CBPF-CS-009/02

TOPICS ON SCIENCE AND TECHNOLOGY

J.I. Vargas

Science and Technology in a Developing Country:

The Brazilian Case

J. I. Vargas

Modern science in Brazil started mainly under the influence of the Brazilian Academy of Science (from 1916 on) [1] and afterwards, particularly in the fourth and fifth decades of last century, under the spell of a group of brilliant young researchers trained at the University of São Paulo. This institution counted with a good number of high-level European scholars as teachers. Nuclear experimental and theoretical physics in particular were, then, at the forefront of world's science, and locally they were aptly explored under the leadership of G. Wataghin and G. Occhialine, both ex-members of Fermi's group, in Italy.

The early contribution of the new Brazilian school to cosmic rays physics and of new associate nuclear physics instrumentation[2] (Ref.6) with the concomitant discovery of penetrating showers (Ref. 7 and 8) and to astrophysics (Ref. 9 and 10) soon met with international prestige, later consolidated through investigations made in Europe (Cambridge, Bristol, Liverpool, Paris and Rome) and in the United States (Chicago, Princeton and Berkeley). The striking discovery of the Π meson by Powell and Lattes (Bristol) (Refs. 11 and 12), and by Burferming, Lattes and Gardner (Berkley) (Ref.13), did exert everywhere great influence, not only because it was taken as a confirmation of early theoretical work by

[1] 1 For ample information on Brazilian science see ref. 1 which includes earlier contributions on all fields and references 2,3, 4 and 5.

[2] The described coincidence circuits were ten times faster than any other then existent and allowed for the penetrating shower and other fundamental works on muons that were carried out.

Yukava - which has motivated long, fruitful and still ongoing co-operation between Japanese and Brazilian scientists in the field of high energy particle physics. It also seemed likely to offer, a so far, unimagined approach to nuclear energy production, *via* meson-catalysed fusion of hydrogen- deuterium nuclei, which (Refs.14, 15 and 16) received extremely wide press coverage, but revealed itself to be unfeasible, as shown sometime later by Zeldovich *et al*. and Alvarez. It was thus shown not capable to compete (Refs. 15 and 16)[3] with the newly established uranium fission, that had just achieved the fantastic feat of, so to speak, literally "unplugging" humanity from our sun, the single energy source available to men since immemorial times.

For people of my own and of the preceding generation, the future was considered to be extremely promising. Cheap and abundant nuclear energy would - forever - free mankind from the burden of necessity.

These conquests have thus everywhere induced dedicated men of science, such as Bahba and Menon, in India; Abdus Salam, in Pakistan; Alcina and Sabato, in Argentina; Lattes, Souza Santos, Schemberg, Leite Lopes and Tiomno[4], as well as representatives of the older generation, like Costa Ribeiro, Magalhães Gomes, Bernhard Gros, and Álvaro Alberto[5] in Brazil - both well known to this house - to direct their efforts, at home and at the international arena, to set up institutions dedicated to the fostering of scientific research. In Brazil a National Council for Research, as well as an agency (CAPES) - dedicated to recycling and post-graduate training of university personnel, both in Brazil and abroad - were

---

[3] Because of a too small "sticking probability» of muons to ^{3}He, produced in the muon fusion reaction p+d= ^{3}He+5.5Mev.

[4] Lattes, Leite Lopes and Tiomno are founders in Rio de Janeiro (1951) of the Centro Brasileiro de Pesquisas Físicas (Brazilian Center for Physics Research).

[5] The first is the discoverer of the thermo dielectric effect (electrets); the second, as the founder of the second Brazilian Centre dedicated to the research of nuclear science and technology (IPR), now CDTN – Centro Brasileiro de Desenvolvimento de Tecnologia Nuclear, the third created an important Physics research group on the theoretical aspects of cosmic radiation, on detectors of nuclear radiation, on rheology and dielectrics materials, the last was the founder and first chairman of the National Research Council.

established in 1951, immediately after the founding of the Brazilian Centre for Physics Research (CBPF), in Rio, by these pioneers. Their statutes were inspired by those followed by the very prestigious British research establishment. In fact, many of the new Brazilian research leaders were trained in England - perhaps in recollection of the still prevailing reputation justly enjoyed by Lord Rutherford's Cambridge School.

Another important initiative was taken with the creation of a science and technology Financing Agency (FINEP) with a view to distribute grants for the implantation of major university equipment as well as of soft (low interest) loans for science and technology development in industries. It also launched the development of Brazilian consulting firms with a view to foster the autonomous development of innovative projects. It has had important impact in many fields, notably in the area of new materials, nuclear science and the aeronautics. The last sector resulted from a close association with the Massachusetts Institute of Technology scholars and that, later on, was engaged in space research, mostly with French institutions, with NASA in the USA, and more recently with China. The local production of middle jet planes by EMBRAER - an off shot of the very modern Aeronautics Technological Institute (ITA), also created in the fifties - led it to become the third supplier of middle range jet and conventional training planes in the world. Its success can be judged by its current backlog of aircraft orders, which totalled US$ 23.5 billion in June 2001 (US$ 10.7 billion in firm orders and US$ 12.8 in options). The Brazilian policy, which more modestly is parallel to those of India and China, resulted in the production and orbit placing of two homemade data collecting satellites and another remote sensing and also data collecting satellite in association with China (CBERS - China-Brazil earth research satellite). Brazil is also the only developing country participating albeit in a small scale in the construction and future exploitation of the International Space Station.

In spite of these laudable efforts, along more than 50 years, science (and technology) has still to face and overcome the vagaries of Brazilian history, that have shaped its socio-economic relative retardation. Some years ago, an Admiral, ex-chairman of the Brazilian National Atomic Commission used to state (and not in jest…), that Brazil was the only country in the world that had Brazilian problems. To my mind he was, of course, equally right and wrong. He was right because a good share of the startling Brazilian problems results from the heritage, up to a point unique, of the past colonial system established by Portugal, as well known in our historiography. The Portuguese colonial system, although set up by an European nation, had been bypassed by the Industrial Revolution and by its "Illuminist" source, the originator of modern western science. [6]

In contrast with the Spanish colonies where, in spite of a domineering obscurantism by the same causes, early illustration started already in the XVI century at universities and publishing houses; in Brazil the printing press was only introduced in 1808, and a conglomerate of a few professional schools - albeit of high quality - came to light under the guise of an university only in 1922, after more than four centuries of intellectually dreary circumstances. However, in truth, during the colonial period, a considerable number of outstanding young Brazilian intellectuals were trained in Coimbra University and in some other European learned institutions. They were sent to work mostly to Freiburg, Edinburgh, Paris and Montpellier. The most distinguished of them all, José Bonifácio de Andrada e Silva, worked with Fourcroy in Paris and Werner in Freiburg (Germany). A member of several most distinguished European Academies, he was a precursor in the discovery of Lithium, served as professor in Upsala, and for many years was the perpetual Secretary of the Portuguese Academy of Sciences. Finally, upon his return to Brazil, he became the Patriarch and key

[6] See however William Joel Simon, "Scientific Expeditions of the Portuguese Overseas Territories (1783-1808), Instituto de Investigação Científica Tropical, Lisboa, 1983.

personality of Brazilian political independence. The dismal evolving situation, that has however anticipated these felicitous developments, resulted, to a large extent, also from the socio-economic activities that along large periods pulsated, upwards and downwards, along at least three economic cycles to obviously attend the necessities of the colonial powers: - at first, in the early colonial days, the predatory extraction of red wood pigments was followed, subsequently, by extensive well known sugar cane plantation-style sugar production, and later on, by gold mining and coffee growing. Almost exclusively slave work and the concomitant lucrative human trade, lasting practically up to the last decade of the XIX century, sustained all these phases. The “modern” African slave exploration, admittedly, was a common feature of the colonial system used by many Western countries, such as Holland, France, England and Belgium, for example.

Our Admiral was nevertheless wrong because, apart from the aforementioned unique cultural traits, just pointed out most Brazilian problems may be found to be similar to those facing some of the largest existing developing countries, such as, among other limitations: lack of local savings and generally rather limited risk capital investments; uneven geographic distribution of economic development as with the consequent inequities in the regional and personal incomes distributions; the frequently wide ranging climatic variations, extending over large semi-arid, tropical and temperate areas (Figure 1) and therefore often demanding widely different technologies. All these factors, one way or another, compose the extreme diversity of features displayed in the pertinent socio-economic indicators, as shown in the 1998 data reported for Brazil, as a whole, to some of its states, and for China, India, Mexico, etc. displayed in Figure 2. (Ref. 17).

After this long digression on national misfortunes, perceived as usual only much later as past history, one should not however loose sight of the considerable economic growth undergone by Brazil, notably during and subsequent to the last two World Wars and along the cold war. In fact, during these and along the intervening periods extending up to the eighties, an induced or deliberately established internal market protection policy, alongside with the intense political competition that prevailed during the Cold War period, the national economic expansion was considerably stimulated, which benefited also other regions. According to the OCDE, during half a century, lying between 1937 and 1987, Brazil's GNP underwent a 13.6 fold growth (Ref.17). This should be compared to a growth factor of 19 for Japan and 8 for Germany, along the same period. A conventional explanation of this process, generated mainly at CEPAL (United Nations Latin American Economic Commission) and widely accepted in many quarters, considers this policy as to observe a so called "import substitution model", which however in our view would rather be better defined as consisting of a massive "technology importation model", and whose virtues, were undeniable under the prevailing circumstances.

The last conceptualization entails a better understanding of the paradoxical role played by human capital in Brazilian development. Education is justly recognised as a key factor for the understanding of the process, and it may be considered as one of the main facets responsible both for the relative success, and the limitations of the "model" that, ultimately, came to affect negatively the very adopted policies. In fact, the policy has, for some time, enjoyed a major success in so far as it permitted the system to train a labour force almost exclusively only prepared for the absorption and utilisation of imported technology. This aspect may be taken as one of the pillars of the protected market model. However, as anticipated, ultimately, it has at least in part failed, because the traditional educational level revealed itself incapable of responding to the needs that would be later demanded by the more advanced educational standards, deemed to be indispensable for the insertion of Brazil in the new knowledge geared and extremely competitive international economic environment. Consequently, as elsewhere in the developing world, the local industry participation in science and technology and on their applications, within a market newly oriented to the appropriation and creation of highly innovative processes, was extremely limited. Industry's complacency fed by this policy has therefore alienated universities and the scientific community from the pivotal role they had to play in the generation of new high technology based services and products. It should be noted that the science actors, in turn, were unfortunately not as vocal as they should have been on the importance of their alliance with industry. Therefore, by the eighties, Brazil found itself as a minor participant of the new emerging global economy. This unsatisfactory situation was therefore composed, for example, by the losses incurred in the use of a profoundly inadequate patent legislation, and is further illustrated by a misguided concentration of efforts almost exclusively on the development of a purely autonomous production of hardware. This approach was further aggravated by the decision to extend only negligible attention to the development of the more easily manageable, dynamic and cheaper software sector of I.C.T. These are instances that illustrate some of the misbegotten policies that at least in part led to the final collapse of the "import substitution model", which were of course “added” by some inevitable impacts of the "open market" global policies adopted more successfully in regions such as South East Asia. These lessons are now well taken by the Brazilian Government. It has started, in the beginning of the nineties to pay increasing attention to those science and technology policies conducive to the creation of more competitive enterprises. They have already led to a 36.6% participation of the productive sector in science and technology and research and development expenditures. To that effect, all along the decade and particularly in the last three years, a number of incentive laws have been enacted to promote the integration of science with the entrepreneurial sector. They consist basically in directing part of the incomes resulting from the concessions during the privatisation programme to R&D. To this objective, a list of these legal instruments may be found in Annex I to this paper. It is to be expected that this legislation shall soon induce S&T and R&D investments to reach a total of at least the magic 2% participation in the GNP.

In spite of the previously considered shortcomings, Brazil now still ranks among the world's top ten countries in economic size, as shown in Table 1 (Ref. 5). To have reached and observe upgrading to this rank, heavy investments in capital intensive infra-structural facilities and in human resources had to be made and must be further accelerated. The results of this new policy may also be made apparent by a number of interesting indicators. Among them, stands out the obvious correlation existing between the attained GNP and energy consumption, as shown in Figure 3. After all, energy is just the capacity to do work, and consequently investment in energy, thanks to its strong participation in - among other fields - the important industrial transformation sector, it is still deemed to be indispensable for development and must continue to be so for a long time to come. Figure 4 displays the evolution of the installed hydroelectric potential that has been steadily pursued from 1910 to 1998(Ref. 19). The rates of GNP growth and of energy consumption have thus been practically the same: they have reached 4.6% per annum, and 4.4% per annum, respectively. The ordinates displayed in figure 4, as well as in others to be shown later in this talk (Ln F/1-F), represent elements of a solution (logistic) of Volterra-Lotka equation, summarised in Annex II and in ref. 20 and 21. It has frequently been utilised by Cesare Marchetti, at the International Institute for Applied System Analysis, to describe a large number of evolutionary phenomena (Ref. 22). The good fitting of the observed data by the logistic equation is so impressive that it is claimed to allow for rather reliable predictions to be made on the future evolution of many systems under scrutiny (Ref.21). Figure 5 displays on this representation the generation of Electricity from 1940 to 1998.

Deviations from the secular logistic equation, displayed in its linear (Fisher- Price) format, are found to present oscillatory behaviour, describing cycles of economic growth, depression and/or stability (Ref. 23). This pattern is displayed in Figure 6, relative to the deviation of the installed hydroelectricity capacity, highlights the evidence of an ongoing Brazilian energy supply crisis. This situation originates from unforeseen recent climatic anomalies – the most severe draught in 70 years – that have forced the system to work at exceedingly high “charge factors”. It has also been provoked by the exaggerated present share of 92% of hydro-electricity in the Brazilian electricity generation (Ref. 24). This graph also indicates that Brazil probably should not be able to revert to a "normal" situation – an economic growth of about 4% a year - described by the secular strait line and presented in Fig. 6, before the years 2004-2005. This crises scenario is already exerting a negative impact on the national economy. In fact, such gloomy predictions have already been conjectured through the previously described modelling carried out back in 1992. Energy is of course essential for the quality of life and hence to life expectancy itself, as shown in Figure 7. This graph relates the per capita electricity used per annum in 127 countries, assembled in groups of 10, with life expectancy, as presented by the World Energy Conference in 1992.

While energy is thus undoubtedly a good general indicator of all socio-economic activities, it can only be produced, managed and widely applied by educated human beings. As you may remark from the previous illustrations, energy production and use constitute a surprisingly steady and long-range phenomena, which consumes large amounts of both time and money. So does education, as can be judged by Figure 8, where it is shown that it took over 120 years for Belgium, England and Italy, and 95 years for Japan to reduce their population's illiteracy from 90% to 10% (Ref.25). Interestingly enough Brazil has taken about the same span of time to reduce illiteracy, in its above 15-years-old age group, as shown in Figure 9. A similar behaviour has been observed for most Latin American countries (Ref.25). In Brazil fortunately, thanks to large recent governmental efforts, 97% of the children aged between 7 and 14 years are now attending school and, likewise, vocational training has, for decades, been meeting with considerable success, as shown in Figure 10 (Ref.26). SENAI and SENAC have between 1942 and 2000, trained 61 million secondary level technicians. The present enrolment (2000) reaches 4.7 million of students for both institutions. On the other hand, the total of enrolments in the formal secondary technical education for 2000 reached 2,859,135 students, which is a number similar to the 2,694,245 university enrolment.

Development however, demands not only continuous efforts to promote general education but it critically also calls for intensive training in science and, of course, in applied science – for "there is no applied science without science", a phase framed and repeatedly invoked by the late Abus Salam. Science and technology consequently imply considerable and steady investments. Awareness of the inevitable problems posed by the new globalised and politically altered environment, has led Brazil's public and private sectors to devote, as already mentioned, an increasing share of their resources to this end, as illustrated in Figure 11 (Refs.3,4 and 5). Figure 12 and Table 2 show that, in spite of successive severe economic crises that have affected the country, the concession of scholarships to train scientific personnel has not been reduced. Thus the number of university students has been multiplied, from 1937 to 1998, by a factor of 85, to reach, at present, more than two million students; the number of doctorate diplomas conferred at home and abroad has increased from 1994 to 2000 by a factor of more than three. This expansion has led to an increased participation of

Brazilian scientific papers indexed in the international literature. Figure 13, as indicated by the Institute for Scientific Information, displays the percent participation of a selected number of countries in the world’s scientific production. As can be seen, the developing countries participation is still rather meagre. Brazil participates, in 1996, with about 1% of the publications, following India and the Republic of China. However, as far as the quality of the papers is concerned, as measured by the citation impact - the average number of citations induced by the published papers - Brazilian performance, as shown in Figures 14 and 15, ranks better than those of China, India and South Korea (Refs. 5 and 27). In fact Brazil's rank has advanced from the 28th place in 1981 to the 17th last year. An equally relevant data on the country's development is the number of PhDs and engineers actually working in science. For Brazil, it amounts to 3% of slightly more than 90,000 participants assembled in a survey carried out by the National Science Foundation, the OECD and the Brazilian Ministry of Science and Technology. Brazil ranks reasonably well as compared to other developing and even some major industrialised countries. Its position compares well with that of Spain (2.8%); of South Korea (2.4%); of Canada (2.4%) and of Italy (1.8%). It is inferior to that of China (5.9%); of India (4.4%) and of Japan (6.8%) (Ref. 5). It is no surprise that the United States ranks first with 30% of this kind of the world's qualified personnel. In Brazil, whenever all research fields are considered, it is found that 70% of the practising scientists are involved with the natural sciences (Ref. 5). These figures should not obscure the fact that Brazil’s position is much more precarious when counting is done on a per capita basis.

The transformation of scientific knowledge into services and products, *via* technology, constitutes a long and complex chain of events. Development implies, starting at basic research, a complex sequence of actions involving pre-competitive R&D, applications experiments and trials up to the product, followed by the development engineering phase and the corresponding market trials and product improvement, as summarised in Figure 16 (Ref. 28). It displays the increasing cost of the sequence basic science, experimental development, model testing until finally the market introduction of the new product. It shows that the cost of the last phase is easily ten times bigger than the investment spent in basic scientific research.

The modern economy is frequently characterised almost only by the indication of the explosive growth of the number of registered patents, as shown in Figure 17 (calculated with data supplied by the WIPO, ref. 29). From about half a million demands registered in 1995, the corresponding number reported for 1999 attained the staggering level of 7 million of registered demands. The number of patents applications in Brazil in 1999 reaches nearly 16,000 (Ref. 5).

The corresponding figures for a selected number of countries describing patent registered in the all important American market, from 1977-79 to the year 2000, varies from 66 to 113 for Brazil; from 67 to 63 for Argentina; from 113 to 100 for Mexico and from 25 to 3,472 for South Korea. These figures are sufficiently eloquent for me to refrain from further comments (Ref. 5).

It is however worthwhile to recall that in many cases the patent laws, resulting from the Uruguay Rounds (TRIPS) agreements, are relatively new and the preceding legislation, as happened for Brazil, often did not involve more dynamic fields such as modern food technology, pharmaceuticals, microelectronic and computer sciences.

Despite the fact that the role of patents as indicators of technological intensity is undeniable, one should not forget a whole range of other broader, perhaps more meaningful indicators – such as the ones adopted by OECD countries, which comprise up to 82 evaluation categories. Perhaps for the evolution of technological density more meaningful is the technological balance – an indicator describing how much is spent and how much is gained by a given country in its technology international transactions. A careful study conducted for Brazil's case, is shown in Figure 18. In 1999, it has attained 4.3 billion US dollars, exports reaching almost 50% of the imports value. This result is better than the performance of Spain (46%) and slightly worse than that observed for Italy (51%) (Refs. 5 and 30).

So far the beacon of the new age is considered to be information and communication technologies. The Brazilian situation in these fields is rapidly evolving. For Internet use, it represents more than the double (in fact, 61%) of Latin American clients.

Figure 19 shows de recent evolution of telecom. It can be noted that the number of fixed telephones was increased by 25% in 1999, while the number of mobile phones has grown, in the same period, by 83%. 3.4 billion US dollars have been invested in the national optical fibre network.

The personal computers' market is also fast growing. It is foreseen that, for the same period, it will rise from the present 10.5 million to 25 million units (Figure 20, ref.28). This expressive growth in PC utilisation may be anticipated to be observed for China, India, South East Asia and Latin America in the near future, which however are all still relatively much smaller than the presently saturated American and European markets. It remains to be seen whether the emerging market shall be sufficient to counter the ongoing “new economy” I.C.T. crises. Cheap computers, that have been reportedly developed both in Brazil and in India, shall probably respond positively to governmental intentions to connect most of the households of those countries. If this comes through and considering growing demands from China and Russia, it may contribute to reduce the present prevalent I.C.T. crises.

Brazil’s Internet coverage is also still modest and there remains a relatively large potential for further growth. However, the last few years’ extremely fast evolution of mobile telephone terminals and Internet hosts are displayed in Figures 21 and 22. Despite the previously referred to ongoing world-wide collapse in the expansion of the I.C.T technologies, the number of installed mobile telephones shall attain in Brazil over 40 million units in the next 5 years.

With the anticipated saturation of the information and communication technology market, it might be surmised that the next wave of applied science market penetration will continue to emerge from the extraordinary - both recent and also not altogether new - discoveries in the life science field, in particular from molecular biology. Additional progress may be achieved in the applications that might result from the development of more ductile and higher transition temperature super-conductors.[7] Quantum computers might constitute good candidates to join these new and exciting future achievements. The utilisation of nuclear research reactors for assaying and evaluating environmental problems (health, agriculture and pollution) supportive of sustainable development policies, exemplified by the outstanding work conducted by the International Centre for Environmental and Nuclear Sciences, in Kingston, Jamaica, emphasized the important contribution and the novelty of a multidisciplinary approach to solve complex phenomena with rather traditional techniques. They may also still generate meaningful results in basic science. Time limitation does not allow me to dwell in more speculations, which are, after all, "the bread and butter of scientists”.

Let me finish with two remarks. The first one is that nuclear energy is bound, everywhere in the near future, to undergo considerable expansion. If it succeeds in so doing, it

---

[7] While finishing up this paper, J.H.Schön, C.H.Cloc and B.Batlogg reported the existence of a new organic material super conductor reaching a transition temperature of 117°K, Science, 30th August 2001.

shall fulfil, at least in part, the youthful dreams of my generation. But it has first to show itself capable of finding acceptable solutions to the radioactive waste disposal problem. Thanks to its characteristics, it will certainly contribute to reduce the impact of the greenhouse effect. (Incidentally, let me recall that the Brazilian contribution to the global emission of greenhouse gases is rather limited (Table 3, ref. 17), renewable energy responding to 68% of its energy matrix.) Nuclear energy has to be cheaper than other existing alternatives. Projections on the future cost of energy seem to confirm its lower cost for widespread utilisation (Table 4). An optimistic vision of such future expansion has already sometime ago been expressed by Marchetti and is summarised in Figure 23, taken from ref. 31. As far as Brazil is concerned, the complete command of the nuclear fuel fabrication using its locally produced enriched uranium will certainly induce it to join, in the future, the new nuclear band-wagon of the peaceful users of nuclear energy. Under these circumstances, it shall expand its presently modest installed potential (2 million kW), profiting from its rank as the fifth depository of the world's uranium reserves. This policy would also open the opportunity to employ a considerable number of highly trained specialists who have, in fact - due to the observed general ongoing almost worldwide mitigation of nuclear energy utilisation - played important roles in improving the quality and the design and construction of a wide-range of industrial equipment. The Brazilian sugar cane based alcohol fuel program - the largest renewable energy project in the world - constitutes a good example of this past contribution.

The expected renewal of nuclear energy utilisation shall naturally take place under the aegis of this Agency, that Brazil has helped to create. It is our hope that not only non-proliferation of mass destruction weapons, but also effective general abolition of all nuclear weapons shall finally take place. It will eventually allow this Agency - on behalf of the international community - to fulfil its lofty and unique objective of promoting peace and also contribute to curtail terrorism originating mostly from the lesser developing countries. Brazil and Argentina pride themselves of having created a mechanism of mutual inspection of their nuclear activities, under the supervision of IAEA, which impedes a nuclear arms- race in our southern continent. The roles of both national scientific communities nurtured by this Agency is well recognised. May this example stimulate others to adopt similar initiatives. This attitude is coherent with the Brazilian stand, having lived peacefully for the last hundred and fifty years with all its neighbours. In fact our Constitution limits nuclear applications exclusively to peaceful use (Ref. Article 21, paragraph 23, indented line a).

It gives me great pleasure and honour to recall that the chairmanship of the very first, still interim Board of Governors of this novel international organisation, whose fortieth anniversary is now being commemorated, was exerted by a Brazilian, the late ambassador Carlos Alfredo Bernardes, to whose memory I wish to pay a most respectful tribute.

The second remark is that our dreams of using science and technology to promote human peace and progress, to alleviate misery and its trail of disease and famine, are on the march. This can be judged by the data contained in Figure 26. It summarises the continuous growth of the so called human "development index" for some representative countries, both rich and poor (Ref. 32).

Admittedly, much remains to be done to alleviate the pangs of sorrows that still affect many human beings, thriving that they remain with incomes that are scandalously laying bellow the poverty line (Figure 27, ref. 32).

I am however proud of the Brazilian progress in agricultural technology, in genomics, in molecular biology (Figure 24, ref. 19) and in reducing AIDS provoked mortality, which would have attained more than 15 thousand deaths per annum, in the absence of the use of good science, originated everywhere and of a high quality national management. Figure 28 indicates that this scourge will shortly revert to its 1983 value, when the disease started (Ref. 33).

Finally, as you all know, scientists constitute a lucky lot, for they are all engaged in and benefiting from the happiness of pursuit; let us now all – poor and rich - strive for the establishment of a new social contract that shall make science contribute to the pursuit of happiness for all humanity, and never forget the most pertinent reflection made by one of the founding fathers of modern humanism, François Rabelais: "La Science sans conscience c'est la ruine de l'âme".

A JOHANNESBURG AGENDA: CHANGE THE LIFE STYLE OF THE RICH; ABOLISH THE TRADE BARRIERS TO PROMOTE SCIENCE AND EDUCATION FOR ALL.

J.I.Vargas*

Sustainability, as well known, depends on the relationship developed along ages between man and his environment. This interaction has been intensified after the Industrial Revolution, where the scale and the localization of energy utilization has been extremely diversified and intensified. The steam engine initially driven by wood and charcoal, and later, by mineral coal (mainly cock) have started an almost irreversible degradation of the environment, both in the industrialized countries and, later on, in the so called developing regions, where large amounts of raw materials have been collected to feed this behaviour that eventually has been extended to the rest of the world.

Pollution and depletion of natural resources have thus been the result of technological change driven mostly by increased energy utilization, that had grown since 1860 worldwide at a yearly rate of 2,3% (3% for the United States and, for instance, 4% for Brazil since 1914). The parallel increased development of science, affecting food production (largely by the use of fertilizers and other chemical inputs) and of health care, thanks to medical progress epitomized by the "pasteurian" revolution, have induced explosive population growth, creating additional burden on the environment. So, science and its derived technology are the culprits. However, as widely realised, no solution to sustainability shall be reached without the increasing utilisation and progress of science itself. But science can only be developed through a determined effort towards universal education.

Education, as all social changes, is a long process, covering several decades to be effective. Indeed, the reduction of illiteracy from 90% to 10% took more than 100 years in the industrialized countries. Although the growth rate in primary education for the developing countries has observed a higher pace, it still remains largely insufficient to respond to the demands of the poorer sections of mankind. Education is in fact indispensable not only to begin understanding the most elementary workings of nature and, hence, to start appreciating the delicate balance between living matter itself and the life supporting systems – fresh water, land and the oceans with their complex interaction with the atmosphere - but also contributes to perceive some of the more salient social factors that define the very texture of communal life itself.

The last 50 years have incorporated not only socio-economic development, but has also involved increased use of fossil fuels, the largest share in the primary energy consumption. It has also testified a tremendous development of new science. Quantum mechanics, the origin, among others achievements, of modern communication technologies, and of the unification of Biology, thanks to the deciphering of the genetic code may be singled out. It is perhaps the most significant scientific advance in our times. These advances demand novel approaches to literacy work. One should conclude that, if one is to achieve a truly worldwide sustainable development, it is insufficient to merely have acquired literacy, a quality education being thus

---

* Member of the Board of the Institute of Advanced Studies, United Nations University, Tokyo. Director of the Third World Academy of Sciences. Professor Emeritus of Physical Chemistry, Federal University of Minas

deemed indispensable at all levels, certainly involving the implantation of a lifelong education scheme.

Admittedly such a proposition which, among others, was expressed in the Rio 92 Agenda 21, calls for enormous economic efforts. This indeed is the position adopted by the Brazilian Government: Not to relinquish the agreements reached at in that occasion, although, unfortunately, they have largely been ignored by the richer countries. Admittedly, they are at the same time the beneficiaries and the victims of the largely detrimental circumstances of their own doing.

Regarding education, the international community has recently drawn, in Dakar, plans and established engagements aiming to abolish children's illiteracy by the year 2015. However, it is expedient to recall that in the eighties, the engagement was adopted that illiteracy was to be abolished by the year 2000. Alas, the relevant numbers have not substantially been changed: 1 billion illiterates in 1980, and almost 900 million remain at present out of school.

Obviously, both public international and national institutions have been unable to tackle this basic, all important pre-condition for development in general, and most particularly, to reach the eagerly desired sustainable development. Despite some progress – scientific and economic – observed in the last 20 years or so, this process has been accompanied by a globalisation, basically induced by the pressures resulting from the extraordinary concomitant expansion of foreign trade. This new dimension of the world problematic, with its crying inequities and unbalances has to be taken into account if the sustainability process is to succeed at all.

Gerais, Brazil.

The lack of sustainability may thus be undoubtedly considered to result from the absence of a determined political will from the powers that be, the industrialised countries. They have been in fact paralysed by the incapacity of changing their consumption habits, which have lead to the observed pressures on the environment, particularly on the earth's climate, on bio-diversity patterns and more generally on the reduction of other material resources.

Thus an objective examination of the world's trade patterns leads one to realise that such problems may only be faced whenever the present barriers to international trade are abolished. These barriers have been serving only the interests of industrialised countries, to the detriment of their own population. To single out the case of the consequent barriers to the commerce of agricultural products established by the European Union, their consumers have to pay for some goods a price lying 20 to 30 % higher, on average, than those that would be produced in some Third Word countries. They represent, more than 40 billion euros yearly expenses. Higher figures prevail in other regions. The numbers are made much more dramatically aggressive if the barriers to industrialised and semi-industrialised goods from the Third Word are taken into account. This sum is almost seven times larger than the total aid to development announced to be delivered to these countries. This aid represents today a mere 0,22% of the industrialised countries' GNP, and shall, by the way, be largely directed mostly to serve the donors' own interests.

The pangs and sorrows of disease, poverty and the wanton lack of education, predominant in the present situation, are, as pointed out above, the heritage of the disgraceful development style that has now lasted for almost 100 years. In addition to education, sanitation, health care, and the rational use of materials and of energy, constitute fields demanding immediate action, for they cover most of the international engagements inscribed in the Climate and Bio-diversity Protection Conventions signed at Rio.

As regards the last item, havoc will be raised in the whole Earth's climate if the present consumption rate of fossil fuel, reserves that may only last only for about 60 years, is maintained [*]. However, technical solutions do exist to substantially reduce the negative impact of this misbehaviour on the environment. A larger utilization of non-renewable sources – despite the more expensive prices currently observed for them – may be compensated by a taxation and by the implementation of the Clean Development Mechanism, as approved in Kyoto. This last mechanism appears to be specially appropriate to induce the utilisation of bio fuels, notably deleting sugar-cane alcohol, to feed the automobiles' fleets. Their emissions do originate most of the observed air pollution in the urban areas. The production of bio fuels may thrive in tropical climates, which include the majority of the developing countries. Furthermore, their use would not only benefit the environment, but also improve the much needed income level for this part of the world. It would be in the interest of the large oil producing multinationals, as well as of the oil producing countries, that, endowed with considerable financial reserves, could invest in the promotion of this option. They would, thus, safeguard their own economic future, put at risk by the unavoidable depletion of their own limited natural resources.

Unfortunately, these options are not presently being seriously pursued : a) alternative technologies aiming at the production of alcohol fuel from cellulosic materials have been

---

[*] The United States which contents 5% of the world population consumes 35% of the world energy.

largely abandoned. Indeed the micro biological hydrolyses of cellulose would be specially interesting to respond positively to these purposes.

b) Other approaches, somewhat more traditional but still undergoing only limited use, are the wind and the sun energies (both photovoltaic and heat generating modes), which together with novel non polluting nuclear and fuel cells sources, would certainly contribute to the advances of sustainability. Energy availability does in fact imply greater capacity of doing useful work and hence constitutes an essential factor for development.

One should recall the Brazilian fuel alcohol programme, which feeds about 4 million cars with pure ethanol and an additional 15 million ones with a 20% alcohol/gasoline blend (250.000 barrels of oil equivalent/day). This programme could be considerably extended to others countries like India and Australia and to parts of Africa, and possibly even also to some oil producing ones like Mexico and Indonesia. These countries, by the way, count among the 60 sugar-cane world producers, thus being potential adepts of the use of this technically simple approach.

Let us now resort to another poor men's technology - the charcoal based metallurgy. Fast growing charcoal producing trees, which have been employed in the past only in small scale pig iron and steel production, merits new attention. It should be recalled that, in the Northern countries, they have indeed been employed for the production of high grade special steels.

The pre-reduction of iron minerals with carbon monoxide resulting from charcoal fuelled blast furnaces, merits also consideration, as regards the efficiency of bio mass metallurgical utilisation. Support from the World Bank Coal Fund for such initiatives have recently been forthcoming. This support is a result of the introduction of special high yelled tree's breeds .

Water utilisation, of course, does bear on most sanitation and health problems that currently affect the poor. Insect transmitted as well as other diseases thrive on water ponds like malaria, schistosomiasis, etc.

The high HIV/AIDS that so dramatically is affecting sub-saharian Africa finally composes the string of problems for which a clear sighted political will to foster widely science application, and, hence, the establishment of institutional framework directed to the promotion of wider quality education spreading – in short, development constitutes the essential component of mankind's agenda.

Johannesburg may thus well be considered a new starting point for the reawakening of the so far unfulfilled hopes raised in Rio. It is felt that only the wise utilisation of resources made by the dismantling of the existing barriers to foreign trade, together with a concomitant change in the life style of the rich, are a successful road to sustainability. Voluntary aid from the rich, while duly welcome and appreciate, can not face the pressing problems affecting the whole of humanity.

Without any further comment, see annex 1.

Science and Development in half a century

J.I.Vargas

Speech presented on the ceremony of the Third World Academy of Sciences Abdus Salam Medal
New Delhi 22 October 2002

I am deeply honoured today to be among so many scientists and friends. I am equally honoured to have been chosen to join the company of M.G.K. Menon, Thomas Odhiambo and Federico Mayor, who besides their own important individual roles and specific work have, in their different ways, contributed so much to the development of international scientific cooperation. I would like to recall that Odjambo and Menon were distinguished companions of Abdus Salam in his international leadership and common effort for the creation of TWAS.

As you know, I joined the Academy and later on I chaired it thanks to the kind suggestion and at the urging of Abdus Salam. In fact, who would dare to resist his proddings? His determination to serve the cause of science has been an inspiration to his own and certainly to future generations. Even if he had not dwelled at the heights of the frontiers of science , his brainchildren, ICTP and TWAS, would constitute crowning achievements by themselves.

This award comes after almost fifty years of my own involvement with science. These fifty years were shaped by awesome events, including many scientific achievements that were at the same time extraordinarily interesting, beneficial and marvellous.

The last century was indeed marked by major revolutions that, one way or the other, have changed peoples' lives: the Theory of Relativity, Quantum Mechanics, Radioactivity and, that more recently, has led to the important conquests of Molecular Biology. As regards the latter, attention should be specially be paid to the marvellous development on the Genomics of a mosquito, together with the parasite responsible for malaria , a disease that, as you know, causes the death of millions of individuals every year. All these conquests have had a decisive influence on the choices made by scientists of my own generation. Many of our fellows, like Salam, recognised that the increasing knowledge of the atomic nuclei opened the way to undreamed of possibilities , such as that of supplying abundant and cheap energy, capable of freeing humanity from the realm of necessity. Indeed, this increased capacity to do work would be propitious to the comfort of every human being.

As we know, the ability to forecast is intrinsic to science, that with determinism and predictability form the basis for drawing the rational picture of the world. In this respect, science differs from any other realm of knowledge, for which the individual destiny remains unpredictable, as well as is the case for many features of social evolution itself. However it is clear that each individual destiny may be shaped by his social environment. According to the Spanish philosopher Ortega y Gasset, each man is himself and his circumstances. The circumstances that have shaped my life were, of course, determined by my own country, Brazil: the Brazil of the last 50 years, resulting from its own peculiar past.

In fact, a former President of my country's Research Council added weight to this vision saying that Brazil was the only country in the world that presents Brazilian problems. Half in jest and half seriously, I tend to agree with this motto. Modern Brazil, a country that I practically saw being born, emerged after a long period of turbulence. This turbulence was caused basically by the economic features that were at the basis of the Brazilian society, which from its very inception had adopted slavery as its productive system, this system which is the most primitive of all productive systems, it has as a result, contrary to the spanish speaking neighbours, that only in 1808 the printing press was introduced in our country. The first University having come to life only in 1922. The most important advances in our subsequent development came about only one and a half century after our independence, and resulted basically from the implantation of many independent, high-level technical and professional schools. In fact, it was in those schools that quality engineering and the life sciences came into being in Brazil.

It was in the first half of the last century that Brazil was driven to profound institutional changes in response to the absolute need, which prevailed during the world wars, to substitute imported goods. These changes affected not only the material basis but also the country's strategy. Thus, provincial universities that were by that time merely surviving for the lack of means (with the exceptions of the University of São Paulo and the University of Brazil, in Rio de Janeiro), were all put under the financial and administrative umbrella of the Federal Government. They went through accelerated of material and intellectual improvements. By that same moment, the *Brazilian National Research Council (CNPq)* was created to provide support to research. Advanced training of university teachers was made viable by the launching of a high quality Post-Graduate system that has greatly expanded along the years thanks to the support of a newly created organization dedicated exclusevely to fulfil this task - the *CAPES* (*Commission for the Training of Personnel at University Level), under the auspices of the Ministery of Education.*

Industry and agriculture, as well as the energy, transportation and communication infrastructures, expanded as well under the same spur. A modern system of norms and standards was of course called for to replace our outmoded practices.

Several institutes were created under the aegis of the *CNPq*. Among them I want to mention especially the *Centro Brasileiro de Pesquisas Físicas - CBPF (Brazilian Centre for Physics Research*) *in fact the continuator of modern physics research initiated at the University of São Paulo, which was responsible, for example, for the discovery of the* *penetrating cosmic rays showers and also of the Π-meson with the collaboration of Powells' Group of Liverpool. In Mathematics, activities were carried by* the *Instituto Nacional de Matemática Pura e Aplicada – IMPA (National Institute for Pure and Applied Mathematics*), that was to become well-known thanks to its contribution to the research on dynamical systems. Life sciences which were traditionally investigated at the *Oswaldo Cruz Institute*, in Rio de Janeiro, were continued in a large multi-centred research enterprise – EMBRAPA - together with a number of other institutions and university departments dedicated to these fields.

As a consequence, the availability of a sizeable capability in basic sciences made possible the training and expansion of university personnel capable of adapting and sometimes even innovating in the field of the applied sciences, thus confirming Abdus Salam's motto: "There is no applied science without science".

The strengthening of local universities helped the diffusion of development in various fields and in most parts of the country. For instance, in my place of birth, the state of Minas Gerais, a special Secretariat, a Development Bank and an Institute for the Promotion of Industrial Development were created alongside a technological centre (CETEC) to deal with development in general and with environmental issues. Another example was the policy, first implemented by the state of São Paulo, consisting in dedicating a given percentage share of its tax revenue to finance science. This local experience was then generally adopted elsewhere thanks to the new 1988 Federal Constitution.

Brazil started to grow. The combination of research and basic sciences; the creation of new institutes devoted to the development of technology; the linkage between the productive sector and the product standardization; adding value to primary mineral, energetic and agricultural products. Foreign investment contributed decisively to fulfil the needs of a newly created market economy that has grown almost as fast as the population rate. These choices have allowed Brazil to become the tenth economy in the world.

However important, this feat should be analysed with circumspection, for with development there emerged not only social but also considerable regional imbalances.

This style of development latter on led Brazil to an insertion, even though still modest into the dynamic and competitive international market. This market is now characterised by the amazing revolution brought about by the information and communication technologies. That model of development, based mostly on the import substitution , revealed itself to be incompatible with the present-day style of growth, which demands an ever increasing innovation content: the so-called "knowledge-based society". On the other hand, the new development style represents a real danger to the future overall development of our country.

It was the awareness of the danger of an interruption in the national process of development itself that shaped Brazilian society from the 1940s till the beginning of the '80s, that constituted a major factor in bringing about the necessary corrective measures. In the last ten years, increasing investments and profound institutional reforms were carried out so as to circumvent those problems to permit a renewed growth faith. Special emphasis was placed on the expansion of general basic education and on the indigenous development of areas considered as bearers of the future, such as genetics, molecular biology, the aerospace industry, pharmaceutical products, etc. while continued attention was given to the basic sciences.

So, the Brazilian scientific production, as measured by the world indexed literature, grew from 0,8% by 1985 to 1,45% by the year 2000. Computer science, telecommunication and information technologies have also been increasing at considerable rates.

It is heartening to verify that despite its still modest participation qualitywise, the Brazilian scientific production as measured by the traditional citation index finds itself in a better position than that observed by much more active developing countries.

Those have been my circumstances for the last 50 years. They are of course typical of any active third world scientist, for whom the initial spell of dedication to basic sciences was frequently interrupted at an early stage by activities dealing with planning and administration - to the detriment of science itself - as demanded by the call to positions of responsibility in public life. Therefore, one finds oneself under the pressure of responding to unforeseen demands . Even though there is the consolation of having striven to do one's best, we are led to wonder if another choice would not have led us to "greener valleys"...

But, as we all know, time is unredeemable, and no complaints are therefore justified. I have, on the contrary, to be most thankful to my teachers, my family and many friends who have so generously helped me to fulfil my destiny.

As a Brazilian and a scientist I have also been profoundly marked by the changes that have taken place in the world at large, in the last 50 years. It is to be noted that fortunately it has become a happier place more bound by solidarity, as reflects the timely creation of the international UN system with its many specialised agencies, of which *UNESCO* is the most note worthing. Specialised institutions were also dedicated to respond to well-identified emerging needs, such as the *International Agency for Atomic Energy* and the *Pan-American Nuclear Energy Commission*, to all of which I have often been connected.

Even though their performance remains less enthralling than one would have hoped for, international co-operation shall remain as a mark of our generation's achievements. Co-operation in science remains perhaps the single most important bridge that unites all of us over and beyond political, religious or racial differences.

The life of nations, like that of individuals, constitutes a mix of successes and failures. Failures are many and in general, are orphans... Success is well known to have many fathers... The Brazilian successes, which are obviously have a collective origin, are deemed to result from our capacity to live in peace with our neighbours over the past 140 years; it may also result from a conviviality that allows for the harmonious living together of people originating from every corner of this vast world. Perhaps our climate – as varied as our own society is - equatorial, tropical, semi-arid and temperate - all at the same time – has also something to do with these virtues. In fact, these cultural and environmental traits might explain the good disposition always displayed by Brazil towards international co-operation. Maybe, and to conclude, these characteristics might be one of the reasons for the great esteem in which TWAS is held: an organisation of individuals moved by the same thirst for knowledge, always eager to understand this "immense machinery that compounds the universe ", led by the same spirit and vision that has guided its founding fathers under the leadership of Abdus Salam. According to Carlos Drummond de Andrade, we, at TWAS, are "moved by a measured passion..."

FIGURE CAPTIONS

Figure 1**: Brazil**

Figure 2**: Brazil and some of its states as compared to some selected countries – GDP per capita**

Figure 3 : Brazil : GNP and energy evolution

Figure 4 : Installed hydropower capacity (1910-1998)

Figure 5 : Hydropower electricity generation in Brazil

Figure 6 : Deviation of the installed electrical capacity (1910-1998)

Figure 7 : Lifetime expectancy x Electricity use in 127 countries

Figure 8 : Literacy evolution in some industrialized countries

Figure 9 : Illiteracy in Brazil (above 15 years old)

Figure 10 : Vocational training in Brazil

Figure 11 : Investments in Science and Technology in Brazil in R$ and as percent of GNP (1990-1999)

Figure 12 Brazil : GDP, Schollarships for scientists and science

Figure 13: Relative scientific production for selected countries (%) as compared to the world scientific publications.

Figure 14 : Number of scientific papers (Brazil, India, People's Republic of China, South Korea)

Figure 15 : Citation impact of the scientific production (Brazil, India, People's Republic of China, South Korea)

Figure 16 : Dynamics of innovation in the New Economy

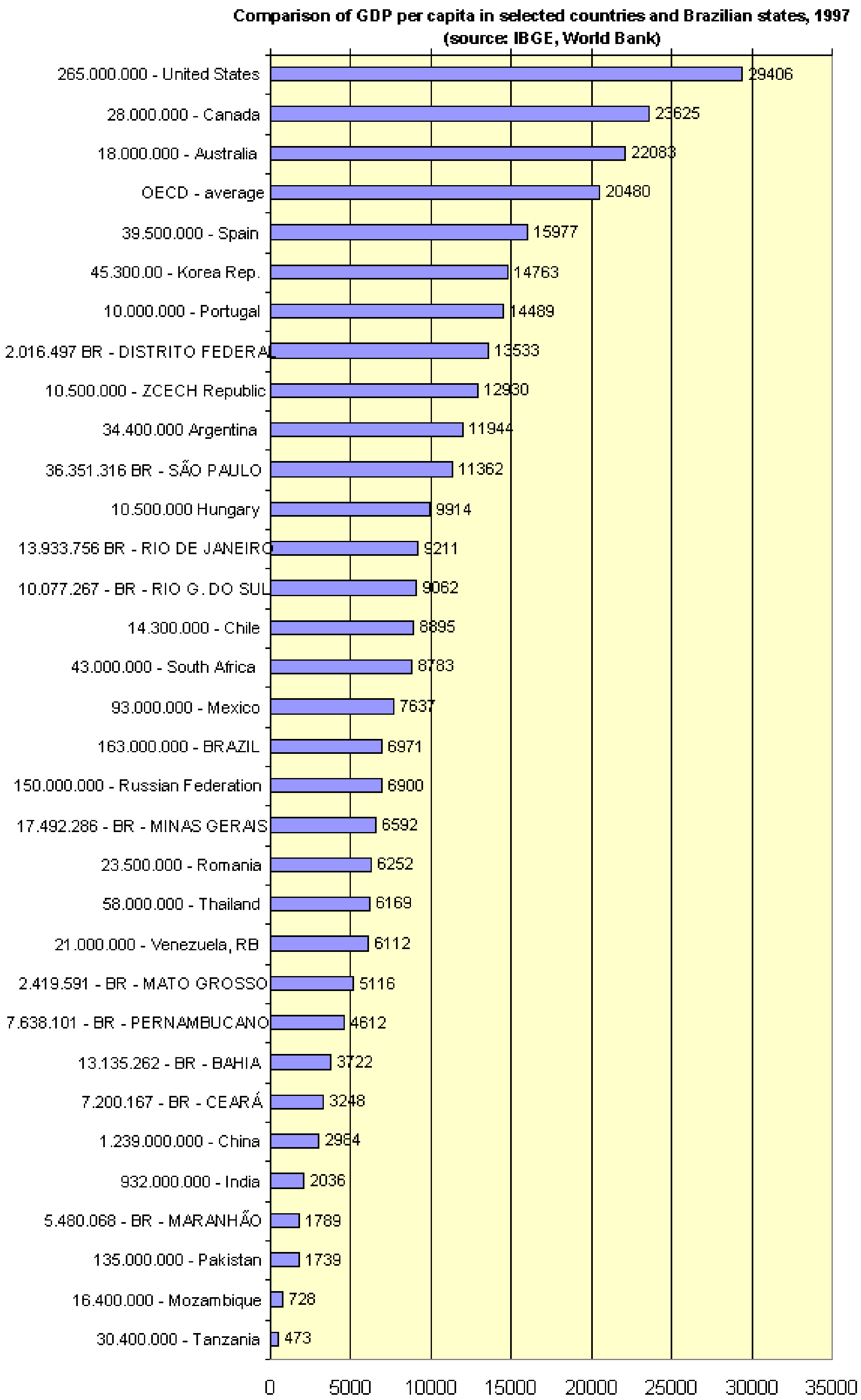
Figure 17 : World patent applications

Figure 18 : Brazilian technology balance (MCT)

TABLES :


Brazil
Surface 8,5 Km² M
Population 160 M
GDP/99 US$ 580 B
Imports US$ 49 B
Export US$ 48 B
Total trade US$ 97 B
Inflation/00 6%

Figure 1


Comparison of GDP per capita in selected countries and Brazilian states, 1997
(source: IBGE, World Bank)
265.000.000 - United States
29406
28.000.000 - Canada
23625
18.000.000 - Australia
22083
OECD - average
20480
39.500.000 - Spain
15977
45.300.00 - Korea Rep.
14763
10.000.000 - Portugal
14489
2.016.497 BR - DISTRITO FEDERAL
13533
10.500.000 - ZCECH Republic
12930
34.400.000 Argentina
11944
36.351.316 BR - SÃO PAULO
11362
10.500.000 Hungary
9914
13.933.756 BR - RIO DE JANEIRO
9211
10.077.267 - BR - RIO G. DO SUL
9062
14.300.000 - Chile
8895
43.000.000 - South Africa
8783
93.000.000 - Mexico
7637
163.000.000 - BRAZIL
6971
150.000.000 - Russian Federation
6900
17.492.286 - BR - MINAS GERAIS
6592
23.500.000 - Romania
6252
58.000.000 - Thailand
6169
21.000.000 - Venezuela, RB
6112
2.419.591 - BR - MATO GROSSO
5116
7.638.101 - BR - PERNAMBUCANO
4612
13.135.262 - BR - BAHIA
3722
7.200.167 - BR - CEARÁ
3248
1.239.000.000 - China
2964
932.000.000 - India
2036
5.480.068 - BR - MARANHÃO
1789
135.000.000 - Pakistan
1739
16.400.000 - Mozambique
728
30.400.000 - Tanzania
473
0
5000
10000
15000
20000
25000
30000
35000

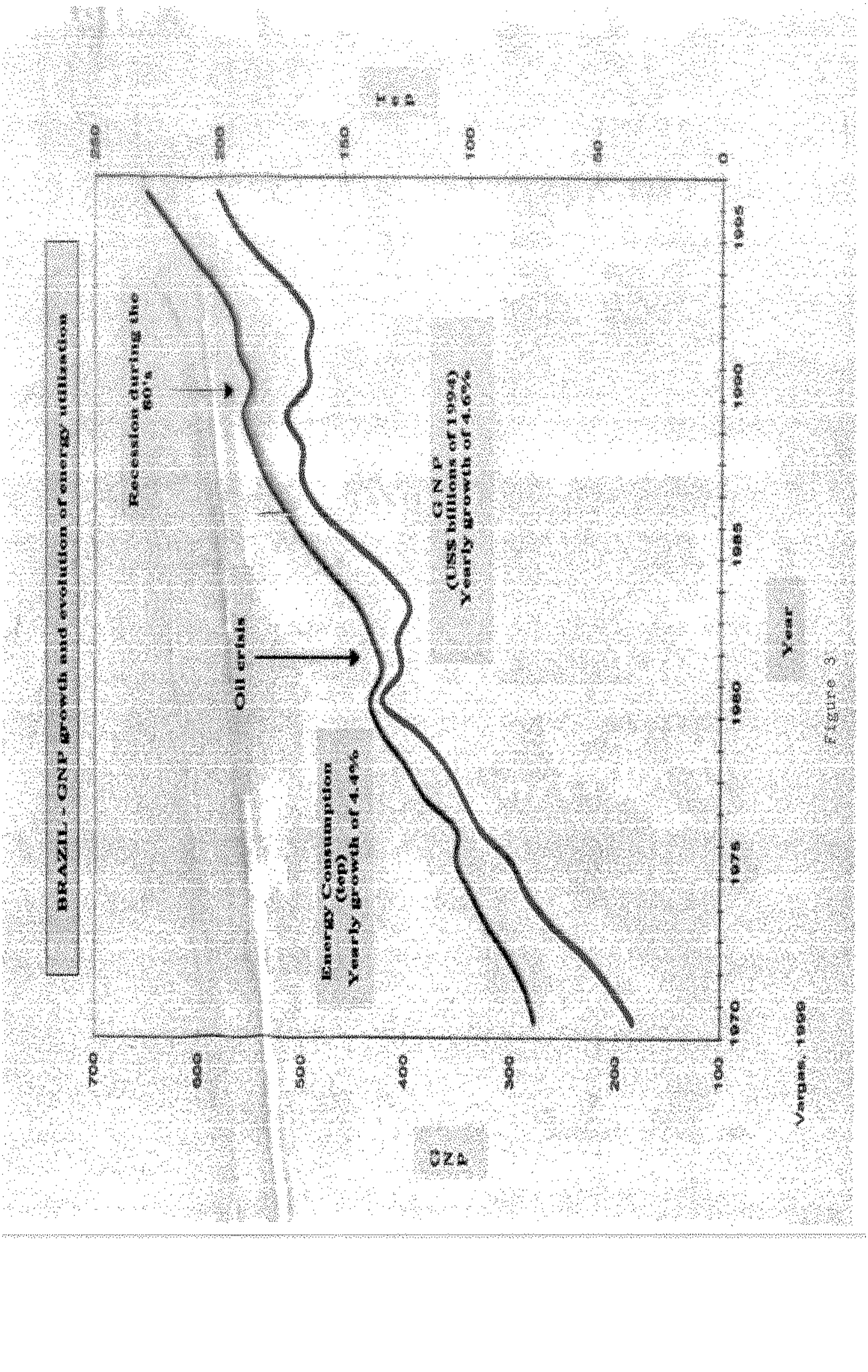
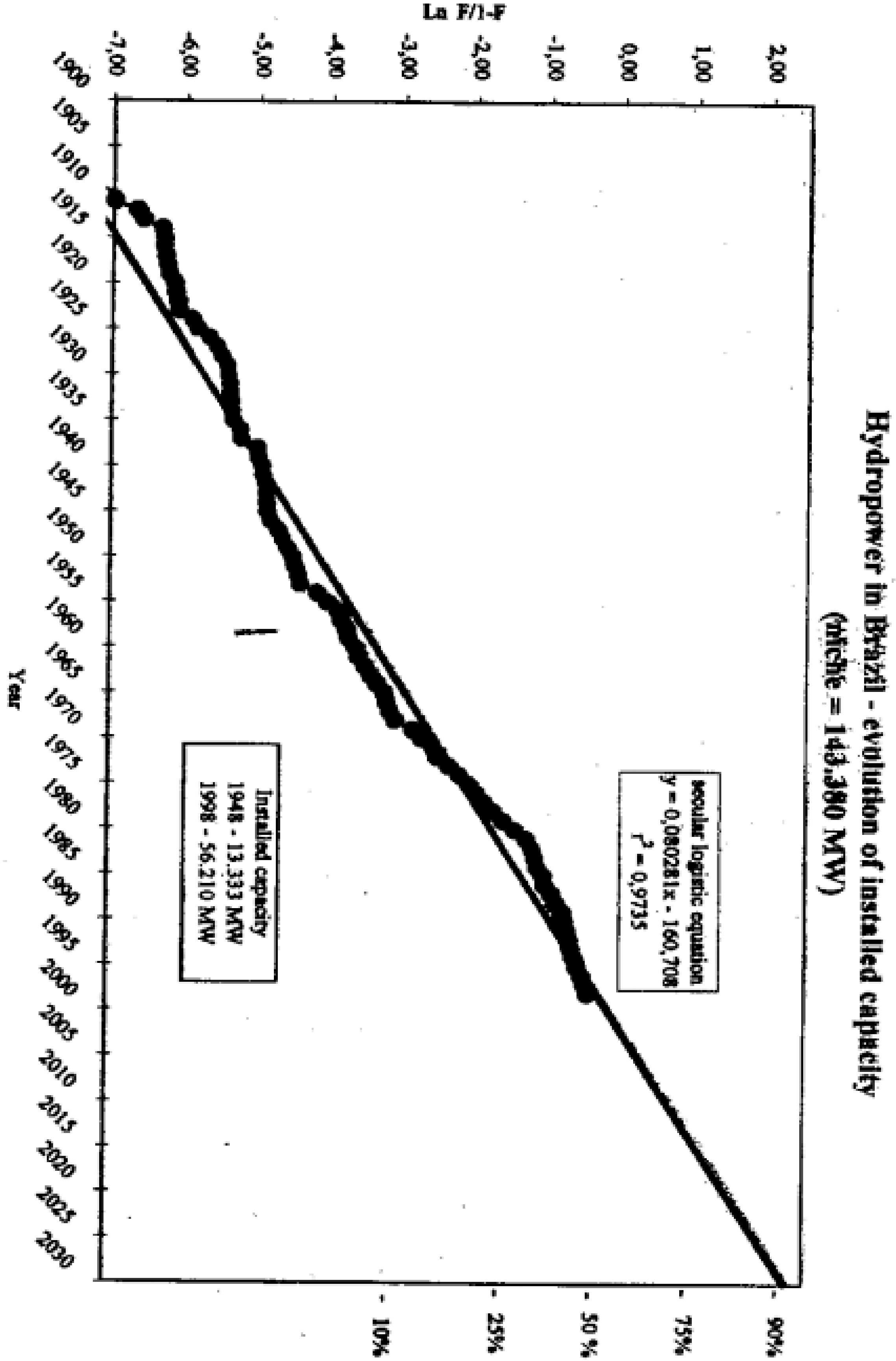

BRAZIL - GNP growth and evolution of energy utilization
Recession during the 80's
Oil crisis
Energy Consumption
(tep)
Yearly growth of 4.4%
G N P
(US$ billions of 1994)
Yearly growth of 4.6%
Year

Figure 3

Figure 4


Hydropower in Brazil - evolution of installed capacity
(niche = 143.380 MW)
secular logistic equation
y = 0,080281x - 160,708
r² = 0,9735
Installed capacity
1948 - 13.333 MW
1998 - 56.210 MW
Ln F/1-F
Year
90%
75%
50 %
25%
10%

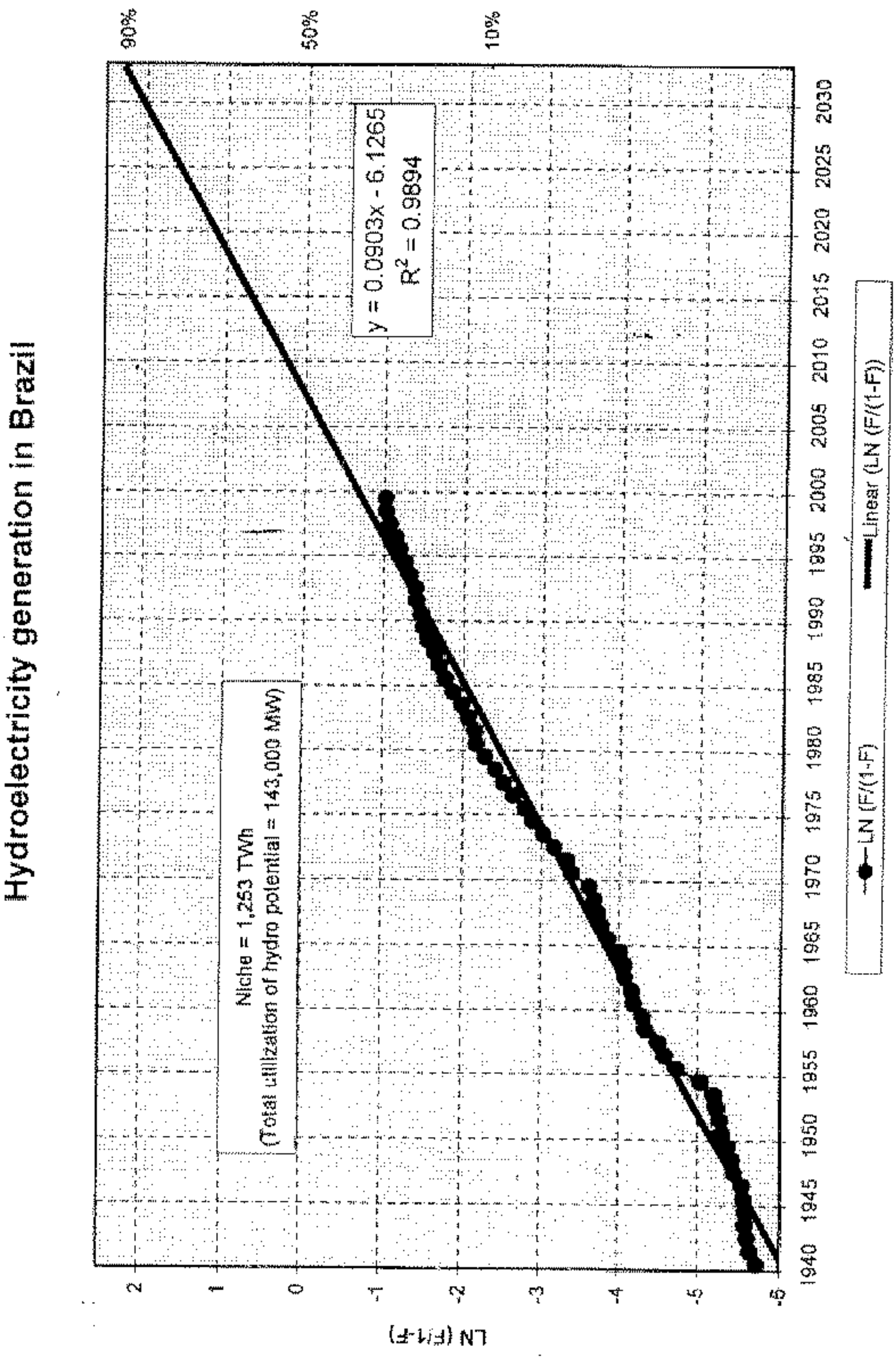

Hydroelectricity generation in Brazil
Niche = 1,253 TWh
(Total utilization of hydro potential = 143,000 MW)
y = 0.0903x - 6.1265
R² = 0.9894
90%
50%
10%
LN (F/1-F)
LN (F/(1-F)
Linear (LN (F/(1-F))

Figure 5

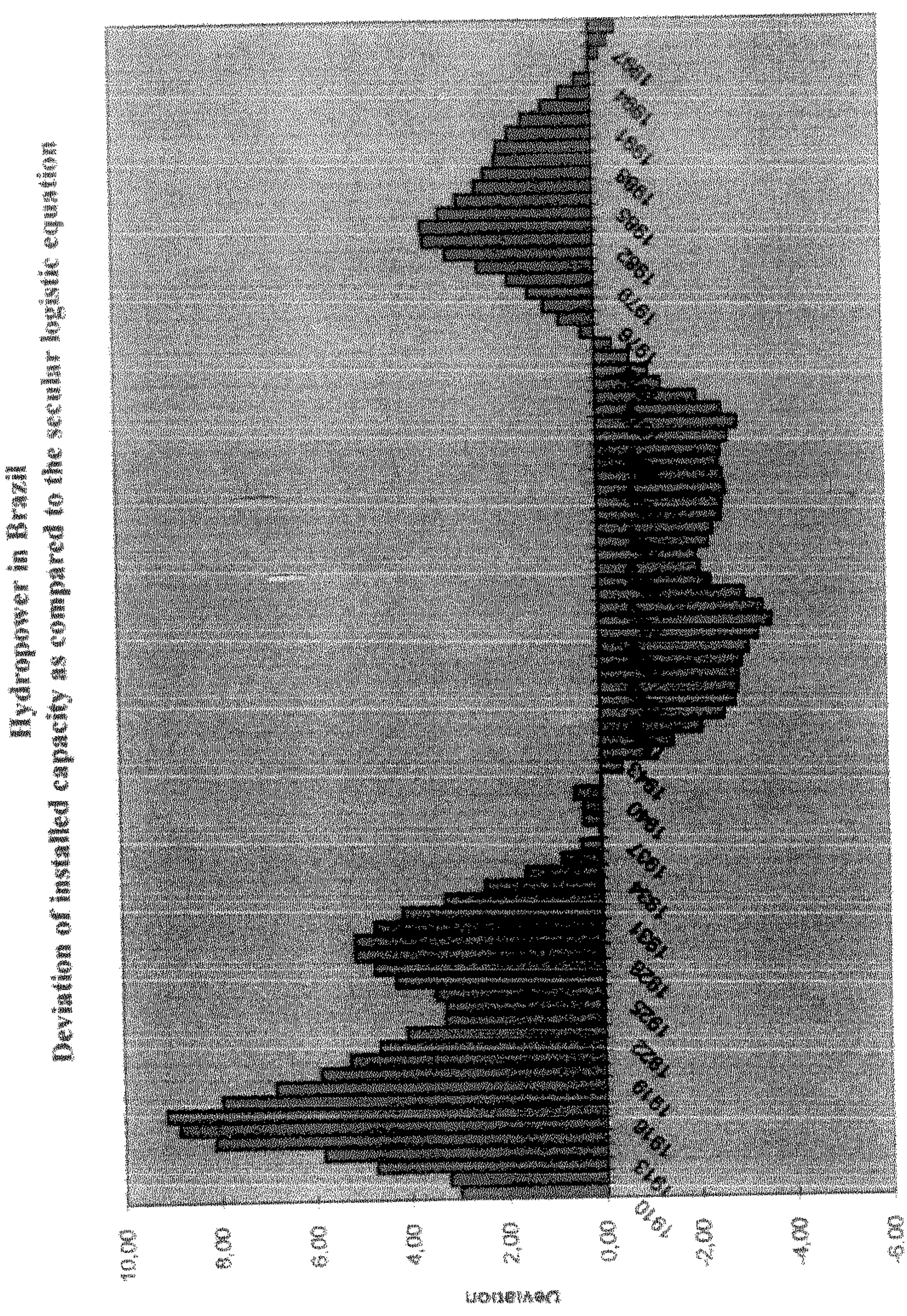

Hydropower in Brazil
Deviation of installed capacity as compared to the secular logistic equation
Deviation
10,00
8,00
6,00
4,00
2,00
0,00
-2,00
-4,00
-6,00
1910
1913
1916
1919
1922
1925
1928
1931
1934
1937
1940
1943
1976
1979
1982
1985
1988
1991
1994
1997

Figure 6

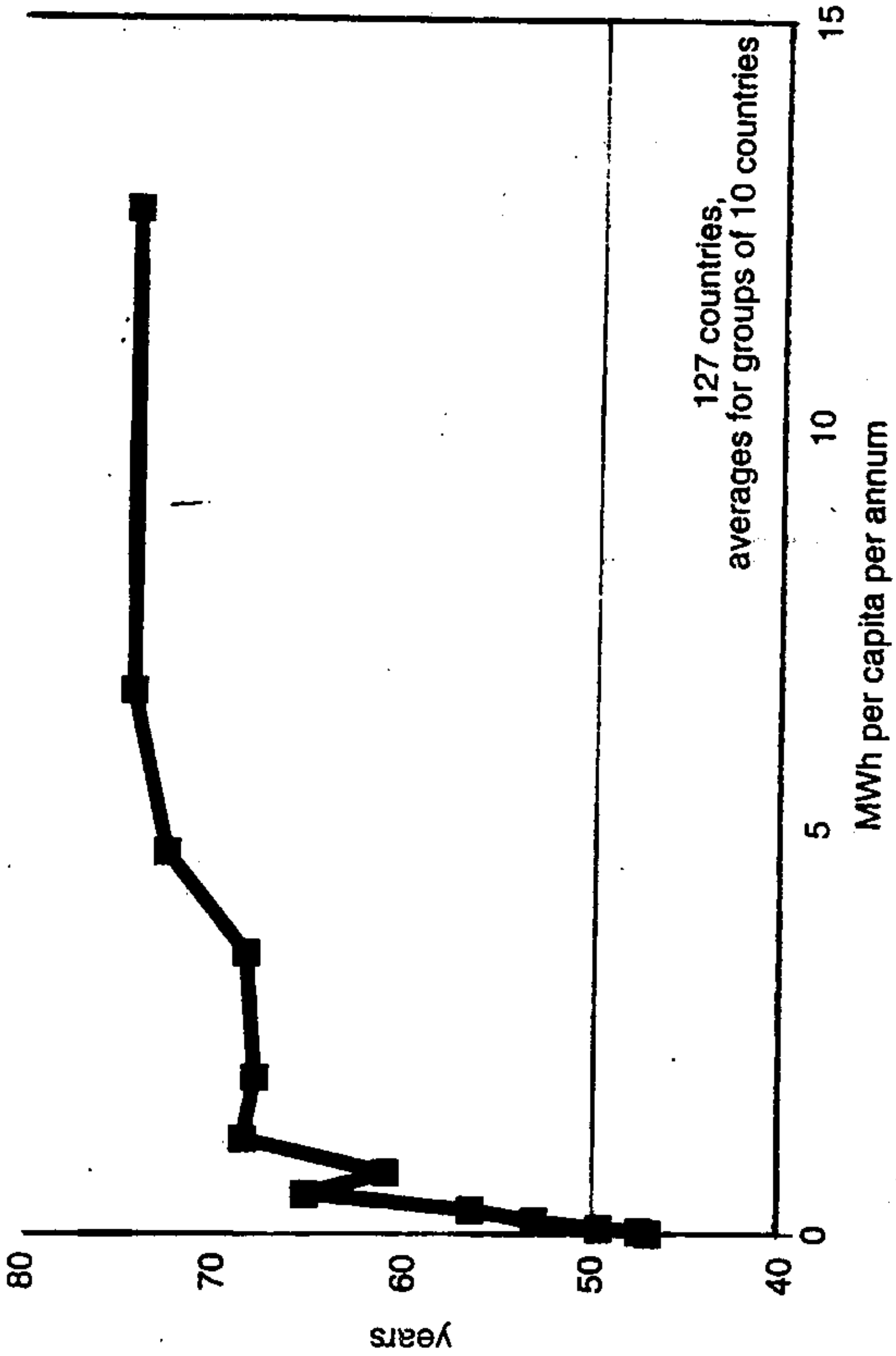


Figure 7 Life-time Expectancy *vs* Electricity Use

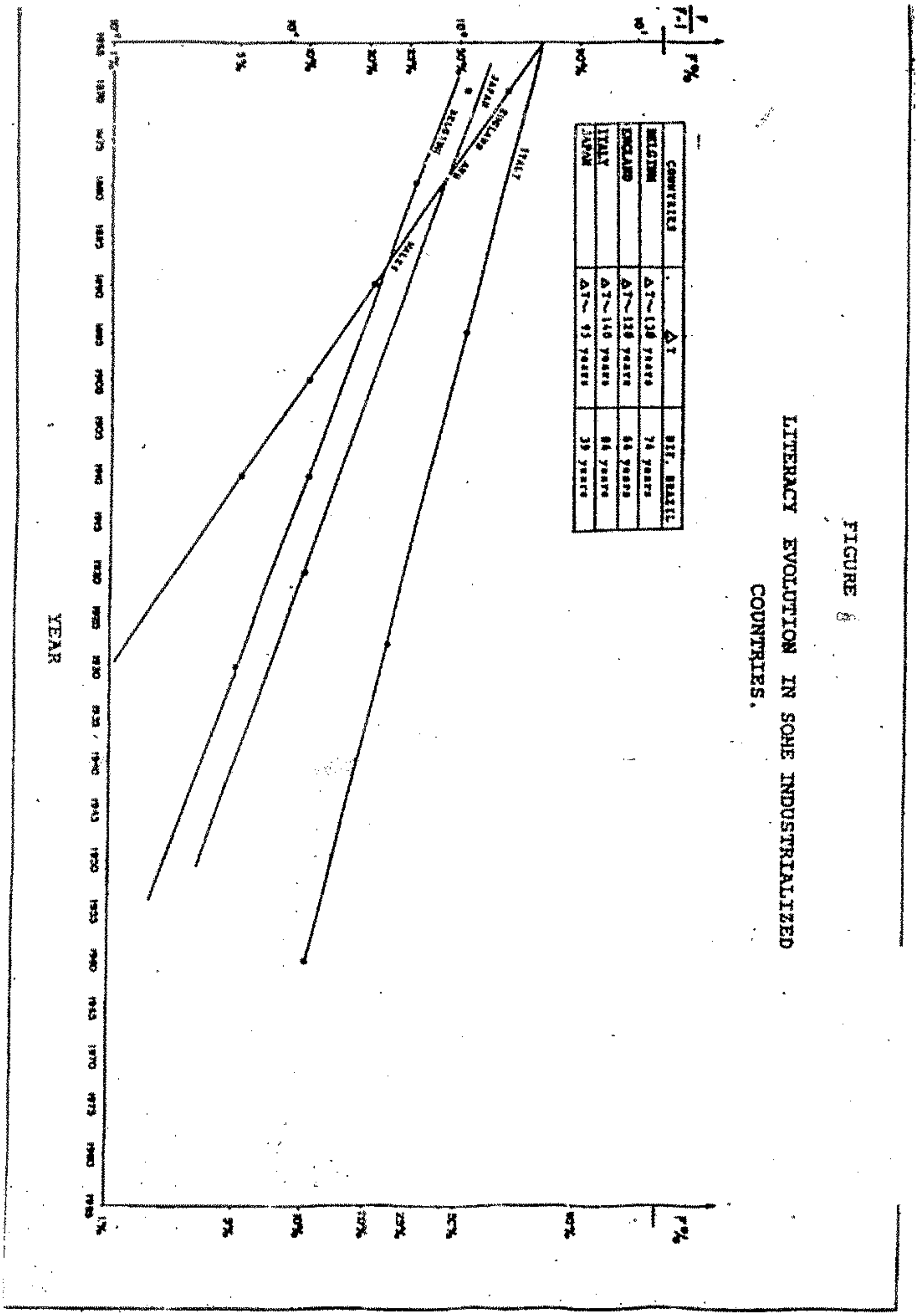


FIGURE 6

LITERACY EVOLUTION IN SOME INDUSTRIALIZED COUNTRIES.

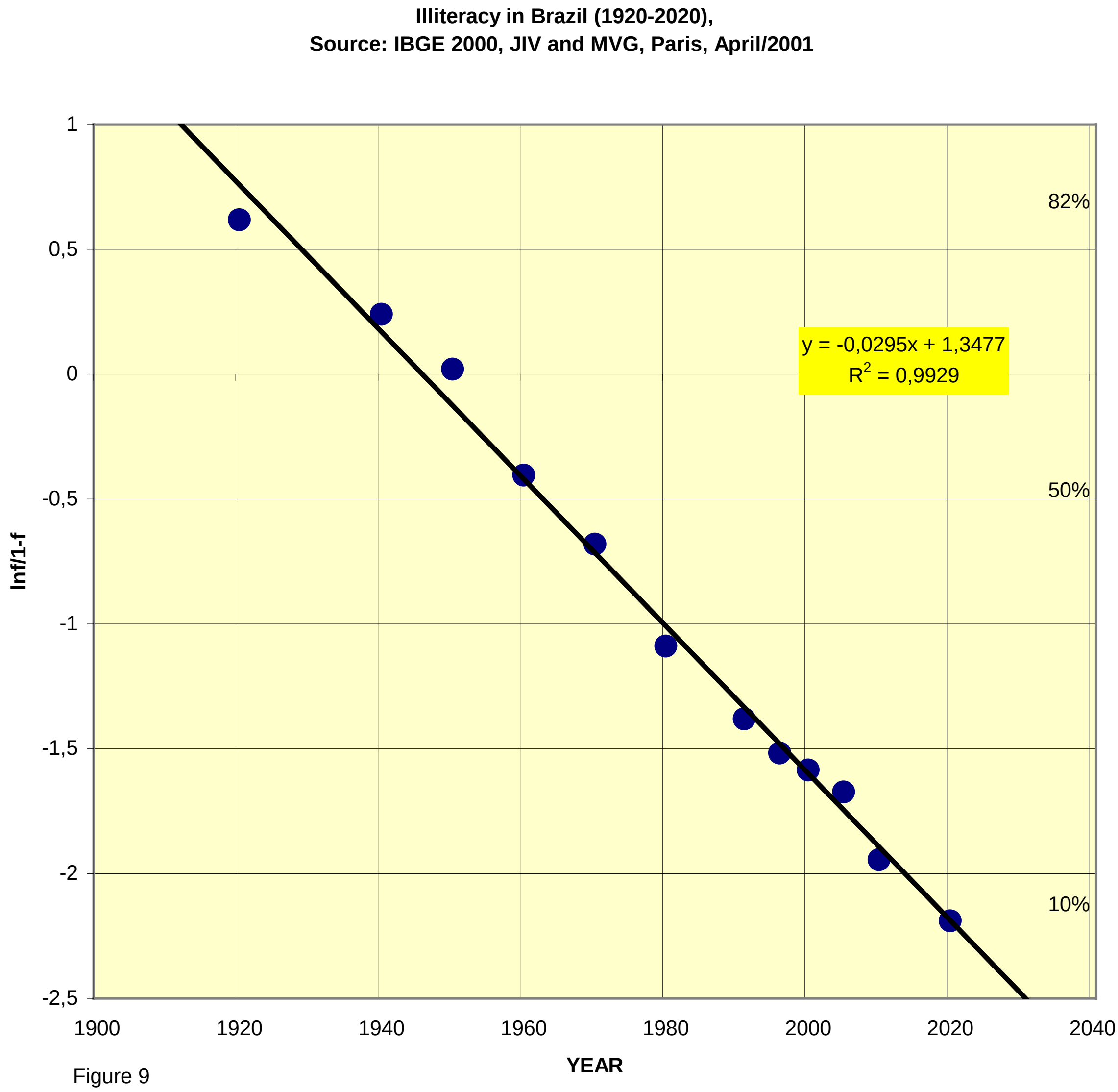

Illiteracy in Brazil (1920-2020),
Source: IBGE 2000, JIV and MVG, Paris, April/2001
1
0,5
0
-0,5
-1
-1,5
-2
-2,5
lnf/1-f
1900
1920
1940
1960
1980
2000
2020
2040
YEAR
82%
50%
10%
y = -0,0295x + 1,3477
R2 = 0,9929

Figure 9

VOCATIONAL TRAINING IN BRAZIL

(Two major professional training institutions in Brazil)

Source: Ministry of Education (www.mec.gov.br)

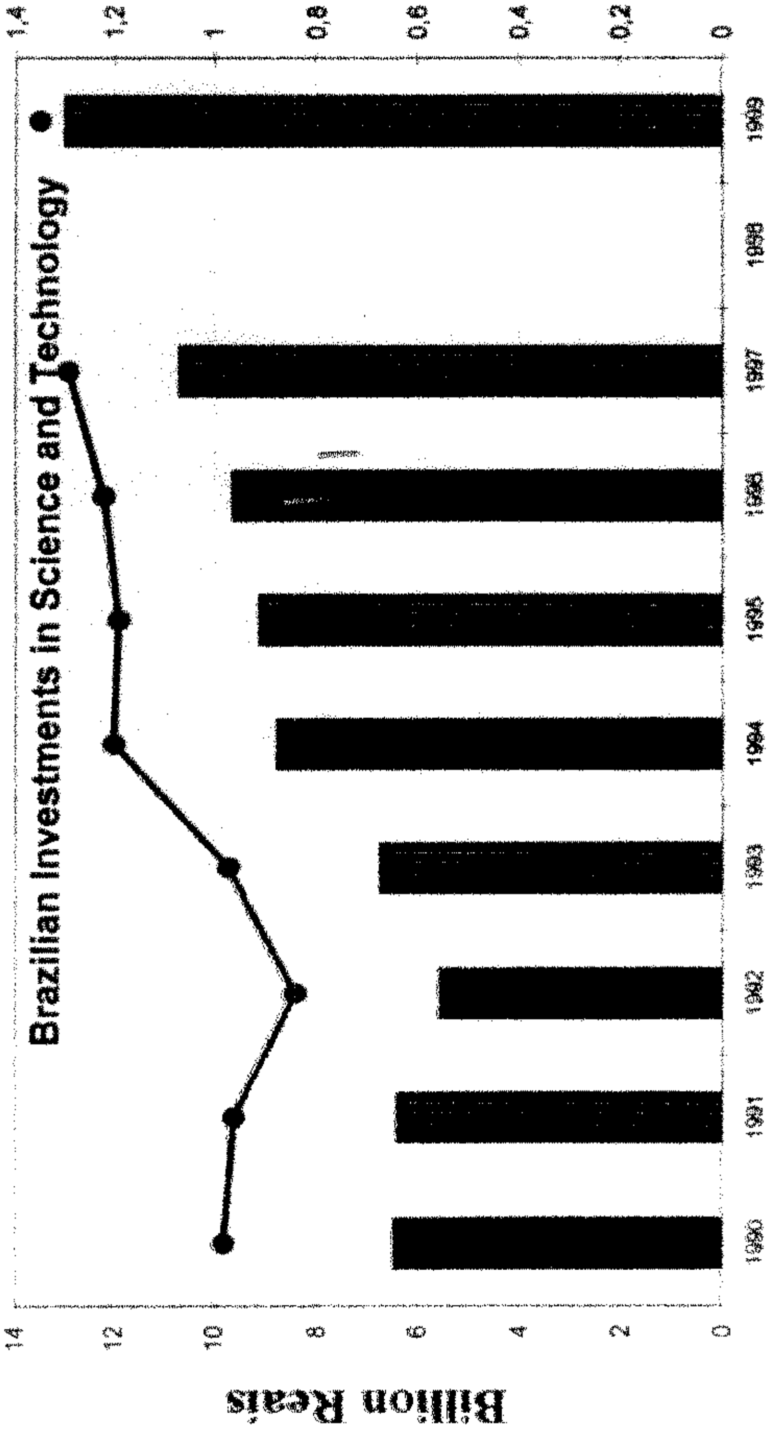
Brazilian Confederation of Industry and Commerce Institutions	[redacted]	SENAC
Inception date	[redacted]	1946
Enrolment - 2000	[redacted]	1,8 million
Training courses	[redacted]	514
Graduated students	[redacted]	31 millions

Total of enrolments in the 3 levels * of professional education for 2000 in 5.451 public and private courses **	2,8 millions

* Basic, technical and technological

** Traditional primary, secondary and university education excluded

Figure 10



- GROWTH INVESTMENT FROM: 1992 - 1997: 14%YEAR / 1994 - 1997: 12,4% YEAR / 1995 - 1997: 6,7% YEAR
- IN TERMS OF GNP FROM: 1992 - 1997: 9,1% / 1994 - 1997: 7,6% / 1995 - 1997: 2,7%

Figure 11

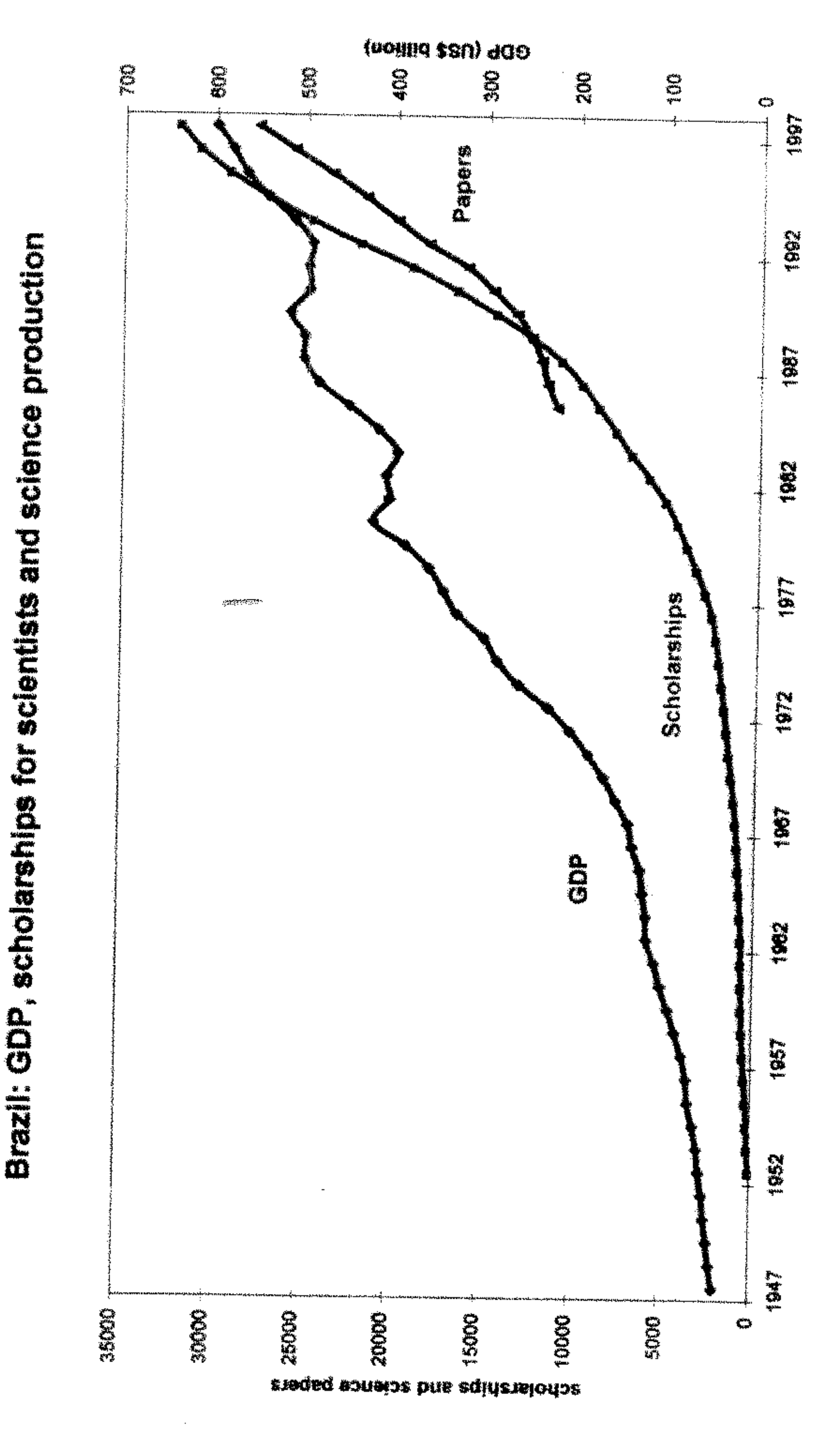


Figure 12

23/04/99

Vargas

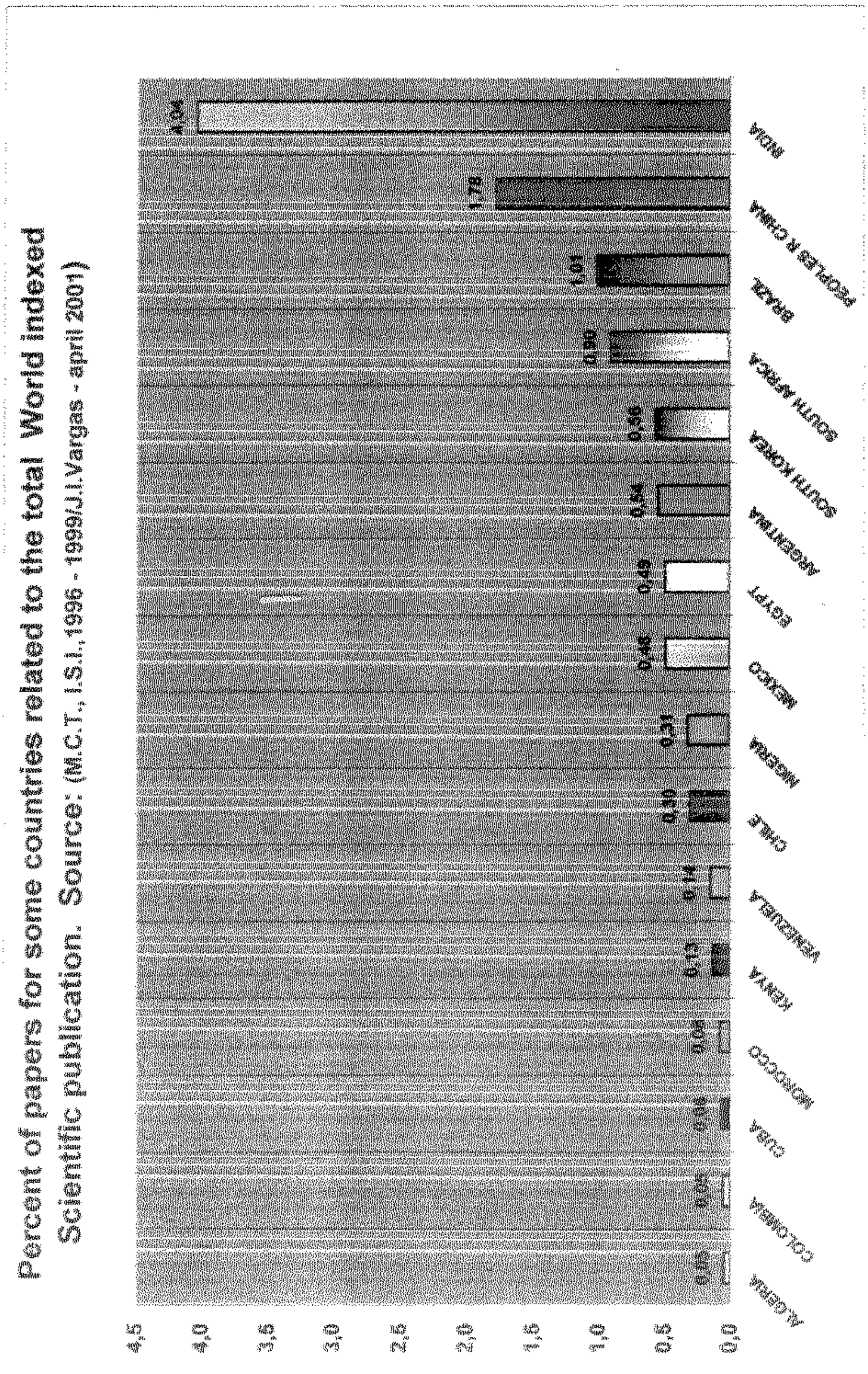
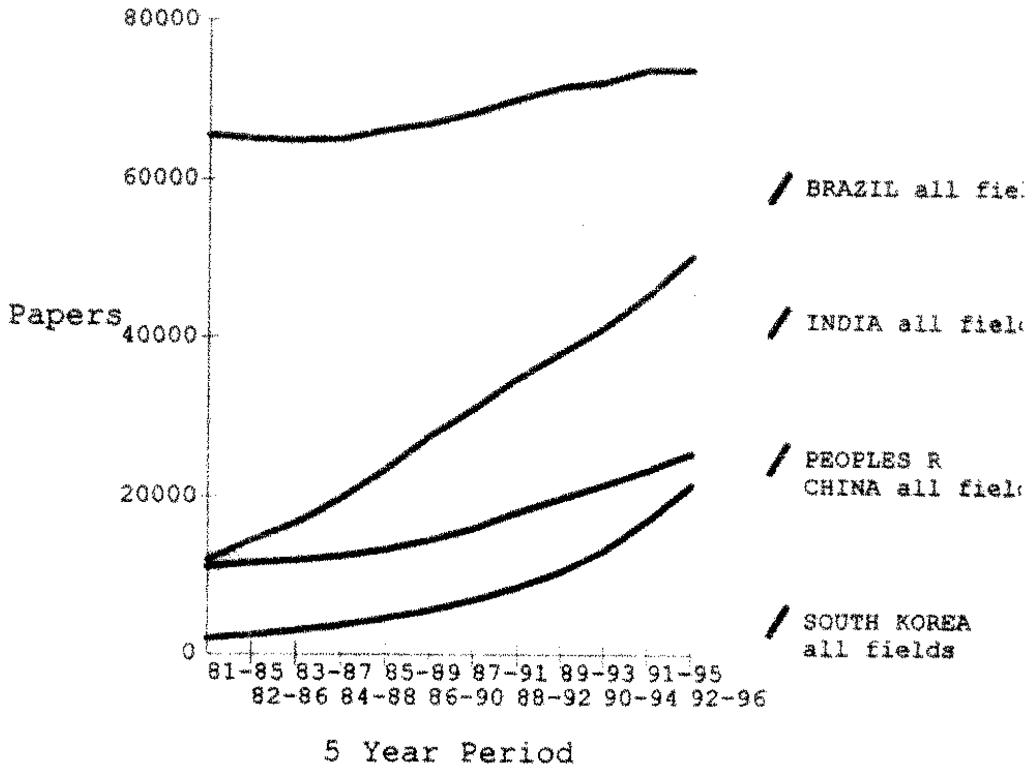


Figure 13

Prescott,E



80000
60000
Papers
40000
20000
0
81-85 83-87 85-89 87-91 89-93 91-95
82-86 84-88 86-90 88-92 90-94 92-96
5 Year Period
BRAZIL all fie
INDIA all fiel
PEOPLES R CHINA all fiel
SOUTH KOREA all fields

Figure 14

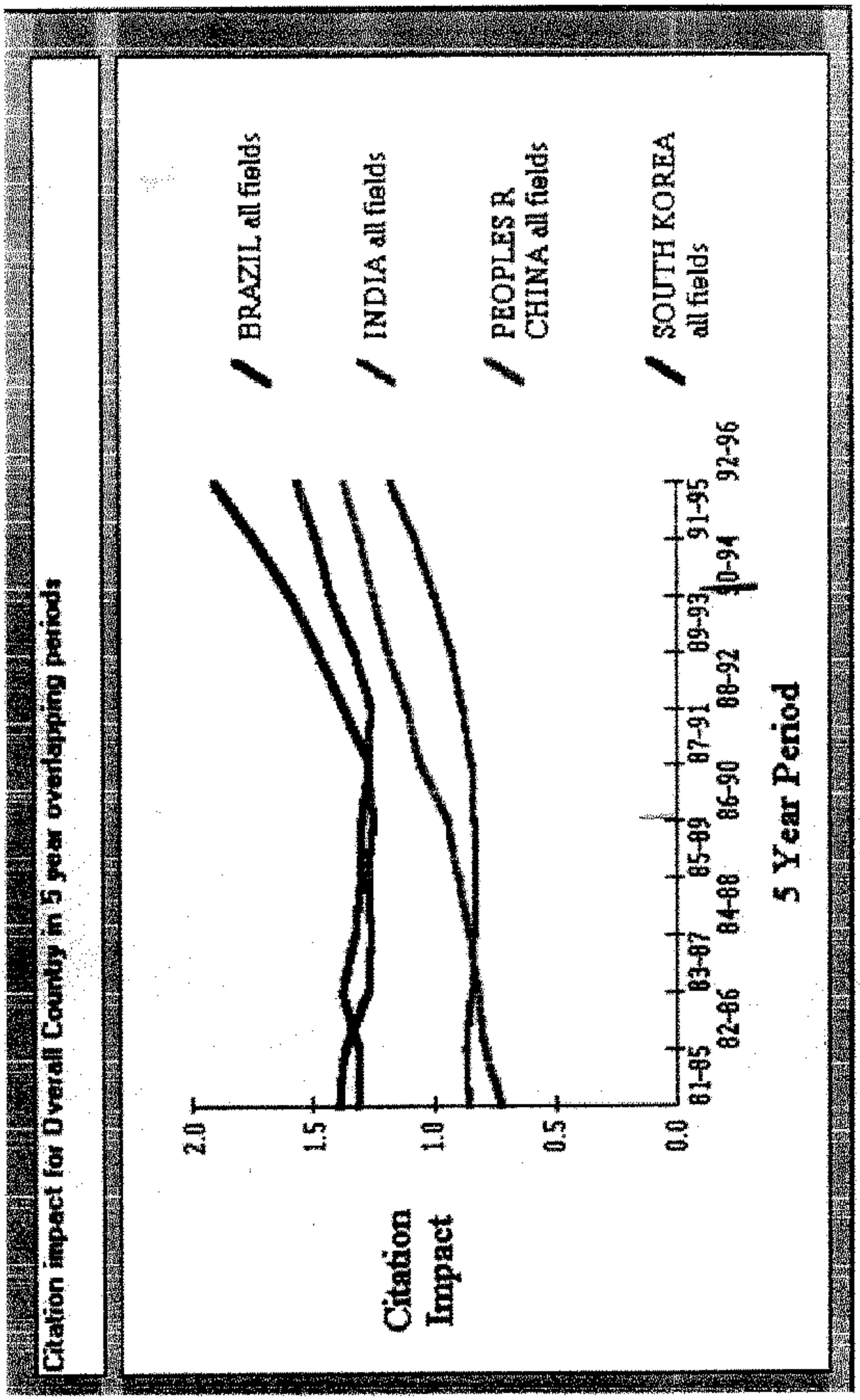

Citation impact for Overall Country in 5 year overlapping periods
Citation Impact
2.0
1.5
1.0
0.5
0.0
81-85
82-86
83-87
84-88
85-89
86-90
87-91
88-92
89-93
90-94
91-95
92-96
5 Year Period
BRAZIL all fields
INDIA all fields
PEOPLES R CHINA all fields
SOUTH KOREA all fields

Figure 15

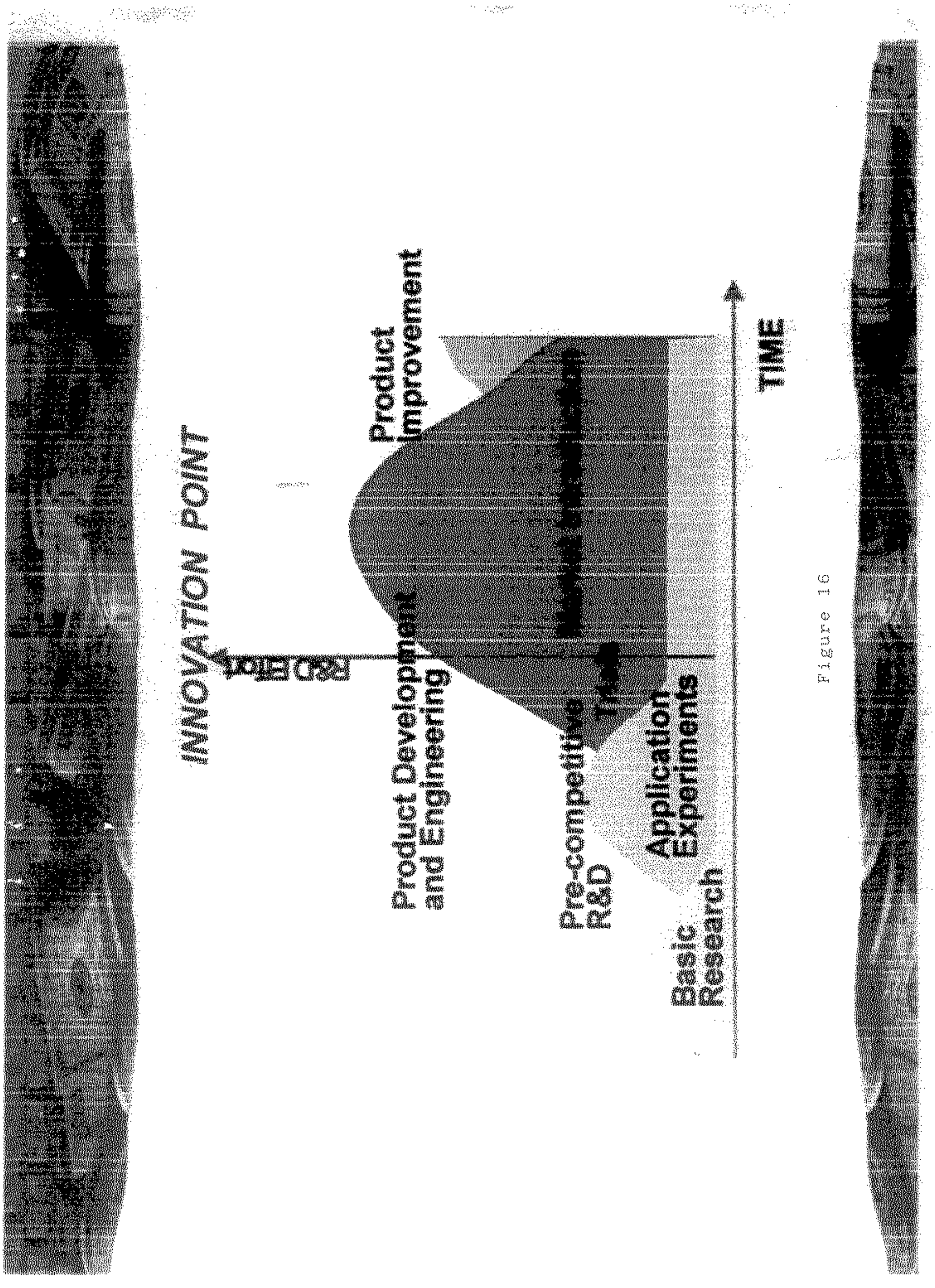

INNOVATION POINT
R&D Effort
Product Development and Engineering
Product Improvement
Pre-competitive R&D
Application Experiments
Basic Research
TIME

Figure 16

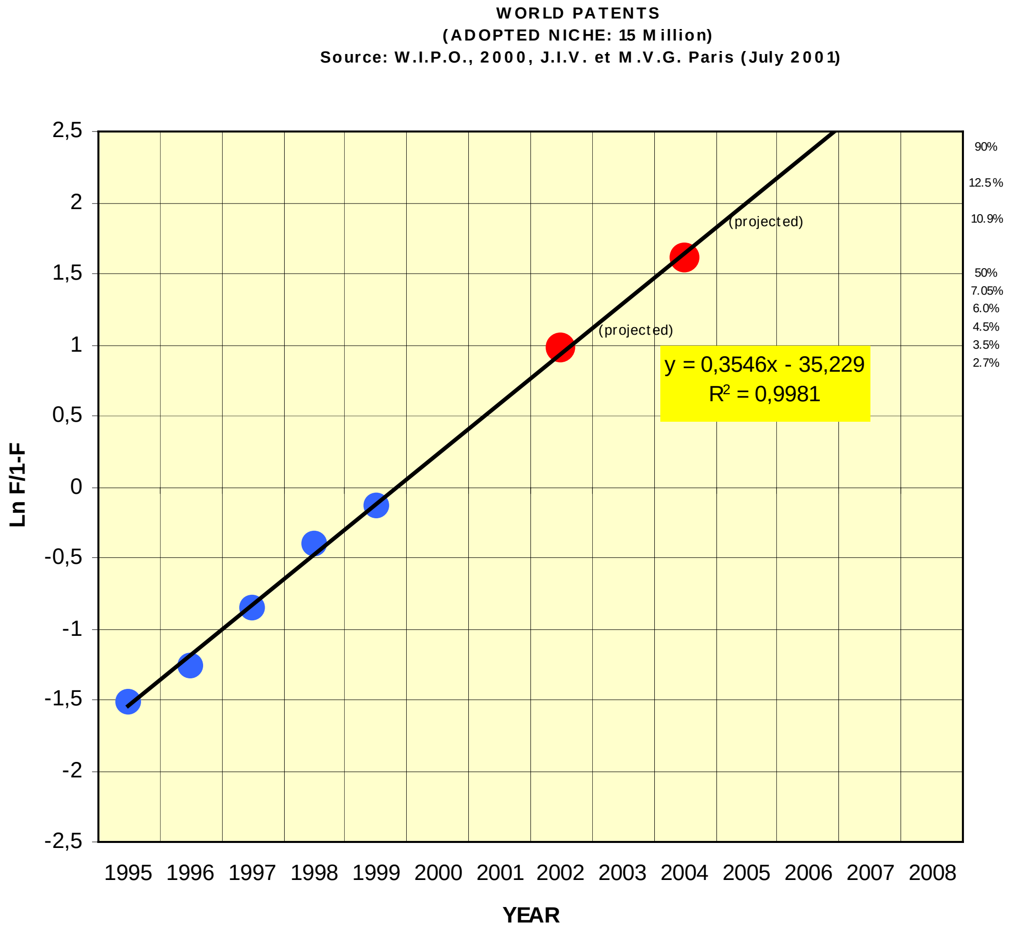

WORLD PATENTS
(ADOPTED NICHE: 15 Million)
Source: W.I.P.O., 2000, J.I.V. et M.V.G. Paris (July 2001)
Ln F/1-F
2,5
2
1,5
1
0,5
0
-0,5
-1
-1,5
-2
-2,5
1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008
YEAR
(projected)
(projected)
y = 0,3546x - 35,229
R2 = 0,9981
90%
12.5%
10.9%
50%
7.05%
6.0%
4.5%
3.5%
2.7%

FIGURE 17

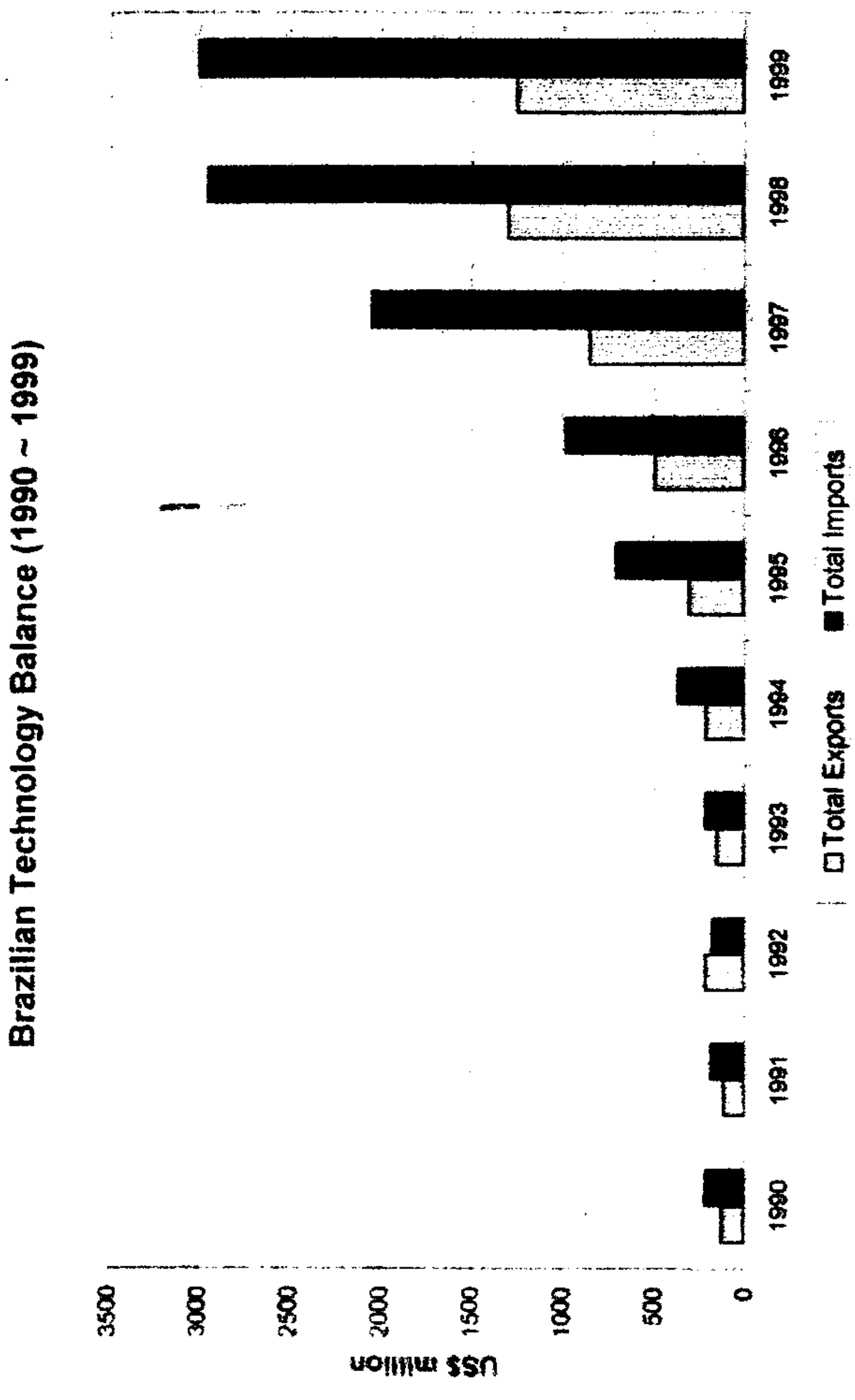

Brazilian Technology Balance (1990 ~ 1999)
US$ million
3500
3000
2500
2000
1500
1000
500
0
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
Total Exports
Total Imports

Figure 18

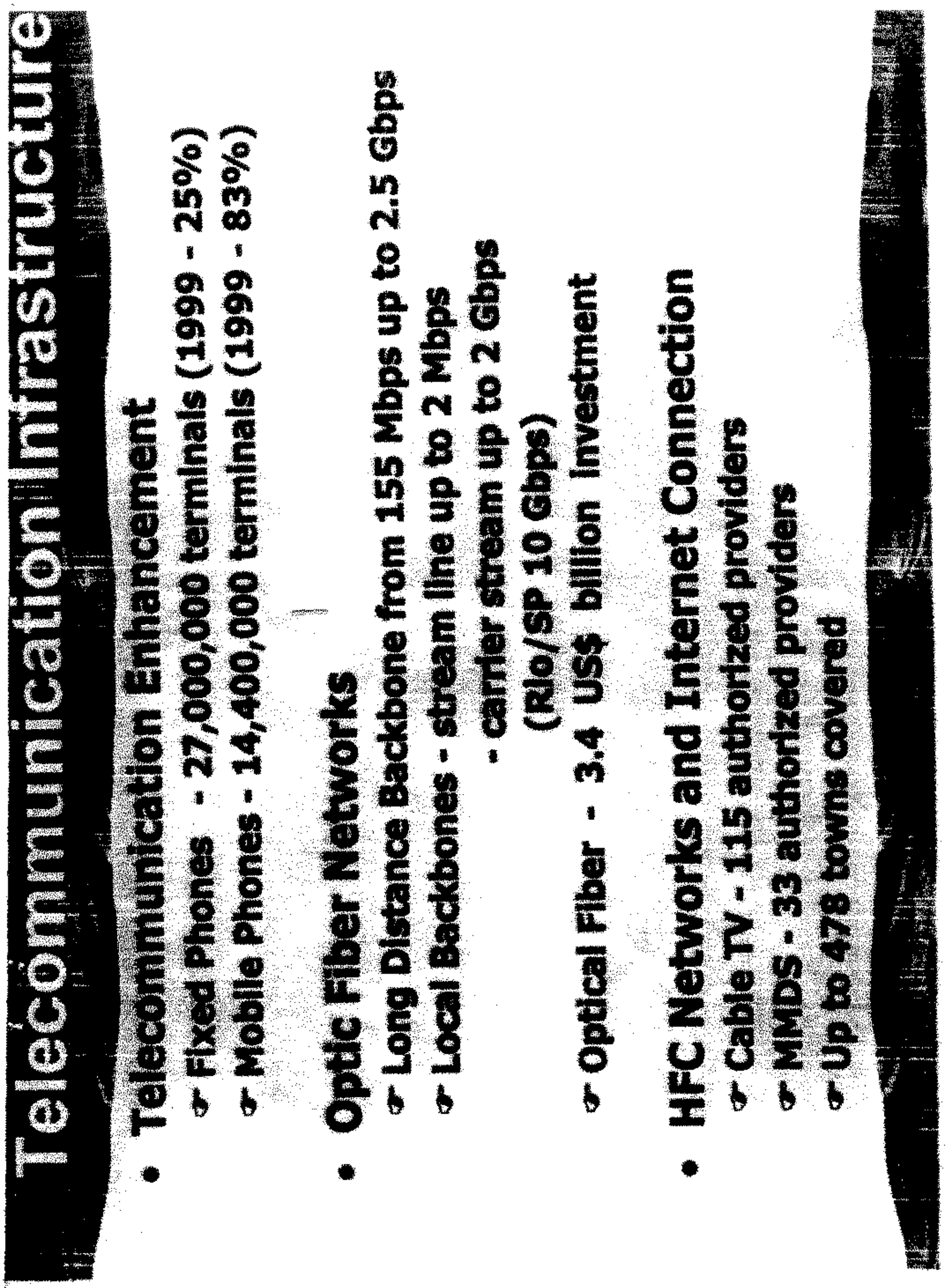

Telecommunication Infrastructure
• Telecommunication Enhancement
Fixed Phones - 27,000,000 terminals (1999 - 25%)
Mobile Phones - 14,400,000 terminals (1999 - 83%)
• Optic Fiber Networks
Long Distance Backbone from 155 Mbps up to 2.5 Gbps
Local Backbones - stream line up to 2 Mbps
- carrier stream up to 2 Gbps
(Rio/SP 10 Gbps)
Optical Fiber - 3.4 US$ billion Investment
• HFC Networks and Internet Connection
Cable TV - 115 authorized providers
MMDS - 33 authorized providers
Up to 478 towns covered

Figure 19

Personal Computers in Brazil
(NICHE: 50 millions)
SOURCE: R. Campos, A. Informática no Brasil, Vol. III, 1999
JIV et MVG, Paris, 2001

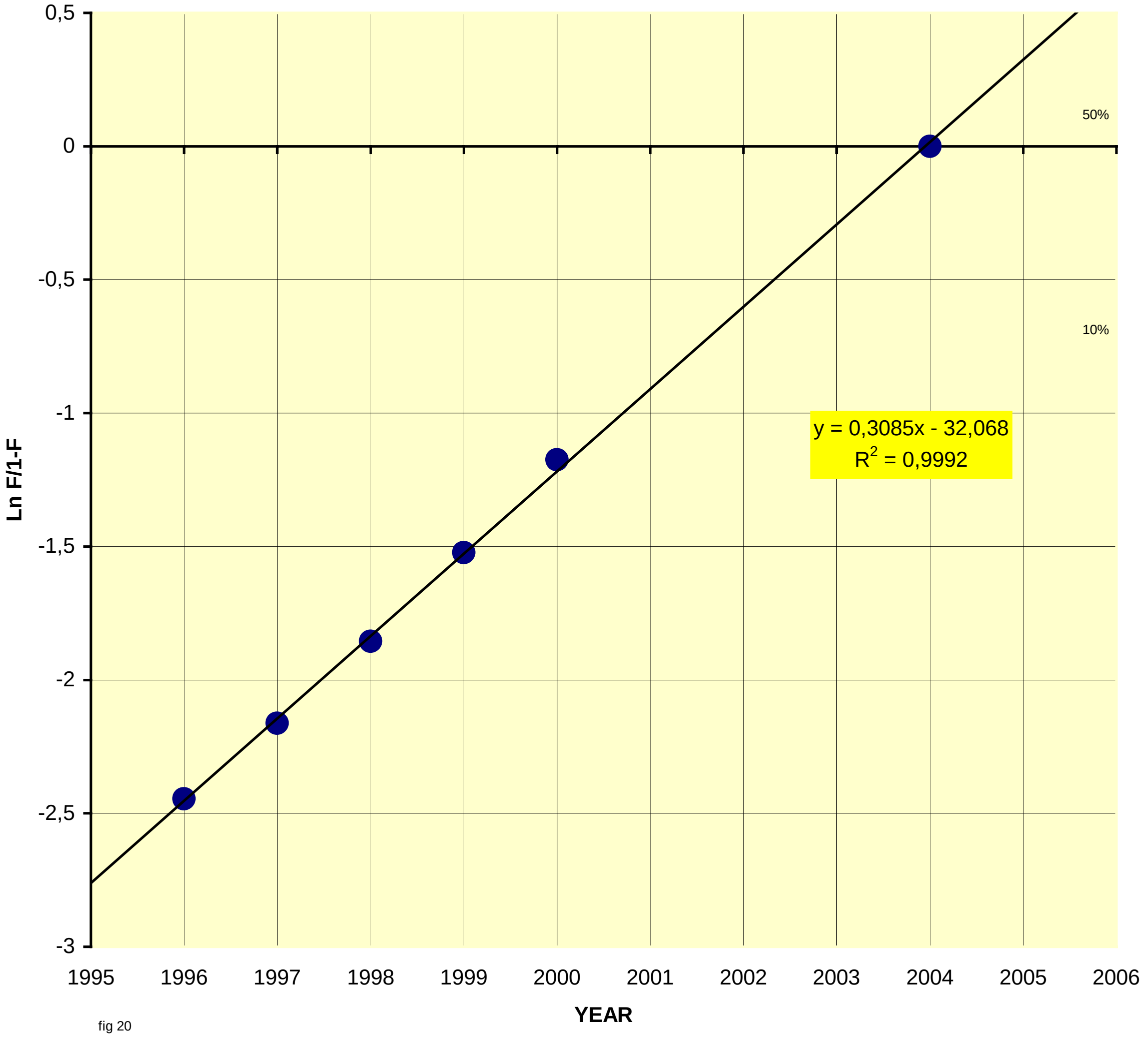


fig 20

EVOLUTION OF THE NUMBER OF MOBILE TELEPHONE IN BRAZIL
(Ref. ANATEL, JIV and MVG Paris, April 2001, F=N/50 millions)

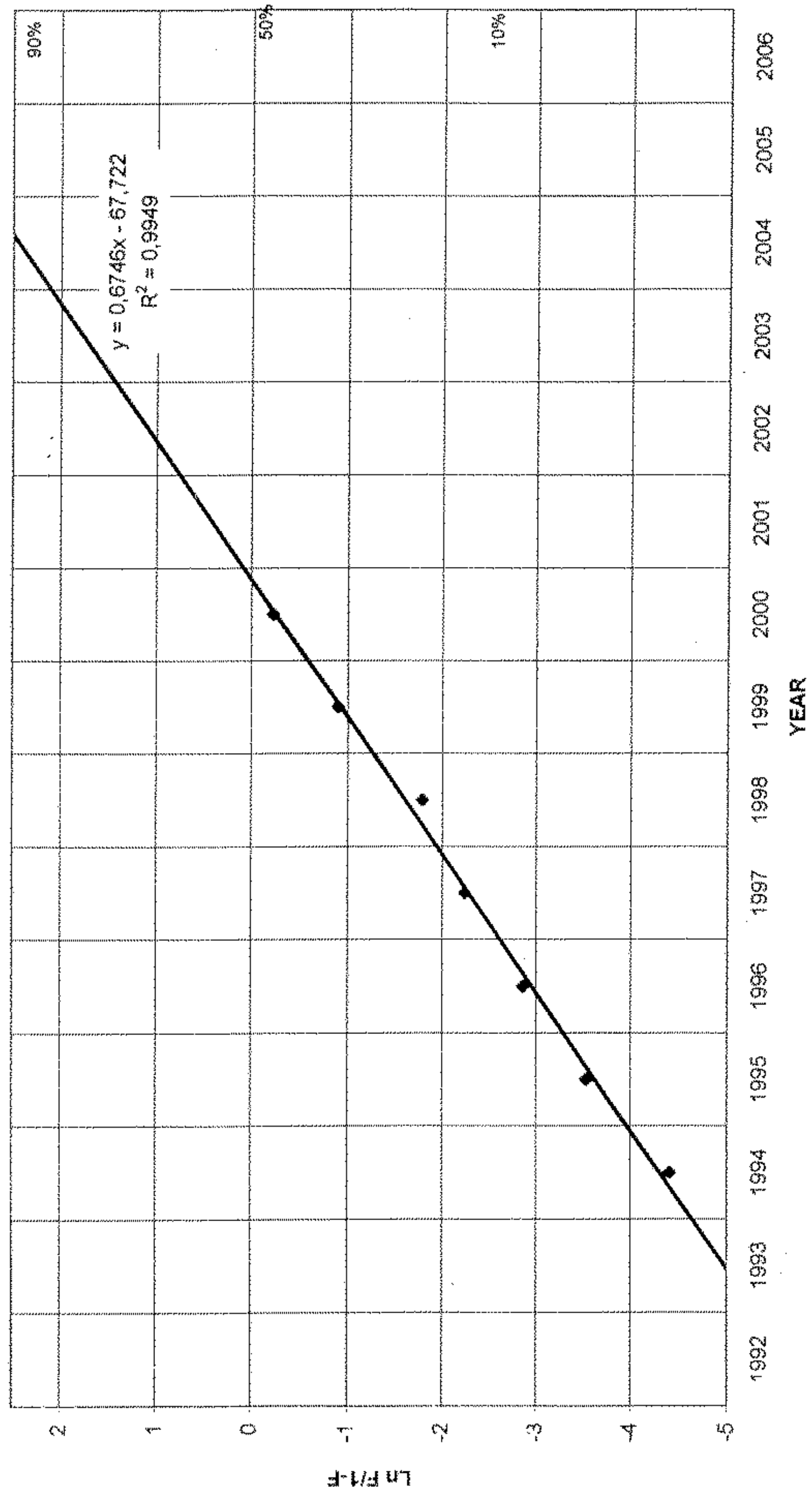


Figure 21

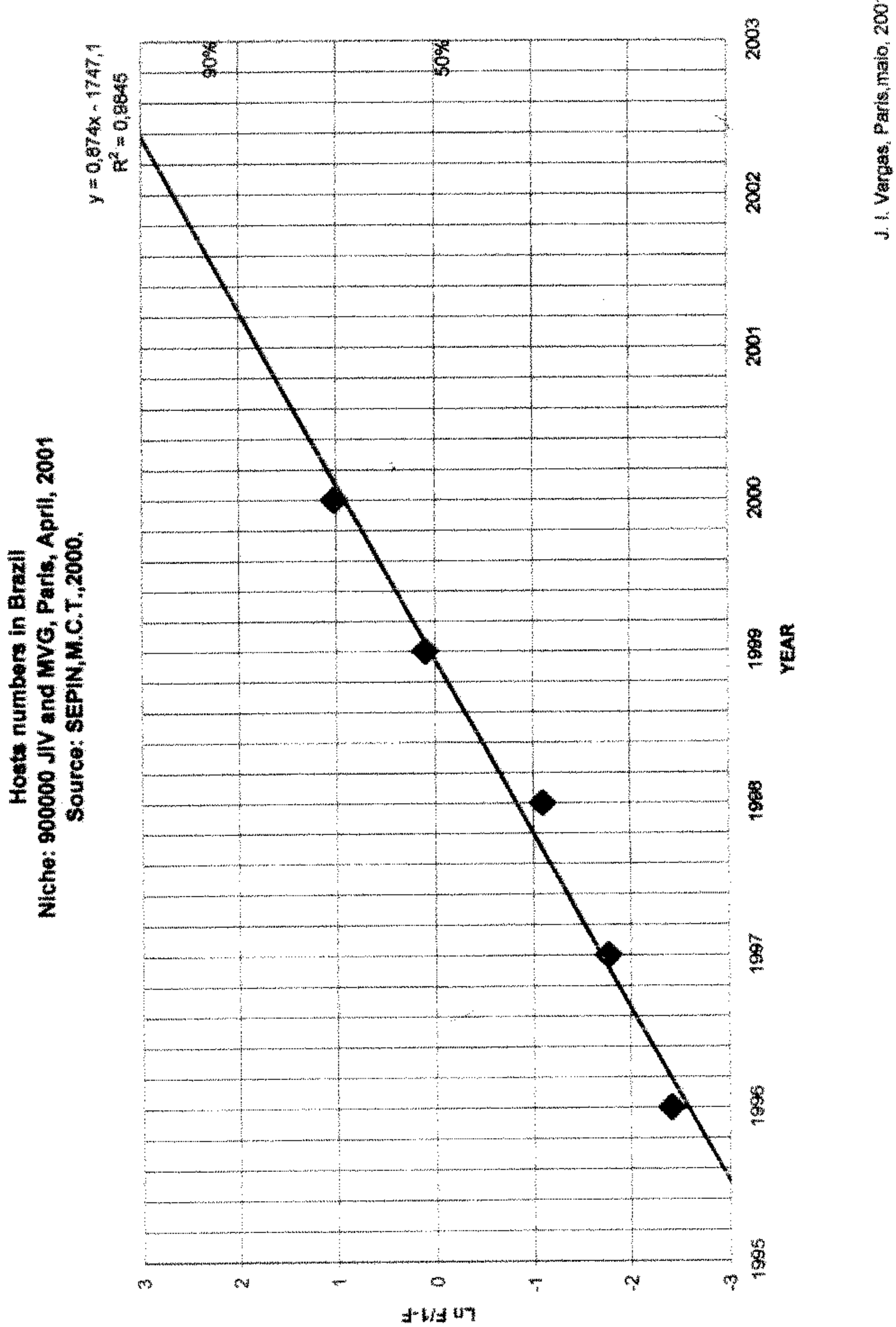
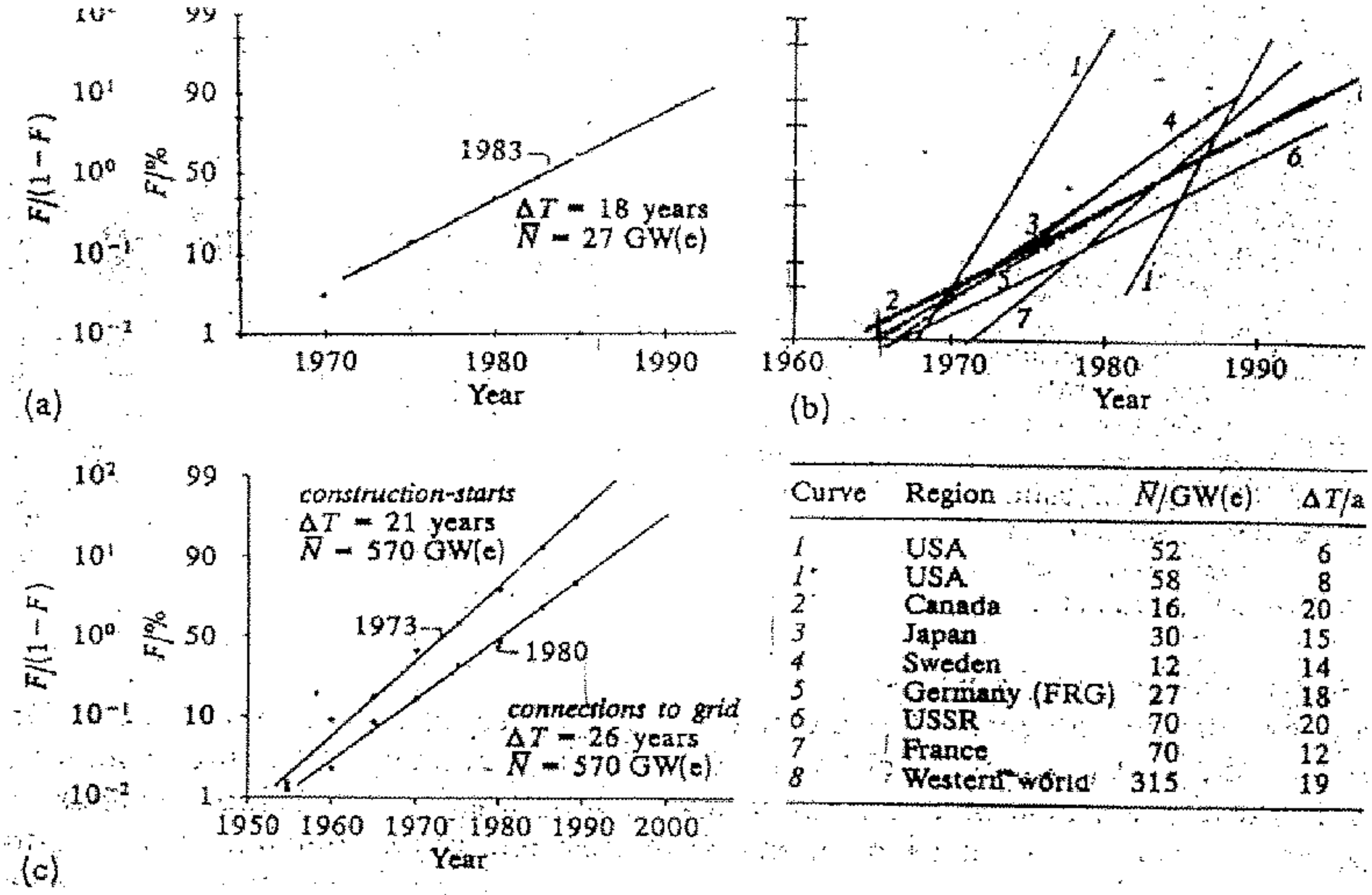

Hosts numbers in Brazil
Niche: 900000 JIV and MVG, Paris, April, 2001
Source: SEPIN,M.C.T.,2000.
y = 0,874x - 1747,1
R^2 = 0,9845
90%
50%
3
2
1
0
-1
-2
-3
Ln F/1-F
1995
1996
1997
1998
1999
2000
2001
2002
2003
YEAR
J. I. Vargas, Paris,maio, 2001.

Figure 22

FIGURE 23



Curve	Region	$\bar{N}$/GW(e)	ΔT/a
1	USA	52	6
1'	USA	58	8
2	Canada	16	20
3	Japan	30	15
4	Sweden	12	14
5	Germany (FRG)	27	18
6	USSR	70	20
7	France	70	12
8	Western world	315	19

Marchetti,C. Perspectives in Energy, 2, 19-34, 1992

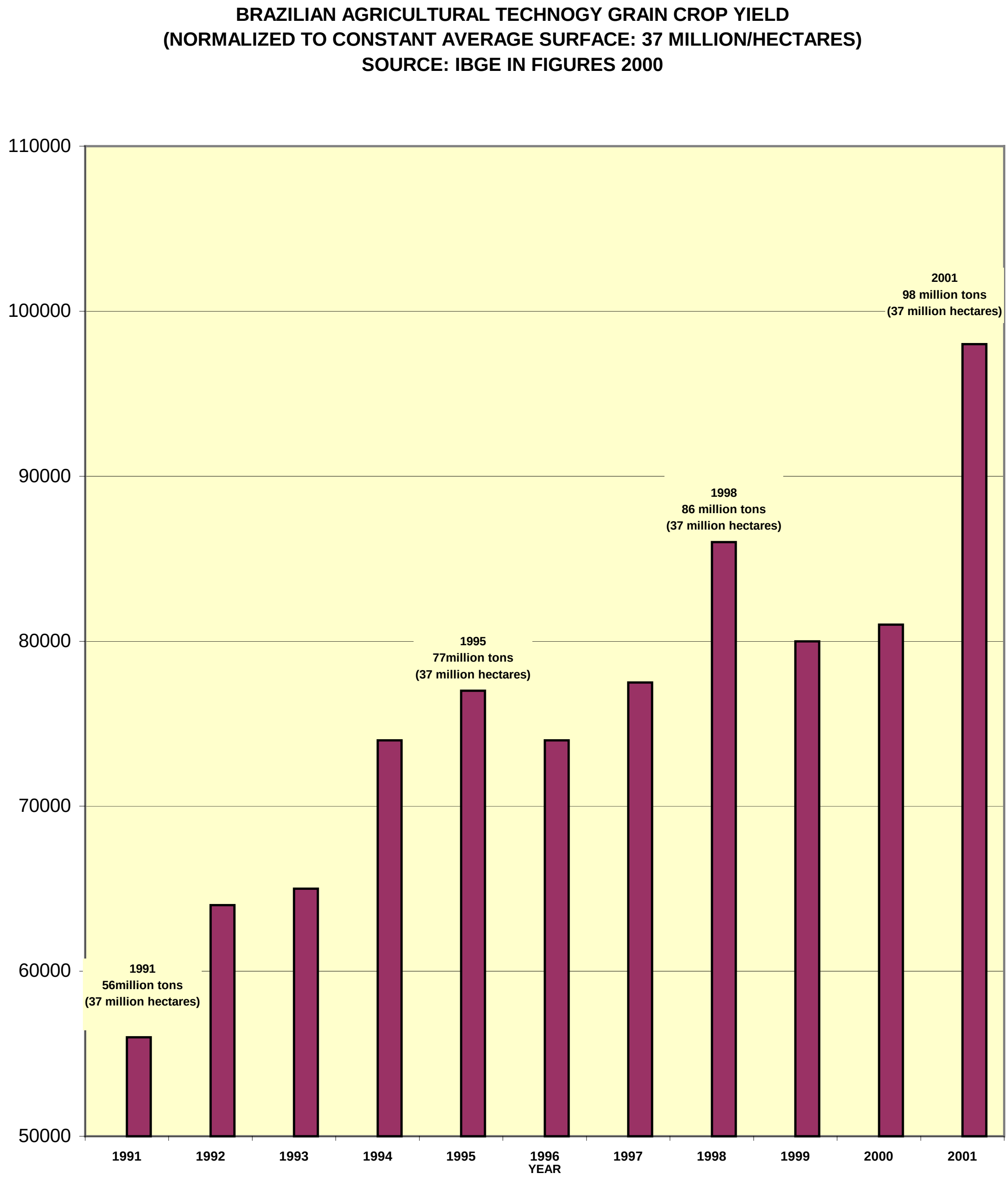

BRAZILIAN AGRICULTURAL TECHNOGY GRAIN CROP YIELD
(NORMALIZED TO CONSTANT AVERAGE SURFACE: 37 MILLION/HECTARES)
SOURCE: IBGE IN FIGURES 2000
110000
100000
90000
80000
70000
60000
50000
1991
56million tons
(37 million hectares)
1995
77million tons
(37 million hectares)
1998
86 million tons
(37 million hectares)
2001
98 million tons
(37 million hectares)
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
YEAR

FIG. 24

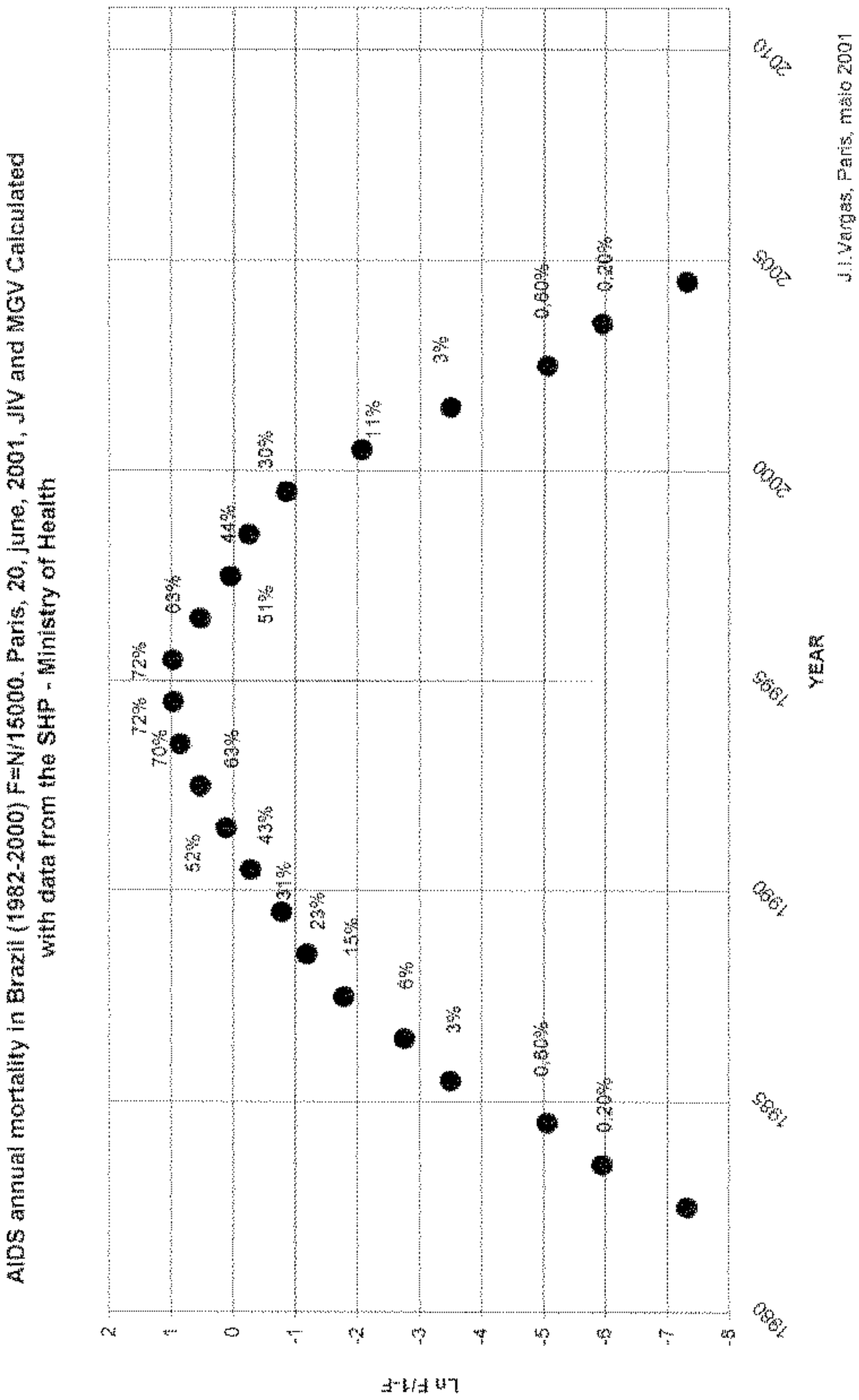

AIDS annual mortality in Brazil (1982-2000) F=N/15000. Paris, 20, june, 2001, JIV and MGV Calculated
with data from the SHP - Ministry of Health
Ln F/1-F
YEAR
1980
1985
1990
1995
2000
2005
2010
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
0,20%
0,60%
3%
6%
15%
23%
31%
43%
52%
63%
70%
72%
72%
63%
51%
44%
30%
11%
3%
0,60%
0,20%
J.I.Vargas, Paris, maio 2001

Figure 25

Figure 26

Human development index in selected countries

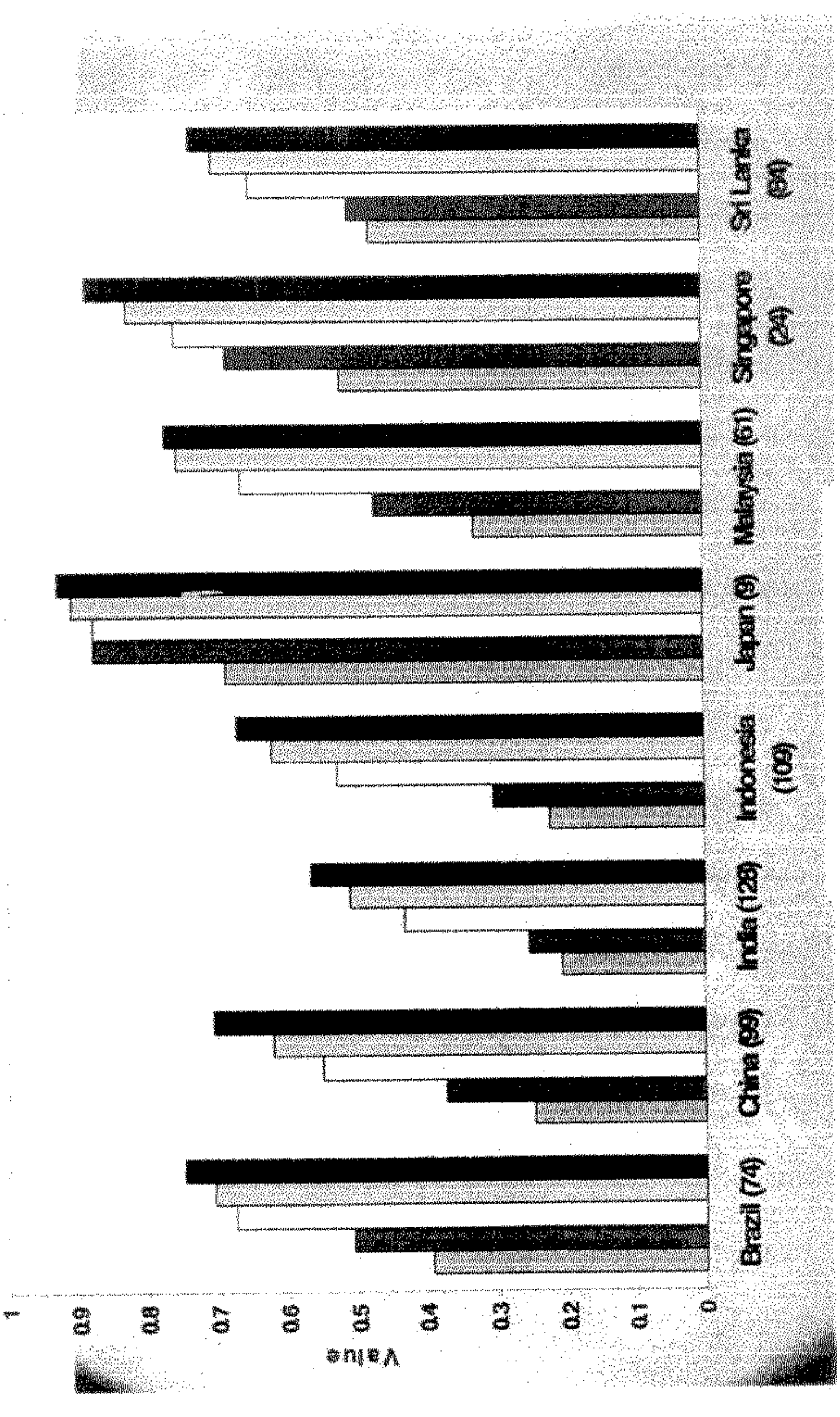


Figure 27

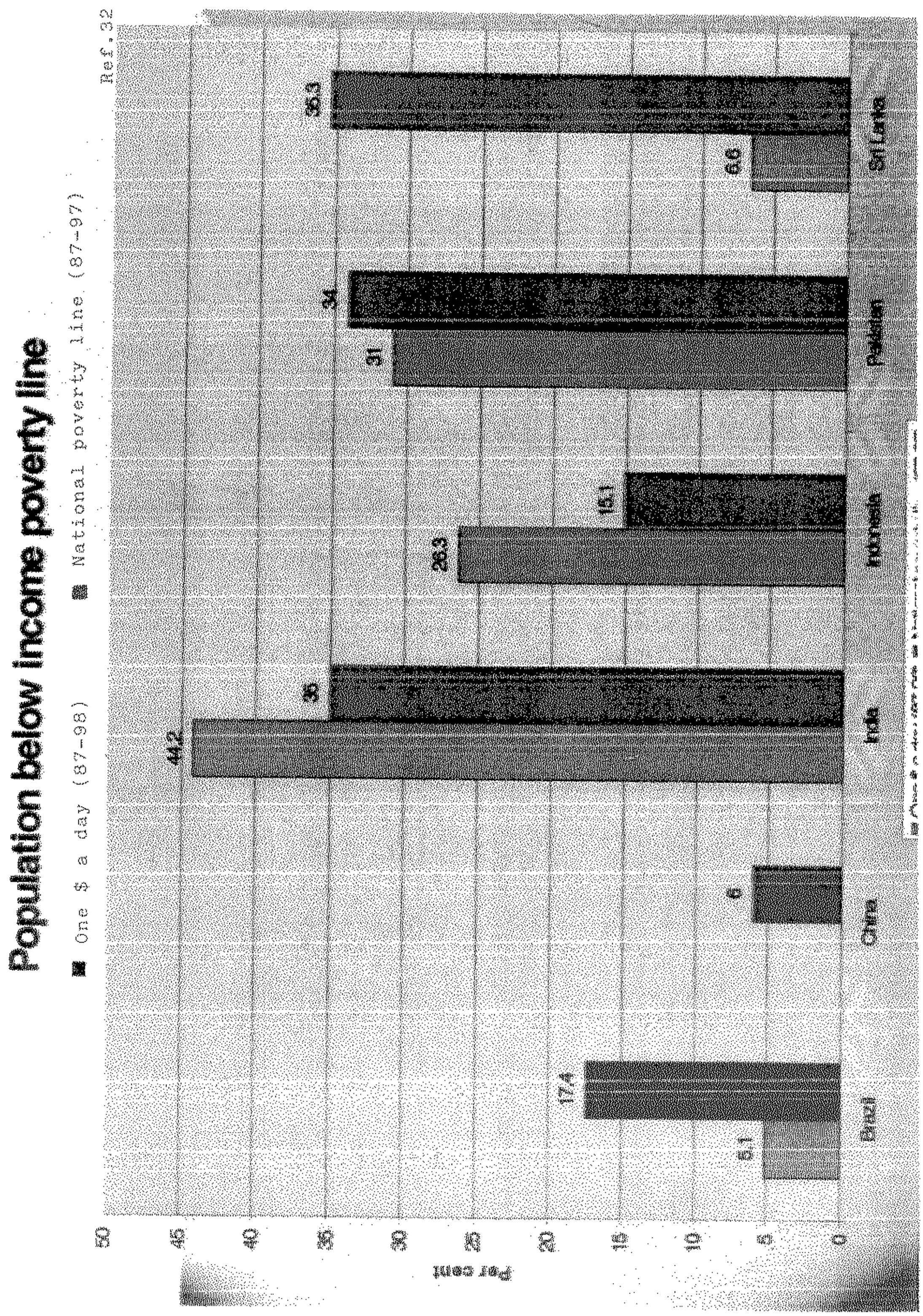

Population below income poverty line
One $ a day (87-98)
National poverty line (87-97)
Ref. 32
Per cent
0
5
10
15
20
25
30
35
40
45
50
Brazil
China
India
Indonesia
Pakistan
Sri Lanka
5.1
17.4
6
44.2
35
26.3
15.1
31
34
6.6
35.3

Table 1

World top-10 countries by economic size, 1998

	GDP, PPP (current international $)		GDP at market prices (current US$)		Population, total	
	bn. US$	In % of world	bn. US$	In % of world	Million	In % of world
United States	8002.2	21.3	8230.4	28.6	270.3	4.6
China	3846.2	10.2	959.0	3.3	1238.6	21.3
Japan	2940.0	7.8	3783.0	13.2	126.4	2.2
India	2034.6	5.4	430.0	1.5	979.7	16.8
Germany	1818.9	4.8	2134.2	7.4	82.0	1.4
France	1246.1	3.3	1427.0	5.0	58.8	1.0
United Kingdom	1201.0	3.2	1357.2	4.7	59.1	1.0
Italy	1185.5	3.2	1171.9	4.1	57.6	1.0
Brazil	1097.7	2.9	778.2	2.7	165.9	2.9
Russian Federation	947.7	2.5	276.6	1.0	146.9	2.5

Source: World Bank.

"Country Survey: Brazil", OECD 2001

Table 2 :

MAIN INDICATORS ON THE BRAZILIAN HIGHER EDUCATION SYSTEM

	1937	1994	1998	GROWTH
UNIVERSITIES	2	127	973	486
HIGHER EDUCATION PROGRAMMES	200	4.367		218
PROFESSORS	3.300	160.000	174.289	53
UNDERGRADUATE STUDENTS	25.000	1.600.000	2.125.958	85

Source : IBGE.Brazil in Figures, 2.000

	1994	2000
POST-GRADUATE PROGRAMMES : DOCTORATE	562	837
POST-GRADUATE PROGRAMMES : MASTER	1.074	1.537
MASTER STUDENTS	41.400	63.591
DOCTORATE STUDENTS	16.300	33.004
MASTER DIPLOMAS CONFERRED	7.500	18.374
DOCTORATE DIPLOMAS CONFERRED	1.700	5.344

Source : MCT/ABC. LIVRO VERDE 2001

Table 3

Brazil main energy and CO_2 emission indicators, comparisons with selected large countries,1998

	Brazil	Argentina	Mexico	India	China	South Korea	Japan	OECD Europe	USA
Total TPES (Mtoe)	**175**	62	148	476	1.031	163	510	1.737	2.182
% annual growth 71-98	***3.5%***	*2.3%*	*4.5%*	*3.6%*	*3.7%*	*8.9%*	*2.4%*	*1.2%*	*1.2%*
TPES per capita (toe)	**1.1**	1.7	1.5	0.5	0.8	3.5	4.0	3.4	8.1
% annual growth 71-98	***1.5%***	*0.8%*	*2.0%*	*1.5%*	*2.2%*	*7.5%*	*1.7%*	*0.7%*	*0.2%*
Electricity cons. per capita (kWh)	**1.939**	2.053	1.906	504	942	5.068	8.192	5.893	14.135
% annual growth 71-98	***5.0%***	*2.8%*	*4.3%*	*5.5%*	*6.7%*	*10.8%*	*3.0%*	*2.4%*	*2.0%*
Energy import dependency (% of TPES)[1]	**28%**	-29%	-54%	13%	1%	83%	78%	35%	22%
Energy intensity (TPES/GDP, toe/'000 US$)	**193**	209	195	320	248	303	198	223	310
CO_2 per capita (tonnes)	**1.8**	3.8	3.7	0.9	2.3	8.0	8.9	7.7	20.1
Carbon intensity (CO_2/GDP, tonnes/'000 US$)	**326**	466	470	611	687	687	437	504	768
Carbon intensity of energy mix (CO_2/TPES, tonnes/toe)	**1.69**	2.23	2.41	1.91	2.77	2.27	2.21	2.26	2.48

1. A negative figure indicate an exporting country.
Source: IEA

"Country Survey: Brazil", OECD 2001

Table 4

Eletricity costs

Some comparative elecrtricity generating cost projections for 2005-2010, in cents per kilowatt-hour.

	Nuclear	Coal	Gass
France	3.22	4.64	4.74
Russia	2.69	4.63	3.54
Japan	5.75	5.58	7.91
South Korea	3.07	3.44	4.25
Spain	4.1	4.22	4.79
United States	3.33	2.48	2.33-2.71
Canada	2.47-2.96	2.92	3.00
China	2.54-3.08	3.18	

Source:OECD/IEA NEA

ANNEX 1

BRAZILIAN LEGISLATION ON INCENTIVES TO PROMOTE SCIENCE AND TECHNOLOGY

LAWS

Law n° 10197, of February 14, 2001.
Adds provisions to Decree-law n° 719 of June 31, 1969 to treat about financing the introduction and the restoring of research infrastructure in higher education or research Public Institutions, and takes other measures.

Law n° 10168 of December 29, 2000
Creates a contribution of intervention in the economic field with the goal to finance the Incentive Program of Company-University Integration to the Support of Innovation, and takes other measures.

Law n° 10148 of December 21, 2000
Gives new wording to art. 1 of Law n° 9530 of December 10, 1997 that treats about financial dividendes and surplus of indirect Federal Public Administration funds or entities.

Law n° 10052 of December 24, 2000
Creates the Telecomunications Technological Development Fund – FUNTEL – and takes other measures.

Law n° 9994 of July 24, 2000
Creates the Technic and Scientific Development Program for space sector, and takes other measures.

Law n° 9993 of July 24, 2000
Assigns financial allowance from hydric resources utilisation to generate electric energy and from mineral working to science and technology sector.

Law n° 9992 of July 24, 2000
Changes the assignment of proprer revenues coming from contracts signed with National Road Department with the goal to finance scientific research programs and projects and to technicaly develop the productive sector of land transportation, and takes other measures.

Law n° 9991 of July 24, 2000
Takes provisions about investments in develop and research and in energetic efficiency made by enterprises who were given concessions, permissions and autorisations to deal in energy sector, and takes other measures.

Law n° 9478 of August 6, 1997
Takes provisions about national energetic policy, activities related to oil monopoly and creates the Energetic Policy's National Council and the Oil National Agency, and take other measures.

(regulated by law no 9847 of October 26, 1999 and by Decrees nos 2455 of January 14, 1998 – 2457 of January 14, 1998 – 2705 of August 3, 1998 – 2745 of August 24, 1998 2851 of November 30, 1998 – 2926 of January 7, 1999)
(See Decree no 2851 of November 30, 1998 – Decree no 3520 of June 21, 2000 – Order MCT no 552 of December 8, 1999 and Order no 553 of December 8, 1999)
Law n° 8172 of January 22, 1991
Restores the Scientific and Technologic Development Fund – FNDCT

Law n° 8001 of March 13, 1990
Defines the distribution parts of financial allowance treated by law no 7990 of December 28, 1989, and takes other measures.

* With changes stated by laws nos 9433 of January 8, 1997 and 9993 of July 24, 2000.

Law n° 7990 of December 28, 1989
Creates for states, federal district and local disctricts a financial allowance for results coming from tapping of oil and natural gaz, hydric resources generating electric energy and mineral resources, in their respectives lands, continental platforms, territorial waters and exclusively economic zones, and takes other measures.
(with changes stated by laws nos 8001 of March 13, 1990 – 9648 of May 27, 1998 and 9993 of July 24, 2000.)
(regulated by decree no1 of January 11, 1991)

DECREES

Decree n° 3737 of January 30, 2001
Takes provisions about the FUNTEL (Telecommunications Technologic Development Fund) regulation, and takes other measures

Decree of April 3, 2000
Creates the work group with the goal to set up a Scientific and Technologic Development Program to health sector and its own financing model.

Decree of April 3, 2000
Creates the work group with the goal to set up a Scientific and Technologic Development Program to agriculture business and its own financing model.

Decree of April 3, 2000
Creates the work group with the goal to set up a Scientific and Technologic Development Program to aerial navigation and its own financing model.

Decree n° 2851 of November 30, 1998
Takes provisions about Scientific and Technic Research Support Programs applied to oil industry , and takes other measures.
(with changes stated by Decree no 3318 of December 30, 1999)
(See law no 9478 of August 6, 1997 – Order MCT no 552 of December 8, 1999 and Order MCT no 553 of December 8, 1999)

Decree n° 2705 of August 3, 1998
Defines standards for the counting and the collecting of government shares treated by law no 9478 of August 6, 1997, applicable to working, development and production activities on oil and natural gaz, and takes other measures.

Decree n° 1 of January 11, 1991
Regulates the financial allowance payement created by law no 7990 of December 28, 1989, and takes other measures.

INTERMINISTERIAL ORDERS

Order MCT/MEC n° 509 of August 24, 2000
Designates delegates to form the interministerial comitee as stated by art 2 of intern measure no 2021-4 of July 28, 2000 taking provisions about financing the introduction and the restoring of research infrastructure in research and higher education Public Institutions.

ORDERS

Order MCT n° 1004 of December 19, 2000
Designates delegates to form the coordination cometee that manages the application of resources provided to FNDCT (Scientific and Technologic Development Fund) as a substitute of another member designated by Order MCT no 205 of May 24, 1999.

Order MCT n° 968 of November 30, 2000
Designates delegates to form the coordination cometee that manages the application of resources provided to FNDCT (Scientific and Technologic Development Fund) as a substitute of another member designated by Order MCT no 205 of May 24, 1999.

Order MCT n° 795 of September 28, 2000
Designates delegates to form the coordination cometee that manages the application of resources provided to FNDCT (Scientific and Technologic Development Fund) as a substitute of members designated by Order MCT no 205 of May 24, 1999.

Order MCT n° 553 of December 8, 1999
Confirms the internal rules o the coordination cometee of Scientific and Technic National Plan for oil and natural gaz sector. CTPETRO.

Order MCT n° 552 of December 8, 1999
Confirms the Scientific and Technic National Plan for oil and natural gaz sector – CTPETRO for period 1999-2003.

Order MCT n° 205 of May 24, 1999
Designates delegates to form the coordination cometee that manages the application of resources provided to FNDCT (Scientific and Technologic Development Fund)
* with changes stated by orders MCT nos 795 of September 28, 2000 – 968 of November 30, 2000 and 1004 of December 12, 2000.

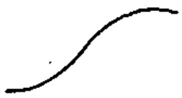
Appendix II
The Mathematical Methodology *

The mathematics used in this analysis is extremely simple. Because historians may not be familiar with it, we add this note for illustration. The basic concept that *action paradigms* diffuse epidemically, is condensed in the epidemic equation:

$$dN = aN(\overline{N} - N)dt$$

saying that the number of *new* adopters (dN) during time dt is proportional (a) to the number of actual adopters (N) multiplied by the number of potential adopters ($\overline{N} - N$), where $\overline{N}$ is the final number of adopters.

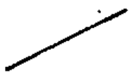
The integration of this equation gives



$$N = \overline{N}/[1 + \exp -(at + b)]$$

which is the expression of a logistic S-curve well known to epidemologists and demographers. *We apply it to ideas.*

In the charts of the present paper the logistic equation is presented in an intuitively more pregnant form. N is measured in relative terms as fraction of $\overline{N}(F = N/\overline{N})$, and the S-curve is "straightened" by plotting $\log(F/1 - F)$ (Fisher–Pry transform).



$$\log(F/1 - F) = at + b\ .$$

The time constant ΔT is the time to go from $F \simeq 0.1$ to $F \simeq 0.9$. It takes the central part of the process (80%) and the relation between ΔT and the a in the equation is $\Delta T = 4.39/a$.

The central date T_0 is defined as b/a .

The final number of adopters $\overline{N}$ is given as a number in parenthesis.

* C. Marchetti, Antropological Invariants in Travel Behavior. International Institute for Applied Systems Analysis, Laxenburg, Austria. August 1992.

List of References

1. **AZEVEDO,** Fernando ed., As Ciências no Brasil, 2 vol., Edições Melhoramentos, São Paulo, 1954.

2. **SCHWARTZMAN,** Simon, Formação da Comunidade Científica no Brasil, Editora FINEP, Rio de Janeiro, 1979.

3. **MCT,** Ciência e Tecnologia nos Anos 90, Brasília (DF), 1998.

4. **VARGAS,** J.I. Political Constraints to Science led Development in the South: the case of Brazil, Third World Academy of Science Ministerial Meeting, 5th TWAS General Conference, Rio de Janeiro, 1996.

5. **MCT and Academia Brasileira de Ciências,** Ciência, Tecnologia e Inovação, Brasília (DF), Julho 2001.

6. **SANTOS**, M.D.S. Ann. Acad. Bras. Ciências, Rio de Janeiro, 1940.

7. **WATHAGIN,** G.; **POMPEIA,** A. **and SANTOS,** M.D.S., Phys. Rev. 57, 51.

8. **WATHAGIN,** G. **and. SANTOS,** M.D.S**.,** Cosmic Rays at Great Depth, **Ann.** Acad. Bras. of Sciences, 11, 1970.

9. **LATTES,** C.M.G. and **WATHAGIN,** G. Phys. Rev. 69, 1946.

10. **SHOENBERG**, M. and **GAMOW,** G., Phys. Rev., 59, 7, 539-547, New York, 1941.

11. **LATTES**, C.M.G.; **OCCHIALINI,** G.P.S. and **POWELL,** C.S.,Nature**,** 159, 694 – 697, and also 453, 1947.

12. **LATTES**, C.M.G.; **OCCHIALINI**, G.P.S. and **POWELL**, C.S.,Nature, 1947, 160, 486 – 492.

13. **BURFERMING,** J.; **GARDNER,** E. and **LATTES,** C.M.G., Phys. Rev., 75, 112 – 117, 1949.

14. **FRANK,** C. Nature, 160, 525.

15. **ZELDOVICH,** Y.B. Dokl. Akad. Nan.K SSSR 95, 493, 1954.

16. **ALVAREZ**, L.W. et al Phys. Rev., 105, 11-27, 1957.

17. Calculated from **OECD,** **Economic Survey – Brazil**, Preliminary Version**,** 232, June 2001.

18. **MADISON,** Angus, Historia del Desarollo Capitalista – sus fuerzas dinamicas, Ariel S.A. Ed.,Mexico DF, 1990.

19. **VARGAS ,**J.I. and **KLINGL,** O. calculated from data contained in a) Estatísticas Históricas do Brasil, vol. 3, Séries Econômicas, Demográficas e Sociais, 1550 a 1985, IBGE, Rio de Janeiro, 1987 ; b) IBGE Brazil in Figures, 8 and from MINISTÉRIO DE MINAS E ENERGIA, Balanço Energético Nacional, 2000 Brasília (DF), 2000.

20. **VARGAS**, J.I. "A Prospectiva Tecnológica: Modelos Matemáticos" Parcerias Estratégicas, Secretaria Especial de Assuntos Estratégicos, 1, 49, Brasilia (DF), 1995.

21. **MODIS,** Theodore, Predictions, Simon & Schuster Eds.,New York,1992.

22. **MARCHETTI**, C. Society as a Learning System: Discovery, Invention **and** Innovation Cycles Revisited, IIASA, Technological Forecasting and Social Change, 18, 267 – 282, 1980.

23 MARCHETTI, C. Fifty Year pulsation in Human Affairs: Analysis of some Physical Indicators, Futures, 17, 376 – 388, IIASA , Laxenburg, Austria, 1986.

24.VARGAS, J.I. " Brazillian Energy Scenario", Roundtable 8, G.T.N. – UNESCO Science Symposium, CBPF, CS – 003/ 92 Rio de Janeiro 1992 and data used from reference 12.

25. VARGAS, J.I. (apud **MARCHETTI**) Science and Technology Development: Government Action and some Human Resources Issues**,** Colloquium on Science and Technology for the Future of Latin America, UNESCO, Mexico City, 2 – 6 Dec. 1990 and IBGE, Brazil in Figures, 8, Brasília (DF) 2000. (Figure 9 – calculated with data from last reference by **VARGAS,**J.I. and **GARZON,**M.V., Paris, April 2001.

26. Data from Confederação Nacional da Indústria and Confederação Nacional do Comércio, and personal communication, INEP (National Institute for Educational Research), Brasília(DF), August 2000.

27. INSTITUTE FOR SCIENTIFIC INFORMATION, 1981 – 2000, obtained through the Ministry of Science and Technology of Brazil.

28. MCT, Secretary for Information Technology Policy, Report, Brasilia (DF), 2000.

29. VARGAS,J.I. **and GARZON,**M.V., Paris, April 2001, calculated with **Data** from World Intellectual Property Organization, Geneva, 2000.

30. CASSIOLATO, J. "Balanço Tecnológico do Brasil 1990 – 1996", MCT / FINEP report, Rio de Janeiro, 1997. Data from the Brazilian Central Bank **and** the Brazilian Institute for Industrial Property (INPI) up to 1996; for 1995 – 1999, data from the Brazilian Central Bank / DEPEC/ DEPRAP, summed up in reference 4.

31. MARCHETTI, C. Perspectives in Energy, 2 , 19 – 34, 1992.

32. WEI ZHANG, M. and **COORAY,** N.S. "Sustainable Industrialization in East and Southeast Asia: Indonesia and China compared in the 1990", Symposium on Sustainable Development in an Era_of Rapid Technological Change, Institute of Advanced Studies, United Nations University, Tokyo, June 14th 2001.

33. Ministry of Health, Secretariat for Health Policies, National Coordination for STD and Aids, The Brazilian Response to HIV/AIDS: Best Practices, Brasília (DF), 2000.