# APL and Economic Education

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## Abstract

The experience of teaching economics with computers is discussed. Using APL and GRAN provides for very interactive graphical interpretation of classical economic models. The static Leontieff's model, the business cycle model and the macro equilibrium model are considered as examples.

Two approaches to the teaching of economics with computers are proposed. The first is the simultaneous teaching of APL and economics. APL permits the very fast and concise coding of the models (the comparison is made with Kuboniwa's book) and their interactive exploration.. The second approach represents a dialog between the computer and the students as well as the animation of illustrations of classical economic courses.

## Economic education and the computer

Until recently humanitarian education in Russia, and in particular economic education, was a set of dogma, which constituted in sum total the so-called Marx-Leninist theory. The teaching of other socio-economic models was treated as "bourgeois theories critics". Now a fundamental transformation of Russian humanitarian education system has taken place. The classical economic courses are becoming accessible to Russian students, such as P.Samuelson [1], C.R. MacConnell & S.L. Brue[2] or S.Fisher & R. Dornbusch & R. Schmalensee[3]. The methodology of education is now very current in Russia.

Specific to economic education is the use of elementary mathematical methods, especially function research and matrix algebra, plus graphic interpretation. It is natural to use software which provides for the interactive study of models and also for interactive graphic interpretation. APL, supplemented with interactive graphics is very convenient for such problems.

It is not a new idea to use the computer in economic education. Masaaki Kuboniwa proposed[4] the name "MICONOMICS" for such a course. His book includes programs in Basic, which illustrate such economic concepts as national balance, aggregation, utility theory, production functions, macroequilibrium, and magistral theory. The program source code occupies half of the book's pages.

Some results of my experience in teaching economics with APL are presented below. In most cases the models are from Kuboniwa's book..

## APL and Miconomics

In APL the texts of programs illustrating the models are much more concise. Experiments with the models become easier. Two factors are most important:

a) It is easy to manipulate arrays in APL and to use its linear algebra functions.

b) the use of interactive graphics (with the GRAN Workspace[5]).

Extremely impressive is the simplification in the simulation of Leontieff's model and also in the case of econometric methods due to the ⌹ primitive function. For example, if we want to analyze the dependence of value added $V$ on prices $P$ in static Leontieff's model with matrix $A$, we can use the following function:


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```
[0] P←A PriceL V;r;I
[1] ⍝Static Leontieff's model with matrix A
[2] ⍝The program calculates prices in
      dependence of value added
[3] I←(⍳r)∘.=⍳r←1↑⍴A ⍝Unit matrix
[4] P←V⌹I-⍉A
```

How much are the deviations in prices if the deviations of value added are *dpV* (in percentages)? The answer is:

```
100 ×A PriceL .01 ×dpV ×V
```

(All variables, i.e. the matrix $A$, the vectors $V$ and $dpV$ are predefined, of course, before this expression is executed.)

One other example. With the aid of GRAN we can plot the trajectory of inflation, if the dynamics of value-added $V(t)$ is known. The task for the graph in this case is:

```
→⍉A PriceL V
```

The matrix $V$ must be predefined as a matrix the rows of which are the trajectories of the value-added in each sector of economics. For example, let us consider the three industrial model, the length of trajectory is equal to 50, the dynamics of value-added is sinus-like with initial values 1 1 1. Then we must form the matrix $V$ in the following way:

```
V←1 1 1∘.×1+1○0.1×⍳T←50
```

Figure 1 illustrates some experiments with Leontieff's model described above.

Let us discuss one other model, the so called Business Cycle Model (BCM). This dynamic economic model is very often represented with differential or difference equations. We can code the model with APL-function which implements the Euler method and produces the trajectory (or trajectories) of the model.

BCM is described by the following equations:

$$Y(t) = C(t) + I(t)$$

$$C(t) = aY(t-1) + b$$

$$I(t) = v[Y(t-1) - Y(t-2)]$$

where:

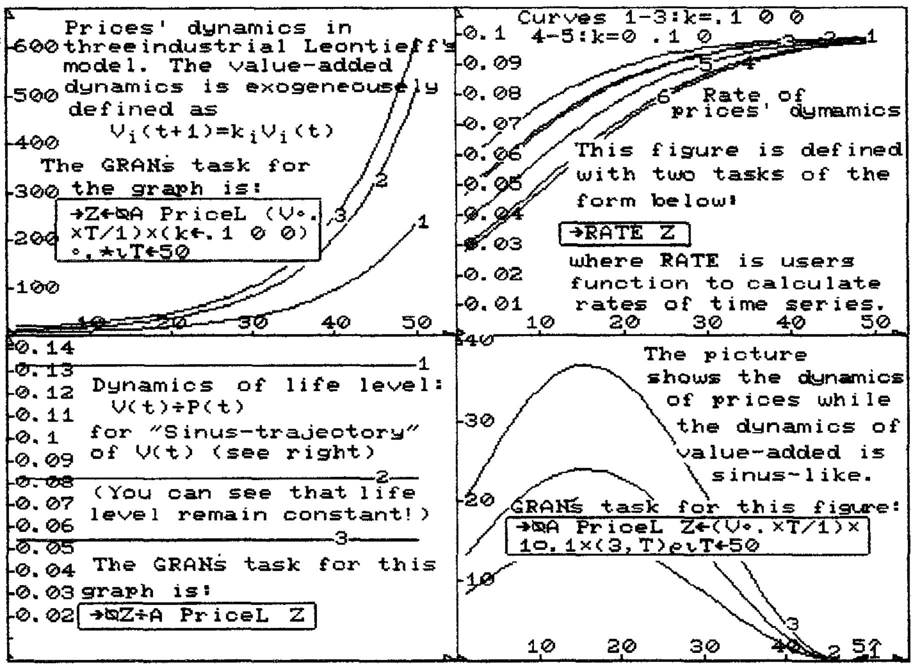
$Y(t)$ is General Domestic Product in the year $t$;
$C(t)$ is national Consumption;
$I(t)$ is national Investments.

These equations give the following difference equation:

$$Y(t) = (a+v)Y(t-1) - vY(t-2) + b \qquad (1)$$

The following function generates the trajectory $Y = Y(t), t = 1, 2, \ldots T$ of equation (1) :

Fig. 1
The experiments with threeindustrial static Leontieff's model.



```
[0] Y←T BCM par;a;b;v;t
[1] ⍝T - time horizon
[2] ⍝par - the set of parameters of
        equation (1):
[3] a←par[1] ⍝Consumption coefficient
[4] b←par[2] ⍝Minimal consumption
[5] v←par[3] ⍝Investment accelerator
[6] Y←T↑ par[4 5] ⍝The initial values for Y
[7] t←2
[8] Loop:→(T<t←t+1)/0
[9] Y[t]←b+((a+v)×Y[t-1])-v×Y[t-2]
[10] → Loop
```

The equation (1) has the different types of solutions in dependence of parameters $a$ and $v$. Is $v$ approximately equal to 1 the equation (1) has an oscillatory solution which is interpreted as the cycles of economic conjuncture.

After the function is coded, we may use the following GRAN task to display the trajectory:

```
→50 BCM .75 20 1.05 10 10
```

We may vary the right argument in this task to see various types of solution on the graphic screen. For example, it is very interesting to observe how the oscillatory solution is transforming into an exponential solution.

You can see in fig.1 that not only graph plotting is possible with GRAN, but also other design elements can be incorporated, such as the subscription of remarks. Thus, the student can make a personal library of illustrations for his economics tutorial.

## Play Economics!

The question is whether the student in economics must study some programming language or not. The economics tutorial can be organized as a game with the models. The interactivity of APL can be used as a tool to compare the different models which are coded in advance.

GRAN is an open system and permits the loading of any APL object during the session. Due to this property a dialog between GRAN and the student is possible.

One fragment of such an interactive tutorial course is described below. The fragment is devoted to the classic theme "Macroeconomic equilibrium". At first the picture with the description of models involved appears on the screen. Let us consider two models - the so called "classic" and "keynesian" models (see,for example, the book of L. Stoleru [6]):

| | **Classic** | **Keynes** | |
|---|---|---|---|
| | Capital market | | |
| (3.1) | $S(i) = I(i)$ | $Y = C(Y) + I(i)$ | (3.5) |
| | Money market | | |
| (3.2) | $vM_0 = pY(L)$ | $M_0 = pY/v + M(i)$ | (3.6) |
| | Labor market | | |
| (3.3) | $dY/dL(L) = w$ | $dY/dL(L) = s_0/p$ | (3.7) |
| (3.4) | $L = L(w)$ | $Y = Y(L)$ | (3.8) |

where the following functions are used:

- $S(i)$ - National savings $S$ in dependence of interest rate $i$;
- $I(i)$ - Investments $I$ in dependence of interest rate $i$;
- $Y(L)$ - production function (Domestic Product $Y$ in dependence of labor $L$);
- $L(w)$ - dependence of labor supply $L$ of real wage $w$;
- $C(Y)$ - consumption function (National Consumption $C$ in dependence on Domestic product $Y$);
- $M(i)$ - "Speculative money demand" $M$ in dependence of interest rate $i$,

and the other variables are:

- $p$ - price of Domestic Product;
- $v$ - intensity of money flow;
- $M$ - money aggregate;
- $s$ - nominal wage.

If the functions involved are known, then each system (3.1)-(3.4) and (3.5)-(3.8) generates the equilibrium solution $\overline{p}, \overline{Y}$. This solution depends on the parameters of models, such as $M_0, s_0$ and other. In economic tutorials these relations are usually discussed in terms of demand-supply curves in the (p,Y)-plain.

After the first picture the student can see the second one, which describes graphically the functions involved and the rules to play with supply-demand curves (see fig.2).

Our tutorial workspace contains functions, which generate the data for demand and supply curves of the classical and the keynesian model respectively. (That is they generate data for prices $p$ for fixed set of product $Y$). The arguments of this function are different, as described in the fig.2. Only a simple task such as

```
Y→Classic_Demand 10
```

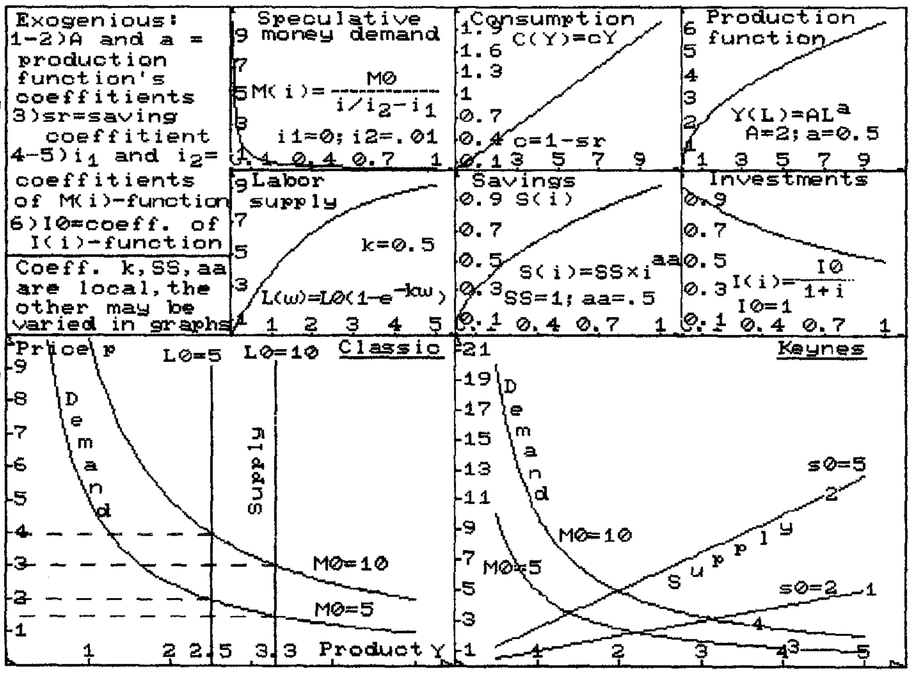
is needed to explore how the curves and the equilibrium point shift while the main control parameters $M_0, L_0$ (the total supply of labor), and $s_0$ are changed.

Fig.2
Macroequilibrium models.

The functions, which generate the demand and supply curves are located in workspace preliminary.

To plot the curves the student can use the following GRANs tasks:

Y←Classic_Supply L0 to plot supply curve of classical model for any L0 or
Y←Classic_Demand M0
or
Y←Keynes_Supply s0
or
Y←Keynes_Demand M0
The point of intersection can be investigated immediately in GRAN.




The main control parameters are the arguments of the functions like given above. But the global variables such as *sr* or *I*0 (see fig.2) or other may also be changed in GRAN with a task of the following form:

*i1←100→*

## Conclusions

I think the most interesting aspect for my students was the high illustrativity of the experiments. For example, the students observe with great interest how the trajectories to limit cycle converge (in equations like Volterra's).

As to the difficulties of the course we may point to the following features of APL:

a. The iterative calculations are processed rather slowly and

b. The processing of arrays is not standard.

One more problem for the Russian speaking user is the domestication of APL. In general, serious work with APL must be on a regular basis; and love of APL does not come at once.

Tutorials in classic natural sciences such as physics or chemistry include the description of models and the experiments illustrating these models. Step by step economics acquires the features of classic science of such kind. But the direct economic experimentation is highly expensive, if possible; computer experiments are preferable.

The experience of interactive simulation described above gives economic students the scientific habit of experimentation.

While the models appear to be difficult (and they are becoming more difficult permanently) the conclusions about their behaviour become more ambiguous. In the case the humanitarians refer to their own intuition and one has nothing to do but to believe them. Such trust contradicts the scientific approach.

To demonstrate to students studying economics the possibility of quick computer simulation is the main purpose of the courses described above.

## References


1 Samuelson,P. *Economics.* (Russian edition), Moscow, 1990

2 MacConnell,C.R.,S.L.Brue. *Economics.* (Russian edition), Moscow, 1991

3 Fisher,.S, R.Dornbusch, R.Schmalensee. *Economics.* (Russian edition), Moscow, 1993

4 Kuboniwa,M.(ed.) *Mathematical economics in personal computer* (Russian edition), Moscow,1991

5 Buzin,A.Yu., I.G.Pospelov. *APL technology of Computer Simulation.* APL Quote Quad,vol.21-4, Aug.1991, pp.47-50

6 Stoleru,L. *Equilibrium and economic growth* (Russian edition), Moscow,1974