Introducing the MONIAC: an early and innovative economic model

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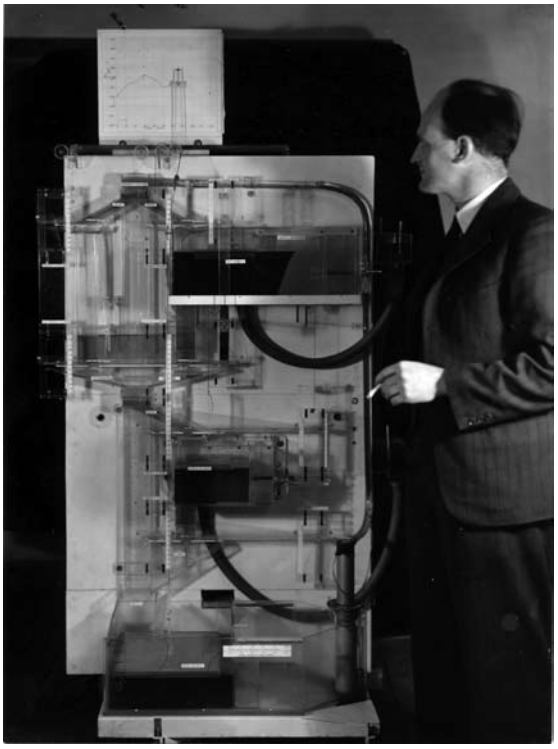
The MONIAC hydraulic computer is an example of a mechanical economic model dating to the 1940s. This article introduces the MONIAC and its creator, New Zealand economist Bill Phillips. Although the MONIAC is not used for policy analysis at the Reserve Bank, large-scale, practical macroeconomic modelling has long been part of our research and policy effort. Our modelling has evolved considerably in the nearly 40 years since macroeconomic modelling was introduced in the Bank, reflecting developments in economic theory and understanding of the New Zealand economy as it changes over time. In no small part, the improvement has been facilitated by the enormous increase in computing power in the decades since MONIAC was developed. The only working MONIAC in the southern hemisphere is on display in the Reserve Bank Museum, on long-term loan from the New Zealand Institute of Economic Research (NZIER).

1 Bill Phillips and the MONIAC

Alban William Housego (Bill) Phillips (1914-1975) was one of New Zealand's most accomplished economists. Born in New Zealand and brought up on a dairy farm, he moved to Australia soon after leaving school. In 1937 he went to China. He escaped ahead of the Japanese invasion, reached Britain via the Trans-Siberian Railway, and studied electrical engineering there.

When the Second World War broke out Phillips joined the Royal Air Force and was posted to Singapore. When the island fell to Japanese forces, he escaped to Java, but was then captured there by the Japanese. He quickly put his engineering skills to use in his POW camp, building a miniature radio hidden in a clog and creating an immersion element, run from the camp lighting, to boil water for hot drinks. At war's end, Phillips was awarded a New Zealand Forces scholarship. With these funds he attended the London School of Economics (LSE) from 1946, studying first sociology and then economics. It was here that he developed a machine for demonstrating and performing calculations on the workings of the macroeconomy – the broad relationships between income, employment, interest rates and other economic variables.

Phillips built his prototype machine for around £400 in the late 1940s, including parts scavenged from a Lancaster bomber. He thought of calling it the 'financephalograph', but it shortly gained the acronym MONIAC – 'Monetary National Income Analogue Computer'. Supposedly, this moniker was invented to echo the ENIAC ('Electronic Numerical Integrator and Computer') computer developed in the US in the mid-1940s by John Mauchly and J. Presper Eckert of the University of Pennsylvania.



Bill Phillips with the prototype MONIAC (London School of Economics LSE/LSE History Photographs/6/2/P D).

By contrast with the ENIAC and the handful of other computing machines of that time based on early digital technology, the MONIAC operated wholly on analogue principles. The MONIAC was also one of the world's first computers designed to simulate economic phenomena. The

Above and below: Dr Alan Bollard, Governor of the Reserve Bank of New Zealand, explains the MONIAC on display in the Reserve Bank Museum to staff (Stephen A'Court, RBNZ).

prevailing mechanical computation application of the time was ballistics calculations for the military. The MONIAC could perform logical functions that no other computer of the day could match, due to a combination of its analogue calculation principles and the use of water flow as the calculating medium. The other analogue calculating machines of the same era, such as the differential analysers built by Vannevar Bush in the 1930s, were electro-mechanical, relying on cogs, gears and pulleys.

Phillips based the relationships represented in the MONIAC on Keynesian and classical economic principles, showing the circular flow of income, expressed mathematically as Y = C + I + G + (X-M) (income equals household expenditure plus business investment plus government expenditure plus export sales, less purchase of imports). Separate water tanks represent households, business, government, exporting and importing sectors of the economy. Coloured water pumped around the system measures income, spending and GDP. The system is programmable and capable of solving nine simultaneous equations in response to any change of the parameters, to reach a new equilibrium. A plotter can record changes in the trade balance, GDP and interest rates on

MONIAC restoration

The MONIAC on display in the Reserve Bank Museum is the first production example, originally calibrated for the British economy, and is the only MONIAC known to be in working order in the southern hemisphere. In its use at the LSE, it was often paired with a second MONIAC calibrated to represent the 'rest of the world'.

In 1987 the LSE donated the machine to the NZIER, and it was restored to working order in 1991. It was refurbished again in 2003 before being displayed as part of a New Zealand display at the 50th Venice Biennale of Contemporary Art. The NZIER kindly offered the MONIAC to the Reserve Bank Museum in 2006, on long-term loan, and it underwent further restoration before being put on display in mid-2007.

Geoff Bertram of Victoria University working on the MONIAC in the Reserve Bank's workshop, November 2006 (RBNZ).

New pump assemblies, on left, ready for replacement (RBNZ).

Issues that had to be overcome included corrosion in pumps and re-sealing many of the tanks. The pictures highlight some of the steps required to bring the MONIAC to public display as a working museum exhibit.

The MONIAC reassembled, May 2007 (RBNZ).

Robbie MacInarlin (back to camera) and others install the MONIAC in the Reserve Bank Museum (RBNZ).

The MONIAC in its display case in the Reserve Bank Museum. The MONIAC sits on a stainless steel tray designed to catch any leakages and allow the machine to be drained (Stephen A'Court, RBNZ).

paper. Simulation experiments with fiscal policy, monetary policy and exchange rates can be carried out. Although the MONIAC was conceived as a teaching tool, it is also capable of generating economic forecasts. Phillips himself used the MONIAC as a teaching tool at the London School of Economics. Around 14 machines were built, selling for USD4,300 in 1952 – just over NZD293,000 today.

In addition to his contribution to early economic modelling through the MONIAC, Phillips made far-reaching theoretical contributions to economics, for which he is probably better remembered. His particular contribution was the concept of the Phillips Curve, an inverse relationship between unemployment and inflation, which he published in 1958.

The Phillips Curve relationship became a significant part of economic policy analysis in the developed world through the next decade. The theory struggled, however, to explain the persistent and strongly rising inflation from the mid-60s through the 1970s, which occurred without corresponding falls in unemployment. In another major theoretical advance in economics, the simple form of the Phillips Curve was augmented to account for the crucial influence of inflation expectations. The result was a relationship that incorporated the 'monetarist' principle that the level of inflation and the level of unemployment are independent in the long run. This form of the Phillips Curve survives to this day as a core principle in macroeconomics.

In 1967, Phillips moved to Australia and took up a position in the Australian National University. He suffered a stroke two years later and retired to New Zealand, where he taught at the University of Auckland. Phillips died in March 1975.

2 Computer technology and economic modelling at the Reserve Bank

During the late twentieth century, computerised economic modelling and forecasting became an integral part of monetary policy formulation in virtually every central bank in the world. The technologies of economic modeling – and to some extent the models themselves – have inevitably reflected the nature of the computing systems on which

Figure 1

A simplified flow diagram of the MONIAC

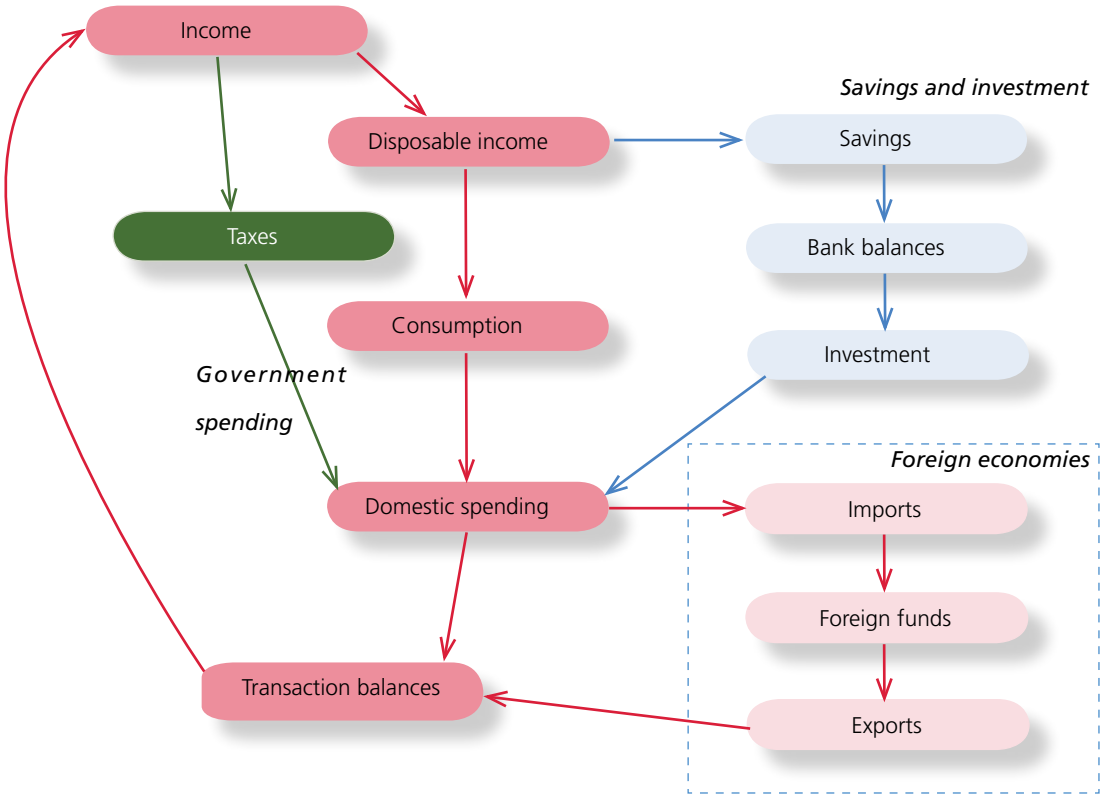


Figure 2

Stocks and flows as represented in the Forecasting and Policy System

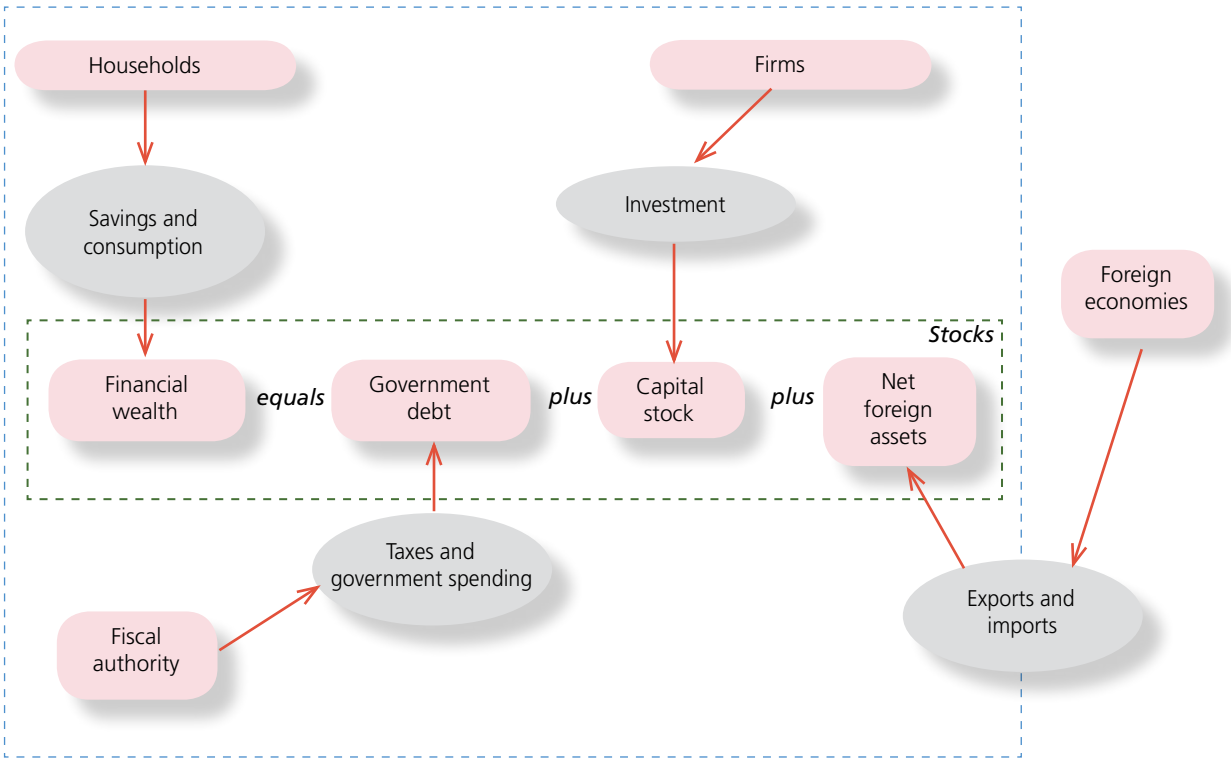


Figure 3

Sample FPS equations

Consumption

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c:        c = crt + cfl
crt:      crt = ydrt/pc
cfl:      cfl = (cfl_eq + cv1*((ydfl(-2)/pc(-2))/(ydfl_eq(-2)/pc_eq(-2))-1)
          - cv2*(rsl(-2)-rsl_eq(-2))*cfl_eq(-2)
          + cv3*(nfa/pc-nfa_eq/pc_eq) - cfladj)

c_eq:     c_eq = cfl_eq + crt_eq
crt_eq:   pc_eq*crt_eq = ydrt_eq
cfl_eq:   pc_eq*cfl_eq = mpcw_eq*twfl_eq + zeta*(fa_eq-fa_ss)
mpcw_eq:  1/mpcw_eq = (1-gamma)*delta**sigma *(pc_eq/pc_eq(+1)
          *(1+rcon_eq))**(sigma-1)/mpcw_eq(1) + 1
twfl_eq:  twfl_eq = hwfl_eq + (1+rcon_eq(-1))*fa_eq(-1)/(1+ydot_eq)
hwfl_eq:  hwfl_eq = ydfl_eq + risk_eq + (1-gamma) * (1+qdot_eq) *hwfl_eq(1)/(1+rcon_eq(1))
fa_eq:    fa_eq + pc_eq*cfl_eq = ydfl_eq + risk_eq + (1+rcon_eq(-1)) *fa_eq(-1)/(1+ydot_eq)
fa_ss:    fa_ss = fa_ss(1)
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Key:

c	Consumption
c_eq	Equilibrium consumption
cfl	Consumption by forward-looking consumers
cfl_eq	Equilibrium consumption by forward-looking consumers
crt	Consumption by rule-of-thumb consumers
crt_eq	Equilibrium consumption by rule-of-thumb consumers
delta	Household discount rate
fa_eq	Equilibrium real financial assets
fa_ss	Steady-state real financial assets
gamma	Probability of death
hwfl_eq	Equilibrium human wealth
mpcw_eq	Equilibrium marginal propensity to consume out of wealth
nfa	Real net foreign-asset ratio
nfa_eq	Equilibrium real net foreign-asset ratio
pc	Relative price of consumption
pc_eq	Equilibrium relative price of consumption
qdot_eq	Equilibrium growth rate of labour-augmenting technical progress
rcon_eq	Equilibrium real interest rate for consumers
risk_eq	Equilibrium transfer to individuals from asset holders
rsl	Slope of the yield curve
rsl_eq	Equilibrium slope of the yield curve
sigma	Consumers' coefficient of intertemporal substitution
twfl_eq	Equilibrium total wealth
ydfl	Real disposable income for forward-looking consumers
ydfl_eq	Equilibrium real disposable income for forward-looking consumers
ydot_eq	Equilibrium trend output growth rate
ydrt	Real disposable income for rule-of-thumb consumers
ydrt_eq	Equilibrium real disposable income for rule-of-thumb consumers

they operate. The field has grown markedly since the MONIAC's time, taking advantage of enormous advances in computing power, and comparably large reductions in the price of computers. Over this period, computers made the transition from what we might call the 'white-coated scientist/engineer' world represented by the MONIAC – a mechanical hands-on environment in which the coat was a practical garb protecting the operator from grease and water splashes – to everyday desktop appliances present, in some form, in virtually every business and household.

The Reserve Bank began economic model-building for policy analysis in 1970. Since then, more than a dozen larger-scale models – that is, models with more than a handful of equations – have been used by the Reserve Bank for various purposes. The hardware has run the gamut from IBM mainframes to Digital VAX mini-computers, to the current Windows-based desktop computers, each generation radically more powerful and physically smaller than the last.

The Bank's current model, the Forecasting and Policy System (FPS), has been in active use for policy analysis and forecasting since 1997. The broad economic relationships represented in FPS bear a perhaps striking similarity to those in the MONIAC. The factors influencing the broad expenditure components in each model, for example, are illustrated in figures 1 and 2. Yet as a comparison between the circular-flow equation on p.47 and Figure 3 reveals, at a detailed level the mathematics of the newer model are very much more complex. This is in part because increased computing power has enabled much larger sets of numbers to be crunched in many more ways. Advances in economic modelling and computing technology have shed light on many important questions in economics and policy – and yet other questions about the interactions between growth, employment, taxes, inflation, interest rates and the exchange rate, remain to be explored more deeply.

Next year marks the 50th anniversary of the publication of Phillips' 1958 article about the Phillips Curve. To mark this event, Bill Phillips' life and work will be celebrated in July 2008 at an international economists' symposium in Wellington.

Further Reading

– "The forecasting and policy system: an introduction", Reserve Bank of New Zealand *Bulletin*, Vol. 60 (3), September 1997.

– "The Moniac, economics in thirty fascinating minutes", *Fortune*, March 1952.

Hawke, Gary, *Between Governments and Banks*, Government Print, Wellington, 1973.

The Reserve Bank Museum is open to the public 9.30am-4.00pm weekdays, except for private functions. Entry is free.