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ENTREPRENEURSHIP AND REGIONAL ECONOMIC DYNAMICS: EVIDENCE FROM THE LIBEREC REGION (2002–2024) USING GRANGER CAUSALITY AND VAR MODELS

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Abstract. This study examines the correlation between entrepreneurship and regional economic success in the Liberec Region of the Czech Republic from 2002 to 2024. Utilizing yearly data on GDP per capita, unemployment, average income, investment, and new business formation, the study employs descriptive statistics, multiple regression, Granger causality tests, and Vector Autoregression (VAR) modeling. The results show that GDP per capita and average income have been steadily rising, whereas entrepreneurship has been following a cyclical pattern that is the opposite of unemployment trends. Regression research indicates that unemployment and income are the primary predictors of GDP, but the establishment of new firms exerts less short-term impact. Nonetheless, causality studies reveal a delayed, bidirectional link between entrepreneurship and GDP: economic progress fosters company creation, which, in turn, bolsters growth after a temporal lag. The results using VAR further support the idea that historical GDP values and lagged impacts of unemployment and entrepreneurship affect how regions expand over time. Entrepreneurship does not yield immediate benefits; instead, it fosters long-term growth by enhancing feedback loops within the regional economy. These findings indicate that policies designed to promote high-quality entrepreneurial activity, enhance labor market outcomes, and maintain investment are crucial for facilitating inclusive growth. This study contributes empirical data to the existing literature on entrepreneurship and regional development by concentrating on a specific Czech area, offering insights for policymakers in Central and Eastern Europe.

Keywords: entrepreneurship; regional economic development; Granger Causality; VAR, Liberec Region; Czech Republic

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JEL Classifications: L26, R11, C32

1. Introduction

Entrepreneurship, which has its roots in economics, has evolved into an influential force shaping regional development, requiring an integrated analysis of various economic indicators. Entrepreneurship education enhances self-reliance and decision-making skills, with economic literacy programs significantly boosting financial knowledge and encouraging early entrepreneurial abilities (Manchidi, 2025). These skills interact with institutional factors, where informal elements like networking often have more influence than formal factors such as education or income (Razminienė & Tvaronavičienė, 2024; Šimelytė et al., 2024). In this environment, radical innovation stands out as a key driver of entrepreneurship and regional growth, though it remains underexplored in current research (Cabelkova et al., 2021; Audretsch et al., 2022). Accurately measuring

innovative entrepreneurship by combining start-up activity and self-employment in high-tech industries is essential for assessing regional growth precisely (Piccinetti et al., 2023). Additionally, regional governments and universities serve not only as regulators but also as creators of knowledge, with investments in R&D directly boosting entrepreneurial activity (Aparicio et al., 2022). Building on these foundations, this study investigates new company formation in the Liberec Region and its effect on economic performance.

Since the early 2000s, there have been regional differences in wealth, productivity, and innovation capability in the Czech Republic. The Liberec Region, located in the country's north, is an especially fascinating case study for investigating the relationship between entrepreneurship and economic success. Historically known for its industry base, notably in textile and glass manufacture, the region has seen major restructuring since the country entered the European Union. Over the last two decades, Liberec has faced both possibilities and problems in developing new businesses, responding to global competition, and harmonizing with EU structural policy.

Research on the relationship between unemployment and new firm development in Poland and Slovakia reveals complicated patterns. According to studies, there is a favorable association between growing unemployment and an increase in new business registrations, notably in the service sector (Wosiek, 2021). This implies the existence of "necessity entrepreneurship" motivated by unemployment. However, the extent of this influence differs by geography and industry (Wosiek et al., 2022). In Slovakia, an examination of investment aid from 2002 to 2018 reveals that it was not properly targeted at disadvantaged regions, with 56% of investments flowing to places with below-average unemployment rates (Hvolkova & Klement, 2020). Furthermore, research in the Moravian-Silesian Region of Czechia indicates an inverse association between unemployment and economic indices such as GDP and gross value added, corroborating Okun's Law (Kalinová & Kroutlová, 2023). These findings emphasize the complicated relationship between unemployment, entrepreneurship, and regional economic growth.

This study seeks to address this gap by investigating the link between entrepreneurship and regional economic dynamics in the Liberec Region from 2002 to 2024. The methodology uses time series data on GDP per capita, average income, unemployment, and new firm formation to examine directionality and temporal correlations. Additionally, impulse response functions and variance decomposition are used to represent the propagation of shocks across variables. As a result, our work raises two significant research questions:

RQ1: How has the formation of new companies in the Liberec Region evolved between 2002 and 2024, and what is its relationship with key economic indicators such as GDP per capita, unemployment rate, average income, and investment rate?

RQ2: Does the activity of new company formation in the Liberec Region have a short-term or long-term impact on regional economic performance, and how do economic shocks influence this relationship?

By focusing on a single Czech region over more than two decades, this paper contributes to both the literature on regional entrepreneurship and the methodological advancement of causality-based econometric analysis in regional studies. The findings are expected to provide valuable insights not only for academic discourse but also for policymakers seeking to design evidence-based strategies that enhance entrepreneurship as a catalyst for regional development.

2. Literature Review

2.1 Entrepreneurship and Growth in the Area

Entrepreneurship has always been recognized as a vital catalyst for economic growth and structural transformation at both national and regional scales. Evidence from Zambia indicates that institutional frameworks, such as the small firm's regime, frequently fail to achieve their intended objectives, underscoring the necessity for more customized support mechanisms (Phiri, 2023). Historical analyses indicate that social entrepreneurship has operated as a collective movement, disseminating innovations in welfare, education, and healthcare in Northeast England during the 19th and early 20th centuries, thereby providing benchmarks for comprehending the contemporary social economy (Maclean et al., 2024). Scholars contend that, beyond liberal

models, even planned economies may have institutional incentives for innovation and entrepreneurship, hence contesting the traditional Austrian School view on efficiency (Nieto, 2022). Critiques of the gig economy emphasize that framing insecure work as entrepreneurship-exemplified by Uber's model-obscures inequities and perpetuates neoliberal labor market dynamics (Ahsan, 2020). These works collectively illustrate the varied and occasionally contentious role of entrepreneurship in promoting economic and social progress.

2.2 Circular Economy and Entrepreneurial Business Models

The use of circular economy (CE) ideas in company models has been an expanding focus within entrepreneurship studies. In Spain, rural CE enterprises have slower development yet greater survival rates and profitability in comparison to their urban counterparts, indicating that the environment significantly influences outcomes (Magdalena et al., 2025). Other research shows that local and international companies use CE principles in diverse ways, and that this varies a lot from one industry to the next (Silva et al., 2024). Some businesses, including the agri-food sector, have gotten better at reporting on corporate sustainability, but there are still big gaps in meeting EU regulatory standards (Falkenberg et al., 2023). Transitioning to circular service-based models is further hampered by obstacles in reverse supply chain architecture and market identification, complicating profitability (van Loon & Van Wassenhove, 2020). Sectoral studies provide further insights: Slovak textile companies exhibit favorable revenue trends but encounter legal and institutional obstacles (Hanulakova et al., 2021), whereas greentech enterprises utilizing food waste yield various socio-economic advantages despite inconsistent results (Scaffidi, 2022).

2.3 Digital Economy, New Ideas, and Starting a Business

The digital economy has become a key component in determining entrepreneurship, innovation, and competitiveness. In China, digitalization cuts down on carbon emissions by making better use of resources. However, significant state interference makes these advantages weaker (Chen, 2022). Firm-level research indicates that digitalization promotes green innovation by reinforcing internal controls and long-term investment strategies, especially in companies with significant management ownership (Liu et al., 2024). The digital revolution also helps save energy, mostly through new ideas from entrepreneurs. However, the consequences are different in different places, with periphery cities getting less benefit (Wang & Shao, 2023). More in-depth studies show that digital ecosystems and cooperation between government, business, and academia are necessary for long-term competitiveness (He et al., 2024). Simultaneously, digital transformation has demonstrated the capacity to foster disruptive innovation, with entrepreneurship serving as a moderating influence; however, this correlation is less pronounced in state-owned firms (Wu & Li, 2024).

2.4 The relationship between entrepreneurship, law, and institutions

Legal systems and institutional frameworks have a big impact on how well entrepreneurs do. In the developing space economy, businesses intentionally highlight their social advantages while minimizing dangers, demonstrating how legitimacy theory elucidates selective corporate disclosures (Di Tullio & Rea, 2024). At the regulatory level, disparate approaches to megaconstellations, private space stations, and orbital services underscore enduring deficiencies in space law and governance (Daniels-Dawes et al., 2024). Similar dynamics manifest in conventional industries: global oilfield service companies are adopting Industry 4.0 innovations, whereas Russian enterprises are hindered by restricted investment, limited technological scope, and inadequate state support, highlighting the significance of regulatory and institutional contexts (Razmanova & Andrukhova, 2020). These results illustrate that entrepreneurship is inextricably linked to its institutional and legal frameworks, which significantly influence firm-level tactics and sectoral results.

2.5 The Gig Economy and New Types of Business Ownership

The emergence of the gig economy has sparked fresh discussions on the definition of entrepreneurship in modern labor markets. Bibliometric evaluations delineate the disjointed nature of research in this domain, highlighting clusters related to self-employment, digitalization, and platform work, while emphasizing that the pivotal role of gig workers is still inadequately examined (Silva & Moreira, 2022). In addition, critical studies say that gig platforms like Uber purposely position unstable jobs as entrepreneurship, which hurts workers' rights and makes inequality worse (Ahsan, 2020). These viewpoints indicate that the gig economy broadens the parameters of entrepreneurial dialogue while concurrently posing essential inquiries on equality, regulation, and the genuine liberty of workers.

2.6 Gap in Research

The research elucidates the multifaceted interactions between entrepreneurship and regional development, transitions to a circular economy, digital innovation, institutional frameworks, and labor markets. These studies collectively emphasize the significance of entrepreneurship as a catalyst for economic development and structural transformation; nonetheless, notable gaps persist. First, the majority of empirical studies have concentrated on national or cross-national assessments, with little focus on regional dynamics, particularly in Central and Eastern Europe. Second, while circular economy and digitalization are often associated with entrepreneurship, their impacts on conventional regional growth metrics such as GDP per capita, unemployment, and investment are seldom examined within a cohesive econometric framework. Third, a significant portion of the current literature depends on descriptive or qualitative data, with a limited number of studies employing causality-based econometric techniques (e.g., Granger causality, VAR models) to elucidate dynamic feedback processes between entrepreneurship and economic results. Lastly, the Czech Republic is still not well-represented in this research, with Prague and other big cities getting more attention than less important areas.

In addition, although recent scholarship has advanced hybrid decision-support models, fuzzy logic approaches, and algorithmic personalization in areas such as tourism, healthcare, and media ecosystems (Gavurova et al., 2023–2025), their direct application to regional entrepreneurship and growth remains underexplored. Most of these contributions emphasize sectoral or institutional contexts, without explicitly linking such tools to entrepreneurial ecosystems or regional development trajectories. Lastly, the Czech Republic remains insufficiently represented in this body of work, with Prague and other metropolitan centers receiving more scholarly attention than peripheral regions such as Liberec.

This study fills these gaps by looking at the Liberec Region from 2002 to 2024 using a mix of descriptive analysis, regression modeling, and dynamic econometric methods. Concentrating on a specific region over a span of two decades offers innovative perspectives on the directional and temporal dynamics of the link among entrepreneurship, GDP per capita, unemployment, and investment. In doing so, it adds to the larger body of work on regional entrepreneurship and gives policymakers who want to improve entrepreneurial ecosystems in areas that haven't been researched as much evidence-based advice.

2.7 Decision-Support Systems and Digital Transformation

Recent scholarship has increasingly emphasized the integration of digital transformation, decision-support systems, and information technologies across diverse domains of economic and social development. Gavurova et al. (2025) highlight the socio-economic implications of digital transformation in tourism, proposing hybrid decision-support models to improve sectoral efficiency. Complementary research extends these models to socially sensitive contexts, such as travel planning for people with disabilities, where fuzzy set theory enables greater inclusivity in decision-making (Gavurova & Polishchuk, 2025). The role of algorithmic personalization and digital media literacy has also been scrutinized, revealing persistent knowledge gaps in adapting individuals and institutions to rapidly evolving information environments (Moravec et al., 2025). Within healthcare, scholars examine both the managerial and evaluative dimensions of information technology integration (Smolanka et al., 2024; Chilunjika, Uwizeyimana, 2024) and the development of intellectual models to manage patient trust in primary care institutions (Gavurova, Smolanka & Polishchuk, 2024). Parallel efforts address the assessment of automated news content in relation to demographic structures, underscoring the broader relevance of information-analytical systems for media literacy and public communication (Gavurova et al., 2024). At the same time, contributions by Skare, Gavurova, and Polishchuk (2023) underscore the importance of large-scale decision-making models for financing tourism infrastructure and start-up ventures through crowdfunding, thereby linking entrepreneurial financing to regional development priorities. In the healthcare domain, fuzzy decision-support approaches have been employed for the evaluation and prioritization of competing projects, further demonstrating the adaptability of such methods across sectors (Gavurova et al., 2023).

Collectively, these studies illustrate the growing relevance of fuzzy logic, hybrid decision-support systems, and algorithmic personalization in both public and private sector decision-making. They emphasize how digital transformation and information integration reshape entrepreneurship, tourism, healthcare, and media

ecosystems, while highlighting the need for adaptive models that account for uncertainty, inclusivity, and dynamic institutional contexts.

3. Methodology

This study employs a quantitative research design to analyze the dynamics of new company formation in the Liberec Region and its relationship with key economic indicators over the period 2002–2024. The methodological framework integrates descriptive statistics, econometric modeling, and time-series analysis to address the two research questions. Data were obtained from the Czech Statistical Office and regional economic reports, ensuring consistency and accuracy across the study period. The dataset includes annual observations for GDP per capita (CZK), unemployment rate (%), average income (CZK), investment rate (%), and the number of newly established companies in the Liberec Region. All statistical and econometric analyses were conducted using Python (pandas, statsmodels, matplotlib) for data processing and visualization, ensuring reproducibility. The investment rate has two missing values for 2023 and 2024 due to unavailability in official records, which were kept as NaN in the dataset.

For Research Question 1, the analysis uses absolute values of each variable to explore long-term trends and cross-variable relationships. For Research Question 2, GDP per capita is converted into annual growth rates, while unemployment and new company formation are differenced to achieve stationarity based on Augmented Dickey–Fuller (ADF) test results. The new company formation variable required a second difference before achieving stationarity.

The methodological process follows four main stages. At first, descriptive and correlation analyses were used to visualize trends and examine preliminary associations between new company formation and economic indicators. Then these results will be presented in the form of line graphs for the individual variables and a heatmap for the correlation matrix.

Secondly, Multiple regression models were used to assess the statistical significance and magnitude of relationships for RQ1. To investigate the relationship between GDP per capita and key economic indicators in the Liberec Region, Ordinary Least Squares (OLS) regression models were estimated. This approach quantifies the linear association between the dependent variable (GDP per capita) and selected explanatory variables, allowing for the assessment of individual and joint effects. There will be three regression models made, at first combining all, and later combining two different variables each: Equation 1 shows the models 1:

$$GDP_t = \beta_0 + \beta_1 N_t + \beta_2 U_t + \beta_3 A_t + \beta_4 I_t + \varepsilon_t \quad (1)$$

Where, GDP_t is the Gross Domestic Product per capita at the time t , β_0 to β_4 represent the estimated coefficients for the independent variables, N_t , U_t , A_t , and I_t are the New companies, Unemployment, Average Income, Investment rate in the region at time t . ε_t is the error term capturing unexplained variation.

To assess multicollinearity among the independent variables, the Variance Inflation Factor (VIF) was calculated, ensuring that the regression estimates were not distorted by high intercorrelations. The VIF can be calculated by using the equation:

$$VIF_i = \frac{1}{1 - R_i^2} \quad (2)$$

Where R_i^2 is obtained by regressing the i -th independent variable on all remaining predictors. Values above the conventional threshold (typically 10) indicate potential multicollinearity concerns.

Model 1: GDP per capita ~ New companies + Unemployment: The first regression model was formulated to examine the relationship between GDP per capita (GDP_t) and two key predictors-new company formation (N) and unemployment rate (U) in the Liberec Region, expressed as:

$$GDP_t = \beta_0 + \beta_1 N_t + \beta_2 U_t + \varepsilon_t \quad (3)$$

Model 2: GDP per capita ~ New companies + Investment rate: The second regression model was formulated to examine the relationship between GDP per capita (GDP_t) and two key predictors-new company formation (N) and investment rate (I) in the Liberec Region. The model is expressed as:

$$GDP_t = \beta_0 + \beta_1 N_t + \beta_2 I_t + \varepsilon_t \quad (4)$$

Thirdly, stationarity and VAR modeling-ADF tests were conducted for each variable, succeeded by differencing where required. A Vector Autoregression (VAR) model was then estimated for RQ2 to capture interdependencies between variables, and Granger causality tests were applied to assess the predictive relationships between new company formation, GDP per capita, and unemployment.

Next, The Augmented Dickey-Fuller (ADF) test was applied to examine the presence of unit roots. The test was specified as:

$$\Delta S_t^{(d)} = \alpha + \beta t + \gamma S_{t-1}^{(d)} + \sum_{i=1}^p \delta_i \Delta S_{t-i}^{(d)} + \varepsilon_t \quad (5)$$

where S_t is the original series (GDP per capita, unemployment, new companies). $S_t^{(d)} = \Delta S_t$ is the series after applying d differences to achieve (or test for) stationarity. For example, $d=1$ for the first differences; $d=2$ for second differences. $\Delta S_t^{(d)} = S_t^{(d)} - S_{t-1}^{(d)}$. α is the intercept, βt is an optional time trend, γ is the unit-root coefficient, and δ_i control serial correlation upto lag p . ε_t is the white-noise error term. Here the null hypothesis written as $H_0: \gamma = 0$ (unit root; $S_t^{(d)}$ is non-stationary) and the alternative hypothesis is, $H_a: \gamma < 0$ (stationary).

Granger Causality Analysis is used to investigate potential directional relationships between GDP per capita (GDP_t), new company formation (N), and unemployment rate (U) in the Liberec Region, the Granger causality test was applied. The test determines whether past values of one time series contain predictive information about another time series, beyond the information already contained in its own past values. The general form of the Granger causality model can be expressed as:

$$Y_t = \alpha_0 + \sum_{i=1}^p \alpha_i Y_{t-i} + \sum_{i=1}^p \beta_i X_{t-i} + \varepsilon_t \quad (6)$$

where Y_t and X_t are stationary time series, p is the number of lags, α_i and β_i are parameters to be estimated, and ε_t is the error term. If the coefficients β_i are jointly statistically significant, X is said to “Granger-cause” Y . Optimal lag lengths (p) were selected to capture short- and medium-term dynamics, with tests performed for one, two, and three lags. The analysis reported both F-statistics and Chi-square statistics, with significance determined at the 5% level based on Chi-square p-values. The test outcomes provided evidence on whether GDP per capita, new company formation, and unemployment rates have predictive relationships over different time horizons.

Finally, Impulse Response Functions (IRFs)-to evaluate the short-term and long-term impact of economic shocks (e.g., new company formation shocks) on GDP growth and unemployment. This mixed approach enables both a macro-level understanding of the evolution of new company formation in the Liberec Region and a dynamic analysis of how shocks propagate through the regional economy.

4. Results

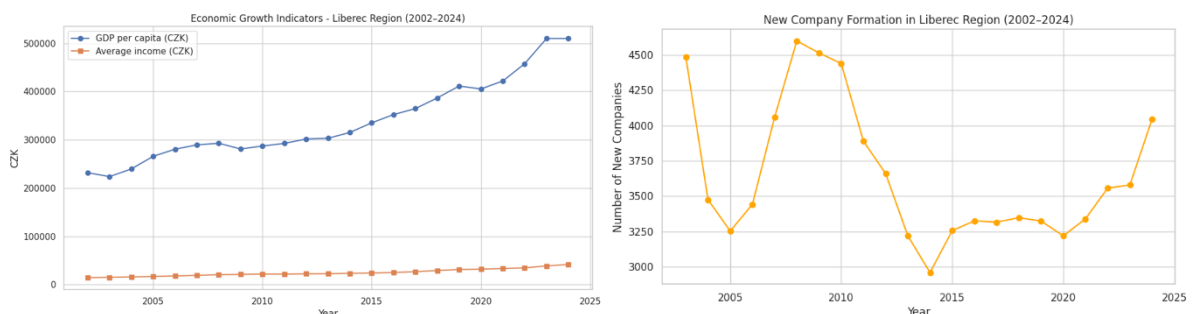
For the first research question, the descriptive statistics from Table 1 show a clear pathway of understanding regarding the dataset contains the variables GDP per capita, unemployment, average income, the number of new companies, and the investment rate in the Liberec region in the Czech Republic from the period of 2002 to 2024. Out of the total 23 yearly observations, the New companies and the investment rate from the Liberec region lack one and two observations, respectively. From the data, it's clearly visible that there is a strong expansion in the GDP per capita, which has risen from 223,734 to 510,000 CZK ($\approx +128\%$ span). In the same way, the average income climbed from 14,113 to 41,549 CZK/month ($\approx +195\%$), and the investment rate from 41,275 to 114,868 CZK ($\approx +178\%$). The GDP, income, and investment show right-skewed growth, and the labor market shows sizable cyclical swings. And also, the Entrepreneurial activity is steadier in the region. In the bottom line, the Liberec regions exhibit sustained economic growth in output, incomes, and investment from 2002–2024, volatile unemployment, and a moderately stable pace of new firm creation.

Table 1. Descriptive Statistics of Key Economic Indicators for the Czech Republic (2002-2024)

	Count	mean	std	min	25%	50%	75%	max
GDP_per_capita	23	337383.87	83035.91	223734	284064	303186	396122	510000
Unemployment	23	6.59	2.54	2.95	4.015	6.5	8.68	11.1
Avg_income	23	24603.83	7550.08	14113	19699	22424	30056.5	41549
New_companies	22	3650.05	493.31	2959	3318	3458.5	4006	4599
Investment_rate	21	73245	19876.26	41275	57942	68482	78962	114868

Source: Own Research

From 2002 to 2024, the Liberec Region shows steady growth in GDP per capita, with a notable acceleration after 2018, reaching nearly 500,000 CZK, while average income increases more slowly. This widening gap between total output and household income highlights growing inequality. The formation of new companies follows a cyclical pattern: an initial decline, a peak from 2008 to 2010, contraction until 2014, then stabilization and a rebound after 2021. This pattern inversely mirrors unemployment rates; higher joblessness coincides with lower startup entry rates, while a decrease in unemployment from 2014 to 2019 aligns with modest growth in startups and a partial recovery after 2020. The investment rate is on an upward trend, with significant increases from 2018 to 2020, remaining at historically high levels that support capital-driven growth. The data indicate that strong investment and improved labor market conditions drive GDP growth, that entrepreneurial activity responds to macroeconomic shocks with a delay, and that the faster rise in production compared to incomes raises concerns about the inclusiveness of recent development (Figure 1).



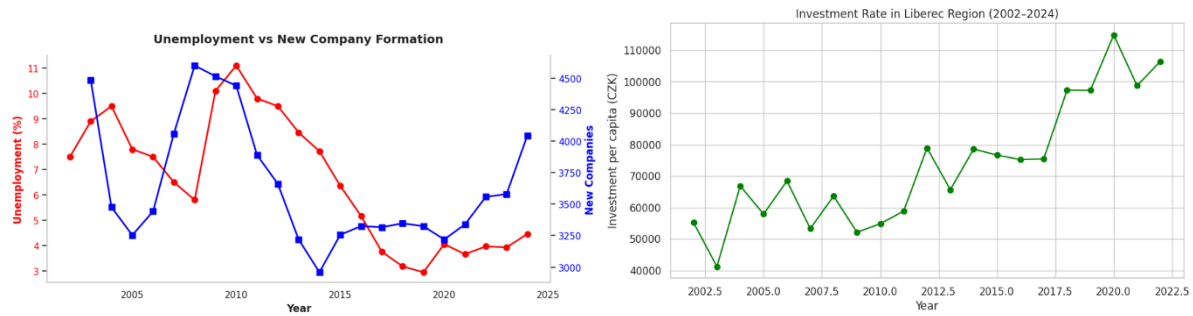


Figure 1. Economic Dynamics in the Liberec Region (2002–2024)-GDP per capita & average income, new company formation, unemployment vs. new companies, and investment rate per capita.

Source: Own Research

The correlation study for the Liberec Region from 2002 to 2024, as the in Figure 2, shows a steady pattern of economic interdependence. GDP per capita, average income, and investment rates are all strongly and positively linked, indicating that periods of rapid economic growth are usually accompanied by rising wages and increased capital investment. Conversely, unemployment has a notable negative relationship with both GDP per capita and average income, demonstrating that improvements in economic performance are closely tied to reductions in joblessness. Interestingly, new firm formation shows only a small negative correlation with GDP per capita and income, but a slight positive link with unemployment, suggesting that entrepreneurial activity may slightly rise during times of labor market slack. Additionally, the investment rate is significantly negatively correlated with new company formation, implying that higher capital flows don't always coincide with increases in entrepreneurial entries, highlighting different factors that drive investment and firm growth.

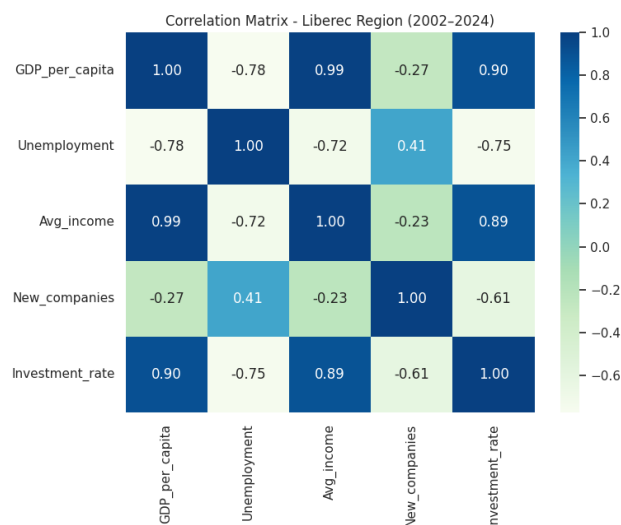


Figure 2. Correlation Matrix of Key Economic Indicators - Liberec Region (2002–2024)

Source: Own Research

Regression Modeling: The OLS regression findings from Table 2 show very good explanatory power, with an R-squared of 0.987, implying that the selected variables account for over 99% of the variation in GDP per capita in the Liberec Region. Average income has a strong positive correlation with GDP per capita ($\beta = 9.26$, $p < 0.001$), indicating that income increase is a vital factor driving regional economic progress. Unemployment has a substantial negative connection ($\beta = -4482.44$, $p = 0.001$), indicating an adverse correlation between labor market performance and economic production. However, the coefficients for new firm formation and investment rate are statistically negligible, implying that their direct effects on GDP per capita are weak in this formulation. The large condition number (1.24×10^6) indicates considerable multicollinearity, most likely due to close correlations between average income, investment rate, and GDP per capita. Individual coefficient magnitudes should be interpreted with caution.

Table 2. OLS Regression Estimating the Determinants of GDP per Capita in the Liberec Region (2002-2024)

Dep. Variable:	GDP_per_capita			R-squared:	0.987	
Model:	OLS			Adj. R-squared:	0.984	
Method:	Least Squares			F-statistic:	290.7	
No. Observations:	20			Prob (F-statistic):	5.16E-14	
Df Residuals:	15			Log-Likelihood:	-205.6	
Df Model:	4			AIC:	421.2	
Covariance Type:	nonrobust			BIC:	426.2	
	coef	std err	t	P> t	[0.025	0.975]
const	1.59E+05	2.82E+04	5.635	0	9.87E+04	2.19E+05
New_companies	-5.1853	5.041	-1.029	0.32	-15.93	5.559
Unemployment	-4482.4407	1152.716	-3.889	0.001	-6939.397	-2025.484
Avg_income	9.2626	0.81	11.442	0	7.537	10.988
Investment_rate	-0.0327	0.264	-0.124	0.903	-0.594	0.529
Omnibus:	5.937			Durbin-Watson:	1.313	
Prob(Omnibus):	0.051			Jarque-Bera (JB):	3.66	
Skew:	0.98			Prob(JB):	0.16	
Kurtosis:	3.742			Cond. No.	1.24E+06	

Notes: [1] Standard Errors assume that the covariance matrix of the errors is correctly specified. [2] The condition number is large, 1.24e+06. This might indicate that there are strong multicollinearity or other numerical problems.

Source: Own Research

Variance Inflation Factor (VIF): The Variance Inflation Factor (VIF) results from Table 3 show extreme multicollinearity among the independent variables, with all VIF values significantly higher than the usually recognized threshold of 10. The average income (VIF = 116.06) and investment rate (VIF ≈ 82.94) exhibit exceptional collinearity, showing significant duplication in the information they give, possibly due to their strong correlation with GDP per capita and each other. New firm creation (VIF = 45.82) and unemployment (VIF ≈ 15.42) show substantial multicollinearity, but to a lower level. Such exaggerated VIF values indicate that coefficient estimates may be unstable and susceptible to minor changes in the model, distorting statistical significance and interpretability. To address this issue, variable selection, transformation, or regularization procedures may be required to ensure more trustworthy inference.

Table 3. Variance Inflation Factor (VIF) for Independent Variables in the GDP per Capita Model

Variable	VIF
New companies	45.81772
Unemployment	15.417931
Avg_income	116.059724
Investment_rate	82.944315

Source: Own Research

Model 1: GDP per capita ~ New companies + Unemployment: Model 1 accounts for 69.6% of the variation in GDP per capita ($R^2 = 0.696$), with an adjusted R^2 of 0.661, indicating a reasonable match. Unemployment is a significant predictor ($p < 0.001$) with a big negative coefficient ($-19,190$), suggesting that more unemployment leads to lower GDP per capita. New firm creation has a negative coefficient (-13.23) but is statistically insignificant ($p = 0.495$), indicating no direct impact on GDP per capita in this formulation. The comparatively low Durbin-Watson value (0.433) suggests that the residuals may have positive autocorrelation, which might compromise the dependability of standard errors. Overall, the model identifies unemployment as a major driver of GDP per capita in the Liberec region, whereas new firm creation appears to have a less immediate influence (Table 4).

Table 4. OLS Regression Results for GDP per Capita on New Company Formation and Unemployment

Dep. Variable:	GDP_per_capita			R-squared:	0.696	
Model:	OLS			Adj. R-squared:	0.661	
Method:	Least Squares			F-statistic:	19.49	
No. Observations:	20			Prob (F-statistic):	3.99E-05	
Df Residuals:	17			Log-Likelihood:	-237.31	
Df Model:	2			AIC:	480.6	
Covariance Type:	nonrobust			BIC:	483.6	
	coef	std err	t	P> t	[0.025	0.975]
const	5.04E+05	6.20E+04	8.127	0	3.73E+05	6.35E+05
New_companies	-13.2335	18.994	-0.697	0.495	-53.308	26.841
Unemployment	-1.92E+04	3719.349	-5.161	0	-2.70E+04	-1.13E+04
Omnibus:	0.927			Durbin-Watson:	0.433	
Prob(Omnibus):	0.629			Jarque-Bera (JB):	0.896	
Skew:	0.402			Prob(JB):	0.639	
Kurtosis:	2.346			Cond. No.	2.72E+04	

Notes: [1] Standard Errors assume that the covariance matrix of the errors is correctly specified. [2] The condition number is large, 2.72e+04. This might indicate that there are strong multicollinearity or other numerical problems. Unemployment shows a significant negative association with GDP per capita, while new company formation is not statistically significant in this model.

Source: Own Research

Model 2: GDP per capita ~ New companies + Investment rate: Model 2 shows a strong explanatory power, with an R^2 of 0.828 and an adjusted R^2 of 0.808, indicating that around 80% of the variation in GDP per capita is explained by new company formation and investment rate. The investment rate emerges as a highly significant predictor ($p < 0.001$) with a positive coefficient (3.175), suggesting that higher investment levels are strongly associated with increases in GDP per capita. In contrast, the effect of new company formation remains statistically insignificant ($p = 0.296$) despite a positive coefficient (17.30), indicating that its direct contribution to GDP per capita is less clear in this model. The Durbin-Watson statistic of 2.097 suggests no major autocorrelation concerns, and residual diagnostics indicate no severe normality issues. Overall, the model underscores the pivotal role of investment rate in driving regional economic growth, while the impact of new company formation appears less immediate (Table 5).

Table 5. OLS Regression Results for GDP per Capita on New Company Formation and Investment Rate

Dep. Variable:	GDP_per_capita			R-squared:	0.828	
Model:	OLS			Adj. R-squared:	0.808	
Method:	Least Squares			F-statistic:	40.88	
No. Observations:	20			Prob (F-statistic):	3.20E-07	
Df Residuals:	17			Log-Likelihood:	-231.64	
Df Model:	2			AIC:	469.3	
Covariance Type:	nonrobust			BIC:	472.3	
	coef	std err	t	P> t	[0.025	0.975]
const	2.71E+04	8.08E+04	0.336	0.741	-1.43E+05	1.98E+05
New_companies	17.2989	16.032	1.079	0.296	-16.526	51.123
Investment_rate	3.175	0.41	7.744	0	2.31	4.04
Omnibus:	1.853			Durbin-Watson:	2.097	
Prob(Omnibus):	0.396			Jarque-Bera (JB):	1.395	
Skew:	-0.624			Prob(JB):	0.498	
Kurtosis:	2.659			Cond. No.	9.87E+05	

Notes: [1] Standard Errors assume that the covariance matrix of the errors is correctly specified. [2] The condition number is large, 9.87e+05. This might indicate that there are strong multicollinearity or other numerical problems. Investment rate is a significant positive driver of GDP per capita, whereas new company formation does not show a statistically significant effect in this model.

Source: Own Research

Pairwise Relationships with Regression Lines: These scatterplots from Figure 3 below show the pairwise correlations between GDP per capita and major economic indicators in the Liberec Region from 2002 to 2024. The first figure (New Companies versus GDP per Capita) shows a slightly negative slope, showing that greater rates of new company creation are weakly related to lower GDP per capita; however, the association looks minor and is undoubtedly impacted by external variables. The second plot (Unemployment versus GDP per Capita) shows a strong negative association, with rises in unemployment resulting in considerable drops in GDP per capita, showing the severe economic consequences of joblessness. The final plot (Investment Rate versus GDP per Capita) shows a significant positive connection, indicating that greater investment rates are substantially associated with higher GDP per capita, emphasizing the importance of capital investment in regional economic growth. Together, these visual patterns correspond to regression results in which unemployment has a substantial negative influence, investment rates have a strong positive impact, and new firm creation has a smaller direct effect on GDP per capita.

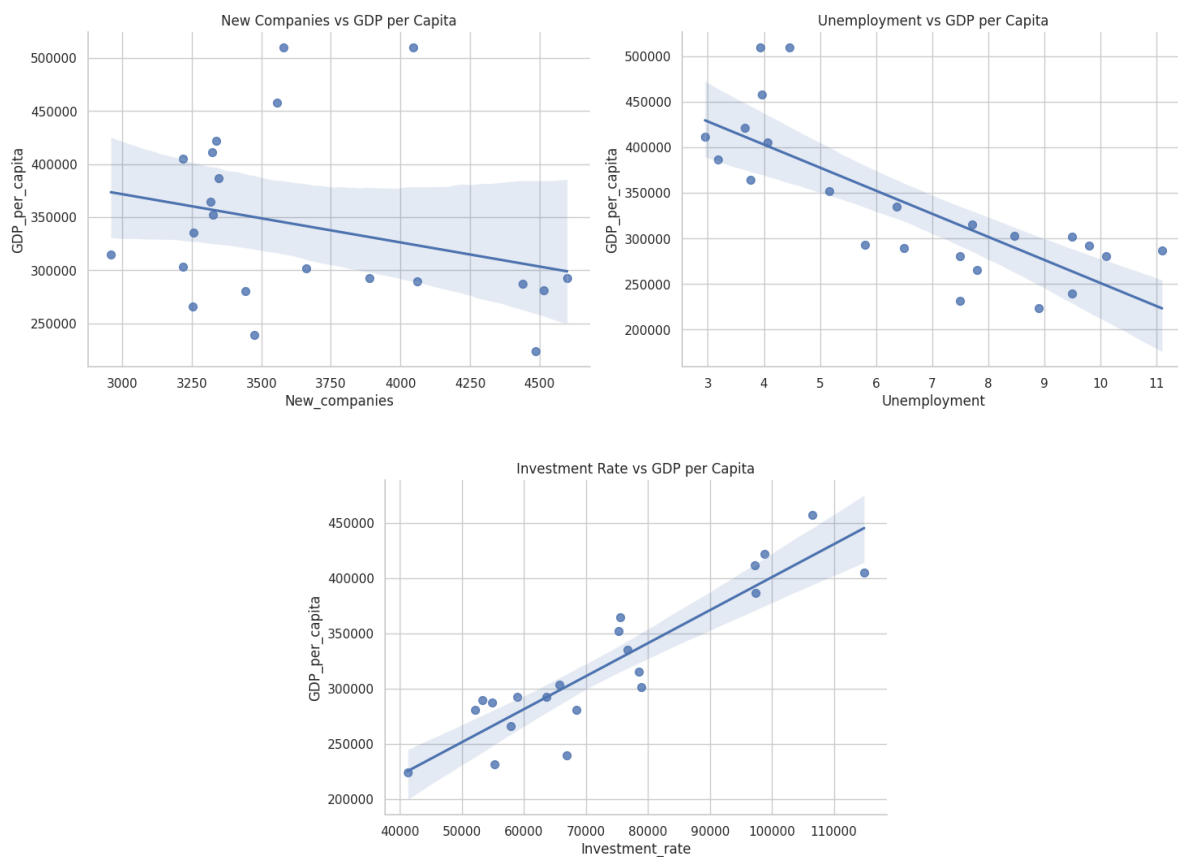


Figure 3. Scatter Plots - Relationships Between GDP per Capita and Key Economic Indicators in the Liberec Region (2002-2024)
Source: Own Research

For the second research question, the analysis begins with preparing the time series data for GDP per capita (expressed as a growth rate percentage), unemployment rate, and new company formation for econometric modeling. As a first step, stationarity checks were performed using the Augmented Dickey-Fuller (ADF) test to ensure that the variables meet the requirements for time series analysis. Initial results indicated that all three series were non-stationary in their level form, meaning they exhibited trends or other non-constant statistical properties over time. Applying first differencing transformed GDP per capita growth and the unemployment rate into stationary series, while the new company formation series remained non-stationary. A second differencing was therefore applied to the new company data, which successfully achieved stationarity. This transformation process ensures that all variables are now suitable for subsequent vector autoregression (VAR) and impulse response function (IRF) analyses, minimizing the risk of spurious regression results and enabling reliable dynamic relationship estimation.

The Granger causality results from Table 6 reveal bidirectional relationships between GDP per capita and new company formation, although the statistical significance varies with lag length. Specifically, the chi-square test indicates that new company formation Granger-causes GDP per capita at a lag of three years, while GDP per capita Granger-causes new company formation at lags two and three years. This suggests a dynamic interplay where entrepreneurial activity and economic growth reinforce each other, although with some temporal delay. For labor market dynamics, the results show that new company formation Granger-causes unemployment at a lag of two years, and unemployment also Granger-causes new company formation at the same lag. This bidirectional relationship might indicate that job market conditions influence entrepreneurial behavior, while business creation subsequently affects employment opportunities. However, significance is not consistent across all lags, implying that these effects are context- and period-specific. Overall, the findings support the presence of time-lagged feedback loops between economic growth, business formation, and unemployment in the Liberec region, emphasizing the importance of considering temporal dynamics when designing regional economic policies.

Table 6. Granger Causality Test Results (GDP per capita, New Companies, and Unemployment - Liberec Region)

Direction of Causality	Lags	F-statistic	p-value	Chi-square	p-value	Significant at 5%?
New Companies → GDP	1	0.5813	0.4585	0.7059	0.4008	No
	2	0.8684	0.4465	2.5264	0.2827	No
	3	1.9131	0.2060	10.7611	0.0131	Yes (Chi ²)
GDP → New Companies	1	1.6575	0.2188	2.0126	0.1560	No
	2	2.7237	0.1094	7.9234	0.0190	Yes (Chi ²)
	3	1.4642	0.2956	8.2361	0.0414	Yes (Chi ²)
New Companies → Unemployment	1	0.4753	0.5018	0.5771	0.4474	No
	2	2.4574	0.1311	7.1488	0.0280	Yes (Chi ²)
	3	0.2788	0.8393	1.5680	0.6667	No
Unemployment → New Companies	1	1.7585	0.2060	2.1353	0.1439	No
	2	2.6433	0.1155	7.6895	0.0214	Yes (Chi ²)
	3	1.0075	0.4382	5.6669	0.1290	No

Source: Own Research

Vector Autoregression (VAR) and Impulse Response Analysis: The VAR(3) model from Table 7 shows that GDP growth in the Liberec region is heavily impacted by its own historical values, with all three lag factors (L1-L3) having substantial and negative coefficients. This shows a pattern of mean reversion, in which strong GDP growth in one era is followed by reduced growth in succeeding periods. Furthermore, the model shows that unemployment fluctuations with a three-year lag have a positive and statistically significant effect on GDP growth. This unexpected conclusion might be due to delayed labor market adjustments or cyclical effects, in which earlier unemployment reductions result in stronger productivity and production increases after a lag. Furthermore, new business creation (at lag 3) has a minor but substantial negative influence on GDP growth, which might reflect short-term disruption costs or that newly founded enterprises need time to contribute favorably to the economy. No variables were statistically significant at conventional levels in the unemployment and new firm formation equations, indicating that these factors have weaker direct short-term predictive associations within the specified lag structure. The residual correlation matrix shows a high negative correlation (-0.70) between GDP growth and changes in unemployment, as predicted by economic theory, and a moderate positive correlation (0.50) between GDP growth and changes in new firm creation (Table 8).

Table 7. Model order selection criteria (minimum values highlighted):

Lag	AIC	BIC	FPE	HQIC
0	14.32	14.46	1.651e+06	14.31
1	14.63	15.20	2.351e+06	14.62
2	15.03	16.02	4.256e+06	15.02
3	12.42	13.83	5.646e+05	12.40

Note: The selected optimal lag length is 3, based on AIC, BIC, FPE, and HQIC.

Source: Own Research

Table 8. VAR(3) Model Results - GDP Growth, Unemployment, and New Company Formation

Dependent Variable	Variable	Coefficient	Std. Error	t-Stat	p-Value	Sig.
GDP_diff	const	1.7996	0.6668	2.699	0.007	Yes
	L1.GDP_diff	-0.7560	0.2117	-3.572	0.000	Yes
	L1.Unemp_diff	0.0315	0.6644	0.047	0.962	No
	L1.NewCo_diff2	0.0037	0.0029	1.272	0.203	No
	L2.GDP_diff	-1.1079	0.2087	-5.308	0.000	Yes
	L2.Unemp_diff	-0.5871	0.5897	-0.996	0.319	No
	L2.NewCo_diff2	0.0002	0.0027	0.076	0.939	No
	L3.GDP_diff	-1.0006	0.2490	-4.019	0.000	Yes
	L3.Unemp_diff	1.6391	0.6161	2.661	0.008	Yes
	L3.NewCo_diff2	-0.0058	0.0021	-2.792	0.005	Yes
Unemp_diff	const	-0.4486	0.3265	-1.374	0.169	No
	L1.GDP_diff	0.0209	0.1036	0.202	0.840	No
	L1.Unemp_diff	0.2800	0.3253	0.861	0.389	No
	L1.NewCo_diff2	-0.0004	0.0014	-0.299	0.765	No
	L2.GDP_diff	0.0424	0.1022	0.415	0.678	No
	L2.Unemp_diff	-0.1116	0.2887	-0.386	0.699	No
	L2.NewCo_diff2	0.0001	0.0013	0.058	0.954	No
	L3.GDP_diff	-0.0012	0.1219	-0.010	0.992	No
	L3.Unemp_diff	-0.0793	0.3017	-0.263	0.793	No
	L3.NewCo_diff2	0.0006	0.0010	0.546	0.585	No
NewCo_diff2	const	-67.4645	97.8060	-0.690	0.490	No
	L1.GDP_diff	-11.0341	31.0449	-0.355	0.722	No
	L1.Unemp_diff	-36.0637	97.4448	-0.370	0.711	No
	L1.NewCo_diff2	-0.1341	0.4264	-0.314	0.753	No
	L2.GDP_diff	37.9190	30.6113	1.239	0.215	No
	L2.Unemp_diff	-39.8623	86.4864	-0.461	0.645	No
	L2.NewCo_diff2	-0.0479	0.3910	-0.122	0.903	No
	L3.GDP_diff	-16.0792	36.5149	-0.440	0.660	No
	L3.Unemp_diff	-78.9104	90.3595	-0.873	0.383	No
	L3.NewCo_diff2	0.0279	0.3041	0.092	0.927	No

Note: Significance at the 5% level is marked as Yes.

Source: Own Research

Table 9. Correlation matrix of residuals:

	GDP_diff	Unemp_diff	NewCo_diff2
GDP_diff	1.000	-0.702	0.503
Unemp_diff	-0.702	1.000	0.111
NewCo_diff2	0.503	0.111	1.000

Source: Own Research

The impulse response (Figures 4 and 5) study indicates that GDP shocks produce transient impacts, with early growth momentum dissipating within two years. Shocks to unemployment have diverse effects, whereas shocks to the establishment of new businesses have little to no effect on GDP or unemployment. In the same way, shocks to GDP impact company development, whereas shocks to unemployment only create short-term changes. In general, the connections between GDP, unemployment, and entrepreneurship are weak. They have only a little short-term impact and greater signs of delayed or outside influences.

Impulse Response Functions

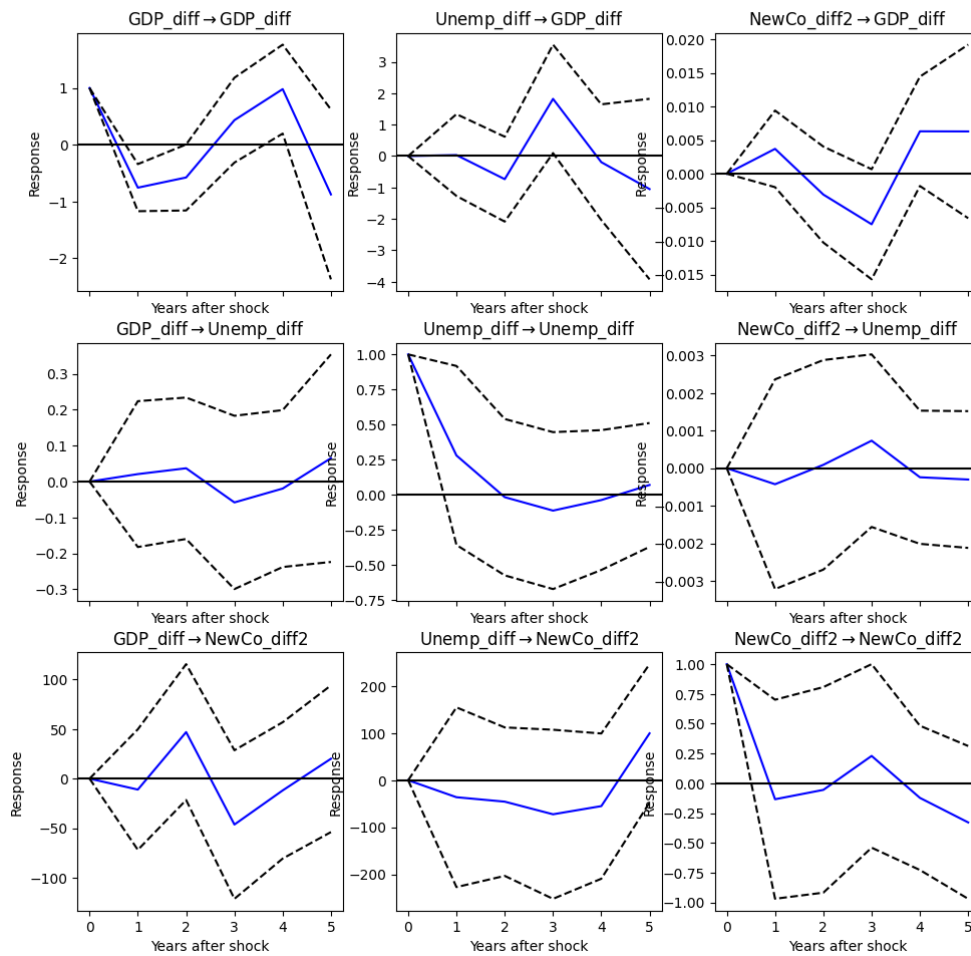


Figure 4. Impulse Response Functions for GDP Growth, Unemployment, and New Company Formation
Source: Own Research

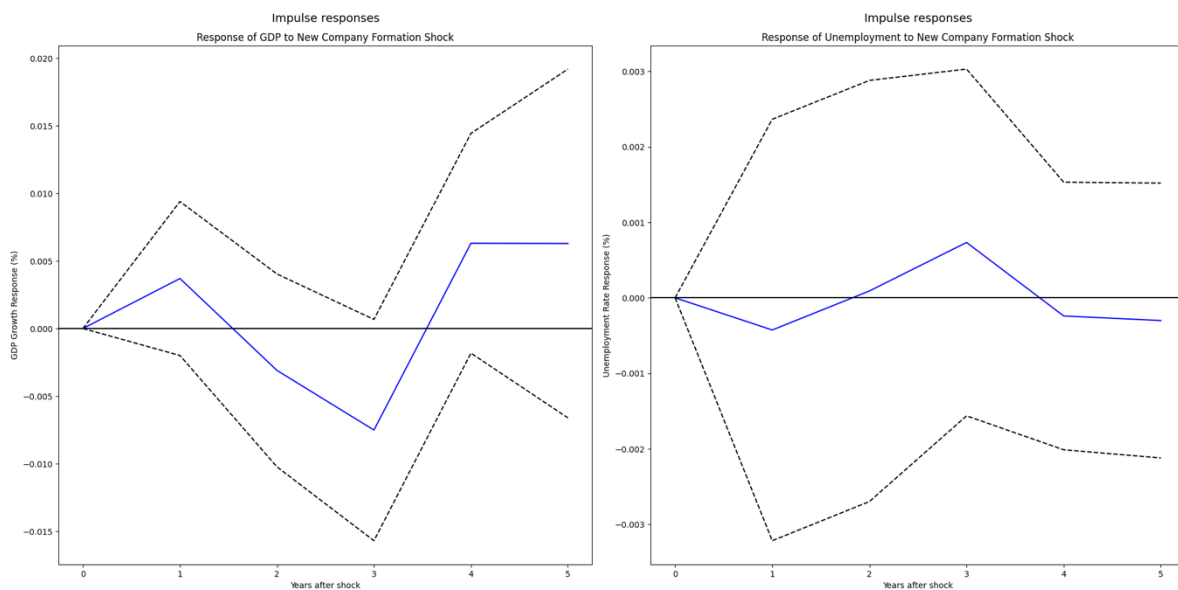


Figure 5. Responses of GDP Growth and Unemployment to a New Company Formation Shock
Source: Own Research

5. Discussion of Results

Relationship between GDP per capita, new companies, unemployment, average income, and investment rate: The RQ1 study indicates that although GDP per capita is affected by several factors, only unemployment and average income have significant and persistent influences. Unemployment has a negative effect, which is in line with Okun's Law, whereas increased earnings have a favorable effect on growth. New businesses and investments didn't have any big short-term benefits, perhaps because of problems with firm survival, disparities in efficiency, and multicollinearity. In simplified models, unemployment continued to be a big negative effect, while investment seemed to be a positive one. However, entrepreneurship still didn't seem to matter. Overall, the functioning of the labor market and growing earnings have the most effect on regional growth in Liberec. In the near term, entrepreneurship and investment don't matter as much. This means that their effects are more delayed and depend on quality rather than quantity. So, policy should focus on lowering unemployment and encouraging long-term income growth, while also encouraging productive, creative companies over just more of them.

Dynamic and Causal Relationships Between GDP per Capita, New Companies, and Unemployment: Stationarity tests showed that GDP and unemployment were stable after the first differencing, while new enterprises needed the second differencing. Granger causation showed a delayed two-way relationship between GDP per capita and the creation of new businesses. Economic development encourages entrepreneurship after 2–3 years, while new businesses need time to add to GDP. The connection between new businesses and unemployment was not strong and didn't always hold up. There was some indication of mutual effect at two-year delays. The VAR(3) model showed that GDP growth is mostly caused by its own historical values. Unemployment (positive at lag 3) and new firm creation (negative at lag 3, which means short-term adjustment costs) both have delayed impacts on GDP growth. No notable predictors were identified in the unemployment or new company equations, indicating the influence of external structural issues. The findings indicate that entrepreneurship fosters growth only after a certain period, whereas the consequences of unemployment are indirect and less substantial. This shows that regional growth can only happen if there is long-term, continuous policy support for entrepreneurship.

6. Conclusion

This study examined the relationship among GDP per capita, new company formation, and unemployment in the Liberec Region (2002–2024), utilizing stationarity diagnostics, Granger causality tests, and a Vector Autoregression (VAR) framework. The results show that there is a delayed, two-way link between entrepreneurship and economic growth. For example, GDP growth leads to the creation of new businesses, while entrepreneurship leads to an increase in the long run. Conversely, the relationship between entrepreneurship and unemployment was shown to be weaker and less stable, indicating that the impacts on job creation are contingent upon larger structural and regulatory frameworks. The VAR findings showed that GDP dynamics are affected by both their own past values and the lagged impacts of unemployment and entrepreneurship. This shows how regional economic linkages might take time to show themselves. The consequences for policy show that entrepreneurship needs long-term assistance that lasts. Short-term actions alone are unlikely to yield rapid enhancements in the labor market; nevertheless, promoting high-quality, innovative enterprises and fortifying institutional frameworks can yield long-term growth benefits. The study has certain problems, such as a short dataset, a restricted range of variables, and the necessity for differencing, which might hide long-term correlations. Future studies ought to augment the dataset, including supplementary macroeconomic and institutional variables, and utilize sophisticated methodologies such as VECM or non-linear models to comprehensively capture both short-term and long-term dynamics.

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