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FACULTY OF SOCIAL SCIENCES

Institute of International Studies

Department of Russian and East European Studies

Master's Thesis

2024 **Zhuoran Wang**

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A study on the relationships among foreign direct investment, innovation and economic growth in European countries from 1998 to 2021

Master's Thesis

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Declaration

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2. I hereby declare that my thesis has not been used to gain any other academic title.
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In Prague on 27/07/2024 Zhuoran Wang

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Abstract

Globalization has facilitated capital movement around the world, and the growth pattern of the European economy has received widespread attention. The relevant literature reveals that FDI's influence on economic growth is mainly in capital accumulation, technology transfer, and the introduction of management experience. Moreover, innovation is important factor to drive long-term economic development. Meanwhile, it is found that the joint effect between FDI and innovation may impact the economy's growth. This thesis adopts the analytical method of panel data fixed-effects regression and collects relevant data from several European countries between 1998 and 2021, including FDI inflows, innovation indicators (e.g., research and development expenditure, scientific articles, and patent applications) and the GDP, etc. The data show that FDI is significantly and positively correlated with the economy's growth in European countries. Specifically, the scientific articles also significantly and positively affect the growth of the economy in European countries. Our analysis finds that there is a threshold for the volume of R&D and FDI in European economies. Finally, this thesis presents and discusses a series of policy recommendations.

Keywords

FDI; innovation; economic growth; CEE; European countries;

Klíčová slova

inovace; hospodářský růst; evropské země; přímé zahraniční investice; CEE

Title

A study on the relationships among foreign direct investment, innovation and economic growth in European countries from 1998 to 2021

Název práce

Studie vztahů mezi přímými zahraničními investicemi, inovacemi a hospodářským růstem v evropských zemích v letech 1998-2021

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Introduction

International trade has generated rapid development, driven by the context of economic globalization. Rapidly developing global trade not only promotes the free movement of factors around the world but also facilitates the exchange and division of labor among different countries, thereby achieving a win-win situation. Trade liberalization has impacted the country's economic changes, and Adam Smith's theory of "surplus exports" and Robertson's argument that "trade is the engine of economic growth" prove the intrinsic link between trade and the economy's growth. FDI (Foreign direct investment) serves as one indicator of a country's trade openness and an important way to compete internationally. On the one hand, it can reduce the funding gap, catalyze the development of new industries, and develop local innovation based on investment's spillover effect. On the other hand, as FDI's main carriers, multinational corporations (MNCs) can pose challenges to host markets, monopoly power, suppressing patents, locking up technologies, and interfering with policies.

Between 1998 and 2021, Europe experienced a number of major economic changes, such as the unification of the official currency of the euro, the eastward expansion of the European Union, the financial crisis, and the global epidemic. These crises have caused the European economy to perform differently at different times. At the beginning of the century, the growth trend appeared in the European economy, which was accompanied by rapid technological advances and driven by European integration. However, the 2008 financial crisis had slowed the impact on economic development in Europe, with many European countries experiencing a decline in GDP and taking a long time to recover. Increase in unemployment and severe employment trends appeared because of the financial crisis. Countries have made efforts to recover after the crisis, but poor regional recovery efforts, including structural reforms and austerity measures. It has led to gradual improvements in employment rates, but disparities in development between regions remain. The new wave of challenges posed by the new crown epidemic in 2020-2021 had also led to constrained economic development and an increase in unemployment. In addition,

Europe is undergoing an economic transition towards digitalization and a green, low-carbon economy.

This period between 1998 and 2021 is full of technological advancements and new opportunities as well as risks for companies and multinational corporations and provides a unique ground for FDI research. During the period, FDI research highlighted the correlation with economic growth (Moudatsou, 2003; Tsimpida & Bitzenis, 2023), as well as the correlation between innovation and economic growth (Pece et al., 2015; Phung et al., 2019; Nihal et al., 2023). This thesis aims to econometrically assess and discuss the complex relationship between FDI, innovation, and economic growth. Specific research questions include: What is FDI's influence on economic growth? What is innovation's influence on economic growth, and do FDI and innovation interact and work together to affect economic growth?

In the thesis, fixed-effects panel data regression is used to form the structure of FDI, innovation, and economic growth, with FDI and innovation as the independent variables. This has very important theoretical and practical significance. Firstly, the relationship between FDI, innovation, and economy and its impact in Europe is systematically explored with the support of new trade theory, FDI-related theory, innovation theory, and economic growth theory. Secondly, Europe is now undergoing strategic economic restructuring. Under the premise of ensuring internal economic security and supply and demand balance, it is of great practical significance to discuss how to better attract and utilize high-quality foreign investment and rely on different innovation modes' influence on economic growth to solve energy problems, digitalization, and industrial upgrading in the transformation of the European economy. Thirdly, comparing the Central and Eastern Europe (CEE) region as a whole with other European countries and categorizing and discussing it geospatially with great significance in focusing on the CEE's future development. Regional heterogeneity is considered in the discussion to obtain better policy recommendations and promote coordinated economic development in Europe.

The first part of this thesis introduces the research motivation, research questions, and research significance by analyzing the current status of key issues. The second part first

introduces the current situation and basic concept definitions, after which it extends the relevant theoretical foundations and the relevant results of previous research and finds the research gaps through analysis. The third part introduces the methodology of this paper, which mainly covers the research methodology, the design of research, the collection of data, and the methods of analysis, etc. The fourth part analyzes the data results, mainly including results of descriptive statistics, analysis of correlation, and results of empirical tests. The fifth part discusses the results, makes policy recommendations, and suggests the subsequent research's development based on the thesis's limitations. The sixth part then summarizes the whole paper.

Results show that FDI can effectively promote economic growth in European countries, but R&D's effect on economic growth is not obvious. Patent applications have a non-significant negative correlation with GDP, but the number of scientific articles significantly and positively affect economic growth. In addition, the interaction of FDI and R&D expenditure suggests a threshold to the volume of R&D and FDI volumes in European economies.

1. Literature review

1.1 Current situation analysis

1.1.1 FDI situation analysis

The size of FDI in Europe saw a decrease in 2023, the first decrease since the Global epidemic[1]. According to Ernst & Young's 2024 survey, the number of FDI projects in Europe stood at 5,694 in 2023, down 4% year-on-year from 5,962 projects in 2022. France, the UK, and Germany, the main countries that attract FDI, saw a 5% decrease in France and a 12% decrease in Germany. However, the UK grew by 6%. Meanwhile, job creation in Europe decreased by 7% in 2023 (Gee, 2024). This shows that despite the growth of

[1] Global epidemic also known as COVID-19, is a global pandemic caused by the SARS-CoV-2 virus.

investment projects in some countries, the overall employment impact is still affected by slowing economic growth, uncertain geopolitical environments due to wars, and so on. Due to the rapid technological development and the concepts' application, such as sustainability and artificial intelligence, new regulations and laws have been established in various countries to address the new business environment. Although the EU itself does not currently have harmonized norms for FDI regulation and review, the European Commission encourages individual countries to adapt and cooperate on their respective FDI review regimes to promote coordinated enforcement (Berg et al., 2024). Currently, despite the challenges in FDI development, Europe remains an attractive and investable region for FDI (Dettoni, 2024).

1.1.2 Innovation situation analysis

The end of the 1990s and the beginning of the 21st century were important periods for promoting European scientific and technological progress. As the impact and scope of the EU R&D framework program in the early 1980s exceeded the stated objectives, it gave impetus to the consolidation of S&T resources and the process of S&T integration within the EU. The European economy began to survive the currency and economic crises in the late 1990s. The rapid development of communication information technology and biotechnology led to the recovery and growth of the European economy. For example, the information technology industry in Germany is expected to become the most dynamic economic and job-creating industry in Germany, employing as many as 1.8 million people and adding at least another 750,000 new jobs in the next ten years. The economic growth rate of the euro area in 2000 reached 3.5 percent (Zhou & Shen, 2000, p. 18). Economic growth and scientific and technological competitiveness enhance the EU's comprehensive strength over the United States of America's self-confidence. 2000 EU Lisbon Summit put forward the EU's first ten-year economic development plan, the "Lisbon Strategy," focusing on scientific research investment, economic growth, and employment growth in three areas. The content of the EU's development strategy for digitalization can be shown in the Lisbon Strategy, specifically by increasing investment in scientific research to

promote innovative knowledge-based economic development. The “EU 2020” is planned based on the “Lisbon Strategy.” The plan has three priorities: economic innovation, sustainable growth, and competitive advantage. EU 2020 seeks to make Europe a smarter, more sustainable, and more inclusive place to live, putting EU digitization officially on the agenda.

Currently, European innovation intensity is significantly influenced by artificial intelligence, a technology that is transforming the field of innovation research. According to recent literature from the European Commission, the emergence of AI can accelerate the output of scientific discoveries and address major societal challenges such as climate change and health issues. However, it also faces challenges such as ethical considerations and the need for researchers to adapt to new technologies (European Commission, 2023).

1.1.3 Economic growth current situation analysis

The European economy faces complex and multifaceted challenges and opportunities in 2024. In 2023, economic growth in Europe slowed down, especially in the second half of the year when economic activity almost came to a standstill. GDP growth in the euro area is expected to pick up slightly in 2024 but remain at a low level. According to the Ernst & Young’s report, GDP growth in the Eurozone is expected to be 1.1% in 2024, compared to only 0.6% in 2023 (Gee, 2024). This moderate growth is mainly constrained by tight monetary policy and a slow recovery in external demand. Inflation begins to decline after peaking in 2023. Headline inflation in the euro area is expected to fall to 2.5% in 2024, while core inflation is projected to fall to 2% in 2025. Nonetheless, inflation in the services sector remains more stubborn, mainly driven by wage growth (Gee, 2024). Job vacancies have declined, and working hours have stagnated, suggesting that the labor market’s resilience may be overestimated. The unemployment rate is expected to remain around 6.5% in 2024 (Raithatha, 2024). Europe’s exports will decrease in 2023, but the overall trade balance remains positive. However, the global trade environment remains challenging, especially with the negative impact of slower growth in the US and China on the demand for European exports evident (Gee, 2024). The ECB (European Central Bank)

in 2024 is expected to begin a gradual easing of monetary policy, with deposit rates projected to fall to 2.75%-3% by the end of 2024 (Gee, 2024). This will help ease pressure on economic activity, but the magnitude and pace of rate cuts may be influenced by inflationary pressures. Overall, the European economy will continue to face the twin challenges of inflation and growth in 2024. Despite some easing of inflation, growth remains fragile, with greater uncertainty about the recovery, particularly in consumer spending and investment activity. Differences in economic performance will continue to exist between countries, with Central and Eastern European (CEE) countries experiencing relatively high growth potential and Western European (WEO) countries experiencing relatively slow growth. Monetary policy adjustments in the global trade environment will influence the economy's direction in the coming years.

1.2 Basic concepts and definitions

1.2.1 Foreign direct investment (FDI)

FDI is an important component of global economic integration and has far-reaching effects on both host and home economies. Host countries refer to it as FDI (foreign direct investment), and investor countries refer to it as OFDI (outward foreign direct investment). The IMF defines FDI as an international investment in which an investor holds at least 10% voting rights or equity of a firm in another country to get significant control and long-term benefits. This definition emphasizes the investor's long-term influence and managerial involvement in the firm (International Monetary Fund, 2003; Galeza & Chan, 2017). This definition helps to better analyze FDI's long-term impact on the host economy, including capital inflow stability and its contribution to the economy's growth.

Current FDI types can be categorized into three types. Markusen and Maskus (2002) discussed three different models of FDI in their paper. Firstly, the horizontal type of FDI refers to investors setting up subsidiaries or branches that produce the same product in a foreign market, i.e., multi-plant enterprises that replicate roughly the same activity in many locations. Secondly, vertical FDI refers to firms that geographically split production into

different stages, usually based on factor intensity. Vertical FDI sets up different links in the production chain in foreign markets and arranges skilled labor-intensive activities in skilled labor-rich countries to reduce production costs or access resources. In addition, hybrid FDI, i.e., combining horizontal and vertical forms of investment.

To enable FDI, Dunning (2000) comprehensively analyzed four different types of motives for FDI. Firstly, market-seeking FDI is to meet foreign markets' specific needs or range. Secondly, supply-oriented FDI is to acquire natural resources, such as agricultural products, unskilled labor, and minerals. Thirdly, efficiency-seeking FDI is designed to enhance the efficiency of existing domestic and foreign asset portfolios through more efficient labor division or specialization within the multinational enterprise. Usually, this type of FDI is carried out sequentially after implementing the first or second type of FDI. Fourthly, strategic asset-seeking FDI can enhance or protect the investing firm's ownership-specific advantages and reduce its competitors' advantages.

1.2.2 Innovation

Innovation can often be described as a new approach or the process of introducing something new. This can include a new service, a new product, a new technology, a new business model, or a new process that results in a recombination of conditions and factors of production, introducing new combinations in the system of production (Schumpeter, 1934).

Innovation's classical definition derives from the economic and management branch of innovation studies (IS), whose main focus is the role and evolution of technology in the application and production of technological and scientific knowledge over time (i.e., research and development, R&D). Martin (2016) stated that innovation was mainly relevant to developed countries' manufacturing in the 1960s. Large firms developed it, and it was based on technology. Moreover, innovation was involved before R&D and was usually based on R&D carried out in large companies' laboratories involving patents. It acknowledged that most indicators used to measure such innovation might "miss" a large number of countervailing innovative activities, namely incremental innovations, which did

not take the form of innovations in manufacturing products, involved no formal or little R&D, and were not patented.

However, innovation can be categorized into different types. Firstly, the technological innovation. The classic concept of technological innovation derives from Schumpeter's typology of innovation, which emphasizes the importance of technological innovation in manufacturing based on R&D. Schumpeter noted that technological innovation involves "the opening up of markets, domestic or foreign, and the development of organizations from workshops to factories," such as steel-making technology, which embodied the process of industrial change that continues to revolutionize the structure of the economy from within (Schumpeter, 1942). Secondly, the innovation of product. Gault (2018) proposed product innovation as "a product offered to potential users that is new or significantly changed in its characteristics or intended use." Process and product innovation have an internal interaction, and significant changes in the production or delivery process often trigger product innovation. Thirdly, the service innovation. Service innovation can be described as developing and delivering new service models. It is significantly different from manufacturing innovation and is usually more incremental, less technological, and less organized (Gallouj & Weinstein, 1997). Fourthly, the innovation of the business model. The business model is an important carrier for innovation and one of the sources of innovation. The scholars suggested that business model innovation is innovation's new dimension that complements process, product, or organizational innovation (Amit & Zott, 2012). Advances in the Internet and ICT had facilitated experimentation and innovation in business models.

"Invention," "novelty," and "change" present the essential property of innovation. They form characteristics that depend on the elements involved and processes, such as participants, purpose, inputs, resources and drivers, structural and institutional contexts, value generation, activities and outcomes, and other relevant background factors. These elements or aspects have undergone and continue to undergo rapid change, which challenges the innovation's classical scope and the technological innovation's definition (Schachter, 2018).

1.2.3 Economic growth

Economic growth usually represents the quantitative expansion of the economy's size, i.e., the output increase of services and goods and in a region or a country over a certain period of time. For example, the inputs of production's factors or an improvement in efficiency increase. It is measured by aggregate indicators such as national income and GDP (gross domestic product) (Wei & Hou, 2007), which is an overall reflection of the dynamic process and results of social reproduction.

As an economic growth indicator, GDP is defined differently under different calculation standards. Firstly, GDP is the sum of all final services and goods produced in a region or country during a given period's market value. It is the broadest and most comprehensive measure of economic activity in an economy. Secondly, nominal GDP is GDP at current market prices, including the inflation factor. Thus, nominal GDP can reflect changes in current market prices. Thirdly, real GDP is calculated using base year prices, which excludes the inflation factor and more truly reflects the actual economic growth situation (Callen, 2024).

Factors affecting economic growth can be categorized into a variety of factors. Firstly, capital accumulation (e.g., investment in infrastructure, technology, and equipment) can accelerate the economy's growth. A capital increase directly enhances the productive capacity and thus promotes economic development (Wang et al., 2023). Secondly, the labor force and human capital. The quality and quantity of the labor force (i.e., human capital) have an important effect on the economy's growth. Education and training can increase the skills and productivity of the labor force, which in turn drives economic growth (Renelt, 1991). Thirdly, technological innovation and R&D activities can improve productivity and product quality, which are two factors that drive the economy's growth. Technological progress includes not only hardware technology but also management and organizational innovation (Chien, 2015). Fourthly, the trade policy is an important factor. Economic freedom (e.g., stability of policies, markets' openness) can positively impact the economy's growth. Economies with efficient markets are usually better able to allocate resources and promote productivity (Renelt, 1991).

A series of theories have been derived from various scholars' research and the continuous development of the economy's growth. Classical growth theory, proposed by economists such as Smith (1776) and Ricardo (1817), emphasized the capital accumulation's effect and labor force increase in the growth economy. Derived from the neoclassical growth theory proposed by Solow (1956), which stated that long-term growth of economy was mainly driven by technological progress. It then evolved into the internal growth theory proposed by economists such as Romer (1990), which argued that knowledge accumulation and technological progress are endogenous to the economy's system. Endogenous growth theory emphasizes R&D (research and development), the role of education, innovation, and knowledge spillovers as long-term drivers of economic growth. Economic development theories have been changing with the times and have provided the basis and reference for economic development and policy formulation in various countries. This thesis will utilize the endogenous growth theories that focus on innovation activities and trade openness.

1.3 Theoretical foundation

1.3.1 Trade and FDI

The trade theory's basic idea was first proposed by Adam Smith in 1776 as the theory of absolute advantage. He argued that if a country has an absolute cost advantage over other countries in the production of a certain good, then it should focus on producing the good in which it had an absolute advantage and exchange with other countries the goods that they were not good at producing (Smith, 1776). This allowed all countries to benefit from trade by utilizing the most efficient productive resources while increasing overall productivity and consumer welfare.

Later, in 1817, David Ricardo further developed Adam Smith's ideas by introducing the theory of comparative advantage. That was, the differences in labor productivity across countries for different products reminded us that each country should focus on its own comparative advantage in production (Ricardo, 1817). For example, country A has higher

costs than country B in both products X and Z. Country B has relatively better production capability in product Z. Therefore, according to the comparative advantage theory, country B should focus on the production of product Z and country A on product X even though country A is not as efficient as country B in producing both products. Through specialization and trade, both countries can obtain more goods, which is a win-win situation. This theory greatly contributed to the free trade development.

At the 20th century's beginning, neoclassical theory revised and expanded the traditional classical trade theory for the above two points. Its core international trade is not only driven by absolute or comparative advantage, but also affected by the differences between countries in the abundance of factors of production.

Heckscher and Ohlin (1933), representatives of neoclassical theory, proposed the theory of factor endowment, which argued that differences are existing in resource endowments between regions or countries, i.e., countries had different amounts and types of factors of production. Therefore, countries with relatively abundant production factors have a comparative advantage in the production of corresponding products. Countries should import products produced using relatively scarce production factors and produce and export products that are intensively produced using their abundant factors, which can enable individual countries to profit from international trade. For instance, if the relatively abundant factor of production in country C is D, then country C has a comparative advantage in producing products that are factor-intensive using D at a lower cost. Thus, the abundance of factors of production determines the level of costs. This theory explains the relationship between resource endowments and international trade patterns.

In the 1980s, the rapid expansion of global trade gave rise to new trade theories and modern trade theories, as well as an expansion of traditional trade theories. Firstly, in the new trade theory, based on the original factor endowment theory, Krugman (1979) introduced the concepts of economies of scale and monopolistic competition. It explains that in the real world, trade and gains from trade also occur between countries with the same demand, technology, and factor endowments. The new trade theory emphasizes the impact of market size, product differentiation, and economies of scale on international

trade. Secondly, in terms of modern trade theory, Melitz (2003) proposed the dynamic model of heterogeneous firms considering differences in production efficiency across firms on the basis of trade model of Krugman (1979) and analyzed how trade policy affects firms' decisions to enter and exit the market. Together, the above theories enrich our understanding of international trade and the economy's growth.

The above theories of trade illustrate that trade can be conducted in a way that is profitable to countries based on increased specialization and different degrees of division of labor and that FDI plays an important role in market access, resource-seeking, efficiency enhancement, and strategic asset acquisition. Therefore, FDI, as a major channel for international capital flows, can accelerate global trade development and further affect the growth of the economy by facilitating the international division of labor and the formation of global value chains.

1.3.2 Development of FDI Theory

Early FDI theories focus on the flow of capital between countries. Macdougall (1960), a British scholar, explored the multifaceted impacts of international capital flows (especially foreign private investment) on both recipient and capital-exporting countries, laying a theoretical foundation for FDI to promote economic growth. It reveals how capital flows promote economic growth by increasing productivity, optimizing resource allocation, and promoting technological progress. It suggests that capital flows under open conditions can benefit both capital-rich and capital-short countries. Hymer (1976) argued that, among international capital flows, the direct investment's capital flows were closely related to the firms' international operations, and their flows were mainly determined by the scope of international operations. The international operations of TNCs had a significant impact on home and host country incomes. Overall, the international operations of TNCs not only enhance the profitability of the firms themselves but also positively affect the national and global economy by promoting economic growth and technological progress.

In addition to this, Vernon (1966), in Product Life Cycle Theory, demonstrated how FDI works at the product life cycle's different stages. Firms innovate and produce initially

in their home markets, mainly in the new product stage, while in the product maturity and standardization stage, they set up production facilities in foreign markets through FDI to expand market coverage and reduce production costs. This theory provides new tools and perspectives for understanding international investment and trade.

Later, Buckley and Casson (1976) developed the internalization theory, which explained why firms chose to control foreign operations through internal rather than market transactions. It emphasizes that MNCs avoid the uncertainty and transaction costs of the external market through the internal market and that the essence of a firm's OFDI is the control and management's expansion of the firm on the basis of ownership rather than on the capital transfer. The result is using a firm's internal management mechanism to replace the external market mechanism to have the internalization advantage of multinational operations and reduce transaction costs. Thus, it can explain the firms' choice of engaging in FDI rather than market transactions for international expansion.

Dunning (1977) developed the internalization theory by proposing the eclectic theory (OLI paradigm). OLI, the tri-advantage theory of Ownership, Location, and Internalization, employs a multivariate analysis to explain the various main objective conditions. It comprehensively explains the motivation of FDI, emphasizing that the economy's development level has an important effect in determining the capacity and motivation of a country's enterprises to make outward FDI. Firms undertake FDI because they have an advantage in certain assets (ownership advantages), which offer higher returns in the target market (locational advantages), and because transaction costs can be reduced through internalization. The theory provides a theoretical basis for comprehensive decision-making by multinational corporations.

With the changing times, the development of modern FDI theory involves several aspects of economic activities and theoretical models. Firstly, the institutional theory aspect. A good institutional environment, such as a transparent and stable legal framework, is a key factor in attracting FDI. It can provide a higher sense of security and certainty, which reduces investment risk and attracts more foreign investors (Sabir et al., 2019). Secondly, dynamic capability emphasizes the firms' need to maintain a competitive

advantage in a rapidly changing global marketplace by continuously adapting and optimizing their resources and capabilities. Pitelis (2022) provided a critical assessment of the dynamic capability view (DCV), criticizing the conceptual and empirical limitations of the dynamic capability view and proposing improvements on its application to multinational enterprises, and it also suggested improvements in its application to multinational enterprises and business model innovation. In addition to this, network theory suggests that in the process of internationalization, not only can firms rely on their own resources and capabilities, but they also achieve their goals through global supply chains and networks of relationships to enter and operate more effectively in international markets. Schoeneman et al. (2020) used weighted networks to examine the ERGM (Exponential Random Graph Model) and found that FDI networks show strong pass-through and reciprocity. It analyzes new perspectives on cross-border investment flows and their economic and political consequences, as well as the broader globalization dynamics.

Currently, with the acceleration of globalization, theoretical studies of FDI focus on the deepening of global economic integration and the role of policy, progress of technology, and corporate governance. Multinational enterprises have allocated resources and laid out production networks globally through FDI, promoting close ties between national economies. The rise of emerging market countries has also been the focus of research, especially how they have influenced the global economic structure and accelerated the global economy development through FDI.

1.3.3 Theories of innovation

Schumpeter proposed the “innovation” concept in “Theory of Economic Development” in 1911 and to release the technological innovation theory. According to Schumpeter, innovation is a new production function establishment, i.e., the recombination of production conditions and factors. The development of the economy refers to new unions that are constantly being realized throughout capitalist society. To maximize the acquisition of excess profits, innovation is one driving force of the economy’s growth. He also

proposed the “creative destruction” concept, i.e., new technology and new products constantly replacing the old and promoting economic progress. This theory not only explains the cyclical fluctuations of the economy but also emphasizes the important effect of innovation on the economy’s growth (Schumpeter, 1934).

In the mid-20th century, Robert Solow introduced the factor of technological progress in his growth model, assuming that technology remained constant and focused on the contribution of capital to economic growth. The technological progress contribution (including innovation) to the long-term growth of the economy is emphasized. When technological change occurs in a neutral manner (by increasing the efficiency of the production function), the growth of output rate, the specific effects on capital accumulation, and the real wage of labor are discussed. These discussions demonstrated the critical effect of technological innovation in promoting the economy’s growth and increasing productivity (Solow, 1956). Solow’s study showed that after considering the effects of technological change, one could further discover how shifts in the production function affect economic growth. Technological progress could further explain the portion of a economy’s growth that could not be explained by capital and labor inputs and plays an important role in driving productivity growth (Solow, 1957).

Walt Whitman Rostow, an American economist, put forward the take-off theory in 1960, which divided the economic process growth into six stages, and argued that the industrialization achievement was the key to economic take-off, in which technological innovations displayed different characteristics at each stage, and were accompanied by continuous improvements and sustained roles in different stages of development (Rostow, 1960).

In the 1980s, Paul Romer proposed that, unlike the traditional model of growth with diminishing returns, technological progress was the economy’s endogenous variable and was the knowledge accumulation’s result, and he considered that it promoted the long-term growth of the economy (Romer, 1986). In 1990, Paul Romer’s analysis in Endogenous Technological Change demonstrated the critical role of knowledge accumulation and endogenous technological change in the economy’s long-term growth, while the paper

showed that technological innovation and economic growth could be effectively promoted through appropriate policy incentives and increased investment in human capital (Romer, 1990).

At the beginning of the 21st century, Henry Chesbrough proposed the open innovation theory, suggesting the knowledge outflows and inflows used to expand the firm's external resources and collaborations and accelerated the firm's internal innovation to drive innovation. Open innovation could reduce costs and increase profits, as well as reduce product development time (Chesbrough, 2003). This theory changes the traditional closed internal innovation concept and promotes cross-organizational knowledge flow and cooperation.

Currently, modern innovation theories include various aspects of radical innovation, the economics of innovation, and responsible innovation. Firstly, radical innovation usually introduces products or technologies that are significantly different from existing solutions, emphasizing innovation by disrupting existing industries. Veryzer (1998), using intermittent innovation as an example (one of the forms of radical innovation), found that the development process of intermittent innovation had its own unique managerial needs and challenges, suggesting that radical innovation required a more flexible and exploratory approach to deal with technological and market uncertainty. Secondly, innovation economics focuses on the complexity and dynamics of the innovation process. Pyka and Andersen (2012) provided insights into the effect of innovation on the long-term development of the economy. These discussions enrich the theoretical body of innovation economics by providing a more comprehensive, systematic, and dynamic model of economic development. Finally, responsible innovation emphasizes the consideration of social and environmental impacts in the innovation process. Stilgoe et al. (2019) proposed responsible innovation's four dimensions in their article: foresight, reflection, inclusiveness, and responsiveness. Together, these dimensions form a framework for responsible innovation that focuses innovation not only on technological advances but also on their social and ethical impacts. This approach emphasizes the collective nature and systemic impact of science and innovation, making their work not only technologically advanced

but requiring all parties to share political responsibility to ensure that the innovation process is in line with society's expectations and values. This approach contributes to the realization of broader social and ethical responsibility in the innovation process and provides a more solid and sustainable basis for future scientific and technological progress.

The above theories suggest that innovation has an important effect on the different stages of the economy's development, not only as one factor explaining the fluctuations of the economy's cycles but also as influencing long-term economic growth, which provides support for the research of the relationship between economic growth and innovation. 21st-century modern theories synthesize the results of multidisciplinary research, and innovation is regarded as a systematic process that can form innovation with a comprehensive understanding and its influence on economic growth. Thus, the innovation's comprehensive understanding and its influence on the growth of the economy has emerged.

1.3.4 Theories of economic growth

The economic growth's study has long been a highly debated topic in academia. Since the growth of the economy is directly related to living standards improvement and the country's welfare and its inhabitants, economic policymakers have tried to enhance the comprehensive competitiveness of the country, build the overall well-being of mankind, and promote the overall progress of society through the study of economic growth.

The theoretical foundation of modern economic growth theory is the classical economic growth theory, which is built on the basis of mercantilism and reverses the mercantilist conception of national wealth as mainly focused on monetary accumulation, thus shifting the focus of research to the field of actual material production, and beginning to explore the factors and mechanisms that influence long-term growth of the economy. The classical theory of economy's growth has Adam Smith as its founder, who suggested the importance of labor division and capital accumulation for the growth of the economy (Smith, 1776). The theory was further developed by David Ricardo, who proposed the diminishing marginal productivity principle for additional labor on a given piece of land

and applied it to the economic growth theory, forming the original form of the law of diminishing marginal productivity emphasized by the later neoclassical production function (Ricardo, 1817). However, the classical theory was flawed by its inadequate explanation of the long-run growth of the economy and its overemphasis on capital accumulation. It was not until the end of the 19th century that the transition from classical to neoclassical began with the “marginal revolution” of Walras and others.

Solow (1956) proposed neoclassical growth theory in the 1950s, which provided a tool for understanding and analyzing the economic growth mechanism. He identified the main force behind capital and labor is technological progress that maintains sustained growth of the economy. The capital accumulation contribution and labor growth to long-term growth are limited because they are marginally decreasing. However, due to the two major shortcomings of “diminishing returns” and “homogenization of technological progress,” economic policymakers have pushed forward the development of economic growth theory to solve this problem, and the endogenous growth theory has emerged.

The theory of endogenous growth emerged in the 1980s and 1990s, and its main representatives include Paul Romer, who emphasized the endogeneity of technological progress, knowledge accumulation, and human capital. In the mid-1980s, Romer’s new growth theory began to emerge, so the problems of the Solow model were solved. Romer (1990) incorporated the four elements of capital, labor, human capital, and technological level into the model, endogenizing exogenous technology and revealing the relationship between knowledge spillovers, human capital, and openness to the outside world and technological progress, which further contributed to economic growth. One of the core variables in this paper is economic growth, and it is significant to clarify the development of the economy’s growth theory to explore the core variables.

Emerging theories of economic growth are more concerned with the role of non-economic factors in driving or stunting economic growth, with key aspects such as institutional economics, green growth, and innovation economics. These theories have enriched our recognition of the economic growth drivers and put forward new policy recommendations and practical directions.

Firstly, institutional economics pays more attention to the institutions' impact on the growth of the economy. Institutions can be categorized into formal rules, including laws and regulations, and informal rules, such as customs and culture etc. North (1990) provided a pioneering analysis of the structure of the economy to interpret how institutional change affects the performance of the economy over time. He argued that institutions exist because of uncertainty in human interactions, and they were constraints designed to achieve economic growth. Secondly, green growth theory emphasizes that economic growth should be coordinated with environmental protection and sustainable development, while environmental protection is a new opportunity for the economy's growth. The theory suggests that economic growth sustainability can be achieved through the development of clean energy, improved resource efficiency, and the implementation of environmentally friendly policies. OECD (2011) proposed that "Green growth" means promoting economic development and growth while ensuring that natural assets can provide environmental services and a wide range of resources for human well-being. It is a way to "promote economic growth and development while ensuring that natural assets continue to provide a range of resource and environmental services for human well-being." Finally, innovation economics emphasizes the importance of innovation and entrepreneurship's importance in economic growth. The basis of this theory can be traced back to Schumpeter (1934), who argued that technological change and industrial renewal brought about by innovation are the economic growth's main drivers, and Romer (1990) suggested that technological progress can sustainably drive the growth of the economy and that the investment in R&D by economic agents determined the rate of technological progress, and thus the economic growth's long-term rate.

1.3.5 Theories Summary

The development of FDI theories, innovation theories, and economic growth theories are deeply linked. FDI theory is concerned with how foreign direct investment (FDI) contributes to the economy's growth through capital provision, transfer of technology, and managerial expertise. Key theories include the eclectic paradigm, product life-cycle theory,

and internalization theory, which explain why firms invest abroad and how these investments affect the host economy. Innovation theories, particularly Schumpeterian theory, emphasize the technological change importance and entrepreneurship in the development of the economy. It highlights how innovation leads to new processes and products that stimulate the economy's growth. Economic growth theories, such as the endogenous growth model, integrate these aspects by emphasizing the importance of technology, human capital, and policies in sustaining long-term growth. The integration of these theories suggests that policies that promote foreign direct investment, foster innovation, and create an enabling environment for economic activity can synergize to promote economic growth. For example, countries with strong innovation systems attract more FDI, promoting economic growth through technological spillovers and productivity gains. It provides a strong theoretical foundation for our study and has led many scholars to investigate all three based on specific data and examples. The next section explains the prior studies in detail.

1.4 Prior studies

1.4.1 FDI and economic growth

Modern economists first based their research on the linear relationship between trade and the economy's growth. Wacziarg and Welch's research showed that the average annual growth rate of countries that liberalized trade in 1950-1998 was about 1.5% higher than the pre-liberalization rate (Wacziarg & Welch, 2008). The investment rate increased by 1.5-2.0 percentage points after liberalization, which confirmed that liberalization contributed to the economy's growth partly through its influence on the accumulation of physical capital. Frankel and Romer (1999) used different geographical characteristics of different countries for heterogeneity analysis and concluded that trade contributed to economic growth. Silajdzic and Mehic (2018) provided insights into how the volume of trade affects growth performance and the effectiveness of policies of trade liberalization in improving the growth performance of CEE countries by looking at the trade openness' importance on the

economy's growth of CEE (Central and Eastern European) countries from 1995 to 2013. It was shown that trade intensity indicators are positively correlated with the growth of the economy.

After that, scholars started to explore FDI and regional economic growth's relationship because foreign investment has an important influence on foreign trade, e.g., it accounts for a larger share of trade and has a significant effect on the growth of the economy. The relationship between FDI and the growth economy have been extensively studied in European countries with different results.

On the one hand, the two have a positive correlation. Moudatsou (2003) used data from 14 EU countries from 1980 to 1996, estimated the FDI's growth effect for each country separately, and also analyzed the data aggregated for the whole EU. The results illustrated the FDI's positive effects on the EU economic growth, both directly and indirectly (through trade enhancement). This suggested that FDI not only contributes directly to capital formation but also indirectly to economic growth through productivity enhancement and exports. Tsimpida and Bitzenis (2023), using EU countries' annual data from 1996 to 2018, employed a panel ARDL analysis to show the relationship between economic growth and FDI in the original and new EU member states. The long-term positive correlation emphasized the need for policies to attract FDI and address corruption. Sokhanvar (2022) used data for 11 EU member states in CEE (Central and Eastern Europe) for the period from 1995 to 2019 and, according to the study, indicated that FDI was significantly and positively correlated with the EU 11 countries' economic growth. Popescu (2014) studied the influence of foreign capital inflows in CEE countries by examining the foreign capital inflows in CEE countries. It showed that FDI has a significant impact on the development of CEE countries' economic growth. Gherghina et al. (2019), using data from 11 CEE countries between 2003 and 2016, supported the existence of a non-linear and univocal causality.

The relationship between FDI and economic growth in European countries is complex and sometimes ambiguous or even negative. The author reviews several studies that explore these dynamics. Sağlam (2017) examined 14 European transition economies' panel

data from 1995 to 2014. The study found that the FDI's long-run impact on economic growth was negative, i.e., FDI's 1% increase led to economic growth's 0.0162% decrease, which was contrary to conventional theory. At the same time, different countries showed different directions of correlation, which suggested that different countries have different special circumstances and specific policy implications. The study by Žarković et al. (2018) focused on Central European (CEE) and South-Eastern European (SEE) countries and utilized the panel data methodology for the regression analysis. The research found that while FDI flows had a statistically significant impact on the growth of the economy in the CEE region, the magnitude of this impact was almost negligible in the SEE region. This negligible impact suggested that despite high expectations, FDI alone was not sufficient to drive significant economic growth without accompanying structural reforms and efficient institutional frameworks. Shkodra et al. (2022) investigated the FDI flows' impact on economic growth in the SEE region by examining the FDI flows' impact on the growth of the economy in six countries in the SEE region for the FDI and economic growth data in the period 2005-2020, found that in some countries FDI and economic growth have a positive correlation between.

According to previous studies, it can be found that the FDI and economic growth's relationship is complicated. In different economic periods, different regions and different countries have different performances. Therefore, a comprehensive and in-depth research of the FDI and economic growth's relationship is necessary and meaningful.

1.4.2 Innovation and economic growth

In recent years, research on the innovation and economic growth's relationship has attracted much attention. Most of the literature suggests that innovation is positively affect the economic growth, but there are also some studies that suggest that innovation negatively affect economic growth.

Firstly, in terms of positive correlation, Ulku (2004) found a positive correlation between innovation and GDP per capita in both non-OECD and OECD countries, but R&D stock's effect on innovation was significant only in OECD countries with larger markets.

Phung et al. (2019) used data from 69 developing and developed countries between 2006 and 2014, applying a two-step systematic GMM (generalized method of moments) for empirical analysis. The results showed that innovation had a direct and positive impact on economic growth, along with the openness of countries, FDI inflows, and government spending on education. The research also found that institutional quality and FDI spillovers played a positive mediating role in improving the relationship between economic growth and innovation. Nihal et al. (2023) used a vector auto-regression (VAR) model and penal regression with the G8 countries' data between 1996 and 2020, and through the Johansen cointegration test results found evidence of a positive and significant correlation between innovation and growth of the economy. Floroiu (2020) analyzed the European innovation framework with a focus on the four Eurozone candidate countries. Nearly two-quarters of Europe's economic growth over the past few decades had been driven by innovation. Pece et al. (2015) analyzed data from CEE countries between 2000 and 2013 and concluded that there was a positive link between economic growth and innovation and that innovation significantly and positively affects economic growth. Innovation and R&D investment and technology are drivers of competitiveness, progress, and sustainable economic growth rates.

The impact of innovation on the growth of the economy is a complex and multidimensional issue. While innovation is often considered an important economic growth driver, its impact can be negative or even not significant in some cases. Firstly, technological innovation may exacerbate economic inequality, especially between low-income and high-income countries, increasing income inequality and uneven development that significantly affects global economic growth (UN News, 2020). Secondly, Hammad Naeem et al. (2023) used 92 cross-sectional data for the period from 2002 to 2020, and different combinations of explanatory variables were used to compare the results for developing and developed countries. The results showed a negative relationship between financial innovation and economic growth. Dempere et al. (2023) found that economic growth due to innovation relies heavily on a country's institutional and policy environment by analyzing data from 120 countries using, among other things, the Global

Innovation Index for the period 2013 to 2019. Innovation activities may not be economically significant if they take place in countries with poor innovation policies and infrastructure.

1.4.3 FDI, Innovation and economic growth

The rationale for the FDI's spillover effect on the economy's growth is that TNCs can bring a wealth of knowledge and technological innovation to host countries. Thus, FDI is important in technological innovation. Firstly, in developing countries, FDI stimulates economic growth and helps local firms' innovation process in the early stages by enabling them to utilize and adapt to new technologies. Ali et al. (2023) found that FDI (foreign direct investment), economic growth, trade openness, and R&D expenditures positively affected on technological innovation by testing the data of BRICS countries from 2000 to 2020. On the contrary, Darfo-Oduro and Stejskal (2022) showed that knowledge spillovers in V4 countries did not effectively complement domestic R&D activities to enhance innovation by examining panel data of V4 countries from 2003 to 2012 in the OECD database and pointed out that the complex relationship was between FDI and economic outcomes. In addition to this, the FDI's impact on green innovation had also received attention. By analyzing data from 262 Chinese cities, it found that FDI can significantly accelerate green innovation, and its effect depended on the cities' absorptive capacity. Especially when the local absorptive capacity was high, factors such as environmental regulations, economic growth, industry size, and human capital played a key role in maximizing these benefits (Qin et al., 2022). In addition, Sugiharti et al. (2022) found that in Indonesia, the spillover effects of increased FDI, which could be combined with increased technological absorptive capacity, had increased the productivity and technical efficiency of manufacturing firms, especially those with high technology intensity.

1.5 Research gaps

To sort out and summarize the above literature, it is found that many scholars at home and abroad have carried out in-depth research on FDI, innovation, and economic growth

relationship, achieved fruitful research results, and made great contributions to the study of the two-two relationship, and this thesis makes certain additions on the basis of the previous research. Firstly, there are fewer articles focusing on the study of the three, so this paper incorporates the FDI, innovation and economic growth's relationship into the same research framework, which allows for a more in-depth analysis of the relationship between the three, and trying to fill the gap by exploring the spillover effects of FDI on innovation and how it affects economic growth. By doing so, this thesis provides a more nuanced recognition of the pathways through which these elements act.

Secondly, the temporal context is unique. By choosing the time period from 1998 to 2021 as the timeframe for the study, it is able to cover an important historical phase from the rapid development of technology, innovation, and science to the digital economy era. At the same time, this period is particularly relevant to CEE (Central and Eastern European) countries that have undergone major political and economic transformations. The study of this period can help us understand how these transformations have affected the relationship between FDI, innovation, and economic growth.

Thirdly, a comparative analysis of CEE and other European countries is lacking. While there are numerous studies on European countries' economic development, there is a dearth of comparative analyses of CEE countries compared to other European countries. Such comparisons are essential to understanding the similarities and differences in how different economic entities respond to globalization and technological innovation. By comparing CEE countries with other European countries, this paper can reveal the differences and similarities between different economies in facing the challenges of globalization and the trend of technological innovation. This gap is bridged by emphasizing how regional differences and policy choices affect economic development. This approach can provide valuable lessons by revealing the role of institutional and structural factors in shaping economic outcomes.

Fourthly, this study is exploring the role of innovation. There is a need for more research on how innovation can accelerate economic growth, especially in the context of rapid advances in information technology and digitization. Existing research has tended to

overlook the mechanisms through which innovation drives economic growth in different country contexts. This thesis explores these mechanisms, focusing on how innovation contributes to economic development across countries. In doing so, it aims to gain a clearer understanding of the conditions under which innovation is most effective in promoting economic growth.

Fifthly, a comprehensive multivariate analysis exists. Many studies have focused on single-variable analysis, which fails to capture the complexity of factors affecting economic growth. There is a need for a comprehensive multivariate analysis that considers the role of various factors such as FDI inflows, technological innovation indicators, and other economic variables. By using classification and regression methods, the study not only analyzes a single factor but is able to integrate the impact of multiple variables (e.g., FDI inflows, technological innovation indicators, etc.), which provides a more sophisticated and comprehensive analytical approach to economic growth.

In addition, there are gaps in existing research on the mechanisms by which innovation drives economic growth in different country contexts. Explore the mechanisms of how innovation can accelerate economic growth in different country contexts, especially at a time when information technology and digitization are rapidly evolving.

Finally, innovations in data processing and modeling applications. There are gaps in the application of advanced data processing techniques and statistical modeling in the FDI, technological innovation, and economic growth research. Traditional methods cannot fully capture the complexity of these relationships. This study utilizes state-of-the-art statistical software and algorithms to process complex datasets and employs advanced statistical models to improve the reliability and accuracy of the findings. Such methodological innovations are essential to produce more robust and accurate results, thus advancing methodological advances in the field.

In conclusion, while existing research has significantly advanced our understanding of the relationship between FDI, technological innovation, and economic growth, a number of gaps remain. Gaps include the need for an integrated analysis of the three, consideration of unique temporal contexts, comparative studies across regions, comprehensive multivariate

analyses, empirical policy impact assessments, exploration of the role of technological progress, and application of innovative data processing and modeling techniques. Filling these gaps leads to a nuanced and comprehensive recognition of how FDI and innovation drive economic growth, thus providing valuable insights for scholars and policymakers.

2. Methodology

This thesis uses a quantitative research methodology to research FDI (foreign direct investment), innovation and economic growth relationship by using annual data for 30 European countries between 1998 and 2021. The quantitative research method is suitable because it allows for statistical analysis and objective measurement of the relationship between the variables. The use of large datasets and advanced econometric techniques helps to draw generalizable and reliable conclusions from the empirical analysis.

There are several key factors in selecting a quantitative research methodology. Firstly, it is helpful to explore the research question. The main research question aims to quantify the impact of FDI and innovation on economic growth, which requires numerical data and statistical analysis to draw valid conclusions. Secondly, the availability of data provides possibilities for quantitative research. The WDI (World Development Indicators) dataset provides reliable quantitative data for multiple countries over this long period. Therefore, it is feasible to conduct a rigorous quantitative analysis. Thirdly, the econometric analysis itself requires quantitative results. Investigating the relationship between FDI, innovation, and economic growth involves econometric techniques such as regression analysis. These techniques are quantitative and require numerical data to estimate parameters and test hypotheses. Fourthly, the findings from quantitative methods are intuitive and generalizable. Quantitative research allows for data analysis with many countries and years and produces intuitive quantitative results, thereby increasing the generalizability of the findings in a broader context.

2.1 Research design

The research design's first step is to specify the research question or hypothesis. In this study, it concerns with the relationship between FDI, innovation and economic growth. Specific research questions include: what is the FDI's impact on economic growth? What is the innovation's impact on economic growth? Is there an interaction between FDI and innovation and together they affect economic growth?

Based on the clarification of the research question, literature review, and theoretical framework, the research hypotheses are formulated. The relationship between the various variables of the specific study and the link between the hypotheses is clearly shown in figure 2-1 below.

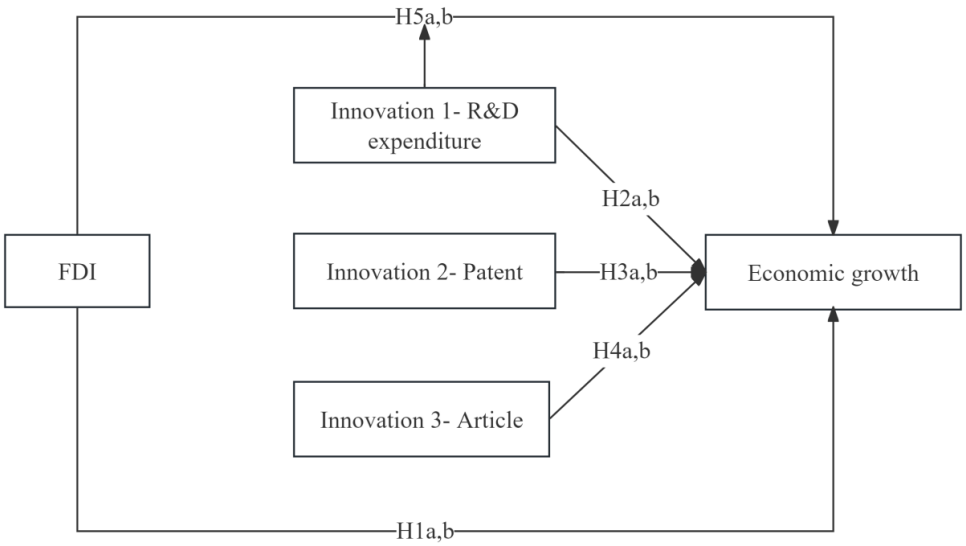

Figure 2-1: Relationships established by each hypothesis

Source: Author's production

Based on the above Figure 2-1, it can establish the hypotheses as follows:

Hypothesis 1a: FDI has a significant positive impact on economic growth. Hypothesis 1b: FDI has a significant negative impact on economic growth.

Hypothesis 2a: R&D expenditure has a significant positive impact on economic growth. Hypothesis 2b: R&D expenditure significantly negatively impacts economic growth.

Hypothesis 3a: Patents have a significant positive impact on economic growth. Hypothesis 3b: Patents have a significant negative impact on economic growth.

Hypothesis 4a: The article has a significant positive impact on economic growth. Hypothesis 4b: The article significantly negatively impacts economic growth.

Hypothesis 5a: FDI and R&D expenditure interact positively to enhance their impact on economic growth. Hypothesis 5b: FDI and R&D expenditure interact negatively to weaken each other's impact on economic growth.

Due to the above five assumptions, this thesis searches for the appropriate data to measure and combines the equations to get the results.

2.2 Data source and samples

2.2.1 Data source and data collection method

Firstly, from the perspective of data type, the data type of this study is panel data. This thesis uses data from the World Bank's WDI (World Development Indicators) dataset, so it is the secondary data. This dataset is a public dataset that is accessible to users both inside and outside the World Bank. The WDI is the collection of key development indicators compiled from officially recognized international sources. It provides accurate global development and the most up-to-date data, including global, regional, and country estimates (The World Bank, 2024).

In term of data collection method, data are collected from the WDI database through a structured query to extract relevant indicators of foreign direct investment, innovation (as measured by research and development expenditures, patent applications and the number of scientific and technical journal articles) and the growth of economy. They are also compiled into a panel dataset to provide STATA software for statistical results.

2.2.2 Sampling

The sample selection for this study includes 30 countries to ensure representation and breadth. 12 of the 30 countries are CEE countries as defined by the OECD (n.d.), including Poland, Czech Republic, Hungary, Slovak, Slovenia, Lithuania, Latvia, Estonia, Croatia, Romania, Bulgaria, and Albania. And the OECD (n.d.) includes 18 European countries

other than the 12 CEE countries mentioned above, including Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, and the United Kingdom.

Table 2-1: Specific countries and categories

Types	Countries
12 CEE countries as defined by OECD organization	Poland, Czech Republic, Hungary, Slovak, Slovenia, Lithuania, Latvia, Estonia, Croatia, Romania, Bulgaria, and Albania
18 other European countries in OECD	Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, and the United Kingdom

Source: OECD

Moreover, the sample consists of annual data from 1998 through 2021, resulting in a balanced panel dataset of 720 observations (30 countries and 24 years). This number of countries and time period is chosen for six reasons.

Firstly, 1998 coincided with a critical period of significant expansion and economic integration processes in the EU. The euro was officially launched in 1998 and became legal tender in the euro-zone countries in 2002, a period of monetary harmonization that facilitated intra-regional trade and investment. Between 2004 and 2007, the European Union carried out two large-scale expansions (Eastern and Central Europe), and these countries went from the original relatively backward economic system to the market economy transition, attracting a large number of FDI. This expansion affects not only the new member states' economic situation but also the entire economic map of the European Union and has had a far-reaching impact.

Secondly, globalization, the rapid development of the technological revolution, the spread of the Internet, and the information technology revolution have greatly contributed to innovation and productivity gains. Studying the situation in this period can provide a deep understanding of innovation and economic development. At the same time, FDI and innovation's influence on the economy is not fully reflected in the current year's data

performance. Therefore, using a long period of observation of 24 years can better reveal the independent variables' influence on the dependent variable.

Thirdly, competitiveness and regional differences. European countries have different level of economic development and innovation capacity. Western European countries usually have a strong innovative capacity and economic base, while Central and Eastern European countries have gone through the transition from planned to market economies. Studying this period can get an in-depth recognition of the regional differences' impact on the overall economy.

Fourthly, the 2008 global financial crisis caused severe economic recession in many countries. The economic fluctuations during this period provide an opportunity to study how economic policies, FDI flows, and innovation activities affect economic recovery during and after the crisis. Analyzing FDI and innovation activity before and after the crisis helps to understand the role and performance of these factors during economic distress and in the recovery phase.

Fifthly, during the period 1998-2021, economic policies and reforms were implemented at the EU level, including preferential policies for FDI, innovation incentives, and economic restructuring. For example, the European Union has launched the "2020 Strategy", which wants to improve inclusive, sustainable, and smart growth, and through this strategy, it is possible to observe the policies' impact in promoting economic growth and innovation. Studying this period allows us to assess the actual effects of these policies on attracting FDI, promoting innovation, and boosting economic growth.

Sixthly, European states were gradually transforming into knowledge-based and service economies, with the share of traditional manufacturing declining and that of science, technology, innovation, and services rising. Especially under the pressure of climate change and environmental protection, green innovation and sustainable development have become important issues for countries. Studying this period and these states can reveal FDI and innovation's influence on the transformation of the economy and how to balance economic growth and sustainable development.

2.3 Data analysis method

2.3.1 Model design

The construction of this thesis's empirical model begins with the extension of the neoclassical growth model (equation 1). In this model, a neoclassical production function includes the efficiency factor, and constant scale returns are introduced under the assumption of perfect competition.

$$Y = AK^{\alpha}H^{\beta}L^{\gamma} \quad (1)$$

Expanded the above equation and then added more control variables based on other people's research and reality for reference, obtaining the following equations. To verify hypotheses 1a and 1b, this study sets up the following model for verification:

$$GDP_{it} = \alpha_0 + \alpha_1 FDI_{it} + \alpha_2 Gov_{it} + \alpha_3 Inf_{it} + \alpha_4 Gro_{it} + \alpha_5 Labor_{it} + \alpha_6 Unemply_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (2)$$

Where i is on behalf of the country, t is on behalf of the year, α0 is on behalf of the intercept term, and αi (i =l,2,3...) is the regression coefficient. GDP_{it} is the economy's growth for country i at time t; FDI_{it} is the foreign direct investment for country i at time t; Gov_{it}, Inf_{it}, Gro_{it}, $Labor_{it}$, $Unemply_{it}$ are control variables for country i at time t. μ_i captures country-specific effects, λ_t captures time-specific effects, and ε_{it} is the residual term.

To verify hypotheses 2a and 2b, model (3) has been established:

$$GDP_{it} = \alpha_0 + \alpha_1 R\&D_{it} + \alpha_2 Gov_{it} + \alpha_3 Inf_{it} + \alpha_4 Gro_{it} + \alpha_5 Labor_{it} + \alpha_6 Unemply_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (3)$$

In model (3), R&D is the explained variable and it represents the R&D expenditure. The other are control variables, and the control variables of model (3) are consistent with model (2).

To verify hypotheses 3a and 3b, model (4) has been established:

$$GDP_{it} = \alpha_0 + \alpha_1 Patent_{it} + \alpha_2 Gov_{it} + \alpha_3 Inf_{it} + \alpha_4 Gro_{it} + \alpha_5 Labor_{it} + \alpha_6 Unemply_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (4)$$

In model (4), patent is the explained variable and it represents the total number of

patents applications included residents and non-resident. The other are control variables, and the control variables of model (4) are consistent with model (2).

To verify hypotheses 4a and 4b, model (5) has been established:

$$GDP_{it} = \alpha_0 + \alpha_1 Article_{it} + \alpha_2 Gov_{it} + \alpha_3 Inf_{it} + \alpha_4 Gro_{it} + \alpha_5 Labor_{it} + \alpha_6 Unemply_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (5)$$

In model (5), article is the explained variable and it represents number of scientific and technical journal articles. The control variables of model (5) are consistent with model (2).

To verify hypotheses 5a and 5b, model (6) has been established:

$$GDP_{it} = \beta_0 + \beta_1 FDI_{it} + \beta_2 R\&D_{it} + \beta_3 FDI^* R\&D_{it} + \beta_4 Gov_{it} + \beta_5 Inf_{it} + \beta_6 Gro_{it} + \beta_7 Labor_{it} + \beta_8 Unemply_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (6)$$

In model (6), $FDI^* R\&D_{it}$ is the interaction term and it represents the interaction of FDI and R&D. The other are control variables, and the control variables of model (6) are consistent with model (2). To address endogeneity, the study uses also the GMM estimator. The GMM approach helps mitigate biases that arise from reverse causality and omitted variable bias.

Based on the above formula, each variable is interpreted specifically. The dependent variable is gross domestic product, which is expressed as logarithm of GDP per capita (Phung et al., 2019). The increase of gross domestic product can represent the economic growth. The independent variables such like FDI and innovation: FDI is expressed as the logarithm of FDI net inflows; innovation is expressed as logarithm of R&D expenditures to GDP, the number of patent applications, or the number of scientific research articles (Maradana et al., 2017; Ulku, 2004). The control variables include government expenditure, inflation rate, gross fixed capital, total number of labor and unemployment rate (Ayanwale, 2007). The explanation of the definition of each specific variable is presented in Table 3-2.

Table 2-2: Variables definition

Type	Name	Name	Meaning
Explained variable	Gross Domestic Product	GDP	Logarithm of GDP per capita (current US$) (lngdpdollar)

Explanatory variables	Foreign direct investment	FDI	Logarithm of foreign direct investment, net inflows (BoP, current US$) (lnfdidollar)
	Research and development expenditure	R&D	Logarithm of research and development expenditure (% of GDP) (lnRDexpenditure)
	Total number of patent	Patent	Logarithm of the total number of patents represents the sum of the number of patent applications filed by residents and non-residents. (lnpatentsum)
	Articles	Article	Logarithm of the number of scientific and technical journal articles (lnarticle)
Control variables	Gross fixed capital formation	Gro	Logarithm of gross fixed capital formation (current US$) (lngross)
	Labor	Labor	Logarithm of labor force, total (lnlabor)
	Inflation Index	Inf	Inflation, consumer prices (annual %)
	Government expenditure	Gov	General government final consumption expenditure (% of GDP)
	Unemployment rate	Unemploy	Unemployment, total (% of total labor force)

Source: WDI (World Development Indicators) dataset

2.3.2 Data analysis process

In terms of the choice of research methodology. Firstly, this study uses panel data to test this through a fixed effects regression model (point-in-time individual fixed effects model), which is a panel data analysis method and an extension of OLS. Originally, OLS is an estimation of the parameter's method of a linear regression model, but it applies to situations where there are no individual specificities among observations or where these individual specificities are unrelated to the explanatory variables. OLS combines the data for all time periods and individuals in a combined treatment, ignoring inter-individual differences. Meanwhile, after doing the test, it is found that this study is not applicable to the random effect model. Therefore, this study extends the use of a fixed effect regression model for controlling individual characteristics of countries that do not change over time and to reduce the bias caused by omitted variables.

Secondly, according to the research (Phung et al., 2019; Ulku, 2004) and the realities of article research, this thesis uses a one-step system GMM (Generalized Method of Moments) in the test. The GMM method proposed by Hansen (1982) allows random error terms' serial correlation and heteroskedasticity, and thus, yielding is more efficient than other methods of parameter estimation. One-step system GMM deals with endogeneity by constructing multiple instrumental variables. It uses lagged values of variables as instrumental variables that are theoretically exogenous and thus effectively reduce the bias introduced by endogeneity.

Thirdly, the robustness of the model estimates can be verified by using lagged independent variables of the first order. The main conclusions of the model (i.e., those of the fixed effects model) still hold if the lagged independent variables are used. This indicates that the model results are more robust and are not affected by specific assumptions or methodological choices. In addition, this method increases the model's explanatory power. Currently, the influence of FDI and innovation on the growth of the economy may not be evident in the same year. Because they need time to develop, then, they can influence the change in economic data. Therefore, lagged independent variables can provide more information and a more scientific explanation of the conclusions. At the same time, it helps to improve the fit of the model and recognize the relationship between the dependent and independent variables more comprehensively.

Fourthly, the use of different country-region categorizations as a test for heterogeneity. Different countries and regions may have significant differences in culture, policies, and levels of economic development. By using these different countries and regions as a source of heterogeneity, researchers can better understand and control the potential impact of these variables on research results. It helps policymakers and business decision-makers to develop more targeted and effective strategies and policies.

In the process of research, the first step is data collecting and preprocessing. It can deal with missing values, outliers, and data transformation. Secondly, the descriptive statistics for variables should be explored. The third step is the model estimation using a fixed-effects regression model, which controls for time-invariant country-specific

characteristics. Then, to address potential endogeneity issues, the GMM is used for endogeneity tests. After that, robustness tests use the method of lagging the independent variables by one order. Finally, they are performed in groups, one group of 12 CEE countries and another group of 18 other European countries in the OECD. STATA was used for data analysis.

This article ensures the reliability of the data by using widely recognized data sources (WDI). The empirical tests use the econometric methods of fixed effects regression and GMM methods, thus the methods are reliable. In terms of content validity, the paper chooses indicators of FDI, innovation and economic growth for testing. Endogeneity, robustness and heterogeneity tests were also conducted.

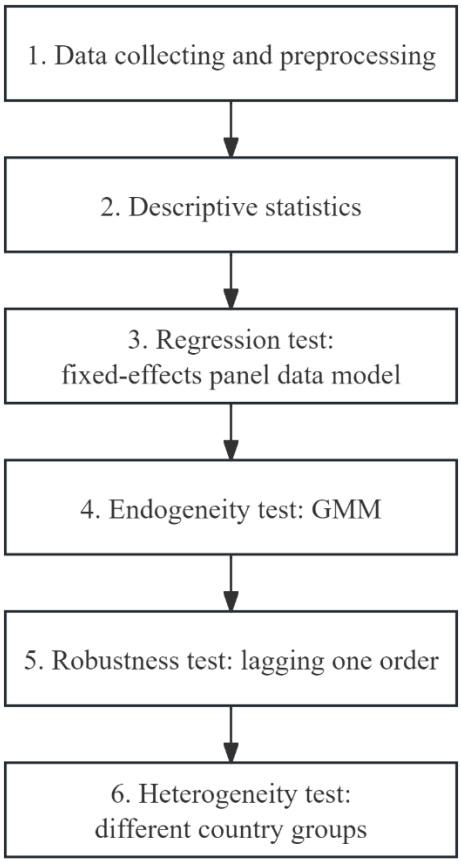

Figure 2-2 Research method and process

Source: Author's production

3. Analysis procedures and findings

3.1 Descriptive statistics

Table 3-1 Results of descriptive statistics, sample of 30 European countries，1998-2021

Variables	Obs	Mean	Std. Dev.	Min	Max
GDP	720	10.037	.929	6.702	11.803
FDI	652	22.608	1.886	14.509	27.322
R&D	666	.299	.608	-2.435	1.354
Patent	677	7.004	1.795	1.386	11.126
Article	690	8.763	1.743	2.885	11.603
Labor	720	15.169	1.314	11.979	17.609
Gro	720	24.419	1.588	20.120	27.538
Inf	720	2.757	4.231	-4.478	59.097
Gov	713	12.106	6.956	2.893	25.885
Unemploy	716	8.400	4.528	1.805	32.61

This thesis analyzes descriptive statistics for several economic variables, and the results of the tabular kind of data show the basic situation of each variable. Firstly, GDP, a total of 720 observations, with a maximum of 11.803 and a minimum is 6.702. The standard deviation is 0.929 and the mean is 10.037. It displays that differences exist in the economic strength and economic development level in different countries or regions.

Secondly, FDI, a total of 652 observations, some countries lack relevant data, and some of the negative values, indicating that foreign direct investment is outflow, reflecting the size of the country's enterprises investing abroad exceeds the size of the country. The standard deviation is 1.886, and the mean value is 22.608. The maximum is 27.322 and the minimum is 14.509. High standard deviation reflects the significant differences in FDI among the countries in the sample, with some countries attracting a large amount of foreign investment, while others are less attractive to foreign investment inflows.

Thirdly, R&D has a sample size of 666, with missing data for some countries and years. The standard deviation is 0.608 and the mean is 0.299. The maximum is 1.354 and the minimum is -2.435. This shows that some countries have invested unusually little in R&D, and the majority of countries spend a similar amount on R&D as a percentage of GDP in percentile.

Fourthly, the patent has a sample size of 677, with data missing for some countries and years. The standard deviation is 1.795 and the mean is 7.004. In addition, the maximum is 11.126 and the minimum is 1.386. It displays that variation exists in innovation patenting outcomes across countries. Part of countries produced more innovation patenting outcomes, highlighting the country's innovation capacity. The other part of the countries has fewer innovation patent application outcomes and fewer innovation outcomes.

Fifthly, the article has 690 observations with missing data for some countries and years. The standard deviation is 1.743, and the mean is 8.763. Moreover, the maximum value is 11.603, and the minimum value is 2.885. There are significant differences between research and academic achievements in different countries and regions.

Moreover, the Labor has 720 observations, with a maximum of 17.609, a standard deviation of 1.314, and a minimum of 11.979. Gross fixed capital formation (Gro) also has 720 observations, with a standard deviation of 1.588, a mean of 24.419, a maximum of 27.538, and a minimum of 20.120. Because of the small standard deviation, it is relatively evenly distributed in the sample, but the difference between the minimum and maximum values still shows a certain degree of variability.

The inflation rate (Inf)' s sample size is 720. The standard deviation is 4.231, and the average value is 2.757. The maximum value is 59.097, and the minimum value is -4.478. A large standard deviation and maximum value show that some countries experience high inflation while some other countries are relatively stable. Government expenditure (Gov) has 713 observations, and the standard deviation is 6.956. The mean is 12.106, and the minimum is 2.893. The maximum is 25.885. The large standard deviation suggests that government expenditures vary across countries.

Finally, the unemployment rate's sample size is 716. The standard deviation is 4.528, and the mean is 8.400. The maximum is 32.61, and the minimum is 1.805. This suggests that there is a large amount of variability in the unemployment rate across countries, reflecting the different challenges that each country faces concerning employment.

The above analysis of descriptive statistics reveals that differences exist across

countries in terms of economic development, investment, innovation, labor force, inflation, and unemployment. These differences may stem from a variety of factors, including economic policies, market environment, level of technology, education and training systems, structure of government spending, and macroeconomic environment. For example, the variability in GDP and FDI reflects differences in the ability of different countries to attract international capital and drive economic growth. Data on R&D expenditures and total patents, on the other hand, reveal the importance of innovation capacity and investment in science and technology in a country's economy. The distribution of the gross fixed capital formation and labor force reflects countries' investments in economic infrastructure and human resources. Differences in inflation and unemployment rates highlight the effectiveness of macroeconomic policies and market regulation.

An in-depth analysis of these variables allows us to identify the key factors affecting economic development and provides valuable insights for policymakers to promote economic growth, increase employment, and improve social welfare. These descriptive statistical analyses lay a solid foundation for subsequent regression analyses and causal inference, helping us to better understand the mechanisms and laws behind economic phenomena.

3.2 Correlation analysis

3.2.1 FDI and GDP

Table 3-2 Results of Pearson correlation coefficient

Variables	GDP	FDI	Labor	Gro	Inf	Gov	Unemploy
GDP	1.000						
FDI	0.542	1.000					
Labor	0.032	0.585	1.000				
Gro	0.562	0.768	0.836	1.000			
Inf	-0.406	-0.204	-0.037	-0.254	1.000		
Gov	-0.502	-0.308	-0.200	-0.433	0.169	1.000	
Unemploy	-0.488	-0.257	0.098	-0.210	-0.023	0.152	1.000

The results of Pearson correlation coefficients between the variables in the correlation matrix are in the table above. Between FDI and GDP, 0.542 is the correlation coefficient,

which displays the medium and positive correlation between them. It shows that the FDI's increase may be accompanied by the GDP's increase. Between GDP and Labor, 0.032 is the correlation coefficient value, which displays a weak and positive correlation, suggesting that more Labor may contribute to a weak increase in GDP. There is a positive correlation between GDP and gross fixed capital formation (Gro), and the coefficient is 0.562, showing a middle-level positive correlation. This suggests that a GDP increase usually leads to a gross fixed capital formation increase. Gross fixed capital formation (Gro) also has high correlation coefficients of 0.768 with FDI and 0.836 with Labor. It displays that Gro is strongly correlated with FDI and Labor, and Gro's growth promotes significant growth in FDI and Labor. Government expenditure (Gov) shows a moderate negative correlation with gross fixed capital formation (-0.433) and GDP (-0.502), which may imply that an increase in Gov has a dampening effect on gross fixed capital formation (Gro) and GDP. The unemployment rate (Unemploy) generally has weak correlations with other variables but shows a negative correlation with GDP and FDI, implying that the unemployment rate increase may have a negative impact on GDP and FDI.

Analysis of the correlation matrix provides the study with initial insight into the relationship between the variables. Although correlations do not indicate causality, they help identify potentially important economic relationships that provide a basis for further regression analysis and causal inference.

3.2.2 R&D expenditure and GDP

Table 3-3 Results of Pearson correlation coefficient

Variables	GDP	R&D	Labor	Gro	Inf	Gov	Unemploy
GDP	1.000						
R&D	0.757	1.000					
Labor	0.032	0.087	1.000				
Gro	0.562	0.465	0.836	1.000			
Inf	-0.406	-0.329	-0.037	-0.254	1.000		
Gov	-0.502	-0.365	-0.200	-0.433	0.169	1.000	
Unemploy	-0.488	-0.410	0.098	-0.210	-0.023	0.152	1.000

Based on the above results in the table, R&D and GDP have a high correlation coefficient, which is 0.757. It displays a positive correlation between GDP and R&D. This

coefficient implies that as R&D increases, GDP increases accordingly. R&D expenditure can promote technological innovation, which drives economic growth. Gro and Labor have the highest correlation coefficient, which is 0.836. It shows a positive correlation, and it reveals that the growth of the gross fixed capital also increases the demand for labor to improve the production capacity.

3.2.3 Patent and GDP

Table 3-4 Results of Pearson correlation coefficient

Variables	GDP	Patent	Labor	Gro	Inf	Gov	Unemploy
GDP	1.000						
Patent	0.267	1.000					
Labor	0.032	0.802	1.000				
Gro	0.562	0.806	0.836	1.000			
Inf	-0.406	-0.066	-0.037	-0.254	1.000		
Gov	-0.502	-0.258	-0.200	-0.433	0.169	1.000	
Unemploy	-0.488	-0.094	0.098	-0.210	-0.023	0.152	1.000

Patents and GDP have a coefficient of 0.267 > 0, which is positive, and it shows that patent growth can lead to an increase in GDP. In addition, Gro and Labor have the highest correlation coefficient, which is 0.836. It shows a positive correlation between Labor and Gro. It reveals that the growth of the gross fixed capital also increases the demand for labor to improve the production capacity. Moreover, the coefficient between the Gro and the Patent is 0.806, and it is also a positive correlation. This may be because fixed capital's growth usually reflects a higher number of patent applications, which in turn contributes to the growth of innovation and the economy.

3.2.4 Article and GDP

Table 3-5 Results of Pearson correlation coefficient

Variables	GDP	Article	Labor	Gro	Inf	Gov	Unemploy
GDP	1.000						
Article	0.443	1.000					
Labor	0.032	0.856	1.000				
Gro	0.562	0.927	0.836	1.000			
Inf	-0.406	-0.213	-0.037	-0.254	1.000		
Gov	-0.502	-0.262	-0.200	-0.433	0.169	1.000	

Unemploy	-0.488	-0.100	0.098	-0.210	-0.023	0.152	1.000

Article and GDP have a coefficient of 0.443>0, which is positive, and it shows that article volume growth can lead to an increase in GDP. In addition, Gro and Article have the highest correlation coefficient, which is 0.927. It shows a very strong positive correlation between the number of articles and gross capital formation. This coefficient implies that as the number of articles increases, the capital increases accordingly. This may be due to the fact that more articles reflect the vibrancy of research activities, which in turn promotes capital formation and economic growth.

3.2.5 FDI, R&D, and GDP

Table 3-6 Results of Pearson correlation coefficient

Variables	GDP	FDI	R&D	FDI*R&D	Labor	Gro	Inf	Gov	Unemploy
GDP	1.000								
FDI	0.542	1.000							
R&D	0.757	0.400	1.000						
FDI*R&D	0.755	0.441	0.996	1.000					
Labor	0.032	0.585	0.087	0.139	1.000				
Gro	0.562	0.768	0.465	0.499	0.836	1.000			
Inf	-0.406	-0.204	-0.329	-0.326	-0.037	-0.254	1.000		
Gov	-0.502	-0.308	-0.365	-0.374	-0.200	-0.433	0.169	1.000	
Unemploy	-0.488	-0.257	-0.410	-0.385	0.098	-0.210	-0.023	0.152	1.000

The interaction terms of FDI*R&D, and GDP have a coefficient of 0.755>0, which is positive, and it displays that FDI*R&D's growth can lead to the GDP's increase. 0.996 is the highest correlation coefficient. It displays a strong positive correlation between the interaction term of FDI*R&D and R&D. This coefficient is close to 1, which means that the increase in R&D has an important effect on the interaction between FDI and R&D. This may be because R&D expenditure brings more financial and technological resources, which further promotes FDI and R&D activities' confidence and hence economic growth.

3.3 FDI and economic growth

3.3.1 Regression test - Fixed-effects panel data model

Table 3-7 Fixed-effects panel data model results

GDP	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
FDI	.014	.006	2.50	.018	.003	.026	**
Labor	-1.11	.225	-4.93	.000	-1.57	-.649	***
Gro	.561	.052	10.79	.000	.455	.668	***
Inf	-.001	.004	-0.21	.832	-.008	.007	
Gov	-.011	.01	-1.12	.273	-.031	.009	
Unemploy	-.000	.004	-0.13	.895	-.008	.007	
Constant	12.652	3.246	3.90	.001	6.013	19.292	***
R-squared		0.960	Number of obs		643		
F-test		19409.845	Prob > F		0.000		

* p<.1, ** p<.05, *** p<.01

This thesis analyzes the effects of FDI, labor force, gross fixed capital formation, inflation rate, government expenditure, and unemployment rate on GDP using the way of fixed effects panel data model for regression. The results show that FDI has a positive coefficient (0.014>0) and it has a significant effect on GDP on a 5% significant level (p value = 0.018 < 0.05), indicating that increasing FDI's increase can effectively promote the growth of the economy. Meanwhile, some effects of the inflation rate and government expenditure need to be analyzed with negative coefficients with no significance on three significant levels. The impact of the national unemployment rate on GDP is weak and negative, suggesting that the employment issue needs to be analyzed in the process of making economic policy and achieving stable economic growth. Thus, hypothesis 1a - FDI has a significant and positive impact on the growth of the economy, which is verified to hold.

3.3.2 Endogeneity test - GMM model

Table 3-8 Endogeneity test results

GDP	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
L. GDP	.679	.102	6.65	.000	.479	.88	***
FDI	.025	.01	2.60	.009	.006	.044	***
Labor	-.282	.113	-2.51	.012	-.502	-.061	**
Gro	.241	.091	2.65	.008	.062	.419	***
Inf	-.002	.002	-0.85	.395	-.006	.002	
Gov	-.004	.004	-1.16	.248	-.012	.003	
Unemploy	-.004	.002	-2.27	.023	-.008	-.001	**
Constant	1.146	.712	1.61	.108	-.251	2.542	

Mean dependent var	9.999	SD dependent var	0.913
Number of obs	616	Chi-square	432533.011

* p<.1, ** p<.05, *** p<.01

Arellano-Bond test for AR (1) in first differences:	z = -1.74	Pr > z = 0.082
Arellano-Bond test for AR (2) in first differences:	z = 0.17	Pr > z = 0.867
Sargan test of overid. restrictions:	chi2(8) = 8.16	Prob > chi2 = 0.418
Hansen test of overid. restrictions:	chi2(8) = 3.34	Prob > chi2 = 0.912

This table displays that the lagged period of GDP has a positive and significant relationship with the current GDP, indicating that the GDP has a strong self-continuity. FDI and the GDP have a significant and positive relationship, which shows the important role of FDI in the growth of the economy. This is the same as the findings of the above fixed-effects model. In addition, the national unemployment's increase can hurt GDP. Inflation rate and government expenditure have insignificant effects on GDP, indicating that these factors do not have a significant effect on the growth of the economy in the test. The findings emphasize the key role of FDI in the growth of the economy. The results of AR (1) = 0.082 < 0.1 and AR (2) = 0.867 > 0.1, and tests indicate correct specification of lag structure, i.e., there is no autocorrelation problem, and Hansen test = 0.912 > 0.1 suggest that instrumental variables' choice is valid. These prove that the above endogeneity test's model is valid. Hypothesis 1a - has a significant and positive impact on the growth of the economy, which is verified to hold. These findings provide empirical evidence for the formulation of policies to promote economic growth.

3.3.3 Robustness test - Lag first order

Table 3-9 Robust test results

GDP	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
L1.FDI	.015	.006	2.42	.022	.002	.027	**
Labor	-1.172	.232	-5.06	.000	-1.646	-.698	***
Gro	.549	.053	10.34	.000	.44	.658	***
Inf	-.001	.004	-0.36	.723	-.01	.007	
Gov	-.006	.01	-0.57	.574	-.026	.015	
Unemploy	-.002	.004	-0.42	.677	-.009	.006	

Constant	13.816	3.418	4.04	.000	6.826	20.805	***
R-squared		0.958	Number of obs		617		
F-test		5411.410	Prob > F		0.000		

* p<.1, ** p<.05, *** p<.01

This thesis lags the dependent variable by one period in this test based on the original regression model for robustness testing. The estimated coefficient of lagged one-period FDI in the results indicates the impact of prior-period FDI on current-period GDP. The coefficient of this variable is positive and significant, indicating that FDI positively impacts GDP. In addition, the Labor (labor force) and Gro (gross fixed capital formation) coefficients are significant, indicating that labor force and gross fixed capital formation have a significant impact on economic growth. Moreover, the negative coefficients on the estimated values of the inflation rate, government expenditure of GDP, and national unemployment rate indicate that an increase in the values of these three variables may have a dampening effect on economic growth.

Robustness test results show that the effect of the explanatory variable on GDP is still significant after controlling for fixed effects and heteroskedasticity issues, indicating the robustness of the model results. Specifically, statistical indicators such as t-values, p-values, standard errors, and coefficients in the regression results further validate the model's reliability.

3.3.4 Heterogeneity test - different country group - CEE

Table 3-10 Heterogeneity test results - CEE

GDP	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
FDI	-.000	.010	-0.04	.968	-.023	.022	
Labor	-.771	.337	-2.29	.043	-1.513	-.03	**
Gro	.564	.074	7.60	.000	.401	.727	***
Inf	.003	.002	1.44	.177	-.002	.009	
Gov	-.006	.01	-0.61	.556	-.029	.016	
Unemploy	.006	.003	2.09	.061	-.000	.013	*
Constant	7.027	5.818	1.21	.252	-5.777	19.831	
R-squared		0.986	Number of obs		274		
F-test[#]		.	Prob > F		.		

* p<.1, ** p<.05, *** p<.01 [#]because of low number of obs. F test could not be computed

This thesis explores different variables' effects on economic development through empirical analysis and tests for heterogeneity for countries in Central and Eastern Europe (CEE) and other European countries that are members of the Organization for Economic Cooperation and Development (OECD). A regression analysis was conducted on the two data sets using a fixed effects model, and the conclusions can be compared, a step that ensures that the characteristics of the different economies can be examined separately in subsequent analyses.

The coefficient of FDI is less than zero and does not significantly impact GDP in CEE countries, reflecting that FDI not significantly impacts growth of the economy in CEE countries. The Labor variable shows a significant negative correlation, indicating that the increase in labor resources affects the decrease in economic growth. Gro (Gross fixed capital formation) has a significant and positive correlation with GDP, which further validates that gross fixed capital increase can improve economic development. The inflation and unemployment rates are positively but insignificantly correlated with GDP at a 5% significant level, and government expenditure is negatively but insignificantly correlated with GDP. These three variables do not show a significant correlation and may be influenced by the efficiency of government expenditure and employment policies.

3.3.5 Heterogeneity test - different country group - other European countries in OECD

Table 3-11 Heterogeneity test results- other European countries in OECD

GDP	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
FDI	.010	.003	2.97	.009	.003	.017	***
Labor	.017	.122	0.14	.892	-.241	.275	
Gro	.37	.026	14.29	.000	.315	.424	***
Inf	-.012	.003	-3.57	.002	-.019	-.005	***
Gov	-.015	.005	-3.23	.005	-.025	-.005	***
Unemploy	.001	.002	0.57	.573	-.003	.005	
Constant	.615	1.734	0.35	.727	-3.043	4.272	
R-squared		0.976	Number of obs		369		
F-test[#]		.	Prob > F		.		

* p<.1, ** p<.05, *** p<.01 [#] because of low number of obs. F test could not be computed

Unlike in the CEE group, FDI has a significant positive effect on economic growth. Inflation rate and government expenditure show a significant negative correlation in the OECD countries' group, which differs from the non-significant case performance in the CEE group. The unemployment rate shows the same result in the OECD group as in the CEE group, with a non-significant positive correlation on economic growth at a 5% significant level. The heterogeneity test results show significant differences between the economies. The CEE countries are not significant in terms of FDI for economic growth. In contrast, the OECD countries are very significant in terms of FDI for economic growth.

In summary, this study reveals the different impacts of economic variables on GDP growth through detailed regression analyses of CEE countries and OECD member European countries, providing empirical evidence for understanding the economic development patterns of different economies. These findings not only enrich the theory of economic growth but also have important reference value for policymaking. Especially for Central and Eastern European countries, how to promote economic growth through FDI and change the existing FDI status quo and the formulation of appropriate policies related to foreign investment may be particularly critical.

3.4 R&D and economic growth

3.4.1 Regression test - Fixed-effects panel data model

Table 3-12 Fixed-effects panel data model results

GDP	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
R&D	.096	.061	1.56	.129	-.029	.221	
Labor	-1.024	.285	-3.60	.001	-1.606	-.442	***
Gro	.551	.062	8.90	.000	.424	.677	***
Inf	-.002	.004	-0.57	.570	-.011	.006	
Gov	-.012	.01	-1.18	.246	-.032	.009	
Unemploy	-.002	.004	-0.39	.700	-.01	.007	
Constant	11.975	4.012	2.98	.006	3.769	20.18	***
R-squared		0.958	Number of obs		659		
F-test		20733421.119	Prob > F		0.000		

* p<.1, ** p<.05, *** p<.01

From the table, it can be seen that the R&D expenditure effect on GDP is positive, with a coefficient of 0.096. However, the effect is insignificant (p-value = 0.129 > 0.05), so this indicates that an R&D expenditure increase can result in a GDP increase, but it is insignificant. The effect of Labor (labor force) and Gro (gross fixed capital formation) is significant (p-value < 0.05), where the labor force's coefficient is negative, which indicates that the labor force is negatively correlated with the increase in GDP and the increase in gross fixed capital formation is positively correlated with GDP. The Inf (inflation rate), Gov (government expenditure), and Unemploy (unemployment rate) are negatively related to GDP, and the effect are not significant (p-value > 0.05). Hypothesis 2a: R&D's significantly positive impact on economic growth can't be verified to hold.

3.4.2 Endogeneity test - GMM model

Table 3-13 Endogeneity test results

GDP	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
L. GDP	.585	.091	6.42	.000	.406	.764	***
R&D	.093	.067	1.40	.161	-.037	.224	
Labor	-.397	.076	-5.24	.000	-.546	-.249	***
Gro	.360	.071	5.05	.000	.220	.499	***
Inf	.003	.002	1.37	.170	-.001	.007	
Gov	-.004	.003	-1.50	.135	-.01	.001	
Unemploy	.007	.003	2.49	.013	.002	.013	**
Constant	1.401	.661	2.12	.034	.105	2.697	**
Mean dependent var		10.098	SD dependent var		0.848		
Number of obs		638	Chi-square		2023555.548		

* p<.1, ** p<.05, *** p<.01

Arellano-Bond test for AR (1) in first differences:	z = -1.80	Pr > z = 0.072
Arellano-Bond test for AR (2) in first differences:	z = -0.57	Pr > z = 0.566
Sargan test of overid. restrictions:	chi2(15) = 62.66	Prob > chi2 = 0.000
Hansen test of overid. restrictions:	chi2(15) = 0.00	Prob > chi2 = 1.000

Results show that the previous period's GDP significantly and positively affects the current GDP (coefficient = 0.585, p-value = 0.000 < 0.05). R&D expenditure is positively correlated with GDP (coefficient = 0.093), but the effect is insignificant, p-value = 0.161 > 0.05. In contrast, the labor force has a significant and negative correlation with GDP (p-value = 0.000 < 0.05). Gro (gross fixed capital formation) positively and significantly correlates with GDP. Inf (Inflation rate) and Gov (government expenditure) are insignificant to GDP, where government expenditure negatively affects economic growth. Both the inflation rate and unemployment rate are positively correlated with the growth of the economy. The results of AR (1) = 0.072 < 0.1 and AR (2) = 0.566 > 0.1 tests indicate correct specification of lag structure, i.e., there is no autocorrelation problem, and the results of Hansen test =1.000 > 0.1 indicate that there is the valid choice of instrumental variables. The valid regression model above is proved. Hypothesis 2a - R&D has a significant and positive correlation with economic growth, which can't be verified to hold. This regression analysis further validates the conclusion that the R&D and GDP in the previous section have an insignificant positive correlation and provides empirical evidence for the subsequent recommendations and discussion formulation.

3.4.3 Robustness test - Lag first order

Table 3-14 Robust test results

GDP	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
L1.R&D	.105	.057	1.83	.078	-.012	.223	*
Labor	-1.05	.297	-3.54	.001	-1.657	-.444	***
Gro	.553	.058	9.51	.000	.434	.671	***
Inf	-.004	.005	-0.77	.450	-.013	.006	
Gov	-.006	.01	-0.61	.546	-.026	.014	
Unemploy	-.002	.004	-0.54	.594	-.011	.006	
Constant	12.254	4.219	2.90	.007	3.624	20.883	***
R-squared		0.957	Number of obs		632		
F-test		1918.649	Prob > F		0.000		

* p<.1, ** p<.05, *** p<.01

The table shows that the lagged period of R&D expenditure is positively correlated with GDP (coefficient = 0.105), but the effect is not significant, p-value = 0.078 > 0.05.

Labor (labor force) is significantly and negatively correlated with GDP (coefficient = -1.05 < 0, p-value = 0.001 < 0.05), indicating that the increase in the labor force negatively affects the economy's development. Gro (Gross fixed capital formation) has a significant positive correlation with GDP, so an increase in Gro (gross fixed capital formation) can lead to the development of the economy. The inflation rate, Gov (government expenditure), and unemployment rate are all insignificantly and negatively correlated with GDP. Through this regression analysis, it can be concluded that the R&D' lagged period is insignificantly positively correlated with GDP, which provides empirical evidence for the subsequent recommendations and discussion formulation.

3.4.4 Heterogeneity test - different country group - CEE

Table 3-15 Heterogeneity test results - CEE

GDP	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
R&D	.043	.068	0.63	.541	-.107	.194	
Labor	-1.04	.284	-3.66	.004	-1.665	-.415	***
Gro	.537	.079	6.82	.000	.364	.71	***
Inf	.004	.003	1.55	.150	-.002	.01	
Gov	-.006	.012	-0.52	.614	-.031	.019	
Unemploy	.004	.003	1.31	.216	-.003	.012	
Constant	11.692	4.873	2.40	.035	.967	22.418	**
R-squared		0.988	Number of obs		265		
F-test[#]		.	Prob > F		.		

* p<.1, ** p<.05, *** p<.01 [#] because of low number of obs. F test could not be computed.

The above table tests for heterogeneity through empirical analysis for countries in Central and Eastern Europe (CEE) and other European countries that are members of the OECD. The regression analysis of the two sets of data using a fixed effects model concludes that in CEE countries, R&D has a non-significant positive effect on the growth of the economy, and when R&D increases, GDP grows insignificantly. The Labor variable shows a significant negative correlation, indicating that labor resources' increase can lead to a decrease in the economy's growth. Gro (gross fixed capital formation) is significantly and positively correlated with GDP, further validating fixed capital's importance as a catalyst for economic development. The inflation rate and unemployment rate are positively but not significantly correlated with GDP, and Gov (government expenditure) is

negatively and insignificantly correlated with GDP. These three variables do not show a significant correlation and may be influenced by the efficiency of government expenditure and employment policies.

3.4.5 Heterogeneity test - different country group - other European countries in the OECD

Table 3-16 Heterogeneity test results - other European countries in the OECD

GDP	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
R&D	-.023	.034	-0.69	.496	-.094	.048	
Labor	.058	.116	0.50	.624	-.186	.302	
Gro	.344	.034	10.13	.000	.273	.416	***
Inf	-.015	.004	-4.24	.001	-.023	-.008	***
Gov	-.014	.006	-2.51	.023	-.026	-.002	**
Unemploy	-.000	.002	-0.06	.956	-.005	.005	
Constant	.893	1.69	0.53	.604	-2.672	4.458	
R-squared		0.974	Number of obs		394		
F-test[#]		.	Prob > F		.		

* p<.1, ** p<.05, *** p<.01 [#]because of low number of obs. F test could not be computed.

R&D expenditures and labor force variables contrast the CEE group, where R&D is insignificantly negatively correlated with GDP growth, and Labor (labor force) shows an insignificant positive correlation with FDP growth. Gro (Gross fixed capital formation) is significantly and positively correlated with GDP growth, suggesting that gross fixed capital formation's increase positively affects GDP growth. Inflation rate and government expenditure show a significant negative correlation in the OECD countries, which is different from the non-significant performance in the CEE group. The unemployment rate shows that the results in the OECD group are different from those of the CEE group, with a non-significant negative correlation on GDP. The heterogeneity test results show that significant differences exist in the different economies. In CEE countries, there is a non-significant positive impact on R&D for economic growth, while there is a negative correlation between R&D and economic growth in other European countries in the OECD. Therefore, countries in different regions should take different measures on R&D investment. Especially for CEE countries, in order to promote economic growth through

R&D expenditures and change the existing R&D investment situation, it is very important to formulate appropriate R&D investment policies.

3.5 Patent and economic growth

3.5.1 Regression test - Fixed-effects panel data model

Table 3-17 Fixed-effects panel data model results

GDP	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Patent	-.034	.021	-1.65	.110	-.076	.008	
Labor	-.999	.302	-3.31	.003	-1.616	-.381	***
Gro	.548	.05	10.98	.000	.446	.65	***
Inf	-.002	.004	-0.61	.546	-.011	.006	
Gov	-.021	.009	-2.40	.023	-.04	-.003	**
Unemploy	.001	.004	0.20	.846	-.007	.008	
Constant	11.992	4.588	2.61	.014	2.608	21.376	**
R-squared		0.958	Number of obs		667		
F-test		278245.900	Prob > F		0.000		

* p<.1, ** p<.05, *** p<.01

This thesis analyzes the effects of the number of patent applications, labor force, inflation rate, gross fixed capital formation, government expenditure, and unemployment rate on GDP by using a fixed-effects regression model. The table's results show that patents have a non-significant effect on GDP (p-value = 0.11 > 0.05), and the two are negatively correlated (coefficient = -0.034 < 0). It shows that increasing the number of patent applications does not effectively promote economic growth. The total labor force and GDP show a significant negative correlation (coefficient is -0.999 < 0, and p-value = 0.003 < 0.05), indicating that the increase in the labor force makes some threshold for economic development. Gro (Gross fixed capital formation) and the growth of GDP show a significant positive correlation, indicating that the increase in gross fixed capital formation can promote GDP growth. Meanwhile, the inflation rate and government expenditure are negatively correlated with GDP, and the national unemployment rate positively correlates with GDP. The relationship between the above three variables and GDP needs to be analyzed with specific coefficients and significance levels.

3.5.2 Endogeneity test - GMM model

Table 3-18 Endogeneity test results

GDP	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
L.GDP	.790	.096	8.20	.000	.601	.979	***
Patent	-.038	.043	-0.87	.382	-.123	.047	
Labor	-.191	.103	-1.85	.064	-.393	.011	*
Gro	.170	.094	1.81	.070	-.014	.354	*
Inf	-.003	.004	-0.82	.413	-.011	.005	
Gov	-.006	.005	-1.23	.219	-.015	.003	
Unemploy	.006	.004	1.40	.162	-.002	.014	
Constant	1.136	1.14	1.00	.319	-1.099	3.371	
Mean dependent var		10.074	SD dependent var		0.896		
Number of obs		643	Chi-square		11702867.051		

* p<.1, ** p<.05, *** p<.01

Arellano-Bond test for AR (1) in first differences:	z = -1.88	Pr > z = 0.060
Arellano-Bond test for AR (2) in first differences:	z = -0.80	Pr > z = 0.426
Sargan test of overid. restrictions:	chi2(13) = 23.89	Prob > chi2 = 0.032
Hansen test of overid. restrictions:	chi2(13) = 0.00	Prob > chi2 = 1.000

The table shows that the GDP's previous period has a positive and significant effect on the current GDP (coefficient = 0.790, p = 0.000 < 0.05), indicating that the increase in the previous year's economy can improve the current year's economic development. Patent applications negatively correlated with GDP (coefficient = -0.038), but the effect is insignificant, p-value = 0.382> 0.05. The labor force has a negative correlation with GDP. Gro (Gross fixed capital formation) is positively correlated with GDP. The inflation rate, government expenditure, and unemployment rate have an insignificant effect on GDP, where the unemployment rate positively affects economic growth, and both the inflation rate and government expenditure have a negative correlation with the economy's growth. The results of AR (1) = 0.060 < 0.1 and AR (2) = 0.426 > 0.1 tests indicate correct specification of lag structure, i.e., there is no autocorrelation problem, and Hansen test result = 1.000 > 0.1 indicates that instrumental variables' choice is valid. These prove that

the regression model above is valid. Hypothesis 3b cannot be verified to hold. This regression analysis further discusses the relationship between patent applications and GDP in the previous section, providing empirical evidence for subsequent recommendations and discussion development.

3.5.3 Robustness test - Lag first order

Table 3-19 Robust test results

GDP	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
L1. Patent	-.031	.02	-1.53	.137	-.073	.01	
Labor	-1.026	.319	-3.21	.003	-1.679	-.373	***
Gro	.545	.047	11.53	.000	.448	.642	***
Inf	-.003	.004	-0.70	.487	-.012	.006	
Gov	-.017	.01	-1.69	.101	-.037	.003	
Unemploy	.000	.004	0.02	.985	-.008	.008	
Constant	12.383	4.831	2.56	.016	2.503	22.263	**
R-squared		0.956	Number of obs		640		
F-test		16869.015	Prob > F		0.000		

* p<.1, ** p<.05, *** p<.01

The table shows that patent in the lagged period is negatively correlated with GDP (coefficient = -0.031), but the effect is not significant on a 5% significant level (p-value = 0.137 > 0.05). Therefore, the lagged one-period patent increase cannot significantly lead to a GDP increase. In addition, the Labor (labor force) has a significant negative correlation with GDP (coefficient = -1.026, p = 0.003 < 0.05), and this conclusion is the same as the conclusion of the regression test. The increase in the labor force can lead to a significant decrease in the economy. Gro (Gross fixed capital formation) is significantly and positively correlated to GDP, so an increase in gross fixed capital formation can accelerate the economy's development. Besides, Inf (Inflation rate), Gov (government expenditure) and unemployment have insignificant effects on GDP. This regression analysis further concludes that patent applications in the lagged period have a non-significant negative correlation with GDP, providing empirical evidence for the subsequent recommendations and discussion formulation.

3.5.4 Heterogeneity test - different country group - CEE

Table 3-20 Heterogeneity test results - CEE

GDP	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Patent	-.021	.015	-1.42	.183	-.053	.011	
Labor	-.935	.356	-2.63	.024	-1.718	-.151	**
Gro	.547	.082	6.66	.000	.366	.728	***
Inf	.004	.003	1.41	.186	-.002	.009	
Gov	-.006	.012	-0.55	.59	-.032	.019	
Unemploy	.006	.003	1.93	.079	-.001	.013	*
Constant	10.009	6.357	1.57	.144	-3.981	24	
R-squared		0.986	Number of obs		270		
F-test[#]		.	Prob > F		.		

* p<.1, ** p<.05, *** p<.01 [#]because of low number of obs. F test could not be computed

The above table tests for heterogeneity through empirical analysis for CEE (central and Eastern European) countries and other European countries that are members of the OECD (Organization for Economic Cooperation and Development). The regression analysis of the two sets of data using a fixed-effects regression model concludes that patents have an insignificant negative effect on the growth of the economy in CEE countries. The labor force shows a significant negative correlation, indicating that the growth of labor resources can decrease the economy's growth. Gro (Gross fixed capital formation) shows a significant positive correlation with GDP, further verifying its role in promoting economic development. Inflation and unemployment rates are positively but insignificantly correlated with GDP, and Gov (government expenditure) is negatively and insignificantly correlated with GDP. These three variables do not show a significant correlation and may be influenced by the efficiency of government expenditure and employment policies. Discussions need to be separated based on regional specificities.

3.5.5 Heterogeneity test - different country group - other European countries in the OECD

Table 3-21 Heterogeneity test results - other European countries in the OECD

GDP	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Patent	.016	.011	1.48	.156	-.007	.038	
Labor	.055	.123	0.45	.657	-.204	.315	

Gro	.365	.041	8.94	.000	.279	.451	***
Inf	-.019	.003	-5.89	.000	-.025	-.012	***
Gov	-.012	.009	-1.35	.196	-.03	.007	
Unemploy	.001	.002	0.40	.697	-.004	.006	
Constant	.278	1.44	0.19	.849	-2.76	3.317	
R-squared	0.973		Number of obs		397		
F-test[#]	.		Prob > F		.		

* p<.1, ** p<.05, *** p<.01 [#]because of low number of obs. F test could not be computed

Patent applications and labor force variables are in contrast to the CEE group, where both of them show a non-significant positive correlation with GDP growth, which is contrary to the negative correlation concluded by the CEE countries. Gro (Gross fixed capital formation) is significantly and positively correlated with GDP, indicating that an increase in gross fixed capital formation can accelerate GDP growth. The inflation rate is significantly and negatively correlated with GDP in the OECD countries, which is different from the non-significant performance in the CEE group. Gov (Government expenditure) and unemployment rate show the same result in the OECD group as in the CEE group, with a non-significant and separate identical correlation on the economy's growth. The heterogeneity test results show that significant differences are existing between the different economies and regions. In terms of the increase in patent applications, the CEE countries lead to a decrease in economic growth, whereas the OECD countries' patents have a positive correlation with economic growth. Therefore, different measures should be taken by countries in different regions in terms of patent applications. Especially for CEE countries, promoting economic growth and changing the status quo through the change of patent application volume is very important in formulating appropriate patent application policies.

3.6 Article and economic growth

3.6.1 Regression test - Fixed-effects panel data model

Table 3-22 Fixed-effects panel data model results

GDP	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Article	.208	.03	6.88	.000	.146	.27	***

Labor	-1.086	.142	-7.63	.000	-1.377	-.795	***
Gro	.487	.05	9.72	.000	.384	.589	***
Inf	-.001	.004	-0.24	.810	-.009	.007	
Gov	-.009	.009	-0.94	.354	-.028	.01	
Unemploy	-.003	.003	-0.98	.336	-.01	.004	
Constant	12.661	2.102	6.02	.000	8.362	16.96	***
R-squared	0.968		Number of obs		681		
F-test	12987.435		Prob > F		0.000		

* p<.1, ** p<.05, *** p<.01

This thesis analyzes the effects of the number of scientific and technical journal articles, gross fixed capital formation, total labor force, government expenditure, inflation rate, and unemployment rate on GDP by using a fixed-effects panel data regression model. The results display that the number of scientific and technical journal articles significantly affects GDP growth (p-value = 0.000 < 0.05), and the two are positively correlated (coefficient = 0.208 > 0). It shows that increasing the number of articles can effectively promote economic growth. The total labor force is significantly and negatively correlated with GDP (coefficient = -1.086 < 0, and p-value = 0.000 < 0.05), suggesting that the increase in the labor force can lead to a decrease in the growth of the economy. Gro (Gross fixed capital formation) is significantly and positively correlated with GDP, indicating that the increase in gross fixed capital formation positively accelerates the economy's growth. Meanwhile, inflation rate, government expenditure, and national unemployment rate negatively relate to GDP. The relationship between the above three variables and GDP needs to be analyzed with specific coefficients and significance levels. Thus, Hypothesis 4a - Article has a significant positive impact on economic growth is verified to hold.

3.6.2 Endogeneity test - GMM model

Table 3-23 Endogeneity test results

GDP	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
L.GDP	.593	.071	8.39	.000	.454	.731	***
Article	.066	.03	2.20	.028	.007	.124	**
Labor	-.451	.084	-5.37	.000	-.616	-.287	***
Gro	.349	.056	6.26	.000	.24	.459	***
Inf	.002	.003	0.92	.356	-.003	.007	
Gov	-.005	.003	-1.66	.097	-.012	.001	*
Unemploy	.006	.002	2.66	.008	.002	.01	***

Constant	1.746	.726	2.41	.016	.323	3.168	**
Mean dependent var	10.046		SD dependent var		0.916		
Number of obs	654		Chi-square		1141484077.346		

* p<.1, ** p<.05, *** p<.01

Arellano-Bond test for AR (1) in first differences:	z = -2.50	Pr > z = 0.012
Arellano-Bond test for AR (2) in first differences:	z = 0.69	Pr > z = 0.492
Sargan test of overid. restrictions:	chi2(18) = 70.22	Prob > chi2 = 0.000
Hansen test of overid. restrictions:	chi2(18) = 1.90	Prob > chi2 = 1.000

The results of the table show that the GDP of the previous period significantly and positively influenced the current GDP (coefficient = 0.593, p = 0.000 < 0.05), suggesting that the previous year's economic development can accelerate the economic development of the current year. The number of scientific articles is significantly and positively correlated with GDP (coefficient = 0.066 > 0, p-value = 0.028 < 0.05). This further supports the conclusion drawn in the previous section that the number of scientific and technical journal articles is significantly and positively correlated with the growth of the economy. At the same time, the labor force has a significant negative correlation with GDP. Gro (Gross fixed capital formation) is significantly and positively correlated with GDP. Inflation rate and government expenditure insignificantly affect GDP, in which the inflation rate has a positive relationship with GDP, and government expenditure is negatively correlated with economic growth. Unemployment has a significant positive correlation with GDP. The results of AR (1) = 0.012 < 0.1 and AR (2) = 0.492 > 0.1 tests indicate correct specification of lag structure, i.e., there is no autocorrelation problem, and the results of Hansen's test = 1.000 > 0.1 show that it is a valid choice of instrumental variables. These prove that the regression model above is valid. Hypothesis 4a - The article that has a significant positive impact on economic growth is verified to hold. The regression analysis further justifies the conclusion of the previous section on the relationship between the number of scientific and technical journal articles and GDP, providing empirical evidence for subsequent recommendations and discussion development.

3.6.3 Robustness test - Lag first order

Table 3-24 Robust test results

GDP	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
L1. Article	.206	.029	7.12	.000	.147	.266	***
Labor	-1.125	.124	-9.05	.000	-1.379	-.871	***
Gro	.506	.048	10.44	.000	.407	.605	***
Inf	-.001	.004	-0.20	.840	-.009	.007	
Gov	-.003	.008	-0.39	.700	-.019	.013	
Unemploy	-.004	.004	-1.09	.287	-.011	.003	
Constant	12.745	1.906	6.69	.000	8.847	16.644	***
R-squared	0.967		Number of obs		682		
F-test	18547.973		Prob > F		0.000		

* p<.1, ** p<.05, *** p<.01

From the table, the data results show that the number of scientific and technical journal articles in the lagged period is positively correlated with GDP (coefficient = 0.206) and has a significant effect (p-value = 0.00 < 0.05). At the same time, the labor force has a significant negative correlation with GDP (coefficient = -1.125, p = 0.000 < 0.05), which means that the increase in the labor force can decrease the GDP and slow the development of the economy. Gro (Gross fixed capital formation) is significantly and positively correlated with GDP, so the gross fixed capital formation increase can promote the development of the economy. Inflation rate, government expenditure, and unemployment rate are all insignificantly negatively correlated with GDP. This regression analysis further leads to the conclusion that an increase in the number of scientific and technical journal articles in the lagged time period is significantly and positively correlated with the growth of GDP, providing empirical evidence for subsequent recommendations and discussion development.

3.6.4 Heterogeneity test - different country group - CEE

Table 3-25 Heterogeneity test results - CEE

GDP	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Article	.115	.026	4.41	.001	.057	.172	***
Labor	-.541	.291	-1.86	.090	-1.183	.1	*
Gro	.545	.063	8.65	.000	.407	.684	***
Inf	.002	.002	0.97	.355	-.003	.008	

Gov	-.009	.01	-0.89	.392	-.032	.013	
Unemploy	.005	.003	1.89	.085	-.001	.01	*
Constant	3.306	4.96	0.67	.519	-7.611	14.223	
R-squared			0.988	Number of obs		275	
F-test[#]			.	Prob > F		.	

* p<.1, ** p<.05, *** p<.01 [#]because of low number of obs., F test could not be computed

In this thesis, the heterogeneity of CEE (Central and Eastern European) countries and other European countries in the OECD (Organization for Economic Cooperation and Development) are tested through empirical analysis. Regression analyses were performed on both sets of data using a fixed-effects panel data model, and the empirical results can be compared.

The number of scientific and technical journal articles is significantly and positively correlated with GDP, reflecting that the number of articles in promoting economic growth is very significant in CEE countries. The labor force variable shows a non-significant negative correlation, which cannot directly reflect that labor resources have a significant effect on slower economic development. Gro (Gross fixed capital formation) shows a significant positive correlation with GDP, which further verifies that the increase in gross fixed capital promotes the economy's growth. The inflation rate and unemployment rate are positively but not significantly correlated with GDP, and Gov (government expenditure) is negatively and insignificantly correlated with GDP. These three variables do not show a significant correlation, and further analysis is needed to determine the efficiency of government spending and employment policies.

3.6.5 Heterogeneity test - different country group - other European countries in the OECD

Table 3-26 Heterogeneity test results - other European countries in the OECD

GDP	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Article	.102	.028	3.66	.002	.043	.161	***
Labor	-.224	.128	-1.75	.099	-.494	.047	*
Gro	.383	.034	11.18	.000	.311	.455	***
Inf	-.013	.004	-3.04	.007	-.022	-.004	***
Gov	-.005	.006	-0.82	.423	-.017	.007	
Unemploy	.001	.003	0.30	.769	-.005	.006	

Constant	3.263	1.7	1.92	.072	-.324	6.851	*
R-squared		0.978	Number of obs		406		
F-test[#]		.	Prob > F		.		

* p<.1, ** p<.05, *** p<.01 [#]because of low number of obs., F test could not be computed

Similar to the findings of the CEE group, the number of scientific and technical journal articles is significantly and positively correlated with GDP, and the number of articles can make a positive contribution to the GDP's increase. Labor (labor force) is insignificantly and negatively correlated with GDP, so whether the number of labor forces in other European countries can contribute to economic growth needs further research and discussion. Gro (Gross fixed capital formation) is significantly and positively correlated with GDP's increase, indicating that the Gro (gross fixed capital formation) increase can accelerate the GDP's growth. Inflation rate and government expenditure show a negative correlation in OECD countries, which is different from the one positive and one negative relationship in the CEE group. The unemployment rate shows the same result in the OECD group as in the CEE group, with a non-significant positive correlation on economic growth at the 5% significant level. The heterogeneity test findings show that there are differences existing between economies and that the increase in the number of articles significantly contributes to the growth of the economy. How to promote economic growth through changes in the number of articles and change the status quo, it is important to develop appropriate policies to incentivize the publication of articles.

3.7 FDI, R&D and economic growth

3.7.1 Regression test - Fixed-effects panel data model

Table 3-27 Fixed-effects panel data model results

GDP	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
FDI	.015	.008	1.91	.067	-.001	.031	*
R&D	.529	.199	2.66	.012	.123	.936	**
FDI*R&D	-.02	.009	-2.13	.042	-.038	-.001	**
Labor	-.992	.247	-4.02	.000	-1.496	-.488	***
Gro	.558	.056	9.95	.000	.443	.673	***
Inf	-.001	.004	-0.36	.720	-.009	.007	

Gov	-.011	.01	-1.11	.276	-.03	.009	
Unemploy	-.001	.004	-0.23	.821	-.009	.007	
Constant	10.973	3.618	3.03	.005	3.574	18.372	***
R-squared		0.964	Number of obs		598		
F-test[#]		.	Prob > F		.		

* p<.1, ** p<.05, *** p<.01 [#]because of low number of obs., F test could not be computed

The data in the table indicates that FDI has a non-significant positive correlation with GDP (coefficient = 0.015 > 0, p = 0.067 > 0.05). R&D expenditure is significantly and positively correlated with GDP (coefficient = 0.529 > 0, p = 0.012 < 0.05). The coefficient of the interaction term between FDI and R&D expenditure is less than 0 (coefficient = -0.02 < 0, so it is negatively correlated with GDP. Because the p-value = 0.042 < 0.05, so the interaction term has a significant effect on GDP. The Labor (labor force) is significantly and negatively correlated with GDP (coefficient = -0.992 < 0, and p-value = 0.000 < 0.05), indicating that an increase in the labor force can slow the growth of the economy. Gro (Gross fixed capital formation) is significantly and positively correlated with GDP growth, indicating that an increase in gross fixed capital formation has a positive effect on GDP growth. At the same time, inflation rate, government expenditure, and national unemployment rate are negatively related to GDP. The relationship between the above three variables and GDP needs to be analyzed with specific coefficients and significance levels. Hypothesis 5b - A significant negative interaction between FDI and R&D expenditure weakens each other's impact on economic growth, which is verified to hold.

3.7.2 Endogeneity test - GMM model

Table 3-28 Endogeneity test results

GDP	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
L.GDP	.697	.085	8.17	.000	.53	.864	***
FDI	.029	.016	1.82	.069	-.002	.061	*
R&D	.828	.348	2.38	.017	.147	1.51	**
FDI*R&D	-.035	.015	-2.29	.022	-.065	-.005	**
Labor	-.25	.073	-3.41	.001	-.393	-.106	***
Gro	.221	.084	2.62	.009	.056	.387	***
Inf	-.000	.003	-0.04	.970	-.006	.006	
Gov	-.004	.003	-1.54	.124	-.009	.001	
Unemploy	.002	.002	0.89	.372	-.003	.007	
Constant	.893	.666	1.34	.18	-.413	2.198	

Mean dependent var	10.037	SD dependent var	0.848
Number of obs	577	Chi-square	821758.524

* p<.1, ** p<.05, *** p<.01

Arellano-Bond test for AR (1) in first differences:	z = -2.99	Pr > z = 0.003
Arellano-Bond test for AR (2) in first differences:	z = 1.04	Pr > z = 0.299
Sargan test of overid. restrictions:	chi2(12) = 19.11	Prob > chi2 = 0.086
Hansen test of overid. restrictions:	chi2(12) = 0.00	Prob > chi2 = 1.000

From the table, it can be seen that the lagged period GDP is significantly and positively correlated with the GDP of the current period (coefficient = 0.697, p = 0.000 < 0.05), which indicates that the economic development of the previous year can be significantly and positively with the economic development of the current year. FDI has an insignificant positive correlation with the GDP (coefficient = 0.029>0, p-value = 0.069 > 0.05), which is the same as the conclusion drawn in the previous part. The conclusion reached in the previous section, and the increase in significance is more convincing when some of the endogeneity issues are resolved. R&D expenditure is significantly and positively correlated with GDP (coefficient = 0.828 > 0, p-value = 0.017 < 0.05), which is the same as in the fixed-effects regression model. The interaction term is significantly negative between FDI and R&D expenditure and economic growth (coefficient = -0.035 < 0, p-value = 0.022 < 0.05), which is the same as in the previous section - a conclusion so as to justify the regression test's conclusion above. Labor (labor force) is significantly and negatively correlated with GDP (coefficient = -0.25 < 0, p-value = 0.001 < 0.05), and Gro (gross fixed capital formation) is positively and significantly correlated with GDP (coefficient = 0.221 > 0, p-value = 0.009 < 0.05). Inf (Inflation rate) and Gov (government expenditure) are both insignificantly negatively correlated with GDP, and unemployment rate is insignificantly and positively correlated with economic growth. The results of the AR (1) = 0.003 < 0.1 and AR (2) = 0.299 > 0.1 tests indicate correct specification of lag structure, i.e., there is no autocorrelation problem, and the results of the Hansen test = 1.000 > 0.1 indicate that there is the valid choice of instrumental variables. These prove that the regression model above is valid. Hypothesis 5b - A negative interaction between

FDI and R&D weakens each other's impact on economic growth, which is verified to hold. This regression analysis further validates the findings above and provides empirical evidence for subsequent recommendations and discussion formulation.

3.7.3 Robustness test - Lag first order

Table 3-29 Robust test results

GDP	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
L. FDI	.015	.007	1.97	.059	-.001	.03	*
L. R&D	.576	.193	2.98	.006	.18	.971	***
L. FDI*R&D	-.021	.009	-2.38	.024	-.039	-.003	**
Labor	-1.036	.25	-4.14	.000	-1.548	-.524	***
Gro	.545	.057	9.57	.000	.428	.661	***
Inf	-.003	.004	-0.61	.549	-.011	.006	
Gov	-.005	.009	-0.59	.560	-.025	.014	
Unemploy	-.002	.004	-0.57	.575	-.01	.006	
Constant	11.919	3.653	3.26	.003	4.447	19.391	***
R-squared		0.963	Number of obs		573		
F-test[#]		.	Prob > F		.		

* p<.1, ** p<.05, *** p<.01 [#]because of low number of obs. F test could not be computed

From the table, it can be seen that lag one period FDI is positively and insignificantly correlated with GDP (coefficient = 0.015 > 0, but the effect is insignificant (p-value = 0.059 > 0.05). Lagged one-period R&D expenditure is significantly and positively correlated with GDP (coefficient = 0.576 > 0, p-value = 0.006 < 0.05). The interaction term of lagged one-period R&D and FDI has a significant and negative relationship with GDP (coefficient = -0.021 < 0, p-value = 0.024 < 0.05). Labor (labor force) has a significant negative correlation with GDP (coefficient = -1.036 < 0, p-value = 0.000 < 0.05), indicating that the increase in the labor force can slow economic development. Gro (Gross fixed capital formation) and GDP are significantly and positively correlated (coefficient = 0.545 > 0, p-value = 0.000 < 0.05), so the increase of gross fixed capital formation can promote the development of economic growth. The inflation rate, Gov (government expenditure), and unemployment rate are all negatively and insignificantly correlated with GDP. This regression analysis further concluded that the interaction term of lagged period R&D investment and FDI is negatively correlated with GDP, which provides empirical

evidence for the subsequent recommendations and discussion formulation.

3.7.4 Heterogeneity test - different country group - CEE

Table 3-30 Heterogeneity test results - CEE

GDP	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
FDI	-.02	.013	-1.53	.154	-.048	.009	
R&D	-.256	.482	-0.53	.606	-1.318	.805	
FDI*R&D	.028	.025	1.14	.277	-.026	.083	
Labor	-.599	.761	-0.79	.447	-2.274	1.075	
Gro	.926	.052	17.91	.000	.812	1.04	***
Inf	-.002	.005	-0.38	.714	-.013	.009	
Gov	-.003	.014	-0.18	.860	-.034	.029	
Unemploy	.004	.005	0.93	.371	-.006	.015	
Constant	-2.993	11.56	-0.26	.800	-28.435	22.45	
R-squared		0.946	Number of obs		253		
F-test		1649.396	Prob > F		0.000		

* p<.1, ** p<.05, *** p<.01

In the CEE countries, FDI and R&D expenditures are all negatively and insignificantly related to GDP, and the interaction term between FDI and R&D expenditures is positively and insignificantly related to GDP. This is contrary to the findings of the regressions for the total sample in the fixed-effects regression model, suggesting that the increase in FDI and R&D expenditures alone may have a decrease in GDP growth in the CEE countries. However, the interaction term between FDI and R&D expenditures is positive and insignificant (coefficient = 0.028 > 0, p = 0.277 > 0.05), which suggests that the increase in the two combined can lead to an increase in the GDP. In addition, Labor (labor force) shows an insignificant and negative correlation with GDP, which can directly respond to the fact that the increase in labor resources doesn't have a significant obstructive effect on economic growth. Gro (Gross fixed capital formation) is significantly and positively correlated with GDP, which further verifies that the growth of gross fixed capital formation has a promotion effect on the economy's growth. The inflation rate and Gov (government expenditure) are insignificantly and negatively correlated with GDP, and the unemployment is positively and insignificantly correlated with GDP. These three variables do not show a significant correlation, and further analysis is needed based on the efficiency

of government spending and employment policies.

3.7.5 Heterogeneity test - different country group - other European countries in the OECD

Table 3-31 Heterogeneity test results - other European countries in the OECD

GDP	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
FDI	.014	.003	5.31	.000	.008	.02	***
R&D	.254	.084	3.03	.008	.077	.431	***
FDI*R&D	-.012	.003	-3.53	.003	-.018	-.005	***
Labor	.03	.12	0.25	.803	-.223	.284	
Gro	.363	.023	15.59	.000	.314	.412	***
Inf	-.011	.003	-3.53	.003	-.017	-.004	***
Gov	-.014	.005	-3.03	.008	-.024	-.004	***
Unemploy	.001	.002	0.26	.794	-.004	.005	
Constant	.46	1.755	0.26	.796	-3.242	4.162	
R-squared		0.977	Number of obs		345		
F-test[#]		.	Prob > F		.		

* p<.1, ** p<.05, *** p<.01 # because of low number of obs. F test could not be computed

In the other European countries of the OECD, FDI, and R&D expenditures are all significantly and positively correlated with GDP, and the interaction term of FDI and R&D expenditures is significantly negatively correlated with GDP. This is the same conclusion as the regression test for the total sample in the fixed-effects regression model, suggesting that the increase in FDI and R&D expenditure alone can accelerate the GDP growth in other European countries. However, the interaction term between FDI and R&D expenditures is significant and negative with GDP (coefficient = -0.012 < 0, p = 0.003 < 0.05), suggesting that the increase of FDI and R&D together can slow the economy's growth. This is contrary to the CEE country findings and reflects regional heterogeneity, suggesting that there are different performances of the effect in different regions, providing a basis for subsequent categorization discussions. In addition, Labor (labor force) shows a non-significant positive correlation with GDP (coefficient = 0.03 > 0, p = 0.803 > 0.05), and Gro (Gross fixed capital formation) is significant and positively correlated with GDP (coefficient = 0.363 > 0, p = 0.000 < 0.05), further validating the growth of gross fixed capital formation can accelerate economic development. Inf (inflation rate) and Gov

(government expenditure) show a significant negative correlation with GDP, while the unemployment and GDP show a positive and insignificant correlation. These three variables correlate with GDP in the same direction but not with the same significance. From the above results, it can be seen that there are differences between regions. Therefore, further discussion is required.

4. Discussion

4.1 Interpretation and key findings

The thesis finds that FDI is significantly and positively correlated with economic growth, indicating that FDI increase can effectively promote economic growth, thus further supporting the theory that FDI can accelerate economic growth (Moudatsou, 2003; Tsimpida & Bitzenis, 2023). However, unlike the findings in other European countries, in CEE (Central and Eastern European) countries, the relationship is not significant or even shows a negative correlation. This is contrary to the findings of previous studies (Jimborean & Kelber, 2017; Sokhanvar, 2022). This may be related to the country's specific market structure and economic environment, which in turn affects the FDI's effect on the growth of the economy.

Although R&D investment is theoretically regarded as an important contributor to economic growth (Pece et al., 2015; Minviel & Ben Bouheni, 2022; Nihal et al., 2023), this thesis finds that between R&D expenditure and GDP, although the relationship is positive, it is not statistically significant, suggesting that there may be other factors, such as industrial structure and innovation efficiency. It affects the economic returns to R&D investment. Apart from that, in other European countries, R&D expenditure is negatively correlated with the growth of the economy.

The relationship between the number of patent applications and the economy's growth shows a non-significant negative correlation, which may reflect the fact that the number of patents does not directly equate to effective technological innovations or economic

applications to promote the growth of the economy. This finding is different from the traditional view in some of the literature that patent applications are directly equivalent to innovation and drive economic growth (Phung et al., 2019). Further judgment and research are needed. In addition, the number of patent applications even shows a non-significant negative correlation with the growth of the economy in the European countries other than the CEE countries in this thesis. Therefore, whether the number of patents needs to continue to be the only variable for innovation measurement in subsequent studies needs to be analyzed and selected according to the specific sample.

The number of scientific articles is significantly and positively correlated with economic growth. This is similar to Pinto and Teixeira (2020) findings that research output significantly and positively affected economic growth. In addition, the number of articles with a lag is also significantly positively correlated with economic growth, a result that emphasizes the knowledge output's importance in promoting economic development, and at the same time has a positive impact on the economy.

The interaction term of FDI and R&D expenditure is significantly negatively related to GDP in the test results. This is different from the traditional view that FDI can promote R&D expenditure and thus further promote the economy (Dhrifi, 2015). However, FDI and R&D expenditure are positively correlated with economic growth, respectively, which side by side shows that when FDI and high R&D expenditure increase at the same time, there may be some efficiency loss or misallocation of resources and therefore appear to be a threshold to volume of R&D and FDI volumes in European economies.

The above provides a basis for policymakers that although FDI generally promotes economic growth, its effect varies in different regions and requires different strategies to be used in different regions to optimize the research and thus promote economic growth. The lack of significant economic returns to R&D expenditures suggests the need for more in-depth research on innovation policy design and implementation efficiency. In addition, it needs to pay more attention to the quality of patenting and scientific output and its alignment with industry needs.

4.2 Policy recommendation

Firstly, in terms of economic policy, the country should optimize the FDI policy. Because of this thesis research, the FDI and economic growth relationship shows a significant and positive correlation in most European countries, which indicates that the FDI increase strongly promotes the economy. Therefore, it is recommended that countries develop more attractive investment policies, such as tax incentives and investment subsidies. Especially in CEE countries, since the current results show that the FDI's promotion of the economy's growth is not significant in CEE countries, strategies need to be adjusted to enhance the promotion of FDI's effect on economic growth. In addition, the climate of investment transparency and the stability of the legal framework should be strengthened to attract more long-term investments.

Secondly, countries should increase the intensity of R&D investment and implement innovation-driven strategies. Although the relationship between R&D expenditures and economic growth's relationship is positive but not significant in this thesis, R&D investment should not be reduced. On the contrary, it may be affected by low R&D efficiency or low efficiency of outcome transformation, so the country should increase R&D efficiency and outcome transformation rate to enhance its ability to drive the growth of the economy. Therefore, it is recommended that public and private sector funding for R&D be increased and that the development of higher education be encouraged to produce more highly educated people. At the same time, it is recommended that cooperation between universities and research institutes or enterprises be promoted to facilitate the commercialization of innovations and build an industrial chain for the transformation of innovations so as to further promote economic development.

Thirdly, the state should adjust the education model and science policies. In the findings of this paper, the number of scientific and technical journal articles is significantly positively correlated with the development of the economy. Therefore, it is recommended that the state increase investment and support for basic science research and improve the higher education system, especially in science and engineering fields, that can output more results. Increased investment in the optimization of the education system will improve

education quality and enhance research capacity at the national level, thereby increasing national knowledge output and sustained technological innovation in the long term.

Fourthly, regional differences should be considered when implementing strategies in individual European countries. The research in this paper shows that differences are existing in the impact of FDI and R&D on the growth of economy across regions such as Central and Eastern Europe. Therefore, policies should take into account regional specificities and be customized to fit the structure and stage of development of each economy.

Finally, cooperation and synergies among various national sectors should be promoted. Closer cooperation between the education, science and technology, and economic sectors should be promoted to ensure policy coherence and efficiency. For example, cross-sectoral committees could be set up with specific responsibility for coordinating and monitoring the implementation of policies and the evaluation of results in these areas.

4.3 Limitation

Firstly, the sample is limited and represents 30 European countries, 12 of which are CEE (Central and Eastern European) countries. Geographically, these countries are located in close proximity and are geographically limited. When trying to generalize the results of this paper to other regions, such as Asia, Africa, or the Americas, the generalization of the research results to the whole world cannot be done or only with limitations.

Different regions have different levels of economic development, policy environments, and cultural backgrounds (Floerkemeier et al., 2021), so these differences may lead to limited application of the results in other regions and lower reference values. Therefore, future research can consider expanding the sample to more countries and regions so that the empirical results can be adapted to more regions and be generalizable.

Secondly, there are limitations in time. The time period studied in this thesis is between 1998 and 2021, and this time limitation also threatens the long-term reference value of the findings. During this time period, the European economy has experienced a number of major events, such as the 2008 financial crisis and the global epidemic in 2020.

These events have had a profound impact on economic activity. However, the findings may not reflect long-term trends beyond this time period. Evolving economic and social structures, new technological advances, and policy changes may alter the applicability of research findings. Therefore, future studies need to update the data and extend the study period to more recent years to capture the latest trends and changes.

Thirdly, there are methodological limitations. Although the fixed effects model and GMM (generalized method of moments) estimation methods are used in thesis to address many issues in econometrics, these methods have limitations of their own. The GMM method, although advantageous in dealing with endogeneity, is dependent on the choice of instrumental variables for its effectiveness, and the quality of the instrumental variables directly influences the accuracy and robustness of the estimation results. In addition to fixed effects and GMM, other advanced techniques, such as vector autoregression models and the Granger causality approach (Nupehewa et al., 2022) etc., may provide more insights and more accurate estimates. Therefore, future research should explore and apply these advanced techniques to enhance the accuracy and credibility of the findings.

Fourthly, there are data limitations. Data quality is the foundation of any empirical study. In the time period from 1998 to 2021, the method of calculating GDP changed sometimes. The ESA 2010 framework replaces the previous ESA 95 and brings some important changes (Eurostat, 2014). However, this does not affect the performance of the data in this article. In addition, this thesis relies on the World Bank's data reports, and the accuracy and consistency of these data are critical to the findings. Although World Bank data are widely used and considered to be of high quality, errors, and biases are inevitable in any data source. For example, variations in data collection methods, inconsistencies in statistical standards, and reporting errors can affect the accuracy of data. If these errors and biases are not adequately identified and corrected, the results of the study may be compromised. Therefore, researchers need to be vigilant about data quality when using data and perform data validation and correction wherever possible to ensure the findings' reliability.

Fifthly, the problem of endogeneity. Endogeneity is a common problem in

econometric research, which refers to the unclear direction of causality or the explanatory variables and the error term correlation in the model. This thesis uses the GMM approach to address the endogeneity problem, an approach that corrects for bias in the model through the instrumental variables' use. However, finding the perfect instrumental variables is challenging, and the choice of instrumental variables is appropriate if they are highly correlated with the endogenous variables but not with the error terms. In practice, however, it is difficult to completely eliminate endogeneity. Some potential endogeneity may still exist, thus affecting the accuracy of the study results. Therefore, future research needs to explore the endogeneity issue in greater depth and explore new methods to address this issue more effectively.

4.4 Recommendation for future development

Firstly, more control variables can be included in the study. Due to the limitation of the control variables volume in the model in this thesis, more control variables can be introduced to reduce the bias caused by the omission of control variables. Introducing more control variables can affect the significance and relevance of the conclusions in the original model, which can be further researched and investigated, thus improving the accuracy of the original model and providing more comprehensive analysis results. Enhances the robustness of the results by adding more control variables. It helps to exclude the influence of other control factors and makes the research results more robust. In addition, more control variables help future studies conduct multi-level analysis, make more targeted policy recommendations, and reduce the risks associated with imperfect policy implementation.

Secondly, indicators for measuring innovation can be added in future studies. In this study, through three indicators to measure innovation, future research should introduce more dimensions of innovation indicators. These indicators can reflect not only the direct results of innovation but also the links and factors in the innovation process. For example, the number of citations to a patent reflects the impact and value of the technology. The number of scientific researchers and scientific degrees awarded can reflect the human

capital of innovation and the ability to cultivate high-quality talents. Introducing relevant innovation policies and regulations can show a country's innovation achievements in the system. The market share and number of exported innovative products can also indicate the international competitiveness and value of a country's innovation capability. The introduction of multi-dimensional indicators to measure innovation can reflect innovation activities more comprehensively and provide more operational policy recommendations.

Thirdly, future research can continue to expand the sample capacity. In this study, we focused on analyzing the performance of European countries, but most of the European countries are developed countries. Future research can expand the sample to countries at different stages of development, such as developing countries. This would help to validate the generalizability of the research results, and at the same time allow for further comparisons between different regions of the world. In addition to this, expanding the sample allows for the use of more complex and advanced statistical models to study more interactions between variables, which helps to understand more complex relationships.

Fourthly, future research can extend the time span and thus analyze cyclical changes. Some of the trends are not obvious in a short period of time, and a longer time period is needed to effectively separate short-term fluctuations from long-term trends. Therefore, a longer time period is more conducive to observing changes, and the designation of long-term development strategies and the collection of national data are of great significance. In addition to the impact of economic cycles, cycles of social and political change can also cause some degree of variation in data results. Extending the time span is more conducive to macro analysis from multiple perspectives, thus overcoming the problems of current policies. In addition, the length of the time period is conducive to improving the predictive accuracy of the existing findings for future outcomes, predicting dangers, and providing solutions to problems that may arise in the future.

Fifthly, more novel and scientific methods are attempted to improve data quality. This study only used data from one database, and data from different data sources should be integrated in future research, which is conducive to reducing data errors, and the credibility and accuracy of the data will be improved. In addition to this, subsequent studies should

validate and proofread the data to reduce errors. The article specifically describes high-quality data to make more transparent and fairer source and processing, which is conducive to the use and judgment of subsequent studies. Finally, high-quality data helps reduce uncertainty in subsequent studies and produce reliable and accurate conclusions.

Conclusion

This thesis mainly researches the relationships among FDI (foreign direct investment), innovation, and economic growth in Europe from 1998 to 2021. Studying the relationship between the three, can enhance the existing research model of FDI and innovation and further promote the coordinated economic development of the European region, after detailed data analysis and empirical studies, such as fixed-effects regression test, endogeneity test, robustness test, and heterogeneity test. This study draws several important conclusions, which not only validate some of the views of the established literature but also propose new insights and reflections.

Firstly. the study finds that FDI's increase can significantly improve the economy in Europe. During the study period, a large amount of FDI was attracted in European countries, which contributed to progress and national economic models' upgrading. It not only enhanced the comprehensive strength and competitiveness of the country but also thereby promoted the economy's development.

Secondly, innovation's importance in driving economic growth has been further validated. The thesis has studied that expenditure on R&D drives economic development insignificantly. In addition, patent applications have a non-significant and negative effect on the growth of the economy, and the number of articles has a significant and positive influence on the economy's growth. Therefore, the increase in innovation activities, such as the expenditure of R&D increase and the scientific articles increase, indirectly drives economic growth in Europe. In addition, it researched that FDI and R&D interaction terms have negative and significant relationship with economy's growth. It indicates that the FDI on R&D expenditures' spillover effect is not substantial enough to push the country's

economic development.

This thesis' primary contribution is providing recent empirical evidence for complex interactions among FDI, innovation, and economic growth, especially their relationship with economic growth in CEE countries. The thesis highlights key areas that policymakers should focus on when promoting economic growth. Through a detailed analysis of European countries, the author finds differences existing in the performance of FDI and innovation across countries and regions. Some countries have been able to capitalize on the opportunities presented by FDI and achieve rapid economic growth. Some countries have not been able to make a significant impact and need to strengthen their economic systems to better attract and utilize FDI.

The study also points out that policymakers should consider the effect of interaction between innovation and FDI when formulating economic policies. It shows that innovation activities are associated with FDI, which allows for the expansion of activities and leads to economic growth. In addition, governments should increase investment in research, encourage technological innovation, and support the transformation and commercialization of scientific and technological achievements. These measures not only help to improve the country's innovation capacity but also attract more high-quality FDI, which can significantly promote the economy's sustainable development.

In conclusion, through relevant data analysis, people now have a clearer cognition of FDI and innovation's importance in the growth of the economy and the dynamic relationships in them. Innovation and FDI are not only economic growth's important drivers but also interact with each other to significantly impact economic development. These findings not only let the existing literature be enriched but also supply valuable references for policy making.

Future research could further explore the differences across countries and industries to deepen the understanding of this relationship. For example, it can examine different types of FDI, innovation, and economic growth's influence, analyze technological innovation in different industries, and explore the moderating role of policy measures in different countries on the interaction between FDI and innovation. In addition, due to the changes in

the global environment of the economy, the study can also focus on the impact of external shocks (e.g., the global financial crisis, epidemics, etc.) on the relationships between innovation and FDI, and provide policy recommendations to cope with future uncertainties.

The analysis in this study not only deepens our cognition of the complex relationships among FDI, innovation, and growth of the economy but also supplies useful lessons for policymakers. Effective policy measures can achieve sustainable economic growth and enhance a country's competitiveness and development by promoting innovation and attracting high-quality FDI. The author hopes that this thesis's results will provide valuable reference and guidance for economic development in Europe and globally.

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