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R&D and Patents: An Attempt of Application of the Griliches's Model in a Transitional Economy

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ABSTRACT

The main aim of this paper is to analyze relations between patent activity and R&D activity in Poland being a transitional economy in Central and Eastern Europe. The macro-perspective will be considered here. The paper begins with data on patents and R&D expenditures in the country in 1990-2010. Then the Griliches's model is presented. The next section is devoted to an empirical verification of this model in Poland. Finally, there will be the main conclusions.

Keywords: R&D, invention, patent, transitional economy

1. Introduction

Many scientists as well as politicians in Poland complain about the decreasing number of patents in the last two decades. The number of domestic patents issued in 2010 amounted only to 40% of the number in 1991 (see Table 1 below). There may be various reasons for such state of affairs (see Jasinski, 2006). One of questions to be answered here is: *Does R&D activity have any influence on such patent activity?* An answer to this question should allow us to better understand relations between patents and R&D. So, the main aim of this paper is to analyze quantitative relations between patent activity and R&D activity in Poland being a transitional economy in Central and Eastern Europe. In the Polish literature, we have not found any publication showing results of such analysis.

2. Patent activity and R&D expenditures in Poland in the transition period

Data on patents and R&D expenditures in Poland in 1990-2010 are presented in Table 1.
The following conclusions can be drawn from Table 1:
(i) The number of domestic patent submissions (Ps) showed a steady tendency to decrease in 1990-2004. The decline was stopped in 2005 and a systematic growth started in 2006 (see also Figure 1.1. in Appendix 1);
(ii) The number of domestic patents issued (Pp) showed a permanent declining tendency till 2003. The decrease was stopped in 2004 and a tendency to increase – with fluctuations – began in 2005 (see Figure 1.2.);
(iii) National expenditures on research and development (GERD) showed a tendency to decrease – with fluctuations – in 1990-2002. The starting level of GERD was achieved in 1998 and again in 2004. A permanent increase started only in 2003 (Figure 1.3.);

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(iv) A systematic decline in the GERD/GDP indicator took place till 2002. In 2002-2007, its value stabilized at a very low level (0.56-0.58). Then the coefficient showed a constant growth from 2008 (Figure 1.4.);

(v) The above declining tendencies were very worrying. The situation began to improve around 2004 when Poland became a member of The European Union. However, the number of patent submissions and patents issued in 2010 were still smaller than at the beginning of the period under analysis. The GERD/GDP ratio did not come back to the starting level either.

Table 1. Patents and R&D expenditures in Poland, 1990-2010

Year	**Domestic patent submissions**	**Domestic patents issued**	**GERD in \$ mln (constant prices of 2005)**	**GERD/GDP (in %)**
1	2	3	4	5
1990	4105	3242	2741.35	0.96
1991	3389	3418	2142.68	0.81
1992	2896	3443	2258.72	0.81
1993	2658	2641	2342.01	0.86
1994	2676	1825	2267.97	0.82
1995	2595	1619	2196.19	0.69
1996	2411	1405	2411.50	0.71
1997	2339	1179	2576.42	0.71
1998	2407	1174	2764.25	0.72
1999	2285	1022	2989.32	0.75
2000	2404	939	2912.03	0.66
2001	2202	851	2850.42	0.64
2002	2313	834	2595.00	0.58
2003	2268	613	2605.50	0.56
2004	2381	778	2831.06	0.58
2005	2028	1054	2982.43	0.57
2006	2157	1122	3106.64	0.56
2007	2392	1575	3384.08	0.57
2008	2488	1451	3790.48	0.60
2009	2899	1536	4303.67	0.67
2010	3203	1385	4876.09	0.74

Source: GUS (subsequent Yearbooks of *Science and technology in Poland* (1996-2012) and OECD (2012)

Various factors influence patent activities in firms, R&D institutions and other organizations (Jasinski, 2003). Among them, there is probably the most important factor, i.e., R&D expenditures. This relation may be explained as follows:

- the result of research and development is production of new (scientific and technological) knowledge, including inventions,
- a growth of R&D expenditures brings a growth of production of this knowledge, including inventions,
- when the knowledge production rises – an increase can be observed in the number of patent submissions, i.e., inventions submitted to a legal protection,
- an increase in patent submissions brings – although not immediately – a growth of patents issued (a new patented knowledge), i.e., inventions protected by patents.

3. The Griliches's model

Inventions and patents have fascinated economists for a long time. Following Rosegger (1986), we may speak of the production of inventions – which usually become patented - as an economic activity, because it requires the commitment of resources to the purposeful search for new knowledge. Therefore, many investigators have dealt with the economic analysis of patent activity. Among them – Griliches (1990), Pavitt (1996) and Stoneman (1987).

In his probably the most famous work, Zvi Griliches (1990) analyzed relationships between R&D and patents in the United States in the post-war period. He argued that patents are a good index of inventive activity, a major aspect of which is measured by research and development expenditures. Then he proved that there is quite a strong relationship between R&D and the number of patents received at the cross-sectional level, across firms and industries. For this purpose, Griliches (1990, p. 1672) constructed the linear model of 'knowledge production function' as follows:

$$P = aK + v = aR + au + v$$

where:
P – patents,
R – research expenditures,
K – additions to economically valuable knowledge,
u – other sources of knowledge growth,
v – random variable,
a – structural parameter of the model.

Afterwards he estimated the regression function P = *a*R + *a*u for the period of 1953-1989. The estimated elasticity of R&D with respect to patents was 0.76, i.e., rather high. Thus, it may be said that, in the long period, there exists a positive relation between R&D and patents which means that the number of patents increases together with the growth of the expenditures on research and development.
Now, a question has emerged: *Does the Griliches's model work in other countries, especially in transitional economies***?** Poland here will be a case-study and the macro-perspective will be considered.

4. An empirical verification in Poland

Patent may be treated as a certain link connecting the R&D sector with industry, because if the invention creator (an individual or an organization) takes a decision to apply for patent, it means that he/she can see a commercial potential of the future innovation that will be based on this invention. In order to find how strong this connection/relation is, a crucial question is: *How to measure both variables* ('patents' and 'R&D')?

As far as patent activity is concerned, the number of patent submissions seems to be a better measurement than the number of patents issued because:

- patent submissions better express the essence of patent activity and
- patent submissions are more directly connected with R&D activity.

So, *the number of domestic patent submissions (Ps)* has been chosen as the endogenous variable. In turn, the exogenous variable will be *GERD in $mln (in constant prices)* due to the fact that, in macro-analysis, research activity is usually expressed by R&D expenditures, universally by GERD. However, we must be fully aware that research expenditure is an input but rather not an output of research production.

An econometric model has been chosen as an analytical tool. Several attempts were done to find an adequate model describing patent-R&D relations in 1990-2010. In each case, the Engle's-Granger's procedure and the Johansen's procedure (Enders, 2010) were applied to estimate both long-term relation models as well as models with the vector error correction (VEC). (The VEC model allows us to incorporate both the long-term and short-term relations at the same time). Afterwards, in each case, the best model was chosen using the determination coefficient R-squared and the significance of parameters as two main model quality measurements.

The models based on absolute values

Using the Johansen's procedure, the following relations were obtained:[1]
The long-term relation model:

(1) $$Ps_t = 484.94 + 0.74 \cdot GERD_t$$

The model with vector error correction:

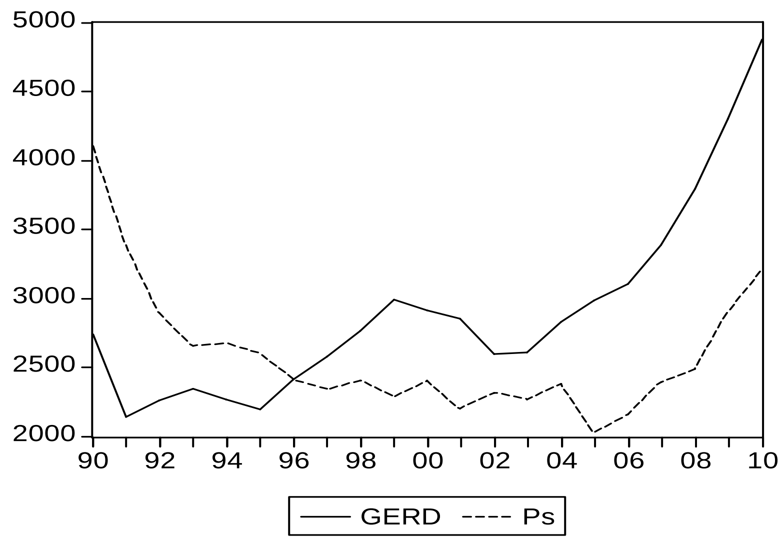
(2)
$$\Delta Ps_t = -45.1 - 0.35 \cdot$$
$$\cdot \left(Ps_{t-1} - 484.94 - 0.74 \cdot GERD_{t-1}\right)$$

R-squared = 0.73, so is relatively high.
Report on estimates of parameters in model (2) – see Table 2.1. in Appendix 2.

The estimated long-term relation model means that the increase in GERD by $100 mln brings the increase in the number of domestic patent submissions by 74 submissions. In 1990-1995, the decreasing GERD pulled patent submissions down, then there were seven years of fluctuations, and finally, in 2003-2010, the growing GERD pulled the submissions up (see Figure 1).

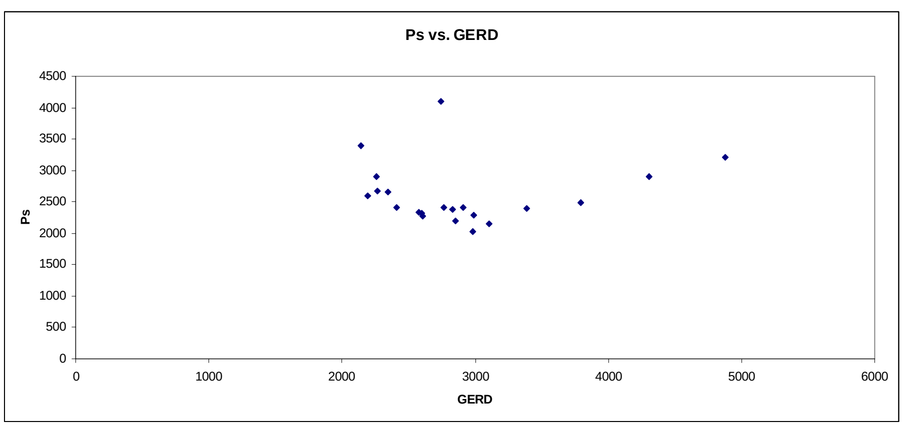
[1] This procedure gave better results than the Engle's-Granger's procedure.

Figure 1. Curves of patent submissions and GERD in 1990-2010 (absolute values)



The relation between patent submissions and GERD is shown in Figure 2. Unfortunately, the figure is not fully explicit because of the observed – as in Figure 1 – deviation of the long-term equilibrium in 1996-2002. So, we tried to build slightly different models.

Figure 2. Patent submissions versus GERD (absolute values)



The models based on logarithms

In order to ascertain the elasticity of patent submissions with respect to GERD, the following relations were obtained using the Johansen's procedure:[2]

The long-term relation model:

(3)

$$\log(Ps_t) = 1.15 + 0.84 \cdot \log(GERD_t)$$

[2] Also in this case, the Johansen's procedure gave better results than the Engle's-Granger's procedure.

The model with vector error correction:
(4)

$$\Delta\log(Ps_t) = -0.012 - 0.30\cdot$$
$$\cdot\left(\log(Ps_{t-1}) - 1.15 - 0.84\cdot\log\left(GERD_{t-1}\right)\right)$$

R-squared = 0.60, so is high enough.
Report on estimates of parameters in model (4) – see Table 2.2. in Appendix 2.

The long-term elasticity of domestic patent submissions with respect to GERD is 0.84 - very high. This result corresponds with the result gained by Griliches (0.76) who has estimated his model based on logarithms, too.
The curves of the logarithms of patent submissions and GERD have the same shapes as in Figure 1, which is obvious.

The models of relation between patent submissions and the GERD/GDP coefficient

Finally, let's check whether there is any relation between domestic patent submissions and the GERD/GDP coefficient. This universally accepted indicator well shows a real scale of the whole country's financial effort for research and development. Truly speaking, a first such attempt was undertaken three years ago (Jasinski and Manikowski, 2010). For the period 1990-2007, the following linear model was estimated:

(5) $$\hat{Ps}_t = 3839.8\cdot\frac{GERD}{GDP}_t,$$

R-squared = 0.54 (acceptable)
which can be interpreted as follows: the increase (decrease) in the GERD/GDP coefficient by 0.10 brought the growth (decline) of the number of patent submissions by 384.
Now, having a bit longer time-series (for 1990-2010), we estimated the same model representing a long-term relation between patent submissions and GERD/GDP:

(6) $$Ps_t = 3729.1\cdot\frac{GERD}{GDP}_t$$

R-squared = 0.57 (acceptable).
Report on estimates of parameters in model (6) – see Table 2.3. in Appendix 2.

So, the change in the coefficient by 0.10 brings the change in the number of patent submissions by 373 (going to the same direction). This is well presented in Figure 3 which shows that, during the better part of the period under analysis, the decreasing GERD/GDP ratio pulled patent submissions down.

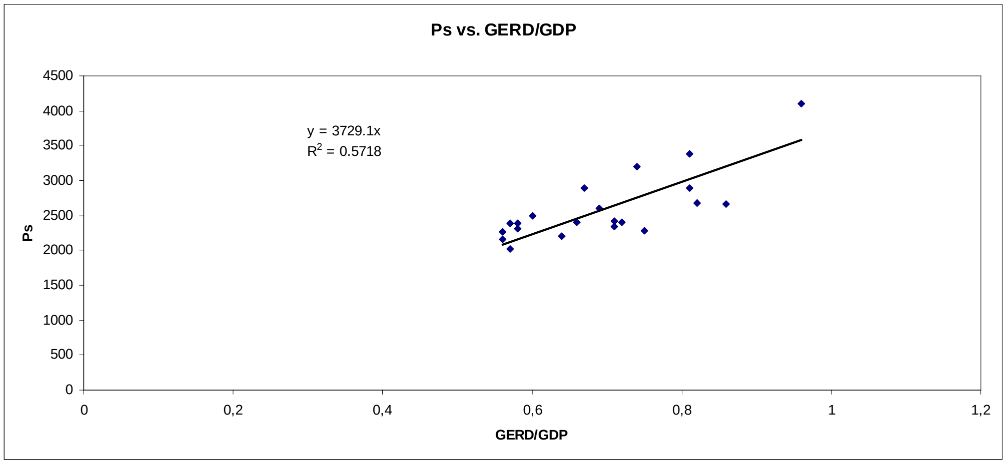
5. Conclusions

We can observe two highly worrying tendencies to decrease in patent activity till 2004/2005, both in patent submissions and patents issued. Although the two declining tendencies were reversed in 2005/2006 but both of the quantities did not reach their levels of 1990.

Two clear sub-periods can be observed within the period under analysis:
(a) 1990 - 2004/2005 – decline and
(b) 2005/2006 - 2010 – growth of patent activity.

Also, very worrying are decreasing tendencies in R&D expenditures. GERD (in constant prices) showed a tendency to decline till 2002. The GERD/GDP coefficient was declining to 2002 too, and afterwards it stabilized at a very low level. GERD started to slowly increase in 2003 but the GERD/GDP ratio – not earlier than in 2008.

Figure 3. Patent submissions versus GERD/GDP



Here two sub-periods are seen, too. They are as follows:

(a) 1990 – 2002 – decrease with fluctuations at the end, and

(b) 2003 - 2010 - stabilization and growth of R&D expenditures.

We can then say that, in the first sub-period, the declining GERD (in absolute and relative values) pulled down patent submissions and patents issued. Afterwards, in the second sub-period, growing GERD pulled up both submissions and patents. However, the two later quantities began to increase not at once but after three years. So, they react to changes in GERD with a certain delay.

The estimated econometric models prove that the relation between patent submissions and R&D expenditures is positive and strong. The elasticity is more than 0.80. These findings seem to confirm that the mechanism described here on page 2 works in reality: a bigger R&D 'produces' more patents. Therefore, one can say that the Griliches's model has found confirmation in Poland being a country in transition.

Important conclusions result from these findings:

- Although there exist various conditions for the increase in patent activity in a transitional economy, one of them is undoubtedly critical, i.e., the growth of national expenditures on research and development,
- Those who are afraid of a very small number of patents in a country must be conscious that one of the reasons of it are too small R&D expenditures,
- Moreover, a growing GERD will pull up patent activity not at once but with a certain delay,
- And finally - further, deeper econometric analyses are needed to construct the models that would even better show relations between the two variables.

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Appendix 1

Figure 1.1. Domestic patent submissions in Poland, 1990-2010

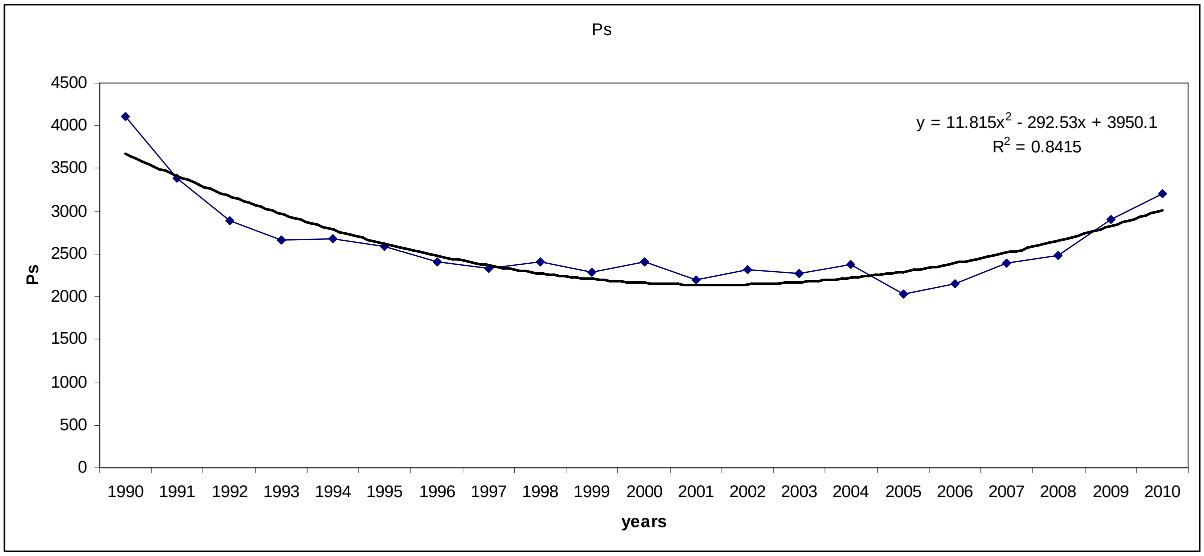


Figure 1.2. Domestic patents issued in Poland, 1990-2010

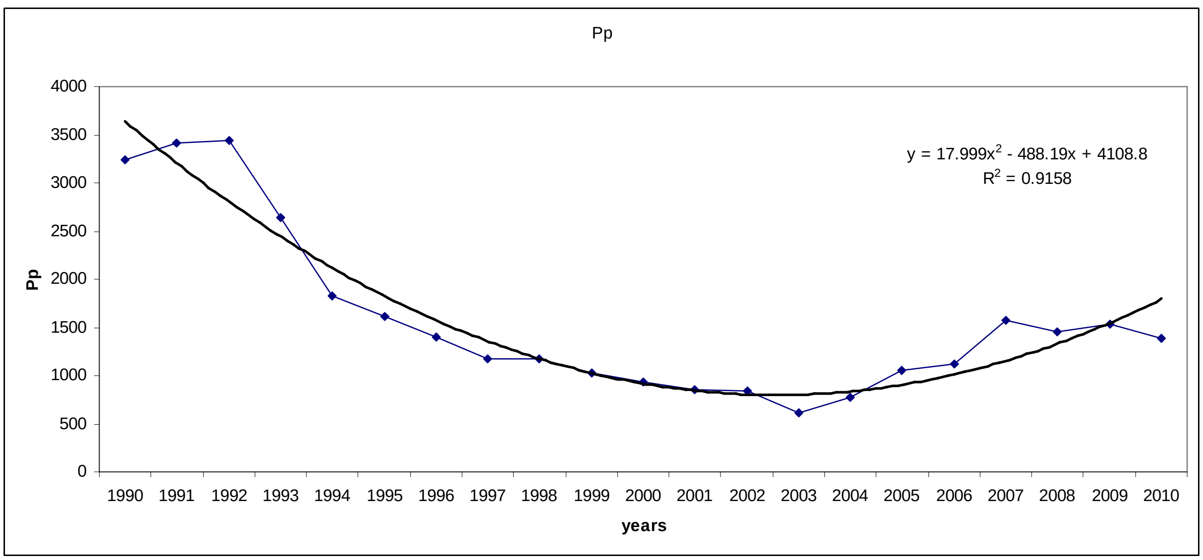


Figure 1.3. GERD in constant prices (in $mln) in Poland, 1990-2010

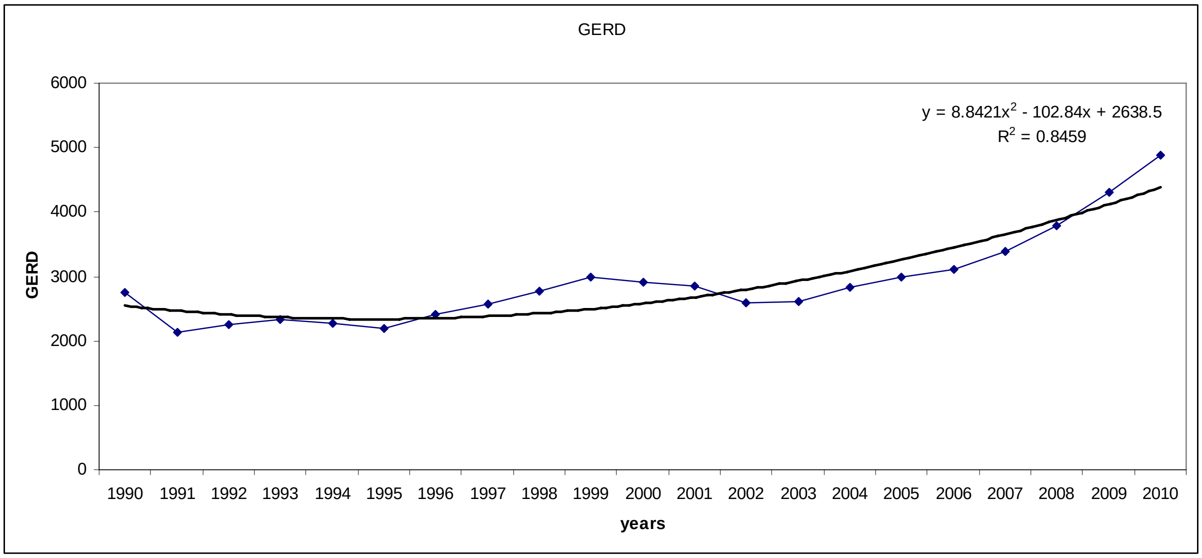
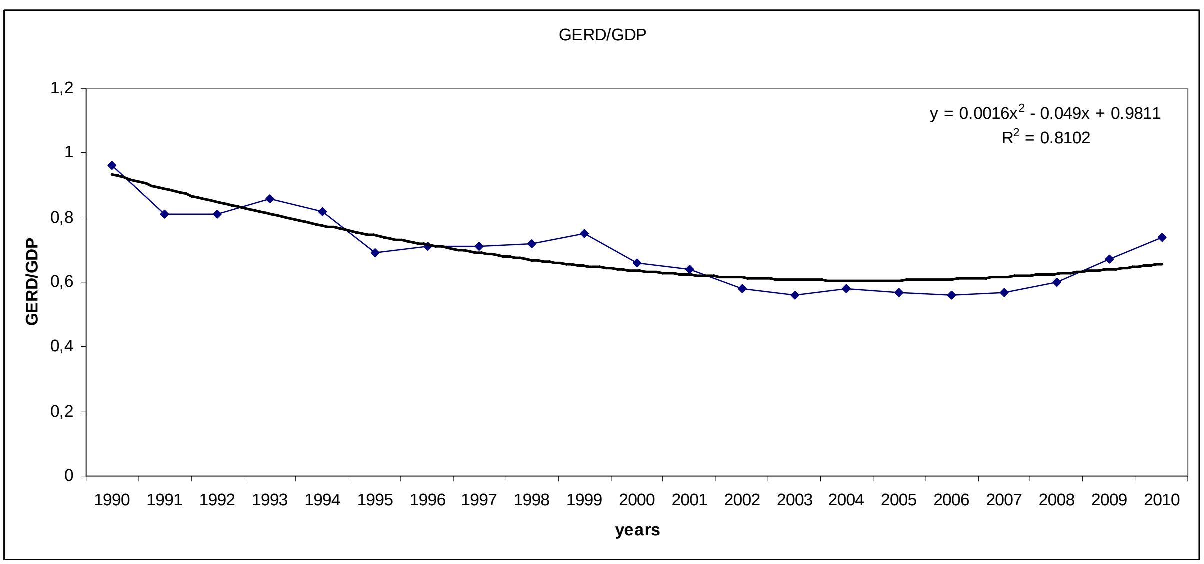


Figure 1.4. The GERD/GDP ratio in Poland, 1990-2010



Appendix 2

Table 2.1. Report on estimates of parameters in model (2)

Vector Error Correction Estimates
Date: 04/09/12 Time: 00:19
Sample(adjusted): 1991 2010
Included observations: 20 after adjusting Endpoints
Standard errors in ( ) & t-statistics in [ ]

Cointegrating Eq:	CointEq1	
Ps(-1)	1.000000	
GERD(-1)	-0.742070 (0.17127) [-4.33287]	
C	-484.9364	
Terror Correction:	D(Ps)	D(GERD)
CointEq1	-0.346602 (0.04947) [-7.00619]	-0.237076 (0.07452) [-3.18119]
C	-45.10000 (32.1426) [-1.40312]	106.7370 (48.4207) [2.20437]
R-squared	0.731690	0.359885
Adj. R-squared	0.716784	0.324323
Sum sq. Resids	371933.7	844042.8
S.E. equation	143.7462	216.5439
F-statistic	49.08663	10.11996
Log likelihood	-126.6862	-134.8810
Akaike AIC	12.86862	13.68810
Schwarz S.C.	12.96819	13.78768
Mean dependent	-45.10000	106.7370
S.D. dependent	270.1081	263.4368
Determinant Residua Covariance		9.05E+08
Log Likelihood		-260.8830
Log Likelihood (d.f. adjusted)		-262.9902
Akaike Information Criteria		26.89902
Schwarz Criteria		27.19774

Table 2.2. Report on estimates of parameters in model (4)

Victor Error Correction Estimates
Date: 04/09/12 Time: 00:23
Sample(adjusted): 1991 2010
Included observations: 20 after adjusting Endpoints
Standard errors in ( ) & t-statistics in [ ]

Cointegrating Eq:	CointEq1	
LOG(Ps(-1))	1.000000	
LOG(GERD(-1))	-0.844367 (0.25281) [-3.33995]	
C	-1.146698	
Error Correction:	D(LOG(Ps))	D(LOG(GERD))
CointEq1	-0.296068 (0.05691) [-5.20253]	-0.166168 (0.07502) [-2.21499]
C	-0.012406 (0.01362) [-0.91103]	0.028795 (0.01795) [1.60405]
R-squared	0.600589	0.214186
Adj. R-squared	0.578399	0.170529
Sum sq. resids	0.066756	0.116009
S.E. equation	0.060899	0.080280
F-statistic	27.06630	4.906174
Log likelihood	28.64564	23.11947
Akaike AIC	-2.664564	-2.111947
Schwarz SC	-2.564990	-2.012374
Mean dependent	-0.012406	0.028795
S.D. dependent	0.093790	0.088147
Determinant Residua Covariance		2.31E-05
Log Likelihood		52.08808
Log Likelihood (d.f. adjusted)		49.98087
Akaike Information Criteria		-4.398087
Schwarz Criteria		-4.099367

Table 2.3. Report on estimates of parameters in model (6)

Dependent Variable: Ps
Metod: Least Squares
Sample: 1990 2010
Included observations: 21

Variable	Coefficient	Std. Error	t-Statistic	Prob.
GERD/GDP	3729.108	98.48065	37.86640	0.0000

R-squared	0.571771	Mean dependent var	2595.048
Adjusted R-squared	0.571771	S.D. dependent var	484.4457
S.E. of regression	317.0174	Akaike info criterion	14.40224
Sum squared resid	2010001.	Schwarz criterion	14.45198
Log likelihood	-150.2235	Durbin-Watson stat	0.644149