EARLY DEVELOPMENT OF ECONOMETRIC SOFTWARE AT THE UNIVERSITY OF AUCKLAND

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Over the period 1964–1970, graduate students of Rex Bergstrom at the University of Auckland in New Zealand developed econometric computer programs to conduct estimation and inference for dynamic linear models, dynamic simultaneous equation models and systems of linear stochastic differential equations. Linear and nonlinear multiple equation regression programs were written in Fortran; and simulation experiments and empirical applications were performed on two small IBM mainframe computers.

The first electronic computer at the University of Auckland was an IBM 1620, which was acquired by the department of physics in 1963.[1] This was followed a few years later in 1967 by the installation of an IBM 1130, which remained the university's central computer until a Burroughs B6700 was acquired during 1973 in a joint arrangement with other New Zealand universities. The 1620 and 1130 were small mainframe computers designed principally for scientific use. Like earlier generations of computer, and unlike the IBM 360 series (launched in 1964), these computers had non-modular designs, so that their main components were wired or soldered rather than plugged together. The modularity design of the 360 contributed greatly to its commercial success[2] and the concept proved even more successful, of course, with the now famous introduction of the IBM PC 5150 in 1981.

For a time, the 1620 was housed in a room in Choral Hall (in the University of Auckland city campus) across the road from the department of economics in no. 4 Alfred Street, from where, with considerable excitement, we saw it being lifted in

[1] The first digital computer in New Zealand was an IBM 650, which was acquired by the New Zealand Treasury department in 1960. This and other interesting historical details (including a discussion of the number system used in Maori culture) can be found in Garry Tee's [15] fascinating account of the pioneers of early computing and connections to New Zealand.

[2] The IBM 360 series changed the nature of mainframe computing and had a huge commercial impact on IBM's market share and profitability. Baldwin and Clark [2] discuss the impact of the IBM 360 series on computing design and the power of modularity in the commercial development of the computing industry.

by crane. The 1130 and its peripherals occupied a room in the newly constructed chemistry building, a convenient block's walk up Symonds Street from the department of economics; and in 1968 the 1620 was moved to a room adjacent to the 1130 in the same building. The console on the 1130 had a futuristic look, complete with flashing lights in hexadecimal code that gave it the appearance of something out of an early science-fiction movie. The main demand for these two machines in the 1960s came from physics, engineering, chemistry, mathematics and economics.[3] Summary statistics on the use of the 1130 were printed each month and these reported individual usage by different departments in the university. During the late 1960s the department of economics was often the heaviest user. At that time, several members of the economics department were running simulation experiments with econometric models and doing applied econometric research for masters and doctoral theses.

The developmental period for this work in econometrics was 1964–1970. Over this period, a succession of graduate students in the department of economics embarked on empirical studies of the New Zealand economy that involved the estimation of dynamic linear models, dynamic simultaneous equation models and systems of linear stochastic differential equations. All of this work was computationally intensive, involving data manipulation and filtering (e.g. for seasonal adjustment), econometric estimation, diagnostic evaluation and statistical testing. With the arrival of the 1620 and 1130, the computational burden in this empirical work shifted from desk calculators to the new computing machines. A series of computer programs were written in Fortran to carry out the necessary computations. By 1970 the department of economics had developed a suite of econometric regression programs to calculate OLS, 2SLS, and 3SLS estimators, some associated test statistics and diagnostics, as well as a multiple equation nonlinear regression program that was based on a Gauss-Newton iterative procedure.

Not all the computational work was done on the 1620 or 1130. The department of economics had some Facit (electric and mechanical) calculating machines and from 1967–1968 an electronic calculator for which there was high demand and for which we queued for access. All of these machines we routinely used for subsidiary calculations and sometimes even major computations (such as large matrix inversions or inversions of complex matrices) when the computers were down or otherwise unavailable. In anticipation of such needs, it was usual practice to obtain fairly complete printouts of subsidiary calculations done on the computer at each run, so that these could be used to cross check results, debug programs and to get work done during the turnaround cycle.

Both computers, but particularly the 1130 (which offered tape and disk storage as well as line printer output), were in heavy demand. Large batch jobs were normally run overnight and there was a special lunchtime service offering quicker

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[3] The University of Auckland had no separate department of statistics in the 1960s. Faculty with research interests in statistics ranged over several departments, including mathematics and economics.

turnaround for short jobs lasting less than 5 minutes, which was convenient for program development and debugging. Otherwise, it was necessary to obtain an operator's license to use the 1130, something that was essential for simulation work where large numbers of repeated runs were required.

To become a computer operator you had to undergo a training program and sit a practical test. The "driving test" took about 15 minutes. In this time, you had to cold-start the machine, put in disk and tape drives, activate the line printer (the size of a large household refrigerator) and run a special batch job through the card reader that was designed to throw up every conceivable problem that might be encountered while running the machine on your own. For example, some cards in the test batch were too thick and they deliberately jammed the card reader. You had to identify this problem and others by reading and interpreting the hexadecimal error codes that showed up in flashing lights on the main console. Once the problem was identified you had to resolve it – in the card reader case by opening the reader and extracting the faulty card. Some cards called you to load tapes or disks. Some caused problems in the processing unit and freeze-ups that required a warm restart. Others set the printer into an endless print cycle that had to be aborted at the main console. Running the operator's license batch job was an ordeal of tribal initiation that the machine technicians had dreamed up to test your understanding of the system components and to deal with non-critical system shutdowns.

This driving test gave us all our first exposure to computer frustration. But every second of tension was worth it when the thrill of the first night's operating shift came along. The excitement of a hands-on computing experience alone in the computer room for 10 hours overnight was an extraordinary intellectual adventure: turning up with flask and sandwiches in the evening, booting up the 1130, loading a simulation in the hopper and waiting for the thunder of the line printer to stamp out thesis results. Nothing short of nirvana to a young scientist!

The individuals involved in the early econometric software development work at Auckland were Derek Ford, Hessel Baas, Viv Hall, Keith Carpenter and Peter Phillips, all students of Rex Bergstrom who was professor of econometrics and the intellectual force behind the research program in econometrics. Derek was the first person to use the 1620 and he wrote an OLS and 2SLS regression program in Fortran around 1964. Derek tutored Hessel and Viv on using the 1620. Over 1965–1967 Hessel developed Derek's programs further and subsequently helped Viv write a LIML program. Viv adapted a seasonal adjustment program originally written by Rex Bergstrom[4] for quarterly data so that it was suited to semi-annual data. Peter worked on the 1620 and 1130 over 1968–1969 and wrote a 3SLS program that allowed for across-equation parameter restrictions and a multiple equation nonlinear regression program with facilities that enabled its use in estimating the exact discrete model corresponding to a system of linear stochastic differential equations.

[4]We recall that Rex wrote this program, punched the cards and was so meticulous in doing so that the batch job ran correctly first time.

The results of this research are reported in the dissertations and research papers listed in the references. Hessel, Viv and Peter each had an operator's licence for running the 1130 after hours. Peter was the largest user, having a large nonlinear estimation simulation experiment to conduct as part of his master's dissertation [11, 12]. Each simulation took about 30 minutes of computing time on average, amounting to around 250 hours of computing time in total for this simulation experiment with 500 replications. Booking the 1130 for two evenings of 10 hours a week meant that some 3 months of computing time was required for this simulation, leaving aside the additional time involved in program development.

Some of the practicalities of programming in the 1960s are worth recalling. Only tiny memory capacities were available. The 1130, for instance, had just 8 kilobytes of memory.[5] It was therefore necessary to tailor programs carefully so that they would fit into memory. In Viv's work with the LIML estimation of a six-equation simultaneous equations macroeconomic system, it was necessary to feed in and estimate the model equation by equation; so not all jointly determined variables were in the system at once, in true limited information style. Peter's work involved multiple equation nonlinear regression with across-equation parameter restrictions and matrix exponential nonlinear functions, which could not be treated equation by equation. In that case, it was necessary to use Call Link statements in Fortran to link segments of the code together and write and recall essential numbers to and from disk so that they were available as subsequent segments of the program became active.

There were tape and hard disk facilities on the 1130 and a fast line printer and card reader. A room outside the 1130 housed three IBM card-punch machines,[6] which were always heavily booked. There was therefore considerable advantage when running simulations to use the computer itself to punch cards (e.g., for subsequent simulations) that could be run as batch jobs during the day, thereby reducing labor input and maximizing computer capital usage. Dimension statements for arrays had to be carefully tailored so that programs would fit in memory. Using variables to dimension arrays helped in this regard, but often it was necessary to put in specific dimensions and change them with each application in order to avoid program crashes and needless waiting time for reruns. Standard protocol in the 1960s was to check draft program and data input carefully in order to avoid needless 24-hour turnaround delays arising from avoidable errors. By contrast, modern desktop hardware, multiprocessing and software aids like debuggers and powerful text editors all contribute enormously to expedite program development. In consequence, present day software development is a vastly accelerated and very different experience.

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[5] Some 7K memory was available for practical use after the operating system loaded. According to folklore at the computing center in the 1960s, Brian Hicks and a small group of systems operators downloaded the operating system of the 1130 in machine code, rewrote it more efficiently and succeeded in substantially enhancing the 1130's performance characteristics to an extent that astounded IBM system engineers when they revisited the machine.

[6] Over time these variously included IBM 026, IBM 560 and IBM 870 machines, but frequently only one, and occasionally none, of these was operational.

The econometric research program at Auckland in the 1960s was conducted under the mentorship of Rex Bergstrom, who was supremely well qualified for the task. Rex's own thesis work was done in Cambridge over the period 1952–1954. It involved the empirical implementation of a 27 equation model of New Zealand exports that had 55 parameters which were estimated by both OLS and LIML. With the help of Alan Brown in the department of applied economics, Rex used the EDSAC computer at Cambridge to invert the moment matrices needed for the calculation of the LIML and OLS estimates. As Rex points out in his interview with *Econometric Theory* [13, p. 307], the EDSAC frequently broke down and it was necessary to invert some 10 by 10 matrices on a desk calculator to complete his work. This study was the most ambitious empirical implementation up to that time of the new Cowles Commission econometric methodology and it showcased the advantages of the new techniques, particularly in the context of small samples of data and in making predictions.

Another important member of the Auckland student econometric group in the 1960s was Clifford Wymer. Cliff was ahead of Derek Ford and completed his master's thesis in 1964 using Facit desk calculators for his empirical work. Cliff also did the number crunching on a Facit to estimate the Bergstrom and Brownlie [3] model of the New Zealand economy (a small dynamic aggregate simultaneous equations model) which involved some 7 by 7 matrix inversions. Cliff did not use the 1620 at Auckland. He left for the LSE to do doctoral work and, starting in 1965, began to develop there a suite of Fortran-based econometric software for the estimation, analysis and use in prediction of linear simultaneous equations models with general analytic restrictions on the coefficients. These programs were developed in modules and were used extensively by later students at the LSE, at other universities in the UK and at the IMF and other international economic agencies. One remarkable feature of this suite of econometric software was their built-in facility for symbolic differentiation of any specified function, so that the score and Hessian were set up automatically. All that the user had to do was to type in the functional form of the equations on cards. This development appears to have been the first of its kind in econometric software. A summary of these programs and some of their properties is given in the Appendix of Bergstrom and Wymer [4].

On the face of it, much has changed since the early days of econometric software development in the 1960s. Nowadays, several user-friendly packages of econometric software are available that make it easy to perform quite complicated tasks of data manipulation, parameter estimation, testing, model evaluation, prediction and even simulation. These packages are routinely used in undergraduate and beginning graduate courses in econometrics to train students in empirical econometric research. Many applied researchers also place heavy reliance on them. Nonetheless, the need for high-end software facilities has not disappeared and has, in fact, grown stronger over the years as econometric technique has become more widespread. New models and data sets often present peculiarities that demand special treatment in the way of modified procedures or new econometric methods, which in turn need programming because they do not fit within the confines of existing packages. In consequence, matrix programming languages like Gauss, Matlab, S+, R, and Ox have become popular among advanced students and researchers in econometrics because of the flexibility they offer with respect to the incorporation of new econometric methodology, not to mention the simplicity with which existing procedures can be programmed. Gauss provides some elegant instances in this regard with supremely simple codes like that for a multivariate least squares regression, viz., b = y/x. The growth of applied econometrics has been so extensive in recent years that this process seems destined to continue.

Just as early researchers in the 1960s coded programs for new estimation procedures like 2SLS and 3SLS in Fortran to complete their empirical projects, present-day researchers code the new programs they need for more recent econometric methods using efficient object oriented and matrix programming languages. The programming tools and hardware at the disposal of the econometrician continue to grow more powerful and are conveniently portable. But the manner of the research process itself has changed less and has many broad similarities with the past: questions are asked, hypotheses are formulated, data is collected, methods are developed and implementation is accomplished using appropriate computational software. When the latter is not available, it needs to be written, just as it did in the 1960s.

Web communications and online support groups now make it much easier to problem solve and to share and download code. A new possibility is also emerging that permits the interactive use of advanced econometric methods by way of a web browser. Rather than use a local software package, users may access a suite of econometric methods and data sets online. Simple web browser selections then initiate econometric software algorithms and results are returned online and by file and graphics downloads. Some possibilities along these lines are outlined in Phillips [14], and a prototype of web-based econometrics for forecasting the NZ economy was developed at the University of Auckland in 1999.

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