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Leontief and the Future of the World Economy

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1. Historical background

The 1950's and 1960's had shown extremely high growth of the world economy, reaching on average a GDP annual rate of 4.5%. This high economic growth raised problems of sustainability considering the progress of pollution and the high use of finite resources such as minerals and hydrocarbons. At the end of the sixties, these ideas were greatly stimulated by the Club of Rome active promotion of a world model using systems dynamics methodologies, a model first defined by Forrester (1971) and then expanded by Meadows (1972). The later study, "Limits to Growth", pointed quantitatively to the impending dangers of world shortages of energy and raw materials, and to vast environmental problems, should the world population, capital formation and economic production continue to grow exponentially at rates such as those observed in the previous decades.

Systems dynamics deals with "multi-loop non-linear feedback systems, a class to which all our social systems belong " (Forrester, 1971, p. 123). The design of the model was fairly simple, the world was treated as a single unit, and the structural validation was rendered specially difficult by the lack of relevant information and consequently by the introduction of arbitrary levels and rates for most variables. Despite the efforts of better quantification by a larger research team, the resulting final world model raised considerable objections, but the debate in itself served the purpose of diffusing the Club of Rome idea of the World Problematique.

Substantial improvements in the methodology and data were introduced in a second report to the Club of Rome by Mesarovic and Pestel (1974), using for the first time a set of interacting regions of the world, but the nature of the debate on world modelling was not substantially changed.

The idea of "Limits" was also developed by Barbara Ward and Rene Dubos (1972) using other means such as the biospheric concept of only one earth that was presented to the UN Conference on Human Environment (Stockholm, 1972).

The UN had been pressing for an International Development Strategy for the 70's (UN, 1971) aiming especially at reducing the disparities between the rich and poor countries, and the new consciousness of earth limits and the interesting progress of modelling of the relevant topics, moved the UN to launch a study dealing with environmental issues raised by world development and looking for "possible alternative policies to promote development while at the same time preserving and improving the environment" (UN, 1973).

For the UN to embark in such a study required a solid methodological basis and Leontief, that had already analysed the relations between the economy and the environment (Leontief, 1970), and had established a long standing relation with the UN organisation (that had hosted in Geneva the International Conferences on Input-Output Techniques of the sixties), was the first choice.

It is reasonable to assume that Wassily Leontief was enthusiastic about the UN project and he developed a first theoretical model already in 1973; this model provided the content for the Stockholm lecture of December 1973, when he received the Nobel Prize in Economic Science (Leontief, 1974). The model was built around a hypothetical context of two regions (developed and less developed countries), three commodities (extraction industry, other production and pollution abatement), two components of final demand (domestic and trade) and two components of value added; its theoretical formulation included both a physical model and its price dual, relying on the basic input-output relations.

With 17 equations and 29 unknowns ,this simple model required 12 exogenous values for actual computation ,and the choice of theses values as well as of possible changes in technical coefficients was to be made in the framework of scenarios .

Peter Petri provided a rough estimate of the necessary technical coefficients ("The numbers are, strictly speaking fictions. But their general order of magnitude reflects crude, preliminary estimates..." p. 825, Leontief 1974), and on this basis, three scenarios were computed for the year 2000.

In the base scenario (case 1) the productivity of labour was expected to be three times as high in 2000 as in 1970, and the developed region would strictly enforce the standards of the 1967 US Clean Air Act, while there was no abatement activity in the less developed region.

In case 2, the less developed region introduces an abatement industry to limit pollution to twice its initial level, and further to it, in case 3 the productivity of labour in the Extraction industry of the developed countries grows at half the initial rate and the technical coefficients for inputs in this extraction industry are doubled, thus reflecting a move towards exhaustion of these natural resources and to increasing extraction costs. As could be expected in a simple linear accounting system, without price sensitive behavioural equations either for demand or for trade, the results of the three scenarios in real terms are not radically different, but between case 2 and case 3 there is a substantial shift of the terms of trade leading to a redistribution of income favouring the less developed countries.

Leontief ended its Nobel Conference stating: “All theories tend to shape the facts they try to explain; any theory may thus turn into a procrustrean bed. Our proposed theoretical formulation is designed to protect the investigator from this danger: it does not permit him to draw any special or general conclusions before he or someone else completes the always difficult and seldom glamorous task of ascertaining the necessary facts” (p. 833, Leontief 1974).

This less than glamorous task was expecting Anne Carter, Peter Petri, and of course Wassily Leontief during the following two years, leading to the report to the UN on the Future of the World Economy (UN, 1976) that was later to be published in book form in several languages, and was deeply discussed both in developed and in developing countries, by economic and environmental organisations.

Before release, the report was discussed by an ad hoc group of experts (Chakravarty, Courcier, el Iman, Klein, Linneman, Mesarovic, Porwit, Ridker, Shishido and myself) that proposed further extensions of the model and the consolidation at the UN of a permanent activity around it, under the heading of UN Project 2000. This was in line with Leontief own wishes: “It is hoped that the model will have a continuing life in which fresh data are used as they become available and in which the model is eventually applied to other development questions" (UN, 1976, p. 7).

Earlier that same year, Richard Stone (1976) had confirmed that developing a world model based on natural accounting data, including sectorial disaggregation raised "serious but not in principle insoluble" problems. "In so far as they are due to the uneven development of the relevant subject areas, all that is needed is for the interest and energies of social scientists and historians to be channelled towards a quantitative approach to their subject: once these scientists had set up the appropriate framework, the data will flow in like pins towards a magnet, as has happen with national accounts statistics in the last thirty years" (p. 32).

As often happens in large organisations, the UN wasn´t interested in funding refinements, and Project 2000 progressively lost momentum, and concentrated on shorter term macroeconomic analyses implementing project LINK under the methodological guidance of L. R. Klein. Leontief made later on further runs of the model with Faye Duchin at the Institute of Economic Analysis, dealing with alternative population forecasts (Leontief, 1978) and other issues. Leontief had proven the point: given adequate resources, it is possible and useful to build world regionalised long term models with the usual restrictions of input-output analysis.

2. The model and the data

The final version of the world model (UN, 1976) included 15 regions, of which 4 covered the advanced industrial countries and the rest distinguished between centrally planned economies and two groups of developing countries, resource rich (3 regions) or resource poor (4 regions). Each region was described in terms of 48 sectors of economic activities including 8 mineral exhaustible resources and hydrocarbons.

Additionally, 8 types of major pollutants and 5 types of abatement activities were identified .The base year was1970 and projections were made to 1980,1990 and 2000.

In total, the 15 interconnected (through trade) sets of regional equations developed into a linear system of 2625 equations.

In some sense the world model is a partitioned hybrid input-output system with agricultural crops and minerals treated in physical units and nominal prices, and the rest of the sectors in value terms with initial unit prices.

An original feature of the model is the use of "world pools" to deal with trade relations. Regions address their import requirements (in function of their own activity levels) to a pool, that distributes the totals to the different exporting countries. The resulting trade flows are valued at uniform world prices (eventually obtained from the dual system of the US model).

Behavioural relations are very simplified, and household consumption of specific goods is allocated with coefficients proportional to the consumption aggregate per capita.

Slacks are introduced as extra additive variables in many equations, simplifying the use of the model in alternative forms (changes of variables from endogenous to exogenous and vice-versa, or even changes in the shape of an equation), an essential requisite for scenario simulation.

While the model, despite its large dimension, is structurally very simple and easy to run, the main difficulty relied in establishing a data base for 1970, and projecting structural changes into the future.

As the core of the model stays with the 15 regional input-output tables, assembling these tables raised many problems. Over 70 countries input-output tables were available with differing classifications and prices, not all of them for 1970. Therefore, the regional tables were estimated mainly on the basis of cross-national regressions of national per capita income; the regression used input-output coefficients for the 8 countries for which actual comparable prices were available (Kravis, 1975).

Adjustments were made to introduce, whenever possible, regional specific information.

Considerable attention was devoted to the input structures for mining activities, starting from a US 485-sector input-output table and modifying the relevant columns to take into account the interregional differences on average costs of extracting each specific resource. US data also helped to establish regional resource consumption coefficients.

The commodities consumption structures for 1970 were based on cross-country regressions on income per capita for the countries of the Kravis study.

International trade data could be structured from UN statistics, and time series helped to identify trends in the relevant input and output trade coefficients.

The coefficients of this complex system were projected into 1980, 1990 and 2000, either as a function of income (per capita or total), or of exogenous techno-economic information. For natural resources, the coefficients also depended on the difference between past cumulated production and the assumption made on reserves. They were expected to increase with the depletion of reserves.

Production determined employment levels and needs for different types of capital stocks. The investment requirements were the sum of the depreciation of past capital stock and of additional capital required.

The following table 1, directly extracted from the report, portrays at a glance the variety of the methods that were used to estimate the initial 1970 base and to make the projection of coefficients to the target years.

Table 1

Coefficient Estimation and Projection for a single Region Block												
	Agriculture	**Metals**	**Energy**	**Input-Output**	**Investment**	**Inventory**	**Pollution**	**Consumption**	**Urban**	**Government**	**Fish**	**Exports**
Agriculture	2	0	0	4	0	4	0	1,2	0		0	4
Metals	0	0	0	2	0	4	0	0	0	0	0	2
Energy	1,2	3	3	2,4	0	4	4	1	2	1	1	2
Industry and Services (fertilizer)	4 2 4	3	3	1,2	4	4	4	1	2	1	4	1
Capital	1,2	3	3	1	0	0	4	1	2	1	1	0
Pollution	2	0	0	2	0	0	4	0	1,2	0	0	0
Labour	1,2	3	3	1,2	0	0	4	1	2	1	1	0
Imports	2	2	2	1	0	0	0	0	0	0	1	0

<u>Coefficient projection methodology</u>

1. Income dependent
2. Specially projected
3. Changing with resource depletion
4. Held constant

	region-specific		other
	column scaled	0	no entry
	benchmarked		row scaled

The task of building a regionalised model of the world economy was so large that, even considering the enormous amount of work done by the authors, it could be easily criticised.

Thus, the ad-hoc Expert Group considered that other methods for endogenous determination of price changes should be reconsidered, that trade relations should be specified again in order to incorporate bilateral flows and price elasticities, and that the dynamic properties of the model should be extended beyond the areas of population, trade and capital formation. But of course nobody discussed the fact that the model, with very crude assumptions, was able to provide some rough quantitative insights into the nature of world economic interdependence. It was a courageous and ambitious endeavour, a pioneering effort in international modelling, and it was recognised as such by the UN and by the academic community. Being essentially an accounting machine with limited behavioural relations, the world model was more transparent than the other attempts made with more endogenous black box methodologies such as system dynamics, but of course provided more conservative projections , and left to the user, while fixing a considerable amount of exogenous variables and technical coefficients, most of the responsibilities on the final results of the simulations. The Leontief world model was a “garde-fou” for explorers of the long-term future of the world economy .

<u>3. Scenarios and results</u>

As the world model was built at the request of the UN, it is obvious that the scenarios explored were relevant essentially for UN issues. In particular the fact that the study was to bring elements to be considered in apprising the International Development Strategy (IDS) for the seventies by exploring longer term horizons (2000) was essential for the definition of the basic scenarios.

Scenarios were defined as combinations of exogenous sets of variables and coefficients (both in terms of their choice and of the values used).

In total, the report discussed the hypotheses and results of eight scenarios, and analysed more in depth the basic scenario, called Scenario X.

Scenario X starts with the observation that, should the objectives of IDS be extended up into 2000, due to higher population growth in developing countries, the income gap would remain stable (ratio of GDP per capita of developed to developing regions: 12 to 1), as shown below in table 2.

Table 2

Growth Rates Under Assumptions of IDS Minimum Targets for Developing Countries, and Extrapolation of Long-Term Growth Rates in the Developed Countries
(% rates per annum, 1970- 2000)

		Gross Domestic Product (GDP)	Population	Gross Domestic Product, per capita
Developed countries		4.5	1.0	3.5
Developing countries		6.0	2.5	3.5
Ratio of average GDP per capita of developed to developing countries	1970	-	-	12:1
	2000	-	-	12:1

Source: *UN (1976) p. 122.*

Therefore, for establishing Scenario X, changes were introduced both for developed countries (where the average GDP rate of growth 1950-70 of 4.5% was slowed down to 4% for 1970-2000, and the population growth rate was also slowed down from 1.0% to 0.7%) and in the developing countries (where the GDP growth rate was increased up to 7.2% per year).

As a result of these changes, in the central X Scenario, the income gap could be brought down to 7.7:1, a ratio that could be considered a reasonable UN policy target.

In an alternative (Scenario C) this ratio could even go down to 7.1, should growth in the developed countries decrease to a 3.6% rate.

Table 3 summarises the basic components of Scenario X :

Table 3

Growth rates and Income Gap in Scenario X		
Growth rates :	Developed countries	Developing countries
Gross Product	4.0	7.2
Population	0.7	2.5
Gross product per capita	3.3	4.7
Ratio in the year 2000 of Gross product per capita (developing countries=1)	7.7	1.0

Needless to say that in Scenario X the regional growth rates were exogenous and the model was used essentially to compute some consequences of this growth on employment, investment, food production and trade, the balances of payments, as well as upon pollution, abatement activities and extraction of minerals and energy. This was the usual way of running the model and was also the case for scenarios C, D, E, H, R and M in which alternative hypotheses mainly related to the size of resource endowments and to changes in trade, aid and capital flow coefficients.

However, Scenario A was run in an entirely different manner as in this case, the GDP growth rates were endogenously computed, and the exogenous constraints related to the need for full employment in the developed countries, and for balance of payments to be in equilibrium in the less developed countries; "the future growth of GDP would tend to be determined either by the projected rates of domestic savings supplemented by funds coming from abroad, or by foreign exchange constraints (operating through the balance of payments) which would limit the imports of raw-materials and capital goods that these countries can not yet produce themselves" (UN,1976, p. 115).

Scenario X and Scenario A provide then the main arguments for discussing the future of the world economy.

Basically, the point made by the authors of the report was that an attempt to reduce the income gap between developed and developing countries would necessarily lead to a substantial increase of the foreign debt of these countries (Scenario X) and that constraining this level of indebtedness would automatically bring down economic growth in developing countries and postpone hopes for reducing the income gap (Scenario A).

As could be expected from a very large disaggregated model, the actual run of the scenarios provides an extremely large amount of information in relevant areas of interest; thus the report (UN, 1976) discusses in detail Scenario X projections for issues such as the changing structure of world manufacturing by regions and sectors, the prospects for food supply and demand, for grain and animal products, for irrigation investments and the need of fertilisers. The market equilibria for minerals such as copper, bauxite or nickel, and hydrocarbons such as petroleum, natural gas and coal, are related to costs and levels of resource endowment, and the capital stocks required for resource extraction are computed. Solid wastes, suspended solids in water, particulates in air pollution, and several other pollutants are analysed in their long term development in terms of emissions and abatements.

All these were the subjects of great concern for the UN, for many governments, and of course, for those devoting efforts to look into the World Problematique, a definition of the complex system of problems expected to be confronted by humanity in the next decades.

But perhaps the most original feature of the Leontief world model was to be found in the area of future trade and capital movements, where essentially economic problems could reasonably take place in not too distant a future.

In Scenario X world trade led by trade in manufacturing was computed to grow at an annual rate of 5.9%, thus above the GDP world average rate of 4.8%. Always at constant prices, the share of manufacturing in world trade was expected to jump from 65.4% in 1970 to 86.4% in 2000.

The detailed results showed that two important regions LAM (Latin America Medium income, including Argentina, Brazil and Mexico) and ASL (Asia low income, including India, Pakistan and South East Asia) that were showing situations close to equilibrium in 1970, could be expected under the conditions of Scenario X, to develop large trade deficits and to have to face an important indebtedness problem. Table 4 summarises these aggregate findings.

Table 4

International Financial flows Scenario X (billions of US dollars, at current prices)				
	LAM		ASL	
	1970	2000	1970	2000
Balance of trade	-0.4	-84.7	-4.2	-81.7
Net capital inflows (1)	0.84	13.6	9.25	4.90
Net aid flows	0.88	0.80	-3.75	18.20
Foreign income or interests (1)	-1.3	-172.7	-0.8	-128.8
Balance of payments (1)	0.0	-243	0.5	-187
(1) Net capital inflows in these computations include additional capital movements which are necessary to balance the payments deficits; foreign income or interest payments are calculated on total foreign capital and debt accumulated as a result of such net capital inflows; balances of payments totals are calculated on the same basis.				
Source: UN (1976), p. 265.				

It was therefore rather clear from the exploration made with the world model, that these two key regions of the developing world would only be able to grow with insufficient level of local savings at the expense of a growing level of foreign indebtedness.

The Scenario A, requiring enforcement of a balance of payment equilibrium with normal levels of capital flows, was designed specifically to further explore this initial conclusion. In this case, the model computes endogenously the growth rate of GDP of all regions and the aggregate results are shown in table 5.

Table 5

Growth Rates and Income Gap in Scenario A (percent rates per annum, 1970-2000)		
Growth rates:	Developed Countries	Developing Countries
Gross product	3.9	5.4
Population	0.7	2.3
Gross product per capita	3.2	3.1
Ratio in the year 2000 of Gross product per capita (developing countries = 1)	11.2	1
Source: UN (1976) p.125.		

Direct comparison of tables 3 and 5 shows, as could be expected, that the growth of developed countries is very lightly affected (from 4.0% to 3.9%), but that the developing countries see their GDP growth rate move from 7.2% in scenario X down to

5.4%. As a consequence, the income gap remains practically constant at 11.2:1 versus 12:1 in 1970.

Bringing per capita income in developing countries closer to the world average would not come all by itself; generous capital transfers were required. A UN report could not spell openly out such a conclusion, but the model was there showing the way to it.

4. Looking backwards from the year 2000

Since the early seventies the world economy has slowed down and even population growth has been lower than expected. Table 6 summarises the most recent estimates for the period, in ways directly comparable to table 3 (Scenario X) and table 5 (Scenario A)

Table 6

Observed Growth Rates and Income Gaps, 1970-2000		
Growth rates:	Developed countries	Developing countries
Gross product	2.5	4.1
Population	0.5	2.2
Gross product per capita (1987 prices)	2.0	1.9
Ratio of GDP per capita in the year 2000		
In US dollars at 1987 constant exchange rates	12.3	1.0
In US dollars at current exchange rates	14.7	1.0
At PPA rates	5.4	1.0
Source: Own estimates, using data from the 1999 World Reports on Human Development, UNDP, usually referred to 1997.		

Inspection of this table shows that the growth rates of the International Development Strategy (IDS) were way out of the future course of events, both for developed and developing countries, for reasons that are tentatively explained below. But probably the most interesting observation stays with the fact that the main objective of reducing the income gap, or lowering the ratio of GDP per capita in developed to developing countries has not been met as it remains very close to the initial 12: 1 level, a result that points to the fact that the world has been moving more in a Scenario A configuration, than in a Scenario X context of fast development of international co-operation.

It should be noted that the gap could be also measured at current exchange rates, in which case the ratio for 2000 would be higher than the initial 1970 ratio, and could obviously be measured at PPP rates, in which case the welfare value of developing countries income is considerably increased. However, the PPP measure is not relevant for a comparison with the initial current US $ exchange rates measures used in the report, either for 1970 or for the target years.

It was impossible for the scenario writers in the mid-seventies, coming from a historically unique period of continuous strong growth, to imagine such a sizeable slow-down. Even if the oil shock and the dismantlement of the Bretton Woods financial stability system had already alerted about the dangers ahead, it was difficult to extract from short term turmoil credible indications about long term structural changes.

It is only later that Freeman (1984), while commenting on the MIT models (Forrester, 1971; Meadows, 1972) could provide with a convincing explanation of what was happening at the time the Leontief world model was built:

> "The characteristics of the MIT models are those of the *fourth Kondratiev* upswing- a techno-economic paradigm based on cheap oil universally available as the foundation for energy-intensive, mass and flow production of standardized homogeneous commodities such as consumer durables, and the associated capital goods, components and services.
>
> This techno-economic paradigm permitted the massive expansion of the world economy during and after World War II, following its successful development in the US automobile industry in the previous three decades and during the war itself. Although it enabled very big productivity increases in many branches of manufacturing and in agriculture, and an enormous associated proliferation of public and private service employment, it ultimately began to encounter *limits* to further growth in the late 1960s and 1970s. This was not *just*, or even *mainly*, a question of the oil price increases, but of a combination of factors including the exhaustion of economies of scale, diminishing returns to further technical advance along existing trajectories (Wolf's Law), market saturation factors, pressures on input prices, declining capital productivity and the erosion of profit margins

> arising from all these factors, as well as the culmination of the competitive pressures from the Schumpeterian *swarming* process" (Freeman, 1984, p. 499).

These comments on the MIT models also apply to the Mesarovic- Pestel (1974) model, as well as to the Leontief world model.

Furthermore, no past trends could explain the radical transformation that were to take place at the end of the eighties, allowing for a general move towards free trade and market economies, or towards greater regional integration processes, even if the analysis of such type of events could and had been already attempted on the basis of subjective a priori probabilities (Fontela, Gabus, 1974).

The present is not what the future used to be, and it is useful to build long term models even if only to help us understand a posteriori the reasons for change.

Probably all world models built in the early seventies shared the same difficulty to explore the future: the lack of processes of change introducing prices and technologies into the picture.

Prices do reflects scarcities, and their evolution induces technological change; similarly, technology changes costs and prices. Such is the dynamics that regulates the problems of "limits".

Of all the models built at that time, the Leontief model was the only one that, in principle, could allow for the introduction of this price-technology dynamics, using price sensitive equations for demand and for technical coefficients. Surely, in the version of the model that was left to us by Carter- Leontief- Petri, these elasticities were not even specified, relying to this matter on some exogenous treatment with very simple and conventional assumptions. But the accounting system was open to these developments of the model that circumstances never allowed to develop at later stages of the modelling exercise.

5. Final remarks

Exploring the future is the objective of “prospective” or futures research. It is never to be identified with forecasting. While forecasting is founded on determinism , futures research has a view of the world based on freedom of choice .

Leontief world model has been one of the most ambitious methodologies ever attempted to explore the long -term future of an infinitely complex system subject to continuous deep structural changes.

The experience was successful, among other things, in pinpointing to the balance of payments constraints in developing countries, and identifying signals of what was later to become the debt crisis. It helped to co-ordinate policies of the many agencies of the UNO, and most probably played an educational role for those involved in decision making affecting the future of the world, both inside and outside the UNO.

Needless to say that Leontief was courageous enough to extend the cooking-recipe beyond its traditional boundaries, thus meeting enormous methodological and data problems, and risking severe criticism from the conventional academic community. But the final output was outstanding thanks to Peter Petri and Anne Carter that with rudimentary data and little computer capacity devoted extraordinary effort to an extraordinary endeavour.

Should research along these lines be continued?. Of course the answer should be, yes. The data has continuously improved and a single statistical observation system for all countries of the world, the 1993 SNA, promises that some of the more severe hypothesis used for data preparation in the world model, soon could be withdrawn. Furthermore, the development of SAMs offers a possibility for more complete descriptions of the regional subsystems, and opens the way to the introduction of behavioural equations along the lines developed since the publication of the world model, by econometric desaggregated models or by general equilibrium models (Fontela, 2000).

It should start to be possible today to build a more technology and price sensitive world model along the original accounting principles of Leontief’s pioneering proposal.

When the market economy extends the world over, and when the new technologies of the Information Society outline a possible long boom for the world economy, it looks as if futures research in this area is again urgent and necessary. This is a key challenge for the input-output research community.

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