UNIT ROOTS IN LIFE AND RESEARCH

By

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July 2017

COWLES FOUNDATION DISCUSSION PAPER NO. 2094

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Unit Roots in Life and Research*

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July 9, 2017

Foreword

Prominent among the many contributions that economics has made to humanity are the ones we witness daily in the normal operations of our national economies and our financial systems. Less prominent is the work in econometrics that is largely done in universities developing theories and techniques, conducting empirical research, and analysing the effects of economic policies and social programs.

Econometrics is the tool that forces our ideas about the economy and society to face the reality of observation. Its methods empower empirical modeling and evidence-based studies throughout the social and business sciences. This graduation speech recounts some experiences and lessons learnt in the author's journey into the world of econometric research. Journeys like this begin with initial conditions rooted in our early lives and education. Teachers, colleagues, students, contemplation, and aspiration all influence our thinking and determine the directions we take in our research. This story is a personal account of the initial conditions and unit roots of experience that have had an enduring impact on my work and career as an econometrician.

I

Rector, Vice Rector, Dean of the School, Ladies and Gentlemen. A very good evening to you all. Thank you Professor Ioannis Kasparis for that wonderfully generous laudation. And for ending with that extra-curricula photograph taken as I was building a deck at my home in New Zealand. You now know there is another side of my work beyond econometrics that also involves measurement.

*Graduation speech delivered on the occasion of the ceremony for the degree of D.Phil (hon) at the University of Cyprus, Nicosia, Cyprus on 7 June, 2017.

I begin with a warm thank you to the University of Cyprus, to the Rector of the University, and to the Department of Economics for this honour and distinction. As Ioannis told you in his oration, I was educated and began to teach and do research in New Zealand. Although I was born in England and have long worked in the United States, I see New Zealand as my home country.

New Zealand and Cyprus have much in common. Both are island nations, both have a small population, and yet both have a venerable tradition in the world of quantitative economics. As some would say, both countries punch well above their weight. That is certainly true per capita in terms of Nobel laureates and Fellowships of the Econometric Society. It is therefore an especially great honour for me to receive this honorary degree from the University of Cyprus and to share the intellectual tradition of this wonderful island nation.

I want to thank Ioannis also for his artistically creative website which features my favorite sculpture *Homage to Newton* by Salvador Dali. This iconic work of art celebrates and imaginatively depicts the open mind and the open heart that lead to ground-breaking research. Like Isaac Newton himself, this sculpture is an inspiration to all of us who work in scientific research and to all of us who aspire to a scientific career.

Homage to Newton (Salvador Dali, 1985)

II

I first started to do research in econometrics in 1969. Since then there has been a half century of change. Not just in economics but in the academic world itself. A ground-shifting example familiar to all of us in universities is the growth

in managerial administration and the centralization of its operational functions. This change has precipitated a bemusing reversal of causality in academic life. Where we used to do administration locally and I dare say minimally, central administration now deluges us with online forms, requests, and new initiatives for us to implement for them. Things may change further. Administrators may soon be replaced by robots and robotic software, like others in the service industry. Then, these robots will be giving us all orders.

Of course, there have also been vast changes in the subject and practice of economics. One is the growing ascendancy of empirical research driven by the availability of electronic data and point and click econometric software, which make it ever easier to do applied work. Popular writings with applications of 'mostly painless' econometric tools now abound. We even have books called *Freakonomics* and associated radio programs that report regressions to general audiences on every aspect of socio-economic life from the economics of crime to the economics of sleeping.

The world of scientific journals and publishing has also changed. In the 1960s the economics profession had only a few major outlets for research. Now there are hundreds of outlets and the numbers continue to grow. Something that university presidents and provosts are all too familiar with. They know that universities pay twice for research: once to create it and once to buy it back from the publishers. We used to have 30 page papers. Now we have 60 page papers with 80 page supplements. This makes the science and the peer review process so much harder. Correspondingly, it has made superficial reporting much more common, reinforcing the world of journalistic commentary.

Perhaps the biggest change of all is in computing horse power, the advent of personal computing, and software capability. It is humbling to imagine how much more productive famous economists of the past like John Maynard Keynes or Ragnar Frisch would have been working with a laptop or tablet. Even in my own lifetime the changes have been staggering. When I started research in the 1960s, there was only a single computer at the University of Auckland and just a handful in the entire country. The Auckland machine was a mainframe with 8K memory (that is 8K, not 8 meg or 8g) and it occupied a very large room. It had to be lifted in by a crane. The card reader looked like a small van, and the main console was a large attractive desk with flashing lights displayed in hexadecimal code on an overhead monitor. The line printer, which printed a line at a time not a page at a time, was bigger than two refrigerators bolted together and it had a 90' long ribbon. I know, because I once had to unwind and rewind the ribbon in the middle of the night when it became entangled with the paper feed.

To run the machine overnight to do your research you needed an operator's ticket. The test was harder than the UK driver's test, and like the driver's test, most failed it. The test required you to cold start the machine, load a hard disk and tape to supplement memory, and run a punch card deck that was custom-designed by the examiners to throw up errors, which had to be resolved within a few minutes. In my own test the examiners had glued two cards together, which jammed the card reader and froze the computer. The hexadecimal error

code flashed up on the console and you had to read, diagnose, and fix the error. It was the 1960s version of the windows blue screen of death but with no IT person around to assist. Of course, IT did not exist in that era. For the next decade or more, faculty working in econometrics typically assumed the IT role in departments of economics.

The bottom line for my work was that it took the Auckland machine 20 minutes to do a single iteration of an extremum estimation calculation and 6 entire months of weekend overnight sessions to complete a simulation study of 100 replications. That task could now be done in a fraction of a second on modern laptop equipment. Small wonder that the world of applied economics has accelerated so quickly.

Another vast change is in data availability. Terabytes of data now descend daily on central banks and statistical agencies. It is an immense task to store, clean and sort such data before they can be modelled and used for policy analysis. Much of this work and data harvesting is now being done by automated software. This leads to autometric algorithms for doing econometric research and the new world that we call machine learning.

III

These developments have wrought big changes in our lives as teachers, in our work as researchers, and in the methods we use in econometrics. Against this background of change over the last half century and since this is a graduation ceremony that celebrates learning, I will tell you something about my own training as an econometrician. Some of the people who taught me, and some of the lessons I learnt on the way.

Before we start, let me comment on the words Unit Roots in the title. They may be a little mysterious to non-economists. It is enough to say here that unit roots involve persistent shocks and when we accumulate these shocks over time we get random trends - trends that wander. Understanding trends of this type has revolutionized our thinking about how to do econometric work. I was part of that revolution that took place in the 1980s, more than 30 years ago. It is hard to overstate its importance today, where it is now largely taken for granted. The work we did then transformed the subject and its applications. Econometrics became an export industry of these methods. First, to the social, political and business sciences, where much of the data wanders randomly as if there was no fixed mean, being driven by a multitude of different influences. More widely still, the methods have been exported to the natural sciences and most recently to the environmental sciences, where a new field of climate econometrics is emerging, studying the effects of greenhouse gas emissions on Earth's climate. Climate change. One of the major issues now facing humankind, up there with the risks of terrorism, nuclear war, and pandemics. The climate challenge is one that has been singularly acknowledged by this university with its pro-active policy of achieving independence of the national grid in Cyprus through its own photoelectric energy production.

In all these subjects, shocks with long-lived effects produce random trends. Examples of these shocks are well known to us: the invention of movable type, the printing press, paper money, bank deposits, central banks, the transistor, the silicon chip, laptop computing, the internet, Wikipedia, smart phones ... The list goes on as the world advances and our lives change.

IV

Just as there are unit roots and random trends in data, similar phenomena occur in our ordinary human lives. Think of the people who have mentored us, the opportunities that have come our way, and the ideas that have changed our work and careers. Colleagues, students, and co-authors enter our lives and sometimes their influence carries forward in unexpected ways. We all experience these persistent shocks. And they form significant events that can change the course of our lives.

My own story is no exception. The changes and opportunities that influenced me began at grammar school in New Zealand. My family migrated in the mid-1950s to New Zealand, a 12,000 mile one-way trip. That's a long journey to get an education. My teachers were erudite scholars whose qualifications and abilities would these days have secured them a university career. This exceptional education and the talented peer group fellowship that accompanied it had a lasting influence on my working life.

So how did I get from grammar school into economics? The simple answer is my headmaster. A single conversation. In my final year, he summoned me to his study, strode up and down in his flowing black gown and confronted me with the question "what do you intend to study in university?".

I said classics and mathematics. My primary loves at school.

To this he retorted, his voice dripping with disdain, "classics is a dead end" and "mathematics is too competitive. You need to climb the intellectual Himalayas to be a world class mathematician. Instead, you should study economics," pronouncing this like it was an incontrovertible truth, and adding "it will be like climbing a few foothills for you. I should know - I've studied it myself!"

As I digested this he followed up with "Do you know what economics is about?" In those days we didn't study economics at school. But I managed to mumble something about trade, money and banking.

"No!" he exclaimed, "that is all wrong. Economics is about tendencies. And tendencies is calculus. You'll find it a push over."

Why calculus? Tendencies give direction, like the tendency for demand to rise when prices drop. My headmaster was a learned man and he knew some economic theory. But he had not heard of random trends and stochastic calculus. That was all in the future for me.

Armed with this advice, I went to town and looked at the economics section of Auckland's main bookstore, where they had the textbooks for all university levels laid out. I looked through the texts for 1st and 2nd year economics courses and all I saw were words and graphs. No sign of serious mathematics

there! Then I picked up a fancy-looking microeconomic theory text for advanced undergraduate and graduate students and discovered it was nothing but calculus. In fact, I could read much of it easily. The derivations in this book were just constrained optimization exercises: what economics and policy are all about – choices under constraints. To a serious mathematician, there was probably only one theorem in the whole book. Here I could see a challenging and interesting future, combining a love of mathematics with an interest in the world around us and empirical science.

My headmaster was right on the mark. I now had a purpose at university. Without his guidance I may have spent my career in lonely corners of libraries doing manuscript archaeology in the classics or writing papers on obscure mathematical constructs for a tiny audience.

V

Like most students in New Zealand, I lived at home and went to my local university - the University of Auckland. I studied economics but happily kept along with mathematics and classics. Four years later I found myself doing graduate work and research. It was in my graduate year at Auckland that I fell in love with econometrics.

Econometrics is the tool that forces economic ideas to face the reality of observation. It offered freshness and vitality, a fascinating connection with empirical research, economic theory, and applied economic modelling. There was no other subject at university like it. It felt like being at one of New Zealand's great open beaches. Full of vigour, sunshine and scope. And there were only a few footprints already in the sand. A vast expanse of possibilities lay open.

My teacher was Rex Bergstrom, a famous NZ economist who was skilled in econometrics, and I was the only graduate student. It was a thrilling year. In those days, you could read most of econometrics in one year. So I was soon ready to do research.

In 1969, Rex called me into his office and asked what ideas I had for masters thesis research. I was just recovering from graduate examinations in economics and mathematics, and had barely thought of research. But two thoughts tumbled out. I won't go into the details here. But I remember feeling quite proud of the ideas at the time. Rex's response was devastating. My first idea might merit a footnote in a major text, if I was lucky. The second idea was beyond the world's best mathematicians. They had worked on it without success for a decade in the 1940s. So what chance did I think I had? Rex had thrown down a gauntlet. I was speechless.

Then Rex suggested an alternate path – to pursue a constructive thesis. To build and estimate a continuous time trade cycle model with discrete data. To develop a general asymptotic theory of estimation and inference for this type of model. To do a simulation study to corroborate and assess the findings. Thank goodness he didn't ask me to do an empirical study. If he had, it would have

taken another year or two and become a Ph.D thesis. Then I would have missed out going to the London School of Economics.

As it happened, I walked out of his office with a thesis topic under my arm. A generous gift. A home run without lifting the bat. Rex gave me more than an idea. He had given me a strategy. A constructive research strategy to a thesis and with it the prospects of a longer term research program. It was spectacularly sound advice for a new researcher. For any researcher at any time, for that matter.

Constructive Strategy in Practice (2007)

Rex had vast experience as a theorist and practitioner. He knew that doing econometrics is so much more than applying statistical methods to economic data. Sadly, that limited view has been creeping into modern thinking about econometrics, against the mantra of past econometric elders. Instead, building a new technology that accommodates economic ideas and the nature of the data that we have available to us is a constructive approach. It is more likely to be important and influential in the long run than solving a purely mathematical problem. No matter how enticing the latter may be.

To give some concrete examples, as we look back we all have favorites among the papers we have written. One of my own favorites was published in *Econometrica* in 1980. I had worked on the problem solidly for two years. It was on exact distribution theory, a subject that was the Rolls Royce of high-tech research areas in the 1970s but which has few followers today. The paper now has about 100 citations, a respectable number in mathematics and other sciences, but paltry compared with an influential applied paper. Nonetheless, its relevance has been vindicated in the massive volume of subsequent work on what we call weak instruments, a name that is a euphemism for saying that finite sample properties are important.

In contrast, a paper I published a few years later on trends in *Biometrika* now has over 14,000 citations. That paper was written with a student and is a

simple extension of technical work I had done earlier on random trends, which has far less citations. The *Biometrika* paper was easy to write. And its vast citations simply reflect the influence it has had on applied research.

A more recent favorite paper of mine was written with my former student Tassos Magdalinos, who happily is with us today. That paper made the remarkable discovery that we can do valid inference with certain types of explosive processes. This opened the door to the econometric analysis of financial bubbles, enabling detection and dating of explosive episodes as they begin to emerge. The paper appeared in 2007 and now has over 200 citations, deservedly double that of my 1980 paper. And a good result for a theory paper. Later applied work using these ideas has many more hundreds of citations. Much more importantly, the work underpins methods that are now being used by central banks to assess the health of financial markets. Which vindicates again the potential impact of new constructive theory that can breathe life into applied research and economic policy.

This approach has driven many successful research strategies in the profession over the past 50 years. Economists among you will know econometric work that has successfully opened up new pathways of applied research. Think vector autoregressions, cointegration, partial identification, and social interaction modeling as prominent examples.

Nonetheless, some of us do not always follow this strategy. Sometimes in life we need to depart from our mentors and go our own way. We glimpse a gap in the clouds and wonder about the infinities of knowledge beyond. We are simply drawn in by the mystery, the majesty of the unknown. And our human minds sometimes hunger for big game – hard challenges that don't fit into any particular constructive strategy. May blue sky research forever continue!

VI

After Auckland, I went on to the London School of Economics to do a Ph.D. Why LSE? The simple answer is that Rex had given me only one suggestion. "Go to LSE and study with Sargan." I said what about North America, what about Harvard, Yale and Princeton. What about Larry Klein, the father of macroeconometric modelling at U.Penn?

"Sargan," he said, "is simply the best econometrician in the world. Larry Klein has done good work but he's over the hill. There's no one as good as Sargan in North America. You don't need to go there." Definitive advice. Which turned out to be excellent advice. I was on the way.

So I moved from New Zealand to the UK in 1971 to work under Denis Sargan. Denis was the world's leading econometric theorist at the time and a pre-eminent figure in mid 20th century economics. He was also a superbly innovative mathematical thinker and unusually creative econometrician. He has still the distinction of being the only economist ever to be senior wrangler (holding first place) in the Cambridge University Mathematics Tripos. This was long considered one of the highest academic distinctions. To put Sargan's achievement in perspective Alfred Marshall was 2nd wrangler, Thomas Malthus

was 9th, Keynes was 12th, and Karl Pearson, the famous statistician, was 3rd. The great mathematician G. H. Hardy was 4th. Sargan was clearly very special.

I only stayed at LSE for 9 months but in that time I learnt many new lessons. From Sargan's work I came to understand that nothing is impossible. With the right mathematics, right models and right approximations you can tackle most problems. In short, as Winston Churchill put it to Roosevelt during World War II, give us the tools and we will do the job. This was utterly inspirational to me. Be challenged but not intimidated by hard problems. Think all the way around a problem, live with it, sleep with it. Reach the stage where it is your constant companion. You will see a way forward and find the tools to do the job. The miracle is, it then turns into one of your best intellectual friends.

In the 1970s, LSE was a very exciting place. In addition to Denis Sargan, the LSE boasted a constellation of senior stars and an impressive phalanx of younger people. I will single out only one other person. The great trade theorist and macroeconomist Harry Johnson who had just arrived at the school on a part time basis from Chicago. Harry was a big man with a strong voice and inexhaustible confidence. Not so well known or remembered these days but a dominant figure in the mid 20^{th} century.

Harry ran a new course called "Contemporary Economics" at the LSE during 1971. Its origins are intriguing. In the late 60s and early 70s there were rampant student protests that economics courses lacked relevance to the real economy. A reasonable concern that surfaces intermittently and probably sounds familiar. It resurfaced again after the 2008 financial crisis with complaints about the irrelevance of macroeconomic theory and its failures to incorporate financial markets. In 1971, the LSE professoriate found themselves at a loss with these demands. But when Harry came back from Chicago, he said he would deal with it. His colleagues asked how. And he said by introducing a new course on contemporary economics.

The course ran for a quarter. Harry's secretary came in before the class started and explained the format. Students would ask questions about any field of economics or real world economic problems and Harry would answer. The next week Harry came back from Chicago and walked in to a packed house and said "Well.... what's the first question?" A fellow in the front row piped up "Should Britain join the EU?" That was certainly the biggest economic question of the time. It is a question that resonates today. A complex question, just like Brexit 2016, with no easy counterfactuals at the time, little evidence-based analysis, and a lot of populist propaganda circulating.

Harry's response was to draw some graphs on the board of aggregate supply and aggregate demand curves, overlay some trade lines and discuss the possible impact on these curves of Britain's joining the EU. He kept talking and moving the curves around in response to possible shifts arising from EU membership, opening up the European market and promoting trade. After 20 minutes of commentary and graph-gazing, he concluded that Britain should join the EU – largely due to the advantages of a big easily accessible market for goods and financial services and gainful access to additional labour. Two things that did eventuate.

Having wrapped up this thorny problem, Harry turned to the class and called out "Let's have the next question." And so it went on ...

Harry's first few classes were packed. After 3 weeks, a curious thing happened. The students started to run out of good questions. By sheer force of intellect confronting head-on the challenge of "economics and reality" Harry had exhausted student demands for relevance that had terrified the LSE professoriate. By the end of the semester there were just 4 of us left in the class. So Harry moved the class up to the faculty bar for the rest of the term. We stood and talked and had a few drinks together, hoping that some of his vast knowledge of economics and penetrating intuition would brush off on us.

After nine months at the LSE, a job opened up and I moved to the University of Essex. And then to the University of Birmingham. A few years later I was thinking of returning to New Zealand when a letter arrived from Yale inviting me for a semester in 1978. That semester turned into the next 40 years.

A tale for another time. The short form of those 40 years is contained in 3 words. With apologies to Julius Caesar: Veni, Vidi, Laboravi. I came, I saw, I worked. And the world changed with new opportunities. Yale was one of the world's leading centres of learning. I was fortunate. Very fortunate indeed.

VII

We are now half a century on. So where is econometrics going? The subject itself follows a random trend. A random trend often accompanied by drift that follows fashions in research. We never know where the big breakthroughs in research will come. But we all have our own ideas and we should follow them as we triangulate out from our existing knowledge into the unknown. Like the Salvador Dali sculpture *Homage to Newton*, we have to keep our minds and our hearts open. Open to all possibilities, like beginners. In the memorable words of the Zen Buddhist master Suzuki Roshi "in the beginner's mind there are many possibilities, in the expert there are few." The beginner's mind is an open mind, a receptive mind. A mind ready to make new journeys. But just as important are our tools. We need to build new tools and to sharpen our saws to meet the challenges in the journeys ahead.

Tracing a Curve with Sharpened Saw (2017)

Econometricians believe in their tools for good reason. We can use a classical analogy. The ancient mythic tales in Western culture of the Aeneid, the Illiad and the Odyssey expose the strengths and weaknesses of their heroes and their heroines. Like these mythic tales, our econometric tools unearth inherent truths that lie within real world mechanisms and they reveal the strengths and weaknesses in our theories that seek to explain them.

VIII

For someone who was educated in New Zealand far away from the major centres of learning in North America and Europe, it is a great honor and surely humbling to be singled out to receive this honorary degree. It is a joy to have spoken to you this evening and to have former students and colleagues here who are creating new paths of understanding and unearthing new truths in their own research.

Thank you all for coming and for your many accolades today and in our conference yesterday. Passing the torch along to the next generation is one of life's greatest pleasures. Surely it is one of the most important Unit Roots in my own life and career.

Thank you for this honor. Thank you for listening. Thank you all very much!

Ceremony Closure with the Dean and Rector of the University

Endnote: This is the graduation speech as I delivered it on the evening of 7 June from a few notes, with the exception of the Foreword, which was circulated with an announcement of the talk, and the story about Harry Johnson at the LSE which I had planned to mention but eliminated in order to keep within the designated time.