PROBABILISTIC GENERATION OF SCENARIOS FOR ARGENTINA, USING A ELEMENTAL HARROD-DOMAR MODEL OF GROWTH.

Juan Rego Juan A. Vega
National Council of Scientific and
Technological Research of Argentina

ABSTRACT

The growing amount of the foreign debt of the developing countries shapes a gloomy future for most of them. The chances for maintained growth fueled by internal saving is nil if the service of the debt is satisfied, as it has to be to avoid international isolation. This is particulary true in the case of Argentina, with a debt equivalent to two thirds of its GDP, and its debt service representing more than 5 per cent of GDP. After showing the historical facts about the Argentine economy, this paper presents a very simple version of a growth model type Harrod-Domar, adapted to the parameters of the local economy. Then the model is used for answering to "what-if" type of questions, wich arise from different plausible scenarios. Finally, it is analyzed the probabilistic generation of scenarios and related technical problems using DYNAMO.

1. INTRODUCTION

The crisis of the early Eighties surprised both, Latin-American debtor countries, and creditor industrialized countries. Those showed sluggish answers to the impacts coming from the unstable world economic centers; these were unable to dominate the required financial adjustments to overcome the emergency.

To believe that the problems of the debtor countries are their own fault, and therefore the solution has to be looked for internally is very unrealistic. Unless the world economic environment become more favorable for the developed countries, the solution of the debt problem would be too far away (Dornbusch 1986). Therefore the eventual recovery of the Latin-American countries will depend strongly on the improvement of the rate of growth of the industrialized countries, net transfers of funds (inflow funds less debt and utilities payments), trade opportunities, and row material prices (Feinberg, Ffrench--Davies 1986, Dornbusch 1986), as well as internal restrictions on the debtor countries. If this is true, then it should be far relevant the "what if" simulation experimenting approach, in a mainly outer generated future.

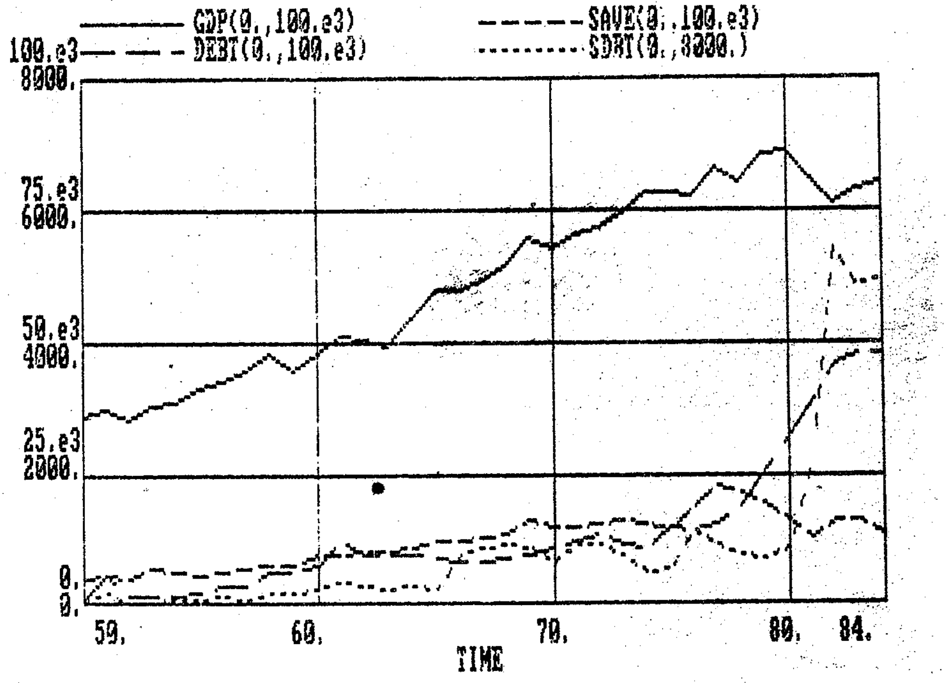
Then, which are the eventual futures open to Argentina? To examine this question is the purpose of this paper, whose authors recognize to be indebted to the writers of a previous one (Broda, De Pablo 1985) with similar objetives, but using econometric methods.

It is explored the ability of the SD methodology in analyzing the questions posed in the mentioned article, freely used here. Beyond such initial orientation it is also aimed to the incorporation of randomness in the generation of the futures throught simulation, as suggested for Stover (1975, 1980) and Mosekilde (1982). To this purpose the usual routine of exploring the consequences of discrete events, one at a time, is followed by scenarios built upon the simultaneous occurence of different events.

2. LAST TENDENCES OF ARGENTINE ECONOMIC HISTORY.

The clear positive tendence shown by the Argentine economic growth, as measured by its Gross Domestic Product, GDP, was broken to the end of the Seventies, when the foreign debt appeared as limitating factor of the Argentine development and a voluminous transfer of resources for the servicing of the debt began to compress the economy.

Figure 1 Historical Gross Domestic Product, External Debt, Saving and Service of the Debt (1950-84). (Source: Broda, De Pablo, 1985, millions of us $ 1985).



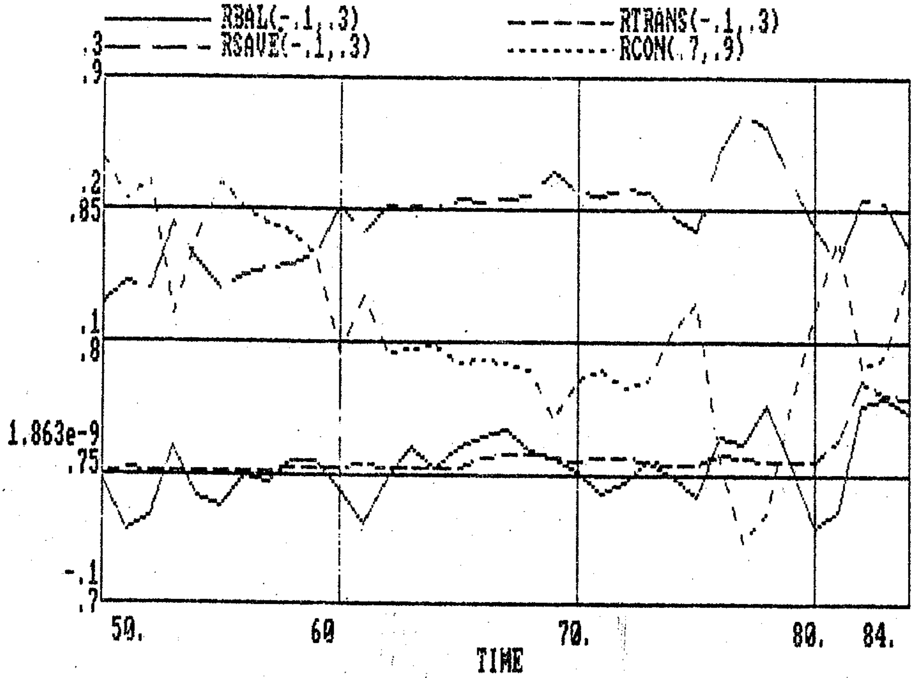
During the last ten years it could be observed that, at the beginning, in 1976, the debt represented the 20% of the GDP, evaluated in 44,200 millions of current American dollars. Ten years later the debt climbed up to 64% of GDP, which amounts to 79,000 million of current dollars. Correspondingly, the service of the debt arose, in the same period, from 1.1% of the GDP, aproximately 500 million dollars, to 6.7% of the GDP, over 5000 million dollars. This means that the service of the debt grew 10 times, when in the same period the Argentine economy did not grow enough for duplicating its initial GDP in terms of current dollars (Broda, De Pablo 1985).

To atribute the crisis to the national budget deficits of the debtor countries is too easy an explanation. A more equilibrated judgement assigns equal responsabilities to bad internal management of Latin-American countries, world economic conditions and unwisely granted credits (Dornbusch 1986).

There are evidence that it was the abundance of international liquidity originated by the deposits of revenue coming from the oil export countries, on the international banking system, that created the over-supply of fresh funds (Dadone, Pescarmona 1984). The less developed countries asked and obtained a good proportion of this money for financing their development, but without foreseeing the future. For them it made sense to accept a loan on a basis of a nominal rate of interest of 5%, which was the historical rate on long term loans for the period 1973-77, against a 10% inflation rate over the same period. However, the effect of the oil revenues on the industrialized countries, particulary in USA, was to accummulate deficits, financed by money emission, which in turn triggered off an inflation process that pushed the international interest rate of loans up. This inflation, added to low prices of raw material and basic products in general, less liquidity and more protectionism on the international scenario, caused an acceleration of the growth of the debt, on the one hand, and lost of payment capacity of the LDC's, on the other hand (Conesa 1985).

Whichever is the case, the pressure of the external debt on the economy in the

Figure 2 Balance, Saving, Consumption and Service of the Debt relative to GDP (1950-84).
(Source: Broda, De Pablo 1986).



Argentine instance, at least, produced a severe reduction of local saving, rather than reducing consumption, as shown in Figure 1. None the less, the pressure upon the Argentine economy gave place to a interesting phenomena. Effectively, the growth of the service of the debt produced, over the period 1980-85, a more favorable balance of payments, providing a badly needed foreign currency. The bad news are the falling of the investments, compared with a growing consumption (Broda, De Pablo 1985).

3. THE DYNAMO FORMULATION OF THE HARROD-DOMAR MODEL.

For the purpose of this paper, it is enough to use the simplest available model, the one proposed by Harrod (1939) and Domar (1946), in order to analyze the economic growth of Argentina. Central to its theory is the dual role of investment, which, on the one side, affects supply, because is capacity generating; on the other side modifies demand, when it generates income and the corresponding consumption.

The equation formulation requires the use of an adequate notation, coherent with the DYNAMO language (Pugh 1976). To this end, let j, k, and l, be three succesive points in time, wich define the jk and kl consecutive periods. Let K.k be the capital in time point k, that is available to the system during starting period kl. In addition, let Y.k, C.k, KD.k and I.k, the income, consumption, capital depreciation and gross investment flows, respectively, measured in dollars-1985 per year, that happen during period kl. Also let kp, a technological constant, be the relationship between income and capital. Finally, let alk be the average life of capital.

a) On the supply side, the use of the key parameter kp allows to convert capital input available in time k, to new capacity, ready in period kl, for supplying the market with new goods. Then

$$Y.k=K.k*kp \tag{1}$$

The same identity holds for the previous period jk:

$$Y.j=K.j*kp \tag{2}$$

And substracting

$$(Y.k-Y.j)=(K.k-K.j)*kp=I.j*kp \tag{3}$$

In other words, the growth of income is equal to kp times I.j, where I.j is investment done during previus period jk, which become producing capital in following period kl, able to generate extra income (Y.k-Y.j), also disposable in period kl. It could be obtained an expression for the rate of growth of income dividing both members of eq. 3 by Y.j, the income of the previous period jk. Let v denote the ratio of investment incurred along the period jk, to the income generated during the same intervale of time, or fraction of income devoted to new investment:

$$(Y.k-Y.j)/Y.j=(I.j/Y.j)*kp=v*kp \tag{4}$$

Equation 4 says that the rate of growth of income depends on the proportion of income devoted to the creation of new capital and the productivity of the new additions to capital. If both v and kp remains constant, so will be the rate of growth of income.

b) On the demand side, the consumption expenditures equation is obtained multiplying the income by the average and marginal propensity to consume of current income, noted apc:

$$C.k=Y.k*apc \quad (5)$$

Considering investment as a function of the change in income over the inmediately preceding periods, it results the investment expenditures equation, where ak is the acceleration coeficient of proportionality:

$$I.k=ak*(Y.k-Y.j) \quad (6)$$

Adding eqs. 5 and 6, it results the total or aggregate demand of the society:

$$Y.k=C.k+I.k=Y.k*apc+ak*(Y.k-Y.j) \quad (7)$$

c) The keynesian static equilibrium condition S=I, considering both public and private expenses as a whole, gives the required link for stablishing the differential equation that regulates the path of growth of the national economy. This trajectory could be found by solving that differential equation. Knowing that saving is the fraction of income not spent in consumption, it follows that the condition means:

$$I.k=S.k=(Y.k-C.k) \quad (8)$$

It is clear that net investment NI.k is the rate of change of the capital stock K, and it is equal to investment after discounting the capital depreciation KD.k. The capital stock decays with time representing the obsolescence and usage rate of the equipament affected to the production of goods to be consumed in the current period kl.

$$KD.k=K.k/alk \quad (9)$$

Now the net investment flow incurred in period kl can be expressed as:

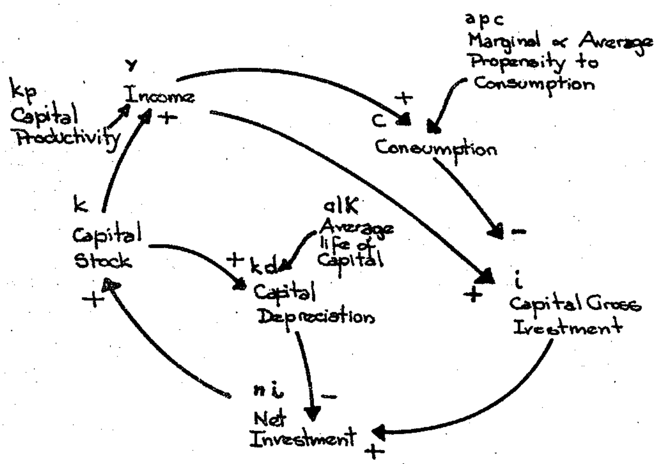
$$\begin{aligned} dK/dt=NI.kl&=(Y.k-C.k)-KD.k= \quad (10)\\ &=(K.k*kp)-(K.k*kp*apc)-(K.k/alk)=\\ &=K.k*((kp)-(apc*kp)-(1/alk))=\\ &=K.k*\ \text{Constant } 1 \end{aligned}$$

Equation 10 is a very simple differential equation, homogenous of first order, solved by a function that shows exponential growth. DYNAMO simulation program obtains this solution for the state-variable K as the integral of the net investment NI flowing into it, using the Euler integration method with a fixed step size of time, dt. The accumulative equation is:

$$K.k=K.j+(dt)*NI.jk \quad (11)$$

The following Figure 3 shows the feedback structure behind the Harrod-Domar model, which represents the key notion of capital accumulation, cause of economic growth. The labor, combined with the capital stock inherited at the beginning of period jk, produces a flow of output, wich priced becomes income of this period jk. A fraction of income is saved and invested in period jk, thus further enlarging the capital stock, available at period kl (Branson 1979). Therefore a positive feedback loop is closed, pushing the growth process up.

Figure 3 Causal Structure of the Harrod-Domar Model



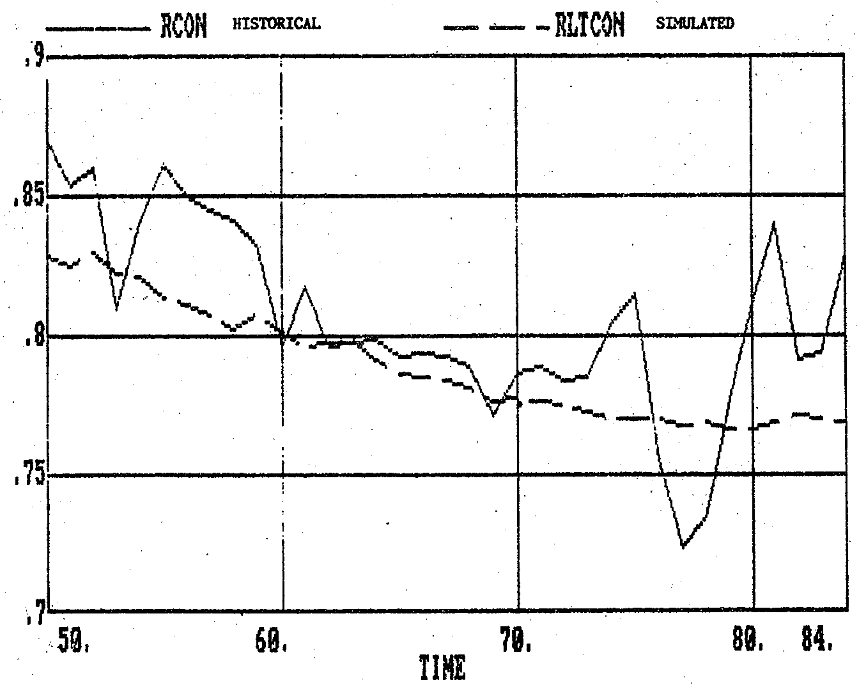
4. EXPLAINING ARGENTINE GROWTH WITH THE HARROD-DOMAR MODEL.

For the most part of the period 1950-85, the historical growth of Argentine income is conveniently simulated by the Harrod-Domar model, when local parameters are used in the simulation. For that period, the doubling time is about 22 years. Then the solution for eq. 10 requires to know the average life capital, estimated in 15 years (Ffrench-Davies 1986), and the propensity to consumption. Next Figure 4 displays the historical consumption relative to GDP, plotted against its OLS adjusted regression (Broda, De Pablo 1985). For the sake of simplicity, apc is assumed in this paper, unless otherwise adverted, as being constantly equal to 0.80, so that the eq. 10 is solved for kp=0.485. Therefore K inicial=GDP inicial/kp=4631/0.485=9262.

The model works well when simulates GDP and consumption, as shown in Figure

5, but tends to underestimate the flow of the net investments and does not foresee the crisis to the end of the period. The problem clearly appears in the last 5 years, when the service of the debt becomes unbearable and additional causal links should be incorporated to the structure shown in Figure 3, for a more realistic representation.

Figure 4 Historical Consumption Relative to GDP and Simulated by an OLS Adjusted Regression Against GDP. (Source: Broda, De Pablo 1986).



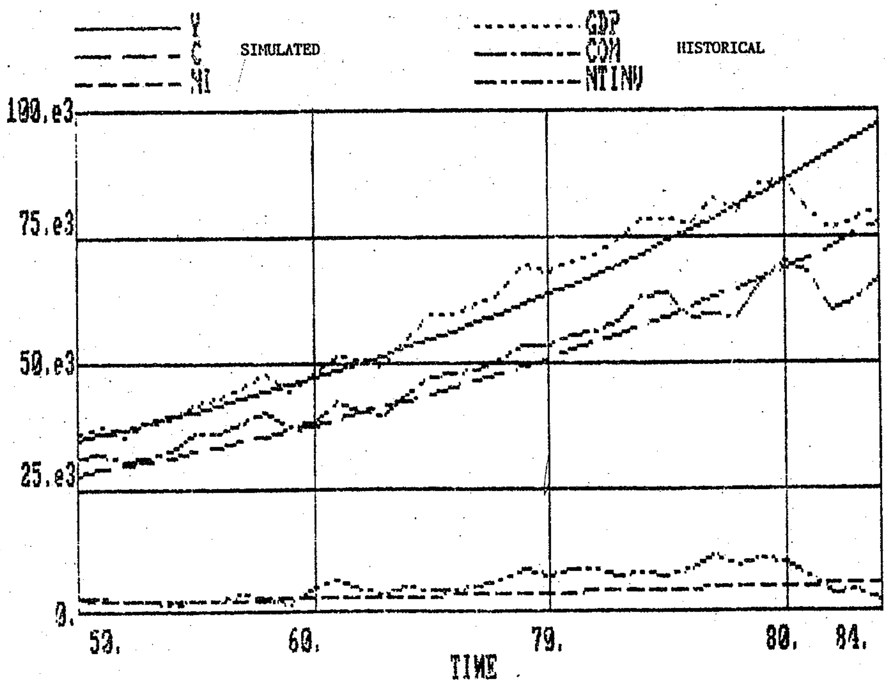
Even when available statistics only allows to estimate marginal productivities of gross and net investments, it is interesting to compare the historical values of these marginal concepts with the ones produced by simulation. To this purpose it is necessary, firstly, to obtain one year lagged time series for both historical and computer generated time series, for GDP, gross and net investments. This is done by using the pipeline type of delay, feature of DYNAMO (Pugh 1976), available as well in DYSMAP (Cavana, Coyle 1982). For example, the one-year lagged variables for actual GDP (pbi) and net investment (ntinv) are oldvpbi, oldvginv and oldvnti, respectively:

oldvpbi.k=delayp(pbi.k,1,pbippl) (12)

oldvginv.k=delayp(grinv.k,1,gippl) (13)

oldvnti.k=delayp(ntinv.k,1,ntppl) (14)

Figure 5 Historical and Simulated Argentine GDP, Consumption and Net Investment (1950-84), millions of us $ 1985.



Then the marginal productivities of historical gross (mgpginv.k) and net (mgpninv.k) investments are, by definition:

mgpginv.k=(pbi.k-oldvpbi.k)/oldvginv.k (15)

mgpninv.k=(pbi.k-oldvpbi.k)/oldvnti.k (16)

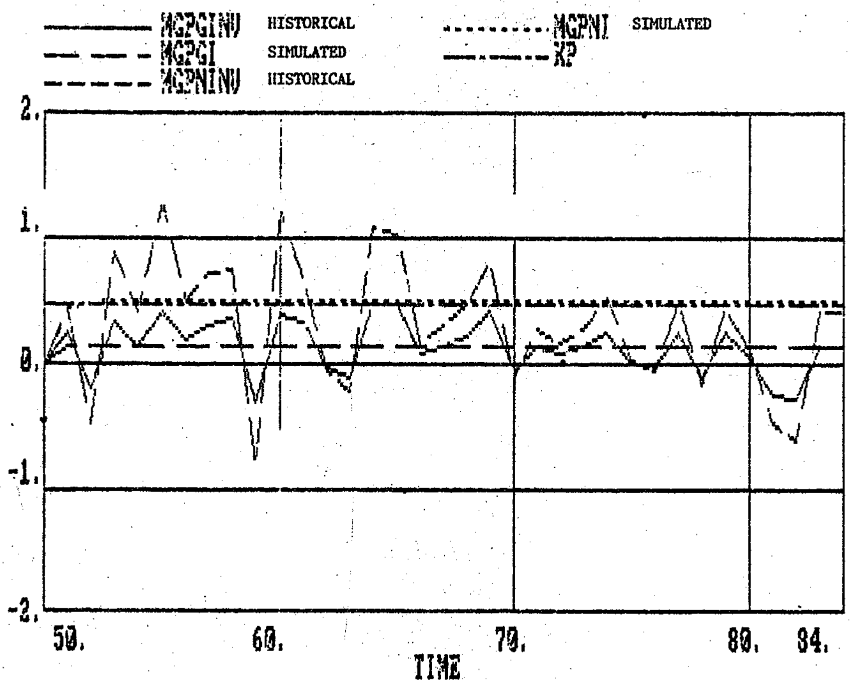
Similarly, for simulated gross (i.k) and net (ni.k) investments, the equations for marginal productivities of net (mgpni) and gross (mgpgi) investments are:

mgpni.k=(y.k-oldvy.k)/oldvni.k (17)

mgpgi.k=(y.k-oldvy.k)/oldvi.k (18)

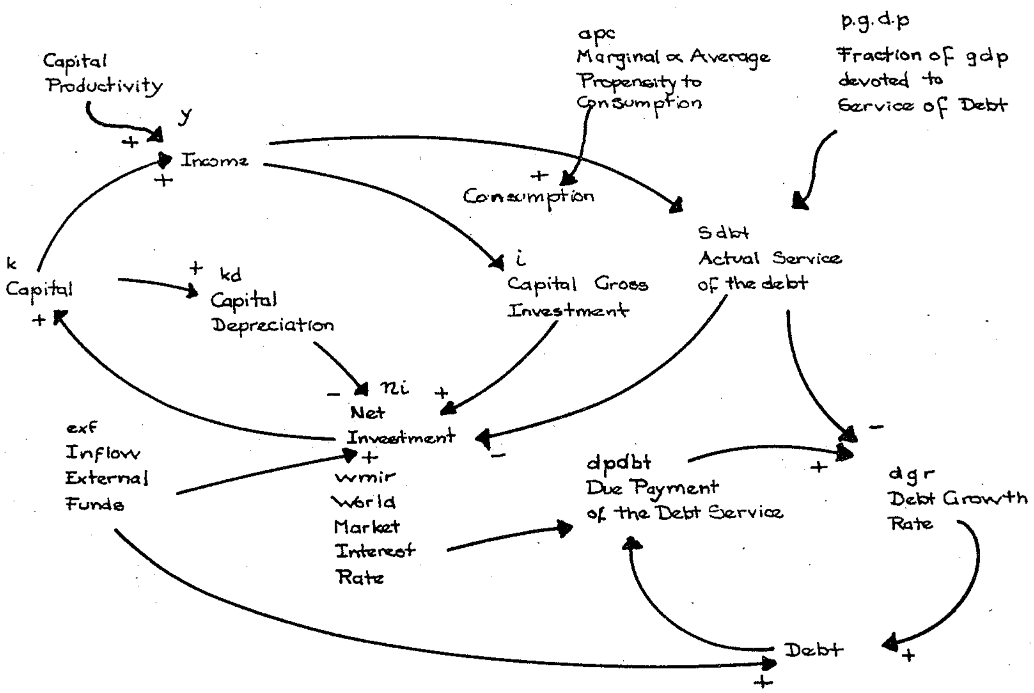
The equation formulation has been solved satisfactorily. Figure 6 presents historical and simulated marginal productivities of gross and net investments. Besides the initial year, when the variables exhibit transient behaviour due to the use of emptied pipeline delays, the results obtained are not so bad, except for the tendence of the model, already met in Figure 5, to underestimate the real values over the end of the run and the fact that the model can not forecast the recession accompanying the acceleration of the rate of growth of the external debt of Argentina. The historical marginal productivity of gross investment fluctuates widely around the 0.485 constant value of the corresponding simulated productivity, being 0.485 also the value of the productivity of the capital found as solution of previous eq. 11. Likewise, the marginal productivity of the net investment floats around 0.15, the simulated value of such productivity, and coincidently, the arithmetic mean of the serie 1953-1984 (Broda, De Pablo 1985).

Figura 6 Historical and Simulated Marginal Productivities of Gross and Net Investments, and Capital Productivity of the Model.



For representing the present circumstances of Argentina it is convenient to modify the simple Harrod-Domar structure shown in previous Figure 3. The investment capacity, after capital depreciation, should also take into account the drainage of funds due to the service of the debt and, eventually, fresh money coming from the international banking system. The following Figure 7 represents the modified structure of the model, where the service of the debt, sdbt.k, is expressed as a fraction, fgdp, of the GDP devoted to the debt, and the inflow of money, exf, as an exogenous input. The amount of the external debt is recorded by an auxiliar state variable, or level variable, D.k, wich is fed or depleted by the debt growth rate, dgr, depending on the due payment of the debt service, dpdbt, compared with the actual flow of Argentine payments, sdbt.k

Figure 7 Causal Structure of the Harrod-Domar Modified Model.



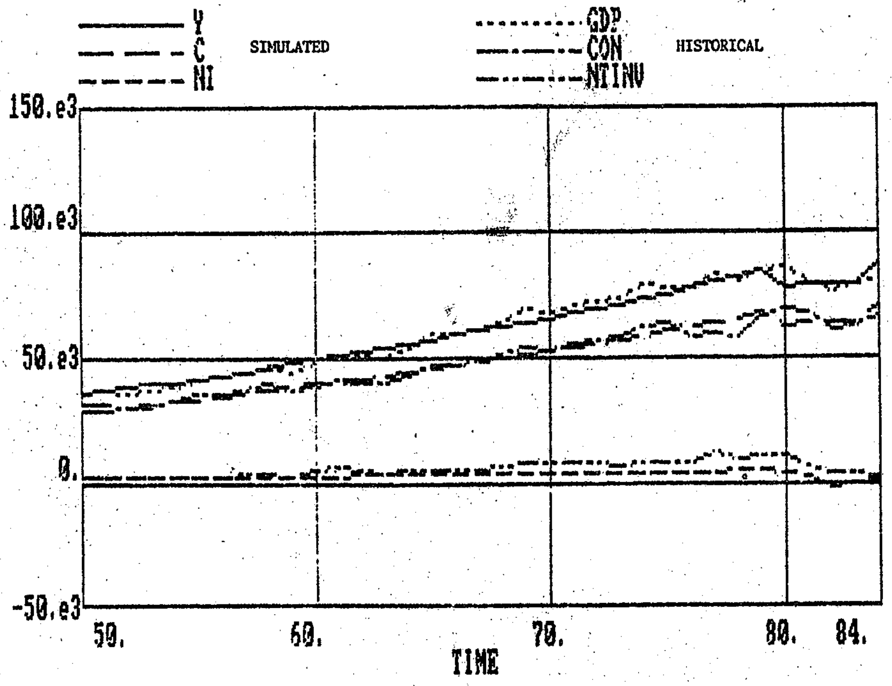
This again could be represented by another first order diferential equation, where the constant C2 is smaller than C1.

$$
\begin{aligned}
dK/dt &= NI.k1=I.k-KD.k= \\
&=(Y.k-C.k-SDBT.k)-KD.k= \\
&=(K.k*kp)-(K.k*kp*apc)-(K.k*kp*fgdp)-(K.k/alk)= \\
&=K.k*(kp-(apc*kp)-(kp*fgdp)-(1/alk))= \\
&=K.k*\ \text{Constant 2.}
\end{aligned}
\tag{19}
$$

Nevertheless, the lineality of the system should be abandoned, because of the necessity of appealling to the use of a STEP function when the equation for capital productivity is formulated. Until 1980, the required value of capital productivity for overcoming the historical service of the debt, traditionally about 1% of GDP, introduced as an exogenous time serie, and simultaneously able to explain the growth of GDP is 0.50. This value was not found as a solution of a differential equation, but for extensive experimentation with the DYNAMO simulator. On reaching year 1980, the actual GDP levelled off, requiring a smaller capital productivity, kp=0.45, for a better adjustment. This again found trough DYNAMO simulation.

Next Figure 8 shows historical and simulated behaviour of Argentine GDP, consumption and net investment, using a modified Harrod-Domar model whose service of the debt is the historical one for the period 1950-84. It could be seen the effects of the debt on GDP growth over the last 10 years.

Figure 8 Historical and Simulated GDP, Consumption and Net Investment (1950-1984).



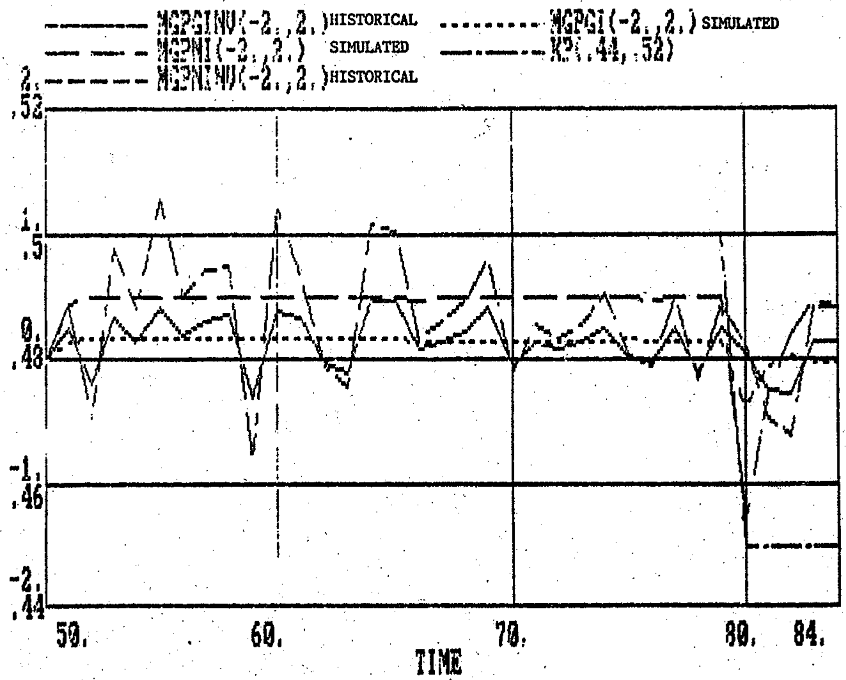
The behaviour of the marginal simulated productivities of gross and net investments follow the drop of kp, falling suddenly in 1980, for recovering slowly, later on, at a lower level in the case of net investment, and gross investment productivity nearly reaching the capital productivity value level. The descripted dynamic is exposed in Figure 9.

4. CONCEIVABLE FUTURES FOR ARGENTINA.

After building some sort of confidence in the Harrod-Domar model for representing the elemental facts of Argentine economic history, is quite a straightforward procedure to generate conceivable futures for Argentina. It can be done, simply, by using different set values for the exogenous variables and parameters, wich would shape the future of Argentina. Also, it could be examined the likelihood of each one of the scenarios generated because of the utilization of the input sets. However, it is useful to obtain firstly, a quick profile of these scenarios by means of the DYNAMO simulator program.

The variables and parameters used are, let it be repeated, the flow of fresh external funds, exf, destined to net investments; the capital productivity, kp, the fraction of GDP devoted to the service of the debt, sdbt and the average propensity to consumption. Another parameter to be applied is the world markets interest rate, wmir, wich defines the payment annual amount.

Figure 9 Historical and Simulated Argentine Marginal Productivities of Gross and Net Investment, and Capital Productivity.



Firstly, it can be tought of the lost future because of the recession. This scenario is obtained by simple extrapolation of the historical growth of Argentina during the 1950-1980 period to the future, ignoring the crisis at the beginning of the Eighties, as if the debt did not exist.

Secondly, if the previous one constitutes a lost opportunity, it could be imagined another where the stagnation of the present decade could not be defeated. There is not external help and the capital productivity does not recover its 0.50 historical value. The disposable income after consumption is not enough for the payment of the debt services. Therefore, what actually happens in the scenario is that the economic system is desinvesting, arriving to year 2000 to a level of GDP 3.4% below the starting 1985 value.

Thirdly, like families bearing hardship, the citizens can fasten their belts, diminishing the fraction of income consumend. In this case it has been assumed a gradual drop to 0.72 from the historical 0.80, in five years time and from then on that lower remains constant level, until the end of the simulation run, in year 2000. It is easy to understand the internal political difficulties of this scenario, which makes so difficult its implementation despite of the significant recovery made possible because of it.

Fourthly, the reference proyection of Argentine development represents the most likely evolution of its economy if not major changes in policy are made and external conditions do no alter significantly, like the drop of the international interest rate or the rise of prices of Argentina traditional export goods. In this case, and assuming the historical value of 0.50 for capital productivity, 15 years of average life capital, the historical 0.80 everage propensity to consumption, a service of the debt of 5.7% of GDP and no external inflow of fresh money coming in the next 15 years. This foreseeable future of Argentine, the one which is felt like the bussines-as--usual scenario, does not stop paying the service of the debt. Argentina just manages to invest the necessary amount which enables the GDP to grow 7.5% over the next 15 years, which means an annual rate of growth of about 0.4%. This is about 10% of the historical rate for the period 1950-1980. As population continues growing at its usual 1.65% annual rate, the available GDP per capita decreases nearly 16%, compasred with the 1985's standars.

Fifthly, it could be tried to maintain at least the life standards enjoyed about the middle of the Seventies, before the external debt crisis. This objetive can be accomplished by borrowing. A steady annual inflow of fresh money of about 2300 million $ 1985, allows to support a constant GDP per capita and an increment of 27.9% in GDP over the 15 years. Sixthly, aproximately the same than in the previous scenario could be achieved by virtue of a gradual improving of the productivity of the capital, thanks to a better management, so that from the starting 0.45 value the economic national system reaches the 0.56 mark, at an 0.8% annual rate of improvement. Seventhly, duplicating the borrowing mentioned in the fifth scenario permits an annual rate of growth of nearly 2.3%, and 48.3% of GDP increment over the 15 years. Eighthly, duplicating the rate at which the productivity improves achieves an overall increment of 57.4% over the 15 years period, at an 3.0% annual rate of growth. And finally, a grand scenario could be built imagining the duplication of both borrowing and improvement of the productivity simultaneously, which means to grow 114% until the end of the XX Century, at an 5.2% annual rate. The following Table 1 summarizes the results obtained when running the different scenarios in the computer.

Table 1. Performance of Argentine Economic Indicators under Alternative Scenarios Conditions.

Scenarios	Parameters and Exogenous Variables in Scenarios.				Perfomance Indicators		
	Inflow External Funds	Capital Productivity	Debt Service	Consumption Propensity	Rate of Growth. GDP	Rate of Growth. GDP/cap.	GDP
	10**6 ($85)	(1)	% of GDP	(1)	% 15y % year	% 15y % year	10**6 ($85)
	EXF	KP	SDBT	APC	GDP	GDPPC	GDP
Historical Period. (1950-1984)		0.50	1.0	0.80	124.4* 2.4	40.4 * 1.0	(%34y)
1. The lost Paradise.	--	0.50	1.0	0.80	52.0 2.8	18.7 1.1	134500
2. Unbeaten Stagnation.	--	0.45	5.7	0.80	-13.6 -0.9	-32.4 -2.5	76880
3. Fastening the belts.	--	0.45	5.7	0.72	32.1 2.7	3.3 0.2	117700
4. Business as-usual.	--	0.50	5.7	0.80	10.5 0.6	-13.5 -0.9	97780
5. Keeping up with the Seventies, but borrowing.	2325	0.50	5.7	0.80	27.8 1.6	0.0 0.0	113100
6. The same, but gradually improving productivity.	--	0.50 (1985) 0.56 (2000)	5.7	0.80	38.8 2.2	8.6 0.5	122800
7. Duplicating the borrowing.	4650	0.50	5.7	0.80	48.3 2.6	16.1 0.9	131200
8. Duplicating the improving of productivity.	--	0.50 (1985) 0.63 (2000)	5.7	0.8	72.7 3.7	35.1 2.0	152800
9. Grand Scenario: borrowing & improving productivity.	4650	0.50 (1985) 0.63 (2000)	5.7	0.8	112.6 5.2	66.3 3.5	188100

The next Figure 10 displays the simulated GDP and debt for different conceivables scenarios which were generated according the parameter value sets described in Table 1. The mechanism of the debt formation, outlined in Figure 7, is a very simple one. The debt growth rate depends on the difference between its due service and the money actually paid by Argentina. If this difference is positive the debt grows; if it is negative the debt falls. It is understood that if payments equal exactly the due service, Argentina is paying only the interest, without any variation of the amount of the debt. The interest rate used for simulating the dynamic of the economy is the corresponding to historical economic data series of the industrialized countries, deflacted by the price of their exporting goods, about 6% (Ffrench-Davies 1986).

Obviously, both income and debt should be considered at the same time, when preferences are expressed. So, even when scenario 9 displays the biggest income at the end of the simulation run, this has to be balanced with the fact that its debt is not so far from the debt of scenario 7, the worst from the viewpoint of the debt formation. However, heavily borrowing accompanied by the vigorous improving of the production, as happens in scenario 9, leaves at the end a falling debt, because of the payment capacity generated by a powerful economy. Undoubtedly, the best from the debt angle is the scenario 8, where an acceptable expansion of the economy is only internally supported, without any foreign help. Fastening the belts, as in scenario 3 does not help too much; it is nearly equivalent to scenario 6, which instead of deppressing consumption, push productivity mildly up, wich is more acceptable politically. If the stagnation of the last decade does not change for the better, that is, capital productivity does not return to the historical levels, external help is not required and the service of the debt is satisfied, as in scenario 2, Argentina should prepare herself for a black future.

6. PROBABILISTIC GENERATION OF SCENARIOS.

The model which produced previous simulation runs has not information about the future, except that included in some of the tests when the step or ramp functions are used. But even so, such information about declining average consumption, step changes in productivity or supply of fresh funds is used considered every phenomena in isolation form all others. The model can be modified to include mutual interactions between external parameters and both ways causal relationships between these parameters and the model variables, as suggested by Stover (1975, 1980). The problem with the Stover solution is that the DYNAMO compiler failed in its attempt to compile the model because of simultaneous equations do not avoided by Stover. The following Figure 11 shows the closed loop proposed by Stover (1980) which is lacking of the corresponding level variables.

The purpose of this section of the paper is to modify the Stover calculating scheme for overcoming the compiling dificulties. So what follows is a modified sequence of calculation which is able to generate scenarios at random. Even when this technique pays off when several events are included in the analysis, say 10 o more, only 4 events are considered here, because of the deliberate simplicity of the model presented in this paper. More complicated versions will require greater number of events and obviously, better information, for a full application of the methodology here discussed.

Figure 10 Historical and Simulated GDP and Debt for Argentine Conceivable Futures (1950-2000), millions of us $ 1985.

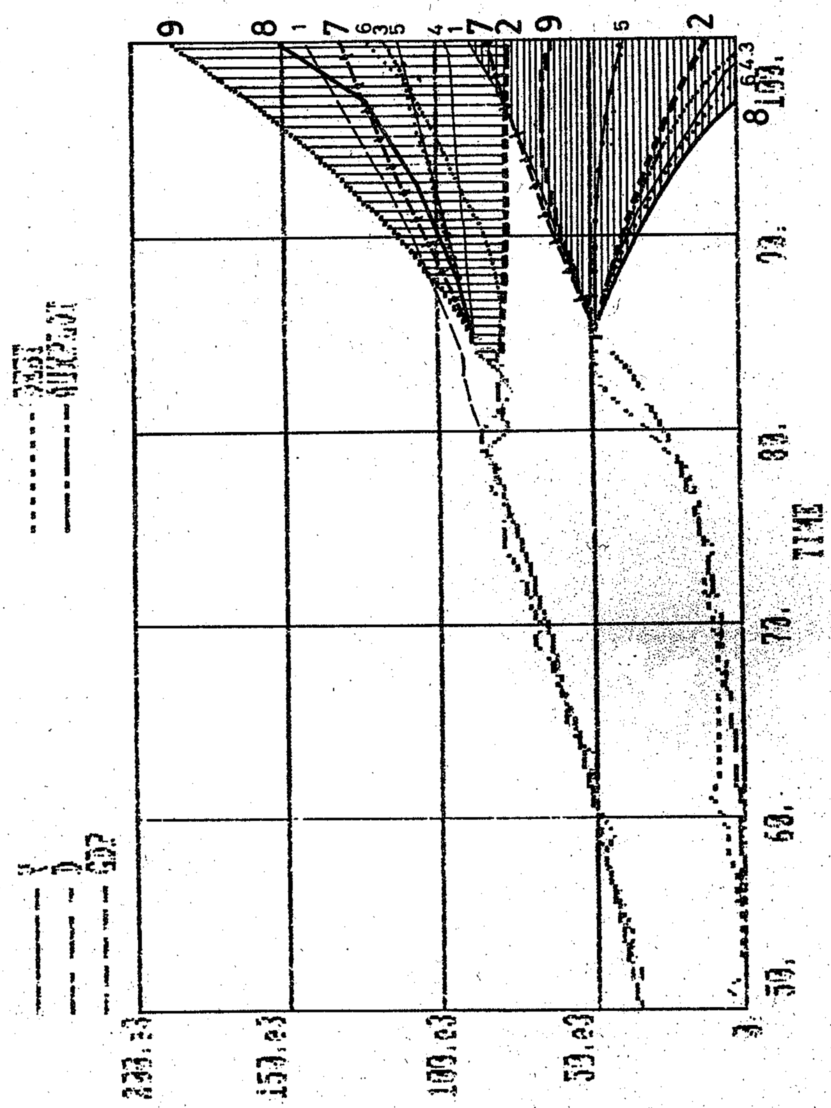
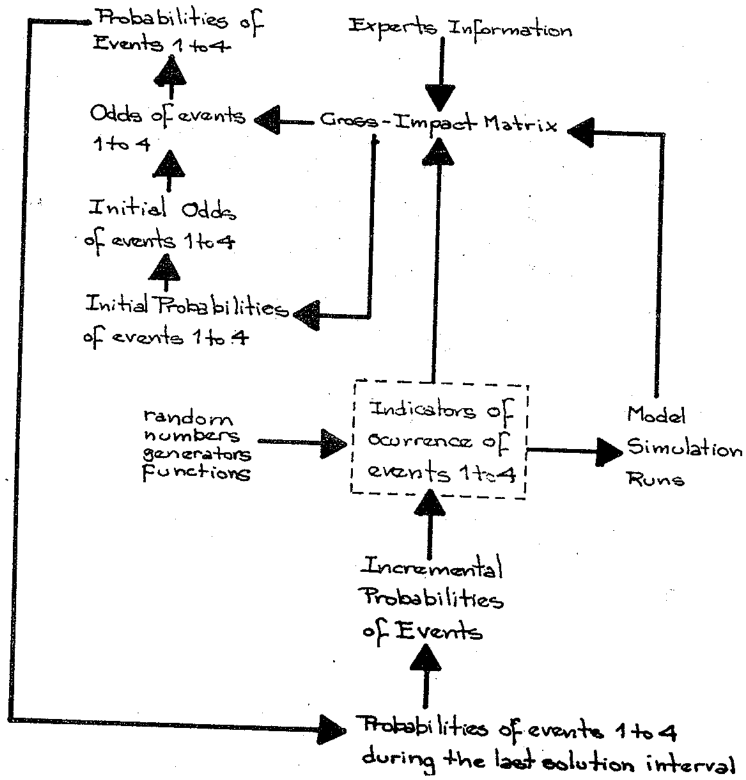


Figure 11 Probabilistic Scenario Generating Loop.



First thing to do is to define the events to be included, which are the ones that conformed the scenarios descripted in Tabla 1: e1, improvement of capital productivity from 0.50 to 0.56; e2, improvement of capital productivity from 0.50 to 0.63; e3, annual provision of fresh money from industrialized countries, equivalent to 2,325 millions of 1985 american dollars; e4, doubling the supply of money to 4,650 millions dollar. The next Table 2 shows an initial estimate of the probability of each event by some future year, say 1990, and the conditional probability matrix. Expert opinion should be sought for determining these probabilities and their alterations with the occurrence of the other events, or conditional probabilities. Meanwhile an educated guess has been made for the authors to ilustrate the technique.

The conditional probability matrix shown in Table 2 expresses the probability of an event given the occurrence of another event. Each probability can be converted to its corresponding odds, according to the transformation rule "odds e=probability e/ (1-probability e)". Then, the odds ratio of the impact

Table 2. Cross-impact Matrix Showing Conditional Probabilities.

If this event occurs.	Initial probability by 1990	The probability of this event becomes 1	2	3	4
e 1. Improving capital productivity.	0.30	####	0.20	0.20	0.12
e 2. Greater improvement of capital productivity.	0.15	0.01	####	0.25	0.15
e 3. Fresh money supply of 2,325 millions $85, annually.	0.20	0.25	0.12	####	0.20
e 4. Doubling the supply of money to 4,650 millions $85, annually.	0.10	0.15	0.10	0.01	####

of event i on event j is defined as the odds of the event j given the occurrence of event i divided by the initial odds of event j, in isolation. The matrix shown in Table 3 contains the odds ratio for every possible pair of events.

Table 3. Occurrence Odds Matrix Ratios.

If this event occurs	The odds of this event are multiplied by 1	2	3	4
e 1. Improving kp	####	1.41	1.00	1.22
e 2. Improving twice kp	0.02	####	1.33	1.58
e 3. Borrowing $2,325 M	0.77	0.77	####	2.25
e 4. Doubling borrowing	0.41	0.62	0.04	####

Having done the matrix which evaluate mutual interactions between events, the DYNAMO programme goes as follows; the probability of the event 1 to 4 are calculated from its odds:

```
prob1.k=odds1.k/(1+odds1.k)
...........................
...........................
prob2.k=odds4.k/(1+odds4.k)
```

The odds of events 1 to 4 are calculated as the initial odds times the impact odds ratios times the impact of model variables on events:

```
odds1.k=iodds1.k*io1o1.k*io2o1.k*io3o1.k*io4o1.k*ivar1.k..
.............................................................
.............................................................
odds4.k=iodds4.k*io1o4.k*io2o4.k*io3o4.k*io4o4.k*ivar1.k..      (21)
```

The initial odds of events 1 to 4 depend on their initial probability values:

```
iodds1.k=iprob1.k/(1-prob1.k)
.............................
.............................
iodds4.k=iprob4.k/(1-prob4.k)                                   (22)
```

The event initial probabilities given as arguments of table functions of time, are provided for the determination of their initial odds. Stover suggests that these values should be requested to experts, who had to estimate such probabilities for years 1990, 1995 and 2000. After calculating the median estimates of the series supplied by the experts a S-shaped curve should be fit to these points to yield a cumulative probability curve (Stove 1975). Provisional estimations have been made by the authors:

```
iprob1.k=tabxt(tiprob1,time.k,85,100,5)
tiprob1=0/.30/.32/.34
........................................
........................................
iprob4.k=tabxt(tiprob4,time.k,85,100,5)
tiprob4=0/.10/.12/.14                                           (23)
```

What comes next is the cross-impact matrix formulation. The impact of event i on event j, ioioj, is set equal to 1, that is without any effect, if event i has not occurred, or the odds ratio expressing the effect of event i on j, which appears in Table 3, if event i has occurred. Obviously the impact of event i onto itself is 1.

```
First row
=========

io1o1.k=1
..........................................
..........................................
io1o4.k=fifge(1.22,1,e1.k1,0.10)

Second row
==========

io2o1.k=fifge(0.02,1,e2.k1,0.10)
..........................................
..........................................
io2o4.k=fifge(1.58,1,e2.k1,0.10)

Third row
=========

io3o1.k=fifge(0.77,1,e3.k1,0.10)
..........................................
..........................................
io3o4.k=fifge(2.25,1,e3.k1,0.10)
```

Fourth row
==========

```
io4o1.k=fifge(0.41,1,e4.kl,0.10)
..................................
..................................
io4o4.k=1                                                    (24)
```

Equation simultaneousness was broken up by a new formulation of the events occurrence. To this purpose e1 to e4 levels, shown in Figure 11 as a box drawn in dashed lines, are being fed by the random occurrence of e1r to e4r flows and depleted in such a way that once any event happens, its level will remain equal to 1 for the rest of the run. Mutual impacts between events are triggered off by the occurrence of events 1 to 4:

```
e1.k=e1.j+dt*((e1r.jk/dt)-(e1.j*e1r.jk/dt))
...........................................
...........................................
e4.k=e1.j+dt*((e4r.jk/dt)-(e4.j*e4r.jk/dt))                  (25)
```

For the events to happen, their corresponding random numbers have to exceed the complement to 1 of the current probability of each one of those events:

```
e1r.kl=fifge(0,1,(1-prob1.k),rn1.k)
....................................
....................................
e4r.kl=fifge(0,1,(1-prob4.k),rn4.k)                          (26)
```

Finally, the random number are generated by using the noise function, which provides a pseudo-random sequence of numbers uniformely distributed between -1/2 and +1/2 (Plugh 1976), used as argument of the equations 26.

```
rn1.k=noise()+0.5
..................
..................
rn4.k=noise()+0.5                                            (27)
```

Once the formulation of equations required for the generation of random generated scenarios is finished, this sector of the programme is easily connected to the Harrod-Domar model. The following equations record the impacts of the events on the model:

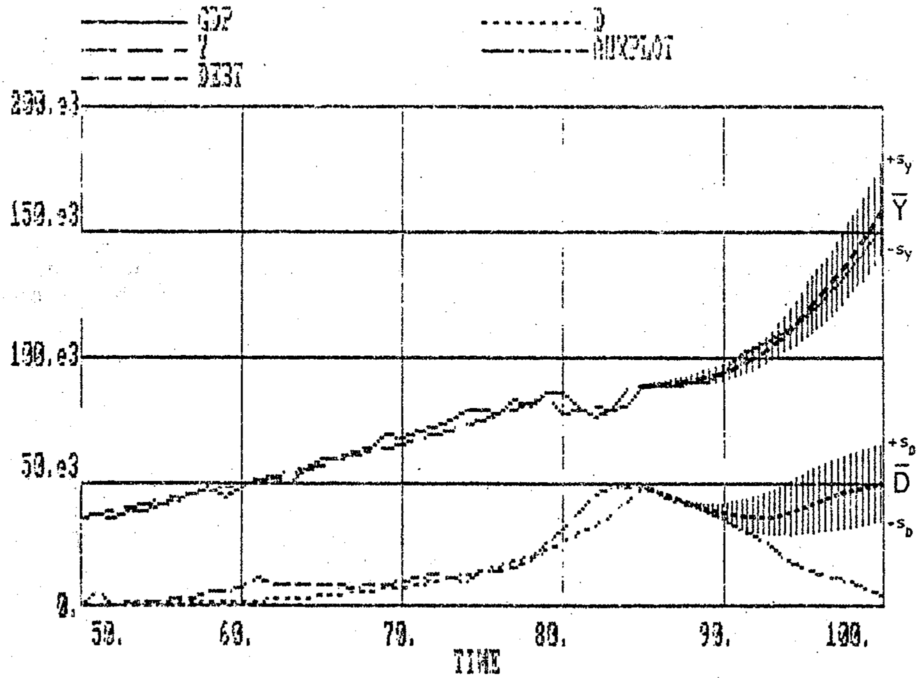
```
kp.k=stgkp+ramp(slp1.k,85)+ramp(slp2.k,85)
stgkp=0.05
slp1.k=0.0045*e1.k
slp2.k=0.009*e2.k                                            (28)

exf.k=0+e3.k*2325+e4.k*4650                                  (29)
```

So, the occurrence and timing of events e1, e2, e3, and e4, are regulated by eqs. 20 to 27. They are able to generate scenarios which will differ widely one another. Therefore, for every solution interval, the model modifies the probability of the events e1 to e4, each time the model run. This resulting in the happening or not of these events, whose impacts are transferred to the Harrod-Domar model through eqs 28 and 29, which provide the required link.

The following Figure 12 summarizes the results of a large number of separate runs performed with Dynamo III/F. The simulated time series were transversely analyzed, yielding an average value and the standard deviation for every solution interval. This Figure 12 displays the historical behaviour of the Argentine GDP and external debt until 1985, in millions of 1985 american dollars, since 1950. After 1985, it can be observed the resulting simulated income and debt, noted y and d, respectively, for a particular random generated scenario. On top of this, has been put the average trayectories of the simulated income and debt and their confidence bands resulting from the 50 experiments. The relevance assigned to the results shown in Figure 12 should be moderate, according to the provisional assumptions made in Table 2.

Figure 12 Average Trayectories of Simulated GDP and Debt and their Confidence Bands, Superimposed on a Particular Simulation Run.



CONCLUSIONS

A very simple Harrod-Domar model is able to yield relevant results when it is used for analysing different scenarios at a macroeconomic level, in the Argentine case, once the model's dynamics shows an acceptable nearness to historical economic data for Argentina. Then the model is used to verify the Stover (1980) solution to the probabilistic generation of futures, using System Dynamics type of programming. Slight modifications are required to avoid equation simultaneousness in such solution.

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