THE RELATIONSHIP BETWEEN PRIVATE EQUITY AND ECONOMIC GROWTH

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Abstract. *The purpose of this paper is to provide empirical evidence on the relationship between private equity, innovations, and economic growth in 13 European countries by using quantitative analysis. The objectives of the paper are as follows: description of private equity; examination of the relationship between private equity and economic growth; investigation of the methods used in the related topics; description and testing of the data used in the empirical research; estimation of the empirical model; reporting and interpretation of the results. The systematic, comparative and critical analysis of the scientific literature is used for determining the relationship between private equity, innovation, and economic growth. Further, the data are tested using unit root tests. The panel vector autoregressive model, Granger causality, impulse response, and variance decomposition analyses are applied for short-term causality. The main findings are as follows: granted patents are the most important measure of innovation, which influence private equity and economic growth. However, patents should be considered an input rather than an output of the private equity investment process. Therefore, granted patents attract private equity, and private equity impacts economic growth by commercializing granted patents in the short term.*

Key words*: private equity investments, economic growth, panel VAR, the Granger causality*

1. Introduction

Private equity investments are experiencing growing interest, especially from the young, small and fast growing enterprises which face a financing problem when borrowing money from the banks due to strict bank requirements. Also, science and technological progress as innovation factors are developing quite rapidly. All this promotes the integration of private equity into the economy. Along with this background and a new strategy of the European Union for 2020 (the Innovation Union), the chosen topic deals with the relationship between private equity and economic growth.

The purpose of this paper is to provide the empirical evidence of the relationship between private equity, innovations, and economic growth in 13 European countries by using quantitative analysis. The research is focused on the Innovation Union strategy "to create an innovation-friendly environment that makes it easier for great ideas to be turned into products and services that will bring Europe's economy growth and

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jobs" (European Commission, 2010). The strategy is implemented through the governments, financial institutions, and programs such as COSME[1] and HORIZON[2], which are directly related to private equity. According to this strategy, innovations, productivity, competitiveness and private equity are a new way to affect the economic growth of the European Union. Therefore, the research question is whether private equity investments really spur the economic growth.

Referring to the private equity contribution to the economic growth, other researchers (Hirukawa, M. and Ueda, M. (2008); Kortum, S. and Lerner, J. (2000); Meyer, T. (2006); Popov, A. and Roosenboom, P. (2008); Sami, M. (2002); Stromberg, P. (2009)) usually examine the cross-country linkage between private equity and factors of innovation, factors of innovation and economic growth in short-term and long-term. This research fills the gap among separate studies and estimates the relationship among private equity, innovation, and economic growth jointly.

In order to achieve the goal of the study, the following research objectives are formulated:

- define private equity;
- examine scientific literature on the relationship between private equity, innovation, and economic growth;
- systemize and compare empirical research related to the research object;
- analyze methods utilized in related topics;
- describe and test the data used in the empirical research
- estimate the empirical model;
- report and interpret the results.

The following methods of scientific research are used in the analysis and examination of the linkage between private equity and economic growth:

- a comparative and systematic analysis of the scientific literature;
- unit root tests and correlation diagrams for panel data analysis;
- panel vector autoregressive (VAR) for short-term causality specification;
- the impulse response and variance decomposition analysis.

The remainder of this article is organized as follows: in the second chapter, the authors describe the private equity, provide a theoretical link between private equity, innovation and economic growth. In the third chapter data, methodology, and results are provided. The paper closes with conclusions and suggestions for further research.

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[1] COSME is the EU program for the Competitiveness of Enterprises and Small and Medium-sized Enterprises (SMEs) running from 2014 to 2020 with a planned budget of €2.3bn.

[2] HORIZON is the biggest European Union Research and Innovation program ever with nearly €80 billion of funding available over 7 years (2014 to 2020) – in addition to the private investment that this money will attract. It promises more breakthroughs, discoveries and world-firsts by taking great ideas from the lab to the market.

2. Literature review

There is no one certain definition which can describe what private equity is, because it can be expressed in many different forms. Different academic studies have defined private equity differently depending on the research field and nature of different economies. Also, the term is intertwined with venture capital (VC), which typically is a form of private equity investment. In Table 1, various definitions utilized in academic literature are presented and compared.

TABLE 1. **Definitions of private equity**

No.	Author	Definition of private equity
1.	Burdel (2009)	A stable platform for the rapid, highly focused growth at crucial points in the development of individual businesses
2.	Conroy and Harris (2007)	Private investments in all stages of a company's life
3.	EVCA (2007)	An investment of equity into private companies which are not quoted on a stock market
4.	Leeds and Sunderland (2003)	A form of financing for early and later stage private companies from third party investors
5.	Moon (2006)	Later stage of business cycle investments
6.	Sami (2002)	Can be expressed as part of FDI. PE is a capital to the enterprises that are not quoted on a stock market. VC as a form of PE specifically employed in the early stages of business development

Source: compiled by the authors.

According to Sami (2002), private equity is an alternative investment that can be expressed as part of foreign direct investments (FDI). Also, he argues that PE is a capital for enterprises, which is not quoted on the stock market. Thus, PE can be used to develop new products and technologies, to expand the working capital, to make acquisitions, to strengthen balance sheets, and to resolve ownership management issues. At the same time, Sami (2002) described VC as a form of private equity specifically employed in the early stages of business development.

Further, Leeds and Sunderland (2003) have defined private equity as a form of financing for early and later stage private companies from third party investors, which are seeking higher returns based on the risk profile of the company and the short-term illiquidity of these investments.

Moon (2006) has defined PE strictly as later stage investments, which are typically control-oriented transactions involving mature companies or includes early stage investments by VC firms. Private equity firms typically become active investors through taking board seats and specifying contractual restricts on management, such as detailed reporting requirements.

Later, the European Private Equity and Venture Capital Association (EVCA, 2007) clarified the definition. Private equity is defined as an investment of equity into private companies, which is not quoted on a stock market. Also, Conroy and Harris (2007) have argued that in practice the term PE can be used in many ways with various subcategories, and one way of defining PE is that it refers to private investments in all stages of a company's life. Similarly to Conroy and Harris (2007), Burdel (2009) has explained PE as a stable platform for a rapid, highly focused growth at crucial points in the development of individual businesses.

In general, PE can be found in various forms, which include VC, leveraged buyouts (LBO), and mezzanine capital (Fig. 1).

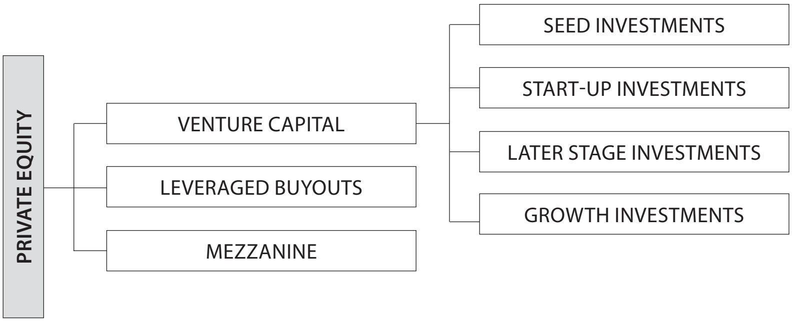

FIG.1. **The structure of private equity**

Source: compiled by the authors based on the data of the EVCA (2013).

VC mainly refers to funds offered to a firm at start-up or an early stage or at a later stage of their life. LBO refers to the acquisition of a firm by a specialized investment firm using a relatively small portion of equity and a relatively large portion of outside debt financing (Stromberg, 2009). The mezzanine capital refers to financing composed of both debt and equity (Meyer, 2006).

Thus, despite a variety of common sources of capital ranging from bank loans to equity capital, PE is becoming a source of financing for firms, especially those with a high growth potential where it enhances business entities to achieve their growth objectives and offers strategic advice to businesses in their various stages of development.

Relationship between private equity and economic growth

In order to link private equity and economic growth, several theoretical questions have to be answered. Does private equity influence innovation, and if so, then how? How large is the impact of private equity on innovation? These questions are not only of theoretical interest: answering them correctly is crucial for designing the best public policies on innovation through which economic growth can be induced.

Kortum and Lerner (2000) examined the impact of venture capital on the patented invention of the United States in 20 industries for nearly 30 years. They used different methods to find out the causal relationship, taking into account the policy changes in 1979 as a factor stimulating the increase in venture capital, and concluded that the increase in venture capital in an industry and higher patenting rates were closely linked. Their results indicated that VC funding accounted for about 14% of U.S. innovative activity by 1998.

Keuschnigg (2004) established a simple equilibrium model of venture capital and technological innovation. The author believed that venture capital did not only offer financial support to new enterprises, but also increased the value of new enterprises. The growth of the VC industry promoted technological innovation, and more VC investment in turn promoted the growth of this industry due to the support of tax policy. This clearly reflected the mechanism of how VC affected the technological innovation.

More recently, Ueda and Hirukawa (2008) have repeated Kortum and Lerner (2000) findings with a longer sample period up to 2001, i.e. including the period of a very high growth of the U.S. VC industry in the late 1990s. They have revealed that VC continued to have a substantial positive impact on the amount of industry patents during the boom period of the late 1990s. Then, Ueda and Hirukawa (2008) have analyzed the impact of VC on different measures of innovative performance, including the TFP growth. They also found that, in contrast to the results with patent counts, VC does not significantly and positively affect TFP growth. It seems that VC funding may be particularly important for one measure of innovative performance – patenting success.

Furthermore, Popov and Roosenboom (2009) have estimated, by using data on PE investments and patenting activity from 21 European countries during the period of 1977–2004, that 12% of the total European industrial innovations are attributable to PE. Moreover, Popov and Roosenboom (2008) have estimated that 116,000 patents are attributable to private equity-backed companies. Thus, applying it to Gambardella et al. (2008) findings that the average value of a patent held by a European company is €3 mln. suggests a total value of €350 bn. over five years.

Since this literature review discovered a robust evidence that PE is linked with innovation, the following key factors are highlighted:

- sectors of economy with private equity investment generate more patents;
- private equity-backed enterprises deliver greater innovation than comparable non-private equity-backed enterprises;
- private equity-backed enterprises deliver more relevant innovation than comparable non-private equity-backed enterprises.

In order to fulfil the transition channel from private equity to economic growth (Fig. 2), the link between innovation and economic growth is examined.

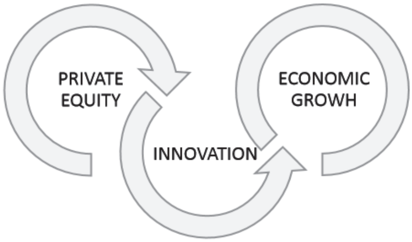

FIG. 2. **Transition channel from private equity to economic growth**

Source: compiled by the authors.

Innovation is the discovery of new or improved technologies, processes and products, which is a key driver of economic growth. In more advanced economies where growth opportunities from capital accumulation are more difficult to utilize, innovation plays the key role in economic development. This is because innovation enables economies to make more out of their existing resources. Innovations improve productivity, competitiveness, and also boost economic growth.

Modern economic literature has developed a strong theoretical framework and relatively broad empirical findings which suggest that the development of innovation can enhance economic growth by pushing the technological frontier and by creating economies of scale and scope. The basic assumption is that when innovation is performed by an individual or a firm, a positive externality is created that benefits all of society and results in the economic progress and growth. Griffith (2000) has presented an empirical framework in which the rate of return to R&D is composed of an effect on productivity through innovation and an effect through the increased potential for imitation. This second component is particularly important for industries and countries far behind the technological frontier. Innovation and technology transfers provide two potential sources of productivity growth for countries behind the technological frontier. A country's distance from the technological frontier is used as a direct measure of the potential for technology transfer, where the frontier is defined for each industry as the country with the highest level of TFP. The further a country lies behind the technological frontier, the greater the potential for R&D to increase the TFP growth through technology transfer from more advanced countries. TFP increases when people learn to obtain more output from a given supply of input that is clearly through technological improvements. Furthermore, Griffith (2000) has provided the econometric evidence that R&D expenditure plays a role in assimilating the research discoveries of others as well as its conventional role as a source of innovation. The size of the spill-overs depends on one's own R&D activity.

Baily (2004) pointed out that innovation (R&D) by the business sector had high social returns and contributed to economic growth. It also confirms the Solow model that economies exhibit sustained growth as a result of technological progress and population growth. Without technological progress, which is brought by R&D, growth will eventually cease as diminishing returns to capital set in.

According to an OECD report (2010), enterprises now invest as much in assets related to innovation (R&D, software, skills, organizational know-how and branding) as they do in traditional capital such as equipment, machinery, and buildings. Such investment in innovative assets accounted for up to one percentage point, or around one-quarter, of labour productivity growth in countries like Austria, Finland, Sweden, the United Kingdom and the United States between 1995 and 2006. This implies that innovation and productivity growth are the two main drivers of economic growth in Europe.

By summing up the findings from the literature review, the conclusions are as follows: first, there is evidence of a positive impact of PE on innovation, measured by patents and R&D, at the macroeconomic level. For example, Kortum and Lerner (2000) have shown that a dollar of venture capital could be as much as 10 times as effective in stimulating patents as a dollar of corporate R&D; second, PE-funded enterprises generally have a higher patenting activity. Therefore, some studies argue that this is because of PE investing into enterprises that are already more innovative, rather than actually increasing the firms' innovativeness. Third, the estimations of cross-country data have revealed a clear positive relationship between private equity and innovation, and between innovation and economic growth.

3. Data, methodology, and results

The panel vector autoregressive (VAR) model is employed in order to analyze causality, impulse response function, as well as variance decomposition of the variables studied. The paper uses annual panel data which contain observations with cross-country sections and time series identifiers covering five variables, 13 European countries, and a 22-year period dating from 1991 to 2012 at an aggregated level with a maximum of 1430 observations (13 × 5 × 22).

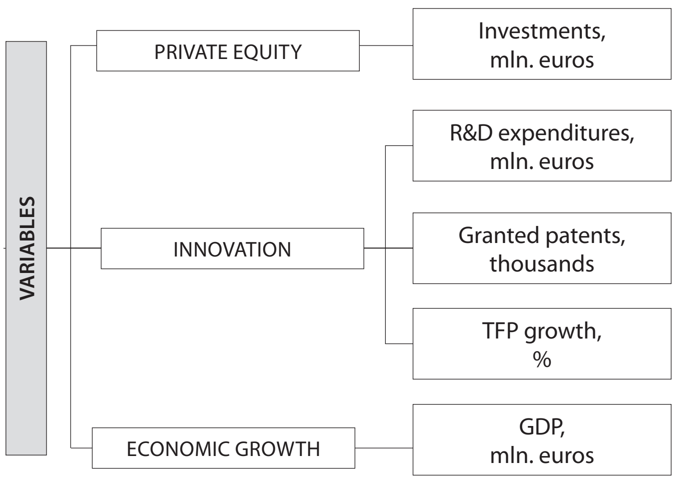

FIG. 3. **The interaction scheme of data**

Source: compiled by the authors.

Private equity, factors of innovation and economic growth are represented by five research variables: private equity investments in mln. Euros (PE), research and development expenditures in mln. Euros (R&D), granted patents[3] in thousands (Patents), total factor productivity growth rates in percentage points (TFP), and real gross domestic product in mln. Euros (GDP) (Fig. 3).

Based on Lerner's (2000) and Ueda's (2008) measurement methodology of innovation, the authors have used the total factor productivity and R&D expenditures which are closely related with TFP growth and granted patents. The main difference between these factors is that the total factor productivity results from adopting a new technology, while patents are based on ideas about new technology which not necessarily has been adopted (Fig. 4).

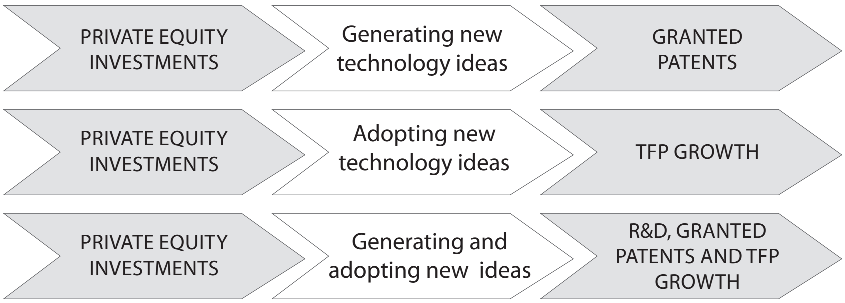

FIG. 4. **Impact of private equity on innovation factors**

Source: compiled by the authors.

Assumptions:

- If private equity investments are used for generating new technology ideas rather than using new technology, the authors expect that private equity affects the granted patent but not the TFP growth.
- If private equity investments are used for adopting a new technology instead of creating it, the authors expect that private equity affects the TFP growth but not the granted patents.
- If private equity investments are used for creating and adopting a new technology, the authors expect that private equity affects R&D, TFP growth, and granted patents.

The specific model is written in Equation 1:

$$GDP_t = f(RD_t, PATENTS_t, TFP_t, PE_t). \quad (1)$$

[3] A granted European patent under the European Patent Convention (EPC) confers to its owner the same right as a national patent in those EPC countries he elected in the application. A European patent changes into a "bundle" of national patents. It implies that, once granted, a European patent can only be annulled by separate proceedings in each elected country. However, during the first nine months after the grant of the patent, anyone can start an opposition procedure at the EPO to annul the patent in all these countries at once.

Equation 1 can be specified in its logarithmic econometric model in the following form:

$$\log(GDP_t) = \alpha + \beta_1 \log(RD_t) + \beta_2 \log(PATENTS_t) + \beta_3 \log(TFP_t) + \\ + \beta_4 \log(PE_t) + \varepsilon_t, \qquad (2)$$

where α denotes the intercept term, $\beta_1, \beta_2, \beta_3$ and β_4 are the coefficients to be estimated, which are assumed to be more than zero ($\beta_t > 0$, $t = 1, 2, 3, 4$), ε_t (ε_t , $t > 0$) is the error term, and the subscripts t are for the dating of variables in time periods.

Before investigating the relationship among PE investments, innovations (R&D, granted patents, and growth of TFP) and economic growth (GDP), unit root tests are applied to examine the stationarity properties of the panel data. Thus, the Levin, Lin and Chu, Augmented Dickey Fuller (ADF) and Phillips–Perron (PP) tests are applied to test the stationary process of the panel data. These tests are done in levels and the first differences in all cases with an intercept, intercept and trend, and no intercept and trend. The appropriate lag length is determined by the Akaike information criterion (AIC). Also, in order to test the existence of a unit root, the authors rely on the a p value. If the calculated p value is less than the 0.05 significance level, then the null hypothesis is rejected. It implies that a series does not contain a unit root, i.e. the series are stationary.

After the application of the Levin, Lin and Chu, ADF, PP tests in levels, and the first differences in all cases with an intercept, intercept and trend, and no intercept and trend, the authors got the results which are shown in Table 2.

The upper part of Table 2 displays the results of tests in levels, where the p value is greater than the 0.05 significance level. Therefore, the authors cannot reject H_0. This implies that the GDP, PE, R&D and granted patents series have a unit root problem and the GDP, PE, R&D, and granted patents series are treated as non-stationary series. However, the tests have discovered some contradictions among different processes. Thus, according to the results GDP and granted patents are stationary in the random walk process with the intercept model, while the remaining unit root tests in the random walk process and the random walk process with intercept and trend models have showed that GDP and granted patents are non-stationary at level. Normally, the value of GDP and granted patents tends to increase over time. Therefore, the means are constantly changing. The graphs have confirmed this theory, and the authors have treated these variables as non-stationary variables at level. Only the TFP growth series are stationary at level (the authors rejected H_0 because the p value was less than the significance level).

In order to solve the issue of non-stationarity, the series are transformed into the first difference of logarithms. Then, the authors reject H_0 (the p value is less than the 0.05 significance level). It implies that the GDP, PE, R&D, and granted patents series have no unit root in any process, and the variables are treated as stationary.

TABLE 2. **Results of unit root tests**

LEVEL					
Variable	Process	Unit root test			Stationarity status
		Levin, Lin & Chu	ADF	PP	
GDP	Random walk	1.0000	1.0000	1.0000	Non-stationary
	Random walk with intercept	0.0000	0.0939	0.0003	Stationary
	Random walk with intercept and trend	0.9998	0.2086	0.0367	Non-stationary
Patent	Random walk	1.0000	1.0000	1.0000	Non-stationary
	Random walk with intercept	0.0000	0.0052	0.0057	Stationary
	Random walk with intercept and trend	0.9776	1.0000	1.0000	Non-stationary
PE	Random walk	0.9947	1.0000	1.0000	Non-stationary
	Random walk with intercept	0.0006	0.4834	0.8898	Non-stationary
	Random walk with intercept and trend	0.7582	0.8689	0.9066	Non-stationary
RD	Random walk	1.0000	1.0000	1.0000	Non-stationary
	Random walk with intercept	0.0000	0.2321	0.5173	Non-stationary
	Random walk with intercept and trend	1.0000	0.4562	0.9874	Non-stationary
TFP	Random walk	0.0000	0.0000	0.0000	Stationary
	Random walk with intercept	0.0000	0.0000	0.0000	Stationary
	Random walk with intercept and trend	0.0000	0.0000	0.0000	Stationary
FIRST DIFFERENCE OF NATURAL LOG					
Variable	Process	Unit root test			Stationarity status
		Levin, Lin & Chu	ADF	PP	
GDP	Random walk	0.0000	0.0000	0.0000	Stationary
	Random walk with intercept	0.0000	0.0000	0.0000	Stationary
	Random walk with intercept and trend	0.0000	0.0000	0.0000	Stationary
Patent	Random walk	0.0000	0.0000	0.0000	Stationary
	Random walk with intercept	0.0000	0.0000	0.0000	Stationary
	Random walk with intercept and trend	0.0000	0.0000	0.0000	Stationary
PE	Random walk	0.0000	0.0000	0.0000	Stationary
	Random walk with intercept	0.0000	0.0000	0.0000	Stationary
	Random walk with intercept and trend	0.0000	0.0000	0.0000	Stationary
RD	Random walk	0.0000	0.0000	0.0000	Stationary
	Random walk with intercept	0.0000	0.0000	0.0000	Stationary
	Random walk with intercept and trend	0.0000	0.0000	0.0000	Stationary

Source: compiled by the authors.

The tests proved that the GDP, PE, R&D, and granted patent variables have a unit root at level, except the TFP series which is treated as stationary at level. The GDP, PE, R&D, and granted patents variables are stationary at the first difference of logarithms.

Once the stationarity is determined, then, for obtaining an ideal lag for the model adopted in this study, the authors have used a VAR lag order selection criterion. The AIC, SC, and HQ test confirmed the most appropriate model to be the panel VAR with one lag.

Despite the fact that the information criterion determined the lag for the panel VAR model, the authors also compared the correlograms of the residuals of variables. Correlograms of the panel VAR model with lag one revealed that the correlation between the residuals existed at least for one of the variables. Correlograms of the panel VAR model with two lags have revealed that there are no obvious correlations between the residuals of the variables and the residuals of its own lags. Therefore, the authors have decided to include two lags instead of one into the panel VAR model. The model is denoted as panel VAR(2).

Thus, the estimated model has the following form:

$$\Delta\, log(GDP_{it}) = \alpha_{10} + \sum_{j=1}^{n} \beta_{11ij}\, \Delta\, log\left(GDP_{it-j}\right) + \sum_{j=1}^{n} \beta_{12ij}\, \Delta\, log\left(RD_{it-j}\right) + \quad (2.1)$$

$$+ \sum_{j=1}^{n} \beta_{13ij}\, \Delta\, log\left(Patents_{it-j}\right) + \sum_{j=1}^{n} \beta_{14ij}\, \Delta\, log\left(TFP_{it-j}\right) +$$

$$+ \sum_{j=1}^{n} \beta_{15ij}\, \Delta\, log\left(PE_{it-j}\right) + \varepsilon_t$$

$$\Delta\, log(RD_{it}) = \alpha_{20} + \sum_{j=1}^{n} \beta_{21ij}\, \Delta\, log\left(GDP_{it-j}\right) + \sum_{j=1}^{n} \beta_{22ij}\, \Delta\, log\left(RD_{it-j}\right) + \quad (2.2)$$

$$+ \sum_{j=1}^{n} \beta_{23ij}\, \Delta\, log\left(Patents_{it-j}\right) + \sum_{j=1}^{n} \beta_{24ij}\, \Delta\, log\left(TFP_{it-j}\right) +$$

$$+ \sum_{j=1}^{n} \beta_{25ij}\, \Delta\, log\left(PE_{it-j}\right) + \varepsilon_t$$

$$\Delta\, log(Patents_{it}) = \alpha_{30} + \sum_{j=1}^{n} \beta_{31ij}\, \Delta\, log\left(GDP_{it-j}\right) + \sum_{j=1}^{n} \beta_{32ij}\, \Delta\, log\left(RD_{it-j}\right) + \quad (2.3)$$

$$+ \sum_{j=1}^{n} \beta_{33ij}\, \Delta\, log\left(Patents_{it-j}\right) + \sum_{j=1}^{n} \beta_{34ij}\, \Delta\, log\left(TFP_{it-j}\right) +$$

$$+ \sum_{j=1}^{n} \beta_{35ij}\, \Delta\, log\left(PE_{it-j}\right) + \varepsilon_t$$

$$\Delta\, log(TFP_{it}) = \alpha_{40} + \sum_{j=1}^{n} \beta_{41ij}\, \Delta\, log\left(GDP_{it-j}\right) + \sum_{j=1}^{n} \beta_{42ij}\, \Delta\, log\left(RD_{it-j}\right) + \quad (2.4)$$

$$+ \sum_{j=1}^{n} \beta_{43ij}\, \Delta\, log\left(Patents_{it-j}\right) + \sum_{j=1}^{n} \beta_{44ij}\, \Delta\, log\left(TFP_{it-j}\right) +$$

$$+ \sum_{j=1}^{n} \beta_{45ij}\, \Delta\, log\left(PE_{it-j}\right) + \varepsilon_t$$

$$\Delta \, log(PE_{it}) = \alpha_{50} + \sum_{j=1}^{n} \beta_{51ij} \, \Delta \, log(GDP_{it-j}) + \sum_{j=1}^{n} \beta_{52ij} \, \Delta \, log(RD_{it-j}) + \tag{2.5}$$

$$+ \sum_{j=1}^{n} \beta_{53ij} \, \Delta \, log(Patents_{it-j}) + \sum_{j=1}^{n} \beta_{54ij} \, \Delta \, log(TFP_{it-j}) +$$

$$+ \sum_{j=1}^{n} \beta_{55ij} \, \Delta \, log(PE_{it-j}) + \varepsilon_t,$$

where α denotes the intercept term, $\beta_1, \beta_{2,} \beta_3$ and β_4 are the coefficients to be estimated, which are assumed to be more than zero ($\beta_t > 0,\ t = 1, 2, 3, 4$), Δ is the first difference operator, ε_t (ε_t , $t > 0$) is a serially uncorrelated error term, n is the number of lags set at two, and i = 1 (13 countries).

Furthermore, the authors have checked the appropriateness of the model. Figure 5 displays the stability of the model, which is tested by the inverse roots of the AR characteristic polynomial test.

The test results have estimated all AR roots to lie inside the unit circle; therefore, the AR roots are strictly less than unity, and the authors conclude that the PVAR (2) model is stable.

In order to detect the presence or absence of multicollinearity, the authors present a correlation matrix (Table 3).

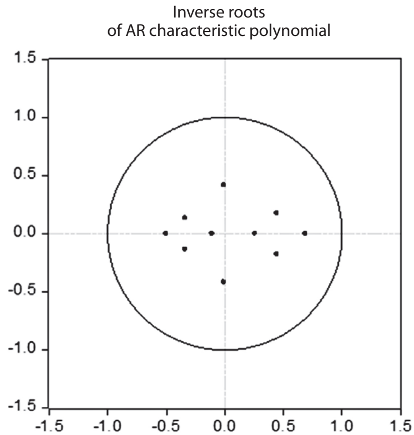

FIG. 5. **Inverse roots of AR characteristic polynomial (PVAR)**

Source: compiled by the authors.

TABLE 3**. A correlation matrix**

	D(LOG(GDP))	D(LOG(RD))	D(LOG(PATENT))	TFP	D(LOG(PE))
D(LOG(GDP))	1.000000	0.581740	0.156954	0.456147	0.270840
D(LOG(RD))	0.581740	1.000000	0.122829	0.183965	0.206432
D(LOG(PATENT))	0.156954	0.122829	1.000000	0.132725	0.222287
TFP	0.456147	0.183965	0.132725	1.000000	0.230161
D(LOG(PE))	0.270840	0.206432	0.222287	0.230161	1.000000

Source: compiled by the authors.

Since the correlation matrix has revealed a very weak and insignificant correlation among the independent variables, the authors assume that there is no multicollinearity among them.

In order to determine the short run causality among the variables, the Wald tests based upon the panel VAR(2) model have been performed (Table 4). The causality test helps to determine whether or not the past changes in PE investment, R&D, granted patents, and TFP help to explain current changes in the GDP. Thus, the authors rely on the *p* value. If the calculated *p* value is less than the 0.1 significance level, then the null hypothesis is rejected. In this case, the authors conclude that Granger causes, otherwise, it does not Granger-cause.

TABLE 4. **PVAR Granger causality / Block Exogeneity Wald tests**

Independent \ Dependent	D(LOG(GDP))	D(LOG(RD))	D(LOG(PATENTS))	TFP	D(LOG(PE))
D(LOG(GDP))		***0.0933***	0.6953	***0.0009***	0.4645
D(LOG(RD))	0.1862		0.4941	0.8777	0.8096
D(LOG(PATENTS))	***0.0000***	***0.0000***		***0.0050***	**0.0000**
TFP	0.7393	0.6539	0.6517		**0.0398**
D(LOG(PE))	**0.0976**	0.5553	***0.0464***	***0.0151***	
Joint causality	***0.0000***	***0.0000***	0.3907	**0.0000**	**0.0003**

Source: compiled by the authors.

According to the test results, a short run causality has been detected. The causality runs from granted patents to GDP, R&D, TFP, and PE. Thus, the results have confirmed the assumption that patents, as a factor of innovation, affect the economic growth. Furthermore, causality runs from PE to GDP, granted patents, and TFP, when the *p* value is less than 0.1 significance level. Further, causality runs from GDP to R&D, and from TFP to PE.

Moreover, joint causality of the variables has been detected, which runs from R&D, granted patents, TFP, and PE to GDP, from GDP, granted patents, TFP and PE to R&D, from GDP, R&D, granted patents and TFP to PE; only granted patents are not caused jointly because the *p* value is more than 0.1 significance level.

Several possible reasons could explain such results. First, granted patents play a more important role in European countries. Second, granted patents have a reverse causality from the private equity. This implies that granted patents attract investments, thereby private equity stimulates the activity of inventors. Third, granted patents and private equity, as complements, cause economic growth jointly. All results have been found statistically significant.

Since the Granger causality test does not reveal the sign of relationship or how long the effect would last, the impulse response and variance decomposition analysis provide more details about the relationship and causality.

The impulse response function presents the results on the effects of granted patents' shock on GDP and PE. The impulse response functions are displayed in Fig. 6, and the significance level is 0.05, the shock is a standard deviation, and the time on the horizontal axis is expressed in years. The authors only present the outcomes of impulse response for significant results in the Granger causality tests related to economic growth.

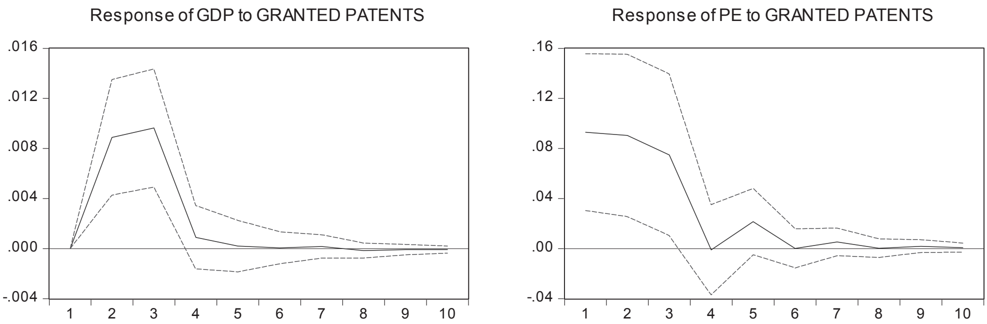

FIG. 6. **Response to Cholesky One S.D. Innovations (PVAR)**

Source: compiled by the authors.

Figure 6 discloses that, when using the recursive panel VAR(2), granted patents lead to a positive response of the GDP. Thus, the positive response of the GDP might be explained in the following way: the patents generate new ideas which are likely commercialized with the help of private equity investments. Therefore, the second impulse response appears. The response of private equity investments to a shock in granted patents has a positive effect. According to Ueda (2009), patents generate new ideas, and private equity investments help to adopt them.

Thus, the results can be treated as significant because the impulse response functions do not present zero values within the confidence intervals, which could be translated into the lack of response to shocks.

The variance decomposition is regressed to measure the contribution of each type of shocks to the variance of the forecast error (Campbell, 1991). Thus, in respect to GDP, the proportions of the variations caused by their own shocks and shocks due to other variables within the system for 10 periods ahead are obtained and reported in Table 5.

It exhibits that 100 percent of the GDP variance could be interpreted by the current GDP in the first period, and the percentages are still significant over the forecasted period. Furthermore, the authors note that granted patents have a slight gradual increase in their contribution compared to R&D expenditures, TFP and PE investments. However, the variance of granted patents is increased from 5.12 percent in the second period, reaching 10.39 percent in the tenth year, while R&D expenditures, TFP and PE investments have achieved only 0.48, 1.24 and 0.49 percent as a higher ratio at the end period, respectively. In this context, it is more evident that the shocks of granted patents are highly linked to the European economies.

TABLE 5.**Variance decomposition of the GDP variable**

Period	D(LOG(GDP))	D(LOG(RD))	D(LOG(PATENTS))	TFP	D(LOG(PE))
1	100.00	0.00	0.00	0.00	0.00
2	93.53	0.09	5.12	1.17	0.10
3	87.62	0.40	10.37	1.21	0.40
4	87.48	0.44	10.40	1.21	0.48
5	87.43	0.46	10.39	1.23	0.48
6	87.42	0.47	10.39	1.24	0.48
7	87.41	0.48	10.39	1.24	0.49
8	87.41	0.48	10.39	1.24	0.49
9	87.41	0.48	10.39	1.24	0.49
10	87.41	0.48	10.39	1.24	0.49

Order: D(LOG(GDP)), D(LOG(RD)), D(LOG(PATENT)), TFP, D(LOG(PE)).

Source: compiled by the authors.

Table 6 illustrates that the forecast error variance of granted patents is significantly linked to its own shock. It exhibits that 97.39 percent of granted patents' variance could be interpreted by current granted patents in the first period, and the percentages are still significant over the forecasted period, while GDP, R&D, TFP and PE have contributed by only 2.46 percent, 0.15 percent, 0 percent, and 0 percent, respectively. This means that the shock of granted patents is largely related to its own shock and slightly to GDP.

TABLE 6. **Variance decomposition of the variable of granted patents**

Period	D(LOG(GDP))	D(LOG(RD))	D(LOG(PATENTS))	TFP	D(LOG(PE))
1	2.46	0.15	97.39	0	0
2	2.56	0.46	95.87	0.91	0.2
3	3.2	0.44	94.33	1.71	0.33
4	3.18	0.49	93.82	2.09	0.42
5	3.18	0.49	93.67	2.17	0.49
6	3.17	0.5	93.6	2.22	0.5
7	3.17	0.51	93.58	2.23	0.51
8	3.17	0.51	93.57	2.24	0.51
9	3.17	0.51	93.56	2.24	0.51
10	3.17	0.51	93.56	2.24	0.51

Order: D(LOG(GDP)), D(LOG(RD)), D(LOG(PATENT)), TFP, D(LOG(PE)).

Source: compiled by the authors.

Furthermore, Table 6 reveals that the granted patents are strongly affected by other factors beyond of this model, which could be attributed to fluctuations of new generated patents.

Table 7 illustrates that the forecast error variance of private equity is significantly linked to its own shock. It exhibits that 87.76 percent of PE variance could be interpreted by the current PE in the first period, and the percentages are still significant over the forecasted period. Furthermore, the authors note that the GDP and granted patents have a slight gradual increase in its contribution compared to R&D expenditures and TFP. However, the variance of the GDP increases from 7.34 percent in the first period to 7.2 percent in the tenth year, as well as the variance of granted patents increases from 3.23 percent in the first period to 7.52 percent in the tenth year, while R&D expenditures and TFP have achieved only 0.58 and 2.83 percent as a higher ratio at the end period, respectively. In this context, it is more evident that the shocks of GDP and granted patents are highly linked to the private equity investments.

TABLE 7. **Variance decomposition of the private equity variable**

Period	D(LOG(GDP))	D(LOG(RD))	D(LOG(PATENTS))	TFP	D(LOG(PE))
1	7.34	0.36	3.23	1.31	87.76
2	7.31	0.57	5.72	1.75	84.65
3	7.24	0.56	7.41	2.49	82.29
4	7.22	0.56	7.38	2.72	82.12
5	7.2	0.56	7.51	2.8	81.92
6	7.2	0.57	7.51	2.82	81.89
7	7.2	0.57	7.52	2.83	81.88
8	7.2	0.57	7.52	2.83	81.88
9	7.2	0.58	7.52	2.83	81.87
10	7.2	0.58	7.52	2.83	81.87

Order: D(LOG(GDP)), D(LOG(RD)), D(LOG(PATENT)), TFP, D(LOG(PE)).

Source: compiled by the authors.

Thus, the results ensure that granted patents are linked to the European economies more than R&D expenditures, TFP and private equity investments. However, despite the empirical results, patents without the contribution of private equity investments likely become worthless.

4. Conclusions and suggestions

The theoretical literature analysis presented in this paper has revealed that each type of relationship among private equity, innovation, and economic growth has its own advocates and the supporting empirical evidence.

Private equity seems to have a positive relationship with economic growth in 13 European countries. The empirical literature has indicated that private equity can stimulate economic growth by commercializing technological innovations. However, the impact of private equity on economic growth has not been substantially highlighted as the key challenge to control for the reverse causality explanation that private equity investments cause technological innovation rather than vice versa.

The main research findings may be presented as follows. A mutual short-term causality is detected between private equity and granted patents when granted patents cause private equity and private equity causes granted patents. These results are found to be statistically significant. However, patents should be considered as an input rather than an output of the private equity investment process, because increased granted patents are expected to contribute to attracting private equity investments. Therefore, private equity investments induce economic growth by commercializing granted patents. Granted patents are based on ideas, and private equity investments help to adopt them. This is suggested by the impulse response analysis where the response of private equity investments to a shock in granted patents has a positive effect. The results of the research are consistent with the majority of studies related to this topic.

The authors highly recommend policy makers not only to back up innovative enterprises but also to promote undertakings to adopt new innovative ideas instead of using an outdated technology in order to become more competitive globally. However, public investments, in particular, should be provided through co-investment schemes where independent private equity investments take the lead.

The panel vector autoregressive model is useful only for a short-run analysis and forecasts among the variables. The disadvantage of the panel VAR model is that the panel VAR is unable to determine the long-run relations among the variables of a system. Therefore, future studies should reveal long-term relationships between private equity and economic growth by using different econometric methods, for instance, the panel vector error correction model. Another suggestion for the further research is to compile a model which includes the subcategory of private equity investments – the venture capital. It should supply more interesting results because private equity is more related to small and medium enterprises, and the venture capital is more related to new innovative enterprises.

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