The impact of the socio-economic crisis of 2001 on the scientific system of Argentina from the scientometric perspective

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Abstract: In recent years a number of studies have addressed the topic of the economic crisis of Argentina in 2001, and its repercussions upon the political, social, and institutional systems of the country. However, no studies to date have analyzed the effects of the crisis upon the country´s scientific system from a scientometric perspective, with an analysis of the resources dedicated to scientific activity as well as the final results in terms of output and impact. The present study attempts to show the effects of the 2001 crisis upon the scientific system by means of a set of scientometric indicators that reflect economic effort, human resources dedicated to research, publications, collaborative relations, and the international visibility of scientific contributions.

Key-words: Scientific system; Scientometric indicators; Socio-economic crisis; 2001; Argentina

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1. Introduction

The investment in science and technology is on the global rise, to the point where leading countries can report a volume between 2% and 3% of their Gross Domestic Product (GDP). Argentina, like many other Latin American countries, allocate few part of the budget to science, only 0.5% of their GDP. Contrariwise to what happens in developed economies, the highest proportion of expenditure on R&D in this region comes from the public sector (MINCYT, 2006). At least, this indicator is calculated by the international standard method based on Frascati principles (OECD, 2002)

Various authors have explored the reasons for such scarce investment in science by Latin American administrations. Some associate it to the fairly recent development of scientific activity in the region —in Latin America, the processes geared towards the institutionalization of scientific activity and the establishment of governmental policies in this realm did not take root until after World War II (Vessuri, 1987). This hypothesis is less convincing if we look at countries such as Brazil, where the processes behind scientific institutionalization took place practically at the same time as in Argentina, or after, but investment in R&D reaches 1% of the GDP.

Still other authors link the poor investment between a lack of demand on the part of society, and a certain disassociation between explicit scientific policies, in the form of laws, statutes and plans, with the implicit policies, or the expression of social demand for national scientific and technological projects within each country (Herrera, 1995).

A somewhat different view is held by Vessuri (1995), who attributes difficulties for the scientific development of Latin American countries to the cyclical processes of advance and retreat that come as a consequence of political, social and economic waves, occurred over the past fifty years. One recent example would be the tribulations that Argentina endured at the end of the 1990´s and into the early years of this century, triggering the worst socioeconomic crisis in the country history.

This background leads us to reaffirm the notion that, despite the universality of the fundamental forms of disciplinary thought and practice, each country configures its own style of producing scientific output, with individual practices conditioned by the social, political, economic and cultural context (Subramanyam, 1983; Vessuri, 1995; Kreimer and Ugartemendía, 2007).

2. The socio-economic context of Argentina in the period 1990-2007

In the first place, we should recall that until the 1980´s Argentina view a series of democratic and *de facto* governments that set the scene for stages of institutionalizing scientific and technological activities, with accompanying public policy. It can be said that 1983 marked the beginning of a new era of institutional reconstruction, with deep and broad social, economic, political, educational, scientific and cultural implications.

The economic scenario should probably least successful, and towards the end of the decade a hyperinflationary trend was set in motion that rapidly got out of hand. Amid a state of social conflict and discontent, official statements supported by the mass media attributed economic deterioration and budgetary insufficiencies to excessive goverment spending, and the deficit generated by public accounts (Buchbinder, 2005). This phenomenon not only accelerated the resignation of the (then) constitutional president, Raúl Alfonsín, and the precipitated assumption of the president-elect, Carlos Menem; it also forced the new administration to adopt a strong set of market-oriented structural measures. These characterized later socio-economic and political endeavours, throughout the 1990´s (Benedetti, 2003).

Key issues include opening the economy to international trade by reducing the custom tariffs and eliminating tax restrictions; the reopening of foreign credit, which had been highly restricted during the previous decade; the privatization of public enterprises; and the so-called Law of Convertibility — enact in March 1991— which set an equal parity between the Argentine peso and the U.S. dollar, and validated contracts in foreign currency.

These measures, in the opinion of many analysts, reflect specific recommendations based on the "Washington Consensus", an economic policy package considered by the international financial and economic centers in Washington, as the best economic agenda to guarantee growth and the reduction of poverty in Latin American countries. Their success was very short lived, and their consequences were negative and persistent.

Among the apparently successful features of this decade we may cite a steep rise in the GDP, especially during the first years of implementation of the reforms; a reduction of inflation; the entry of foreign capital; a large increase in imports; and a significant improvement in the purchasing power of Argentinians, giving rise to more consumer spending.

On the downside, meanwhile, we see the onset of increasing deterioration of national businesses; a reduction in exports; an inverse relation between income and the commercial balance (when the Argentine economy expanded, the commercial balance deteriorated); increased unemployment; and a rise in number of people living in poverty.

After the third quarter of 1998, the economy became a seemingly endless recessive trend. In 2001 there was a bank crash and large flight of capital, which left the country in the most severe economic crisis of its history (Coiteux, 2003). This caused the regime of convertibility to be discontinued, which in turn led to an external depreciation of the national currency some months later.

A number of studies have analysed the effects of Argentina´s 2001 crisis upon the political, economic, social and even the scientific system (Benedetti, 2003; Coiteux, 2003; Anlló et al., 2007). Yet we find no studies attempting to show the repercussions of the crisis on the scientific system from a scientometric perspective, and with an integral focus embracing the resources assigned to this sector as well as the results and the impact of research. Such this is the aim of our study.

3. Methods

We calculated a set of scientometric indicators related to expenditure and human resources dedicated to R&D, the output measured in terms of publications, the performance (productivity and efficiency), the relations of scientific cooperation, and the international visibility of the results. The period of study is 1990-2007, but for some variables the time period is lower. As data sources we used the Indicators of Science and Technology, published by the *Ministerio de Ciencia, Tecnología e Innovación Productiva de la Nación Argentina* (MINCYT), the Web of Science (WoS) and the Journal Citation Report (JCR), both of the Institute for Scientific Information (ISI).

3.1. R&D expenditure and human resources indicators

GERD (Gross Domestic Expenditures on Research and Development): Is the total expenditure on research and development performed on the country during a given period. Is a key indicator of government and

private sector efforts in the generation of new knowledge or in the diffusion and transfer of existing knowledge.

GERD as a percentage of GDP: It expresses the intensity of effort on R&D as a percentage of Gross Domestic Product (GDP). Is the most commonly used indicator for international comparisons and for defining national policies for science and technology.

Res & ResGr FTE: Is the total number of researchers and research grantees in full time equivalent (FTE) devoted to activities of research and development. A researcher is the person working in the creation of new knowledge, products, processes, methods and systems and the management of the pertaining projects. It includes the senior personnel that develop planning and management activities of the scientific and technical aspects of the researchers' work. A research grantee is a young scientist who carries out R&D activities under the supervision of a researcher, usually with training purposes (MINCYT, 2006)

Res & ResGr per thousand of the EAP: Is the number of researchers and research grantees per thousand of the Economically Active Population (EAP). It therefore stands for the human potential in R&D of a country, and is widely used as an indicator for comparison of countries or regions. The source used to estimate the value of the EAP is provisional estimate of total occupational variables extended to urban produced by the *Dirección Nacional de Programación Macroeconómica, Ministerio de Economía y Producción de la Nación Argentina*, based on OCDE standards.

3.2. Output indicators

Docs in WoS & % Docs In WoS: Number and percentage of documents in a time period. All types of documents included in WoS are considered.

Articles in WoS journals & % Articles in WoS journals: Number and percentage of scientific articles and reviews included in WoS are considered

Articles in domestic and foreign journals: Articles in domestic and foreign journals, whether in WoS o not, reported in the MINCYT own ad-hoc and wide range database of the production of argentine authors.

3.3. Performance indicators

Prod: This index measures scientific productivity, the relation between output and the human resources dedicated to R&D activities. Its formula is: IProd = Docs in WoS / Res & ResGr FTE.

Effic: It indicates the efficiency, calculated as the quotient between expenditure in R&D and output. It is meant to reflect the cost, for the country, of each scientific contribution. Its formula is: Effic = Docs in WoS / GERD (millions national currency).

3.4. Collaboration indicators

CoAut: This indicator, known as the coauthorship index represents the average number of authors per Docs in WoS. Also calculate this indicator for both national and international collaboration.

3.5. Impact indicators

IFR: Is a relative measure of the visibility of scientific contributions derivated of the ISI impact factor (IF). First we calculate a weighted normalized impact factor (FINP), explained in detail by Moya et al (2007), in order to generate IF values that conserve variability, while at the same time making the scales of the different categories compatible and comparable. Then, for comparative analysis across countries or regions we compute the relative impact factor (IFR) as the ratio between the FINP of Argentina (a) in the world (w) using the formula IFR = FINP(a) / FINP(w). The value of reference is 1; hence, if IFR > 1 it means that the visibility of the contributions of the country or region is greater than the world average (and so, IFR < 1 indicates low visibility).

4. Results and discussion

4.1. R&D expenditure

Although there are no data available about the expenditure in R&D for all the years covered in this study —only from 1996 to 2007— data suffice to discern three clearly different situations. The first, corresponding to the period 1996-1999, shows only a slight increase in the economic effort; the second, from 2000 to 2001, reveals a drop in investment; and the third, from 2002 to 2007, shows a rapid recovery has and definite upward trend (**Figure 1**).

The magnitude of this recovery would have two different interpretations, depending on which currency we do the analysis (millions of Argentine pesos or millions of U.S. dollars). One key to understanding the evolution of R&D effort over the period analysed, and in particular during the years mentioned above. The Law of Convertibility rule in Argentina from 1991 to mid 2002, establishing a direct exchange parity of 1 peso = 1 dollar more than a decade. The end of convertibility was followed by an external devaluation of the Argentine currency (from 1:1 it went, in a matter of months, to 3:1). Investment in terms of dollars was therefore greatly reduced, generating a widespread negative impact on the scientific system. Repercussions were immediate: in 2002 overall, investment in dollars was 67% lower than that of the year before. Depreciation also affected the subsidies for research projects, and meant the devaluation of scientists´ salaries and difficulties in obtaining equipment or bibliographic material from abroad.

To compensate for the effects of devaluation, the Argentine government adopted a series of measures that included: an increase in R&D investment, an increase in the budget for external credit to adjust subsidies, and a loan from the Inter-American Development Bank to guarantee access to databases and electronic journals of international prestige (LA NACIÓN, 2002). Consequently, from 2003 the economic effort in R&D registered an upward trend, with exponential growth, even greater than the increase of the GDP. But it was impossible to recover the levels of investment in foreign currency attained in the previous period. In other words, despite the significant increase in investment as measured in pesos, the situation of Argentina´s scientific sector was greatly weakened in comparison with that of its international peers.

We should underline that the so-called crisis of 2001 was set off by a recession that began around the third trimester of 1998 (Coiteux, 2003). It is logical, then, that the repercussions of this process, as reflected by the indicators studied, became evident at different time slot.

4.2. Human resources

According to the two variables for human resources of the system, the effects of the recession were already becoming evident in 1999 (**Figure 2**).

Data for the period 1997-2007 show that from 1999 to 2001 there was stagnation in the body of researchers and an actual decrease in the number of research grantees. The stagnation might have begun in previous years, but there are no official data allowing us to test this premise.

While it is unusual for a scientific system to reduce human resources, this is what happened in Argentina. The explanation is linked to the convergence of different factors during this critical period. On the one hand, there was a freeze upon opening positions, and budgetary restrictions were imposed in the 1990´s, hindering the entrance of research grantees. On the other hand, the emigration of scientists was accentuated at this time, and the natural retirement of older researchers could not be avoided. And aside from the drop in grants, there was an overall decrease in the number of students and postgraduate offerings in fields of science and technology in the years just previous. It is therefore not surprising that, sooner or later, the loss of human capital in the system would make itself manifest as a great handicap.

Deserving mention in this context is the diagnosis made by the Government in 1997: it was declared "*crucial to modify the generational profile of the scientific and technical personnel of the country, facilitating the incorporation of young graduates, fomenting interest in the sciences and technology in the educational system, strengthening the postgraduate activities in the universities, and promoting grants for education in the country and abroad*" (MINCYT, 1998).

Even so, it was not until mid 2001 when, after a long period of discontent and claims on the part of the scientific community, the government announced new openings for research personnel and supporting staff of the *Consejo Nacional de Investigaciones Científicas y Técnicas* (CONICET), and the grant program was reinitiated. As the CONICET represent for nearly 40% of the research grantees of the country, this was an important element for the formation of scientists all over the country. Moreover a further measure was announced: the positions for research fellows in the higher education institutions would also be increased (LA NACIÓN, 2001).

The impact of these measures materialized as a recovery in human resources. From 2002 to 2007, the number of research grantees has doubled and researchers increased by 37% (Figure 2). This growth was also

clearly reflected in the indicator of researchers and research grantees per thousand of the EAP, which eventually adopted an upward trend that lasted to the end of the period analysed here (**Figure 3**).

This ignited a process of generational renovation and strengthening of human capital that can still be seen, sustained by the "Bicentennial" National Strategic Plan of Science and Technology (*Plan Estratégico Nacional de Ciencia y Tecnología "Bicentenario"*), 2006-2010, whose objectives include the quantitative and qualitative improvement of the system´s human resources. The measures are aimed not only to incorporate, promote and prepare researchers and maintain grant offerings, but also to improve salaries, equipment and infrastructure (another cause for the brain drain in the past decade).

4.3. Scientific output

The results of this study show the production of publications in the WoS to be the variable that best resisted the crisis. However, as we shall see below, it was affected by the repercussions of the period just after the crisis, due to the devaluation of the currency and the unfavourable economic context.

Firstly, we observe a 6% mean annual growth in scientific output for the period 1990-2007. A previous study, but corresponding to the period 1991-2000, gave a rate of 9% (Miguel et al., 2006). **Figure 4** illustrates a logistic curve with a decrease in growth after a rapid start.

In light of these results, the interruption of growth in output would be tied to the effects of the economic crisis, and particularly to the fall in investment in the first few years of this decade (**Figure 1**), accompanied by the devaluation of the Argentine peso and the loss of research grantees and researchers recorded from 1999 to 2001 (**Figure 2**).

Analysis of the evolution of articles published in domestic and foreign journals (based on data from the MINCYT), as compared with the articles in journals included in the WoS reveals that there was a sharp decline in the percentage of articles published in WoS and foreign journals from 2002 to 2005. The international presence of Argentina, decrese. Noteworthy is the fact that published output, unlike other variables, was not much affected by the years of recession before the 2001 crisis, at least not for papers in WoS and foreign journals. Rather, the decline came at the end of the year of convertibility and depreciation of the peso. Contrariwise, we should point out that relative weight the volume of articles in domestic journals after the devaluation, began to increase their presence up 2005 and later decreased (**Figure 5**).

4.4. Scientific performance

In addition to the above findings, we see that from 2002 to the end of the period studied there was also a downward trend in the indexes of productivity (Prod) and efficiency (Effic) (**Figure 6**). This happened despite injection of investment and human resources in the post-crisis period.

These data help us to shedding light on some possible interpretations. For one, an increase in human resources in the system, as in Argentina from 2002-2003 onward, does not necessarily translate into a rapid increase in scientific productivity. After hiring new peoples and economic resources the work has to be done before papers can be written, and this may be the largest time lag, because a critical mass of scientist is needed. Probably take several years for the groups were strengthened by the incorporation of new researchers to increase publications and improve productivity.

Meanwhile, the increase in R&D investment from 2003 onward did not manage to reverse the falling trend in financing project and the depreciation of researchers´ salaries caused by devaluation of the national currency. This could also interfere with output in foreign journals, and may explain the gradual decline in efficiency: each Argentinian contribution to international science entailed a cost that grew and grew after the years of convertibility.

4.5. Collaboration

Figure 7 illustrated the evolution over time of two variables: CoAut and Docs in WoS. A view of the entire period (1990-2005) showed co-authorship index to increase at a more rapid pace than output *per se*. The CoAut rose at a mean annual rate of 8%, while output rose just 6%.

Nevertheless, if we break down the evolution of these two variables into shorter time spans, the CoAut the registered a strong growth from 1990 to 1998 was at an annual rate of 6.6%; while output grew nearly 9% during the same period. Then, from 1999 to 2003, the CoAut showed an annual variation of -4.7%, and output continued to grow, though at a slower pace, around 4%. A change in trend took place in 2004 and 2005, with a marked rise in co-authorship, while output continued to grow, but only slightly.

The socio-economic crisis affected the co-authorship with foreign collaborators more heavily. As seen in **Figure 8**, between 1999 and 2003 there was a sharp decrease in international co-authorships involving Argentina, though co-authorships among Argentine scientists themselves showed practically no change.

We should also note that the fall in international co-authorship registered from 1994 to 1995 coincides with a pause in the economic growth of Argentina, as a consequence of the Mexican crisis, also know as 'Tequila Effect' (Benedetti, 2003). Furthermore, Argentina was amid a pre-election period which no doubt generated some uncertainty abroad. We surmise that the vulnerability of the internal scientific, political and economic panorama, exacerbated by the external crisis, might have had a negative effect on in international co-authorship.

The data given here also suggest that the decreasing slope of productivity of 2003-2004 was associated with the lack of human resources some years before. In the following biennial (2004-2007) this index continued on the decline, despite indeed most of 'non-experienced' research grantees were included into existing research teams. Probably the larger teams will work on more projects and publish more papers, but there will always be a lag of several years to do the work and write up the results.

4.6. Scientific impact

Figure 9 show a position of Argentine in terms of visibility below the world average from 1995 to 2005. The drop in relative impact factor in 2003 could be due to the declining number of high-impact articles in journals WoS during the previous three years (Miguel, 2008). Also, may reflect the loss of collaboration with foreign authors during the period 1999-2002. However, as we explained above the true effects of the crisis on the output would not be immediately evident, appearing probably some years later.

5. Conclusions

In the **Table 1** we have an excerpt about the economic crisis in Argentine science. We select the three period explained above, and indicate with arrows (↑) the increse and (↓) decrese of each variable. Two arrows mean a strong change (up or down) of the values. Equal symbol means a no significant change.

The period encompassed by this study coincides with a political and economic context of major reforms and many fluctuations, which led Argentina into the worst socio-economic crisis of its history. It also had important repercussions for the development of scientific activity nationwide, as we see from the results obtained.

The first conclusion we may draw is that the development of Argentina´s scientific system is strongly conditioned by the socio-economic context. This is evident in the wake of the 2001 crisis, and strongly suggests that cyclical processes of advancement and stagnation or retreat of the country´s economy are behind some of the difficulties encountered on the scientific level.

Similarly, we see a paradox of sorts between the political, economic and scientific systems. Whereas during the 1990´s science and technology were not considered state priorities, the scientific output of Argentina underwent exponential growth. This was when the economic context and exchange rate were artificially favourable (the parity of 1 peso = 1 dollar). Then, in the midst of the economic recession and the crisis of 2001, just when the Goverment appeared with policies and measures oriented to reactivate and brace the scientific and technological backbones of the country, the rates of scientific output slowed down and ran into difficulties in sustaining international collaboration, publishing in foreign journals, and maintaining the levels of production attained in the previous decade. Despite the favourable political context, the economic context was unfavourable as a result of the external depreciation of the peso. This would be the key to the relative growth or decline of scientific output in the case of Argentina.

In addition, although the economy of Argentina began to grow at an accelerated rate after 2002, with a mean annual rate of growth near 8%, accompanied by the reactivation of many sectors involving science and technology, our findings also suggest that the expansion of the economy at the macroeconomic level and an explicit and favourable scientific policy could be a key to scientific development of a country, but post hoc does not guarantee propter hoc.

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Figure legends

Figure 1 Gross domestic expenditure on R&D (GERD) and R&D expenditure as a percentage of GDP, Argentina, 1996-2007.

Figure 2 Number of researchers and research grantees in full time equivalent (FTE), Argentina, 1997-2007.

Figure 3 Number of researchers and research grantees per thousand of the Economically Active Population (EAP), Argentina, 1997-2007.

Figure 4 Docs in WoS and Articles in WoS journals, Argentina, 1990-2007.

Figure 5 Percentage of the scientific output (Articles in WoS, foreign and domestic journals), Argentina, 1998-2007

Figure 6 Evolution of the productivity and efficiency indicators, Argentina, 1997-2007

Figure 7 Comparative evolution of the coauthorship index and Docs in WoS, Argentina, 1990-2005

Figure 8 Evolution of numbers of the nationally and internationally coauthored documents, Argentina, 1990-2005

Figure 9 Relative impact factor normalized to the world average, Argentina, 1995-2005.

Table 1 Main indicators of the economic crisis in Argentine science.

Figure 1
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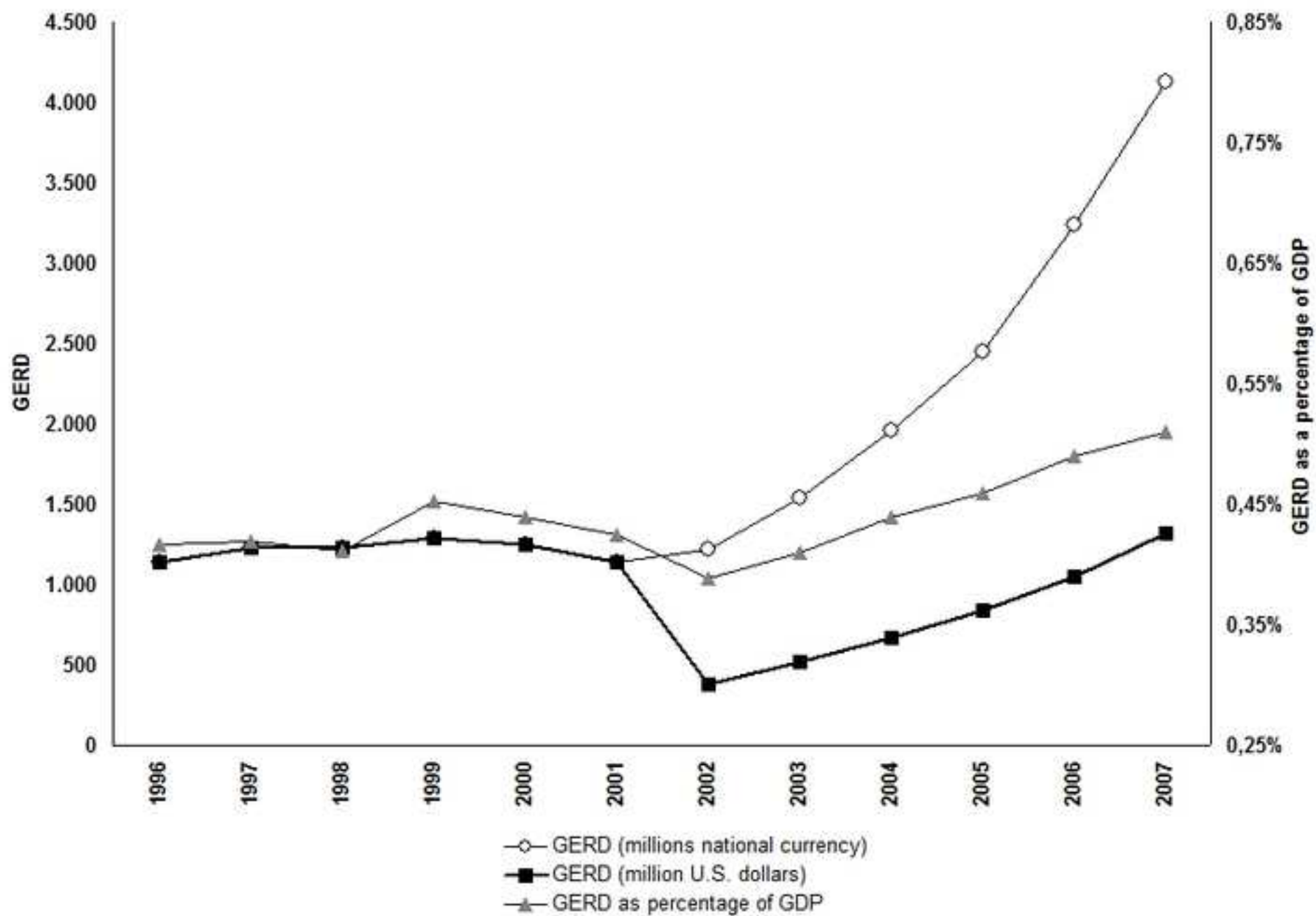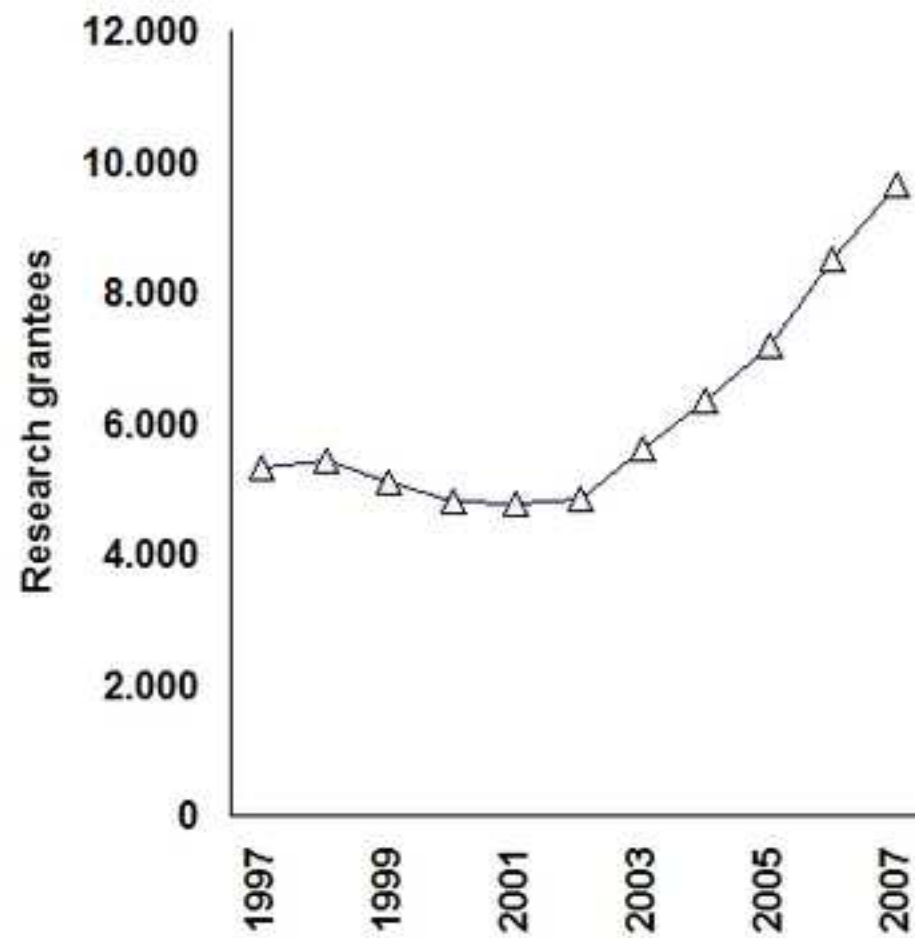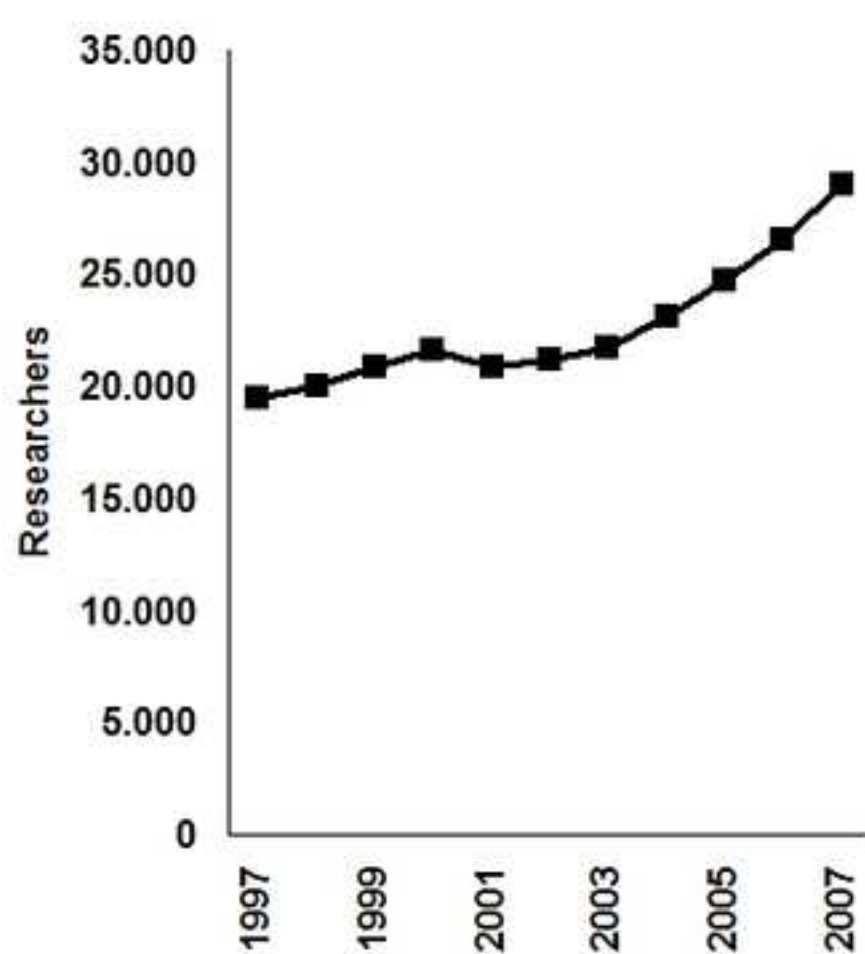
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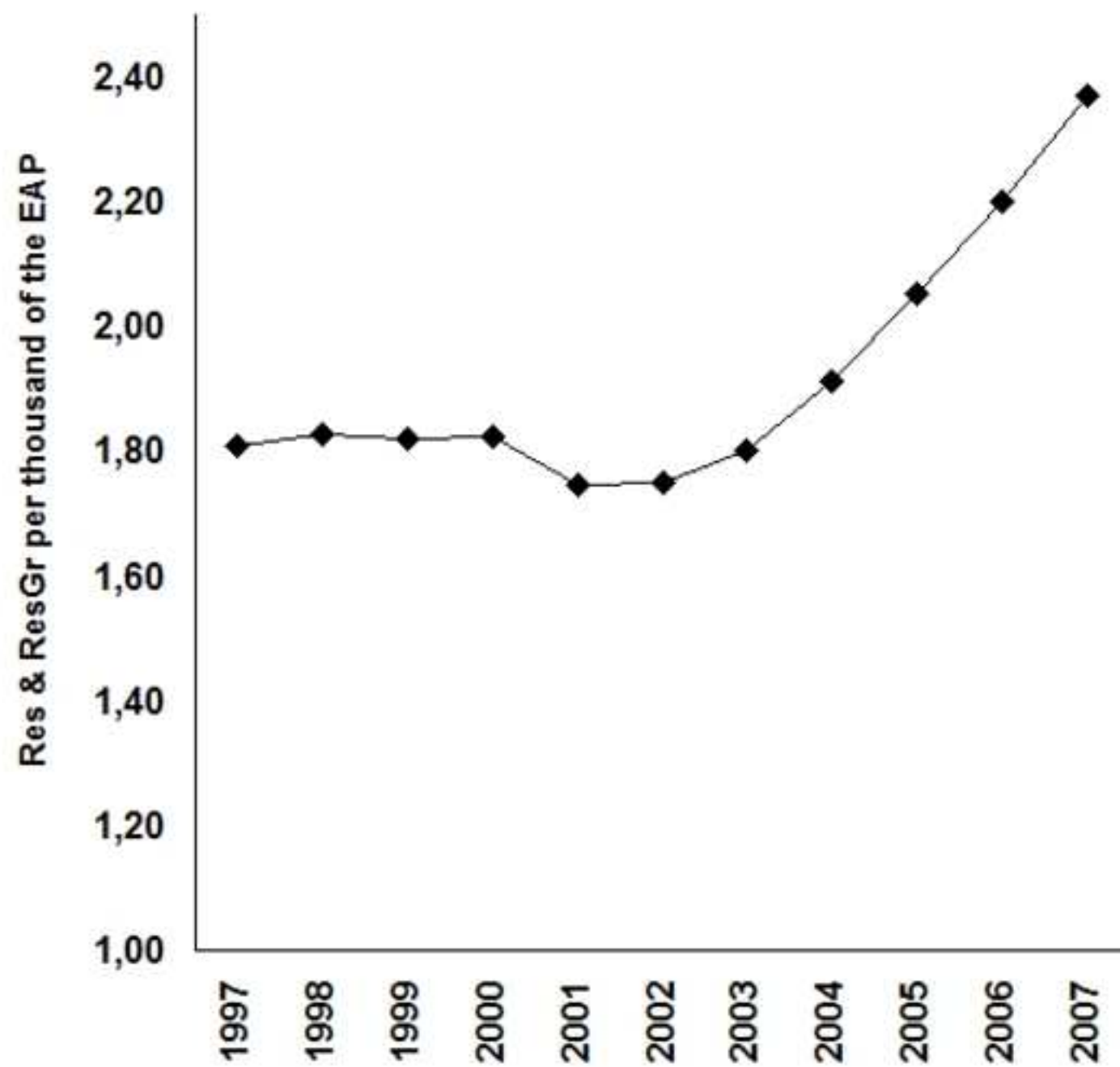
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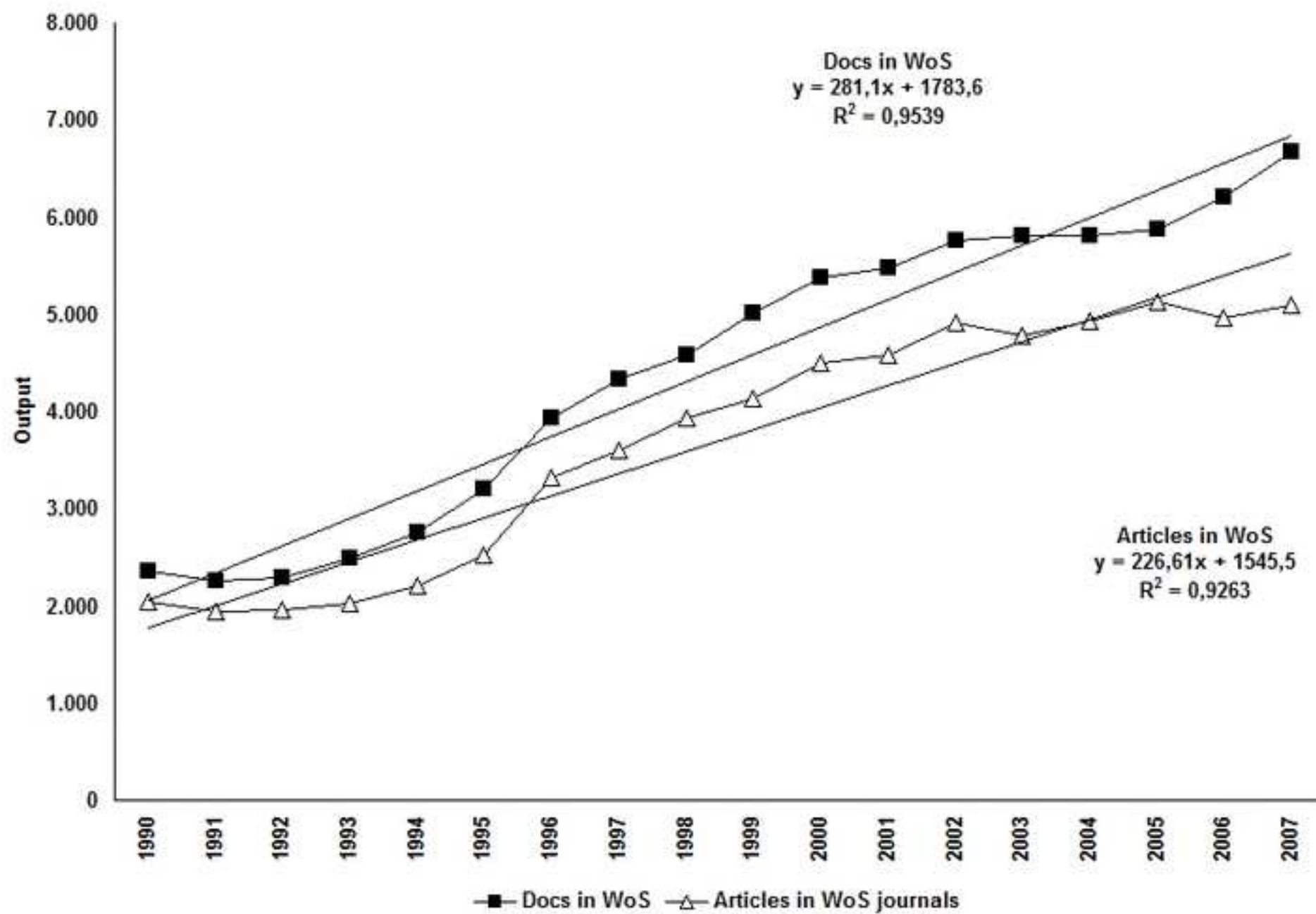
Figure 5

- ◆— % Articles in domestic journals
- △— % Articles in foreign journals
- ■— % Articles in WoS journals
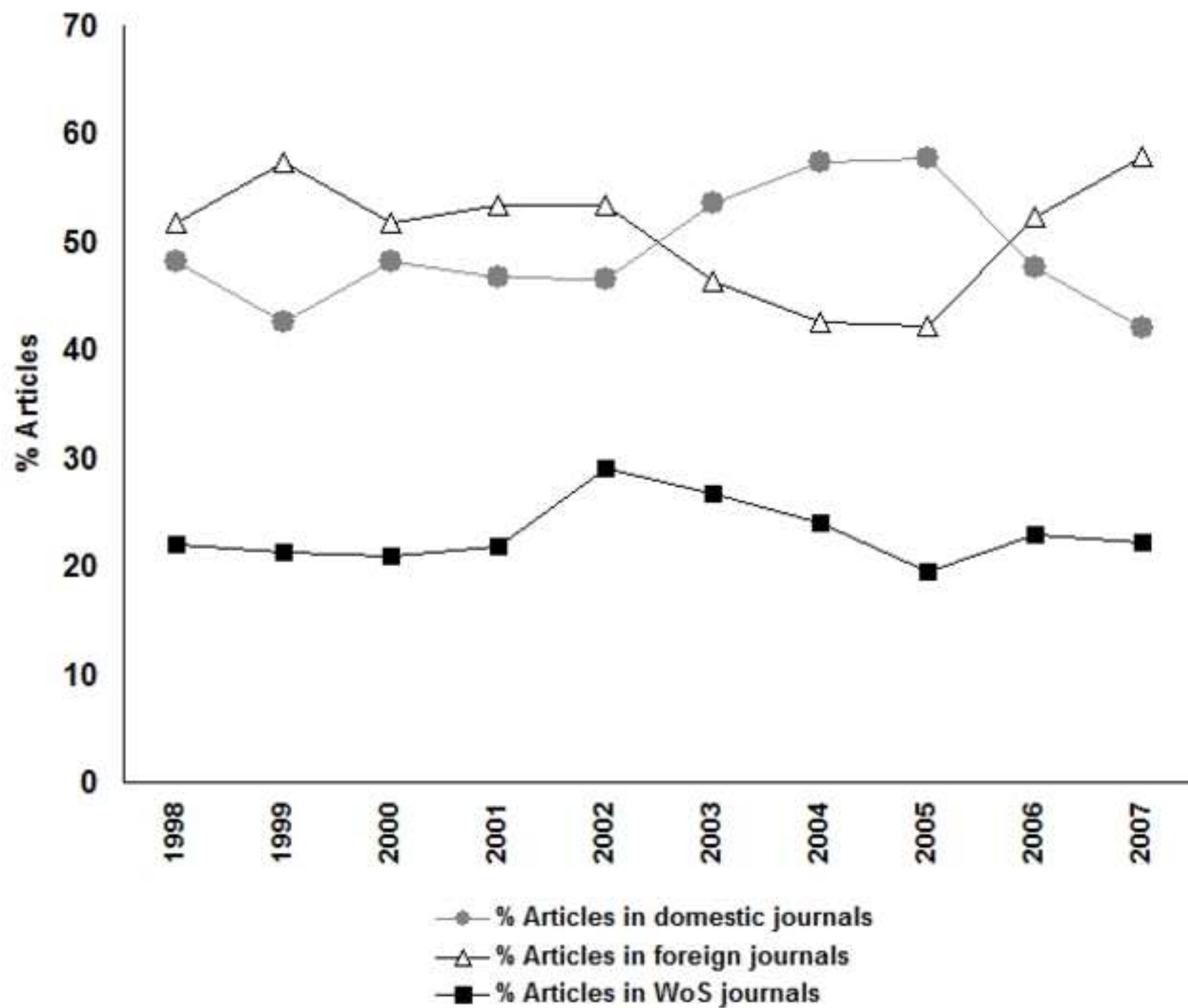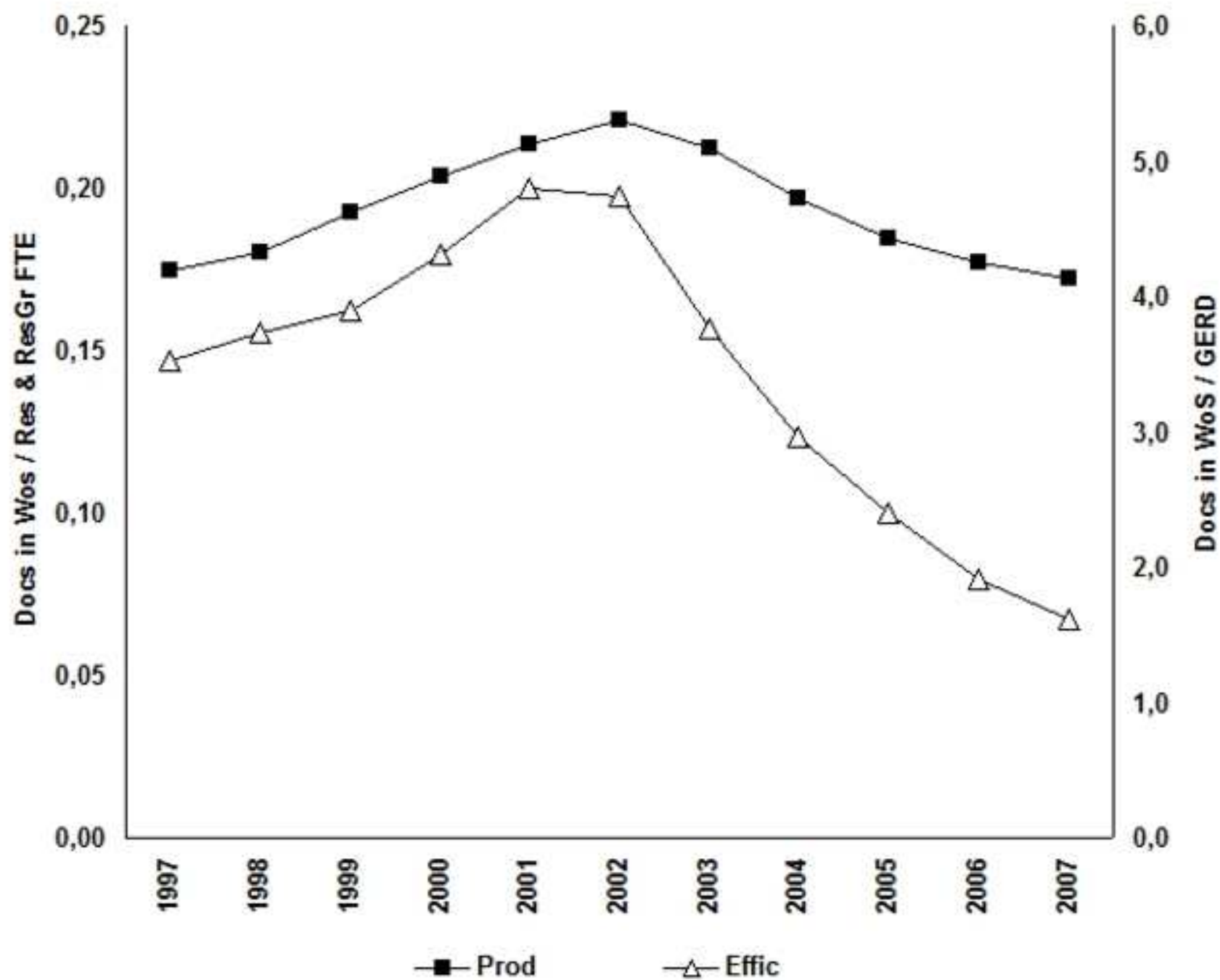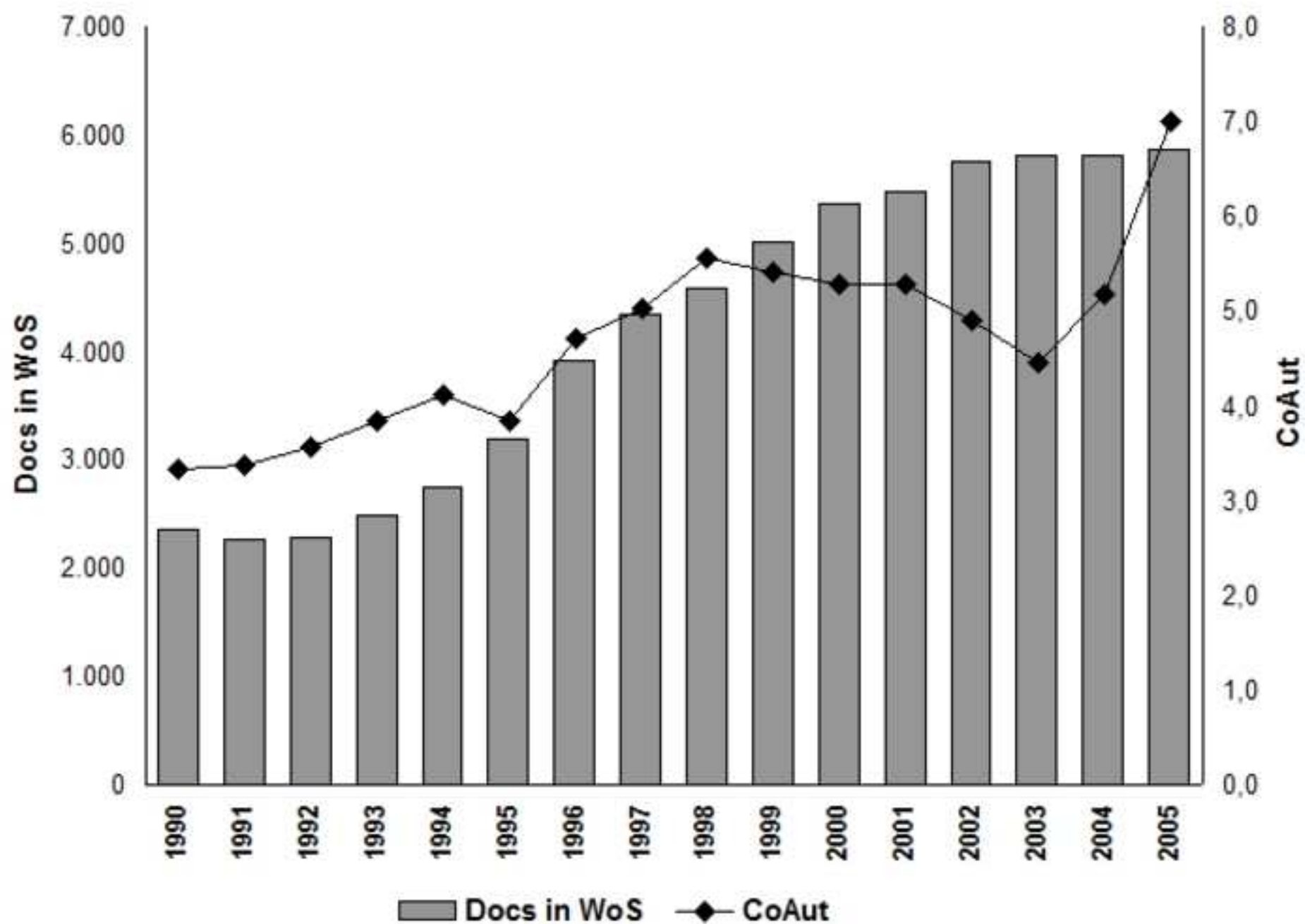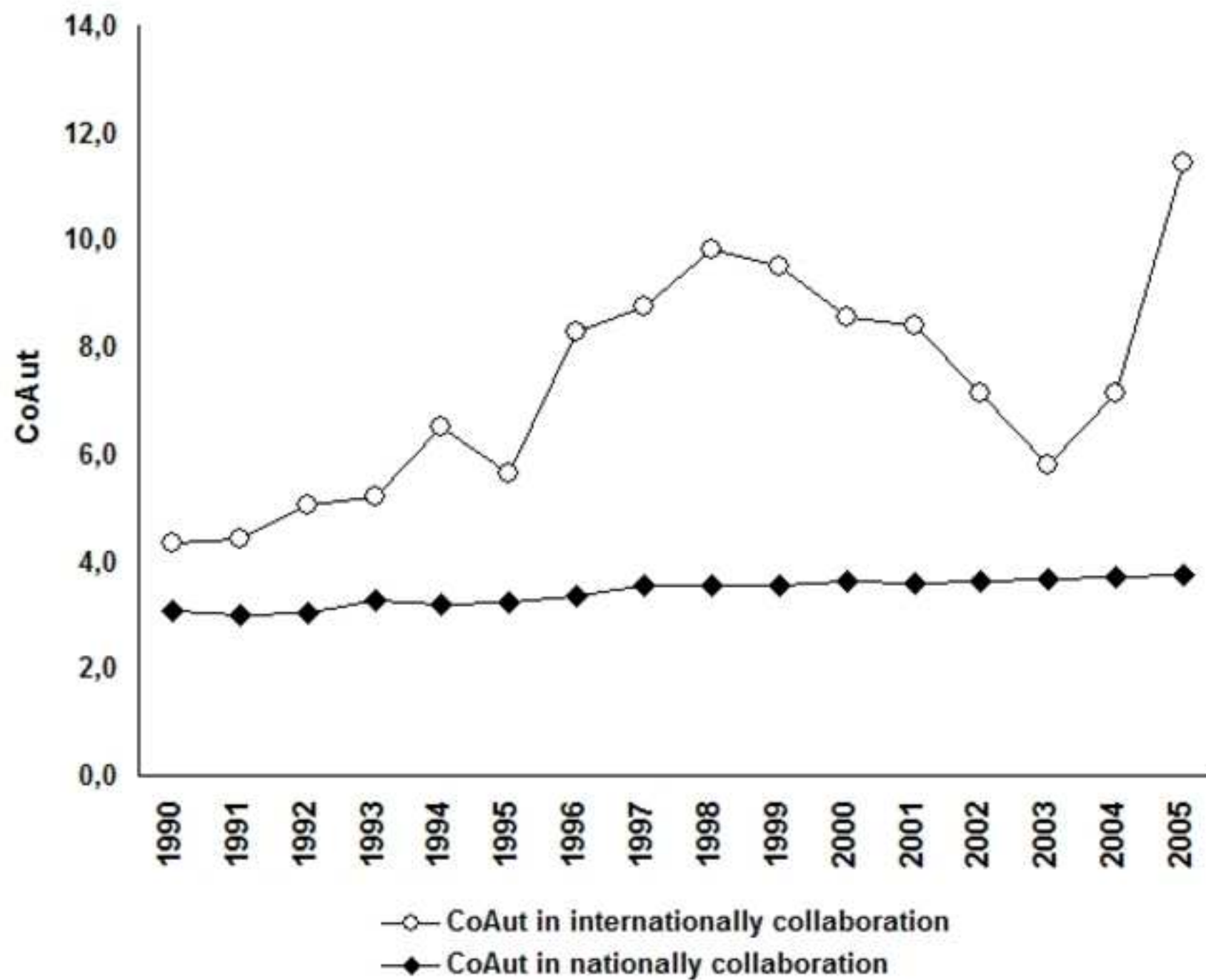
Figure 6

Figure 8

Figure 9
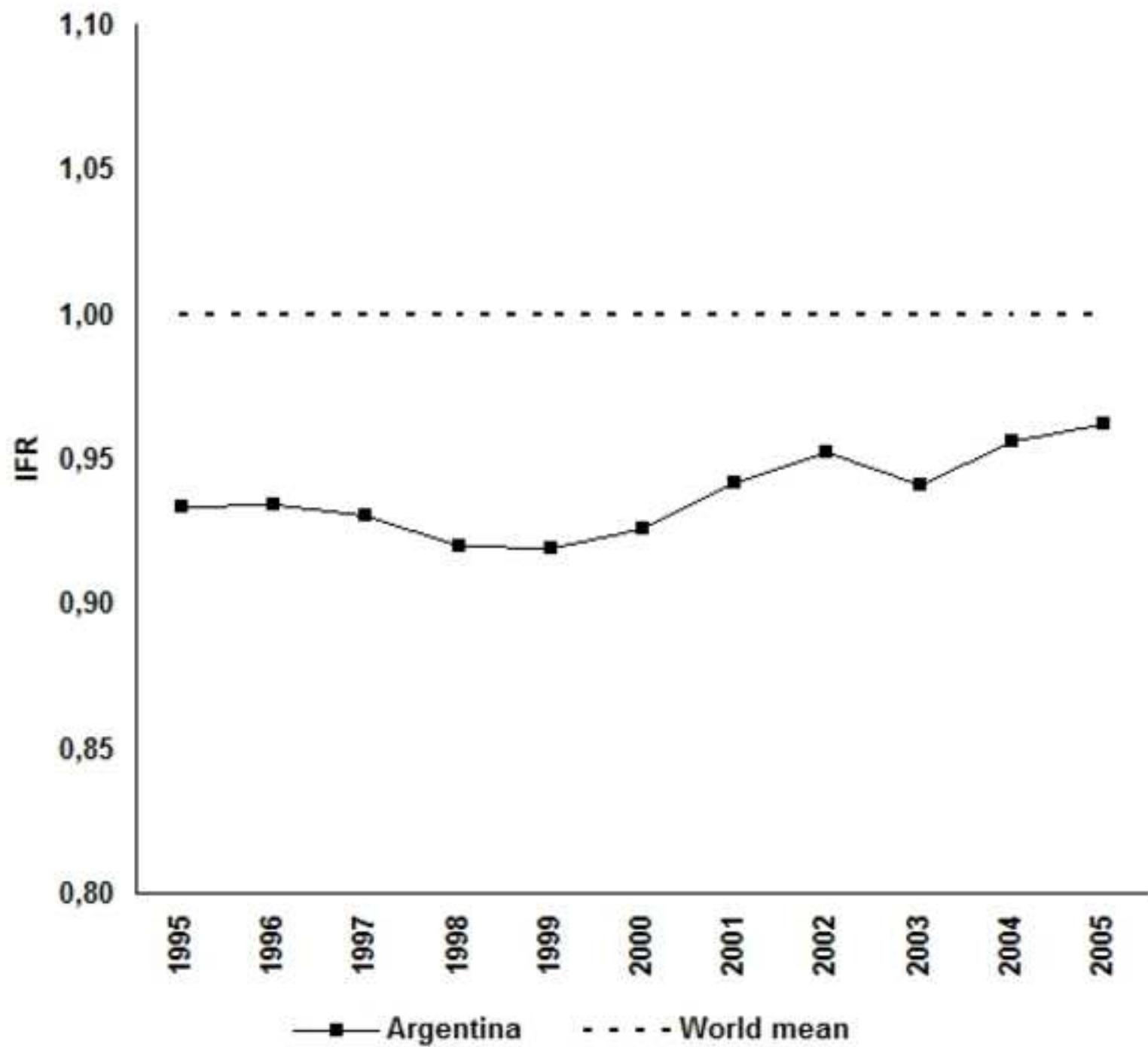
	1996-1999	2000-2001	2002-2007
GERD U$S	=	↓↓	↓
GERD pesos	=	↓	↑↑
Researchers	=	↓	↑
Researchers as EAP	=	↓	↑↑
Coauthorship	↑	↓↓	↑
Docs in WoS	↑	↑	=
Prod	↑	↑	↓
Effic	↑	↑	↓↓