

IMPACT OF PUBLIC AND PRIVATE SPENDINGS ON THE  
INNOVATION PERFORMANCE AND PROPENSITY FOR  
INTERNATIONAL COLLABORATION OF DOMESTIC  
COMPANIES IN POLAND AND OTHER EU COUNTRIES.  
CROSS-COUNTRY COMPARATIVE ANALYSIS USING ADL  
MODEL

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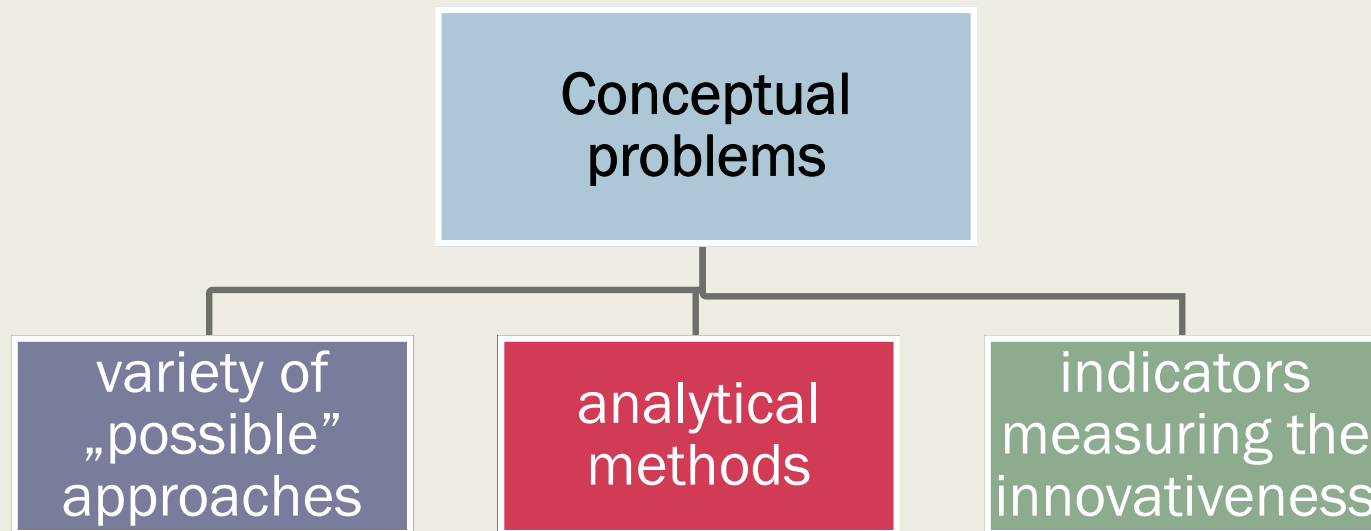


# Improving the innovation potential

- the indispensable base for the future economic growth of every country in the world
- one of key pillars of international competitiveness of the country resulting in e.g. its outcomes in foreign trade, exports of FDI, advantages of domestic products on international markets, widely-understood value creation and – eventually - the good macroeconomic performance and general wellbeing of the society
- Currently: technological rivalry (accelerated in the recent decade) between countries of the world: the “race” for better results in this field.
- This competition reflected in the international rankings of innovativeness (OECD, EU) (various indicators).
- Results should be the function of the country’s (public and private) expenses on science and technology sectors


# The study project purposes

- To analyse the direct impact of the public and private outlays on R&D in Poland and other EU members in the period 2010- 2018
  - innovation performance of firms
  - international innovation-collaboration potential
  - actual results on this field
- The issue of „tracing” the relations between the actual outlays on e.g. R&D and its macroeconomic effects is complicated:



## The study project purposes

- The analysis is also to unveil which innovation indicators are most effectively impacted by the real effective expenditures on R&D realized by the public and private sector
- Detecting the elasticity of performance indicators (measuring the various aspects of countries' results in the international innovation rankings) to outlays on R&D.
- To select „the best” indicators showing the real, i.e. „tangible” indicators reflecting the innovation performance of the country.
- To find the most effective channel of transforming the public and private outlays on innovations (widely-understood) into the real market effects using the chosen quantitative methods: Aggregated Distributed Lag Models (ADL) versus Vector Autoregressive Models (VARs),
- Cross-country comparative perspective. The special focus will be put on the indicators on product, process, organisational and marketing innovative firms, as well as international collaboration potential of the firms in studied countries.



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ANALYSIS USING ADL MODEL

**Possible indicators:**

**OECD Indicators**

**UE indicators (Eurostat)**

**Possible methodological approaches**



## I. Research and development (research)

### Statistics on research and development (rd)

#### *R&D expenditure at national and regional level (rd\_e)*

Intramural R&D expenditure (GERD) by sectors of performance (rd\_e\_gerdtot)

Intramural R&D expenditure (GERD) by sectors of performance and source of funds (rd\_e\_gerdfund)

Intramural R&D expenditure (GERD) by source of funds (rd\_e\_fundgerd)

Intramural R&D expenditure (GERD) by sectors of performance and fields of science (rd\_e\_gerdsc)

Intramural R&D expenditure (GERD) by sectors of performance and type of costs (rd\_e\_gerdcost)

Intramural R&D expenditure (GERD) by sectors of performance and type of R&D activity (rd\_e\_gerdact)

Intramural R&D expenditure (GERD) by sectors of performance and socio-economic objectives according to NABS 2007 (rd\_e\_gerdsobj07)

Intramural R&D expenditure (GERD) by sectors of performance and socio-economic objectives according to NABS 1992 (rd\_e\_gerdsobj92)

Business expenditure on R&D (BERD) by NACE Rev. 2 activity (rd\_e\_berdindr2)

Business expenditure on R&D (BERD) by NACE Rev. 2 activity and source of funds (rd\_e\_berdfundr2)

Business expenditure on R&D (BERD) by NACE Rev. 2 activity and type of costs (rd\_e\_berdcostr2)

Business expenditure on R&D (BERD) by product field of NACE Rev. 2 activity (rd\_e\_berdpfr2)

Business expenditure on R&D (BERD) by NACE Rev. 1.1 activity (rd\_e\_berdind)

Business expenditure on R&D (BERD) by NACE Rev. 1.1 activity and source of funds (rd\_e\_berdfund)

Business expenditure on R&D (BERD) by NACE Rev. 1.1 activity and type of costs (rd\_e\_berdcost)

Business expenditure on R&D (BERD) by size class and source of funds (rd\_e\_berdsize)

Intramural R&D expenditure (GERD) by sectors of performance and NUTS 2 regions (rd\_e\_gerdreg)

R&D personnel at national and regional level (rd\_p)

#### *Government budget appropriations or outlays on R&D (gba)*

Total GBAORD by NABS 2007 socio-economic objectives (gba\_nabsfin07)

Total GBAORD by NABS 1992 socio-economic objectives (gba\_nabsfin92)

Total GBAORD as a % of total general government expenditure (gba\_nabste)

Total GBAORD by funding mode (gba\_fundmod)

National public funding to transnationally coordinated R&D (gba\_tncoor)

## II. Community innovation survey (inn)

### *Results of the community innovation survey 2016 (CIS2016) (inn\_cis10)*

Basic economic information on the enterprises by NACE Rev. 2 activity and size class (inn\_cis10\_bas)

Enterprise by administrative state of the enterprise, NACE Rev. 2 activity and size class (inn\_cis10\_gen)

Enterprises by NACE Rev. 2 activity and size class (inn\_cis10\_type)

Enterprises by percentage of employees with university education, by NACE Rev. 2 activity and size class (inn\_cis10\_educ)

Enterprise by place where goods and/or services are sold, and place of largest market in terms of turnover, by NACE Rev. 2 activity and size class (inn\_cis10\_mrk)

Product and/or process innovative enterprises by type of innovation activity, NACE Rev. 2 activity and size class (inn\_cis10\_iact)

Expenditures in product and/or process innovative enterprises by area of expenditure, NACE Rev. 2 activity and size class (inn\_cis10\_exp)

Enterprises by intellectual property rights (IPRs) and licensing in the enterprise, NACE Rev. 2 activity and size class (inn\_cis10\_ipr)

Product and/or process innovative enterprises engaged in co-operation by co-operation partner, NACE Rev. 2 activity and size class (inn\_cis10\_coop)

Product and/or process innovative enterprises which used information for their innovation activities, by source of information, level of importance of the source, NACE Rev. 2 activity and size class (inn\_cis10\_sou)

Product and/or process innovative enterprises that received public funding for innovation activities by source of funding, NACE Rev. 2 activity and size class (inn\_cis10\_pub)

Innovative and non-innovative enterprises by type of business strategy applied, importance of the strategy, NACE Rev. 2 activity and size class (inn\_cis10\_strat)

Enterprises that introduced innovation of specific types by type of the innovation, NACE Rev. 2 activity and size class (inn\_cis10\_spec)

Product and process innovative enterprises which introduced innovation by type of innovation, innovation developer, NACE Rev.2 activity and size class (inn\_cis10\_prod)

Product innovative enterprises that have introduced new or significantly improved products by NACE Rev. 2 activity and size class (inn\_cis10\_prodn)

Turnover of product innovative enterprises from new or significantly improved products, by NACE Rev. 2 activity and size class (inn\_cis10\_prodt)

## II. Community innovation survey (inn)

### *Results of the community innovation survey 2016 (CIS2016) (inn\_cis10)*

Product and/or process innovative enterprises that have introduced organisational and/or marketing innovation by type of innovation, NACE Rev. 2 activity and size class (inn\_cis10\_mo)

Innovative enterprises by hampering factor for innovation activities, level of importance of the hampering factor, NACE Rev. 2 activity and size class (inn\_cis10\_ham)

Non- innovative enterprises by barrier against innovation activities, level of importance of the barrier, NACE Rev. 2 activity and size class (inn\_cis10\_noin)

Innovative enterprises whose innovation activities have been affected by legislation or regulations by subject of the regulation/legislation, type of effect, NACE Rev. 2 activity and size class (inn\_cis10\_legist)

Innovative enterprises whose innovation activities have been affected, or not affected, by legislation or regulations, by type of effect, NACE Rev.2 activity and size class (inn\_cis10\_legis)

Enterprise that introduced innovation in logistics by type of innovation, NACE Rev. 2 activity and size class (inn\_cis10\_login)

Enterprises with expenditures for innovation in logistics by size classes of expenditure, NACE Rev. 2 activity and size class (inn\_cis10\_logexp)

Enterprises that did not introduce innovation in logistics by barrier, NACE Rev. 2 activity and size class (inn\_cis10\_lognoin)

Enterprises which introduced innovations in logistics by reason of the introduction, level of importance of the reason, NACE Rev. 2 activity and size class (inn\_cis10\_loginr)

Results of the community innovation survey 2014 (CIS2014) (inn\_cis9)

Results of the community innovation survey 2012 (CIS2012) (inn\_cis8)

Results of the community innovation survey 2010 (CIS2010) (inn\_cis7)

Results of the community innovation survey 2008 (CIS2008) (inn\_cis6)

Results of the community innovation survey 2006 (CIS2006) (inn\_cis5)

Results of the fourth community innovation survey (CIS4) (inn\_cis4)

Results of the third community innovation survey (CIS3) (inn\_cis3)

Results of the second community innovation survey (CIS2) (inn\_cis2)

Results of the first community innovation light survey 2002/2003 (CIS light) (inn\_cisl)



### III. High-tech industry and knowledge-intensive services (htec)

#### Economic data on high-tech industry and knowledge-intensive services (HTEC) (htec\_eco)

#### *Venture capital investments in HTEC sectors (htec\_vci)*

Venture capital investment by detailed stage of development (from 2007, source: EVCA) (htec\_vci\_stage2)

Venture capital investment by aggregated stage of development (1989-2006, source: EVCA) (htec\_vci\_stage1)

#### *Business statistics in HTEC sectors (htec\_eco\_bs)*

Enterprises in high-tech sectors by NACE Rev.2 activity (htec\_eco\_ent2)

Enterprises in high-tech sectors by NACE Rev.1.1 activity (htec\_eco\_ent)

Economic data in high-tech sectors by NACE Rev.2 activity (htec\_eco\_sbs2)

Economic data in high-tech sectors by NACE Rev.1.1 activity (htec\_eco\_sbs)

#### *Trade in HTEC sectors (htec\_eco\_trd)*

Total high-tech trade in million euro and as a percentage of total (from 2007, SITC Rev. 4) (htec\_trd\_tot4)

High-tech trade by high-tech group of products in million euro (from 2007, SITC Rev. 4) (htec\_trd\_group4)

High-tech exports - Exports of high technology products as a share of total exports (from 2007, SITC Rev. 4) (htec\_si\_exp4)

#### *Employment in high-tech industry and knowledge-intensive services (HTEC) (htec\_emp)*

#### *Employment in HTEC sectors at national level (htec\_emp\_n)*

Employment statistics on high-tech industries and Knowledge Intensive Services at the national level (from 2008 onwards, NACE Rev. 2) (htec\_emp\_sbs2)

Employment statistics on high-tech industries and Knowledge Intensive Services at the national level (1995-2007, NACE Rev. 1.1) (htec\_emp\_sbs)

Employment in technology and knowledge-intensive sectors at the national level, by sex (from 2008 onwards, NACE Rev. 2) (htec\_emp\_nat2)

Employment in technology and knowledge-intensive sectors at the national level, by sex (1994-2008, NACE Rev. 1.1) (htec\_emp\_nat)

Employment in technology and knowledge-intensive sectors at the national level, by type of occupation (from 2008 onwards, NACE Rev. 2) (htec\_emp\_nisco2)

Employment in technology and knowledge-intensive sectors at the national level, by type of occupation (1994-2008, NACE Rev. 1.1) (htec\_emp\_nisco)

Employment in technology and knowledge-intensive sectors at the national level, by level of education (from 2008 onwards, NACE Rev. 2) (htec\_emp\_niscd2)

Employment in technology and knowledge-intensive sectors at the national level, by level of education (1994-2008, NACE Rev. 1.1) (htec\_emp\_niscd)

Employed HRST by category, age and NACE Rev. 2 activity (from 2008 onwards) (hrst\_st\_nsec2)

Employed HRST by category, age and NACE Rev. 1.1 activity (1994-2007) (hrst\_st\_nsec)

Employed HRST by category, sex, age and NACE Rev. 2 activity (from 2008 onwards) (hrst\_st\_nsecsex2)

Employed HRST by category, sex, age and NACE Rev. 1.1 activity (1994-2007) (hrst\_st\_nsecsex)

### III. High-tech industry and knowledge-intensive services (htec)

#### Economic data on high-tech industry and knowledge-intensive services (HTEC) (htec\_eco)

#### **Employment in HTEC sectors at regional level (htec\_emp\_r)**

Employment in technology and knowledge-intensive sectors by NUTS 2 regions and sex (from 2008 onwards, NACE Rev. 2) (htec\_emp\_reg2)

Employment in technology and knowledge-intensive sectors by NUTS 2 regions and sex (1994-2008, NACE Rev. 1.1) (htec\_emp\_reg)

Employment in technology and knowledge-intensive sectors by NUTS 1 regions and type of occupation (from 2008 onwards, NACE Rev. 2) (htec\_emp\_risco2)

Employment in technology and knowledge-intensive sectors by NUTS 1 regions and type of occupation (1994-2008, NACE Rev. 1.1) (htec\_emp\_risco)

Employment in technology and knowledge-intensive sectors by NUTS 1 regions and level of education (from 2008 onwards, NACE Rev. 2) (htec\_emp\_riscd2)

Employment in technology and knowledge-intensive sectors by NUTS 1 regions and level of education (1994-2008, NACE Rev. 1.1) (htec\_emp\_riscd)

Employed HRST by category, NACE Rev. 2 activity and NUTS 1 regions (from 2008 onwards)(hrst\_st\_rsec2)

Employed HRST by category, NACE Rev. 1.1 activity and NUTS 1 regions (1994 - 2007) (hrst\_st\_rsec)

#### **Knowledge intensive activities (htec\_kia)**

Annual data on employment in knowledge-intensive activities at the national level, by sex (from 2008 onwards, NACE Rev. 2) (htec\_kia\_emp2)

Annual data on employment in knowledge-intensive activities at the national level, by sex (until 2008, NACE Rev. 1.1) (htec\_kia\_emp)

Science and technology in high-tech industry and knowledge-intensive services (HTEC) (htec\_sti)

#### **Research and development (R&D) in HTEC sectors (htec\_sti\_rd)**

Business enterprise R&D expenditure in high-tech sectors - NACE Rev. 2 (htec\_sti\_exp2)

Business enterprise R&D expenditure in high-tech sectors - NACE Rev. 1.1 (htec\_sti\_exp)

Business enterprise R&D personnel in high-tech sectors - NACE Rev. 2 (htec\_sti\_pers2)

Business enterprise R&D personnel in high-tech sectors - NACE Rev. 1.1 (htec\_sti\_pers)

#### **Innovation in HTEC sectors (htec\_sti\_cis)**

Innovation in high-tech sectors (CIS 2008, CIS 2010, CIS 2012), EU Member States and selected countries (htec\_cis6)

Innovation in high-tech sectors (CIS 2006), EU Member States and selected countries (htec\_cis5)

Innovation in high-tech sectors (CIS 2004), EU Member States and selected countries (htec\_cis4)

Innovation in high-tech sectors in SMEs (CIS3), EU Member States and selected countries (htec\_cis3)

Results of the first community innovation light survey 2002/2003 (CIS light) (inn\_cisl)

### III. High-tech industry and knowledge-intensive services (htec)

Economic data on high-tech industry and knowledge-intensive services (HTEC) (htec\_eco)

#### *Patents in HTEC sectors (htec\_sti\_pat)*

High-tech patent applications to the EPO by priority year (pat\_ep\_ntec)

High-tech patents granted by the USPTO by priority year (pat\_us\_ntec)

Biotechnology patent applications to the EPO by priority year (pat\_ep\_nbio)

Biotechnology patents granted by the USPTO by priority year (pat\_us\_nbio)

High-tech patent applications to the EPO by priority year by NUTS 3 regions (pat\_ep\_rtec)

Human Resources in Science & Technology (hrst)

Career Development of Doctorate Holders (cdh)

Intellectual property rights (ipr)

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# Methodology

Augmented Distributed Lag Models (ADL) versus Vector Autoregressive Models (VARs):

Problems associated with VAR (Vector Autoregressive) models.

Use of VAR models is not always accompanied by the indication of the module of the roots of the associated matrix. **Consequence : We cannot know whether the system is stable;**

Frequently the estimations are performed with first-differences, with no reference to ECM (Error Correction Model). **Consequence: Inefficiency if they are cointegrated;**

The same VAR type and order is estimated for different countries, **Consequence: no country specifics considered.**

# ADL - augmented distributed lag

ADL models applying the methodology of Hendry-Krolzig-Doornik (Hendry and Krolzig (2001, 2005) and Hendry and Doornik (2014) of using individual equations and by estimating a simultaneous equation model based on these individual equations.

## The Autoregressive Distributed Lag Model

An autoregressive distributed lag (ADL) model also uses lags of other variables for forecasting. The regressors may include lagged values of the dependent variable and current and lagged values of one or more explanatory variables. This model allows us to determine what the effects are of a change in a policy variable

An ADL(pp,qq) model assumes that a time series  $Y_t$  can be represented by a linear function of pp of its lagged values and qq lags of another time:

# ADL - augmented distributed lag

## A simple model: The ADL(1,1) model:

$y_t = m + \alpha_1 y_{t-1} + \beta_0 x_t + \beta_1 x_{t-1} + u_t$ , where  $y_t$  and  $x_t$  are stationary variables, and  $u_t$  is a white noise

series  $X_t$ :  $Y_t = \beta_0 + \beta_1 Y_{t-1} + \beta_2 Y_{t-2} + \dots + \beta_p Y_{t-p} + \delta_1 X_{t-1} + \delta_2 X_{t-2} + \dots + \delta_q X_{t-q} + u_t$ .  
 $Y_t = \beta_0 + \beta_1 Y_{t-1} + \beta_2 Y_{t-2} + \dots + \beta_p Y_{t-p} + \delta_1 X_{t-1} + \delta_2 X_{t-2} + \dots + \delta_q X_{t-q} + u_t$

is an *autoregressive distributed lag model* with  $pp$  lags of  $Y_t$  and  $qq$  lags of  $X_t$  where  $E(u_t | Y_{t-1}, Y_{t-2}, \dots, X_{t-1}, X_{t-2}, \dots) = 0$ .

# Models/indicators' selection

Two possible approaches:

- 1) Expert's assessment
- 2) Choosing the models by using the means for model selection - information criterion, e.g. Bayesian ([Schwarz](#)) criterion or [Akaike criterion](#) (the most commonly used)

The **Akaike information criterion (AIC)** helps to estimate the relative quality of statistical models for a given set of data. Given a collection of models for the data, AIC estimates the quality of each model, relative to each of the other models.

When a statistical model is used to represent the process that generated the data, the representation will almost never be exact; so some information will be lost by using the model to represent the process. AIC estimates the relative amount of information lost by a given model: the less information a model loses, the higher the quality of that model.

- In estimating the amount of information lost by a model, AIC deals with the trade-off between the [goodness of fit](#) of the model and the simplicity of the model (risk of [overfitting](#) and the risk of underfitting)

# Models/(parameters) indicators' selection

- Bayesian information criterion (BIC) or Schwarz information criterion: criterion for model selection model among a finite set of models;
- It is based on the likelihood function, the model with the lowest BIC is preferred.
- it is closely related to the AIC criterion. The formula for the [Bayesian information criterion](#) (BIC) is similar to the formula for AIC, but with a different penalty for the number of parameters.
- AIC and BIC are appropriate for different tasks. In particular, BIC is more appropriate for selecting the "true model" (i.e. the process that generated the data) from the set of candidate models, whereas AIC is not appropriate [[Burnham & Anderson \(2002\)](#), [Vrieze \(2012\)](#)].
- To be specific, if the "true model" is in the set of candidates, then BIC will select the "true model" with probability 1, as  $n \rightarrow \infty$ ; in contrast, when selection is done via AIC, the probability can be less than 1.

„All models are wrong” (common aphorism in statistics): "true model" (i.e. reality) cannot be in the candidate set.