customers with access to the macroeconomic forecast for a large set of variables. Luke recalls that, in the econometric models of paper sales he had to build, most relevant variables would be, for instance, the level of employment (driving demand for paper), or the interest rate (driving paper mills' financing cost). It would have been impossible for Mead to forecast these variables on its own, since these would require building their own macroeconometric model.[17] Second, Luke had access to all DRI data. This access to data, he emphasized, was amazing because of the quantity of variables, the length of historical series, and also the access to forecast for most individual variables (even outside those of the main model). This was highly useful to his work because he could use these data to perform his own regressions.[18]

DRI went public (listed to NYSE) in 1976. In July 1979, DRI was acquired by McGraw-Hill Inc.[19] According to Eckstein, this acquisition would help DRI to "do more with [its] technology," while preserving DRI's independence ("they won't tell DRI what to forecast about the economy") (Bendheim, 1979; Rowe, 1979). The purchase is of a considerable size ($103 million dollars). But DRI was making $3.1 million profit per year at this point (Rowe, 1979). Eckstein had become a multimillionaire thanks to the acquisition of DRI Inc by McGraw-Hill.[20] However, the 1979's shift in ownership seemed also related to a departure from DRI by seven "senior executives" who "left to start their own competing company;" moreover, it is suggested that these departures had to do with financial issues in the remuneration of personnel or with "a fast growth of the company, [which] had impaired communication among executives" (Rowe, 1979). Departures, however, involved only "two top research economists," the five other departing staff being "five marketing executives and the manager of the west coast office" (*ibid*.). Relationships between DRI and McGraw-Hill remained tense and even worsen through the years (Cooper Interview).

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[16] Luke recounted that he had a previous experience, in a similar role, within NRC Corp., a large computer company. At Meade Corp., executives were mostly "paper people," knowledgeable about paper business but often without any other specific qualification (building their way up from salesmen to executive roles). Nonetheless, these people were sensitive and aware about the reputational stakes of having a more "scientific" approach to planning. On the other hand, since Mead was a big corporation, headquarter management roles were filled with graduates of Ivy League business schools, most of which would have been aware of recent developments in econometrics and aware of the potential of these new methods for running businesses. Finally, there were also an important role of external consultants (Boston Consulting Group then McKenzie), who were constantly around nudging things in this direction (Luke, interview).

[17] Moreover, one had the possibility also to dig more precisely in how the forecast was built (look at the model, at the assumptions), instead of just having "the number" of the forecast. This allowed clients to make judgement and adjustments eventually when entering "the number" of the forecast in his own regressions (Luke, interview).

[18] McManus (interview) also recalled that DRI would offer to customers a consulting service: DRI's specialist would provide analysis or report on specific issues of interest of the customer.

[19] Background on McGraw-Hill.

[20] The acquisition by McGraw-Hill benefited actually all workers of DRI and the macroeconomists who had been receiving DRI's shares as a compensation for their technical assistance (*cf. supra*).

3. A Walk through DRI Computer Room

As recalled by Marron (1984, 537; *cf. infra*), the original Eckstein's insight on DRI's activity was to develop a model, a large dataset, a computer, and a software, that can be characterized by an information system.[21] In this section, we describe the working of the computer infrastructure at DRI, mostly relying on Peter White's recollections.

3.1 The Burroughs Computer

When establishing DRI, Marron and Eckstein had been thinking about choosing the "right hardware" (Marron, 1984, 538). They narrowed down the choice to two companies: University Computing and Burroughs. Marron's argument is that they finally favored Burroughs for three reasons: first, with Burroughs, DRI would have their own (or leased) hardware, while University Computing was only proposing timesharing; second, Burroughs was also located in Lexington, where Eckstein lived and where DRI would be located, so they actually "shared the same building" (for the first "two-three years", 1969-1971/1972; *ibid.*); finally, Burroughs was itself interested in working with DRI as this would open a new market for them and "establish their technical credibility" (White, interview). Indeed, The B5500 was not a common hardware at the time, and Burroughs "was using DRI as a showcase to prove to the computing world that their equipment was as good or better than IBM's (*ibid.*)."[22]

DRI acquired two B5500, eventually acquiring a third B5500 in 1974. Figure 1 below illustrate the physical layout for one single B5500 computer. The actual computer is constituted of the big cabinets in the background of the picture. Data were recorded by several magnetic tape drives (right-hand side of the picture).

Figure 1: Burroughs 5500 computer. From Burroughs' brochure (Computer History Musem's collection; https://www.computerhistory.org/revolution/mainframe-computers/7/166/674 [retrieved 03/11/21])

In 1977, B5500 were replaced by new B7700 computers, which had a faster CPU and more RAM.

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[21] As Bodkin, Klein and Marwah (1991, p. 122) described: "The DRI Model is regarded as the centre-piece of the DRI information system, but the information system is much broader than the basic model. (For instance, fewer than 1000 time series are required to maintain the basic model, while the information system contains over 20 000 time series.)"

[22] This is confirmed by Marron (1984, 539): "At the time [1968] Burroughs' primary customers were financial institutions. If a B-5500 machine were used to deliver Otto's product to the large industrial companies that were expected to be DRI's main customers, we argued, Burroughs could establish its technical credibility with those companies and persuade them to use other types of Burroughs equipment as well." White also adds that "as a showcase, both Burroughs and DRI bigwigs would occasionally bring people through the computer room to show off the equipment and prove how well it was working."

3.2. Computer Operators and Data Inputing and Backup

The operation of the two (then three) B5500 for DRI's activities required the intervention of three professional figures: computer operators, software engineers, and field engineers. With the cooperation of these three professionals, economists at DRI were able to build and use datasets and models to conduct their analyses, and customers of DRI were able to access DRI database and use DRI computers to perform their own analyses.

DRI software engineers were in charge of creating the tools that would be used both by DRI economists and customers (*cf.* section 3).[23] Field engineers were Burrough's employees (and not DRI's). One to three field engineers were permanently working at DRI computer room to ensure that the B5500 were functioning at the best of their capabilities.[24] If necessary, they provided fixing and maintenance "on the spot". White recalls that field engineers' duties included "implement field corrections to the hardware," whenever necessary: that is, literally, opening computer boxes and lay them down on the floor, adjusting or cabling wires with soldering irons.

Computer operators were mostly in charge of two separate aspects: the daily backup of data (*cf. infra*) and running diagnostic tools. The latter checked the optimal use of computer capacities (that the machine was "running smoothly"). Roger Druin had been the chief computer operator during the early 1970s.

Computer operator could be a career-entry job. For instance, White has started his career at DRI as a computer operator, from 1971: at the time, he was a student at MIT, preparing a BSEE (Bachelor of Science in Electrical Engineering) in Computer Science. White took the computer operator job at DRI during a break in his studies, and, after graduating, he would move to a software engineering position (White, interview).

The computer room at DRI had a "T-shaped" layout, as White recalls:

> *The physical layout of the computer room was kind of T-shaped. What normally is the long side of the "T", going up and down, was very short. That short area was where computer operators spent most of their time. There is where the consoles were. At this time, none, none of the consoles were CRT [cathode ray tube]. It was paper. So there were consoles there, one for each of the main computers, and then a couple of extras. We also had the tape drive there. There was also a printer there. Big, huge, line printer, the kind that did 8 ½ by 14 [inches] paper. The horizontal part of the T was where the computers actually were, and also the network equipment. […] two [Burrough] 5500s [were] in that horizontal part of the T. […] Then they eventually brought in a third 5500 and fitted into the space somehow. In addition to the actual computers, this [the horizontal part of the T] was where the disk drives were.* (Peter White, Interview)

[23] "In addition to that, there was a guy in charge of the networks for DRI. He will wander in and out [of the computer room]: he had an office for himself somewhere else in the building, but he will come in [to the computer room] to adjust the equipment and make sure that networks were available for the customers" (White, interview).

[24] Such a deployment of dedicate personnel by Burroughs was not usual, and it was related both to size of DRI's installation and to its strategic importance for Burroughs (*cf. supra*).

On a daily basis, one or two field engineers and two computer operators would walk up and down the room to perform their duties:

> *Mostly we stood. The computer terminals were on stands that were approximately [1.40/1.50m high], and we worked on that [stands], because we were always walking back and forth from the tape drives. Because even when we were not doing backups at night, economists will send us data on tape, and we had to load them. So will walk around, also picking up printouts, and stack them---there was a table in the computer room where we will put the printouts; they were all labelled, whose they were, and we will stack them in the appropriate spot for people to pick up. There was one spot in the computer room where you could sit down at a terminal, but there was not a desk as such.*

Software engineers and economists would not stay in the computer room. They would come in to pick up the printouts. Software engineers would stand around for a while and have a chat with computer operators, since "they had more in common," while economists will just walk in and out.

Peter White recalls that "one of his main duties" as a computer operator was "to create backups of the econometric data on the computers on a daily basis." This was a well-organized routine, consisting of "incremental backups" from Mondays to Thursdays, and a "full backup" on Fridays. Backups would take place during the "night shift" and they will take between from 3 to 6 hours.[25] A backup corresponded to recording on magnetic tapes "of all the data on the disks on the computers (econometric data, software source code, etc.)". These tapes consisted of a set of 6-9 large reels, 1/2'' (inches) wide (= 12mm), and 2400' (foots) long (=72 meters); Monday-Thursday backups would take 5-10 less tapes than the Friday's backup. The tapes reel ran on 6-9 "spinning tape drives" (*cf.* the right-hand side of Figure 1). Tape drives recorded data at different densities (the lowest being 556 bits per-ich).

The duty of the computer operator consisted in "mounting, dismounting, and labelling tapes that entire [backup] shift." The resulting backup tapes were stored offsite, then reused "every month or two," until they had been used "too many times and had to be replaced". This operation, although constituting a routine, would be a delicate one, subject to unforeseen glitches or malfunctions: the role of computer operators was precisely to oversee the process and to intervene in case anything went wrong.[26]

Once the backup was completed, the reels were stocked off-site. Backups were kept for ensuring that economic data (one of DRI's most valuable business asset),[27] as well as models, would not be jeopardized by any hardware failures.

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[25] Working days at DRI were 16-hour days, but the night shift (3pm to 11pm at night) was a distinctive duty of field engineers and computer operators, although software engineers and a few economists could be working also during these late hours. Note that the computers were in operation 24/7, unless a physical problem required to shut the machines down (White, interview).

[26] "Tapes were reused for a while. So they will eventually wear out. The actual magnetic material ion the tape will basically fall off […]. Sometimes the tape drive would chew the tape rather than flow it freely. It was always exciting when that happened, particularly if you were in the middle of a 2400-foot reel: you had to sit there and put the crinkled and ruined tape out. And then the field engineers had to go there and figure out why it got chewed up. […] We might run out of tape, and I will have to go find some. […] I remember once or twice we basically went 95% of the way through the backup and then… there were no more tapes." (White, Interview).

[27] "For DRI, an awful lot of the attraction for the customers was access to the data. I mean, access to the model was important, but most of the customers wanted to do their own modeling using the data." (White, interview)

Although in charge of backing up economic data, computer operators were not directly involved with the collection of economic data. Within DRI, each economic group was in charge of collecting some data, related to the specific industry or economic sector placed under their responsibility. Moreover, White recalls

> *There was a group in New York [of maybe five to ten people], working for DRI, whose sole job was to input the data. They would pull out the Wall Street Journal and other business publications and literally read it of the paper and tape [the data] in. That's what they did all day long.* (White, interview).

While this specific group would directly "tape in" the economic data into DRI's computer database, some other economists would need help to turn economic data from paper format to computer-readable format. White recalls that Roger Druin, the head computer operator at DRI, had as a secondary job the conversion of paper data into cards:

> *The economists often were looking for people to extract numeric data from printed reports published by the various national governments as well as the big corporations. […] My supervisor at the time moonlighted by keypunching the numeric data onto IBM data cards using an IBM 029 Keypunch he had in the front hall of his home. He would get assignments from the economists and show up at work with 10-20 boxes of these cards.*

IBM cards with data would be regrouped in these "boxes," containing around 5000 cards each; each card "would have 5-8 columns of data," to form a time series.

3.3 The Time-Sharing Technology

The Compatible Time-Sharing System (CTSS) was demonstrated in 1961 by a team at the MIT Computation Center (CTSS operated until 1973). This inaugurated a new era: "the first common multi-user systems, with dozens of people online at the same time. Typical 1960s users are a mix of business people, bank employees, students and researchers, and military personnel."[28]

With the mainframe computers, IBM was ahead of Burroughs and had timesharing on its computers for a while. There was also a company in Michigan, ComShare Inc., founded in 1966 by Richard L. Crandall (but the company went public on Nov. 1968), that have built their business on timesharing technology.[29] As Peter While recalled, ComShare "didn't have any particular product: they had computers and they sold computer time on them. And you as a customer would log in to their computer. Somehow you will get your programs loaded on their computer so that you could run them. But you will be running it on a timesharing basis. So, the computers at ComShare … kept track of exactly how much CPU-time you used" and billed clients on the basis of CPU-time, disk usage, and lapse time.[30]

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[28] https://www.computerhistory.org/timeline/, accessed Feb. 19 2022.

[29] Richard Crandall oral history (https://www.rickcrandall.net/comshare-oral-history-software-history-center/), accessed on June 15 2022.

[30] Lapse time refers to the fact that there was a finite number of people that could be logged in at one time, so if a customer is logged into the computer and doing nothing, he is blocking somebody else to be able to log in to the mainframe computer.

Timesharing was introduced by Burroughs (a company also based in Michigan) only in their 5500 model, released in 1964. Timesharing was much valued at the time due to the fact that mainframe computers were so expensive that nobody had their own computer. At DRI, timesharing happened with the use of the 5500 model. And Peter White gives a lively picture of what timesharing amounted to at the time.

> *So DRI had three of this 5500, and they were try to satisfy the needs of the economists and the data entry people, who were actually fairly senior people, I am not saying data entry in the sense that the only thing they knew what to do was type. These guys were researchers and business analysts, things like that. Also the customers would come in and they will log in by a phone line or perhaps a network of some kind. Mostly was through phone lines because this was well before the internet. They log in, they had a user account for the equipment in the computer. They will be able to access the files that they had.*
>
> *Burroughs had actually quite a nice timesharing user interface. I have had some experience with IBMs' user interface, through school. Burroughs was from my point much nicer. It was easier to understand. You did not have to worry about producing job cards to get your program to run. Basically, you had a program that some had produced for you – some of the programs from DRI. You just gave the name of the program and whatever parameters the program was looking for, and it will just run.*

In the 1970s, only large companies afforded to pay for timesharing, and DRI made it central to its business model.

4. The Development and Use of Econometric Programming System (EPS)

Peter White recalls that, during his time as computer operator, he got acquainted with the DRI software engineering team led by Robert Lacey (he was the chief software engineer throughout the 1970s). By 1974, he was given by Lacey "small projects … mostly just as learning exercises, but they also meant that the team did not have to waste their time on them." In 1975, Lacey offered Peter White a new job as software engineer.

Programming on DRI hardware (Burroughs B5500, cf. infra) was done with high-level languages: most work was done in ALGOL, "although a few reports were done using COBOL," which Peter White deems unusual. "FORTRAN was also used between these two languages" (quite logically as this was a lower-level programming language).[31]

Robert Hall had been involved with crafting the original DRI software (Marron, 1984, 398; Renfro, 2004, 32), called "EPL" and based on the "TSP" software he developed slightly earlier while a graduate student at MIT to help him out in his thesis. By 1975-1976, the idea at DRI was to develop a new, in-house software within DRI, which was nicknamed "EPS" ("Econometric Programming System"). While Lacey

[31] ALGOL was the main international programming language, developed from the 1958. It is usually mentioned in the history of programming that the consensus around Algol experienced a sudden stop with the 1968 NATO Conference on Software Engineering, when a part of the community turned their effort into developing an alternative language (UNIX; see e.g. Haigh 2017). COBOL ("Common Business Oriented Language") was designed from 1959 by Grace Hopper within project UNIVAC (the second commercial computer) of Remington-Rand Corp. COBOL was specifically designed to have "English-like" syntax, and was hence aimed at meeting the needs of "corporate" customers.

"did the basic design," Peter White "implemented functions and operators in the EPS programming language," then, when EPS was ready, he took care of diverse features and additions to the program, within a team of "6-7 people still headed up by Robert Lacey". EPS was written in ALGOL: "Robert and 2-3 others including me designed a way to convert the giant set of equations that formed the economists' models into ALGOL." This entailed some "speed and efficiency issue." EPS "was aimed at providing a generalized platform for doing econometric modeling," making it "easier for the economists to do their own programming" (White interview). Peter White complemented:

> *You also had the opportunity to try and use the data directly. At the time I was a computer operator, it was not very easy for an outsider (a non-DRI employee) to do modeling by themselves. It was possible. But you had to be a real expert to do so. But the time I have left DRI, the software that we produced made it much easier for people to do that on their own. They can just sit there, write econometric equations, and then push them to the software and get the results they were hoping for—or not, depending on what the model said, but they get some results out of it without having to involve a DRI economist.*

The EPS software developed by DRI is mentioned by Renfro (2004, 32-33) as one example of the divergent strategies of the "three major econometric forecasting firm" of the time, i.e. DRI, Chase Econometrics and the Wharton Econometric Forecasting Associates (WEFA):

> *A fundamental characteristic of EPS was its design to be used in conjunction with large scale multi-frequency databases, both created by DRI and licensed from other organizations worldwide. During the 1970s, DRI data banks in the aggregate grew to contain literally millions of time series pertaining to a number of national economies, as well as sub-national regions and certain super-national aggregates. EPS began its life as software designed to be used in-house by DRI economists and by DRI clients as a mainframe time-sharing package, accessible from a remote telecommunications terminal; for many years it was used in this form.* (Renfro, 2004b, 407).

So DRI really structured its business model around an information system composed of a large database, a user-friendly econometric software, and timesharing in its Burroughs mainframe computers. With this and their own macroeconometric model, they could offer a set of services to different clients: from data ready to be used in the computer, to the software for the clients to run their own models, to the macroeconomic and sectoral forecasts that its teams prepared regularly. This has made DRI Inc. "an example in the field of economic consulting, of the internationalization of American enterprise" (Bodkin, Klein and Marwah, 1991, 122).

5. Concluding Remarks

Solow (1985, 81) very aptly described that DRI's analysis were not mechanically driven by the forecasts from their macroeconomic model. Eckstein's intuition were critical:

> *… Otto was a very good economist. The forecasts rested on add factors, of course, and the add factors rested on Otto's intuitions, and on the closeness of his ear to the ground. (I don't mean that he did every one personally, but I bet he made damn sure that nothing he regarded as silly every came out of mechanical procedures to see the light of the day.) Similarly with attempts to estimate*

> *the differential incidence of fiscal and monetary policy measures; the written documents have the air of telling it just as the equations of the model say it is, but I doubt that Otto ever released an analysis of an important policy question that didn't make sense to him.*

Eckstein died in March 1984, at age 56, of cancer (Marron, 1984, 542; Chicago Tribune, 1984), and had relinquish his duties as President of DRI since 1981, although supervising the main forecast until Summer 1982 (Arenson, 1984).

Martin Feldstein was hired as a "consultant" to somehow fill-in the reputational gap left by Eckstein's passing (*Chicago Tribune*, 1985). But the *Chicago Tribune* reports that, DRI experienced a fall in profit since Eckstein quit the direction of the company ("profit fell from $10.9 million in 1982 to $8.5 million in 1983, and analysts expect this to drop even more in 1984, perhaps to as low as $6 million;" *Chicago Tribune*, 1985). The owner company, McGraw-Hill Inc, had "carved Data Resources into pieces." More fundamentally, the newspaper suggests that "[DRI] core business—selling the number crunching ability of its big Burroughs computer—is in trouble and the market for economic analysis is flooded with new entrants" (*Chicago Tribune*, 1985).

Furthermore, the assessment mentions technological adaptation as the somehow missed "turn" in DRI business model, when microcomputers was starting to be a reality:

> *Perhaps the area of its greatest disappointment has been its inability to come up with new technologies in the 1980s for delivering its information. [...] It has tried to come up with new products for microcomputers, for mini-computers and for mainframe computers, only to meet with problems on all fronts. [...] Oddly, Data Resources predicted the demise of its key business as far back as 1979, when it saw that smaller computers would eventually replace big mainframes, like its Burroughs. Today, corporate economists are finding that they can make economic calculations at a lower cost by using the vast array of software programs available for personal computers—whether it is a bank trying to determine loan demand from certain industries or a utility trying to project electricity needs. And, to make matters worse for Data Resources, the decline of time-sharing came just as the recession of 1981-82 forced corporations to reduce outside expenses—a trend that has not been significantly reversed in the recovery.* (*Chicago Tribune*, 1985)

This assessment is shared by the 1985 president of DRI Joseph Kasputsy: "We are in the midst of a major technological change where the technology is moving from 100 percent reliance on time-sharing to a situation where clients can have powerful personal computers on their desks" (Kasputys, quoted in *Chicago Tribune*, 1985). By this time, however, the company seems to have 1200 employees (*Chicago Tribune*, 1985). Later, DRI merged with the WEFA (under Global Insight).

The story of DRI in the 1970s is not simply a story of academic developments (the large-scale macroeconometric models) going to private consulting firms. There is this element, with the active involvement of Eckstein and Klein, in addition to many others such as Barro, in the setting up of those consulting firms or developing user-friendly econometric softwares and macroeconomic models. In fact, those models were born at the intersection of academia with policymaking: it was with Tinbergen's (1939) work for the League of Nations, and to Klein's redoing of Tinbergen after Haavelmo in the 1950s (with Arthur Goldberger). This is even more so in the 1960s, when the Fed and the Committee on

Economic Stability of the Social Science Research Council were involved with universities in such projects, leading to the two main macroeconometric models upon which DRI built its own model, the MPS and the Brookings models. But the development of large-scale macroeconometric models by consulting firms such as DRI made those models a successful reality outside academia, demanding several bright newly minted PhDs to work in those firms. This in turn made the path of writing a thesis on a small part of those models, to extend and improve them, very rewarding. And in further developing those models new solution and computational methods were featured in leading economic journals (see, for instance, Fisher 1970 cited in this paper, which is representative of several other such articles). Therefore, DRI is part and parcel of the transformations of macroeconomics in the 1970s, shaping this process and being shaped by it. Clearly the limitation of archival and oral history materials we had with DRI doesn't allow us to go much deeper in the practices in that leading consulting firm. Nonetheless, the paper brought new light to what amounted the computational effort involved in DRI's business model, how economists interacted with other professionals within DRI, and how DRI's clients were served by a network of academic, governmental agencies and private sector economists.

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