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Business spending on research and development and its relationship to invention and innovations

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Motivation for research

- Research and development (R&D) expenditure is often taken as the crucial prerequisite of innovation activities in business sector.
- R&D expenditure have positive efffect on economic growth (Gumus and Celikay, 2015; Akcali and Sismanoglu, 2015; Falk, 2007) and positively linked to significantly higher productivity (Blanco et al., 2015; Nekrep et al., 2018).
- So far, less attention is paid to the transformation of R&D expenditure into innovation.

Aim of the paper

- Our research was primarily focused on the relationship between a firm's commitment to research and development and its innovative outcomes.
- **Our main scientific aim was to examine potential relationship between business R&D expenditure, invention and innovation.**
- We also analysed the extent and structure of business R&D expenditure in the EU countries

Literature

- It is likely that business R&D expenditure also positively affects business economic and financial performance, such as for example profitability (Shen et al., 2017; Apergis and Sorros, 2014; VanderPal, 2015; Freihat and Kanakriyah, 2017) apparent labour productivity (Hunady et al., 2019); turnover (Park et al., 2018) or value-added (Hunady et al., 2019).
- The effect of R&D expenditure on technology development and also innovation can be reflected by the number of patents. Zachariadis (2003) a

Literature

- Effect of R&D expenditure on patents and inventions can be expected to be positive (Artz et al., 2010, Cardinal and Hatfield, 2000).
- However, Acs and Audretsch (1990) argue that the relationship between R&D expenditure and intensity of patenting is more complex and firms can often experience decreasing returns to their R&D investment.
- Some empirical papers also shown that increasing levels of R&D spending over certain threshold is ineffective or even counterproductive for innovation outputs (Graves and Langowitz, 1996).
- Patents is consdered to be a measure of invetion (Artz et al., 2010, Grant, 2008) or sometimes there are also used as proxy for innovation as well (Löfsten, 2014; Bronzini and Piselli, 2016).

Methodology

- Analysis of the extent and structure of R&D expenditure in EU countries.
- Panel Granger causality test, cointegration analysis Pedroni (2004) and Kao (1999)
- Panel cointegrating regression models estimated by the fully modified OLS (FMOLS) - Phillips and Moon (1999).

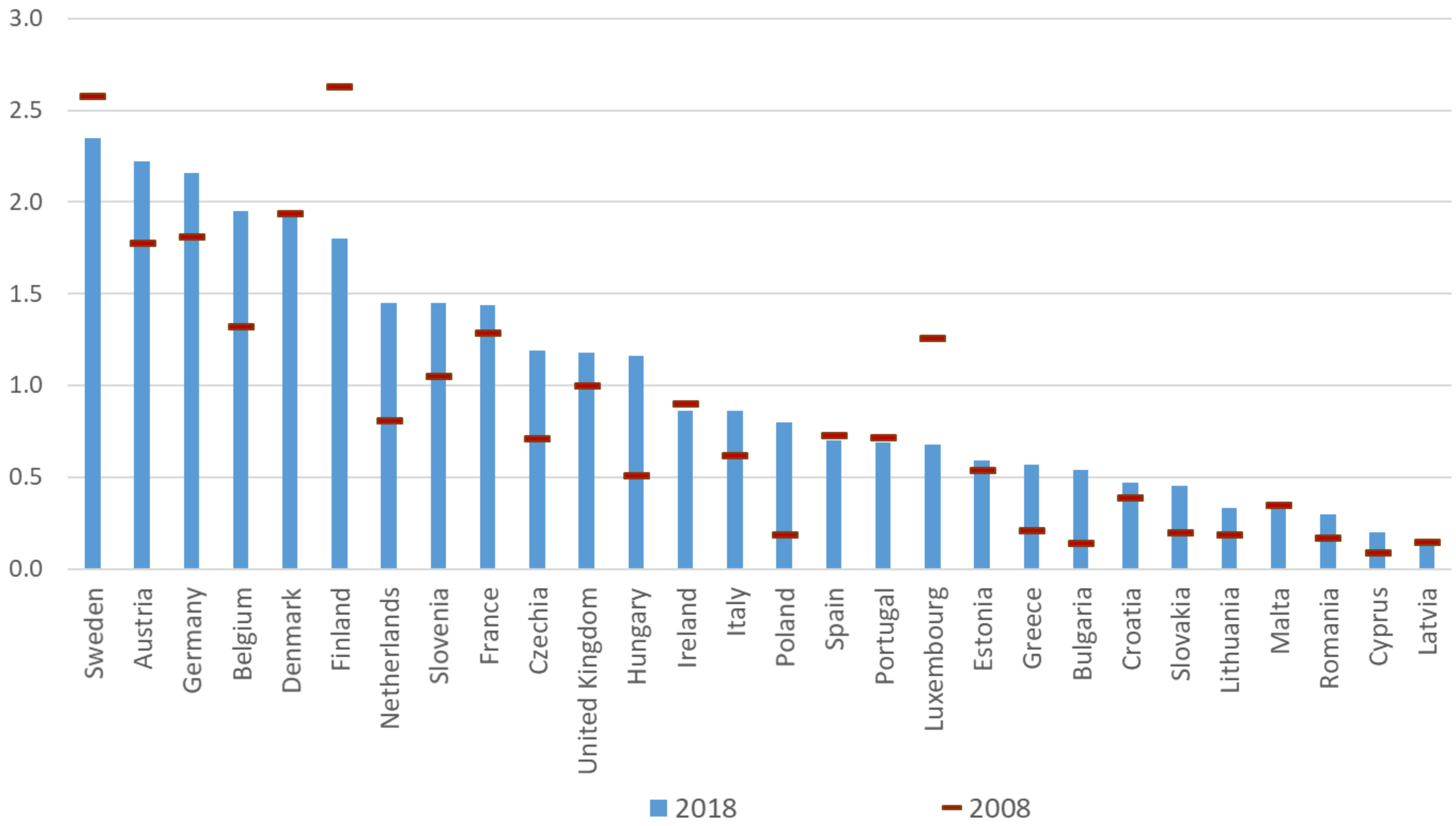
$$\text{Patents}_{it} = \text{f(Business R\&D expenditure}_{it}, \text{GDP per capita}_{it})$$

- robust with respect to the potential problems of serial-correlation and endogeneity (Pedroni, 2000).

Variables used in the models

Variable	Description
Patents (dependent vraibales in regression)	Number of patent applications to the EPO per 10 million inhabitants.
Business R&D exp.	Intramural R&D expenditure (GERD) in Business enterprise sector as % of GDP)
	Intramural R&D expenditure (GERD) in Business enterprise sector (of GDP) in PPS per inhabitant
GDP per capita	Real GDP per capita in PPS
Apparent labour productivity	Value added at factor costs divided by the number of persons employed (in thousands of euros per person employed).
SMEs introducing product or process innovations	The share of SMEs who introduced a new product or a new process to one of their markets on total number of SMES (in %).
SMEs innovating in-house	Share of SMEs with in-house innovation activites on all SMEs (both innovators and non-innovators). This indicator does not include new products or processes developed by other firms.
Employment in High technology and medium tech.	Employment in High technology and medium technology firms as % of total employment. The definition of high- and medium-high technology manufacturing sectors and of knowledge-intensive services is based on a selection of relevant items of NACE Rev. 2 on 2-digit level and is oriented on the ratio of highly qualified working in these areas.

Results



Intramural R&D expenditure (GERD) in business enterprise sector as % of GDP in years 2018 and 2008

Results of panel cointegration tests among all three variables

Cointegration: Patents, Business R&D expenditure (% GDP) , GDP per capita / Intercept			
Null Hypothesis: no cointegration		Statistic	Weighted Stat.
Pedroni test (Engle-Granger based) tests – individual intercept, lag length selection based on SBC	Panel v-Statistic (within dimension)	1.21	-0.73
	Panel rho-Statistic (within dimension)	0.67	0.33
	Panel PP-Statistic (within dimension)	0.001***	-6.70***
	Panel ADF-Statistic (within dimension)	-4.42***	-6.78***
	Group rho-Statistic (between dimension)	2.54	
	Group PP-Statistic (between dimension)	-9.77***	
	Group ADF-Statistic (between dimension)	-7.83***	
Kao coint. test	ADF-Statistic	-2.30**	
Cointegration: Patents, Business R&D expenditure (% GDP), GDP per capita / Intercept & trend			
Pedroni tests (Engle-Granger based) – individual intercept & trend, lag length selection based on SBC	Panel v-Statistic (within dimension)	-2.58	-3.27
	Panel rho-Statistic (within dimension)	3.83	3.57
	Panel PP-Statistic (within dimension)	-0.01	-7.71***
	Panel ADF-Statistic (within dimension)	-1.94**	-6.84***
	Group rho-Statistic (between dimension)	5.32	
	Group PP-Statistic (between dimension)	-13.6***	
	Group ADF-Statistic (between dimension)	-9.11***	

Results of panel cointegrated regression models

Dependent variable: Patents					
Pooled estimator (within dimension)					
	(1) A	(2) B	(3) C	(4) D	(5) E
Business R&D exp. (% of GDP)	11.29* (1.84)	8.33** (2.21)	7.09*** (232.34)	12.38** (2.01)	8.82*** (2.34)
Log(GDP per capita)	3.88 (0.25)	0.53 (0.06)	5.41*** (219.4)	5.65 (0.42)	1.07*** (0.13)
R^2	0.99	0.99	0.99	0.99	0.99
Adj. R^2	0.98	0.98	0.99	0.99	0.99
Long-run variance	203.1	76.44	11.81	11.83	11.81
Observations	280	280	280	280	280

Notes: */**/*** means significance at the 10%/ 5%/ 1% levels; long-run variances calculated based on Bartlett kernel and Newey-West bandwidth have been used for coefficient covariances;
A - FMOLS (pooled estimator), constant included, coefficient covariance matrix with homogenous variances;
B - FMOLS (pooled estimator), constant included, coefficient covariance matrix with heterogenous first-stage coefficients;
C - FMOLS (pooled weigthed estimator), coefficient covariance matrix with homogenous variances;
D - FMOLS (pooled estimator), constant &linear trend, coefficient covariance matrix with homogenous variances;
E - FMOLS (pooled estimator), constant and linar trend as additional regressor, coefficient covariance matrix with homogenous variances.

Conclusions

- Based on our results we can conclude that investments in research and development appears to be important for creation of invention and innovation. Business R&D expenditure on GDP have positive effect on invention expressed by patents.
- This seems to be especially true in the long-run. However, we also found some empirical evidence for short-run causality in Granger sense between both variables.

Conclusions

- Furthermore, we found that countries with higher business R&D expenditure on GDP also mostly experienced higher share of innovative firms as well as higher patenting activity.
- With respect to selected indicators, countries such as Sweden, Germany, Austria or Finland represent the good practice. All four countries also experienced the highest R&D expenditure in business sector in the EU.
- The government financial support of business R&D is very high in Sweden, France and Luxembourg.
- On the other hand, countries such as Latvia, Romania and Cyprus have low level of business R&D expenditure.