INNOVATIVE ACTIVITY AND BUSINESS CYCLE: AUSTRIA IN THE 19TH AND 20TH CENTURY

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Introduction

The period of economic recession and crisis usually intensifies the discussion of policies that aim to increase economic performance. Among these we often find suggestions to increase support of research and development, entrepreneurship and innovations. Economic crises create certain pressures to search for adequate policies in this respect; at the same time, crises seem to be the appropriate periods for implementing new policies. However, the research of the relation between business cycles and innovative activities is still rather marginal.

Innovations are typically studied in relation to economic growth (Greenhalgh & Rogers, 2009). Unlike the cyclical fluctuations, economic growth introduces changes in production potential, which is determined by the supply of production factors and their productivity. In the standard distinction between actual and potential product that is typical for demand theories of the business cycle, economic growth represents the trend; oscillation of the actual product around this trend represents the business cycle.

If we accept the distinction between the actual and potential product, then fluctuation of innovative activity over the business cycle and economic growth are two different phenomena to study. However, economists focused on innovations tend to neglect the problem of cyclical fluctuations of innovative activities. For instance, Greenhalgh and Rogers (2009) devote only one paragraph to the relation of innovations and business cycles while the relation of innovations and economic growth is covered in several chapters of the book. Similarly, the cyclicality of innovation activities is not covered by the rather exhaustive "Handbook of the economics of innovation" (Hall & Rosenberg, 2010).

Even if we reject the distinction between actual and potential product, that is, cyclical changes are not considered to be disequilibria but changes of equilibrium, it makes sense to ask how these fluctuations relate to innovative activity. Innovations may be the cause of equilibrium changes, they may be the outcome of changes caused by different factors, or there is perhaps no systematic (causal) relation between the product and innovative activities.

The relation of business cycles and innovations should have profound implications for economic policy. Could the government help overcome an economic crisis by supporting research and development? Or, is it necessary to initiate the boom otherwise and innovations will follow? What is the impact of stabilization policies on innovative activity? Answers to these questions depend on the explanation of causes and mechanisms of the business cycle and its relation to innovative activity of economic subjects.

In this paper, we aim to describe the relation between the business cycle and innovative activity, particularly regarding a small open economy. In the present context, these characteristics are important for a different reason than in the standard macroeconomics. Smallness of an economy refers to the fact that it is not a global innovation leader and it benefits from import of foreign technologies. Openness refers to availability of foreign technologies through international trade and foreign investments. Also, in line with the traditional macroeconomic theory, a small open economy is subject to significant exogenous shocks that impact its business cycle.

We leave the explication of causes and mechanisms of business cycles to others as such explication is too complex to be covered in this paper. We focus solely on those elements that relate to innovations. First, we

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introduce a theoretical framework that explains the relation between innovative activity and business cycle. Then, we examine this relation empirically using historical data from Austria. All historical output figures refer to present-day territory of Austria (further details Bolt, Zanden and Zanden, 2013; Komlos, 1983).

We choose Austria because it is one of the most innovative countries as measured by triadic patents per million inhabitants (OECD, 2018). Its economic development was comparable to the other European countries in recent history. Based on the data from the Maddison database (Bolt, Zanden, & Zanden, 2013), the average growth of 3.5% between 1850 and 1900 was higher than the development in Denmark (3.4%), Spain (3.1%), Italy (2.5%), Netherlands (2.8%), and similar to the development in the UK and slower than in France (3.6%) and Germany (4.3%).

1. Innovative Activity over the Business Cycle

Geroski and Walters (1995) summarize different approaches to the relation between business cycles and innovation activities. In general, the approaches can be divided into two groups according to their expected causality direction. Some economists prefer the explanation that innovations cause supply shocks, which induce expansions and subsequent crises. Other economists assume that innovation activities are indeed dependent variables influenced by the progress of the business cycle. Both approaches will be presented below in more detail.

The concept that the innovation activity is influenced by the demand is not very new. In the 1960s, Schmookler (1966) introduced the hypothesis that innovation activity is flexible and reacts to profit making opportunities, such as incentives in form of a growth on real and potential markets. The rule should also apply that the higher the need, which we want to satisfy (meaning the demand for a solution), the higher the interest of potential innovators to look for the solution. The chance that the demanded solution will be discovered grows with the higher number of interested parties.

Several studies serve as empirical support of the given hypothesis. For example, findings from Scherer's analysis of American data (Scherer, 1982) are not as strong as Schmookler's; however, Scherer works with the entire production sector, not only with selected branches and essentially confirms the validity of Schmookler's theory. Kleinknecht and Verspagen (1990) replicate Schmookler's analysis using Dutch data. They do however replace the number of patents with an indicator of the company research and development activity intensity. The results are similar to Scherer's findings; the dependency is lower than in Schmookler's analysis; it is, however, statistically relevant. After a decade, Brouwer and Kleinknecht (1999) show (using Dutch data once more) the impact of the growth of the effective (aggregate) demand on the intensity of company research and development.

The demand changes during the course of the business cycle can influence innovation activity in several different ways. It seems that during recession, it is easier to innovate because the opportunity costs are lower. During expansion, companies try to increase production and satisfy the increasing demand, thus earning the highest achievable profit. Potential implementations of innovations newly introduced to the production process or new products could deprive them of some profits. On the other hand, lower rents as a consequence of a decrease in demand during crisis periods represent lower opportunity costs for introducing innovations (Penrose, 2009). Innovation activity should therefore be anticyclical.

Empirical experience does, however, always manifest a procyclical character of innovations. An explanation for this fact can be that during expansion, more new products can be introduced. Consumers have more funds that they can and are willing to spend. Another factor is the limited applicability of innovations. The time between introducing an innovation on the market and the start of imitations can be relatively short. The innovator thereby has only a limited period of producing profit and at the same cover the costs of the innovation. That is why innovators will try to time the introduction of the innovation according to the time when they can achieve the most profit – the period of growing demand (Geroski & Walters, 1995). However, Collins and Yao (1998) write about Geroski and Walters' article suggesting that Granger demand changes lead to innovative activity changes but not vice versa. This issue shows that wrong conclusions can be drawn and suggests a nonexistent two-way causality between production and innovation.

There is another explanation for the procyclical character of innovation activity. For example, Rafferty (2003) explains the procyclicality of innovation is caused by changes in the companies' cash flow. Companies – primarily the smaller ones that do not have a stable access to financing – can invest into innovations only during the expansion, when income from existing production makes financing of innovation projects possible. It can also be presumed that the decrease of the interest rate during the expansion period can make access to the external financing easier, while the difficult access to loans during crisis times ("credit crunch") eliminates financing of research and development projects, which are by definition high-risk.

Explanations based on changes in the cash flow of companies are empirically supported by, for example, Piva and Vivarelli (2007). They do, however, point out that the effect of sales on innovation expenses is not the same in all companies. Giedeman, Isely, and Simons (2007) also observed the differences in cyclicality of innovation activities between different branches. They compared the automotive and semi-conductor industries in the United States of America. According to Filippetti and Archibugi (2011), the impact of the current crises also differs amongst the European countries; the innovation expenses of important innovators are procyclical. Axarloglou (2003) shows that variability in product innovation can be rather explained by changes in the aggregate demand and not in the market demand.

In his model, Andrei Shleifer (1986) presents the influence of the expectations of entrepreneurs on future development. His theory is based on Schmookler's assumption about innovators reacting to profit making opportunities. The expectations of entrepreneurs are however more important than the actual development. If the expectations about the start of the expansion match, entrepreneurs will implement their innovations and as a consequence of positive externalities, they thereby start the revival. If they however expect the continuance of the crisis, innovations will not be implemented and the crisis will continue.

Until now, we have assumed that innovation activity depends on the demand. The situation can however be inverted and the product changes do not have to be the causes of innovation but their consequence. Shleifer's above mentioned theory already allows that the causality between innovations and products can go both ways. We will also mention approaches, in which innovations are the cause of economic fluctuations.

Schumpeter (1927) introduced the classic business cycle theory caused by innovations. According to this theory, innovations followed by imitations by other entrepreneurs cause economic boom. The cyclicality of development is brought about by the fact that innovations are not introduced separately. The more important innovations introduce externalities in the form of stimulating other following innovations. The increasing competition from imitators ultimately essentially lowers profits to zero. This leads to a crisis, which allows the restructuring of the economy, destruction of ineffective investments, and the implementation of new innovations. Schumpeter's theory relates not only to the development of the capitalistic system but also to the explanation of changing individual economic systems (Schumpeter, 1927). In this context, it is noteworthy to mention the discussions about the influence of the market structure on innovations; their description does however exceed the focus of this paper.

Innovations, or technological changes, are also one of the causes of product fluctuations according to the real business-cycle theory (Kydland & Prescott, 1982; Plosser, 1989). Apart from the characterization of real cycles' causes, the theory also explains the mechanism of its propagation, which is the intertemporal substitution of labor and leisure. Employees will prefer to work in the time of higher productivity and higher wages; during the time of lower wages, they will prefer leisure time. This creates the cyclical changes of products.

The real business-cycle theory states that markets are in equilibrium during the times of expansion and recession; deviations in the real product are fluctuations of the potential product. A significant difference between this theory and monetary theories can be observed here. Monetary theories consider cyclical development a fluctuation of the real product around the potential one, caused by the changing aggregate demand. The real business-cycle theory assumes that changes in demand and supply happed as a reaction to technological shocks. For example, Brandner and Neusser (1992) analyze the Austrian and

German business cycles. A series of stylized facts is produced that can be linked to the real business cycle theory. The key findings are that the variability of the GNI is higher in Germany than in Austria; the monetary policy is more important in Germany.

We are basing our research on the results of neoclassical economics about technology spillovers and the analysis of economic fluctuations. For example, Artis, Krolzig and Toro (2004) were able to detect a common European growth cycle. They analyze how the European cycle influences the cycles of individual European countries using methods of neoclassical economics. Kose, Otrok and Whiteman (2003) investigate the common dynamic properties of fluctuations of business cycles. The authors used a Bayesian dynamic latent factor model to assess common components in macroeconomic aggregates in a sample of 60 countries. They conclude that a common world factor represents a key source of volatility for aggregates in the majority of countries, which suggests the existence of a world business cycle. The authors also state that region-specific factors tend to play a small role in providing explanations for fluctuations in economic activity.

The neoclassical economic theory also assumes knowledge spillovers between firms. They can be observed in European economies. Baten et al. (2007) prove that intra-industry externalities are important in the entire spectrum of analyzed firms but are more important for smaller firms. However, our research focuses on historical context as well. This research follows up the work of Alfaro, Lopez and Nevado (2011) and Tkáčová and Siničáková (2015) who presented interesting research questions and dealt with business cycles, analyzed the relationship between economic output and intellectual capital, and presented new structure of composite leading indicators.

2. Historical Context

The issue of economic cycles is widely studied. For example, Spree (1977) argues that the cyclical pattern of German industrialization was not fully explored in economic historiography when compared to discussions of the trend rate of real economic growth changing. Spree creates reference cycles that are based on diffusion indices from series of the deviations of individual economic variables based on their trend level. He also focuses on data about German growth starting in 1840. Furthermore, original estimates for price, wage, and output series are included. Spree suggests that peaks of German business cycles happened in 1847, 1857, 1866 (weakly reasoned), and 1873. The weaker business cycles happened in 1844, 1848, 1859, and 1879 (Spree suggests that the economic crisis majorly effected price movements).

The analysis of the postwar business cycles in Western Europe is provided by Gilbert (1962) who describes that Austria, Norway, and Sweden (all in 1955) and the Netherlands in 1956 and 1957 all tried to reduce the expansion speed due to their problems with balance-of-payments, whereas Belgium and Switzerland could use the opportunities of excess demand without attendant external disequilibrium. The U.S. data are analyzed by Jovanovic and Lach (1997) who focus on microeconomic data (1908-1975) and present key details about new products. They state that it can take a significant amount of time before products can notably influence the market. The authors question why the U.S. GNP data does not display greater autocorrelation at higher lags. While the diffusion speed has major level effects, it does not significantly shape the business cycle.

Schulze (1993) focuses on engineering in Austria-Hungary in 1870-1913. The author states that new output estimates suggest that mechanical engineering evolved differently than previously thought. The Austrian capital goods sector stagnated for a long period time during the “Great Depression” (1870’s and 1880’s). Despite this fact, Austrian mechanical engineering industry made significant contributions to the general industrial growth of the monarchy. The author analyzes financial and investment behavior of key machine-building firms. Further, the structure of Austria-Hungary’s machinery trade is examined, suggesting that the competitive position of the Monarchy’s engineering was impeded by its tariff policy. The author argues that the “Great Depression” was indeed present in Austria-Hungary; after overcoming the depression, the machine-building industry recovered quickly. Austrian economic institutions and their development are analyzed by Wandruszka and Urbanitsch (1978). They focus on describing data of production for various industries. They describe regional distributions of these industries and argue that a period of industrial spurt happened in Austria in the 1880s and 1890s.

The topic of technological spillovers and economic fluctuations is related to the issue of patent law. The patent controversy is analyzed by Machlup and Penrose (1950). They report that the topic had been heatedly discussed between 1850 and 1875. Opponents and advocates of the patent discussed whether the influence of the patent law on the country is harmful or beneficial. However, "younger" economists ceased to be interested in that topic and lawyers and engineers emerged as the "experts" on the economic effects of the patent law and its possible reform.

The social value of patents has been discussed as well. Pakes et al. (1989) investigate the patent renewal rate data sets. Although the analyzed data is perceived as important as they are providing data about patent protection value, they suggest that the value of a patent does not necessarily correlate with the social and/or private value of the patented invention itself. On the other hand, Moser (2005) concludes that inventors from countries lacking patent laws focused on a lesser number of industry areas; innovators from countries with existing patent laws focused on a wider variety of areas. Moser argues that patents help to determine in which direction innovations are moved, and that creating patent laws could potentially have influence on existing patterns of comparative advantage across countries.

In our paper, granted patents are analyzed and are assumed to be the indicator of the country's innovative activity. Patents are not an ideal indicator (Griliches, 1991); however, for the longer historical time series they are the only reliable source of measurement of innovative activity.

Historical data are used for the analysis and the main issue is the presence of missing observation of GDP and patent applications for certain years. One way to correct the missing observation in GDP is to estimate the GDP using the commodities (Gross, 1968). Later Gross (1971) states that representative indicators (such as coal, cotton, and iron) should be used because the data on economic development is scarce. There exists enough data on the three areas and each of them represents various growth patterns/processes.

Other data issues are related to the data reliability. Schulze (1997) argues that due to the minimum size criteria while gathering data and as a result of changes to the set criteria, the three Austrian surveys on industry from 1870, 1880, and 1885 present a minimum level of machine-building output. Schulze also states that the surveys' result does not create a fully tangible collection of information.

This research is aimed at Austria and it is a region with many specifics which should be considered in economic and historical research. For example, Huertas (1978) observes that the Habsburg Monarchy symbolizes a rarity in the 19th in Europe because it was a supranational unit whereas the other states at that time were strictly nation states. The author also states that the Monarchy ultimately failed due to pressures of national movements within the Monarchy. He argues that Austrian economic growth was a sequence of failed takeoffs because the Habsburg Monarchy was unable to solve its historical and natural barriers that hindered economic growth.

National statistics was popular in Austria and The Austrian Institute for Business Cycle Research was created on January 1st 1927. Schmidt (1931) focuses on exploring the difficult years in post-war Austria that are represented by an increasing level of recognition of careful diagnosis of economic conditions by analyzing statistical data. The author explains that the Institute was highly regarded, providing monthly reports, which are currently key sources of information about Austrian economic growth.

3. Data and Methodology

The theory does not provide a clear answer to questions concerning the relation between the business cycle and innovation activity. That is why we explore the relation empirically. In order to analyze the time series, we use data about the real gross domestic product (GDP), the population, and granted patents in current Austria (see Tab. 1). For the 19th century Austria, the real indicator of industrial production is also available. Granted patents for the invention are in force, patent applications are in the application stage and are yet to be granted or rejected.

For the description of the historical data the model of two variables is used (Equation 1, Equation 2). It is built on the so-called cointegration analysis (Johansen, 1995) and

Tab. 1: Overview of used data sources

Data source	Indicator	Unit	Period
Komlos (1983)	Industry Production (IP)	Crowns, prices as in 1913	1830-1913
Maddison (Bolt & van Zanden, 2013)	GDP	GK $, GDP per capita as in 1990	1870-2010
Federico (1964; 2011)	Patents F	Granted patents	1821-1846; 1852-1900
WIPO (2012)	Patents W	Granted patents	1883-1937; 1948-1979

Source: own

Notes: WIPO – World Intellectual Property Organization; GK $ - Geary-Khamis method for calculating the outputs according to international prices of the U.S. dollar and prices of 1990 (United Nations Statistics division, 2007).

the estimation procedure is based on vector error correction (VEC). Based on graphical representations (Fig. 1 and Fig. 2) we can assume that the equation of the two variables VEC model may contain various types of trends (Hamilton, 1994).

$$\Delta y_t = \beta_{y0} + \beta_{yy_1}\Delta y_{t-1} + \\ + \beta_{yx_1}\Delta x_{t-1} + \lambda_y\,(y_{t-1} - \\ - \alpha_0 - \alpha_1 x_{t-1}) + v_t^y \tag{1}$$

$$\Delta x_t = \beta_{x0} + \beta_{xy_1}\Delta y_{t-1} + \\ + \beta_{xx_1}\Delta x_{t-1} + \lambda_x\,(y_{t-1} - \alpha_0 \\ - \alpha_1 x_{t-1}) + v_t^x \tag{2}$$

Linear trend (T) has no restriction and the full potential of VECM model is utilized (see example in Equation 3). Restricted trend (RT) model excludes linear trends in the differenced data (τ = 0), but allows for linear trends in the cointegrating equations (ρ ≠ 0). Both trends (T, RT) imply that the cointegrating equations are assumed to be trend stationary. Unrestricted constant (C) model allows for a linear trend in the undifferenced data (τ = 0 and ρ = 0), cointegrating equations are stationary around a nonzero mean. Restricted constant (RC) is without a linear or quadratic trend in the undifferenced data (τ = 0, ρ = 0, and γ = 0). The cointegrating equations are stationary around nonzero means. Model (N) without a trend and constant (τ = 0, ρ = 0, γ = 0, and μ = 0) has cointegrating equations which are stationary with zero means.

$$\Delta y_t = \alpha\,(\beta y_{t-1} + \mu + \rho t) + \\ + \textstyle\sum_{i=1}^{p-1} \Gamma_i\,\Delta y_{t-i} + \gamma + \tau t + \varepsilon_t \tag{3}$$

It was possible to assemble three full time series (1852-1913, 1870-1937, and 1948-1979). There are breaks in series in 1914 and 1938 because of the wars. The last year of WIPO historical patent series is due to the significant changes in patent legislation in 1979. No own estimations were used and no deliberate cuts in time series were performed (Tab. 2). All the expressions in two variables model (Johansen, 1995) are stationary only if the coefficients of the regression are consistently estimated.

The consistency of estimate was tested: (1) The disturbances in the VEC models were tested for normality (Jarque & Bera, 1987). (2) The residuals were tested for autocorrelation by the Lagrange-multiplier test (discussed in Johansen (1995, p. 21-22)). The test is performed at lags of interest. (3) The VEC model was subsequently tested for full covariant stability of the co-integration vector. In other words, the inference after VEC requires that the cointegrating equations be stationary (test of covariant stability is discussed in Johansen (1995, p. 137-138)). The model, which underwent all three tests (normality, autocorrelation, and full covariant stability), was consistently estimated. Then we can say that there is a reasonable long term statistical relationship between the number of patents and the economic output. Otherwise it was only a seemingly unrelated regression model.

Tab. 2: Overview of used data sources

Variable	Number of observations	Mean	St. Deviation	Min	Max
Austria (1852-1913)					
IP	62	8.46E+08	4.56E+08	2.97E+08	1.81E+09
Patents F	62	2,610.1	1,891.2	402	6,635
Austria (1870-1937)					
GDP	68	1.65E+10	4.76E+09	8.42E+09	2.46E+10
Patents F	68	3,528.0	1,439.0	699	6,635
Austria (1948-1979)					
GDP	32	5.68E+10	2.49E+10	1.92E+10	1.02E+11
Patents W	32	6,067.3	2,170.5	747	9,571

Source: Komlos (1983); Bolt, Zanden and Zanden (2013); Federico (1964; 2011); WIPO (2012)

The resulting number of lags in the model is not arbitrary, it is estimated based on on Hannan–Quinn information criterion (HQIC) method and Schwarz Bayesian information criterion (SBIC) method. Then, based on the established number of lags, the Johansen test for co-integration was carried out (the trace statistic is discussed in Johansen (1995, p. 151-176)). This was done to determine if there was a generally observable long-term relationship between the series (statistically consistent or only a seeming one) which could be estimated by means of the VEC model.

A direct and positive long-term relationship e.g. between patents and output is expected. It means that the first lambda coefficient (first equation) of the VEC model will be positive. Due to the character of the VEC model, second lambda coefficient will be negative (Johansen, 1995). The lambda coefficient expresses the deflection from the long-term balance between the series. Their numerical expression may be interpreted as the rapidity of return to the long-term balance. In other words, if a deflection of the development of the number of patent applications from the development of the GDP occurs, the previous values of number of patent applications and GDP help, on average, to predict the rapidity of return to the long-term equilibrium. This principle is defined through the construction of the co-integration vector (1, $-\alpha_0$, $-\alpha_1$). By means of the selected method (VEC model), it is possible to accurately estimate and describe the long-term relationships between the two variables. This method is justifiably preferred over other estimation methods such as auto-regress or cross-section models with lagged variables (Gonzalo, 1994).

The normalized Johansen equation is a procedure (Johansen, 1995) which produces the long-run equation. This normalized equation identifies the parameters in the cointegrating equation by constraining some of them. In our case the GDP coefficient has been normalized to 1.

4. Empirical Findings

Examining long-term and short-term relations between the output (GDP) and the innovation activity (patent applications – granted patents) will be performed on full time series (no cuts). The results are presented chronologically; the graphical illustration of used time series is always included. The idea of cointegration makes possible for economists to assess models that include nonstationary time series (typically GDP and consumption). The analysis of time series that include nonstationary time series in common regression makes incorrect and deviated conclusions possible. If the combination of these nonstationary time series is chosen appropriately and if it is possible to consider their mutual influence (f.e. the relation between patent and GDP) by using the economic theory, a mutual equilibrium can be presumed, which in case of same level of cointegration

Tab. 3: Overview of the results concerning the relation between GDP and granted patents

Period	Data Series	Obs.	Trend	Long-term equilibrium	Short-term Granger causality	
					Patents on GDP	GDP on patents
1852-1913	Industry production	62	C, T	No	No	No
	PATENTS F					
1870-1937	GDP	68	C, N,	No	No	No
	PATENTS W		RC, RT			
1948-1979	GDP	32	T	Yes	Negative	No
	PATENTS W					
Long term relationship (Tab. 6)						
$Ln(GDP) = 22.53 + 0.1595*Ln(Patents) + 0.0485*Trend + \lambda$						

Source: own

Notes: RT – restrictive linear trend, C – constant, RC – restricted constant, N – no trend. Data sources and abbreviations of variables are in Tab. 1.

creates conditions for a consistent assessment that provides meaningful conclusions for economic analysis (Johansen, 1995). In total, the overview of achieved results is presented in Tab. 3.

Based on the results pictured in Tab. 3, we are not able to confirm the unequivocalness of the long-term relation between innovation activity and output (Tab. 4). Cointegration (long-term relation) is present between the series, but it is not possible to assess it consistently. This result is influenced by the inaccuracy of data in the industry production series, which was taken over and which reflects the assessment of

Tab. 4: VEC models, results for the period 1852-1913

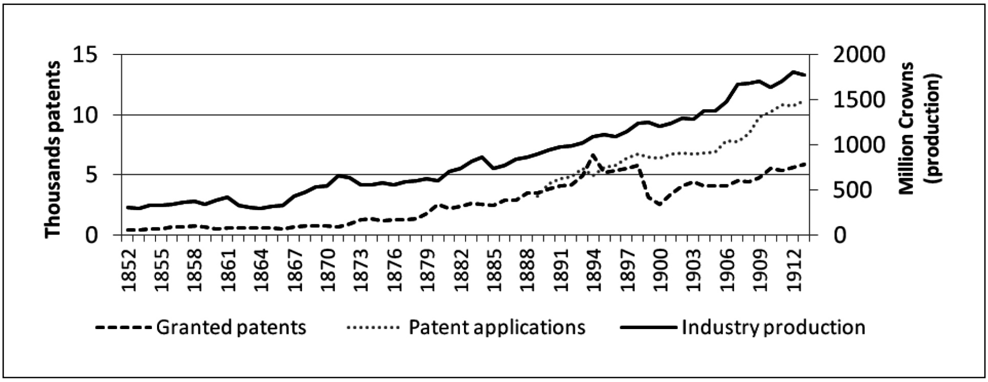
VEC model specification	(1) Trend, 1 Lag	(2) Constant, 1 Lag
$\lambda_y(\Delta IP_{t-1})$	-0.0000756	-0.0376
	(0.000449)	(0.0269)
Linear trend	0.0159	No trend
	(3,796,748.6)	
Constant	497,767.9	0.00637
	(26,834,786.3)	(18,475,794.4)
$\lambda_x(\Delta Patents_{t-1})$	1.19e-08***	0.000000546**
	(4.26e-09)	(0.000000260)
Linear trend	101.5***	No trend
	(36.02)	
Constant	642.3**	439.1**
	(254.6)	(179.2)
Consistency (3 tests)	No	No

Source: own

Notes: * $p< 0.10$; ** $p< 0.05$; *** $p< 0.01$; 61 observations, standard error in the parentheses partial economic output. A short-term Granger causality was not present because the lag-order selection statistics which is based on Schwarz's Bayesian information criterion (SBIC) and the Hannan and Quinn information criterion (HQIC) suggested maximum of 1-year lag in the model.

There is a drop in granted patents around 1900 (Fig. 1). There is no historical evidence or clear interpretation of this sudden decline. Based on the interpretation of Gerschenkron (1977) the years after 1900 can be seen as the period of missed opportunities in relation to the reform program of the Koerber government. In its final stage, the monarchy ultimately missed out on a major industrial boost, the so-called "great spurt" (Gerschenkron, 1977; Eigner, 1997; Hinrichs, 2014). We believe that this drop is partially caused by this economic and political crisis. The number of patent applications continued to grow and it seems that clerks had different agenda and slacken their efforts in demanding verification process of the patent applications and resulted in lower number of granted patents.

Fig. 1: Austria in the 1852-1913 period, output time series and patent applications



Source: Komlos (1983), Federico (1964; 2011).

The second analysis of time series (1870-1937) is like the first one. Again, there is no clearly confirmed long-term relation (Tab. 5). There is cointegration (a long-term relation) between the series but we cannot assess it consistently. Even though it is an inconsistent assessment, we can observe that not even short-term granted patents help explaining industrial production and vice versa. The result is again dependent on the accuracy of the received data about a fraction of the national output. Next model uses the renowned database (Bolt, Zanden, & Zanden 2013) in which the assessments of GDP are continually adjusted. In this period, the patent statistic is also influenced by the high number (Fig. 2) of patent applications and the low number of granted patents by the beginning of the 20th century.

The influence of war is similar. In both series, the number of granted patents dropped as well as the gross domestic product. There is a divergent development of the number of granted patents between 1922 and 1928. The decrease in the granted patents could have been partially caused by financial instability in Austria (Currency reform in 1924 and financial scandals in 1926) and the impact of the revolt in 1927 which caused political instability. Again, the number of patent applications was growing between 1922 and 1928. The lower clerks' productivity due to the political instability probably resulted in the lower number of granted patents.

A long-term relation cannot be securely confirmed in the case of Austria between 1948 and 1979 (Fig. 3) either due to the small number of observations (Tab. 2). The results do however suggest that there is a long-term

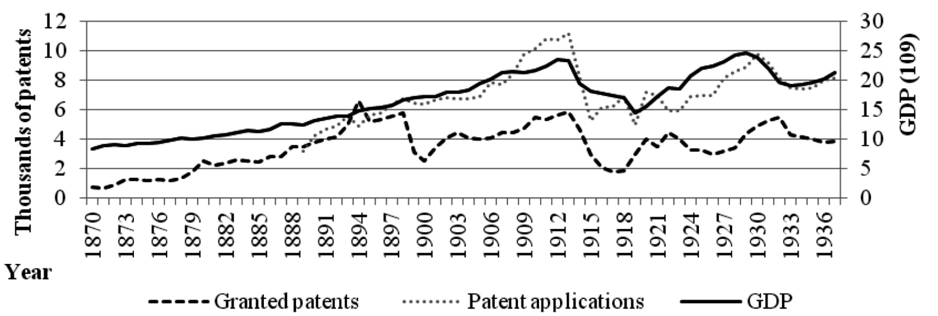
Tab. 5: VEC models, results for the period 1870-1937

VEC model specification	(3) Constant, 2 lags	(4) Restricted Constant, 2 lags	(5) No constant, no trend, 2 lags	(6) Restricted trend, 2 lags
$\lambda_y(GDP_{t-1})$	-0.00998	-0.00963	-0.0187	-0.0805*
	(0.0185)	(0.0184)	(0.0221)	(0.0428)
ΔGDP_{t-1}	0.428***	0.449***	0.452***	0.470***
	(0.117)	(0.116)	(0.115)	(0.118)
$\Delta Patents_{t-1}$	–99,022.6	–91,219.8	–108,662.9	–155,030.5
	(171,168.0)	(172,463.4)	(171,213.1)	(166,948.0)
Constant	0.00217			0.000161
	(238,127,690.6)			(124,503,880.4)
$\lambda_x(\Delta Patents_{t-1})$	4.25e-08***	4.21e-08***	4.90e-08***	8.83e-08***
	(1.30e-08)	(1.29e-08)	(1.56e-08)	(3.15e-08)
ΔGDP_{t-1}	7.82e-08	8.25e-08	8.54e-08	4.93e-08
	(8.27e-08)	(8.14e-08)	(8.13e-08)	(8.67e-08)
$\Delta Patents_{t-1}$	0.264**	0.265**	0.266**	0.241**
	(0.121)	(0.121)	(0.121)	(0.123)
Constant	508.5***			148.0
	(167.8)			(91.75)
Consistency	No	No	No	No

Source: own

Notes: * *p*< 0.10; ** *p*< 0.05; *** *p*< 0.01; 66 observations, standard error in the parentheses

Fig. 2: Austria in 1870-1937, time series of outputs and patent applications



Source: Federico (1964; 2011), Bolt and Luiten van Zanden (2013)

Tab. 6: VEC models, results for the period 1948-1979

VEC model specification (variables in logs)	(1) Trend, 2 Lags
$\lambda_y(\Delta GDP_{t-1})$	-0.608***
	(0.147)
Linear trend	-0.00362***
	(0.000868)
ΔGDP_{t-1}	0.452***
	(0.148)
$\Delta Patents_{t-1}$	-0.0402*
	(0.0220)
Constant	0.118***
	(0.0211)
$\lambda_x(\Delta Patents_{t-1})$	0.582
	(0.635)
Linear trend	-0.00378
	(0.00375)
ΔGDP_{t-1}	0.0596
	(0.641)
$\Delta Patents_{t-1}$	-0.177*
	(0.0950)
Constant	0.0640
	(0.0911)
Consistency (3 tests)	Yes

Source: own

Notes: * *p*< 0.10; ** *p*< 0.05; *** *p*< 0.01; 30 observations, standard error in the parentheses

relationship between the series, which can be consistently assessed thanks to the VEC model. By applying the Granger analysis, it is possible to trace that previous values of granted patents help explain future GDP; on average, these one-year delayed value contribute to the decrease of real GDP by 0.04% while other conditions remain unchanged.

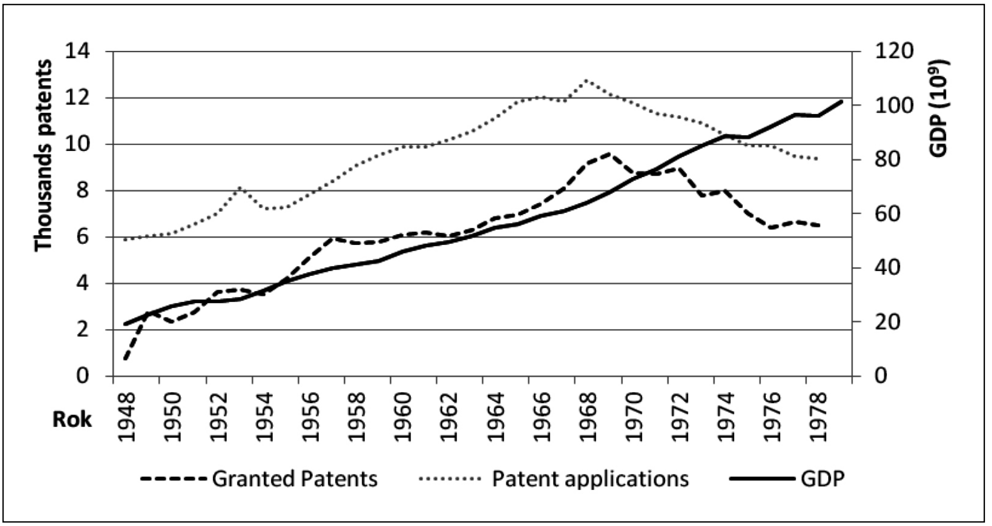
Due to the statistically insignificant lambda coefficient (see VEC specification in Johansen (1995)), we do not know the system of achieving long-term equilibrium in detail; we can however assess the so-called normalized Johansen equation, in which we can formalize long-term direct proportion between granted patents and gross domestic product in Austria between 1948 and 1979.

5. Discussion

The presented results do not provide definite explanation for the relation between innovation activity and the course of the business cycle. The researched cases show the existence of a long-term relation only in the period of 1948-1979; the issues arise from trying to assess this relation. Based on the results, we do not dismiss the hypothesis of the business cycle (or alternatively the aggregate demand) influencing the innovation activity. But our results suggest none or at best a weak relationship between granted patents as indicator of innovative activity and GDP as the indicator of the economic fluctuations.

The quality and accessibility of historical data are significant restrictions to the presented

Fig. 3: Austria in 1948-1979, time series of outputs and patent applications



Source: Bolt and Luiten van Zanden (2013), WIPO (2012)

empirical analysis. Data about the gross domestic product stem from renowned sources and we can see them as the easiest to access; naturally, the historical character of the data means that they are only estimates. Measuring innovations is particularly problematic. In this case, we chose the number of granted patents, which are one of the output indicators of innovation activity. The analysis results can be influences by this choice.

The number of patent applications and granted patents is subjected to the influence of other variables linked to patents. Such variables are for example various direct and indirect expenses on the patent process that companies take into consideration while making decisions about submitting a patent application. The number of granted patents can be significantly influenced by the approach of the patent office and the strictness of the assessment of individual applications. The costs of the patent process, as well as the policy of awarding patents have changed over time. The number of patent applications and granted patents does also not reflect the quality of the innovations.

Other suitable indicators can focus on qualitative assessment of outputs or on other indicators of innovation activity. Geroski and Walters (1995) for example use not only patents but also their own time line of important innovations. Another approach focuses on innovation activity as such, without its outputs. Kleinknecht and Verspagen (1990) and Brouwer and Kleinknecht (1999) used this approach and tried to measure the intensity of company research and development via human resources earmarked for these activities.

Conclusions

In this article, we tried to describe the relation between the development of the business cycle and innovation activity and the possible economic-political implications of this relation. According to the theory of real innovation activity, the innovations can be a positive supply shock that starts economic growth. Supporting innovation activity can therefore be an appropriate policy in times of crisis. If we accept Schumpeter's interpretation, then restructuring economics during crisis leads to establishing a new equilibrium on a higher productivity level. The goal of the crisis is eliminating ineffective enterprises and releasing sources for the effective enterprises. Similarly, the previously mentioned Shleifer's model (Shleifer, 1986) shows that if the expansions are essential to covering big fixed costs of innovation, then the stabilization policy removing cyclic deviations can be an obstacle of technological development.

On the other hand, innovations are motivated by demand as stated by Schmookler (1966) and others; the primary impulse of revival cannot come from innovators. They react to signs of economic activity revival. First then, implementing new approaches and introducing new products can contribute to additional product growth. If we accept Shleifer's view that expansion is launched based on positive expectations of entrepreneurs, at least there has to exist a real impulse for these expectations. Economic policy then has to look for options of starting expansion other than supporting innovation activity. Filippetti and Archibugi (2011) nevertheless recommend policies for maintaining the innovation potential of the country.

Empirical research proves that there exists a long-term relation between economic development and innovation outputs. It also proves that this is a complex relation, which cannot be easily grasped by econometrics. By using the VEC model, we were able to show how the equilibrium between the individual time series is achieved according to the researched data. Nevertheless, it is not possible to dismiss the hypothesis that innovation activity reacts to cyclic deviations of economic output. Our results suggest none or weak at best relationship between granted patents as indicator of innovative activity and GDP in Austria in the researched periods between 1870 and 1979. Also, the patenting procedure seems highly influenced by political stability which has substantial impact on the productivity of patent officers. It is a suggestion for the future research to examine that influence.

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Abstract

INNOVATIVE ACTIVITY AND BUSINESS CYCLE: AUSTRIA IN THE 19TH AND 20TH CENTURY

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This paper focuses on the analysis of the relationship between business cycles and innovative activity in a small open economy. Small economies benefit from imports of foreign technologies through international trade and foreign investments and are subjects to significant exogenous shocks that impact their business cycle. The economic analysis is based on the demand and supply theories of innovation and economic fluctuations. Hypotheses about long term and short term (Granger) effects are tested on Austrian historical data (1852-1979) about the economic output (gross domestic product and industry production) and innovation output (granted patents). The econometric analysis utilizes vector error correction procedure to estimate time-series models of the economy. The results are interpreted in Austrian historical context. The economic-historical analysis suggests that there is no long-term relationship between business cycles and innovative activity between 1852 and 1937. The long-term relationship manifested only between 1948 and 1979. This relationship is very complex and influenced by the historical context, and it is not easy to grasp by the econometric analysis. In the short run, there is no compelling evidence trough-out the analyzed time period (1852-1979). However, we cannot fully reject the hypothesis suggesting a relationship between economic cycles and innovative activities. In the most recent period (1948-1979), we can observe a negative impact (Granger causality) of granted patents on the real GDP. Future research taking into account more countries using parametric as well as non-parametric approach could shed some light on the demand hypothesis in the pre-war and post-war development of small open economies. This paper showed that there is a long-term equilibrium between economic output and innovation activity. This result suggests that long term factors such as political stability are behind the complex relationship.

Key Words: *Business cycle, innovation, innovative activity, Austria.*

JEL Classification: *E32, O40, N13, N14, P52.*

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