THE IMPACT OF GOVERNMENT R&D IN STIMULATING PRIVATE R&D IN OECD COUNTRIES (1981-1998)

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- Abstract -

In this study, it is attempted to identify the relationship between the private and government R&D expenditures based on an analysis conducted for OECD countries for the period 1981-1998. Two phases were distinguished with regard to the comparative levels of private and government R&D expenditures: (i) First phase in which government R&D expenditures remain higher than the private R&D expenditures and (ii) Second phase in which the reverse holds. The hypothesis tested in this study is that in the first phase government R&D activity is very crucial for the private sector R&D performance. For the second phase, the performance of private sector, rather, relies heavily on its accumulated capacity. Empirical findings support the evolution pattern of government-private relation in R&D activity.

Keywords: R&D, Government

JE: Classification: O33, O38

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I. Introduction

Research and Development (R&D) effort is one of the main sources of improvement in the technological capability of a firm or a country. R&D efforts aim to create new technological knowledge as well as diffusion and adoption of existing technological knowledge. Technological capability gained at least partly by R&D efforts constitutes the most essential ingredient of the successful economic growth process. R&D expenditures occupy a central place in the explanations of economic performance. Empirical findings show that R&D expenditure is one of the fundamental factors in explaining cross-country economic growth (Fagerberg, 1988), inter-firm output growth (Griliches, 1995), productivity growth (Gittleman and Wolff, 1995 and Englander and Gurney, 1994); technical change (Perelman, 1995); the rate of efficiency change (Tori, 1992a, 1992b); the pattern of trade (Wolff, 1997; Gustavsson, *et al*., 1997; Dosi, *et al*., 1990); and export performance (Dosi, *et al*., 1990; Fagerberg, 1997, 1996; Greenhalgh, 1988),

Through the end of 1900s, the currently developed OECD countries experienced increasing amounts of R&D efforts which are also referred to as *knowledge creation activities* within the literature (OECD 1996, 1999a). In this process, a significant characteristic of the composition of R&D efforts has been the increasing share of private sector in total R&D expenditure. However, the role of government in stimulating both private and total R&D efforts stands as a challenging issue for theoretical and empirical investigation.

The literature which is mainly concerned with the relation between the government and private R&D expenditures generally attempt to investigate the magnitude and the direction of the effect of government intervention in R&D activities on the private R&D efforts, both with respect to private R&D expenditure and R&D performed by the private sector. However, these attempts do not capture the possibility that the extent of the effect of government R&D expenditures on private R&D efforts may vary depending on the R&D capacities of the countries both with respect to their private and government sectors[1]. That is, the magnitude of the effect of government R&D spending on stimulating private R&D

[1] According to the sectoral classification of Frascati Manual (see OECD (1992, 1993)).

spending may be different for the case in which private R&D capacity is considerably weak than for the case in which private R&D capacity is relatively mature.

In this study, the aim is not investigating how a change in any related factor affects private R&D expenditure. Instead, we aim to investigate the effect of government R&D expenditure on private R&D for two different phases in the evolution pattern of countries. The first phase consists of countries where the R&D capacity of private and government sectors is weak and the second phase includes countries with a strong or mature R&D capacity. The R&D capacity of a country is measured by relative R&D expenditures of private and government sectors. If R&D expenditure of government sector higher than that of the private sector that country regarded as having weak R&D capacity and *vis-a-versa*. The expected outcome is that government R&D expenditure is more effective in stimulating private R&D if R&D capacity of a country is weak. Apparently, empirical findings would give critical policy implications. For this purpose we carry out an analysis on the per capita government and private R&D expenditures of 21 OECD countries for the period of 1981-1998. As expected, it is estimated that there exists a close positive association between the per capita private and government R&D expenditures for the first phase of the evolution patterns of countries. For the second phase, we estimate that a rise in private R&D expenditure relies on its accumulated capacity.

The rest of the paper is organised as follows: In the next section we present the theoretical background for the relation between government and private R&D expenditure. Specification of the empirical model and estimation results are given in sections III and IV. Finally, we conclude in section V.

II. Theoretical Background

The relation between government and private sectors in innovative activities is one of interesting subjects in economics. Different nature and characteristics of innovative activities from ordinary production activities, gives an opportunity to investigate how government could effectively contribute to the private innovative activities.

Externality, market imperfection and cumulativeness could be regarded as the well-known characteristics of innovative activities. In this context, the basic hypothesis of this paper is that up to a certain critical level, intensive government innovative activity is a pro-condition for self-sustaining private sector innovative performance.

Innovative capacity/activity of a firm or a country could be measured by different indicators. Number of patents granted, human capital, R&D intensity and productivity are widely used indicators. In this study, we use R&D measure to analyze the role of government in stimulation private sector innovative activity.

With respect to R&D, there exists a general agreement in the literature that in order to achieve better innovative performance, considerably more than half of R&D activities in a country must be realized by the private sector. On the other hand, it is also argued that, due to the cases of market failure, the government should invest in R&D activities, especially in the fields in which social return (at least at the pre-commercialization stage) appears to be higher than the private rate of return (i.e. defense, energy or public health areas).

Government funding of R&D may broadly be categorized in the following subdivisions:

- Direct funding of business for doing research (under a procurement program or as a grant),
- Tax incentives,
- R&D performed by government itself.

How, different funding schemes of the government, effect the private sector R&D behavior is of critical importance for policy implications. In this regard, a recent study of OECD (1999b) tried to estimate the effects of combinations of different funding schemes of the government on the behavior of private sector's R&D activities. Though, the results supplied in this study provide fruitful insights with respect to policy implications, the study did not take into account the share of R&D realized by the private sector.

Findings of the study by Kim (2000) constitute the departure point of this study. Kim argued that "where demand for technology from the private sector is still dormant, the appropriate market environment, such as a well behaved price mechanism and a competitive market structure, should be established to stimulate indigenous demand for technology, as a prior stage to linkage between demand and supply. Government R&D expenditure has to be made for a certain period of time, as a necessary condition for indigenous private R&D."

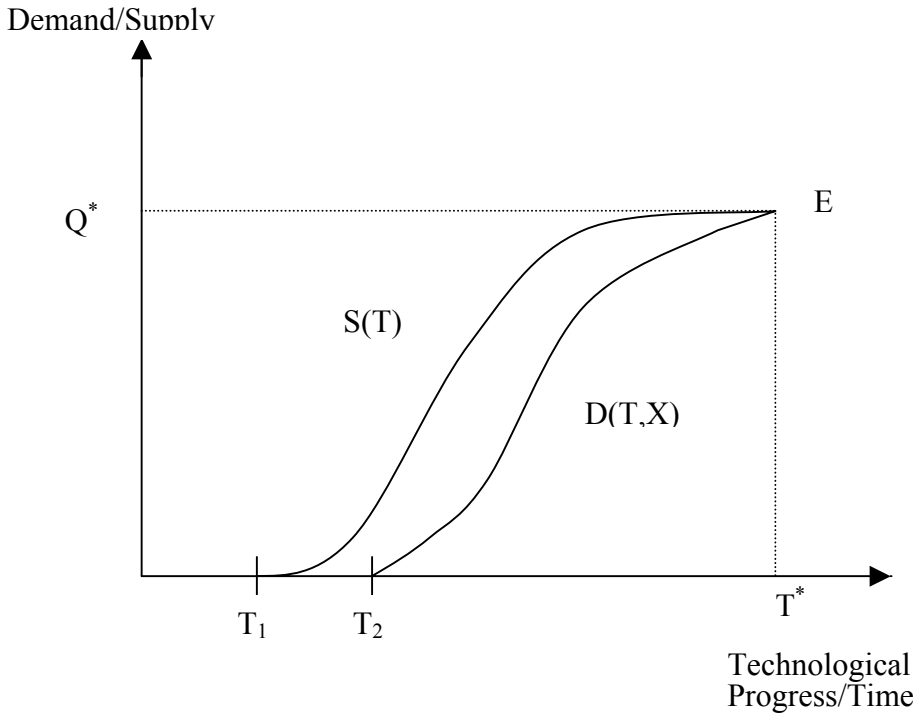
In his argument he defines *demand for technology* as "… all activities by firms acquiring new knowledge, know-how, or plant for their production processes" (i.e. efforts to upgrade their technological level by purchasing technology or advanced machines, contracting licenses, training workers, inviting consultants and so on). On the other hand, *supply of technology* is defined as "… all activities generating or providing technological resources such as manpower, facilities, and information that will be demanded by producers."

Using Figure 1, Kim illustrates the relation between the development pattern of demand for technology with respect to the pattern of supply of technology for the case of S. Korea. It is supposed that the economy's total demand for and supply of technology is negligible until time T_1 at which government starts allocating national resources to the supply of technology. The pattern that government supply follows is illustrated by the curve S(T) in the figure. Assuming that appropriate market environment is satisfied, at time T_2, demand from firms is realized. The pattern which the demand follows is illustrated by the curve D(T,X) in the figure. Finally, at time T^*, both the demand and supply reach point E which is claimed to be the "… starting point for the economy to be self sustaining" (Kim, 2000).

In investigating his arguments underlying Figure 1 for the case of Korea, Kim used government R&D expenditure to measure S(T) and private R&D expenditure to measure

D(T,X). Then, Q^*, in the figure, represents the investment level at which private R&D equals to government R&D.

Figure 1: Conceptual Time Gap Between Demand and Supply Of Technology



Considering the arguments mentioned above, Figure 1 is interpreted as that the development of private effort or capacity in R&D is related with the accumulated supply of R&D from the government. That is, when firms decide to undertake R&D activities (given that appropriate market environment is satisfied), the accumulated government supply of manpower and information remain as the resources which firms can utilise.

In this study, adapting Kim's approach, the relation between government and private R&D is analysed for OECD countries. Using a similar scheme as illustrated in Figure 1, the scatter plots of government and private R&D of OECD countries are formed which are illustrated in Appendix B. It should be noted that in Appendix B, the government and private

R&D expenditures are illustrated in per capita constant PPP $s. In the Figures in Appendix B, three basic patterns can be observed:

- There exist countries whose private R&D has been higher than their government R&D for the period analysed, which are said to be in a *self-sustaining* state by Kim. These countries are Austria, Belgium, Czech Republic, Denmark, Finland, Germany, Japan, Netherlands, Norway, Spain, Sweden, Switzerland and UK.

- Greece, Mexico, Poland and Turkey are the countries in which private R&D has remained negligible for the period analysed compared to the countries mentioned above. Also, in these countries, it can be observed that government R&D has been stable at relatively low levels, which can be interpreted as insufficient supply for stimulating firms to invest in R&D.

- In the figures of Australia, Canada, France, Iceland, Ireland and the US, the point at which the countries start to be self-sustaining can be observed (i.e. point E in Figure 1). Supporting Kim's argument, in the figures of Australia, Canada, France and Iceland, it can clearly be observed that the patterns of government R&D and private R&D (during the period before private and government R&D become equal) resemble the pattern illustrated in Figure 1. On the other hand, in the figures of US and Ireland such a pattern can partly be observed due to the lack of data for the period before 1981.

Considering the countries which are in the self-sustaining state, it can be said that government R&D has continued to be supplied above some level (though slight declines have been observed). This is explained in the literature by the requirement of government intervention in R&D due to "… the existence of market failures associated with R&D" (OECD, 1999).

What can further be inferred from the figures in Appendix B is that, generally, the level of expenditure at which private R&D equals government R&D (i.e. point E in Figure1) has been above PPP $ 50 with the exception that for Ireland this level appears to be around PPP $ 30. (Highest levels which can be observed in the figures of US and Iceland appear to be PPP $ 300 and PPP $ 200)

Referring the discussions mentioned above, it can be claimed that countries may exist in two possible phases with respect to the levels of private R&D expenditure and government R&D expenditure: the phase in which private R&D of the country is dormant (i.e. insufficient government R&D) and the phase in which private R&D is at a self-sustaining state. Within the following, the former phase will be referred to as 1st phase and the latter as 2nd phase. In order to identify in which phase a country is, it will be assumed that if government R&D expenditure of that country is higher than its private R&D expenditure the country is in 1st phase and the reverse holds for the 2nd phase.

III. Specification of the Model

It is claimed in this study that countries are in either of the two possible phases with respect to the levels of private R&D expenditure and government R&D expenditure: the phase in which private R&D of the country is dormant (i.e. insufficient private R&D) and the phase in which private R&D is at a self-sustaining state. In the study, the former phase is referred to as 1st phase and the latter as 2nd phase. In order to identify in which phase a country is, it is assumed that if government R&D expenditure of that country is higher than its private R&D expenditure the country is in 1st phase, and the reverse holds for the 2nd phase.

To estimate the role of government R&D expenditure on private R&D expenditure the following basic model can be specified:

$$P_t = \beta_0 + \beta_1 * G_t + \beta_2 * P_{t-1} + \varepsilon_t \qquad (1)$$

where P represents the amount of per capita private R&D expenditure at time t, G stands for the per capita government R&D expenditure in period t and ε represents the stochastic error term.

The closed form of this formulation is

$$P_n = \beta_0 * \sum_{i=0}^{n-1} \beta_2^{\,i} + \beta_1 * \sum_{i=0}^{n-1} (\beta_2^{\,i} * G_{n-i}) + (\beta_2)^{n} * P_0 + \varepsilon_t \qquad (2)$$

The model presented above (Model (1)) will be estimated for the 1st and the 2nd phases, separately. It is expected that whereas the lagged private R&D expenditure is more crucial for the 2nd phase, government R&D expenditure more is crucial for the 1st phase in explaining current year private R&D expenditures.

Due to the limitations imposed by the data and the nature of the analysis, we use a panel data analysis. By using panel data, we are also able to employ fixed effects to capture the effects of time-invariant country specific factors. The time period covers 1981-1998. In some specifications, a time trend variable is also added to the model. Moreover, we estimate more flexible forms of the model specified above by introducing interaction terms of independent variables. Furthermore, since we have a lagged dependent variable as an explanatory variable in the model, we use first difference form of the variables to avoid statistical problems (see Baltagi (1995).

Especially the increased use of ICT (Information and Communications Technology) may have facilitated the diffusion of codified knowledge and the codification process itself. It is also argued in the literature that, the increase in the diffusion of knowledge has a stimulating effect on the creation process. It should be remembered that the parameters utilised in the model were estimated based on the past performances of the OECD countries (1981-1998) and the utilisation of ICT sharply increased in the recent past years. Therefore, while interpreting the results, attention should be paid that the pace in the utilisation of ICT may affect the contribution of government R&D expenditure on the development of private R&D expenditure.

IV. Empirical Findings

Empirical estimation of the model specified in the section above presented in Table 1 and Table 2. Estimation results for the 1st phase are given in Table 1 and estimation results for the 2nd phase are given in Table 2.

In the first four models in Table 1, the level of per capita private R&D expenditure (*P*) is considered as a function of the level of per capita government R&D (*G*) expenditures and lagged level of per capita private R&D expenditures (*P(-1)*). As expected, the coefficient on

the variable *G* is positive, and generally significantly different from zero at 10 percent confidence level, suggesting that a rise in the government R&D expenditure contributes significantly to a rise in the private R&D expenditure. Using fixed effects leads to an increase in the coefficient of the variable *G* but a decrease in the coefficient of the variable *P(-1)*. The models give very high values of R-square, might be considered as the indication of statistical problems. Moreover, since a lagged dependent variable is used as an explanatory variable, estimation results need cautious interpretation. Residuals from the Model-1 are depicted in Figure 2 in Appendix A.

Table 1: Estimation Results for the 1st Phase

	Model-1	**Model-2**	**Model-3**	**Model-4**
Dependent Variable: P				
Independent Variables				
Fixed Effects	NO	NO	YES	YES
Constant Term	-0,011 *(-0,25)*	-1,116 *(-0,46)*	-	-
G	0,067* *(2,02)*	0,062* *(2,02)*	0,214* *(1,78)*	0,074 *(0,44)*
P(-1)	0,972** *(24,88)*	0,984** *(24,77)*	0,879** *(7,96)*	0,880** *(5,86)*
T	-	0,084 *(0,53)*	-	0,858 *(1,64)*
R^2	0,995	0,995	0,991	0,995
R^2(Adj)	0,995	0,995	0,988	0,993
DW	1,84	1,86	1,98	2,11
F-Statistic	3468	2217	1111	2526
Total Number of Observation	37	37	37	37

Notes: t-ratios are in parenthesis.
(*) Significant at 10% confidence level.
(**) Significant at 5% confidence level

Table 1: Estimation Results for the 1st Phase (Continued)

	Model-5	**Model-6**	**Model-7**	**Model-8**
Dependent Variable: *Δ*P				
Independent Variables				
Fixed Effects	YES	YES	YES	YES
Constant Term	-	-	-	-
ΔG	0,195 *(1,69)*	0,325** *(3,95)*	0,217** *(2,90)*	0,112** *(2,23)*
*Δ(G*G)*	-0,0003 *(-0,72)*	-0,0004 *(-1,10)*	-	-
ΔP(-1)	0,053 *(0,43)*	0,332** *(2,33)*	0,345** *(2,48)*	0,563** *(3,45)*
*Δ(P(-1)*P(-1))*	0,004** *(2,06)*	0,003** *(2,17)*	0,004** *(3,25)*	-
*Δ(G*P(-1))*	-0,006** *(-3,27)*	-0,006** *(-4,41)*	-0,007** *(-6,03)*	-0,006** *(-7,03)*
T	-	0,860** *(9,63)*	0,847** *(9,95)*	0,907** *(9,12)*
R^2	0,909	0,962	0,961	0,926
R^2(Adj)	0,849	0,933	0,937	0,885
DW	1,93	2,38	2,46	2,11
F-Statistic	42,2	80,26	106,1	74,9
Total Number of Observation	29	29	29	29

Notes: t-ratios are in parenthesis.

(*) Significant at 10% confidence level.

(**) Significant at 5% confidence level

In the models 4-8, the first difference form of the variables and more flexible formulation of the basic model are considered by introducing interaction terms. In general, we have more reliable estimation results than previous models. Adjusted R-Square measure is at more reliable levels and Durbin-Watson statistics ranges from 1,93 to 2,46. The coefficient of the variable *G* is positive and more significant, supporting our hypothesis of higher government R&D expenditure is essential for higher private R&D expenditure. Inclusion of a time trend variable into the model improves the estimation results. Residuals from the Model-8 are depicted in Figure 3 in Appendix B.

Estimation results for the second phase are given in Table 2, through the Model-9 to Model-17. For the first four models, we utilise the level of the variables, and for the rest, we utilise the first difference of the variables. Residuals from the Model-9 and Model-15 are presented in Figure 4 in Appendix A.

Estimation results for the second phase are also in line with our expectation. Rather than government R&D expenditures, private sectors part accumulated capacity is estimated as the driving force behind the current R&D performance of the private sector. For most of the estimates, a rise in the government R&D expenditures found as creating crowding-out effects. However, it should be underlined that the role of government in this stage should not be underestimated. As mentioned before, considering the experience of countries which are in the self-sustaining state (second phase), government R&D has continued to be supplied above some critical level. A detailed analysis of this phenomenon is out of the scope of this paper, but further research on this issue would give valuable results.

Another interesting finding from the estimates is that inclusion of the fixed effects into the models significantly improves the explanatory power of the models. It may indicate that unmeasured country-specific factors play an important role in explaining private sector R&D performance. These may include economic and political stability, networks between firms and government, rules and regulations, human capital, etc.

In sum, results of our empirical investigation are in accord with our theoretical expectation. We found that significant government R&D expenditure is a critical factor to support private sector R&D activity at the initial development stage of private sectors, that is

the first stage. In other words, particularly in developing countries such as Turkey, governments should support innovative activities more actively until the self-sustaining stage of the private sector achieved.

Table 2: Estimation Results for the 2nd Phase

	Model-9	**Model-10**	**Model-11**	**Model-12**
Dependent Variable: P				
Independent Variables				
Fixed Effects	NO	NO	YES	YES
Constant Term	3,156** *(3,58)*	5,219** *(5,70)*	-	-
G	0,004 *(0,17)*	0,002 *(0,10)*	-0,089** *(-1,98)*	-0,098** *(-2,15)*
P(-1)	1,018** *(68,43)*	1,022** *(63,22)*	0,992** *(45,55)*	0,969** *(30,39)*
T	-	-0,226** *(-2,71)*	-	0,253 *(1,53)*
R^2	0,987	0,988	0,990	0,990
R^2(Adj)	0,986	0,988	0,989	0,988
DW	1,18	1,19	1,34	1,33
F-Statistic	5504	4020	13671	6508
Total Number of Observation	153	153	153	153

Notes: t-ratios are in parenthesis.

(*) Significant at 10% confidence level.

(**) Significant at 5% confidence level

Table 2: Estimation Results for the 2nd Phase (Continued)

	Model-13	**Model-14**	**Model-15**	**Model-16**	**Model-17**
Dependent Variable: ΔP					
Independent Variables					
Fixed Effects	YES	NO	YES	NO	YES
Constant Term	-	3,107** *(2,89)*	-	3,540** *(2,95)*	-
ΔG	-0,274** *(-2,62)*	-0,174 *(-1,63)*	-0,287** *(-2,79)*	-0,219 *(-1,29)*	-0,374** *(-2,33)*
$\Delta(G*G)$	-	-	-	0,0008 *(0,66)*	0,001 *(0,98)*
$\Delta P(-1)$	0,393** *(6,61)*	0,548** *(7,09)*	0,392** *(6,78)*	0,485** *(3,62)*	0,357** *(2,40)*
$\Delta(P(-1)*P(-1))$	-	-	-	0,0003 *(0,53)*	0,0003 *(0,64)*
$\Delta(G*P(-1))$	-	-	-	-0,0006 *(-0,63)*	-0,001 *(-0,63)*
T	-	0,0005 *(0,99)*	-0,064 *(-0,57)*	-0,007 *(0,94)*	-0,067 *(-0,53)*
R^2	0,747	0,232	0,770	0,265	0,820
R^2(Adj)	0,718	0,215	0,742	0,231	0,793
DW	1,85	1,91	1,85	1,88	1,81
F-Statistic	368,3	13,7	207,0	7,97	110,1
Total Number of Observation	140	140	140	140	140

Notes: t-ratios are in parenthesis.

(*) Significant at 10% confidence level.

(**) Significant at 5% confidence level

V. Conclusion

In this paper, we attempted to investigate the relation between public R&D effort and private R&D performance for a panel of 21 OECD countries for the period 1981-1998. We distinguished two phases for public-private relation in R&D activity. The first phase stands for the initial phase in which both private sector R&D capacity and market demand for technology are weak. The second phase refers the self-sustaining stage for private sector R&D activity in which both private sector capacity and market demand for technology are strong (mature). The hypothesis tested in this study is that in the first phase government R&D activity is very crucial for the private sector R&D performance. For the second phase, the performance of private sector, rather, relies heavily on its accumulated capacity. Empirical findings support the evolution pattern of government-private relation in R&D activity.

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Appendix- A

Figure 2: Residuals of the Model-1

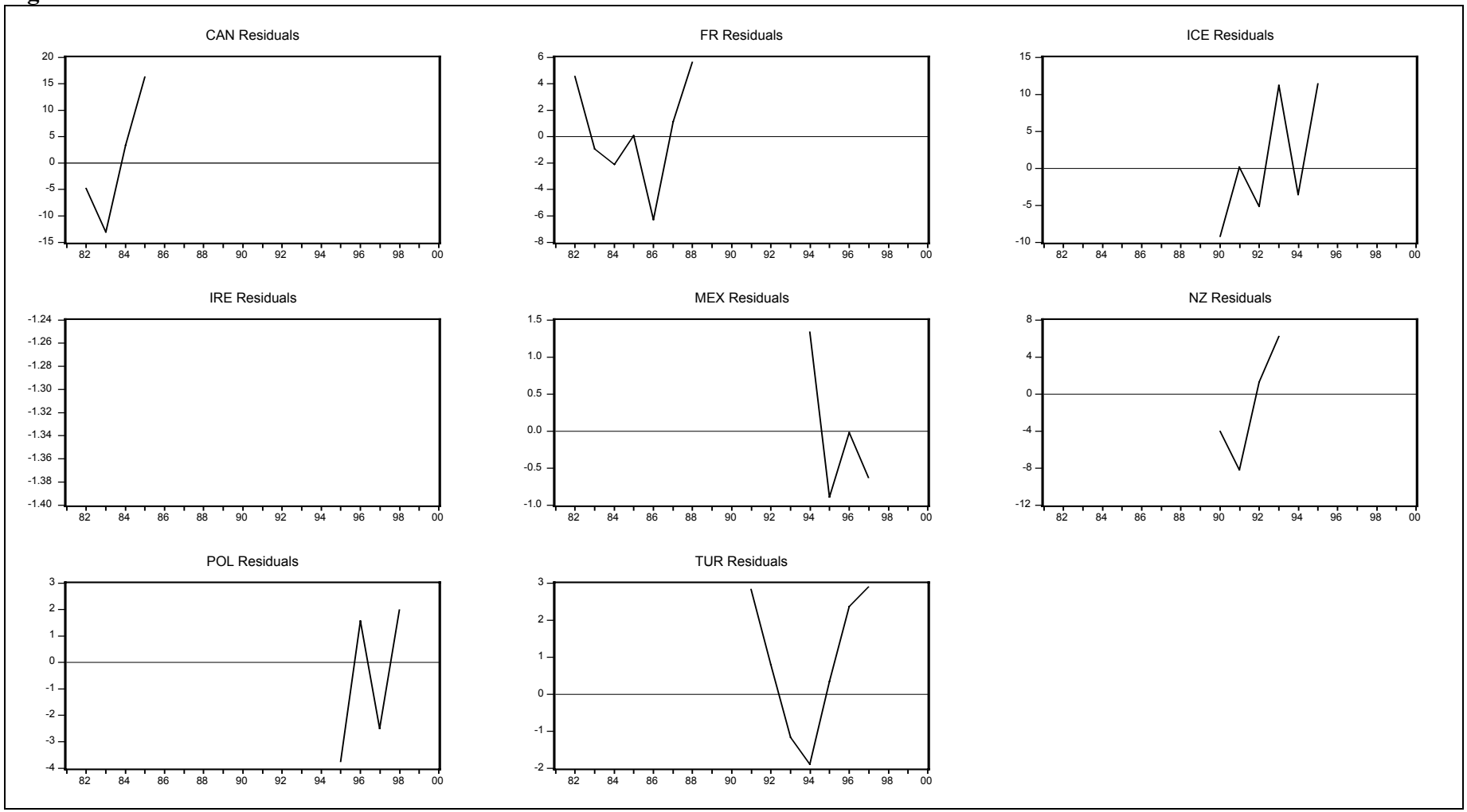


Figure 3: Residuals of the Model-8

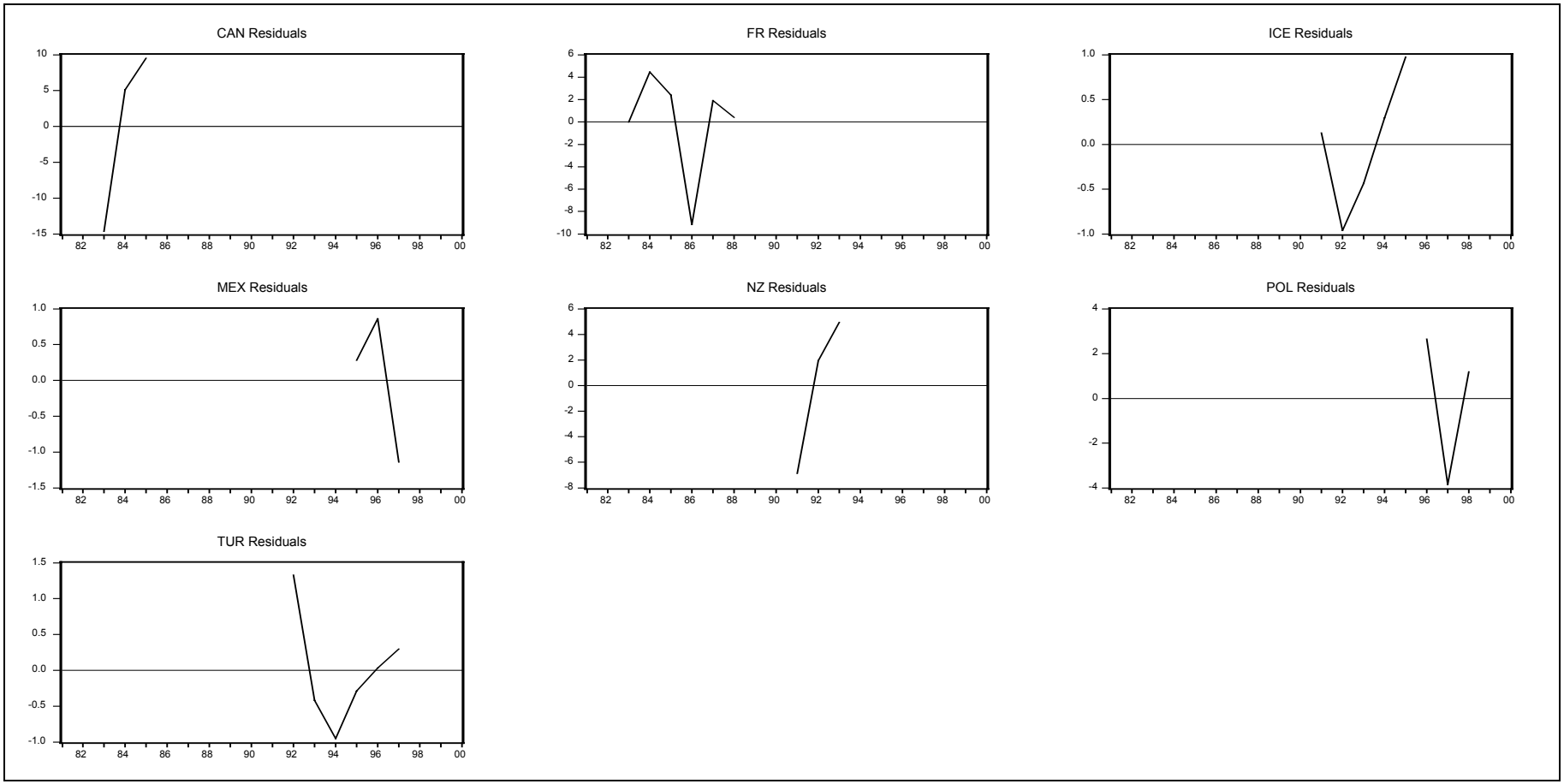


Figure 4: Residuals of the Model-9

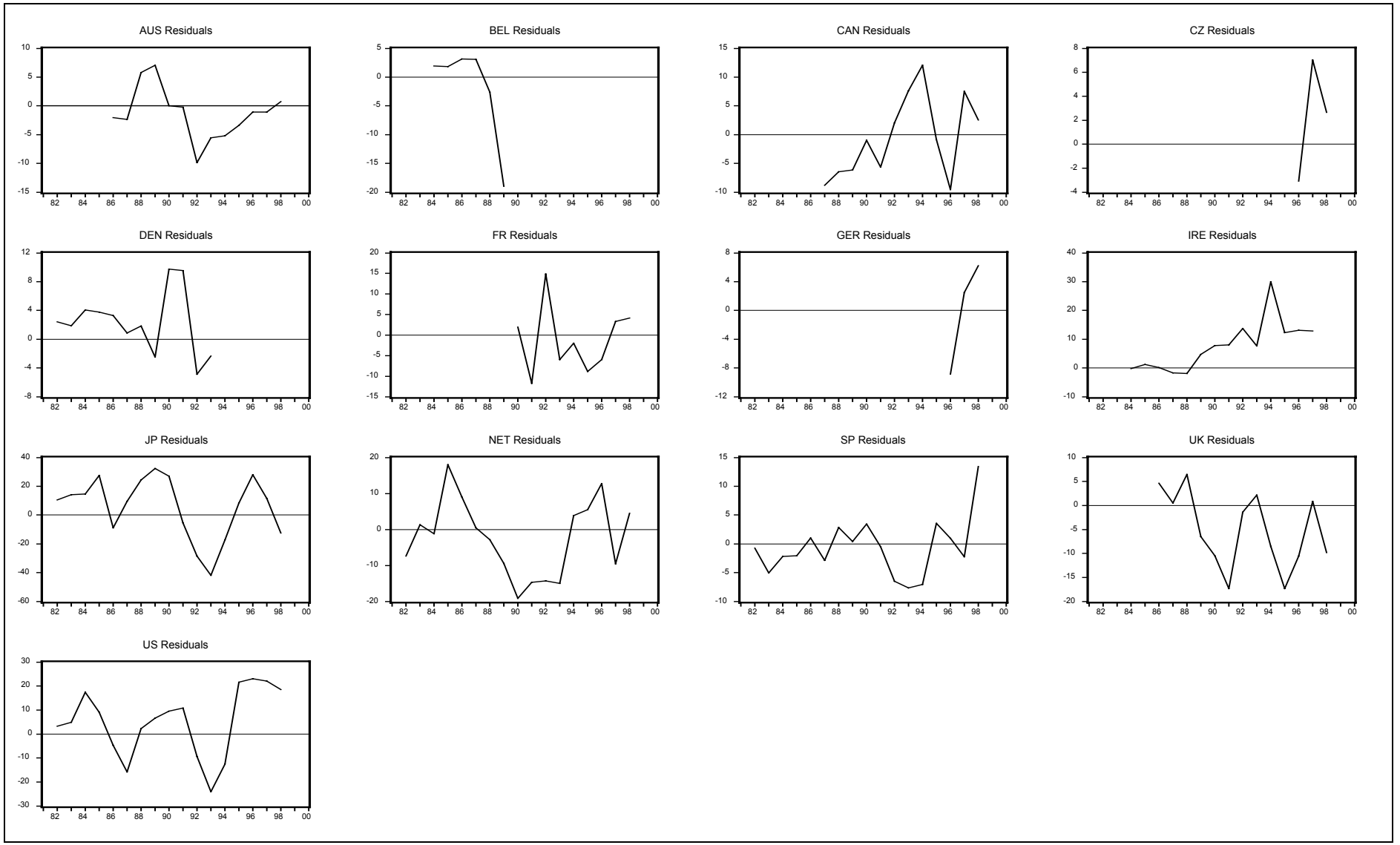
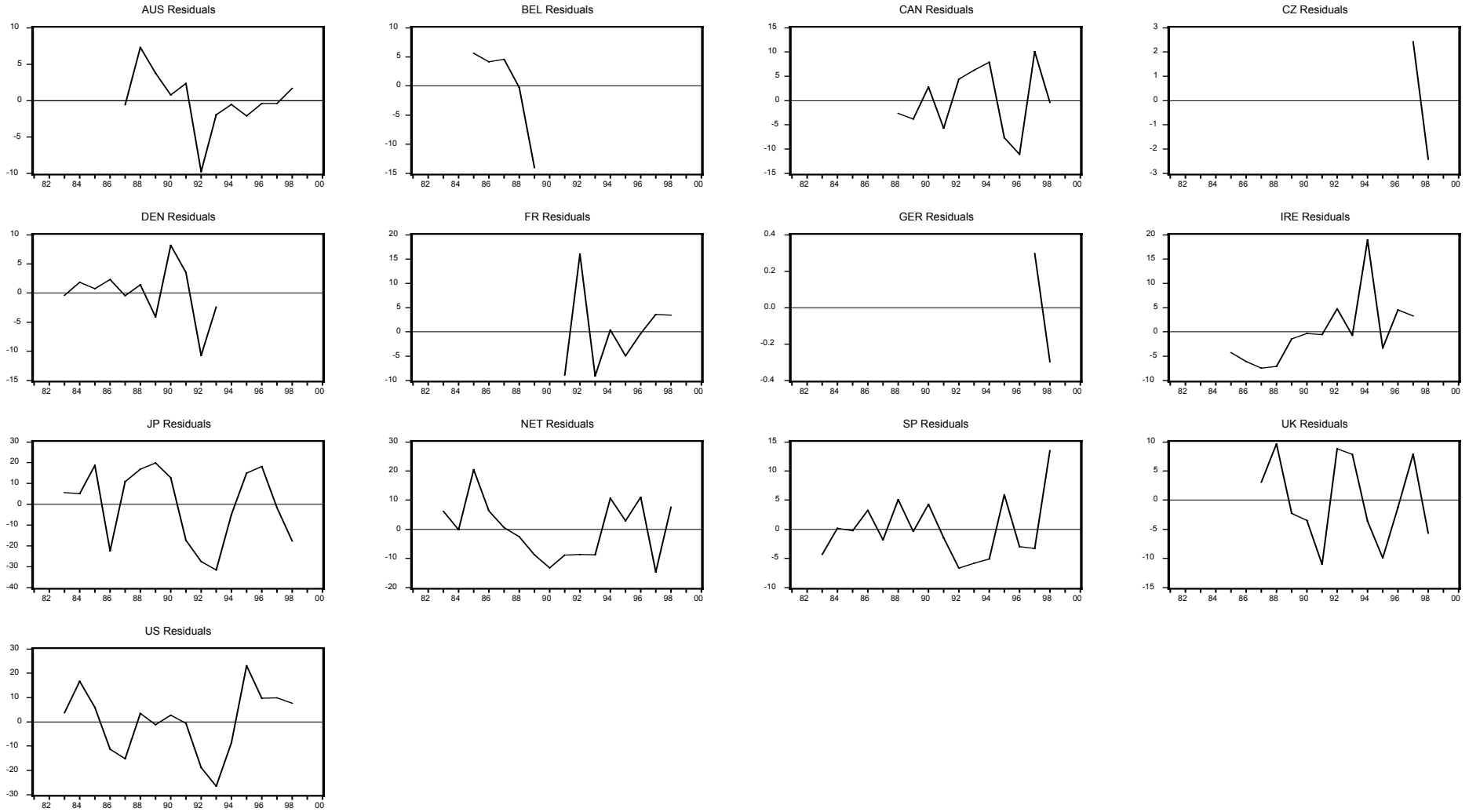
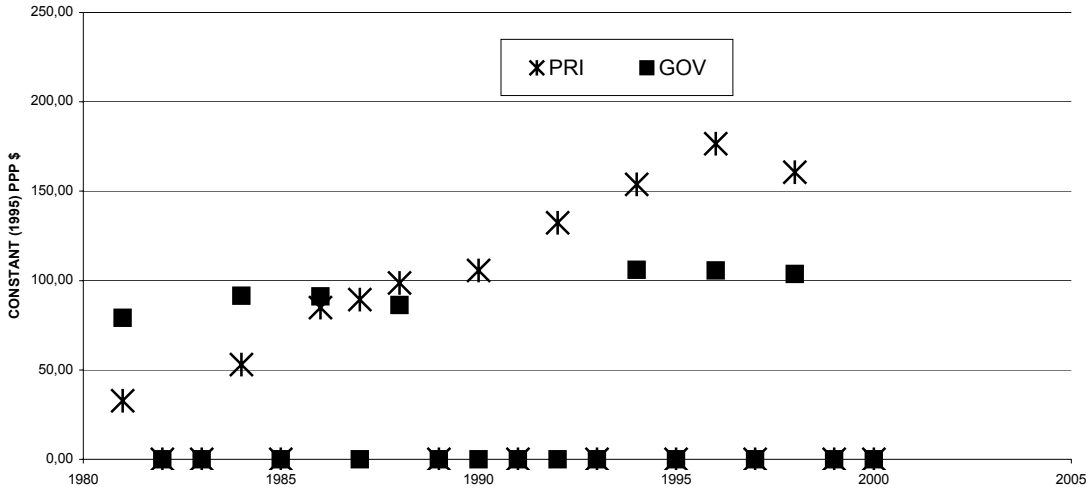


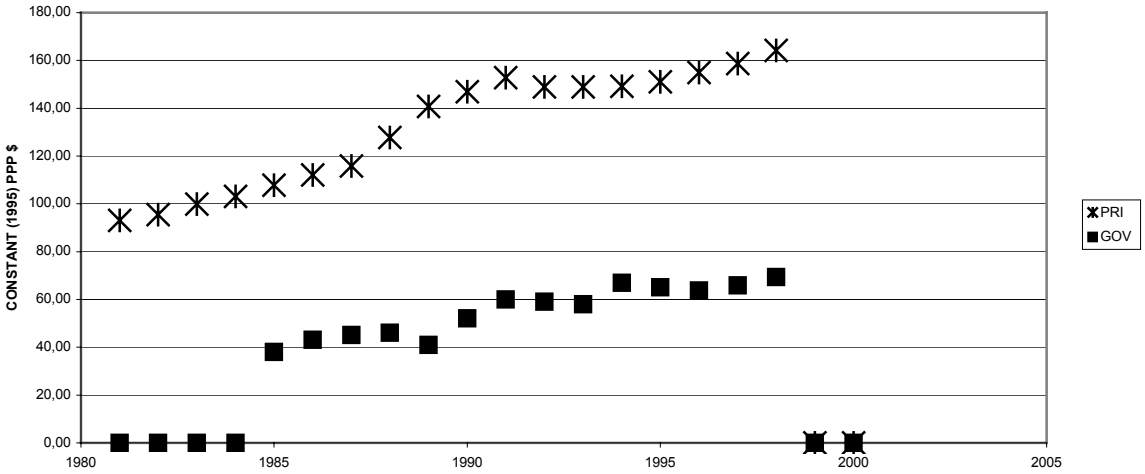
Figure 5: Residuals of The Model-15



Appendix- B
(Per Capita R&D Expenditures by Government and by Private Sectors)



(AUSTRALIA)



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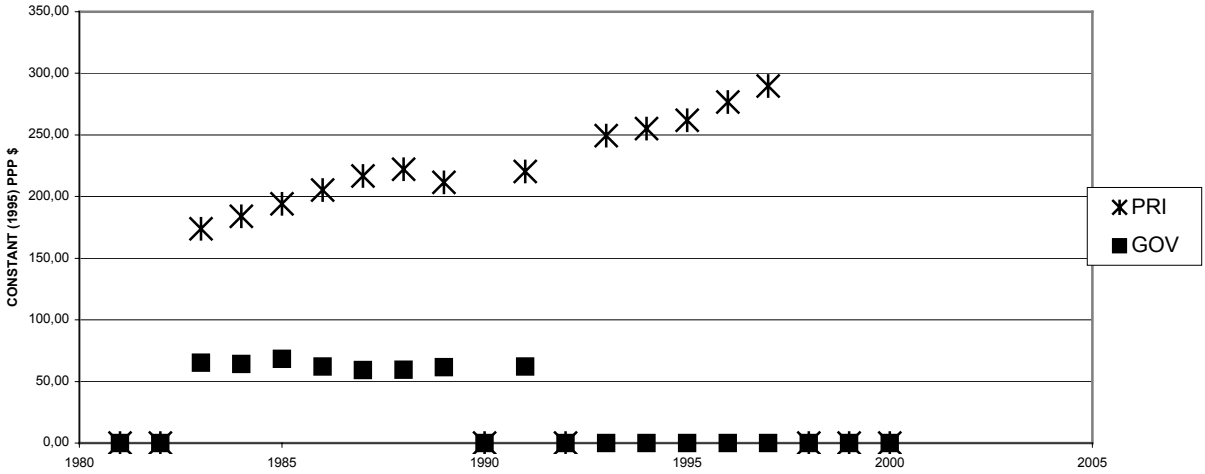

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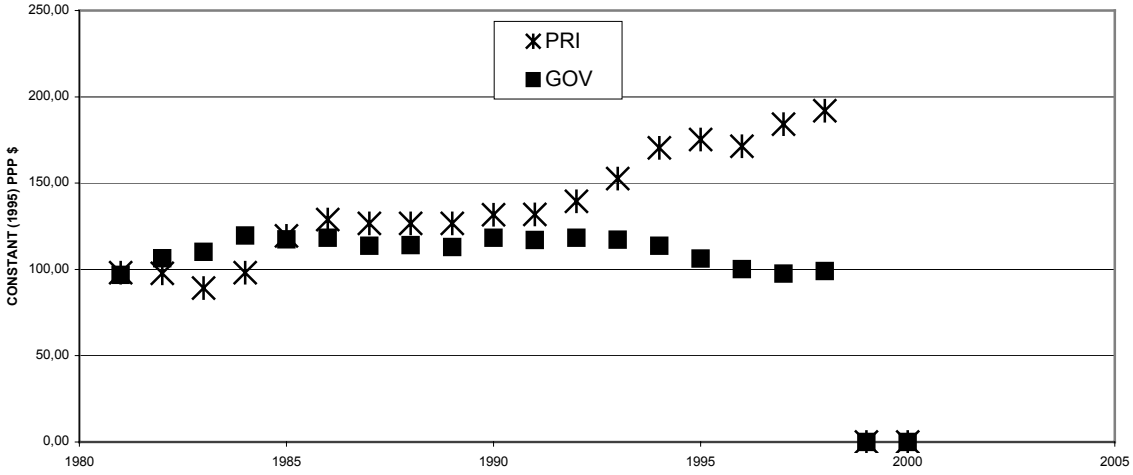

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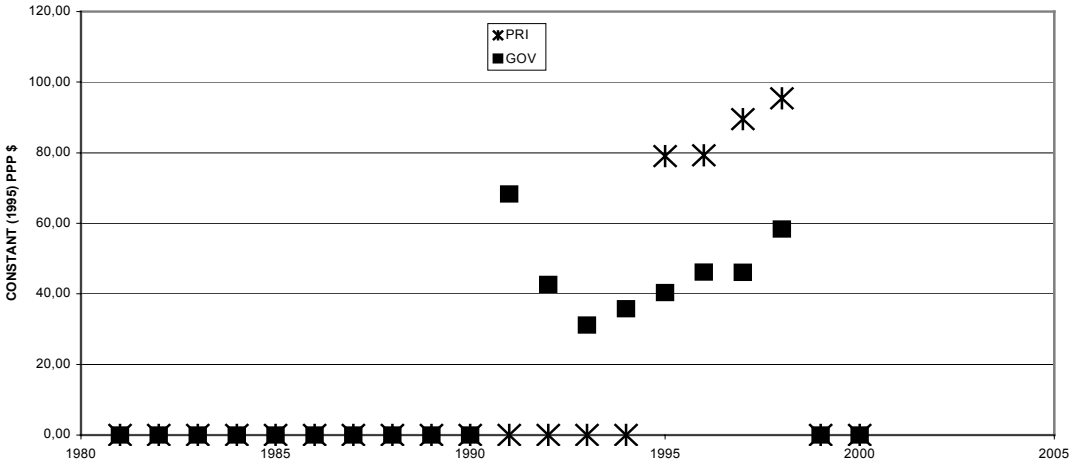

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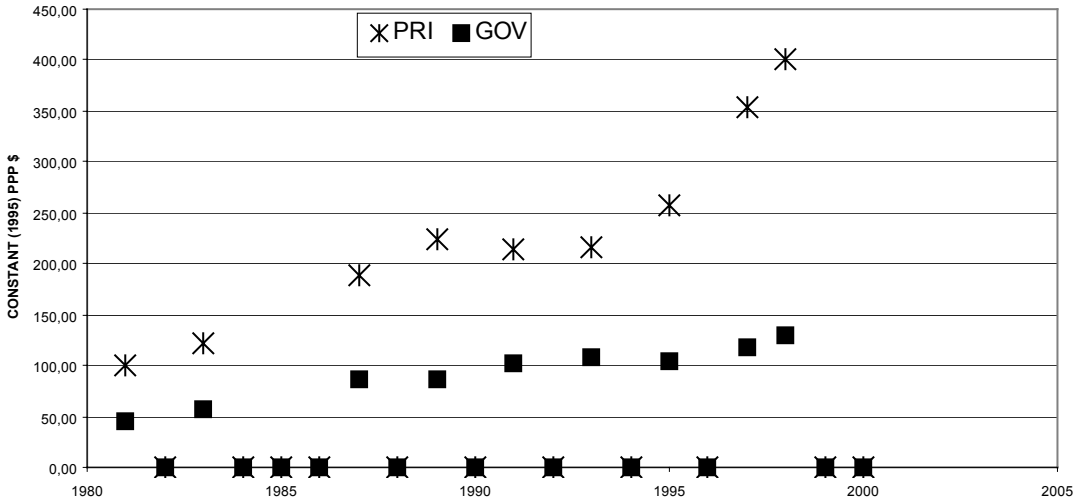

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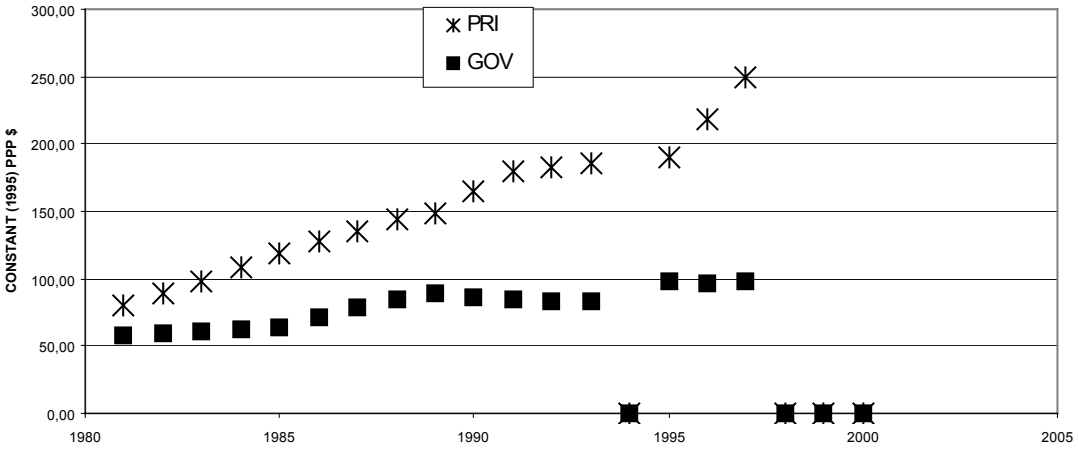

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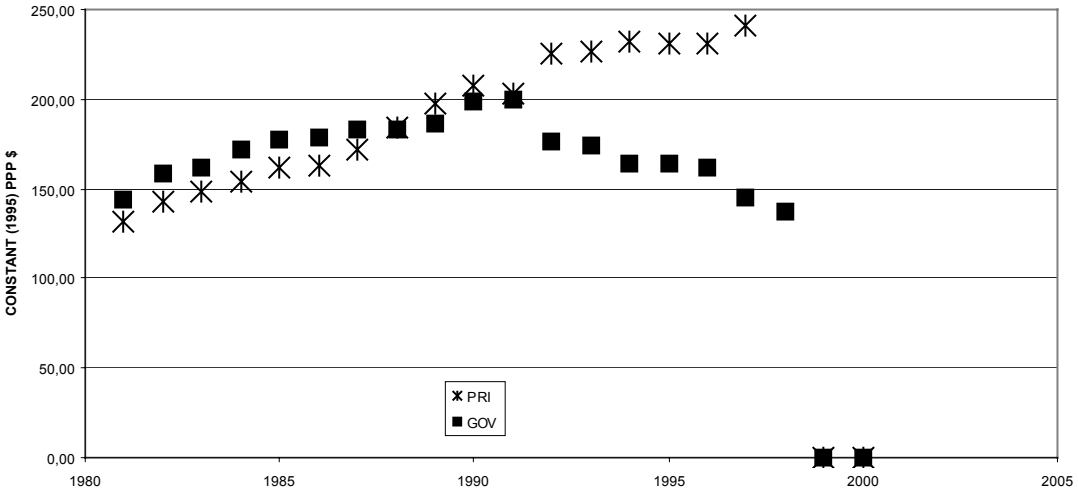

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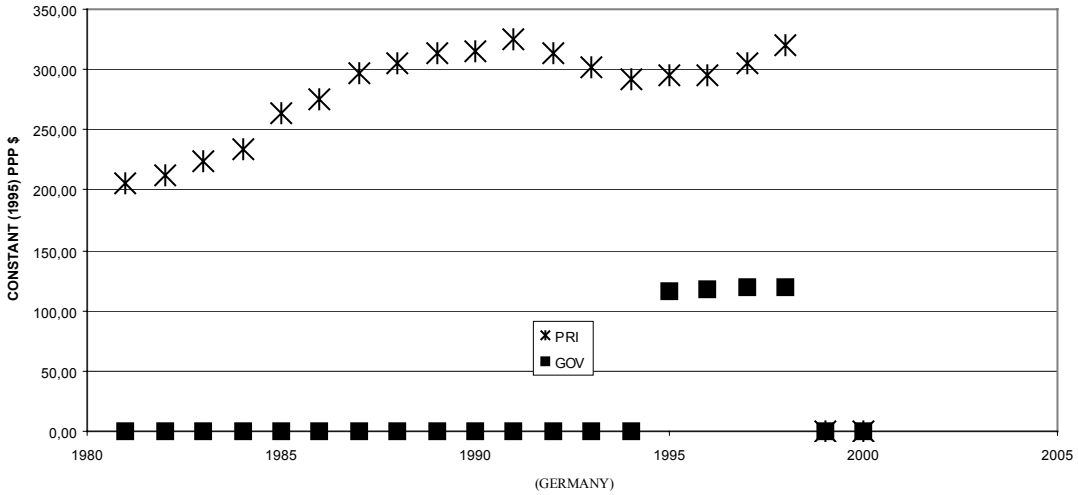

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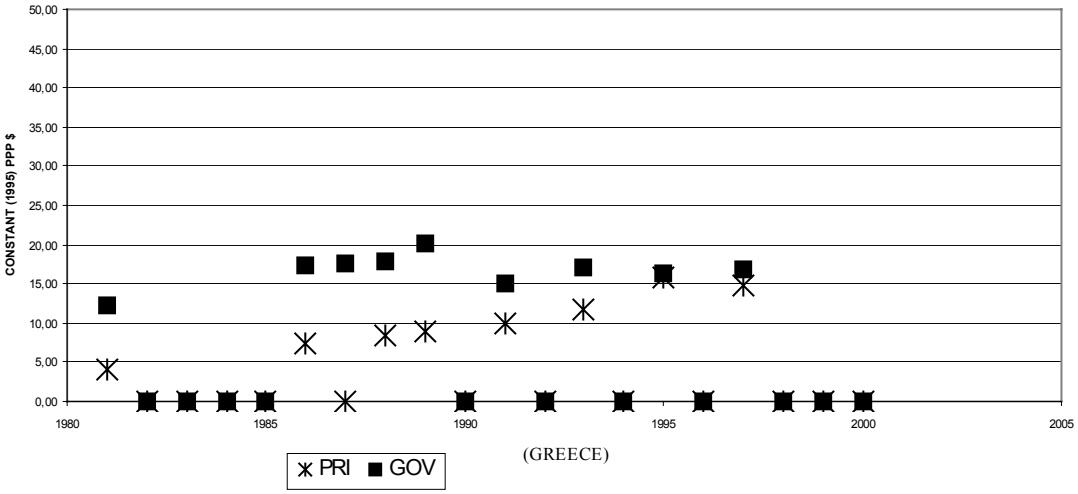

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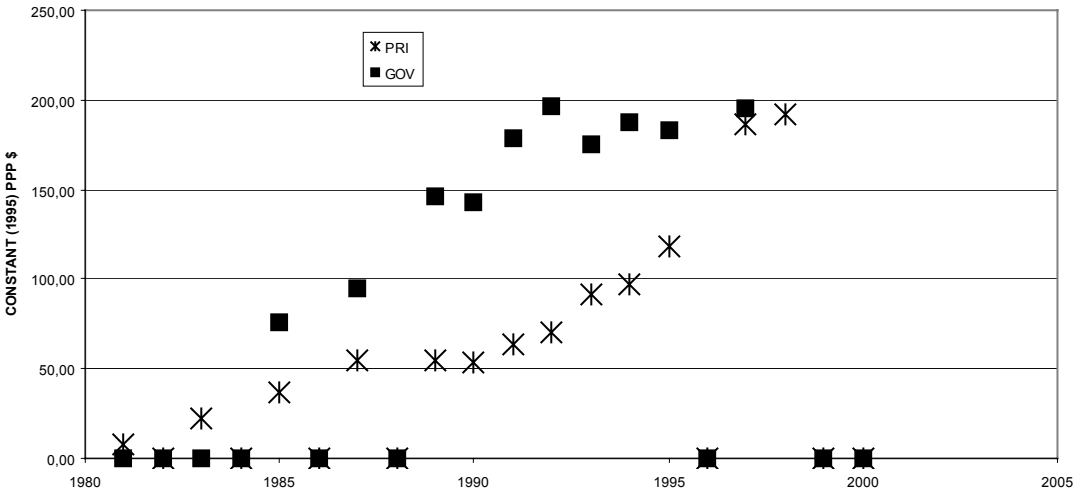

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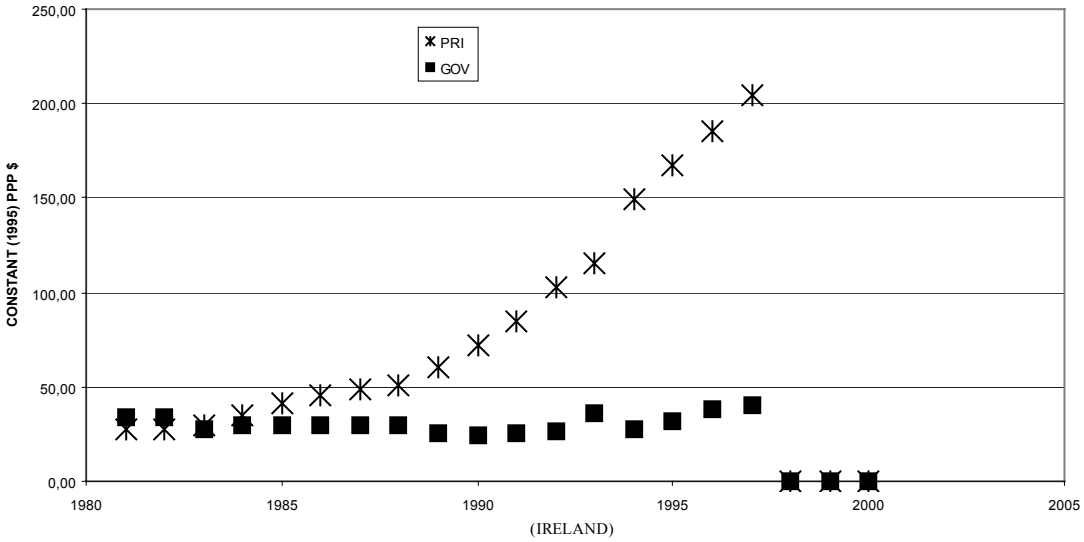
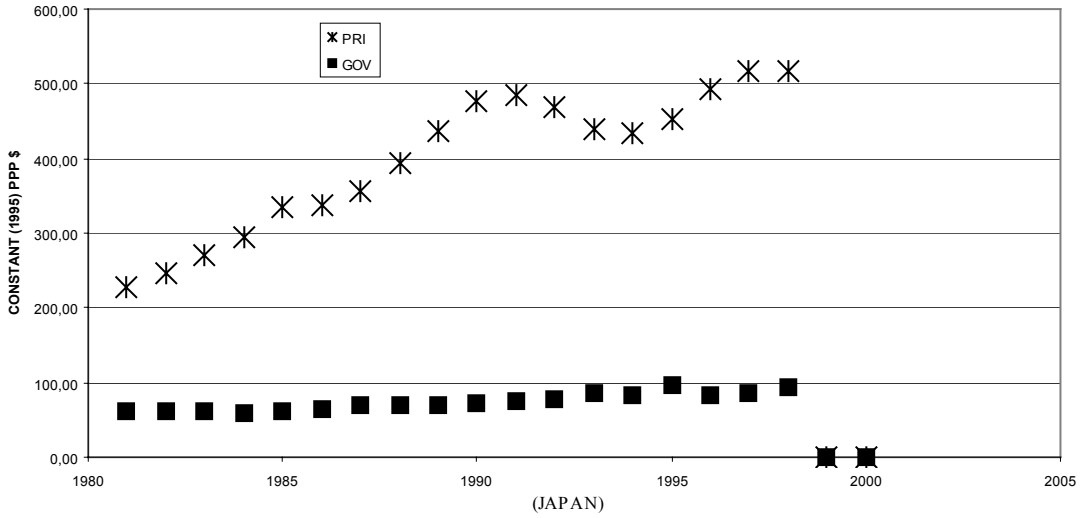


(IRELAND)



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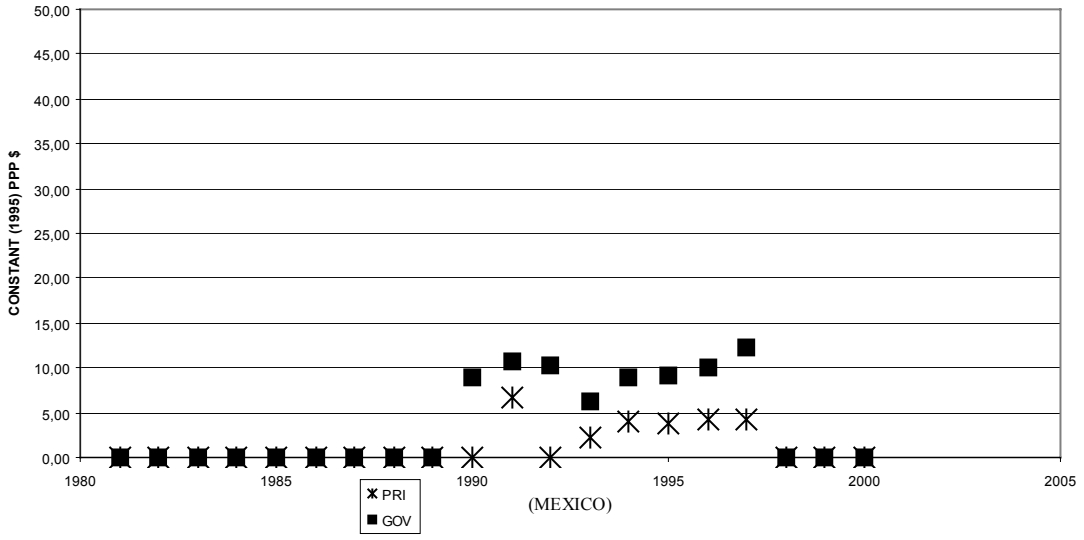

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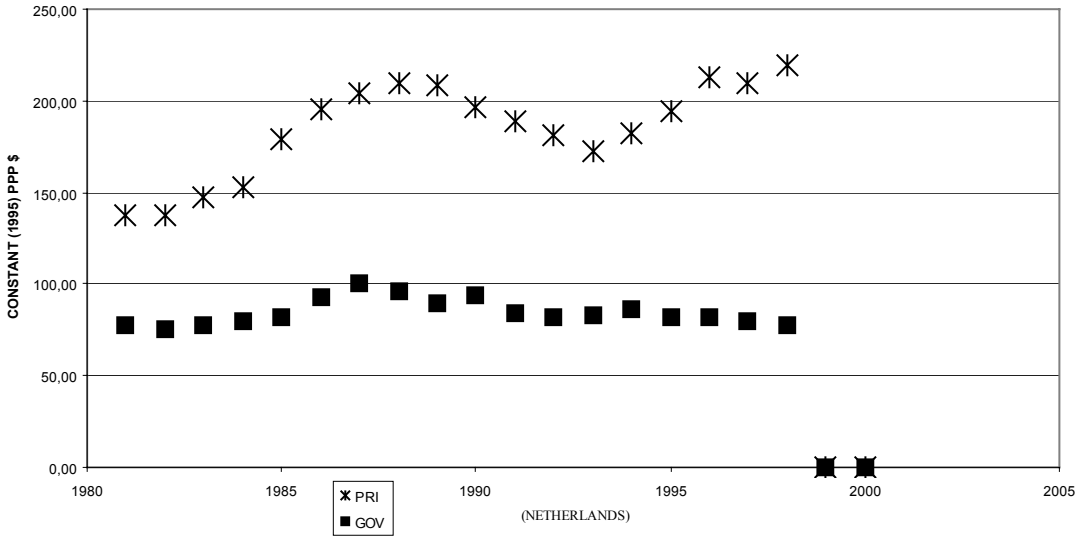
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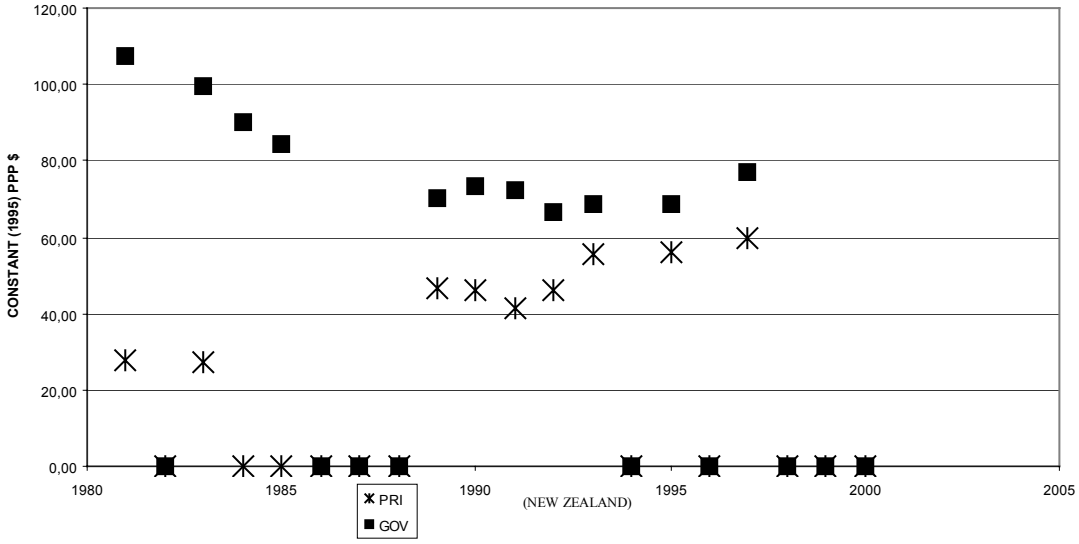
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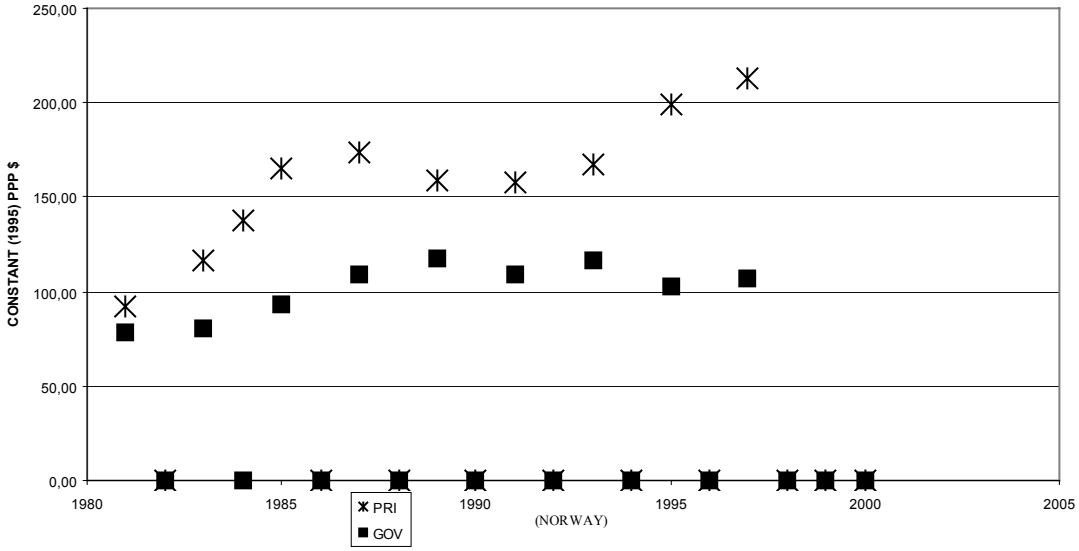
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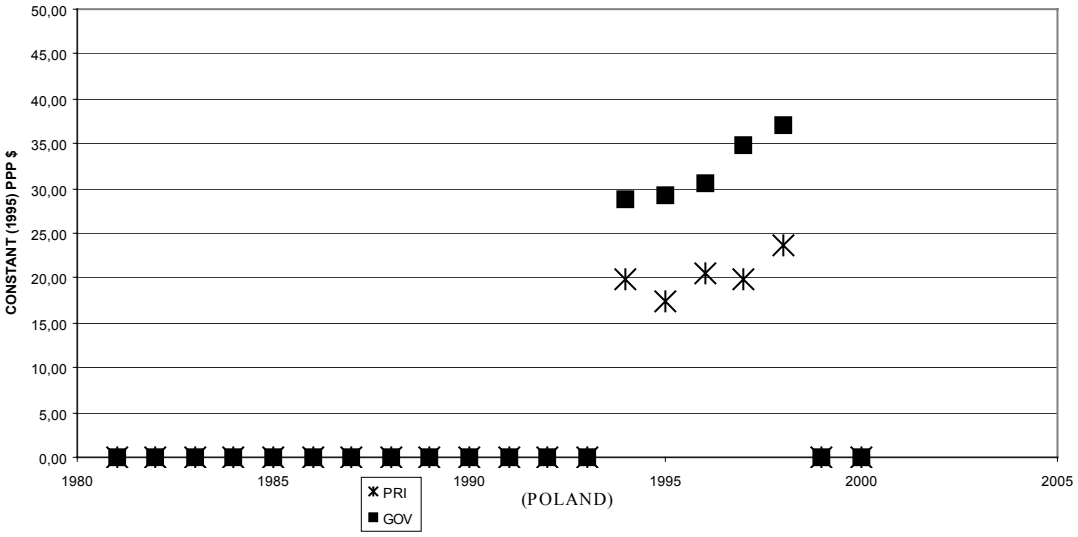

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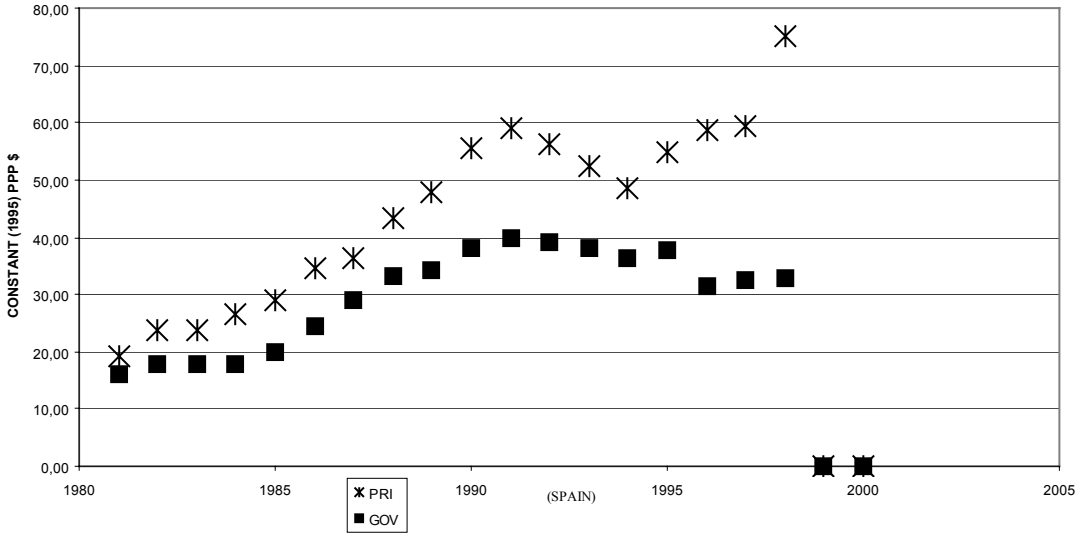

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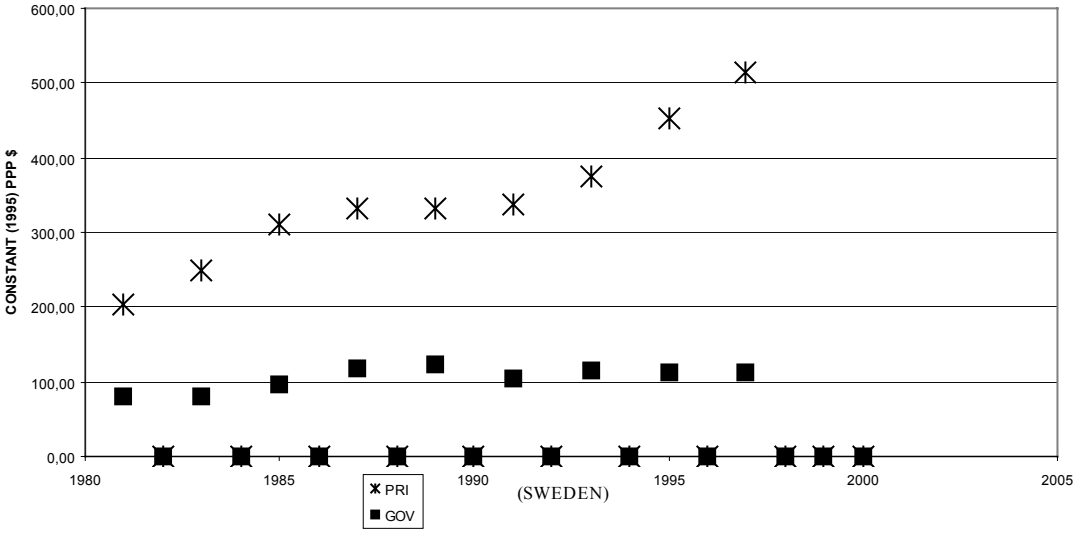

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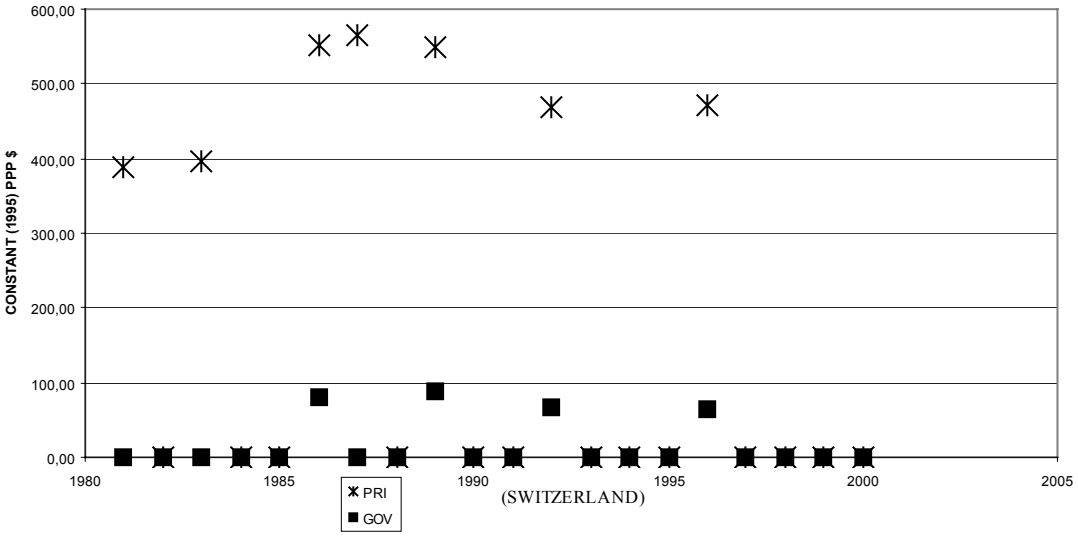
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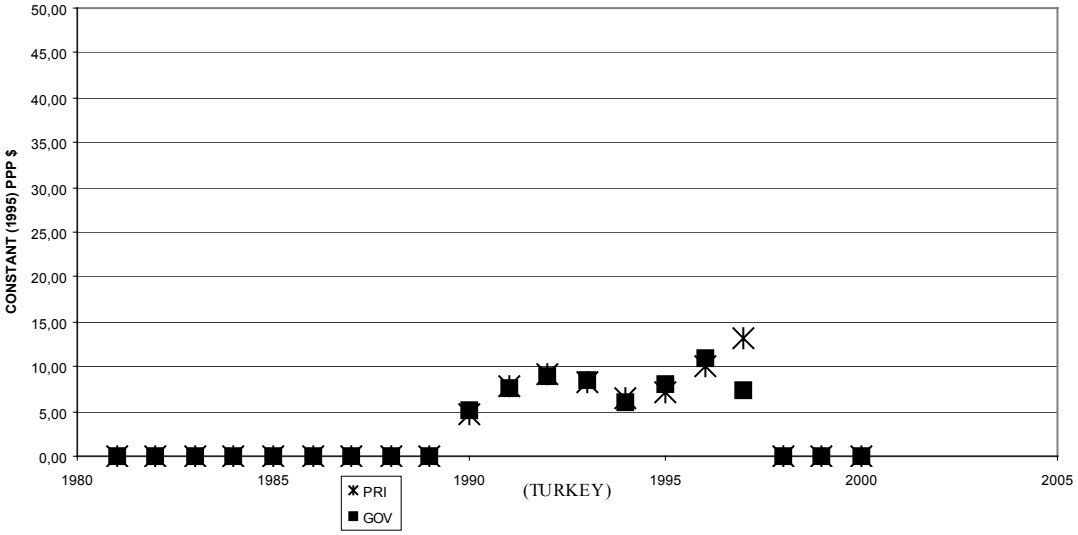
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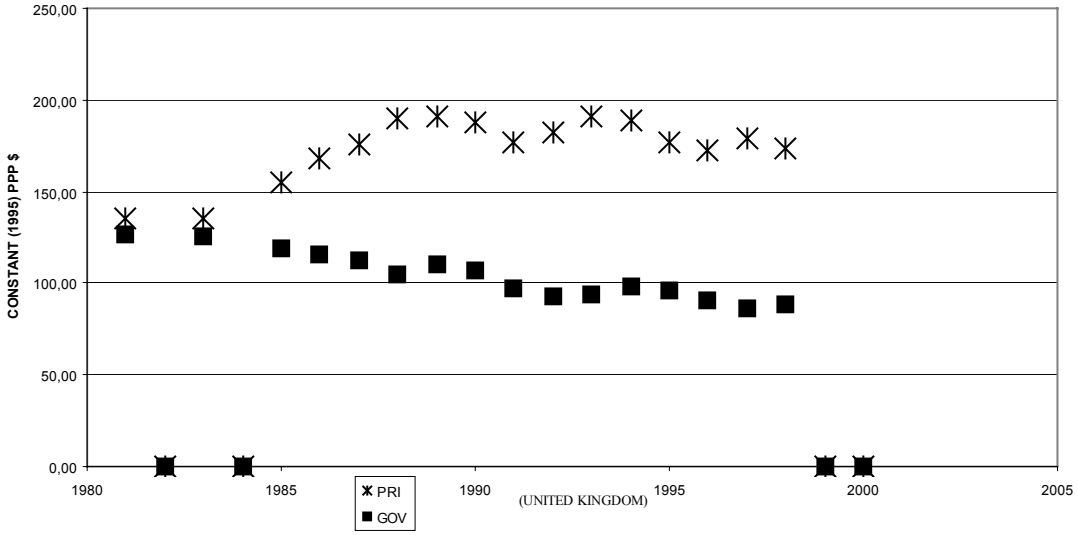
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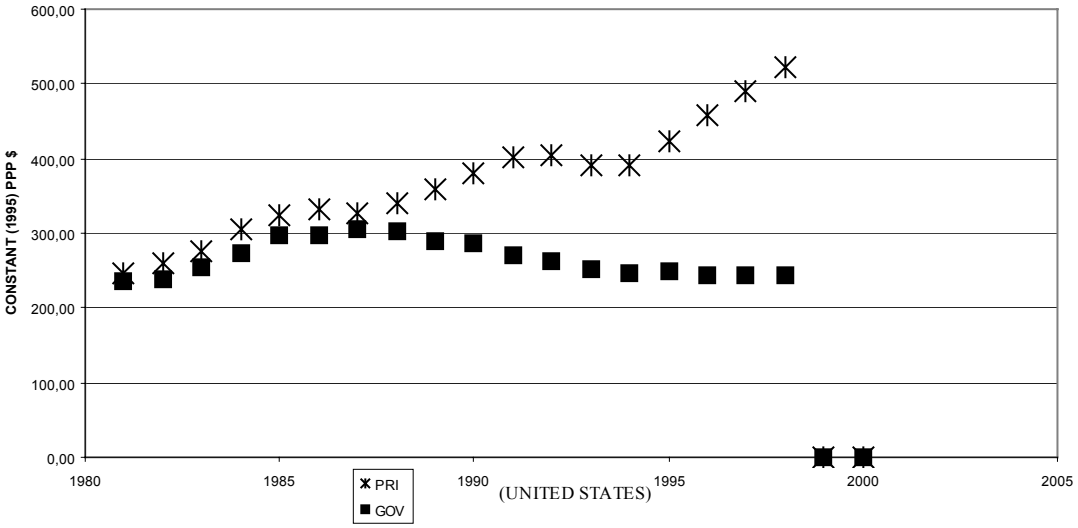
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