Is Poland heading in the direction of high economic prosperity?

Master Thesis

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Executive summary

This thesis investigates whether Poland is on a sustainable path toward long-term economic prosperity, particularly in comparison to advanced economies such as South Korea. Researchers are divided on Poland's growth trajectory, some highlighting promising fundamentals, while others warn of the risk of stagnation (Brzyska, 2023; Piatkowski, 2019). The innovative outcomes of Poland and its R&D spending remain significantly below the averages of both the EU and OECD countries (Vienna Institute for International Economic Studies, 2023). This raises concerns about the country's long-term ability to generate endogenous growth and maintain convergence with more developed economies. Some scientists argue that Poland could experience a stagnation similar to the one experienced in middle-income trap, meaning a rapid growth slowdown after period of growth, but at the high-income level. This study assesses the structural factors behind Poland's growth and identify whether the country is at risk of falling into a middle-income-style trap at the high-income level. More specifically the stuctural factors analysed include human capital, distance to technology frontier, R&D Stock, government spending on education, foreign direct investments, sectoral diversification and product market regulations.

To systematically evaluate Poland's prospects for economic prosperity, this study adopts a three-step analytical approach. First, it examines whether Poland is currently experiencing a growth slowdown. Using the framework proposed by Eichengreen et al. (2014), the findings suggest that Poland has not entered a structural slowdown up to 2019, and therefore does not meet the formal criteria for a growth trap. However, the economy has exhibited periods of decelerated growth following earlier catch-up phases, highlighting a cyclical growth pattern that aligns with economic theory on development waves and reflecting another common finding in the literature: countries closer to the technological frontier tend to grow slower. This gradual deceleration aligns with convergence theory, which predicts that as countries reach higher levels of development, they face diminishing returns to investment and innovation, resulting in lower growth rates even at comparable levels of investment.

In the second step, this study examines the structural factors underpinning long-term economic growth by developing a panel data regression model grounded in endogenous growth theory. The analysis, based on a cross-country dataset of 67 economies, revealed that capital accumulation remains key driver of GDP growth. Importantly, R&D stock and FDI were also found to have a statistically significant and positive influence on growth in certain model specifications. Surprisingly, human capital showed a negative direct influence in all of the cases, a finding that while counterintuitive, is also found in other empirical studies (Stöllinger, 2013). This outcome may arise from the fact that human capital does not directly drive growth in all contexts, but rather functions as an enabling condition that facilitates other growth-enhancing mechanisms. In line with the catch-up effect proposed by Howitt and Mayer-Foulkes (2005) and the concept of absorptive capacity found in endogenous growth theory proposed by Lucas (1988), human capital is particularly important for a country's ability to absorb and apply external knowledge and technologies. This interpretation is supported by the model specification that includes a catch-up term - defined as the interaction between a country's distance to the technology frontier and its absorptive capacity (proxied by human capital in this study), which revealed a positive and statistically significant effect.

Combined, the conducted research showed outcome supported by the literature, meaning that Research and Development together with Foreign Direct Investment has a potential to increase the growth of a country. Additionally, the results support a theory that countries further from the leaders have a grater potential for growth, but must meet the basic levels of human capital to fully use it. On the other hand, the proposed empirical models do not support the claim that human capital is directly improving the GDP growth of a country, but rather is an enabling factor in catch-up potential. Lastly the models' results for Poland closely match the actual GDP values, demonstrating a strong and promising fit.

In the third step of research, South Korea is presented as a reference case, a country that transitioned from poverty to innovation-led prosperity within a few decades. The comparison between Poland and

South Korea reveals that Poland is performing well in total factor productivity, but it lags behind in key technology and structural indicators, especially R&D intensity, human capital quality and sectoral diversification. The country comparison also incorporates insights from the panel regression analysis. Specifically, a simulation was conducted using the estimated endogenous growth model to project the path of Poland's GDP using South Korea's benchmark values. Although this exercise did not produce a dramatic increase in GDP, it nevertheless highlights clear possibilities for Poland to strengthen its innovation inputs and realize more substantial long-term gains.

Based on the findings of this three-step research, several strategic areas of Poland's improvement have been identified, particularly within the framework of the World Bank's "3i" strategy: Investment, Infusion, and Innovation (World Bank, 2024). Although Poland has successfully attracted substantial foreign capital over recent decades based on the findings of the thesis, indicating a relatively strong performance in the investment dimension, the next phase of growth requires more effective deployment of these resources to generate domestic value through knowledge and technology infusion. To facilitate this transition, Poland should focus on, enhancing absorptive capacity through targeted investment in human capital—particularly by strengthening higher education and skills development. This should be followed by the strategic adaptation and integration of foreign technologies and capital across key sectors to ensure they contribute to domestic innovation (Vienna Institute for International Economic Studies, 2023).

Switching to the third "i" of the World Bank (2024) framework - innovation, the data suggests that Poland lags behind advanced economies in R&D intensity, as was shown when compared to South Korea. To address this gap and exploit the potential shown in simulations, policy recommendations point towards expanding access to equity financing, developing more mature capital markets, and building innovation infrastructure such as research centers, incubators, and technology parks to retain and empower domestic talent. These measures align with the World Bank's guidelines for enhancing national innovation capacity and supporting sustained growth in R&D intensity. Addressing the gap in funding for research and start-ups is essential for cultivating homegrown innovation. Similar dynamics have been noted by Mario Draghi in other Western European nations, suggesting that coordinated EU-level initiatives could amplify these efforts and deliver optimal outcomes (Draghi, 2024).

Lastly, based on the empirical model outcomes from the thesis and the U-shaped relationship between sectoral diversification and GDP growth (Imbs & Wacziarg, 2003), Poland should reconsider its fragmented market structure. This theory suggests that while diversification supports growth at early stages of development, excessive diversification can eventually reduce efficiency. Compared to South Korea, Poland's broader sectoral diversification may now limit economies of scale, knowledge spillovers effects and the formation of internationally competitive industrial clusters. Promoting consolidation in key international sectors could allow firms to specialize and be more competitive globally.

Acting on these findings gives Poland's senior economic policymakers, especially the Ministry of Finance, the Ministry of Development Funds and Regional Policy, and parliamentary committees responsible for innovation and industrial strategy, a clear agenda for sustaining high-income growth and securing the country's place among the world's innovation-driven economies. This agenda synthesises the thesis's three-step analytical framework with policy recommendations from the World Bank's respected "3i" strategy (World Bank, 2024) - transforming broad international guidance into concrete, Poland-specific policy actions.

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Introduction

1.1. Background

Poland's transition from a centrally planned to a market-oriented economy, initiated in the early 1990s, has been celebrated as a significant success story among former Eastern Bloc nations (Hunter & Ryan, 2011; Piatkowski, 2013). Following the collapse of the Soviet Union, Poland adopted a series of economic reforms collectively known as the Balcerowicz Plan, which aimed to stabilize inflation, liberalize trade, and privatize state-owned enterprises (Hunter & Ryan, 2011).

A critical factor in this transformation has been Poland's ability to diversify its economic structure, moving away from its historical reliance on agriculture and traditional heavy industries toward a more balanced economy. Today, Poland boasts robust growth in high-value sectors such as technology, high-tech manufacturing, and services. These shifts have not only bolstered GDP growth but also enhanced the country's integration into global value chains, particularly within the European Union, of which it became a member in 2004 (Piatkowski, 2019; World Bank, 2024).

Despite these accomplishments, Poland faces significant hurdles in maintaining its upward trajectory. The nation remains vulnerable to stagnation risks associated with the middle-income trap, a phenomenon where countries experience a very rapid growth from low-income to middle-income followed by a significant growth slowdown that is very difficult to push-through. While Poland has officially reached high-income classification (World Bank, 2024), the comparative developmental gaps with advanced economies like South Korea and the EU average highlight the pressing need for further innovation-driven growth and infrastructural improvements. Addressing these challenges is critical to ensuring Poland's long-term economic success and preventing stagnation in its transition toward a fully developed economy (Brzyska, 2023).

In order to address the risk of stagnation inherent in the middle-income trap, the World Bank developed a framework to help countries continually advance. The core principles of the 3i strategy align in large part with the well-known endogenous growth model by Acs and Sanders (2021), but while the endogenous growth model is more theoretical, the 3i strategy offers practical guidance on the areas that countries should prioritize to prevent long-term stagnation. This pragmatic focus makes the 3i framework particularly useful for comparative analyses, highlighting concrete actions and investments that can sustain and reinforce their economic development over time.

1.2. Problem statement

Although Poland has achieved high-income status according to World Bank (2024), and while its GDP progress is clear in absolute values, progress in factors that influence long-lasting growth remains uneven, raising concerns about its ability to close developmental gaps with leading advanced economies in the long-run. The broader issue lies in Poland's limited success in fostering an ecosystem conducive to innovation, high-value-added economic activities and a lack of specialization (Imbs & Wacziarg, 2003; Vienna Institute for International Economic Studies, 2023). Research and development (R&D) spending as a percentage of GDP, for example, remains below the EU and OECD average, and the country lags in adopting cutting-edge technologies necessary for global competitiveness.

This research seeks to address these challenges by investigating Poland's performance in the critical factors that enable successful transitions from stagnating economies to high-income, growth champion economies in the long-term. By comparing Poland's economic trajectory with that of South Korea, a nation that has successfully avoided the middle-income trap (Lee, 2024). Using a quantitative comparative analysis of key economic indicators within the endogenous growth model and "3i" framework (Investment, Infusion, and Innovation)(World Bank, 2024). The result of the research can be valuable starting point to identify actionable strategies for Poland to overcome stagnation risks, bridge developmental gaps, and enhance its global economic standing, based on the comparison and gathered data. Ultimately, the study contributes to understanding how middle-income economies can achieve sustained advancement in the modern global economic landscape (Brzyska, 2023; Dutta et al., 2024; World Bank, 2024).

Choosing South Korea as a comparative example for Poland's economic development is supported by several compelling reasons. First, South Korea is widely recognized in academic literature as one of the most successful cases of escaping the middle-income trap, evolving into a powerful global economy, and earning its place among the G20 nations (World Bank, 2024). Second, both countries share a history marked by prolonged struggles for independence. In the 19th century, South Korea was under the influence of Japan and China, while Poland was controlled by Prussia, the Habsburg monarchy, and Russia, only regaining its sovereignty in 1918. Furthermore, both nations endured severe hardships during World War II, confronting significant challenges related to civil rights, exploitation, and loss of life. In the post-war period, Poland grappled with the extensive influence of the Soviet Union, whereas South Korea contended with the devastating impacts of the Korean War and persistent external pressures. Finally, the broader economic environments following liberation have similarly influenced their trajectories: Poland has navigated its development amid the economic clout of Germany, while South Korea has evolved in a context shaped by both China and the United States. (Piatkowski, 2019; Yu, 2000).

It is also important to acknowledge that South Korea's growth trajectory began earlier than Poland's, which was delayed by the constraints of a centrally planned economy. South Korea's extraordinary economic transformation, often referred to as the "Miracle on the Han River", began in the mid-1960s, marked by an average annual real growth rate of approximately 9% (Yu, 2000). In contrast, Poland's significant economic growth commenced in 1989, following the market reforms introduced by Hunter and Ryan (2011). Given that Poland embarked on its market-oriented development later than many high-income nations, comparing both countries using the same historical intervals can be misleading. To address this, a time-shifted analysis will be employed, aligning the countries' developmental stages more accurately and providing a more meaningful framework for evaluating Poland's trajectory relative to South Korea's. The specific intervals and parameters of this analysis will be further refined during the research process.

1.3. Research question

To clarify Poland's growth path and it's potential, this thesis begins by posing a central research question and several more focused sub-questions that guide the subsequent analysis. Together, they provide a structured lens through which to diagnose challenges and identify evidence-based policy responses.

Main research question:
To what extent is Poland progressing toward South Korea's level of economic prosperity, measured by GDP growth and labor productivity?

Sub-research question that can help answer the main research question are:

- **sub-RQ1:** Is Poland experiencing stagnation in the lower range of high-income group?

This question seeks to determine whether Poland is at risk of falling into a growth stagnation trap or if it remains in its expansion phase. To address this question, the analytical framework proposed by Eichengreen et al. (2014) will be applied. His methodology provides a structured approach to identifying and assessing episodes of growth slowdowns in a specific income range, commonly referred to as the "middle-income trap." By leveraging this framework, the analysis will evaluate whether Poland exhibits characteristics associated with growth stagnation or if it continues on a path of sustained economic expansion.

- **sub-RQ2:** What are the structural factors most effectively predicting and shaping the acceleration of GDP growth across countries?

This question aims to identify key areas for comparison by evaluating various indicators that may impact economic growth. The initial selection of these indicators is grounded in the innovation-based endogenous growth model. In addition, other factors with potential influence on GDP growth will be examined. Panel data regression analysis will be performed to enable a thorough assessment of the impact of each indicator on GDP growth over time.

- **sub-RQ3:** How does Poland compare to the South Korea in the levels of key economic indicators?

This question will serve as a foundation for the analysis, highlighting the current differences between Poland and South Korea. It will look into the indicators found in the second question and the more general economic indicators such as GDP growth and labor productivity. Additionally, it will provide historical context together with identification of take-off years for both economies and examine growth trends over time. It will allow for a more accurate comparison of the two countries' economic trajectories. Descriptive statistics will be utilized to identify patterns and correlations between the two countries.

- **sub-RQ4:** What are the areas that Poland need to improve in order to secure the long-term prosperity?

This question will serve as a core component of the thesis, focusing on identifying key areas where Poland needs to improve to maximize GDP growth. It will analyze the specific economic measures in which Poland lags behind Korea. The goal is to assess Poland's economic trajectory and compare it to South Korea's historical development. By shifting South Korea's indicators in time, the analysis will evaluate whether Poland is successfully following a similar expansion path.

2

Theoretical background

This chapter will serve as a basis for methodology and result interpretation. Historical growth trajectories of Poland and South Korea are surveyed first; this is followed by a concise overview of growth theory, tracing its evolution from exogenous technology models through endogenous innovation and human-capital frameworks to open-economy approaches that highlight external knowledge diffusion and catch-up dynamics.

2.1. Countries of interest

Poland's economy has climbed from middle- to lower-high-income status over the past two decades, driven mainly by factor accumulation, structural reforms and EU integration rather than an R&D-led innovation strategy (World Bank, 2024). In contrast, South Korea escaped the middle-income trap through a sustained focus on endogenous innovation, high R&D intensity, human-capital investments and the cultivation of domestic technology champions (Lee, 2024). Comparing these two paths, structural catch-up versus innovation-driven growth, highlights the policy priorities essential for maintaining high-income status.

2.1.1. South Korea

In the immediate aftermath of Japanese colonial withdrawal, the devastation of World War II and the Korean War, the South Korean economy exhibited indicators more akin to chronic underdevelopment than to the dynamic growth that would characterize its later trajectory (Yu, 2000). By 1953, GDP per capita was among the lowest in Asia, domestic savings hovered near zero, and the current account deficit, financed almost entirely by U.S. aid and averaged around 10 percent of GDP, while exports fluctuated at approximately 3 percent of GDP annually (Ito & Krueger, 1995). Monetary and fiscal policies in the 1950s were marked by hyperinflation, multiple exchange rates (with an official rate kept unrealistically low to justify further aid), extensive quantitative restrictions on imports, large public-sector deficits, and labor regulations that maintained urban unemployment rates near 25 percent excluding disguised employment (Jong, 2001). Consequently, annual growth rates of 3–4 percent during this period reflected incremental reconstruction rather than a sustained acceleration in productivity or competitiveness (Ito & Krueger, 1995).

Beginning in 1958, however, South Korea embarked on a series of market oriented policy reforms that fundamentally altered its growth dynamics (Ito & Krueger, 1995). The nominal exchange rate was realigned to provide a more competitive basis for exporters, while comprehensive export subsidies and incentives were introduced to offset the import substitution bias inherent in earlier trade regimes (Jong, 2001). Quantitative import controls were progressively dismantled, permitting export-oriented firms uninterrupted access to necessary inputs. Concurrently, budgetary reforms in the mid 1960s reduced fiscal deficits, and inflation declined to an average of around 10 percent by the late 1960s (Ito & Krueger, 1995). These changes precipitated a marked rise in national savings and investment rates, a transformation of the current account from persistent deficits to occasional surpluses by the 1980s, and three decades of rapid GDP growth, averaging nearly 8 percent per year, as South Korea evolved from aid dependency to one of the world's most dynamic economies (Ito & Krueger, 1995; Lee, 2024).

2.1.2. Poland

In the twilight of communism in 1989, Poland emerged as one of Europe's poorest and most indebted states. Decades of centrally planned industrialization and quotas had left its heavy-industry backbone obsolete, agriculture undercapitalized, and consumer goods scarce, shortages so severe that ration coupons were still in use for flour, sugar and even basic toiletries (Piatkowski, 2019). Poland, wanting to escape its poor condition in comparison with other countries in Europe, embarked on one of the most rapid transitions from a centrally planned to a market-based economy among its post-communist peers. The Balcerowicz reform package, implemented January 1990, combined tight macroeconomic stabilization (bringing hyperinflation down from over 50 percent per month), liberalization of prices and foreign trade, and an aggressive privatization program (Hunter & Ryan, 2011). Though real GDP fell by roughly 15 percent between 1989 and 1991, the recession was both shallower and shorter than in neighboring transition economies and by 1996 GDP had returned to its pre-reform level, five years faster than almost any other East European country (De Broeck & Koen, 2006). Between 1996 and 2001, GDP in constant prices grew a further 30 percent, driven by annual average GDP growth rates of over 5 percent and underpinned by a surge in private-sector activity (whose share of GDP rose from 30 percent in 1989 to 70 percent by 2000) and sustained investment, much of it foreign-financed (Salamaga, 2023; Vienna Institute for International Economic Studies, 2023).

By the late 1990s, Poland faced renewed imbalances, including accelerating inflation (peaking at over 10 percent in 2000) and a rising current-account deficit (near 8 percent of GDP), which prompted the central bank to raise interest rates from 13% in 1999 to 19% by September 2000. This tightening, together with weaker external demand following Russia's 1998 crisis, slowed investment growth and carried GDP expansion down to just 1.2% in 2001 (Kjærgaard Larsen, 2002). Nevertheless, by the end of 2001 Poland had already surpassed most transition economies in terms of per-capita output, and its structural transformation from centrally planned economy to market oriented economy transforming the income structure — where industry and agriculture once accounted for over 55 percent of GDP to one where services dominate (Kjærgaard Larsen, 2002). It has drawn it closer to EU standards. With inflation brought back under control and the central bank pivoting again to ease policy in 2001/2002, Poland's long-term growth trajectory remained relatively intact.

Joining the European Union in May 2004 was a turning point that reshaped Poland's economy, governance, and its role in Europe (Piatkowski, 2019). First and foremost, EU membership provided Poland with a clear, binding framework of laws and standards, known as the acquis communautaire, that covered everything from product safety to environmental protection to competition rules. To meet these requirements, Poland overhauled its public administration: thousands of new regulations were adopted, judges and inspectors were retrained, and transparency measures were introduced to reduce corruption. These changes not only aligned Poland with Western Europe's legal and regulatory environment but also built trust among foreign investors and trading partners, giving Polish businesses the confidence to expand and the certainty that contracts and property rights would be respected (Michałek & Hagemejer, 2024).

At the same time, EU membership opened the doors to the single market of over 450 million consumers. German, Dutch, and Scandinavian firms established production lines in Poland, attracted by its skilled workforce and lower labor costs, creating jobs in manufacturing, logistics, and services (Brzyska, 2023). Equally transformative were the structural and cohesion funds: between 2004 and 2013, Poland received more than €67 billion in grants, more financial support than any other member state, to build modern highways, upgrade rail corridors, improve regional airports, and expand broadband internet access (Michałek & Hagemejer, 2024). These investments cut travel times, linked Poland's regions more closely, and provided the digital backbone necessary for a modern, knowledge-based economy. As a result, Polish GDP per capita (in purchasing-power terms) climbed from roughly 40 percent of the EU-15 average in 2004 to over 65 percent by the early 2020s, significantly narrowing the gap with Western Europe and cementing Poland's place as one of the EU's fastest-growing members (Piatkowski, 2019).

2.1.3. Take-off years

Poland and South Korea each faced years of economic struggle before entering periods of rapid growth. In both cases, GDP growth soon surpassed that of their neighbors, driven by a focus on exports and inflows of foreign investment during the early stages. Comparing their experiences highlights how different paths can lead to similar take-offs.

South Korea: After 1962, South Korea shifted to making goods for export, supported by a competitive exchange rate, export incentives, and fewer import restrictions. This change, described in Section 2.1.1, helped the economy grow by over 8% each year for the next thirty years (Kuznets, 1971). Large investments in roads, schools, and training improved productivity and savings, turning Korea from one of Asia's poorest countries into a leader in electronics and shipbuilding. That is why the year of Take off for South Korea would be 1962.

Poland: Poland's fast growth began after the sharp recession of 1989–1991. The "shock-therapy" reforms-freeing prices, cutting government debt, privatizing state companies, and unifying exchange rates, set the stage for market-driven expansion. From 1992 onwards, GDP grew by 4–5% a year, and after joining the EU in 2004, growth picked up further. Like Korea, Poland relied on exports, but it built on an existing industrial base and used EU membership to attract investment and join European supply chains (De Broeck & Koen, 2006). That is why the take-off year for Poland would be 1992.

Both stories show that bold reforms, along with opening to world markets, can spark a strong and lasting take-off. South Korea did this through state-led industrial policies in the 1960s; Poland did it through quick liberalization and EU ties in the 1990s. In each case, a clear plan, investment in competitiveness, and the will to change made the difference.

2.2. Growth Theory

This section reviews the evolution of growth theory and alternative explanations for economic progress, establishing the theoretical backbone for the empirical analysis and shaping the policy recommendations in the concluding chapter.

2.2.1. Exogenous Growth

First introduced in the mid-1950s by Solow (1956) and Swan (1956), the Solow–Swan model, also known as the neoclassical growth model, established the foundational framework for analyzing economic growth. The Solow–Swan model begins by assuming a closed economy with no government or trade, a fixed saving rate s, and exogenous, constant rates of labor growth n and technological progress g. Output is produced by a function

$$Y = F\big(K,\, A,\; L\big) \tag{2.1}$$

where

K physical capital stock (e.g., machinery, buildings, infrastructure),

A total factor productivity (TFP),

L labor input (number of workers or total hours worked).

that exhibits constant returns to scale (doubling all inputs doubles output) and diminishing marginal returns (adding more of one input yields progressively smaller output gains). Technology A grows independently of economic decisions ("exogenous") and only augments labor ("labor–neutral"), ensuring that in steady state output per worker grows at rate g and the economy does not collapse.

In the exogenous model, economies with the same A and $f(\cdot)$ converge to the same level of output. This means that when two countries share similar savings rates, population growth, depreciation rates and access to technology, the country starting with less capital per worker will grow faster and "catch up" to the richer country's capital intensity. The intuition is simple: with fewer machines per worker, each additional unit of capital generates a larger boost to output, so poorer economies enjoy higher marginal returns on investment (Solow, 1994).

Over time, as capital accumulates, these high returns decline, diminishing returns gradually slow the catch-up process. Empirical studies translate this into a "speed of convergence," which tells what fraction of the gap between current capital per worker and the steady state level is closed each year.

However, the exogenous nature of A has been criticized and sparked a new approach for growth modeling.

2.2.2. Endogenous Growth

Over the past few decades, growth theory has moved beyond exogenous models like Solow–Swan toward frameworks that internalize technological progress. Romer's article "Endogenous Technological Change" epitomizes this shift: growth arises from deliberate, incentive-driven investments in knowledge rather than unexplained external forces (Romer, 1990). By treating technology as a nonrival good, Romer introduces a crucial nonconvexity into the production function, which precludes price-taking and requires a monopolistic-competition setting. In this environment, firms allocate resources between production and R&D, earning temporary monopoly profits on new ideas and thereby sustaining innovation.

Robert Lucas proposes a different endogenous-growth paradigm by placing human-capital accumulation at its core (Lucas, 1988). He argues that differences in education, skills and learning-by-doing account for the vast disparities in national growth trajectories. Formally:

$$Y_t \;=\; A_t\, K_t^{1-\beta}\big(h_t L_t\big)^{\beta}, \tag{2.2}$$

where

h_t stock of human capital *per worker*, capturing education, skills, and learning-by-doing; it scales the effectiveness of labour so that total "effective labour" is $h_t L_t$.

In Lucas's framework, spillovers from human-capital investment generate aggregate increasing returns, enabling sustained growth even in the absence of exogenous technological shocks.

Moreover, in open-economy settings, foreign direct investment (FDI) provides a measurable channel for this knowledge spillovers: multinational firms bring capital, advanced technologies, managerial know-how and global networks that domestic actors with high absorptive capacity can recognize, assimilate and extend through local innovation.

Building on these foundations, Howitt and Mayer-Foulkes (2005) propose a two-channel framework in which both innovation and imitation drive productivity gains. R&D remains the source of novel ideas, while imitation allows lagging economies to adapt foreign frontier technologies to their own contexts. The effectiveness of both channels depends critically on a country's absorptive capacity, shaped by human capital, institutional quality and policy environment.

Howitt and Mayer-Foulkes (2005) together with Acemoglu (2009) also emphasize that non-technological "fundamental causes" like: geography, institutions and macroeconomic policies, further shape total factor productivity. Drawing on their derived growth equation, a country's long-run competitiveness and prosperity depend not only on its distance to the global frontier but also on key endogenous parameters:

- λ — productivity of the innovation process
- ϕ — incentive to innovate
- β — incentive to save
- ξ — quality and quantity of education

In the early stages of development, investments in absorptive capacity and imitation skills drive convergence. Lagging countries must therefore strengthen higher education, institutional frameworks and R&D linkages to avoid divergence and sustain long-term growth. As economies approach the frontier, however, "modern R&D" and policies that foster domestic innovation become paramount.

Catch-Up: Two Key Insights

Building on the framework by Howitt and Mayer-Foulkes (2005) and mentioned imitation, the concept of catch-up refers to the additional growth premium available to countries lagging behind the global technological frontier. However, this process is far from automatic. Two important aspects shape how the catch-up mechanism operates in practice:

1. **Large gaps require large investments.** The wider the gap to the global frontier, the greater the effort required to close it. Latecomers must invest disproportionately in R&D, human capital and institutional reform to improve the core parameters that govern innovation and imitation—namely, λ (productivity of innovation), ϕ (incentive to innovate), and ξ (educational quality) (Cohen & Levinthal, 1990; Howitt & Mayer-Foulkes, 2005). Without sufficient absorptive capacity - reflected in education systems, R&D infrastructure, and institutional quality—countries cannot effectively internalize and apply foreign technologies. In such cases, rather than convergence, technological gaps may persist or even widen, leading to long-term divergence.
2. **Further behind can mean faster growth if capacity is adequate.** If a country meets the minimum threshold of absorptive capacity, the distance to the frontier becomes a source of accelerated growth. Formally, this catch-up is defined as the differential growth premium that arises when a country's technology capabilities lies below the frontier, similar to the one observed in the exogenous growth theory but, conditional on its absorptive capacity, the stock of human capital, institutional quality, and R&D infrastructure that determines how well it can internalize and adapt imported technologies (Howitt & Mayer-Foulkes, 2005). This results in a relationship between the size of the gap and growth: the gains from catching up increase with distance, up to the point where absorptive constraints become binding, after which returns taper off (Acemoglu, 2009). This dynamic explains why some countries (e.g., Poland) may initially benefit from imitation-led growth, while others with similar gaps but lower absorptive capacity stagnate. It also underpins convergence-club regressions, which test whether economies like Poland are equipped to exploit their technology gap, or whether human capital bottlenecks and institutional rigidities hinder their progress (Stöllinger, 2013).

This understanding of catch-up is central to the thesis, especially given Poland's gap in innovation and technological capabilities relative to high-performing economies such as South Korea. Verifying the empirical relevance of this imitation mechanism and identifying how it can be strengthened is a key research objective.

Convergence Clubs

Building on above observations, Steven Durlauf show that cross - country growth processes don't need to follow a single, smooth production function but can instead switch between distinct "regimes" once observable thresholds such as: per - capita income, human capital levels, or institutional quality are crossed (Durlauf & Johnson, 1995). In their multiple - regime framework, the elasticities of output with respect to capital, labor, and technology inputs are allowed to take on different values in each regime, uncovering systematic differences in aggregate production functions across countries with varying initial conditions. This regime - switching approach thus provides a formal justification for modeling growth as converging to multiple steady states rather than a single global equilibrium. Empirical work such as the one by Stöllinger (2013) or theoretical work by Howitt and Mayer-Foulkes (2005) typically distinguishes three groups :

- **Innovation Club**: frontier economies with high R&D intensity;
- **Imitation Club**: middle-income followers leveraging adaptation and FDI spillovers;
- **Stagnation Club**: low-skill, low-institution environments trapped far from the frontier

Club membership conditions the speed and even the possibility of convergence. As for the countries of interest, Poland is generally classified in the Imitation Club, while South Korea graduated to the Innovation Club in the 1990s.

Growth Slowdown and the Middle-Income Trap

Switching from the Imitation to the Innovation regime is challenging. Failure to make that leap can lead to the middle-income trap, a critical concept in development economics. It refers to the stagnation many middle-income countries face when they fail to sustain the growth required to transition to high-income status or innovation club member. Researchers such as Aghion and Bircan (2017) and Gill et al. (2007) emphasize that escaping this trap requires transitioning from resource- or labor-intensive growth to innovation-driven growth, also see Table 2.1, which combines the drivers of growth, together with areas of competition for each stages of growth. Other authors also observe this phenomenon, they underline that countries that experienced a significant growth due to catch-up effect (see Section 2.2.2), have to switch their economic approach to sustain growth (Aghion & Bircan, 2017). Unfortunately, when policymakers overlook this shift, economies tend to level off on a growth "plateau," and the rapid expansion observed during the catch-up phase gives way to prolonged slowdown.

Poland, having moved into the high-income category, exhibits strong indicators of economic dynamism but remains vulnerable to stagnation due to weak innovation infrastructure, as suggested by Brzyska (2023). These insights highlight that Poland's economic strategies must address not only short-term GDP growth, but also mitigating the risks of growth slowdowns in the long-run. It can be attained through sustained investment in innovation and technology (World Bank, 2024).

3i strategy

The World Bank (2024) Investment–Infusion–Innovation ("3i strategy") draws on the endogenous growth theory and gives insights for stagnating countries :

1. **Investment** — build core infrastructure and human-capital stock;
2. **Infusion** — import and diffuse frontier technologies and knowledge via trade and FDI;
3. **Innovation** — foster domestic R&D and an ecosystem of entrepreneurship.

The main value provided by this strategy is its practical approach, with easy to understand directions for all the country's leaders to implement. In essence, the 3i strategy provides a comprehensive road map that operationalizes the abstract mechanisms of endogenous growth theory into a sequence of targeted policy initiatives(World Bank, 2024). By first establishing a strong base of investment, then strategically and efficiently infusing the economy with external high value added advances and technologies, and finally fostering an ecosystem of domestic innovation, middle-income countries can create a virtuous cycle of growth. That is in line with the literature about the catch-up (initial phase of growth), and innovation based growth later on in order to push through the middle-income trap (Aghion & Bircan, 2017). This cycle not only accelerates their transition to high-income status but also ensures that the growth achieved is both robust and sustainable over the long term.

Table 2.1: Stages of growth summary

Stages of Growth	Income level	Drivers of growth	World Bank 3i Strategy	Proxy variable(s)	Areas of competition
1. Initial stage	Low-income	Accumulation of physical capital	INVESTMENT	Stock of Capital, FDI inflows, Sectoral diversification	Price competitiveness, Product quality
2. Imitation stage	Middle-income	Absorptive capacity, Assimilation of know-how and technology	INVESTMENT INFUSION	Human Capital, Education quality, FDI inflows, Product market regulations	Mix of: Price competitiveness and Product / services quality
3. Innovation stage	High-income	Domestic innovation	INVESTMENT INFUSION INNOVATION	R&D investments, Sectoral specialization, Human Capital	Technological leadership, Quality of services

2.3. Empirical work

Empirical research on economic growth has evolved significantly over the past four decades, reflecting both methodological innovations and the expanding breadth and depth of available data. In the late 1980s and early 1990s, studies such as Barro (1994) incorporation of human - capital proxies into classical Solow - type regressions and Mankiw (1992) empirical extension of the Solow model laid the groundwork for what became known as the “conditional convergence” literature. Main findings of the work relate to the conditional convergence of countries. Meaning that countries that start from the lower GDP in comparison to frontiers tend to grow faster. However, that is true only if other variables are held constant. The other finding is that human capital - proxied by school attainment in years is different for man and woman. Barro found that male education has a positive effect on GDP growth, while female education appears to have a negative effect. He suggests this may reflect a “convergence” phenomenon: when the gap between male and female schooling is large (women’s education is relatively low) a country is likely less developed and therefore has greater potential for rapid catch-up growth. But in general the human capital have possitive influence on the GDP growth. Economies with more educated workforces not only exhibit higher levels of productivity and faster technology adoption, but they also enjoy more rapid “catch-up” growth when starting from a low income base.

These early works relied on cross - country panels, often fewer than 80 countries and employed ordinary least squares (OLS) regression techniques. Limited by inconsistent national accounts and patchy schooling or investment data series (e.g. Penn World Table v.5), these studies nonetheless provided tentative evidence that, once adjusted for savings rates, population growth, and human - capital investment, poorer economies tended to grow faster than richer ones.

By the mid 1990s, the debate over convergence deepened as scholars like Sala-i-Martin (1996) dramatically increased the sample size, extending tests to nearly 100 countries. His key insight was that each economy tends to converge toward its own steady-state income level, driven by country-specific fundamentals, such as savings behavior, population growth, human-capital accumulation, and institutional quality. Consequently, while poorer countries grow faster than their richer counterparts, they do not all reach the income levels of the wealthiest nations. Instead, they “catch up” only to the point determined by their unique structural characteristics. And more from the modeling perspective, Islam and others pioneered dynamic panel-data estimators to address endogeneity and unobserved heterogeneity (Islam, 1995). As Datasets improve and extended coverage from 1950 through 2000 and later - improved price-index harmonization, researchers could both lengthen their time horizons and explore “club convergence” - the hypothesis that convergence occurs within subgroups of countries rather than universally.

Entering the mid - 2000s, empirical growth studies embraced structural and micro-level data in order to unpack aggregate patterns. Wieser (2005) tested endogenous growth models by examining R&D spillovers. The emergence of rich micro datasets, especially from fast-growing economies like China and India - allowed scholars to link macro - level growth trajectories to firm level investment, technology adoption, and productivity dynamics. Authors found a positive relation in investment in R&D and GDP Growth. Furthermore, indicated that countries (even from lower classes) fail to invest into the R&D efforts they risk spiraling down, and widening the gap between technology frontiers and them.

The most recent trend is to apply machine learning techniques to get more data for the better and more accurate models. With the availability of Big-Data, researchers are including factors that were previously unchecked, and they try to find a causal relation between variables (Harding & Hersh, 2018). Author show how different techniques are changing the landscape of empirical work among economist. The influence of ever richer data is unmistakable. Early cross-country regressions were often noisy, limited by small samples and measurement error - today, long-run panels cover almost a century for well over 150 economies, and daily or even hourly indicators can be brought up and try to find answers on questions of shock transmission.

2.3.1. Product Market Regulation

Building on the empirical findings above, recent research has also turned to institutional and regulatory factors that influence a country’s ability to escape the middle-income trap and benefit from catch-up growth. One key constraint is excessive product-market regulation (Conway et al., 2006).

Restrictive regulations, such as licensing barriers, entry restrictions, and limited competition in service sectors, can significantly slow down the diffusion of new technologies. Empirical panel regressions show that countries with rigid regulatory frameworks recover less output after common productivity shocks compared to more liberal economies. For example, following a frontier innovation, highly regulated economies may regain only a fraction of the output growth observed in more competitive systems. Moreover, tighter regulations are linked to lower investment in information and communication technologies (ICT), reducing the adoption of key general-purpose technologies by 2–3 percentage points. Barriers to foreign direct investment (FDI) further inhibit the presence of foreign-owned affiliates, which are a critical vehicle for technology transfer and global supply chain integration. Empirically, FDI-related spillovers explain nearly a quarter of cross-country variation in affiliate productivity presence (Conway et al., 2006).

Together, these findings support the view, developed in earlier theoretical and empirical sections, that successful catch-up and long-run convergence depend not only on capital or education but also on a regulatory environment that enables innovation, encourages market entry, and facilitates global knowledge diffusion.

3

Methodology and Data

This chapter outlines the step-by-step methodology used in the subsequent analysis. The chosen approach is designed to empirically investigate the research questions introduced in Chapter 1, particularly those concerning growth slowdown and dynamics, convergence patterns, the role of innovation capacity together with comparison of two countries. Each methodological step builds toward generating findings that inform both the empirical results and the final policy recommendations.

3.1. Growth Slowdown

Eichengreen et al. (2014), in the paper Growth Slowdowns Redux, identify growth slowdowns as a significant challenge for middle-income countries striving for sustained progress. He argues that growth slowdowns are less likely in countries with high levels of tertiary education and a significant share of high-tech exports, underscoring the critical role of advancing up the technology ladder and fostering a skilled workforce to avoid the middle-income trap. Author proposes an assessment framework that can define and check if the growth slowdown appeared. Eichengreen developed 3 conditions that have to be met in order to consider a country in the slowdown phase.

$$g_{t,t-n} \geq 0.035 \tag{3.1}$$

$$g_{t,t-n} - g_{t,t+n} \geq 0.02 \tag{3.2}$$

$$y_t > 10,000 \tag{3.3}$$

What stands out in this reasoning, that author does not specify the upper limit of GDP. That means that this conditions can be used also for a high income countries such as Poland. Based on the paper by Hausmann et al. (2005), the proposed period of GDP growth to look into would be 7 years.

3.2. Empirical growth model

The following section outlines the defined models, as well as the processes of data collection and exploratory data analysis.

3.2.1. Determinants of growth

Drawing on the theories above, both exogenous and endogenous, key factors influencing growth were identified. Both domestic dynamics are considered as well as the position of the country on the international arena. To sum things up, the list of determinants used in the model is as follows:

Labor: Primary factor of production that represents the human effort and skill utilized in the generation of goods and services. An increase in labor input, through an expanding workforce, directly contributes to overall output growth. However, this relationship is characterized by diminishing returns - without concurrent improvements in technology or complementary capital investments, the marginal increase in output may decline. Additionally, this factor is only influencing the total GDP however increase in labor will not increase the GDP per-capita, which is more related to the country's prosperity. Nevertheless, it will be included in the model as it controls for the labor force growth in the growth function (Cobb & Douglas, 1928).

Capital stocks: Equally critical within the proposed frameworks is capital stock, which include machinery, infrastructure, and other tangible assets. Capital accumulation amplifies an economy's productive capacity by enabling more efficient production processes and facilitating capital deepening, where each worker is supported by a higher level of capital. Capital investments are not only crucial for providing the immediate tools necessary for production, but also for laying the groundwork for sustained economic development (Cobb & Douglas, 1928). For that reason, it is expected for the factor to have a positive and large influence on the GDP growth.

Relating these components to GDP growth reveals a clear narrative: total economic expansion is fueled by the interplay between increases in labor and the accumulation of physical capital. While growth in the labor force and capital investment undoubtedly lead to higher production levels, the most significant and sustainable gains in economic prosperity can be gained from advancements in efficiency of their use, measured by total factor productivity. These gains effectively shift the entire production function upward, enabling an economy to produce more output from the same quantity of inputs.

Modern literature on economic growth recognizes that additional variables can influence growth directly or indirectly through increases in TFP and these aspects have been explored extensively within endogenous growth frameworks. In particular, researchers such as Howitt and Mayer-Foulkes (2005) have modified the basic production function to incorporate a more detailed description of growth factors that are internal to the economy. These models argue that growth is not solely a function of exogenous technological change but is also shaped by the accumulation of human capital, innovation, and the effective use of new technologies.

Absorptive capacity: That represents the ability of an economy to assimilate, integrate, and effectively utilize new technologies and knowledge. It is a crucial factor in endogenous growth models because it determines how well an economy can leverage external technology, knowledge and know-how. Empirical papers and theoretical models alike underscore the importance of absorptive capacity in enabling countries, especially those not at the technology frontier, to catch up with leading economies. As argued in Howitt and Mayer-Foulkes (2005), robust absorptive capabilities enhance the benefits derived from both domestic innovation and foreign technological spillovers, thereby augmenting the overall productivity growth of the economy (Khan, 2022). Based on that, it is expected that in modeling of growth absorptive capacity would have a positive influence on dependent variable.

Education: Closely related to absorptive capacity, is the education level of the society. Investments in education are directly linked to improvements in labor quality and innovative capacity. Countries that prioritize education and increase education spending, as highlighted by World Bank (2024), tend to experience higher wages, improved productivity, and a transition away from low-wage, low-productivity sectors. In this way, education fosters an environment in which modern R&D activities can thrive, contributing both to immediate output gains and to a higher potential for future growth. Because of that influence on other factors, Education is considered to have positive relation to GDP growth.

R&D stocks: Represent a fundamental measure of an economy's capacity for domestic innovation. The stock of R&D investments encapsulates the resources allocated to scientific research, technological advancement and product development. It is well-documented that higher R&D spending correlates with greater innovation output, leading to breakthrough discoveries and competitive technological improvements. In this sense, the accumulation of R&D investments is both a reflection and a catalyst of endogenous growth, acting to continuously renew an economy's technological base and further improve output growth (Organisation for Economic Co-operation and Development, 2024).

FDI: plays an instrumental role in enhancing a country's growth trajectory. By integrating local firms into larger more advanced economies, FDI fosters greater competition and facilitates knowledge spillovers, thus elevating the absorptive capacity of the workforce, but at the same time requires a minimum amount of this capacity in order to provide value at the beginning. Such inflows of capital and know-how are particularly vital for middle- and low-income countries that face challenges in moving into high-income status due to technological lags. As highlighted in Salamaga (2023), FDI acts as an intermediate for innovation and can accelerate the convergence of these countries with the economic leaders. That considered, it is expected for FDI to have a positive influence on GDP growth

Distance to the frontier: In Acemoglu, Aghion and Zilibotti s Schumpeterian growth framework, the distance to frontier variable captures how far an economy's technology and productivity stock lies below the global leader and, in so doing, endogenizes both the level and the composition of aggregate growth (Acemoglu et al., 2006). Let $A_t(\nu)$ denote productivity in sector ν at date t, and let $\bar{A}_t$ represent the world technology frontier. The distance to frontier is then measured by the ratio

$$\frac{\bar{A}_{t-1}}{A_{t-1}},$$

which is large when a country is far from the frontier (i.e. $A_{t-1} \ll \bar{A}_{t-1}$) and approaches unity as it converges on cutting edge technology. Total factor productivity, denoted by **A** in the function above, captures the efficiency with which the inputs of labor and capital are combined to produce output. TFP encompasses a wide range of factors including technological innovations, better management practices, and overall improvements in resource allocation. Increases in TFP can yield substantial gains in output without the need for additional inputs, thereby serving as a potent driver of long-run economic growth. This aspect of the production process is particularly important in understanding differences in growth rates across economies and be able to compare them through for example relative distance between them (Cobb & Douglas, 1928). This difference in distance can yield positive results due to the catch-up opportunity, and the expected relation is that countries further from the technology frontier grow faster, despite having smaller productivity levels.

Sectoral diversification: Imbs and Wacziarg's "Stage of Diversification" paper provides a clear empirical foundation for treating sectoral diversification as an endogenous, non - monotonic feature of development (Imbs & Wacziarg, 2003). Drawing on extensive cross - country data on both employment and value added, they document that economies initially broaden their sectoral base as they industrialize, moving resources out of agriculture and into a growing array of manufacturing and service activities, only to re - concentrate once they reach higher income levels. Put differently, the degree of sectoral concentration follows a U - shaped pattern in per - capita income: diversification peaks around the newly - industrialized phase, then declines as mature economies specialize in high - value, knowledge - intensive sectors. However, since the sample is mainly focused towards the more advanced economies the relation to the GDP growth should be positive.

Product Market Regulation: As mentioned in the section 2.3.1, Product market regulation plays a crucial role in attracting foreign investment and facilitating the absorption of external knowledge into the domestic economy. By lowering unnecessary barriers to entry and reducing bureaucracy, effective PMR frameworks foster an entrepreneurial culture that makes it easier for new firms to emerge and innovate. In turn, this surge in entrepreneurial activity drives higher levels of innovation output and long-term growth, so the overall influence of PMR on GDP growth should be positive.

3.2.2. Time frame definition

To mitigate the influence of short-term economic fluctuations resulting from business cycles and volatility, variables will be grouped into five-year periods. The approach is similar to what one can find in the literature (Barro, 1994). This methodological choice allows for the calculation of more stable, longer-term growth trends, effectively smoothing out temporary variations. Furthermore, to ensure sufficient data points and maintain methodological consistency in forming these five-year periods, data from the year 1994 will also be integrated into the analysis.

- **Period 1:** 1994 - 1999

- **Period 2:** 1999 - 2004
- **Period 3:** 2004 - 2009
- **Period 4:** 2009 - 2014
- **Period 5:** 2014 - 2019

3.2.3. Variable proxy

The initial step of data preparation was the definition of variable proxies, since some of the variables are difficult or impossible to measure directly.

R&D stocks

Data on R&D expenditures are scarce and difficult to measure in a comparable way across countries. However, since 1995, an increasing number of governments have published annual R&D outlays as a percentage of GDP, providing a uniformly reported flow series. In order to express these flows in terms of accumulated capital stocks, the perpetual inventory method (PIM) was implemented, since it yields a transparent, stock series that is readily incorporated into panel data growth analyses. Under the PIM, real R&D investment flows, obtained by multiplying the reported R&D to GDP ratios by real GDP and then deflating both series with a common GDP deflator index, accumulate over time according to

$$RD_t \;=\; (1-\delta)\, RD_{t-1} \;+\; I_t,$$

where I_t denotes the R&D investment flow in year t and δ is the constant depreciation rate. Following the empirical calibration of de Rassenfosse and Jaffe (2017), who advocate a relatively conservative depreciation range of 1–5% for R&D capital, the upper bound of 5% was adopted to avoid overstating the enduring contribution of past R&D expenditures (de Rassenfosse & Jaffe, 2017). Further, it is assumed that initial stock value is equal to:

$$RD_0 \;=\; I_0/\delta,$$

As a visual presentation, data for Costa Rica is presented below.

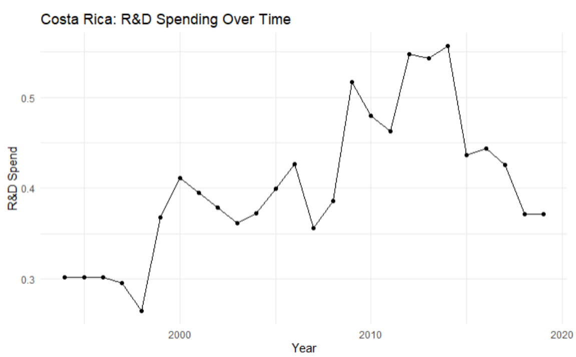

Figure 3.1: Costa Rica R&D spending as % of GDP [Source: (WorldBank, 2025b)]

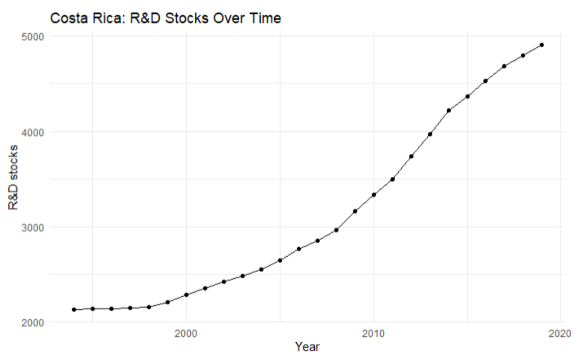

Figure 3.2: Costa Rica R&D stocks [Source: (WorldBank, 2025b), own calculations]

Education

A common proxy for country's educational level and quality is government expenditure on education as a percentage of GDP, thanks to its consistent availability from sources like the World Bank (Trabelisi, 2018).

However, this proxy has drawbacks: it reflects only input volumes, not learning outcomes or allocative efficiency, and it ignores private spending on education. Nonetheless, for the purposes of this thesis - given its clear cross-country comparability and data coverage, it offers a practicable measure of public commitment to education.

Absorptive capacity

Quantifying absorptive capacity is inherently challenging because it encompasses both stock variables (existing human and institutional capital) and flow variables (ongoing learning and adaptation). Researchers commonly proxy it using average years of schooling and apply an assumed return to education rate to translate schooling into a human-capital index. This approach captures the broad knowledge base available to absorb new technologies, but it abstracts from qualitative aspects of education (such as curriculum relevance or R&D training) and from institutional factors (like the strength of research universities or intellectual-property regimes) that also influence a country's learning capacity (Trabelisi, 2018). The used data source is calculating human capital based on the average years of schooling and an assumed rate of return to education.

Sectoral diversification

A widely used quantitative proxy for measuring sectoral diversification is the Herfindahl–Hirschman Index (HHI) (Rhoades, 1995). Originally developed in industrial organization to assess market concentration, the HHI was adapted to gauge the distribution of value-added across sectors within an economy. It is defined as:

$$\text{HHI} = s_1^2 + s_2^2 + s_3^2 + \cdots + s_n^2 \tag{3.4}$$

where s_i denotes the share of sector i in total economy output (typically expressed as a decimal fraction or percentage). By squaring each sector's share, the index gives greater weight to larger sectors, such that an economy dominated by a single industry will yield an HHI close to 1.

3.2.4. Data collection

Data for this analysis was sourced from multiple reputable databases, primarily the Penn World Table (PWT) version 10.01 (Feenstra & Timmer, 2015) and the World Bank's World Development Indicators (WDI) (WorldBank, 2025b).

Table 3.1: Summary of Data Sources and Corresponding Variables

Data Source	Variables
Penn World Table (PWT 10.01)	Real GDP, Capital stock, Labor stock, Total Factor Productivity, human capital
World Development Indicators (WDI)	Education Expenditure, R&D Stocks, FDI
World Integrated Trade Solution (WITS)	Herfindahl–Hirschman Index (HHI)
UN Trade and Development(UNCTAD)	FDI Stocks (FDI)
Organisation for Economic Co-operation and Development (OECD)	Product market regulation (pmr)

3.2.5. Data exploration

Data exploration step was undertaken first to check the correctness and missingness of obtained data. For detailed description of this step see appendix A. Next step was to look deeper into the correlation between variables.

Table 3.2: Correlation table [Source: see Table 3.1]

Descriptives and correlations among variables[1]

Variable	Mean	s.d.	Min	Max	1	2	3	4	5	6	7	8	9
1. Real GDP growth (rgdp_ln)	0.16	0.11	-0.287	0.523	-								
2. Capital stock growth (K_ln)	0.16	0.11	-0.108	0.601	.40**	-							
3. Labor stock growth (L_ln)	0.07	0.08	-0.206	0.298	.38**	.25**	-						
4. Human Capital (HC)	2.86	0.50	1.523	3.734	-.29**	.35**	-.28**	-					
5. HH index (HH)	0.13	0.13	0.0335	0.779	.10	.01	.21**	-.22**	-				
6. R&D Stock growth (RD_ln)	0.14	0.22	-0.071	2.113	.05	.19**	.13	-.10	-.01	-			
7. Gov Edu Spending growth (EDU_ln)	0.21	0.23	-0.698	0.9344	.18**	.29**	.08	-.27**	.17**	.17**	-		
8. FDI Stock growth (FDI_ln)	0.70	0.60	-0.669	3.986	.24**	.07	-.13*	-.06	.04	-.08	.17**	-	
9. Distance to frontier (DF)	2.07	0.98	1	7.511	.55**	-.04	.09	-.30**	.18	.09	.22	.24**	-
10. Product Market Regulations (PMR)	1.66	0.47	0.863	3.169	.31**	.51**	.11	-.52**	.13	.21*	.43**	.15	-.55**

[1] $n = 268$ $^{**}p < .01$; $^{*}p < .05$.

The correlation matrix and descriptive statistics for the variables used in the regression models provide valuable preliminary insights into the structure of the data and potential multicollinearity concerns. The sample consists of 268 observations (apart from PMR variable for which there are only 131 observations due to limited data access), and the variables are either expressed as five-year log-differenced growth rates (e.g., for GDP, capital, labor, R&D, FDI, and education spending) or as level indicators (e.g., human capital, HH index, and distance to frontier).

The average real GDP growth rate (row 1) is 0.16 (SD = 0.11), with a range from -0.287 to 0.523, indicating significant variation across countries and over time. Real GDP growth is positively and significantly correlated with capital stock growth ($r = 0.40$, $p < 0.01$) and labor stock growth ($r = 0.38$, $p < 0.01$), which reinforces their strong and expected roles in driving output, consistent with classical and neoclassical growth models (Barro, 1994).

Interestingly, human capital (HC) is negatively correlated with GDP growth ($r = -0.29$, $p < 0.01$), which confirms the unexpected negative coefficient in the models observed in some other empirical research (Stöllinger, 2013). This counterintuitive relationship was described in numerous publications and it was identified that it could reflect that more advanced human capital is concentrated in mature economies experiencing slower growth, or it might indicate misalignment between education systems and labor market productivity (Docquier & Rapoport, 2012). Also, it is hard to effectively measure the human capital, as mentioned in the previous section - 3.2.3 used index is measured on the school attainment and expected returns. However, it fails to measure other important factors like logical reasoning qualities of society or the transnational education of people directly gaining the absorptive capacities from the advanced country, bringing huge value to the society (Vandenbussche et al., 2006).

Government education spending growth (EDU_ln) exhibit positive and significant correlation with GDP growth ($r = 0.18$ with $p < 0.01$), but in relation to previous point it is also negatively correlated with the level of human capital, which is mainly based on the education attainment not quality nor spending.

R&D Stock growth on the other hand is only statistically significantly correlated with capital stock growth, which can show that new equipment have to be bought in order to assimilate the progress related to research.

Another noteworthy correlation emerges with the Distance to frontier variable, which demonstrates a substantial and statistically significant positive relationship with GDP growth ($r = 0.55$, $p < 0.01$). This finding is consistent with the theoretical expectations rooted in convergence theory and technology diffusion literature. Specifically, countries that are further behind the global technological frontier often possess greater potential for catch-up growth, as they can adopt and adapt existing technologies developed by more advanced economies at relatively lower cost and risk (Acemoglu et al., 2006). In parallel, a negative and significant relationship is observed between Distance to frontier and Human Capital (r = -0.30, p < 0.01), which also aligns well with existing empirical evidence. Nations further from the technological frontier tend to have weaker educational systems, often characterized by lower quality of instruction and lower returns on education. These structural limitations reduce the effectiveness and returns of investment in education. Since the Human Capital Index reported by the Penn World Table (PWT) emphasizes exactly that, a country's increased distance from the frontier translates into lower human capital scores.

Lastly, the Product Market Regulations (PMR) variable supports the initial hypothesis that countries closer to the technological frontier tend to have fewer market regulations. This is evidenced by a strong and statistically significant negative correlation between PMR and the distance to the frontier (r = -0.55, p < 0.01). Furthermore, PMR is positively and significantly correlated with capital stock growth (r = 0.51, p < 0.01). This suggests that lower regulatory barriers may facilitate greater capital investment by enabling firms and individuals to more easily establish and expand businesses.

The correlation table broadly confirms the expected positive relationships between growth and factor accumulation, while also hinting at more complex dynamics involving human capital, distance to frontier and R&D.

A final validation step involves formally assessing the presence of multicollinearity among the explanatory variables.

Table 3.3: Variance Inflation Factors (VIF) and Tolerances for Predictors

Variable	VIF	Tolerance
K_ln	1.336	0.748
L_ln	1.998	0.833
HC_lag	1.379	0.724
HH_lag	1.124	0.889
RD_ln	1.087	0.919
GOV_edu_ln	1.229	0.813
FDI_ln	1.138	0.878
$distance\_to\_frontier\_lag$	1.267	0.788
PMR	2.584	0.386

Table 3.3 presents the variance inflation factors (VIF) and their corresponding tolerances for the eight regressors. All VIF values lie between 1 and 2 (well below the commonly accepted threshold of 5) and all tolerances exceed 0.20. These results indicate that multicollinearity is negligible in the estimated model and that the regressors can be treated as sufficiently independent. Consequently, there is no evidence of inflated standard errors or instability in the coefficient estimates due to collinearity.

3.2.6. Models Specifications

Different specifications try to cover different aspects of endogenous growth models, and interaction between them. Note that some variables are defined as

$$\Delta x_t \;=\; x_t \;-\; x_{t-5}$$

Model Classical:

$$\Delta \ln(\mathsf{Y}_{i,t}) = \beta_0 + \beta_1(\Delta \ln(\mathsf{K}_{i,t})) + \beta_2(\Delta \ln(\mathsf{L}_{i,t})) + \mu_i + \lambda_t + \varepsilon_{i,t}, \tag{3.5}$$

Model Catch-up:

$$\begin{aligned}\Delta \ln(\mathsf{Y}_{i,t}) = \beta_0 + \beta_1(\Delta \ln(\mathsf{K}_{i,t})) + \beta_2(\Delta \ln(\mathsf{L}_{i,t})) + \beta_3(\mathsf{HC}_{i,t-5}) + \\ \beta_4(\mathsf{DF}_{i,t-5}) + \mu_i + \lambda_t + \varepsilon_{i,t},\end{aligned} \tag{3.6}$$

Model Endogenous:

$$\begin{aligned}\Delta \ln(\mathsf{Y}_{i,t}) = \beta_0 + \beta_1(\Delta \ln(\mathsf{K}_{i,t})) + \beta_2(\Delta \ln(\mathsf{L}_{i,t})) + \beta_3(\mathsf{HC}_{i,t-5}) + \\ \beta_4(\mathsf{DF}_{i,t-5}) + \beta_5(\Delta \ln(\mathsf{R\&D}_{i,t-5})) + \beta_6(\Delta \ln(\mathsf{EDU}_{i,t-5})) + \\ \beta_7(\Delta \ln(\mathsf{FDI}_{i,t-5})) + \beta_8(\mathsf{HH}_{i,t-5}) + \mu_i + \lambda_t + \varepsilon_{i,t},\end{aligned} \tag{3.7}$$

Model PMR:

$$\begin{aligned}\Delta \ln(\mathsf{Y}_{i,t}) = \beta_0 + \beta_1(\Delta \ln(\mathsf{K}_{i,t})) + \beta_2(\Delta \ln(\mathsf{L}_{i,t})) + \beta_3(\mathsf{HC}_{i,t-5}) + \\ \beta_4(\mathsf{DF}_{i,t-5}) + \beta_5(\Delta \ln(\mathsf{R\&D}_{i,t-5})) + \beta_6(\Delta \ln(\mathsf{EDU}_{i,t-5})) + \\ \beta_7(\Delta \ln(\mathsf{FDI}_{i,t-5})) + \beta_8(\mathsf{HH}_{i,t-5}) + \beta_9(\mathsf{PMR}_{i,t}) + \mu_i + \lambda_t + \varepsilon_{i,t},\end{aligned} \tag{3.8}$$

Model Catch-up expanded:

$$\begin{aligned}\Delta \ln(\mathsf{Y}_{i,t}) = \beta_0 + \beta_1(\Delta \ln(\mathsf{K}_{i,t})) + \beta_2(\Delta \ln(\mathsf{L}_{i,t})) + \beta_3(\mathsf{HC}_{i,t-5}) + \beta_4(\mathsf{DF}_{i,t-5}) + \\ \beta_5(\Delta \ln(\mathsf{R\&D}_{i,t-5})) + \beta_6(\Delta \ln(\mathsf{EDU}_{i,t-5})) + \beta_7(\Delta \ln(\mathsf{FDI}_{i,t-5})) + \\ \beta_8(\mathsf{HH}_{i,t-5}) + \beta_9(\mathsf{DF}_{i,t-5} * \mathsf{HC}_{i,t-5}) + \mu_i + \lambda_t + \varepsilon_{i,t},\end{aligned} \tag{3.9}$$

where for each country i :

- μ_i and λ_t correspond to country fixed effects and time-specific fixed effects,
- ε_{it} is the error term, and
- $\mathsf{DF}_{i,t-5} * \mathsf{HC}_{i,t-5}$ - covers the catch-up term.

The $\ln$ transformation in each term is related to the ease of interpretation of each variable and it's influence on the Y term. The coefficients tell us the percentage point change in the dependent variable associated with a percentage point change in one of the independent variable, holding other factors constant (Wooldridge, 2013). Additionally, Wooldridge notes that log-transforming variables can reduce heteroskedasticity, especially in cross-country or panel data settings where variance in economic size and investment levels is substantial.

3.2.7. Model shortcomings

Models follows reasoning from the paper Stöllinger (2013), where the author introduce lag to the endogenous variables. That is why the variables like Education, R&D stocks, FDI, HC, HH and distance to the frontier are related to the "previous" period. However, that means that the data will drop one period, so in the end the model is created for 67 countries in the periods starting from period 1999 to 2004.

The purpose of introducing the lag is to capture the the reverse causality of some variables. For example, if the Government spending on education increases it will not attract new capital in the same year, since economies have some inertia. This shortcoming will be addressed using another model specification without the lag, that will be presented in the section bellow.

Specification tests

The dataset employed in this thesis comprises 67 countries and nine core variables (with PMR appended where available), each observed over four time periods for a total of 36 measurements per country. Consistent with standard practice in empirical growth studies, a fixed-effects panel specification is adopted (Barro, 1994). To confirm the suitability of this approach, a Hausman test was conducted on the endogenous growth model comparing random-effects approach with fixed-effects. The test yields $\chi^2(8) = 36.978$ with $p = 1.162 \times 10^{-5}$, decisively rejecting the random-effects specification in favor of fixed effects.

During gathering of the information about the topic, there appeared a risk of a heteroskedasticity being present. In statistics, heteroskedasticity happens when the standard errors of a variable, monitored over a specific amount of time, are non-constant. Models involving a wide range of values are supposedly more prone to heteroskedasticity. That is why Breusch Pagan Test for Model Endogenous (3.7) was performed:

Statistic	$\text{BP} = 65.934$
Degrees of freedom (df)	8
p-value	3.153×10^{-11}
Null hypothesis (H_0)	Homoskedasticity
Alternative (H_1)	Heteroskedasticity

Table 3.4: Breusch–Pagan Test on Model Endogenous

The test resulted in rejection of null hypothesis, that is why it can be concluded that heteroskedasticity occurs in our panel data model

An additional test was conducted to test for whether the data possesses a stochastic trend or "memory" that invalidates many standard statistical methods. The unit root test was conducted and returned a highly significant statistic, allowing to decisively reject the null hypothesis of a unit root in our growth rate series.

Statistic	$\overline{Wtbar} = -43.653$
p-value	$< 2.2 \times 10^{-16}$
Null hypothesis (H_0)	Unit root (non-stationarity)
Alternative (H_1)	Stationarity

Table 3.5: Im–Pesaran–Shin Panel Unit-Root Test results on Model Endogenous

In order to test for the autocorrelation of error term, The Breusch-Godfrey test was used. It helps to detect autocorrelation at different lags, and it's applicable to both linear and non-linear models.

Statistic	$\chi^2 = 57.216$
Degrees of freedom (df)	4
p-value	1.115×10^{-11}
Null hypothesis (H_0)	No serial correlation
Alternative (H_1)	Serial correlation in idiosyncratic errors

Table 3.6: Breusch–Godfrey / Wooldridge Test for Serial Correlation on Model Endogenous

Again, rejected the null hypothesis indicating a serial correlation in errors, which can lead to some incorrect conclusions about the model and causality.

The tests above demonstrated that the model fails to meet the critical requirements. To address this issue, a Driscoll-Kraay approach was adopted. This method employs a nonparametric covariance matrix estimator, producing standard errors that are both heteroskedasticity- and autocorrelation-consistent, and robust to a wide range of spatial and temporal dependencies.

To choose the best

3.3. Country comparison

In order to answer the question of how Poland compares to a country that is widely recognized as one of the most innovative - South Korea (World Intellectual Property, 2023), descriptive statistics were utilized. Graphical comparisons, together with trend analysis, were applied to examine the gap between the two countries in terms of GDP per employed person, innovation indicators (such as R&D investments), sectoral diversification, the Product Market Regulation (PMR) index, and Foreign Direct Investments. These factors enable the formulation of targeted policy recommendations for Poland. Additionally, based on the history of two countries it can be deducted that take-off phase (see section: 2.1) is different for two countries. For the purpose of the comparison (especially the GDP and TFP growth) the analysis should be aligned to the year of take-off so that a clearer picture can be seen.

3.4. Recommendations for Poland

Countries often fail to recognize the moment when it becomes necessary to shift from growth driven by traditional factors, such as the assimilation of physical capital or benefits derived from spillover effects of more advanced neighboring countries, towards more domestically driven growth (Aiyar et al., 2013). To address this challenge, the World Bank has developed a framework that provides guidance on the areas requiring improvement. The “3i” strategy, already described above (see Section 2.2.2), offers a structured approach to achieving long-term growth (see Table 2.1). While it is already known that Poland lags behind in R&D spending and output, this research aims to investigate in greater depth how R&D is structured across different sectors. Based on this analysis, more precise and context-sensitive recommendations will be proposed.

4

Results

4.1. Poland's growth slowdown

The following section will try to provide empirical answer for the sub research question covered in the introduction part of the thesis, on whether Poland is in the stagnation phase, similar to the one experienced by countries in middle-income trap, despite being recognized as high-income country. Methodology described in the Section 3.1 will be followed

The results of moving 7 year CAGR of GDP Per Capita for Poland look like this:

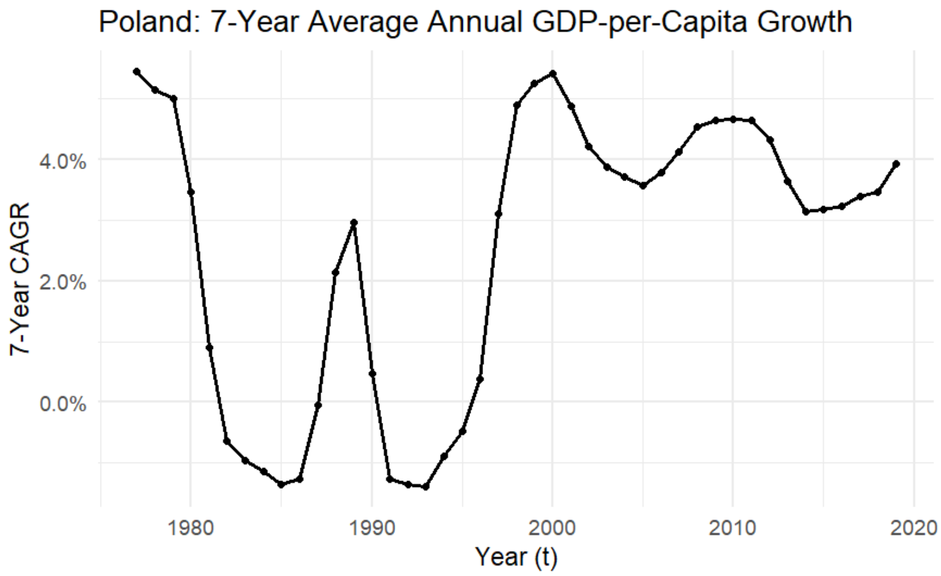

Figure 4.1: Visual representation, of the moving average of 7 year growth change for Poland [Source: (Feenstra & Timmer, 2015), own calculations]

An initial examination of Poland's seven-year compound annual growth rates shows that, up until roughly 1995, the economy endured large, structural swings far beyond the amplitude of a "normal" business cycle. These pre-1995 fluctuations capture the combined effects of late-communist distortions, over-investment in heavy industry, political turmoil, and the sharp transition contraction after 1989 (Piatkowski, 2019). After the mid-1990s, however, the rhythm of growth smooths considerably. Post 1995, Poland's growth rates display more modest oscillations, peaks and troughs on the order of two to three percentage points, lasting roughly four to eight years, that closely resemble the business-cycle patterns documented in the macroeconomic literature (Lucas, 1980).

Table 4.1: Growth slowdowns in Poland

Country	Year	Growth before slowdown (t−7 through t)	Growth after slowdown (t through t+7)	Difference in growth	Per-capita GDP at t ($)
Poland	1977	5.45	-1.1	-6.55	12.067
Poland	2012	4.33	3.92	-0.41	24.476

As can be seen in the table above, year 1977 was definitely a growth slowdown year for Poland, also seen in the graph above. It met all the criteria proposed by Eichengreen et al. (2014). Several factors contributed to the slowdown. The post-war industrialization model, based on heavy investment and central planning, began to yield diminishing returns (De Broeck & Koen, 2006). Productivity in state-owned enterprises stagnated, and limited progress in human capital and institutional reform constrained further development (World Bank Group, 2022). At the same time, rising external debt and the global oil shocks of the mid-1970s created macroeconomic imbalances (Burnett, 1991). Together, these structural and external pressures triggered the slowdown observed in 1977. By contrast, the most recent candidate for a slowdown - 2012 fails to meet Eichengreen's second criterion. Although Poland's per-capita GDP at that date was well above $10 000, and the pre-2012 seven year growth rate of 4.33% comfortably cleared the 3.5% "fast-growth" bar, the subsequent seven-year rate only dipped to 3.92%, a mere 0.41 percentage point drop rather than the required 2 percentage points or more. Such a modest deceleration is fully consistent with normal business-cycle variability, rather than evidence of a true structural slowdown.

In sum, while Poland has clearly suffered a severe growth slowdown in 1977, the data through 2019 show no comparable episode since. The post-2012 moderation in growth remains far too small to qualify under Eichengreen's definition of a slowdown, experienced in the middle-income trap. Hence, using the authors' three-part test, we must conclude that Poland is not currently experiencing a growth stagnation.

4.2. Panel data regression results

In the following section, an effort will be made to conduct empirical research based on the model and data specification from Section 3.2.6 in order to answer the questions what are the key determinants of growth.

Modeling

To better understand how different structural factors influence the GDP growth, different model specifications were introduced. The primary focus was placed on the FDI and R&D variables, which were identified in the theoretical framework as crucial levers that Poland could potentially exploit to enhance its long-term growth prospects (Howitt & Mayer-Foulkes, 2005). Additionally, the catch-up factor was included to examine its potential influence on the growth dynamics within the analyzed sample (Acemoglu et al., 2006).

Table 4.2: Fixed Effect Models results [Source: see Table 3.1, own calculations]

Results of Fixed Effect regression models predicting <real GDP growth>

	Model Classical	Model Catch-up	Model Endogenous	Model PMR	Model Catch-up expanded
Fixed Effect Model					
1. Capital Stock (K_ln)	0.157 (0.084)*	0.275 (0.081)***	0.292 (0.079)***	0.435 (0.161)***	0.275 (0.080)***
2. Labor Stock (L_ln)	0.784 (0.094)***	0.691 (0.091)***	0.679 (0.086)***	0.734 (0.096)***	0.668 (0.086)***
3. Human Capital (HC)		-0.109 (0.033)***	-0.108 (0.039)***	-0.151 (0.056)***	-0.190 (0.059)***
4. Distance to frontier (DF)		0.072 (0.018)***	0.070 (0.012)***	0.094 (0.023)**	-0.041 (0.062)
5. R&D Stock (RD_ln)			0.010 (0.028)*	-0.076 (0.106)	-0.007 (0.030)
6.Gov Education Spending (EDU_ln)			-0.033 (0.022)*	-0.042 (0.039)	-0.033 (0.022)
7. Foreign Direct Investment (FDI_ln)			0.002 (0.010)	-0.030 (0.011)***	-0.001 (0.009)
8. HH_Index (HH)			0.105 (0.101)*	-0.195 (0.185)	0.048 (0.099)
9. PMR				0.003 (0.024)	
10. HC * DF					0.040 (0.022)*
n	268	268	268	131	268
R^2	0.281	0.456	0.466	0.674	0.475
ΔR^2	0.036	0.263	0.261	0.495	0.270
F	38.936***	41.345***	21.017***	19.257***	19.287***

*** $p < .01$ ** $p < .05$; * $p < .1$;
Standardized coefficients are reported with standard errors in parentheses.

4.2.1. Results interpretation

Model Classical

Model Classical serves as a baseline specification, including only two key production inputs: capital stock growth and labor stock growth, both measured as five-year log-differenced variables. These inputs are foundational to neoclassical growth theory, particularly the Solow model, which posits that output growth is driven by capital accumulation and labor force expansion.

The regression results show that labor stock growth has a large and highly statistically significant effect on real GDP growth (β = 0.784, p < 0.01) Meaning that 1 percentage point change in labor stock translates to 0.784 percentage point change in GDP growth. This aligns strongly with theory and prior empirical studies from Mankiw (1992), where population and labor force growth are key contributors to total output expansion, particularly in lower- and middle-income economies with growing labor markets. Comparing to other empirical papers, the resulted coefficient is higher - other results are: 0.355 (Stöllinger, 2013) and 0.130 (Benhabib & Spiegel, 1994).

Capital stock growth is also positively associated with GDP growth (β = 0.157, p < 0.1) indicating that 1 percentage point change in capital stock changes the GDP growth variable by 0.157 percentage points. The result is consistent with theoretical expectations that capital deepening leads to productivity gains and output growth. The coefficient is smaller than that of labor, and slightly smaller than observed in other authors work such as: Stöllinger (2013) observed the value of 0.485 and Benhabib and Spiegel (1994) observed the value of 0.545 .

The model has an R^2 of 0.281, indicating that just over 28% of the within-country variation in real GDP growth can be explained by capital and labor inputs alone. The model's F-statistic is highly significant, supporting the joint explanatory power of these two fundamental production factors. However, the relatively low R^2 suggests that a substantial portion of the variation in growth remains unexplained. This outcome is in line with both theoretical and empirical literature, which consistently highlights the limitations of simple growth models that rely solely on physical capital and labor (Howitt & Mayer-Foulkes, 2005).

Model Catch-up

Model Catch-up builds upon the baseline by incorporating human capital (HC) and distance to the technological frontier (DF) into the regression. This expands the model toward a more endogenous growth perspective in line with the reasoning of Lucas (1988) and Stöllinger (2013), where human capital and space for a country to grow play a crucial role in explaining differences in economic performance.

Capital stock growth increased its positive influence and statistical significance (β = 0.275, p < 0.01), suggesting its continued relevance in explaining growth dynamics, especially when considered with additional variables.

However, the newly introduced human capital variable is negative and significant (β = -0.109, p < 0.01) meaning that one unit point change in human capital decrease GDP growth by 0.109 percentage point. This unexpected result contradicts theoretical expectations from endogenous growth models from Lucas (1988) and Romer (1990), which state that better educated labor should enhance productivity and innovation. One plausible explanation is that the human capital indicator may not fully reflect education quality or its economic relevance, as mentioned above in section 3.2.5. Moreover, highly educated labor might not automatically translate into productivity gains if institutional or market conditions prevent efficient allocation. And finally as also mentioned in the section 3.2.5 the most educated people can migrate to the better developed countries where the economic growth is slower compared to the one observed in the developing countries looking for better financial remuneration for their work - a phenomenon known as brain drain (Docquier & Rapoport, 2012).

Distance to the frontier (DF) is positively associated with growth (β = 0.072, p < 0.01), indicating that one unit point increase in distance to the frontier increases the economic growth by 0.072 percentage point. The result is as to be expected. As also indicated in correlation table 3.2 the countries further from the frontier have a grated potential to catch-up. That empirically confirms a convergence theory from Section 2.2.2.

With the addition of human capital and distance to the frontier, the model's explanatory power improves to R^2 = 0.456, up from 0.281 in Model Classical, with an adjusted R^2 of 0.263. This indicates that institutional and initial endogenous growth variables do contribute to explaining variation in GDP growth. Additionally, larger F-statistic value proves that the regression model is more effective in its explanation of the variation in the dependent variable.

Model Endogenous

Another model accounts education, R&D stock, and foreign direct investment stock (FDI), as well as the HH index and all previous indicators.

Human Capital variable remains negative and statistically significant (β = -0.108, p < 0.039) indicating that even when multiple new variables are introduced the effect of human capital remains negative (at least in the empirical results). However, the model specification still does not cover the potential for spillover-effects, as mentioned in the Lucas (1988) paper.

Distance to frontier variable possess similar explanatory power in comparison to previous model specification. Still positive and statistically significant.

In this model, for the first time influence of R&D stock on GDP growth can be observed. It is positive and statistically positive (β = 0.01, p < 0.1). The size of this influence is smaller than some other researchers indicate, one percentage point increase in R&D stock increases the GDP growth by only 0.01 percentage point, but it still follows the theory from literature part of thesis, that countries investing more into the research and development do grow faster (Howitt & Mayer-Foulkes, 2005).

Government education spending enters with a negative and statistically significant coefficient (β = –0.033, p < 0.01), implying that a one-percentage-point increase in public education outlays is associated with a 0.033 percentage point reduction in GDP growth. Education is typically viewed as a cornerstone of long-term economic development (Trabelisi, 2018), so this counterintuitive finding may reflect inefficiencies within the public system, a mismatch between skills and labor-market demands, or wrong governance of education process as proposed by some other researchers that also observe a negative relation between these two variables (Trabelisi, 2018). Given these factors, the negative coefficient should be interpreted with caution and should not undermine the broader theoretical evidence that, over the longer horizon, stronger education investment ultimately supports higher growth (Barro, 1994).

The effect of FDI is small and not statistically significant (β = 0.002), which suggests that in this sample, inward foreign direct investment does not have a direct or consistent impact on GDP growth.

Lastly, the HH index, which represent the market concentration, is also not statistically significant. Though the coefficient is positive (β = 0.117), it lacks precision, suggesting either limited variation or insufficient explanatory power in this context. Which might be caused by the U-shaped relation described by researchers (Imbs & Wacziarg, 2003).

In terms of empirical performance, Model Endogenous has the higher explanatory power, with an R^2 of 0.466, improving upon previous models. Although the F-statistic decreases in comparison to Model Classical and Model Catch-up to 21.017, this is expected as more variables increase the model's complexity and reduce degrees of freedom, however it still remains statistically significant.

To get a better overview of the results, a simple graph including the errors of each parameter for model Endogenous is presented below

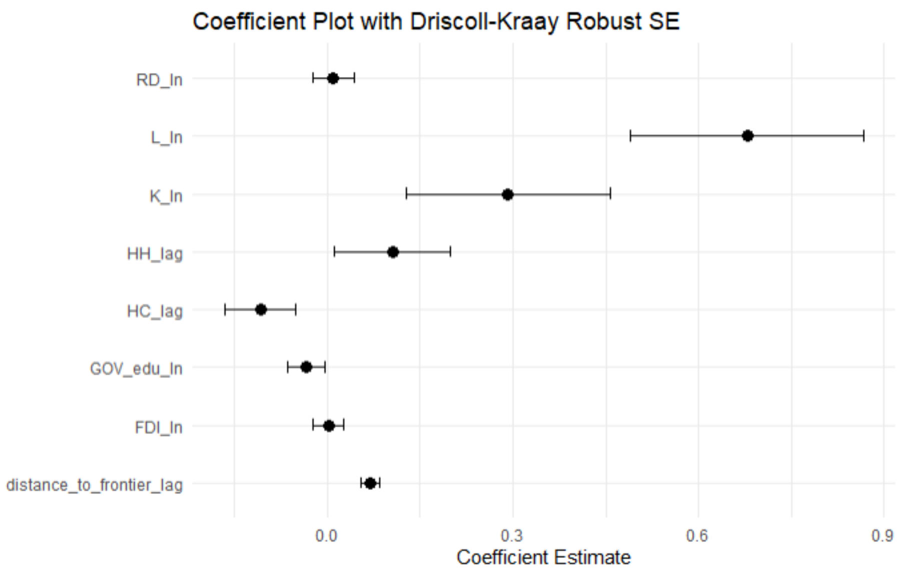

Figure 4.2: Visual representation of coefficient obtained with DriscollKraay robust standard errors method

Model PMR

After obtaining results of Model Endogenous, further model expansion is proposed in order to better understand the potential implications. It was identified that a great potential for influencing the economic growth have the product market regulation index, see section 2.3.1. Obtained dataset only covered OECD countries, that is why used sample is smaller. Further more data was shifted one year so it matches the dataset used in previous models (2004, 2009...), since PMR was reported for years (2005, 2010...).

In this extended specification, Product Market Regulation (PMR) has been introduced as an additional institutional determinant of real GDP growth.

Capital stock growth (β=0.425, p<0.01) remain positive determinants of GDP growth, while human capital continues to exhibit a counterintuitive negative effect (β=–0.151, p<0.01), suggesting mismatches between skill supply and market demand or regulatory dampening of skill returns.

Distance to the frontier remain it's positive influence on growth. Showing that even in a smaller sample, countries further from frontier have grater potential of growth. On the other hand, R&D stocks variable did not show statistically significant results. What is surprising, especially in the economies close to the frontier (OECD dataset), where possibly the investments in the R&D can result in a bigger gain, according to the modern R&D theory (Howitt & Mayer-Foulkes, 2005).

PMR itself (β=0.003) produced a small, statistically insignificant coefficient, indicating that without complementary innovation encouragements and regulatory quality, these factor show limited direct influence on short-run output growth.

The R^2 value is significantly larger in comparison with previous models. One plausible interpretation is that when the sample is restricted to predominantly OECD economies - where data on PMR, market structure, and human capital tend to be more reliable and comparable, the regression is able to exploit higher quality information. In earlier specifications, the inclusion of non-OECD countries, which often exhibit more irregular data collection, measurement error, or unobserved structural heterogeneity, may have hinder the fit of the model and biased some coefficients.

Model Catch-up expanded

In this extended specification, a new variable is introduced - an interaction between distance to the frontier (DF) and absorptive capacity, proxied by human capital (HC). This should capture conditional convergence effects and enabling importance of Human Capital. The standalone coefficient on HC remains negative and statistically significant (β = -0.190, p < 0.01), while the main effect of DF is small, negative and insignificant (β = -0.041).

Because human capital (HC) and distance to the frontier (DF) enter the model in their raw, uncentred form, the reported main-effect coefficients are not meaningful on their own. Interpretation therefore requires combining each main effect with the interaction term. Simmilar to the work of Stöllinger (2013), the positive interaction coefficient reveals a complementarity between absorptive capacity and convergence potential: the growth dividend from closing the technological gap is larger in economies with greater stocks of human capital, and the productivity payoff to additional skills is higher when an economy still lies far from the frontier. Although this coefficient is smaller than that reported by Stöllinger (2013), and the standalone DF coefficient is not statistically significant, the result nonetheless reinforces the view that human capital remains a critical prerequisite for successful convergence.

Other innovation and institutional variables such as: R&D stock, government education spending, FDI inflows, HH index, and PMR - lose significance in this specification, suggesting that their effects on growth are mediated through the HC×DF channel. The rise in R^2 to 0.475 (ΔR^2 = 0.270) and a robust F-statistic (19.29, p < 0.01) demonstrate that incorporating this human-capital-driven catch-up term substantially improves the model's explanatory power. This finding reinforces the notion that human capital, while not directly driving GDP growth, is essential for enabling other growth factors to materialize.

4.2.2. Sample expansion

For the purpose of trying to address the small sample problem mentioned above, a different model structure was proposed - not including the lag for the endogenous variables, meaning that the model looses the potential of reverse causality explanation but increases the sample size for one period.

New model

A new model has been defined dropping the lag effect on the variables, following the reasoning proposed by other authors to check for differences (Wacker et al., 2024). Furthermore, the variable describing the investment in education was also dropped since it did not show huge effect on the growth in previous models and according to the literature it is strongly related to the Human Capital variable - it includes the education attainment. Apart from that, the period from 1999 till 2004 was added as a result of not including the lag. The defined model is as follows:

$$\begin{aligned}\Delta \ln(\mathsf{Y}_{i,t}) = \beta_0 + \beta_1(\Delta \ln(\mathsf{K}_{i,t})) + \beta_2(\Delta \ln(\mathsf{L}_{i,t})) + \beta_3(\mathsf{HC}_{i,t}) + \beta_4(\mathsf{DF}_{i,t}) + \\ \beta_5(\Delta \ln(\mathsf{R\&D}_{i,t})) + \beta_6(\Delta \ln(\mathsf{FDI}_{i,t})) + \beta_7(\mathsf{HH}_{i,t})\mu_i + \lambda_t + \varepsilon_{i,t},\end{aligned} \tag{4.1}$$

Table 4.3: Fixed Effect Model new results [Source: see Table 3.1, own calculations]

Results of Fixed Effect regression models predicting <real GDP growth>

	Model
Fixed Effect Model	
1. Capital Stock (K_ln)	0.0874 (0.081) *
2. Labor Stock (L_ln)	0.779 (0.088) ***
3. Human Capital (HC)	-0.032(0.029) **
4. Distance to frontier (DF)	-0.037(0.014) *
5. R&D Stock (RD_ln)	0.041(0.030) **
6. Foreign Direct Investment (FDI_ln)	0.028(0.010) ***
7. HH_Index (HH)	0.067(0.097)
n	335
R^2	0.357
ΔR^2	0.177
F	20.687***

*** $p < .01$ ** $p < .05$; * $p < .1$;
Standardized coefficients are reported with standard errors in parentheses.

The revised model without the lag indicated several new insights. Distance to the frontier variable changed its sign. From (β= 0.070, p<0.01) to (β=–0.037, p<0.01). This means that one unit increase in distance to the frontier variable will decrease the growth by 0.037. A result that is different from previous specifications and other empirical research (Castellacci, 2011), since according to the theory countries further from the leader should have bigger growth (Acemoglu et al., 2006). That negative effect likely reflects the reverse causality in the variables. In years of rapid expansion, an economy simultaneously narrows its technology gap, so higher growth coincides with a smaller DF value, producing a negative coefficient when the variables are measured in the same period. That is why the previous specification that includes the lag for endogenous variables is easier to interpret. Another value that changed when compared to the Model Endogenous results is the capital variable. Coming from (β= 0.292, p<0.01) to (β= 0.087, p<0.1), it would indicate a large decrease in importance of capital in the growth function when other variables are not lagged. Lastly, the factor that suddenly became more important is the FDI, changing its impact from (β= 0.002, p>0.1) to (β= 0.028, p<0.01). The exact causes are not identified in the thesis, but initial hypothesis is that this can point either to the lag effect that minimizes the impact of FDI or to the introduction of a bigger sample (period 1994 - 1999). However, it's positive sign still remains inline with the literature findings. In the appendixes, a simple sensitivity analysis with respect to different lag can be found (see appendix C.2). Showing how different variables change when different lag is introduced. Because the lagged specifications from Section 4.2 exhibit a better overall fit, yield more stable parameter estimates and are easier to interpret, the Model Endogenous is adopted for the subsequent simulation exercises.

4.2.3. Assessing the calculated model fit to Poland's GDP Data

To check the fit of the model in the case of Poland, Model Endogenous can be used to "predict" GDP Values.

The function will look like:

$$\begin{aligned}\Delta\ln(\mathsf{Y}_{PL,t}) = 0.33 + 0.292(\Delta\ln(\mathsf{K}_{PL,t})) + 0.679(\Delta\ln(\mathsf{L}_{PL,t})) + (-0.108)(\mathsf{HC}_{PL,t-5}) + \\ 0.070(\mathsf{DF}_{PL,t-5}) + 0.010(\Delta\ln(\mathsf{R\&D}_{PL,t-5})) + (-0.033)(\Delta\ln(\mathsf{EDU}_{PL,t-5})) + \\ 0.002(\Delta\ln(\mathsf{FDI}_{PL,t-5})) + 0.105(\mathsf{HH}_{PL,t-5})\end{aligned} \tag{4.2}$$

Intercept values for each country can be found in the appendix B, for Poland it was 0.33.

Obtained results in comparison to real GDP are presented in the figure below:

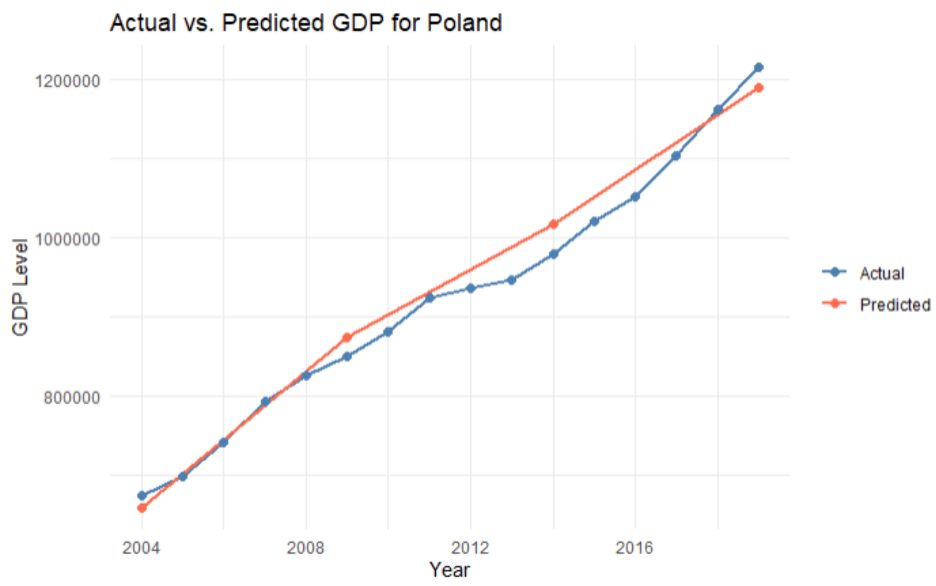

Figure 4.3: Actual vs Predicted values for Poland using Model Endogenous [Source: see Table 3.1]

Although the fitted series does not match the data point-for-point, it successfully reproduces Poland's upward growth trajectory. Estimating the model in five-year differences naturally makes the predicted path more jagged than the observed, annual series. The widest divergence appears around 2012, alligning with the post-crisis turbulence in the European Union. The visual alignment, together with the strong statistical significance of the underlying coefficients indicates that the model's overall fit is adequate for the purposes of this analysis.

4.2.4. Conclusions and economic implications

The empirical results confirm that traditional production inputs: capital and labor, remain foundational in explaining real GDP growth, consistent with the predictions of exogenous growth theory (see Section 2.2.1). However, the central focus of this analysis lies within the framework of endogenous growth theory. A key finding is the significance of the interaction term between human capital and distance to the frontier (HC×DF), which supports the theory of conditional convergence (see Section 2.2.2). Countries do not automatically benefit from being far behind the frontier. They require a minimum threshold of absorptive capacity, proxied here by human capital, to turn this gap into a growth advantage. While human capital on its own shows a negative and statistically significant effect across most models, this likely reflects deeper structural issues such as skills mismatch, low labor-market efficiency, or even brain drain as pointed by empirical researchers (Docquier & Rapoport, 2012). Its positive role within the interaction term, however, confirms that education and knowledge remain critical enablers of catch-up growth when paired with appropriate innovation and institutional environments (Howitt & Mayer-Foulkes, 2005).

Model Endogenous, demonstrates robust explanatory power, with relatively high R^2 and statistically significant F-statistics, indicating a strong fit. Nevertheless, several variables behave in unexpected ways. Government education spending, for example, enters negatively, potentially due to inefficiencies in public allocation, misalignment with labor-market demands, or delayed returns that extend beyond the model's time window as pointed by Trabelisi (2018), but the research of exact reasons for this interaction is not part of the thesis. Similarly, the R&D stock shows a weaker effect than anticipated. This could suggest that R&D investments are either not yet developed enough to generate measurable spillovers (Bart van Ark, 2004), or are subject to reverse causality, where slower-growing countries increase R&D spending in hopes of stimulating future growth (Acemoglu, 2009).

Foreign Direct Investment (FDI) inflows-commonly cited in the literature as a key channel for transferring knowledge, advanced technology, and managerial expertise (De Gregorio et al., 1998), exhibit only a modest impact in the empirical models. This limited effect may stem from structural constraints that hamper the domestic economy's ability to absorb and leverage foreign inputs effectively (Salamaga, 2023). Possible explanations mentioned in the empirical literature include inefficient taxation regimes for foreign enterprises (Francois & Vicard, 2023), weak enforcement of technology-sharing agreements, or a lack of targeted incentives to promote meaningful collaboration between multinationals and domestic firms (World Bank, 2024). Without strong absorptive capacity and strategic integration into the local innovation ecosystem, the growth-enhancing potential of FDI is likely to remain underutilized. Highlighting the need for policy measures that strengthen technology and knowledge transfer.

Despite these nuances, the overall empirical findings broadly validate the conceptual framework outlined in Section 3.2.1. Apart from human capital and government education spending, all core factors like: capital, labor, distance to frontier, and R&D, show the expected positive association with growth. The anomalies observed in some coefficients do not undermine the theoretical relevance of these variables, but rather highlight the importance of context, measurement limitations, and complementary reforms. Taken together, the results support the thesis's central proposition: long-term growth is not only a matter of input accumulation, but of enabling the conditions that allow these inputs, especially innovation and skills, to translate into productivity gains.

4.3. Country comparison

In this section, the comparison between Poland and South Korea will be conducted in order to judge and indicate the places of improvement for Poland when compared to widely recognized technology leader - South Korea. This will try to answer the sub-research question number 3 and 4.

4.3.1. GDP and GDP growth

As described in the Section 2.1 Poland and South Korea have significantly different take-off periods in economic terms. However, both countries managed to escape the middle-income trap (World Bank, 2024).

The take-off years for both countries are:

- **South Korea - 1962**
- **Poland - 1992**

These years are the time of significant reforms for both countries, followed by a rapid growth. The situation for today is that South Korea has a higher GDP per engaged person in comparison to Poland. This relates to the long period of extensive growth, much longer than Poland's (30 year difference).

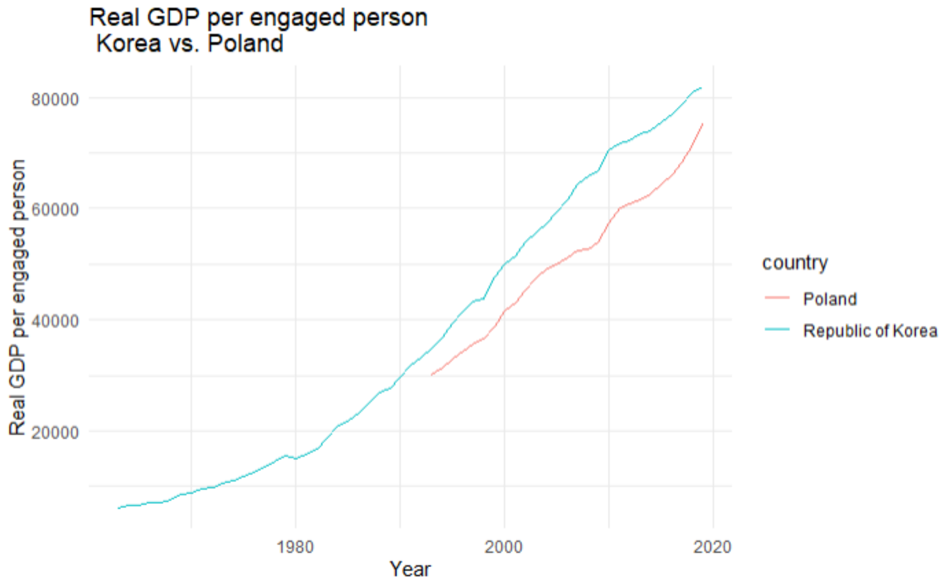

Figure 4.4: Real GDP per person engaged for both countries [Source: (Feenstra & Timmer, 2015)]

Figure 4.5 above shows the actual levels of real GDP per engaged person for South Korea (1961–2019) and Poland (1991–2019) plotted on the same axes, without shifting Poland's series, so that each country's trajectory can be easily compared.
In 1962, South Korea's real GDP per engaged person was only around $6000 (in 2017 US$) climbing gradually through the 1960s and 1970s. By contrast, Poland's growth series begins in 1992 at approximately $29500, reflecting the relatively higher income level it had achieved under the socialist system before transitioning in the early 1990s. The slightly widening gap between the two lines underscores that starting from a higher initial income is no guarantee of faster convergence: Korea not only closed its initial deficit more rapidly, but also outpaced Poland's subsequent advances. In 1993 Poland had the GDP per engaged person at the level of $29852 where Korea had $36935 indicating the difference of $7083, whereas in 2019 the difference was $12 903 (GDP per engaged person for Poland and Korea were: $57515 and $70423 accordingly) This suggests that early, sustained commitment to open market policies, quality education, and technological adoption can have compounding effects that outweigh a one time income head start. However, the initial signs of closing this gap can be seen, indicating that South Korea might be approaching its convergence plateau (see Section 2.2.2) where Poland might still have potential for growth 4.5.

In order to investigate further the patterns occurring between those two countries and a potential catch-up of Poland, the time-frame adjusted CAGR graphs were made:

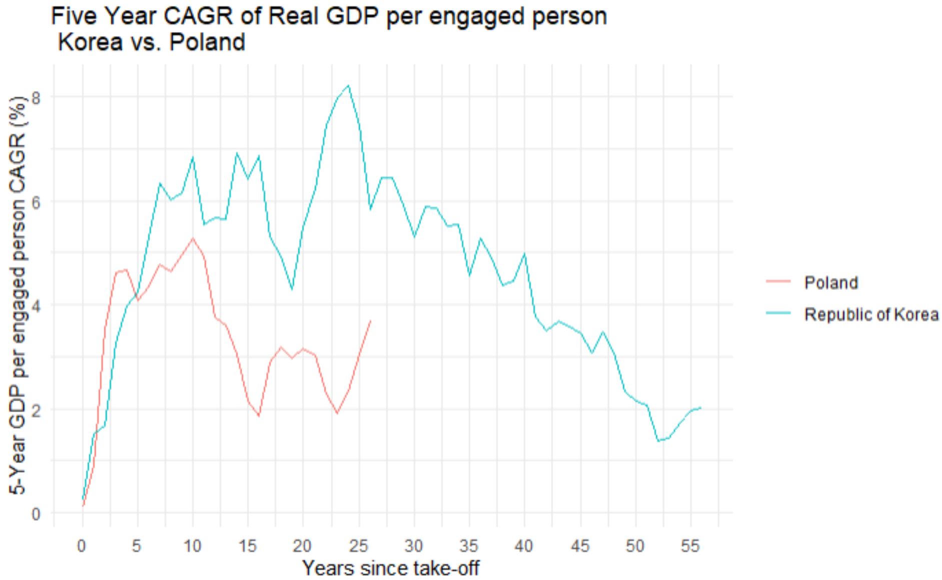

Figure 4.5: Real GDP per engaged person 5 year CAGR for both countries [Source: (Feenstra & Timmer, 2015), own calculations]

South Korea's five-year per-engaged person CAGR climbs above 6% as early as the late 1960s, reaching peaks around 8% in the late-1980s and again. This reflects Korea's shift from a labor-intensive export focus into higher-value manufacturing and heavy industries, underpinned by aggressive public investment in infrastructure and education (Kim, 1995). Poland, by contrast, only begins its sustained acceleration after its post-communist reforms in the mid-1990s: its five-year CAGR climbs from near zero in the early 1990s to around 5% by the late 1990s, a solid performance but one that is not as great as Korea's earlier "miracle" phase. The shifted graph shows a valuable insight - the scale of growth in the first 20 years is smaller in Poland in comparison to South Korea. An additional observation is the length of the economic cycles. In South Korea it can be observed that the cycles lasted longer than in Poland, indicating that the "older" economic market moved slower in comparison to the rapidly changing markets right now. It can also be observed that for the last 20 years the growth of South Korean economy was in a decline (still around 2%), and it declined to the level that is smaller than the one observed in Poland (Korea 2019: 2.01% CAGR; Poland 2019: 3.68% CAGR). This is an indicator that either, country converged to it's peak economy size or that it's growth is stagnating and another reforms are needed in order to bring the previous levels of growth back.

Since their take-off, neither country has experienced any major stagnation also in per-capita terms, and both continue to exhibit growth trajectories that suggest the middle-income like trap has already been overcome. Drawing on Eichengreen et al. (2014) reasoning, a period of stagnation—whether at middle- or higher-income levels—can be identified only if growth first exceeds 3.5% and then declines by more than 2 percentage points immediately thereafter. Applying this criterion to recent data, it becomes clear that only Poland remains at risk of entering a middle-income trap style stagnation, as its growth path meets the initial threshold but shows potential for the requisite decline. In contrast, the South Korean post–take-off expansion was a long-term process and the gradual decrease in GDP growth is caused by the approach of the convergence region for the country - not a stagnation.

To assess the risk of stagnation for Poland more precisely, the methodology outlined in Section 4.1 must be refined in order to capture faster shifts apparent in recent years. Specifically, instead of relying on seven-year intervals to detect changes in growth, five-year periods will be employed in order to provide a more granular perspective on evolving trends. For the purposes of simulation, it will be assumed that Poland's growth rate aligns with South Korea's 2019 figure of 2.5%. Additionally, in calculating per capita growth rates, Poland's population will be held constant at its 2019 level. This assumption simplifies the analysis by isolating output growth from demographic effects, thereby offering a clearer view of changes in output per person.

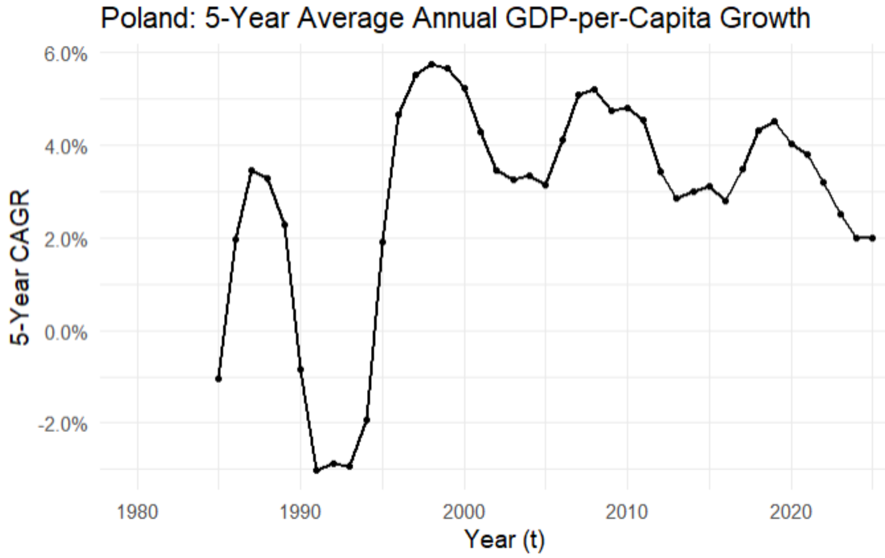

Figure 4.6: Real GDP 5 year CAGR for Poland after the potential slowdown [Source: (Feenstra & Timmer, 2015), own calculations]

Table 4.4: Growth slowdowns in Poland

Country	Year	Growth before slowdown (t−5 through t)	Growth after slowdown (t through t+5)	Difference in growth	Per-capita GDP at t ($)
Poland	2019	4.53	2.50	-2.03	37.165

As illustrated by the graph and table above, if Poland were to replicate South Korea's growth trajectory, it would register a growth stagnation as defined by Eichengreen et al. (2014) criteria. Specifically, Poland's growth rate would fall from 4.53% to 2.50% over the subsequent five-year period. When this decline is considered alongside a per-capita GDP level of $37,165, all of the necessary conditions for identifying a slowdown are satisfied. In other words, the combination of an initial growth rate above 3.5%, followed by a drop exceeding 2 percentage points within five years, together with Poland's income benchmark, confirms that such a scenario would constitute a true stagnation episode under Eichengreen's framework. This outcome underscores a broader pattern in which high-income, high-technology economies tend to record slower growth rates than those still benefiting from catch-up effects (Durlauf & Johnson, 1995). South Korea's more advanced status implies that its marginal gains are smaller, whereas a country like Poland, which remains further from the technological frontier, can sustain higher growth by adopting existing innovations and expanding its productive capacity more rapidly.

4.3.2. Productivity

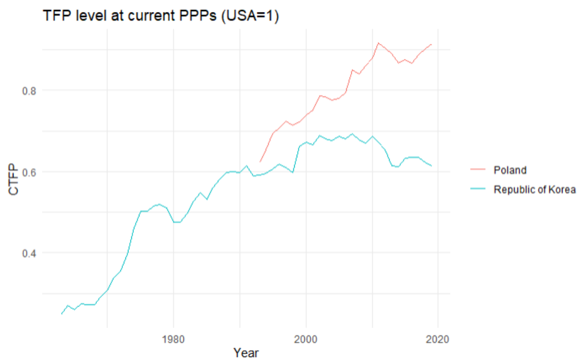

Figure 4.7: TFP level for both countries [Source: (Feenstra & Timmer, 2015)]

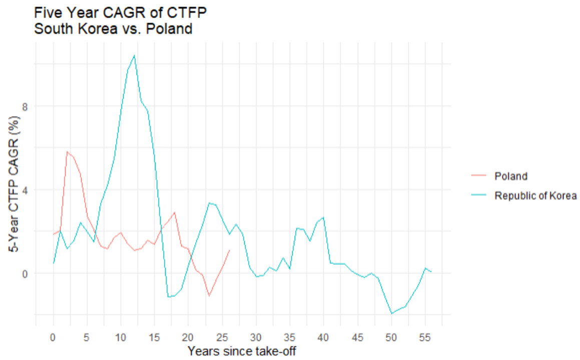

Figure 4.8: TFP 5 year CAGR for both countries [Source: (Feenstra & Timmer, 2015), own calculations]

The latest PWT 10.01 data on TFP levels (ctfp variable is TFP level at current PPPs (USA=1)) reveal that Poland now outperforms South Korea in terms of total factor productivity. As of the early 2000s, Poland's TFP index climbs above 0.8 - nearly reaching the U.S. benchmark, whereas South Korea has plateaued around 0.65-0.7 since the 1990s. Two sets of forces help explain this reversal. First, Poland's integration into the European single market after 2004 unleashed a wave of investment in managerial best practices, quality standards, and service sector automation that could have been easily applied in the Polish economy thanks to absorptive capacities possessed by the economy (Piatkowski, 2019). Second, the structural reforms of the 1990s privatization of state-owned enterprises, liberalization of trade and finance, introduced more sectoral diversification in Polish economy (Hunter & Ryan, 2011).

The timing of that boom is particularly striking when we look at five-year CTFP growth rates plotted against "years since take-off." Poland's productivity surge arrives almost immediately and its five-year CAGR spikes to 6–7 percent within the first decade post-takeoff, reflecting the sharp recovery from socialist stagnation and the shock-therapy reforms of the early 1990s. In contrast, South Korea's strongest productivity acceleration only emerges around 10-15 years after its own take-off point, when five-year growth peaks above 8 percent. This lagged peak is likely tied to Korea's post-war starting conditions: devastated by the Korean War, it had to rebuild basic infrastructure and human capital before reaping the dividends of technology transfer (Jong, 2001). Once those foundational hurdles were cleared, Korea enjoyed its "golden age" of convergence.

One issue that arises is that, when applying the distance-to-the-technology-frontier measure introduced in Chapter 3.2.1, South Korea appears further from the frontier than Poland. This result is particularly surprising, given that Poland is not typically regarded as a leader in innovation—a key determinant of long-term growth according to economic theory. This highlights a limitation of using general distance-to-frontier metrics, as they may not accurately capture differences in innovation capacity across countries. To more accurately assess whether Poland is lagging in terms of innovation, further research focusing on the development and adoption of new technologies is necessary.

From a middle-income-trap like perspective, both South Korea and Poland exhibit warning signs in their CTFP growth trajectories. South Korea's CTFP growth has largely stagnated, or even declined, over recent decades, signaling that the country has already absorbed most readily available productivity gains and is finding it hard to push beyond its current levels. Poland, despite now exhibiting higher CTFP levels than Korea, is not performing much better in terms of momentum: its CTFP growth is modest and often lags behind overall GDP growth, suggesting that productivity is only one of several growth drivers and that further gains may become increasingly difficult. In other words, as Poland's productivity approaches U.S. benchmarks, the distance-to-frontier metric predicts diminishing returns to catch-up, making it harder to sustain rapid TFP expansion.

4.3.3. New technologies

Drawing on the theoretical background, which highlights domestic innovation as the most effective pathway for moving beyond the imitation phase and securing a lasting place within the global innovation club (see Table 2.1) this section compares Poland and South Korea across several key dimensions of innovation both on input side - R&D expenditure, but also on the output side - ICT service exports, medium and high-tech exports and patent applications. This comparision lays the groundwork for targeted policy recommendations to accelerate Poland's transition to an innovation-driven economy.

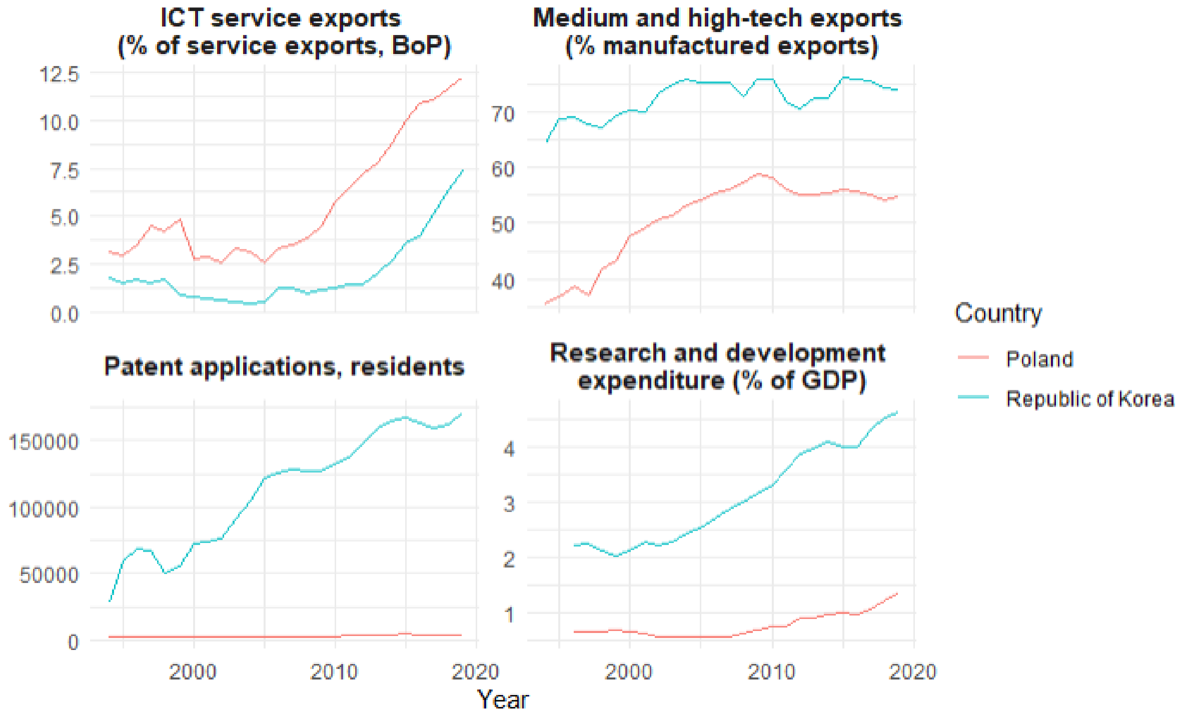

Figure 4.9: Tech indicators comparison [Source: (WorldBank, 2025b)]

Figure 4.9 illustrates that Poland allocates a smaller share of GDP to R&D than does South Korea, a finding that supports prior studies on national innovation expenditure (Vienna Institute for International Economic Studies, 2023). Nevertheless, Poland surpasses Korea in the ICT services sector, as evidenced by its higher proportion of ICT services in total services exports. This discrepancy reflects divergent development strategies:

Korea's post-war "Miracle on the Han River" was based on rapid industrialization and state-guided support for large, export-oriented conglomerates (chaebols) such as Samsung, LG, Hyundai and SK Group, through measures including concessional credit, tax incentives, and directed R&D subsidies (Campbell & Keys, 2002; Kim, 1995). Consequently, Korea has sustained a persistently high ratio of medium- and high-tech manufacturing exports and attained world-class levels of patent activity and R&D intensity (cf. the "Patent applications" and "R&D expenditure" panels in Figure 4.9).

In contrast, Poland has pursued a specialization in ICT—particularly software development services, by attracting foreign multinationals to establish offices together with other necessary facilities, and by cultivating a local contracting ecosystem (Piatkowski, 2019). This strategy has enabled Poland to achieve competitive performance in services exports despite its comparatively lower absolute investment in R&D.

To better understand the gap with more innovative countries, the sectoral breakdown of R&D spending was examined, guiding the development of policies to support the sectors that lag the most.

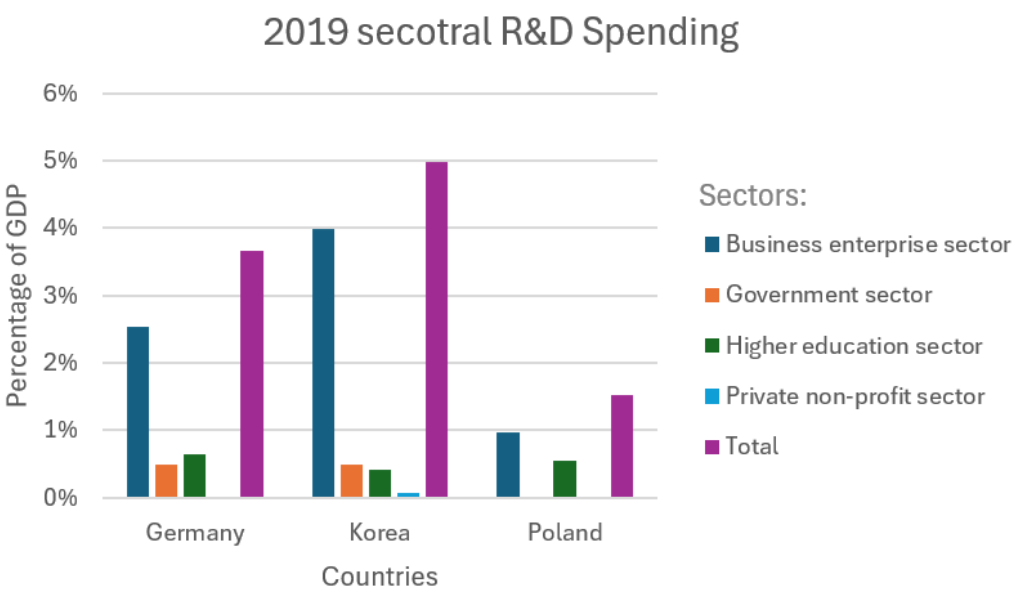

Figure 4.10: Research and Development spending by different sectors for different countries [Source: (Eurostat, 2024b)]

Figure 4.10 illustrates that Poland's total R&D investment, at 1.53% of GDP, is markedly lower than South Korea's 4.97% and Germany's 3.67%. This gap is driven primarily by the business enterprise sector, which in Poland contributes only about 1.0% of GDP, compared with 4.0% in Korea and 2.5% in Germany. By contrast, Poland's higher education sector invests approximately 0.6% of GDP, closely matching South Korea's 0.% and Germany's 0.65%. Government sector R&D spending in Poland - at around 0.02% of GDP, also lags behind both Germany and Korea, which both each allocate about 0.5% to publicly funded research. The resulting imbalance - strong academic R&D alongside weak private- and public-sector engagement, underscores the need for targeted policies to stimulate corporate and government research and development.

Building on the sectoral R&D breakdown, a broader, composite measure of innovation performance can shed further light on Poland's innovation. According to the Global Innovation Index from 2023, done by World Intellectual Property (2023) , Poland ranks 41th out of 133 economies, underperforming relative to expectations, particularly in the institutions and infrastructure pillars, this follows the findings obtained in the figure 4.10, in which government spending on R&D was lower in comparision with other economies. On the other hand, South Korea is firmly established among the world's top innovators: it holds 10th place overall and excels in human capital and research outputs - exactly what was discovered in the figure 4.9, where South Korea outperfrmed Poland. In particular, one of the main factors measured by the index authors, that reduces Poland's index score, is policy stability for doing business, where it scored among the lowest. That underscore the need for innovation oriented policies that empower entrepreneurs to translate their knowledge into new value creating outputs.

4.3.4. Human capital

Both the empirical model developed for this thesis (Section 4.2) and the specification estimated by Stöllinger (2013) indicate a negative relationship between measures of human capital and GDP growth. Although these findings run counter to the broader theoretical consensus, they likely reflect measurement limitations or omitted-variable bias rather than a genuine adverse effect, as shown by other empirical researchers (Vandenbussche et al., 2006). Given this extensive theoretical support for human-capital accumulation, its inclusion remains important. A direct comparison of Poland and South Korea will clarify their possible divergent human-capital trajectories and provide a basis for targeted policy recommendations to strengthen Poland's growth prospects.

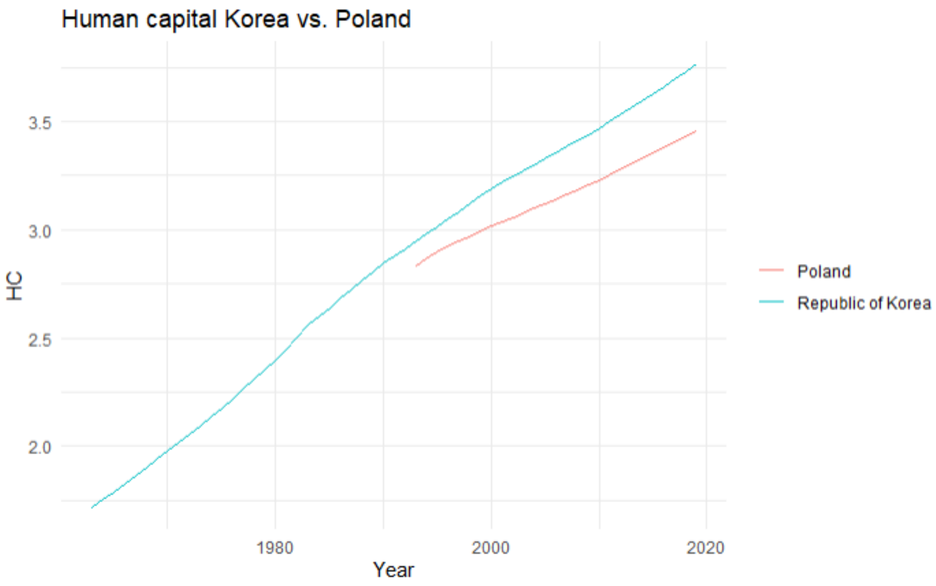

Figure 4.11: Human capital comparison [Source: (Feenstra & Timmer, 2015)]

Human capital in South Korea and Poland has grown steadily over the past half-century, but the timing and intensity of their respective "take-offs" differ markedly. Beginning around 1962, South Korea embarked on a rapid and sustained accumulation of human capital, rising from roughly 1.8 units in the mid-1960s to nearly 3.8 units by 2019. The calculated regression lines below quantify these trends and facilitate a clear comparison of their growth trajectories:

$$\widehat{HC}_{\text{KOR}} = -70.999 \; + \; 0.037\,(\text{Year})$$
$$\widehat{HC}_{\text{POL}} = -42.964 \; + \; 0.023\,(\text{Year})$$

As can be seen in the regression results, annual gain for Korea is at 0.037 HC-units per year. (about 60 % faster than Poland's pace). By contrast, Poland's human capital at the moment of "take off" was already quite high - about 2.9 units. After the take-off it remained in an upward trajectory, climbing to 3.5 units by 2019. Although, Poland has maintained a healthy growth rate since its post-1992 "take-off," it has not yet closed the gap to Korea. Projecting these trends forward suggests the human-capital differential will continue to widen. This underscores the need for targeted policies in Poland to accelerate skill accumulation and narrow this divide.

4.3.5. Product market regulation

As identified by the researchers product market regulation is one of the crucial factors in sustaining long-term growth (Conway et al., 2006). Although the empirical estimates in Table 4.2 did not yield statistically significant coefficients for PMR, it was deemed worthwhile to examine and contrast the regulatory frameworks of South Korea and Poland. PMR remains an essential enabling condition for efficient resource allocation, innovation diffusion, and foreign direct investment.

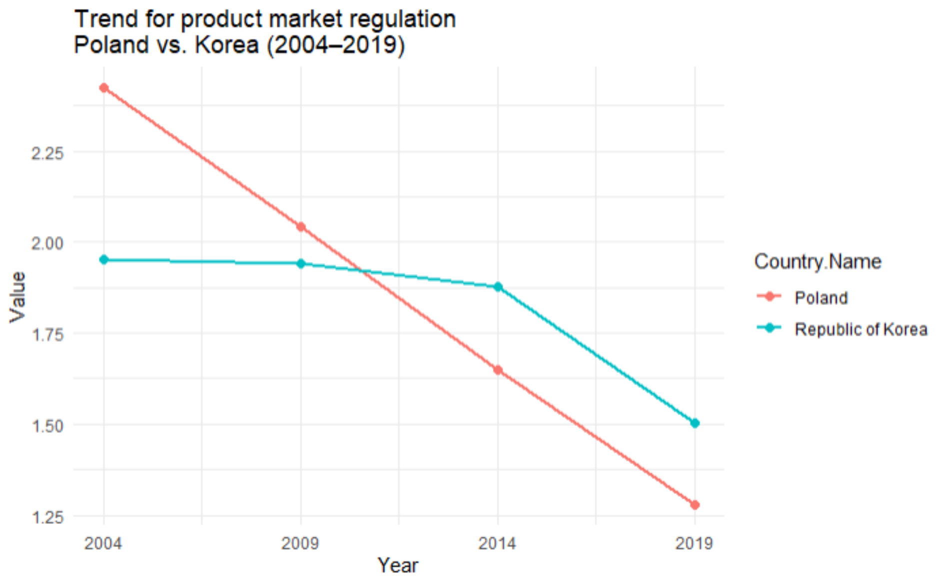

Figure 4.12: PMR comparison [Source: (OECD PMR team, 2020)]

Both countries have steadily liberalized their product market regulations over the 2004–2019 period, fostering a more competitive business environment. Notably, by 2019 Poland's PMR index falls below South Korea's.This convergence, and eventual overtaking, carries some important implications:

- **Innovation diffusion:** A more liberalized market lowers costs and barriers for new entrants and makes it easier for Polish firms to adopt and adapt frontier technologies, closing the gap with global leaders.
- **Foreign investment:** Reduced regulatory barriers enhance Poland's attractiveness to multinational R&D centers and manufacturing facilities, potentially boosting technology transfer and knowledge spillovers.
- **Competition and productivity:** Stronger competitive pressures encourage domestic firms to innovate and improve efficiency, reinforcing the gains from Poland's improved R&D environment.

Taken together, these trends suggest that Poland is now better positioned, at least in terms of product market openness, to capitalize on innovation opportunities. The challenge ahead is to complement this regulatory progress with targeted incentives and support mechanisms that will translate openness into tangible R&D investment and productivity growth.

4.3.6. FDI

Complementing product-market liberalization, foreign direct investment (FDI) serves as a vital channel through which regulatory and economic openness translates into technology transfer, know-how diffusion, and enhanced domestic R&D capacity. In the majority of empirical specifications, including those researched in the thesis (see Table 4.2) FDI enters with a positive coefficient, highlighting its possible importance as an intermediate condition between imitation and innovation.The next section presents a comparative analysis of FDI trends in South Korea and Poland, examining how foreign capital is allocated and its potential for spillovers into R&D and productivity growth.

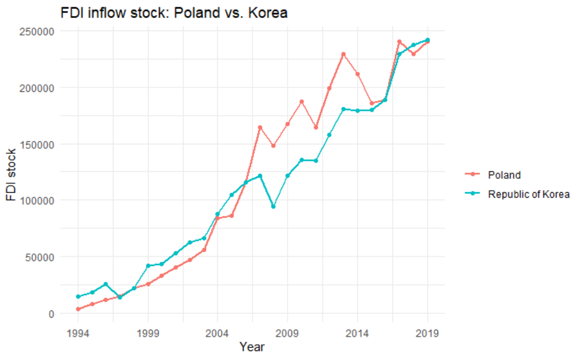

Figure 4.13: FDI stocks comparison [Source: (WorldBank, 2025b)]

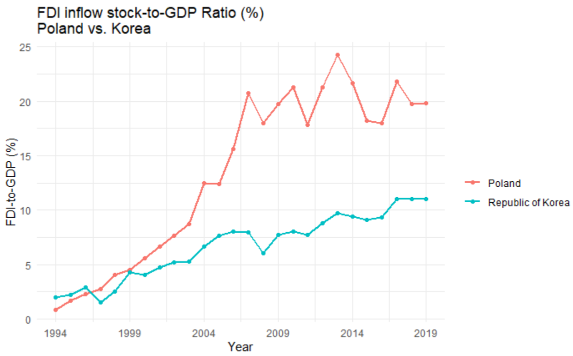

Figure 4.14: FDI to GDP comparison [Source: (WorldBank, 2025b), own calculations]

Poland's FDI stock increased sharply around its 2004 EU accession, a predictable outcome of the single market's liberalized investment regime, which greatly lowered cross-border barriers for investments. Yet over the full 1994–2019 period, both Poland and South Korea accumulated inward FDI at remarkably similar rates, despite Poland's considerably smaller economy and lower GDP per capita. This suggests that investors have been attracted to the "high-growth" prospects of emerging markets, placing relatively less weight on investing in more mature, slower-growing economies like South Korea after the 1994 (at least according to growth graph from section 4.3.1) (Piatkowski, 2019). Moreover, when comparing total FDI stocks figure 4.13 with GDP adjusted measures figure 4.14, it becomes clear that Poland remains more dependent on foreign capital than South Korea, indicating the relative importance of FDI as a growth lever in the Polish economy.

Nevertheless, FDI's benefits depend critically on the effective transmission of capital, innovation, and managerial know-how. The World Bank's "3I" framework (Investment, Innovation, and Infusion) stresses that FDI should do more than provide funding - it must also foster the domestic diffusion of advanced technologies and best practices (World Bank, 2024). In Poland, however, this infusion step remains incomplete. While multinational corporations have introduced modern production methods and organizational techniques, much proprietary knowledge stays confined within foreign-owned affiliates or is repatriated to parent firms abroad. This gap helps explain why Poland's innovation output - measured, for example, by patent applications per residents lags behind peers despite high FDI levels (see figure 4.9) (Brzyska, 2023). In effect, reliance on FDI as a growth engine is double-edged: it underwrote Poland's post-2004 infrastructure and capacity upgrades (Piatkowski, 2019), but identified weak university - industry links and underdeveloped R&D incentives have limited the broader economy's ability to absorb and build upon the advanced techniques brought in by investors.

Building on the comparison of FDI trends, examining the share of gross value added generated by foreign-owned firms in Poland can help understand whether rising capital inflows translate into domestic R&D and innovation or remain trapped within multi-national networks. Higher share implies substantial in country value creation, and by extension innovation, while a lower share suggests that expertise and profits are largely repatriated (Salamaga, 2023). Using this metric as a proxy for foreign R&D engagement, it becomes possible to gauge not only the scale of foreign investment but also the effectiveness of knowledge transfer and the potential leakages from the national economy

Table 4.5: Gross value added and foreign-controlled enterprises value added in Poland [Sources: (Eurostat, 2024a; Główny Urząd Statystyczny (GUS), 2023)]

Indicator	**Value**
Gross value added (PLN)	2,289,681,000,000
Average euro exchange rate 2021	4.599
Gross value added (EUR)	497,821,672,392
Foreign-controlled enterprises value added (EUR)	106,563,000,000
Percentage of foreign value added in gross value added	21%

Table 4.5 shows that in 2021 Poland's gross value added totaled €497.8 billion, of which €106.6 billion, 21 percent, was generated by foreign-controlled enterprises. In other words, more than one-fifth of Poland's value added originates with foreign investors. Compared with the rapid rise in Poland's FDI to GDP ratio (Figure 4.14) and the spillover gaps discussed earlier, this share underscores both the breadth of foreign capital footprint and the urgent need to ensure it support for domestic R&D rather than simply enriching balance sheets.

Multinational affiliates frequently exploit complex, multilayered ownership structures - combined with transfer-pricing techniques and preferential tax rulings, to shift profits to low-tax jurisdictions, eroding the domestic tax base available for reinvestment (Francois & Vicard, 2023). Additionally empirical evidence from Asian economies suggests that only around one-third of MNE profits are retained and reinvested locally, with an even smaller share devoted to R&D (Ing et al., 2017).

Poland faces a similar vulnerability: foreign-owned firms generate more than 21 percent of national gross value added, yet profit-shifting could mean that much of the headline €106 billion in value added never appears as taxable income or as finance for domestic innovation. Consequently, relying on the amount of value added is risking overstating FDI's true contribution to innovation capacity. A more accurate assessment must consider the share of affiliate profits retained onshore, the intensity of R&D spending from those earnings, and the degree of collaboration between foreign owned firms and domestic research institutions. Investment-attraction policies should be therefore calibrated to reward high onshore profit retention, measurable R&D outlays, and deep integration with Poland's innovation ecosystem.

4.3.7. Sectoral diversification

Sectoral diversification offers a further lens for comparison. Both theoretical frameworks and empirical models demonstrate a U-shaped relationship between diversification and economic growth (Imbs & Wacziarg, 2003). In the initial "imitation" phase, broadening the range of productive activities helps economies absorb foreign technologies. As countries transition into the "innovation" group, they benefit from concentrating resources in high-value sectors (see Table 2.1). Contrasting South Korea - a mature, innovation driven economy, with Poland - still in the imitation phase, can reveal whether Poland should pivot from broad diversification toward concentrating its productive efforts on a narrower set of high-growth industries to accelerate its innovation trajectory.

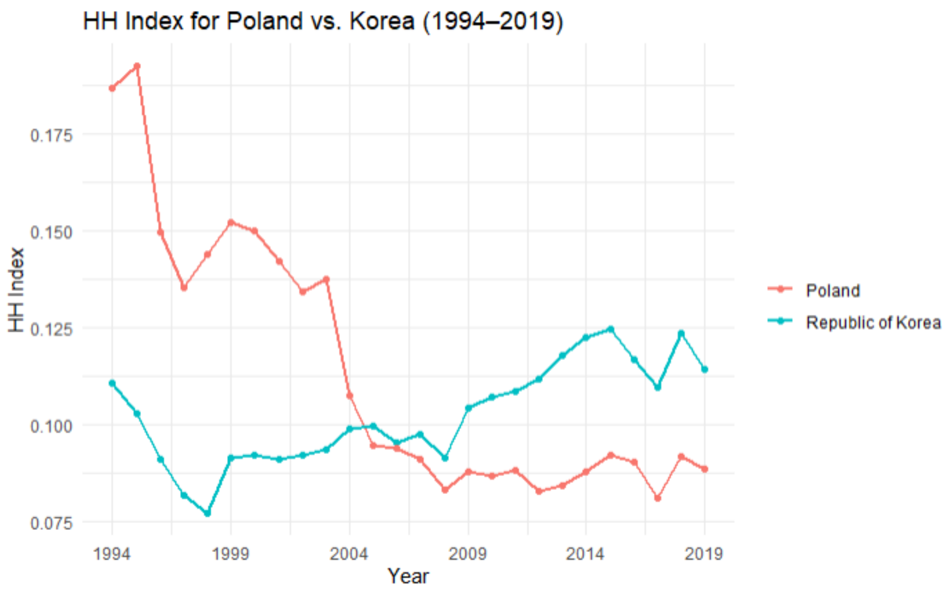

Figure 4.15: HH index comparison [Source: (World Integrated Trade Solution, 2022)]

Poland's transition from a centrally planned economy to a market-oriented system after the collapse of socialism sparked a dramatic surge in private enterprise. Freed from the legacy of state ownership, a growing number of Polish citizens seized the opportunity to establish small and medium-sized enterprises (SMEs) or to purchase formerly nationalized firms, making Poland a more diverse economy in many different sectors. By 1997, the average number of SMEs per capita in Poland had already surpassed the European Union average, showing not only the rapid diversification of the domestic market but also the widespread entrepreneurial enthusiasm that characterized the period (Surdej, 2000).

This diversification efforts can clearly be seen on the graph in the figure 4.15, where Poland's Herfindahl-Hirschman concentration index fell dramatically from roughly 0.18 in 1994 to about 0.09 by 2005, signaling a rapid spread of economic activity across a wider array of industries. After that point, the index stabilized around 0.08–0.09, suggesting that Poland had achieved and sustained a relatively high level of sectoral diversification. In contrast, South Korea, whose HH index began lower at around 0.11 in the mid-1990s, experienced a gradual rise in concentration after 2004, reaching nearly 0.12 by 2018. While this thesis does not decompose the concentration drivers in detail, a leading hypothesis is the continued market dominance of large chaebol conglomerates (e.g., Samsung, Hyundai, LG), which command a significant share of domestic markets and thus keep the overall index elevated (Campbell & Keys, 2002). Positive outcome of this pattern have strong empirical support from the two-stage growth hypothesis advanced by the authors, Imbs and Wacziarg (2003), namely that economies benefit first from broad-based diversification and then, once a critical mass of firms and industries is in place, from a degree of market concentration that enables scale efficiencies and global competitiveness. Therefore, Poland's growth strategy should prioritize specialization in higher-value-added sectors. Approach that aligns closely with the policy recommendations of leading research institutes (Vienna Institute for International Economic Studies, 2023).

4.3.8. GDP simulation for Poland

To integrate the developed panel-data model from Section 4.2 with the country-comparison results of Section 4.3, this section conducts a series of simulations. The estimated coefficients of the Endogenous Model are applied to alternative values of key indicators, such as R&D stock, sectoral diversification and distance to the frontier to project Poland's potential GDP levels under different scenarios. These projections will quantify the contribution of each variable to growth and help prioritize the most impactful innovation policies.

Poland and South Korea

Benchmarking against South Korea provides an estimate of how Poland's GDP trajectory would change if it adopted Korean rates of R&D stock growth and sectoral diversification. Instead of focusing solely on model-based growth rates, absolute GDP paths are simulated to clarify potential gains. Both R&D accumulation and sectoral diversification turned out to have a positive and statistical significantly impact in the endogenous growth equation (Eq. 4.2), yet Poland underperforms Korea on both dimensions. Imposing Korean values for these variables on Poland's baseline GDP path quantifies the additional GDP attainable by closing these gaps.

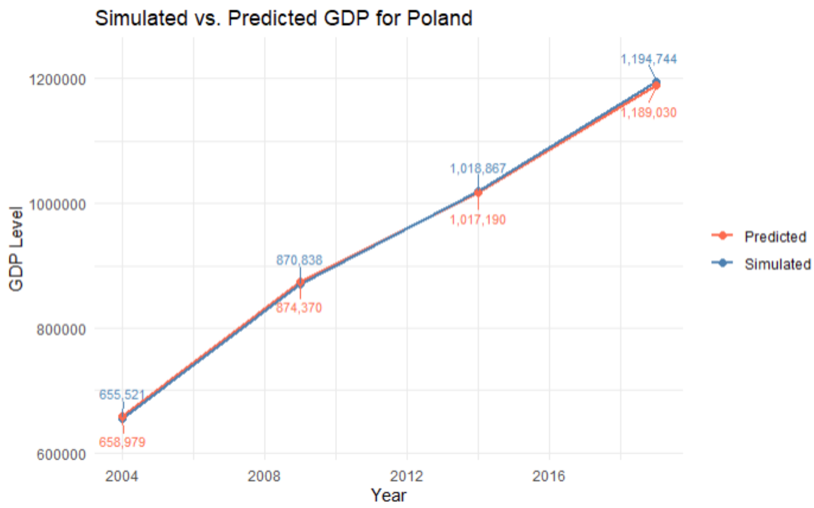

Figure 4.16: Simulated vs Predicted GDP levels for Poland using Model Endogenous and measurements from Korea [Source: see Table 3.1, own calculations]

As illustrated in Figure 4.16, the model's predicted values from Section 4.2.3 track the simulated series based on South Korean benchmarks very closely. The coefficients in Table 4.2 show that a one-percentage-point increase in R&D stock raises GDP growth by just 0.01 percentage point, whereas a one-unit rise in the Herfindahl–Hirschman sectoral-diversification index (HH index) boosts GDP growth by 0.105 percentage point. However, the two variables exhibit very different empirical spreads (Table 3.2): R&D stock growth spans –0.071 to 2.113, while the HH index ranges only from 0.0335 to 0.779. As a result, despite its much larger coefficient, the HH index's narrow variation limits its maximum impact on GDP growth; conversely, the wider dispersion of R&D growth amplifies its (smaller) coefficient. At the extremes, R&D stock's contribution to GDP growth ranges from –0.0007 to 0.0211 percentage points, whereas the HH-index's boundary impact lies between 0.0035 and 0.0818 percentage points. For the purpose of this simulation the values for both countries are:

Table 4.6: R&D Stock, HH Index, changes and impacts on GDP Growth

		Year			
Group	**Measure**	**2004**	**2009**	**2014**	**2019**
Poland					
	R&D stock growth	0.052	0.055	0.108	0.259
	HH index	0.152	0.107	0.087	0.087
South Korea					
	R&D stock growth	0.087	0.211	0.311	0.295
	HH index	0.098	0.104	0.122	0.114
Change in values					
	R&D stock growth	0.035	0.156	0.203	0.036
	HH index	–0.054	–0.003	0.035	0.027
Impact on GDP growth					
	R&D stock growth	0.00035	0.00156	0.00203	0.00036
	HH index	–0.00567	–0.00032	0.00368	0.00284
	Together	**–0.00532**	**0.00125**	**0.00571**	**0.00320**

Table 4.6 shows that the joint contribution of R&D stock and sectoral diversification to annual GDP growth varies from –0.00532 to 0.00571 over the period of 4 years. The largest positive effect occurs in 2014, when R&D stock growth rose by 0.203 percentage points and the HH index increased by 0.035

units. This effect can also be seen in the figure 4.16, where before year 2014 simulated GDP was lower when compared to the one predicted by Polish values. In that year, despite its smaller value, the HH-index change generated a larger growth impact than the R&D change, highlighting the high leverage of further sectoral centralization. To conclude, according to figure 4.16, if Poland had matched South Korea's R&D and diversification levels over the 15-year period, GDP would have been 0.48 percent higher. However, this uplift is modest compared with the magnitudes predicted by endogenous growth models and other empirical studies (Acemoglu, 2009; Imbs & Wacziarg, 2003; Romer, 1990), that place innovation at the heart of economic expansion .

Distance to frontier vs R&D

When South Korean R&D levels are imposed on the model (Figure 4.16), the gains remain muted. To benchmark against another key driver, the distance-to-frontier (DF) indicator is introduced (see Section 2.2). In the Model Endogenous specification (Equation 3.7), both DF and R&D stock growth enter with positive coefficients, where DF captures the catch-up reward for economies lagging behind the technological leader. To test whether innovation can outpace convergence gains, Poland is treated as a technology-frontier economy by setting its distance-to-frontier to the sample minimum, while simultaneously boosting its R&D stock growth to the observed maximum (see Table 3.2).

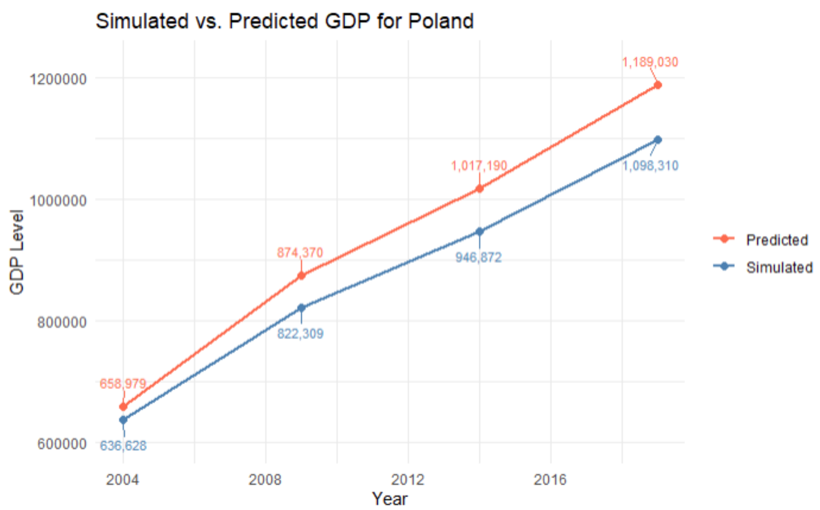

Figure 4.17: Simulated vs Predicted GDP levels for Poland using Model Endogenous, together with the lowest gap to tech frontier and highest R&D stock growth [Source: see Table 3.1, own calculations]

Figure 4.17 shows that, even when Poland's distance-to-frontier is set to its sample minimum and R&D stock growth is pushed to its observed maximum, the endogenous-growth model does not predict any acceleration in GDP growth versus the baseline. This outcome highlights the dominant influence of the convergence (catch-up) effect relative to the innovation channel. In fact, to achieve the previously predicted growth path using only an R&D stock, R&D stock growth rate of approximately 400 % is required. This magnitude is deemed exceptionally high and largely implausible within realistic economic scenarios

R&D Spending increase

Finally, to isolate the effect of R&D on its own, the simulation holds Poland's distance□to□frontier constant, at the real measured value, while applying the highest observed R&D stock growth rate.

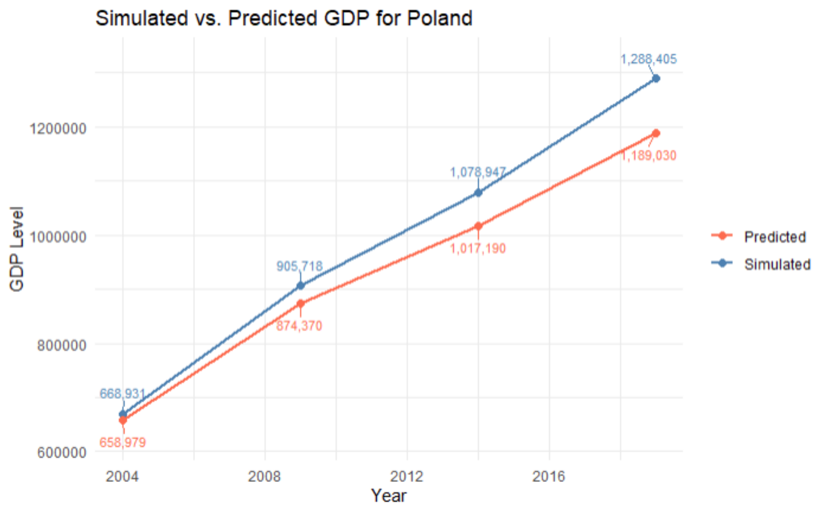

Figure 4.18: Simulated vs Predicted GDP levels for Poland using Model Endogenous, increasing R&D and maintaining the gap to the frontier [Source: see Table 3.1, own calculations]

Figure 4.18 show a potential of growth when Poland would increase it's spending on R&D. Results show that by the year 2019 it's GDP would increase by 8% to the level of 1,288,405 (in mil. 2017US$). While this highlights a considerable growth potential attributable to enhanced R&D investment, it is crucial to acknowledge the magnitude of the underlying R&D input: a 211% growth of R&D stocks. Achieving such a substantial shift necessitates not only a significant increase in R&D spending but also a fundamental transformation and strengthening of Poland's innovation infrastructure and policy framework.

4.4. Areas of improvement for Poland

In the following section, an effort would be made to answer the last sub-research question, regarding what actual things Poland could do in order to become a more prosperous country. Drawing on the comparative analysis and simulated growth potential discussed in the previous section, several priority areas emerge where Poland must strengthen its capabilities to sustain and accelerate economic development. These areas are closely aligned with the World Bank's 3i strategy - which provides a practical framework for identifying key policy levers for countries aiming to catch up with global frontiers.

4.4.1. Infusion - 2i strategy

One of the most critical enablers of sustainable growth and improved living standards is human capital. Despite some puzzling outcomes in the empirical models (see Table 4.2), human capital remains a widely recognized determinant of long-term development. Numerous studies confirm its positive role in diverse econometric specifications (Barro, 1994). Furthermore, the theory of conditional convergence suggests that countries aspiring to catch up with the global technological frontier must meet certain thresholds in absorptive capacity, typically proxied by the quality of human capital,to effectively benefit from their relative distance to the frontier. (Acemoglu et al., 2006)

When compared to South Korea, Poland lags behind in the quality of human capital. As shown in the regression analysis in Section 4.3.4, the trajectories of both countries diverge, with South Korea outperforming Poland in educational attainment and assumed rate of return to educaiton (two aspects considered by dataset authors when calculating human capital (Feenstra & Timmer, 2015)). Enhancing human capital, or more broadly, improving infusion capabilities is therefore essential for Poland to fully utilize its investment base and technological opportunities.

According to the World Bank's 3i framework, technology infusion is a cornerstone for countries in the "imitation club". While Poland has successfully attracted significant investment flows (World Bank, 2024), the challenge now lies in effectively internalizing and disseminating the knowledge and technologies embedded in these flows. This requires not only stronger education systems but also broader social development to reduce inequality and improve quality of life.

Poland has made commendable progress in education tertiary enrollment rose from 15% in 2000 to 42% in 2012 (World Bank, 2024). However, the attainment and relevance of curriculum in higher education, especially within public universities, remain areas for improvement (Brzyska, 2023). Moreover, empirical studies, such as those by Barro, indicate that significant gender disparities in education can constrain the growth prospects of countries positioned further from the global technology frontier (Barro, 1994). To strengthen Polish infusion capabilities, policies must aim to reduce entry barriers for women and disadvantaged groups, ensuring their skills are recognized and rewarded in the labor market. This can be facilitated through expanded scholarship programs, targeted outreach, and public campaigns encouraging higher education in high-value-added sectors (World Bank, 2024).

Another key observation from the Poland–South Korea comparison is the high volume of foreign direct investment (FDI) in Poland around 20% of GDP, compared to roughly 10% in South Korea. While this may appear advantageous, it also risks the leakage of value added and limited integration of foreign firms into the domestic innovation ecosystem. Despite the limited direct contribution of FDI stock growth to GDP (an estimated 0.002 percentage point increase in GDP growth for each additional percentage point in FDI stock—see Table 4.2), the effective utilization of FDI is potentially far more impactful. The World Bank emphasizes that knowledge and technology transfer from FDI is a prerequisite for countries striving to transition from imitation to innovation-led growth (World Bank, 2024)

To capitalize on this potential, Polish policy should aim to strengthen linkages between multinational enterprises (MNEs) and domestic SMEs. This could include targeted grant programs for collaborative R&D, tax incentives conditioned on joint ventures anchored in Poland, and stronger local content requirements in key strategic sectors, as proposed by World Bank (World Bank, 2024). Exposing domestic firms to global competition and technological leaders would create incentives for continuous performance improvements across both the private and public sectors. Such measures would not only enhance the absorptive capacity of Polish companies but also facilitate the diffusion of advanced technologies, managerial expertise, and innovation practices—ultimately helping to close the innovation gap with leading economies such as South Korea (Brzyska, 2023; Salamaga, 2023).

4.4.2. Innovation - 3i strategy

Simulations based on the Endogenous Growth Model suggest that increased investment in R&D can generate a positive impact on GDP growth (see Figure 4.18). However, realizing these gains requires sustained and substantial investment in innovation capabilities. Theoretical literature also emphasizes the central role of innovation, particularly ”modern R&D”, as a key driver of long-term economic progress. According to Howitt and Mayer-Foulkes (2005), countries that fail to continuously invest in innovation risk falling into a ”development trap,” whereby insufficient R&D effort leads to technological stagnation and long-run divergence from the global frontier. Moreover, once this divergence begins, catching up requires disproportionately higher investments, making early and consistent innovation policy essential for convergence and prosperity. This context makes Poland’s lag in key innovation indicators especially concerning (see Section 4.3.3). The R&D expenditure gap between Poland and South Korea exceeds 3% of GDP—Poland invests only 1.53%, compared to South Korea’s 4.97%. Further analysis reveals that the underperformance of Poland’s business enterprise sector is a primary driver of this gap, see figure 4.10. Addressing this weakness should therefore be a top policy priority.

Stimulating innovation within the private sector requires a set of targeted and well-structured policy interventions. Expanding the depth and accessibility of domestic equity and bond markets, alongside the development of robust venture capital and private equity ecosystems, has the potential to significantly strengthen innovation outcomes. These financial instruments play a critical role in enabling high-risk, high-reward R&D activities that are often underfunded through traditional channels. In parallel, the establishment of tailored accelerator programs can serve as a foundational platform for emerging entrepreneurs, offering not only funding but also mentorship, infrastructure, and market access (World Bank, 2024). Empirical evidence from the United States supports the effectiveness of such an approach: the combination of abundant venture capital availability and globally recognized startup accelerators—such as Y Combinator—has contributed to the creation of a dynamic and innovation-driven entrepreneurial ecosystem (Peniaz, 2023).

In addition to strengthening financial support mechanisms, Poland should also prioritize improving the institutional and regulatory environment for new and innovative businesses. While Poland outperforms South Korea in certain dimensions of Product Market Regulation (PMR), as shown in Section 4.3.5, broader assessments reveal institutional weaknesses that may hinder innovation-led growth. For instance, widely recognized innovation indices identify institutions as one of Poland's most underperforming components (World Intellectual Property, 2023). This apparent contradiction suggests that while market entry conditions and competition policy may be relatively favorable, other institutional dimensions, such as regulatory quality, protection of intellectual property, rule of law, and public-sector efficiency remain insufficiently developed to support a dynamic domestic innovation ecosystem. To address these gaps, policy reforms should focus on strengthening legal and administrative transparency, streamlining business registration and licensing procedures, and enhancing the enforcement of IP rights. Building a trustworthy, efficient, and innovation-friendly institutional framework would not only support start-up formation but also improve the long-term competitiveness of Poland's economy.

The policy prescriptions outlined above closely mirror those put forward in Draghi (2024) Competitiveness Report, which calls on European economies to prioritize greater investment in innovation while simultaneously rolling back excessive regulatory burdens. Draghi argues that only by striking the right balance between dynamic, knowledge-driven sectors and a lean, transparent regulatory framework can the region restore its global competitiveness. For Poland, embracing this dual agenda offers a powerful opportunity to deepen and sustain its recent growth trajectory. In practical terms, Warsaw can leverage EU structural funds and the newly established funds to finance R&D partnerships between universities and industry sectors, while also undertaking targeted deregulation in sectors such as energy and telecommunications to encourage entry by new, high-tech firms.

4.4.3. Market concentration

The model developed in this thesis 4.2, together with findings from the wider literature (Imbs & Wacziarg, 2003), suggests that economies initially benefit from a broad-based diversification phase but must ultimately transition toward specialization if they are to occupy the global technology frontier in selected sectors. However, when benchmarked against South Korea, a country whose sectors remain tightly focused, Polish industries appear fragmented and lacks the critical mass needed to generate strong productivity spillovers and to climb higher rungs in the global markets, as shown in Figure 4.15. To reduce this imbalance, Poland should gradually encourage the consolidation of capacity around a narrower set of high-value-added activities (Vienna Institute for International Economic Studies, 2023). In practice, this could mean channeling support toward scale-up initiatives in sectors where Poland already holds relative strength, such as ICT services, and fostering deeper linkages between these best firms and domestic R&D institutions. By shifting from “too many small players” to “fewer, more specialized champions,” Poland can unlock the economies of scale, learning-by-doing effects, and international market credibility that underpin frontier level innovation and sustainable long-term prosperity.

5
Conclusions

5.1. Poland's growth final conclusions

This thesis set out to evaluate whether Poland is on a sustainable path toward high economic prosperity by benchmarking its structural and innovation capacity against South Korea, a widely recognized success case of transition from imitation-led to innovation-driven growth (Lee, 2024). Using a three-stage analytical approach, consisting of growth slowdown diagnostics, a panel regression grounded in endogenous growth theory, and a comparative country analysis, the study systematically addressed the four sub-research questions posed in the introduction.

Applying the growth slowdown criteria proposed by Eichengreen et al. (2014), the analysis found no evidence that Poland is currently undergoing a structural stagnation. Although GDP growth has moderated since 2012, the observed deceleration remained within the range of typical cyclical fluctuations and did not surpass the 2 percentage point threshold required to classify as a growth slowdown. However, forward-looking scenarios, such as Poland converging to South Korea's present growth rate, suggest the country may soon face a threshold beyond which catch-up dynamics begin to lose momentum and a stagnation can occur. This underscores the growing importance of transitioning towards an innovation-led growth model to sustain Poland's growing economy status.

The panel regression analysis yielded several noteworthy insights into the structural factors shaping economic growth. Capital accumulation emerged as the consistent and significant driver, confirming traditional exogenous growth theory. Additionally, R&D stock and foreign direct investment (FDI) - both central to endogenous growth frameworks (Howitt & Mayer-Foulkes, 2005; Lucas, 1988), were found to positively influence GDP growth in some model specifications, thereby empirically validating their roles in fostering innovation and enabling technology diffusion. Unexpectedly, absorptive capacity, proxied by a human capital index based on educational attainment, showed a negative direct effect on growth. However, when analyzed in interaction with a country's distance to the technological frontier, the combined effect was positive and statistically significant. This supports theories of conditional convergence and absorptive capacity (Durlauf & Johnson, 1995), highlighting that it is not merely the level of human capital that matters, but its ability to complement technological catch-up that determines its growth-enhancing potential.

The country comparison confirmed the initial hypothesis that Poland's GDP per employed person remains lower than that of South Korea, indicating unrealized growth potential. While Poland performs relatively well in Total Factor Productivity (TFP), even surpassing South Korea in some recent measures, it substantially lags in R&D expenditure, patent applications, and sectoral specialization. South Korea's focused innovation strategy, underpinned by large-scale business R&D and industrial policy centered around tech-conglomerates, has yielded superior innovation outcomes. By contrast, Poland's economy remains more fragmented. Its broad sectoral diversification, while beneficial at earlier development stages (Imbs & Wacziarg, 2003), now likely hampers productivity spillovers, economies of scale, and the emergence of internationally competitive specialized clusters. Poland's human capital development has also fallen behind Korea's, suggesting that despite impressive post-communist growth, the country has not yet succeeded in upgrading its education system or maximizing returns on education (key elements determining the human capital in the data source used). Moreover, it was identified that despite substantial FDI inflows, a key enabler of imitation-led growth (Salamaga, 2023), Poland has not fully leveraged these inflows to strengthen its domestic innovation system.

Based on the empirical findings and in line with the World Bank's 3i strategy (World Bank, 2024), this thesis identifies three strategic priority areas to secure Poland's long-term prosperity:

- **Infusion:** Enhance absorptive capacity through targeted improvements in human capital. This involves not just expanding educational access, but aligning curricula with labor market needs and boosting R&D-relevant skills. In parallel, Poland must better leverage foreign capital as a channel for acquiring best practices and facilitating knowledge transfer. This can be achieved through policy instruments that incentivize deeper collaboration between multinational enterprises and domestic firms (World Bank, 2024).
- **Innovation:** Narrow the R&D investment gap by scaling up both public and private sector contributions. This includes expanding access to equity and venture capital, fostering start-up ecosystems, and investing in enabling infrastructure such as accelerators, research centers, and tech parks. Poland can draw lessons from South Korea's robust business-led R&D model (Campbell & Keys, 2002), as well as the United States' leadership in innovation infrastructure and entrepreneurial finance (Peniaz, 2023).
- **Market Structure:** Shift from a policy emphasis on broad diversification toward more strategic specialization in high-value-added sectors. The literature, including the U-shaped relationship between sectoral diversification and GDP growth (Imbs & Wacziarg, 2003), and this thesis's empirical findings both suggest that Poland should now consolidate around globally competitive sectors, following the example of South Korea's scale- and export-driven clusters.

Overall, the findings of this thesis support the conclusion that Poland remains on a positive growth trajectory, yet it now faces a pivotal moment. To sustain momentum and avoid stagnation, Poland must strategically pivot toward innovation-driven growth. Long-term convergence with global technology leaders will depend on the country's ability to operationalize the priorities outlined in the "3i" framework — particularly enhancing absorptive capacity, fostering domestic innovation ecosystems, and encouraging strategic sectoral specialization. Creating the institutional and economic conditions for resilient, inclusive, and innovation-led development is no longer optional — it is a prerequisite for ensuring Poland's sustained prosperity in the decades ahead.

5.2. Reflection and limitations of research

5.2.1. Empirical models

The main empirical model was defined based on the literature that includes variables with lag, a step meant to reveal the true direction of causality between economic inputs and GDP growth. Yet even with this timing adjustment, several coefficients are either statistically insignificant or display signs that run counter to theory and prior studies. Additionally, vast amount of different statistical tools can give different results. To test how the model would behave, it would be interesting to see how different tools compare against each other.

5.2.2. Data

Another problem of the thesis is the data. Most of the data comes from renewed sources like World Development Indicators or Penn World Table, but still the data was fragmented and missing for many countries. Especially in low-income group, making the group of stagnation countries hard to analyze and draw conclusions. For the future work I recommend trying to find more and better data, focusing for example on more granular micro-economic data, following the newest research in growth (Harding & Hersh, 2018).

5.2.3. Choice of variables

Variables selected for the model, and subsequently for the analysis, were chosen based on an extensive literature review. Nevertheless, the extent of theoretical considerations remains overwhelming. The primary focus of this thesis is on human capital and innovation within economies. However, many econometricians attempt to construct more comprehensive models by incorporating additional factors, such as infrastructure (Esfahani & Ramírez, 2003). Due to limited data availability, only the variables described in Section 3.2.1 were included. Although this set of variables explains a portion of the variance in the model (with an R^2 of 0.466 in the specification: Model Endogenous), a substantial amount of variance remains unexplained. Incorporating further variables could potentially account for additional variation and improve model fit.

In the case of Poland, even though above research has demonstrated positive trends in economic growth relative to other countries, indicators related to the human dimension remain comparatively low when judged against high-income country benchmarks. Many scholars argue that national progress cannot be captured solely by GDP growth (dependent variable in thesis) instead, assessments should encompass a broader array of factors that contribute to citizens' overall well-being-such as health outcomes, educational attainment, and standards of living (Sagar & Najam, 1998). The Human Development Index (HDI), for instance, combines life expectancy, mean years of schooling, and gross national income per capita to provide a more comprehensive measure of societal prosperity. According to the latest HDI data, Poland continues to lag substantially behind South Korea, which exemplifies how two countries from high income levels can diverge even more than just in the GDP per capita levels, once human-development dimensions are taken into account. This gap suggests that, despite Poland's commendable economic performance, there is still considerable room for policy interventions aimed at improving healthcare provision, raising educational quality, and increasing access to higher-value employment opportunities, areas in which high-income economies such as Korea have already made significant strides.

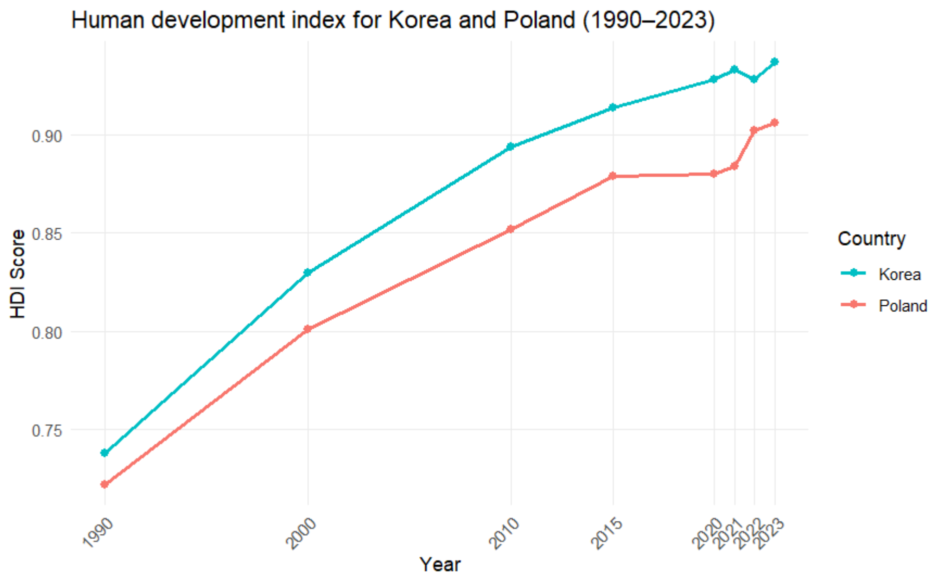

Figure 5.1: Human Development Index comparison

In 1990 Korea's HDI was just a little higher than Poland's, and by 2023 the gap is still about the same size. That shows that "closing the economic gap" doesn't automatically mean everyone's quality of life improves at the same pace. In order to catch up in this type of indexes also, Poland should focus on the quality of living for the people. Making effort in the direction of improving the infrastructure, institutions and politics.

5.2.4. Tools used

During the master thesis process, a variety of analytical tools and methods were applied, with the main objective being to identify the key factors influencing the economic growth of countries. To achieve this, panel data regression was employed as the central methodological approach. Panel data regression is particularly well-suited for this type of analysis, as it allows for the examination of general trends across multiple entities(in this case, countries) over a period of time. By combining both cross-sectional and time-series data, this method enables a more comprehensive understanding of how different variables impact growth dynamics, while accounting for both individual country-specific effects and temporal changes.

One of the main advantages of using panel data is its ability to control for unobserved heterogeneity—factors that may influence growth but are not directly measured in the model. This is achieved by employing fixed-effects model, which help isolate the impact of the variables of interest from country-specific characteristics that remain constant over time. Additionally, panel data increases the number of observations, thereby improving the statistical power and robustness of the results. In this thesis, lagged variables were also introduced into the regression models to better capture causal relationships and reduce issues related to endogeneity. While the results did not always align with theoretical expectations, the panel data approach proved to be an effective and flexible tool for exploring complex economic relationships and uncovering patterns that would not be visible through simpler analytical methods.

To implement the panel data regression models, the statistical programming language R was used. R provided a powerful and flexible environment for data cleaning, model building, and result visualization. Packages such as PLM were particularly useful for estimating fixed effect model, while libraries like stargazer and ggplot2 helped with formatting regression output and creating clear visualizations. The source code is available in the appendixes part of the thesis.

5.3. Personal remarks

5.3.1. Study program relevance

The Master's program in Management of Technology at TU Delft has provided a solid foundation for conducting this thesis, both in terms of theoretical understanding and practical skill set. Throughout the program, a strong emphasis was placed on the intersection of technology, innovation, and economics, making it highly relevant for this research, which investigates Poland's innovation capabilities and growth trajectory from both a macroeconomic and policy-oriented perspective.

Courses on innovation, economics, and decision-making offered the necessary frameworks to evaluate long-term growth strategies and benchmark them against leading economies such as South Korea. Moreover, the program's focus on empirical methods and data-driven decision-making proved essential during the research process. Tools and algorithms introduced during the coursework, including statistical modeling and regressions, were directly applied in building and validating the analytical model. The use of statistical software such as R, practiced during the program, played a crucial role in processing large datasets, executing regression techniques, and visualizing relationships.

Additionally, the program encouraged a wider policy-relevant and future-oriented perspective that was essential in formulating recommendations for Poland's economic growth.

5.3.2. AI statement

In preparing this master thesis, AI tools were employed primarily as brainstorming aids. By providing the AI with an initial topic outline and engaging in iterative dialogue, I was able to uncover relevant areas and concepts that complemented my own reasoning. These AI-generated suggestions were then investigated and checked through traditional academic databases and search engines, ensuring rigorous source validation. In this way, the AI functioned as a virtual supervisor, particularly effective for the economic focus of this project.

Occasionally, the AI also facilitated the refinement of scientific prose and served as a translator, improving the clarity and precision of my writing. However, its limitations became apparent in source exploration: the AI frequently produced references to nonexistent documents, so all sources were independently located, read and analyzed.

Overall, AI enhanced the conceptual breadth of the proposal and streamlined language editing. Without its assistance, important insights may have been overlooked.

5.3.3. Topic

The chosen thesis topic turned out to be not only highly engaging but also intellectually enriching. Learning about the various factors that influence a country's economic growth was truly eye-opening. What stood out was the sheer volume and diversity of existing literature and theories attempting to explain growth, each offering a different lens through which to understand this complex phenomenon. It was surprising to see how different schools of thought approach the issue: some emphasize the importance of capital, particularly through investment in high-tech R&D to boost the technology in the country, while others highlight the critical role of human capital development, such as education and skills training. Both perspectives are extensively covered in academic research, and navigating through them was both fascinating and, at times, overwhelming, especially coming from an engineering background, where problems tend to have clear, correct solutions grounded in equations.

In contrast, the field of economics and growth research often deals with ambiguity, competing theories, and interpretations that are not always directly testable. During the research, an effort was made to explore multiple theoretical perspectives and understand their core arguments, while also identifying key similarities and differences in how they interpret growth dynamics. From a methodological perspective, one of the most interesting aspects was how many authors use lagged variables to better capture causal relationships in panel data. This was applied in the empirical part of the thesis, but the results obtained differed significantly from what was suggested by theory. Nevertheless, rather than treating this as a failure, it became an opportunity to reflect more critically on the assumptions behind growth models and the limitations of data.

Another surprising outcome was related to the initial hypothesis: that Poland is currently experiencing growth stagnation and is potentially trapped in the so-called middle-income trap (but in the high-income range). This hypothesis was not supported by the data. On the contrary, when comparing Poland to a high-growth country like South Korea, several unexpected findings emerged, particularly in the area of productivity levels. It turned out that Poland is relatively strong in medium- to high-tech services, which was not anticipated at the beginning of the thesis. These insights challenged common assumptions and added a valuable new dimension to the analysis.

Finally, the policy recommendations were grounded in the World Bank's 3i strategy for long-term growth, which emphasizes innovation, inclusion, and investment. These recommendations were not only theoretically sound but also appear to be practical and implementable in the Polish context. Overall, the thesis provided a unique opportunity to bridge theoretical models with real-world observations, and to contribute to a broader discussion on how countries like Poland can sustain dynamic and inclusive economic growth in the future making sure not to fall back to the middle-income trap again.

5.3.4. Thesis process

The thesis process itself turned out to be considerably more challenging than initially expected. One of the main difficulties came from the complexity and depth of the academic literature, combined with the fact that my academic background included relatively few courses in economics. This made the early stages of the project particularly demanding. The literature review phase was especially overwhelming - many papers presented conflicting theories, methodologies, and conclusions, which made it difficult to filter out the noise and focus on a clear analytical direction. Navigating through this sea of sometimes contradictory perspectives required a lot of trial and error, critical thinking and most importantly patience.

A crucial point in the process was the guidance and support of my first supervisor, PhD Roman Stöllinger. His expertise and methodical approach helped clarify the most relevant frameworks and best practices in empirical economic research. His ability to explain complex concepts in a clear and structured manner played a crucial role in helping me gain confidence and make progress, especially during the more uncertain early stages. A great deal of credit is owed to his mentorship. If the process were to be repeated, definitely more meeting and feedback sessions would be much appreciated.

The feedback I received throughout the process was at times direct and even harsh, but it was always constructive. In hindsight, this critical feedback proved to be extremely valuable. It pushed me to question methods, refine the structure of the thesis, and adopt a more rigorous and academic tone. As a result, the quality of the work improved significantly over time, both in terms of analytical depth and clarity of presentation.

Overall, the process was a steep learning curve, but one that was ultimately rewarding. It taught me not only about the subject itself, but also about academic discipline, resilience, and the importance of continuous feedback and iteration in research.

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A

Used data

A.0.1. Data collection

Data for this analysis was sourced from multiple reputable databases, primarily the Penn World Table (PWT) version 10.01 (Feenstra & Timmer, 2015) and the World Bank's World Development Indicators (WDI) (WorldBank, 2025b).

The Penn World Table 10.01 provides comprehensive information covering relative levels of income, output, input, and productivity across 183 countries for the years 1950 to 2019. This database is particularly valuable due to its extensive temporal and geographical coverage, allowing for robust comparative analyses. Furthermore, PWT includes clear and detailed documentation outlining the definitions, applications, and limitations of each variable, enabling straightforward utilization.

The World Development Indicators dataset represents the World Bank's primary compilation of global development indicators, sourced from officially recognized international organizations. It includes the most recent, accurate, and reliable data available, presenting estimates at national, regional, and global levels. However, specific variables of interest, such as expenditures on education, research and development (R&D) stocks, foreign direct investment (FDI), and gross fixed capital formation (GFCF), exhibited gaps, particularly noticeable for the period between 1960 and 1995. Despite taking the period from 1995 into consideration still there were some missing values that necessitated supplementary data imputation techniques or alternative methodological adjustments to ensure the continuity and reliability of subsequent analyses.

An additional source utilized in this research was the World Integrated Trade Solution (WITS) database, specifically employing the Herfindahl–Hirschman Index (HHI) (WorldBank, 2025a).

A.0.2. Time frame definition

Literature on endogenous growth models extensively covers developments beginning in the 1970s, highlighting various theoretical and empirical advancements in understanding economic growth dynamics. Analysis explicitly aims to include as many countries as possible, thereby improving the representativeness and generalizability of the findings.

The selected time frame for this master's thesis has been deliberately aligned with the availability and reliability of economic data. Prior to 1995, economic indicators were predominantly reported by only the most developed countries, creating significant gaps for lower- and middle-income nations. Consequently, incorporating data from periods earlier than 1995 could introduce bias into the analysis due to the under representation of less developed economies, potentially distorting results and limiting their applicability.

Conversely, the most recent dataset from the Penn World Table (PWT) version 10.01 extends through to 2019, naturally defining the upper boundary of the analytical time frame. This endpoint ensures the inclusion of the latest available data, thereby enhancing the relevance and applicability of the research findings.

A.0.3. Data cleaning

Analysis of Missing Data and Data Completion Strategy

Despite being sourced from the most up-to-date and frequently renewed databases for econometric analyses, the dataset still exhibited a significant amount of missing data. Missing values can adversely affect both the estimation accuracy and the predictive power of econometric models. In our case, the lack of sufficient observations even for basic computations meant the introduction of a data filtering rule.

Filtering Criteria

To ensure the reliability of subsequent analyses, criterion was adopted whereby countries with fewer than 5 observations per variable over the period from 1994 to 2019 were omitted. This decision was motivated by the need to avoid biased results and unreliable estimates that can arise when the sample size is too small. Removing these countries allowed to focus on cases where the data were sufficiently complete to support modeling.

Identifying Key Data Gaps

After applying the initial filtering, the next step was to identify which variables and countries still contained substantial amounts of missing data. As illustrated in Table A.1, the variables with the highest number of missing observations were **R&D spending as % of GDP** and **Government spending on Education as % of GDP**. The prevalence of missing data in these indicators can be attributed to a variety of factors (Kang, 2013), such as:

- **Inconsistent Reporting:** Variations in national reporting standards and timing can lead to incomplete datasets.
- **Data Collection Challenges:** Differences in administrative capacity and resources across countries may hinder systematic data collection.
- **Lag in Data Updates:** Some countries experience delays in updating their databases, resulting in outdated or missing entries.

Data Completion Framework

To address the problem of missing data, a systematic, multi-step framework was implemented and designed to maximize the completeness of the dataset while maintaining data integrity. The framework consists of the following steps:

1. **Cross-Reference with Alternative Datasets:** Examination of other reputable data sources to determine if missing values could be filled using complementary information. This cross-verification helps in enhancing the overall data quality.
2. **Utilize Regional Data:** In instances where country-specific data were not available, the possibility of using regional aggregates as proxies was explored. This approach relies on the assumption that regional trends can approximate the conditions in individual countries within that region.
3. **Interpolation of Missing Values:** When data gaps occurred within a time series, interpolation techniques were applied to estimate the missing values. Interpolation leverages the trend and pattern of observed data points to fill in the gaps, thus ensuring a smoother continuity in the series.
4. **Edge Value Imputation:** For missing data at the beginning or end of a series, simple imputation method was applied by assigning the first or last available value to the missing entries. This method preserves the overall trend and minimizes distortion in time series analyses.

Table A.1: Missing Data Counts by Country and Variable

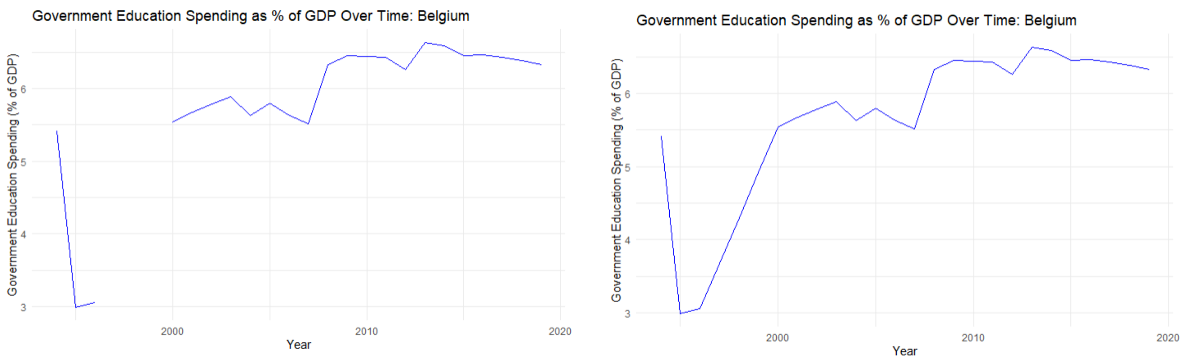
Country Name	Variable Name	Missing Count
Tajikistan	HH index	21
Morocco	R&D spending as % of GDP	20
Nicaragua	R&D spending as % of GDP	19
Zambia	R&D spending as % of GDP	19
Indonesia	R&D spending as % of GDP	18
Nicaragua	patent applications	18
Switzerland	R&D spending as % of GDP	18
Honduras	R&D spending as % of GDP	17
Philippines	R&D spending as % of GDP	17
Honduras	Government spending on Education as % of GDP	16
Zambia	GFCF	16
Saudi Arabia	R&D spending as % of GDP	15
Morocco	Government spending on Education as % of GDP	14
New Zealand	R&D spending as % of GDP	14
Nicaragua	Government spending on Education as % of GDP	14
Panama	patent applications	14
Sri Lanka	R&D spending as % of GDP	14
Australia	R&D spending as % of GDP	13
Chile	R&D spending as % of GDP	13
Mauritius	R&D spending as % of GDP	13
Paraguay	patent applications	13
Honduras	patent applications	12
Nicaragua	GFCF	12
Saudi Arabia	Government spending on Education as % of GDP	12
Sri Lanka	Government spending on Education as % of GDP	12
Cyprus	patent applications	11
Ecuador	Government spending on Education as % of GDP	11
Ecuador	R&D spending as % of GDP	11
Guatemala	R&D spending as % of GDP	11
Malaysia	R&D spending as % of GDP	11
Mauritius	patent applications	11
Paraguay	R&D spending as % of GDP	11
Trinidad and Tobago	patent applications	11
Guatemala	Government spending on Education as % of GDP	10
Italy	patent applications	10
New Zealand	Government spending on Education as % of GDP	10

R&D spending examination:
The initial step was to compare the primary dataset with an alternative source. Data from the UNESCO Institute for Statistics was selected, and the comparison showed that both sources had identical coverage. Further examination revealed that both the World Bank and UNESCO used the same underlying data sources, which led to the need for additional processing steps.

Attention then turned to the next step of the framework namely:regional spending on R&D, which was found to also be limited. Two additional data sources, OECD and UNESCO, were examined, both lacked complete information on regional averages. The only data available was provided by World Bank. However the regions were defined broadly, resulting in overestimating the average, making the input biased. As an example the one problematic country was Nicaragua, country in Latin America. Taking the average of Latin America (even the regional data excluding high-income countries) the values were 10x larger than the acctual readings. Nicaragua spend 0.035% of their GDP on R&D in 2002, whereas the regional average was 0.53% - over 15x more. Having that in mind , a pragmatic approach was adopted to preserve the representation of countries from underrepresented regions while still capturing changes in R&D spending over time.

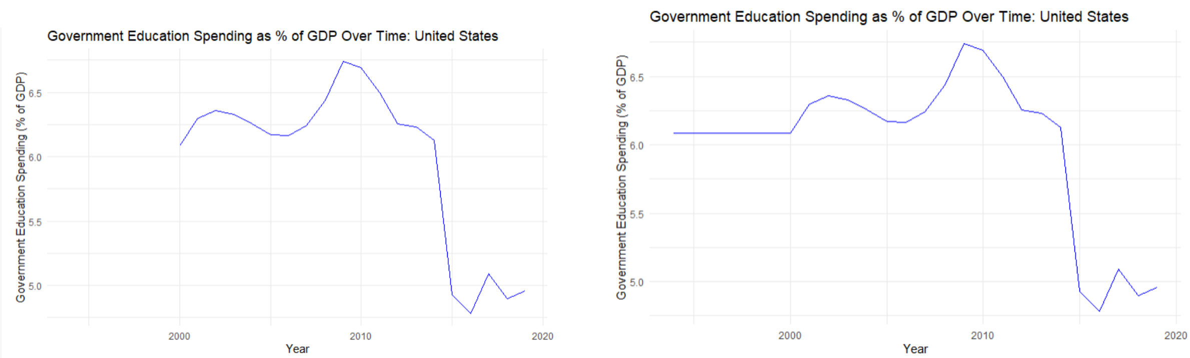
Interpolation techniques were employed to estimate missing values based on available time series data. For missing data at the beginning or end of a series, edge value imputation was used by assigning the first or last observed value to the missing entries. Although this approach has drawbacks, it was necessary to avoid excluding important countries from the analysis.

Government spending on Education as % of GDP:
The case with Government spending on Education was more challenging since the data was limited and each website linked it's dataset to the one already used (world development indicators). That is why the effort was focused on interpolation and value imputation in order to create a complete dataset.



(a) Before interpolation example for Belgium **(b)** After interpolation example for Belgium

Figure A.1: Graphical display of interpolation - Missing data within a time series



(a) Before interpolation example for USA **(b)** After interpolation example for USA

Figure A.2: Graphical display of interpolation - Missing data at the beginning of a time series

A.0.4. Further data exploration

In Figure A.1a, a significant gap can be observed in the data between the years 1996 and 2000. Initially, this irregularity led to the hypothesis that the dataset might be flawed or incomplete. However, a deeper investigation into the historical context of the Belgian education system revealed a plausible explanation. Between 1997 and 2000, Belgium underwent major reforms in its education sector, which likely contributed to the observed fluctuations in spending and statistical reporting during that period (Geyer, 2009). This historical shift confirmed that the irregularities in the data were not errors but reflected genuine structural changes.

In contrast, Figure A.2a illustrates a minor dip in education spending in the United States around 2014. Upon closer examination, this decline is at the same year as the Senate elections, an event that often influences budget allocations and public spending priorities. While the effect appears modest, it is important to acknowledge the potential political influence on education funding.

Moreover, it is important to note that the World Bank, the source of the data, ensures yearly maintenance and verification of its datasets (World Bank, 2024). Professional statisticians and analysts work consistently to validate and update the information, striving to maintain its accuracy and reliability. Given the credibility of the source and the historical factors accounting for the observed anomalies, the decision was made to use the original data without applying additional data cleaning or modifications. This approach preserves the integrity of the dataset and ensures that the analysis remains faithful to real-world developments.

B

Raw results

The following table represents Intercept term for each country calculated with Model Endogenous (see: 3.7)

Table B.1: Country-specific Intercept values based on model endogenous

Country	Estimate	Std. Error	t-value	p
Argentina	0.1623095	0.1181698	1.3735	0.171182
Armenia	0.4397895	0.1328958	3.3093	0.001116 **
Australia	0.2876415	0.1443522	1.9926	0.047710 *
Austria	0.2546548	0.1338990	1.9018	0.058681 .
Belgium	0.2538264	0.1264869	2.0067	0.046173 *
Brazil	0.1258767	0.1032046	1.2197	0.224074
Bulgaria	0.2747645	0.1280683	2.1455	0.033166 *
Canada	0.2421586	0.1659582	1.4592	0.146148
Chile	0.2253938	0.1240905	1.8164	0.070866 .
China	0.1829298	0.1169215	1.5646	0.119326
Costa Rica	0.1667271	0.1127744	1.4784	0.140927
Croatia	0.2323878	0.1320762	1.7595	0.080077 .
Cyprus	0.1963886	0.1170478	1.6778	0.094995 .
Denmark	0.2999038	0.1380418	2.1726	0.031032 *
Ecuador	0.0649256	0.1180025	0.5502	0.582815
Estonia	0.3224197	0.1406375	2.2926	0.022952 *
Finland	0.2680394	0.1338973	2.0018	0.046704 *
France	0.2549434	0.1239035	2.0576	0.040973 *
Germany	0.3177522	0.1462116	2.1732	0.030981 *
Greece	0.1809289	0.1177675	1.5363	0.126097
Guatemala	0.0610811	0.0882806	0.6919	0.489834
Honduras	0.0268848	0.1126788	0.2386	0.811671
Hungary	0.2685489	0.1315252	2.0418	0.042531 *
Iceland	0.3078618	0.1259146	2.4450	0.015382 *
India	0.1372373	0.0974394	1.4084	0.160610
Indonesia	0.1610358	0.1067231	1.5089	0.132956
Israel	0.2886325	0.1459386	1.9778	0.049378 *
Italy	0.1816823	0.1206451	1.5059	0.133722
Japan	0.2592411	0.1416109	1.8307	0.068694 .
Kazakhstan	0.3191180	0.1373624	2.3232	0.021211 *
Latvia	0.3185794	0.1242190	2.5647	0.011088 *

(continued on next page)

Table B.1 (continued)

Country	Estimate	Std. Error	t-value	p
Lithuania	0.3705493	0.1269272	2.9194	0.003924 **
Luxembourg	0.2335702	0.1301598	1.7945	0.074300 .
Malaysia	0.2232387	0.1185103	1.8837	0.061108 .
Malta	0.2706284	0.1257697	2.1518	0.032657 *
Mauritius	0.2713814	0.1055354	2.5715	0.010879 *
Mexico	0.0805420	0.1319044	0.6106	0.542177
Mongolia	0.1188831	0.1431292	0.8306	0.407226
Morocco	0.1451357	0.0824854	1.7595	0.080071 .
New Zealand	0.2805626	0.1350505	2.0775	0.039082 *
Nicaragua	0.0104288	0.1070855	0.0974	0.922520
Norway	0.3013055	0.1433036	2.1026	0.036800 *
Panama	0.2402840	0.1191567	2.0165	0.045130 *
Paraguay	0.1405278	0.1058049	1.3282	0.185688
Peru	0.1654270	0.1199406	1.3792	0.169416
Philippines	0.1956507	0.1141271	1.7143	0.088075 .
Poland	0.3328868	0.1328229	2.5062	0.013028 *
Portugal	0.1408832	0.0987543	1.4266	0.155310
Romania	0.3527183	0.1293786	2.7262	0.006996 **
Russian Federation	0.2753719	0.1376691	2.0002	0.046876 *
Saudi Arabia	0.0522764	0.1076886	0.4854	0.627914
Singapore	0.2652942	0.1259226	2.1068	0.036427 *
Slovenia	0.2914779	0.1379521	2.1129	0.035895 *
South Africa	0.1580151	0.1027032	1.5386	0.125550
Spain	0.2079412	0.1149651	1.8087	0.072049 .
Sri Lanka	0.2792254	0.1240738	2.2505	0.025547 *
Sweden	0.3112463	0.1352460	2.3013	0.022441 *
Switzerland	0.3145944	0.1477819	2.1288	0.034541 *
Tajikistan	0.2687741	0.1479063	1.8172	0.070739 .
Thailand	0.1501135	0.1088023	1.3797	0.169278
Trinidad and Tobago	0.2274731	0.1276138	1.7825	0.076238 .
Tunisia	0.1605083	0.0954414	1.6817	0.094235 .
Ukraine	0.2261607	0.1363043	1.6592	0.098693 .
United Kingdom	0.3110848	0.1477554	2.1054	0.036550 *
United States	0.3514226	0.1484839	2.3667	0.018936 *
Uruguay	0.2114581	0.1110758	1.9037	0.058433 .
Zambia	-0.0014133	0.1163977	-0.0121	0.990325

Note. * $p < .05$, ** $p < .01$, *** $p < .001$, "." $p < .1$.

C

Further analysis

In this appendix section further analysis is introduced. The results are separate from the main theoretical reasoning, however, despite being sometimes contradictory to the main storyline of thesis, they bring value to the discussion.

C.1. Sensitivity analysis

In order to check how coefficients change when different lag is being introduced, a table of sensitivity analysis was performed. It is important to notice that for this purpose one of the periods is dropped, meaning that the measurements are to years (2004, 2009, 2014, 2019) Not including 1999, as in the table 4.3, and that is why it can be compared for the impact of including one period more. On the other end 5 year lag analysis did not include the education variable that is why it can be compared with the Model Endogenous from table 4.2 for the impact of this variable, since it was already mentioned that some of the effects can be captured by the Human Capital variable.

Table C.1: Sensitivity analysis with respect to lag

Sensitivity analysis with respect to the different lag values of variables

	0 year lag	1 year lag	2 year lag	3 year lag	4 year lag	5 year lag
Fixed Effect Model						
1. Capital Stock	0.108 (0.088)	0.111 (0.091)	0.223 (0.093) ***	0.239 (0.084) **	0.222 (0.081) *	0.274 (0.079) *
2. Labor Stock	0.655 (0.089) ***	0.701 (0.091) ***	0.703 (0.090) ***	0.717(0.089) ***	0.712(0.088) ***	0.693(0.086) ***
3. Human Capital	-0.060 (0.031) **	-0.067(0.034) **	-0.109 (0.037) **	-0.115 (0.039) *	-0.059 (0.040) *	-0.108 (0.039) *
4. Distance to frontier	0.044 (0.019) *	0.037 (0.016) *	0.059 (0.015) ***	0.061(0.009) ***	0.055(0.011) ***	0.074(0.012) ***
5. R&D Stock	0.067 (0.029) ***	0.040(0.031) ***	0.033 (0.034) ***	0.0004(0.034)	-0.005(0.031)	0.011(0.028)
6. Foreign Direct Investment	0.036 (0.010) ***	0.022(0.010) **	0.002 (0.009)	-0.006(0.009)	0.004(0.008)	0.0002(0.009)
7. HH_Index	0.339 (0.104) ***	0.250(0.107) *	0.132 (0.110) ***	0.103(0.101) ***	0.106(0.102) ***	0.084 (0.094) ***
R^2	0.405	0.372	0.376	0.389	0.414	0.459
ΔR^2	0.181	0.135	0.141	0.159	0.194	0.256
F	18.863***	16.382***	16.695***	17.636***	19.583***	23.532***

$n = 268$. $^{***}p < .01$ $^{**}p < .05$; $^{*}p < .1$;
Standardized coefficients are reported with standard errors in parentheses.

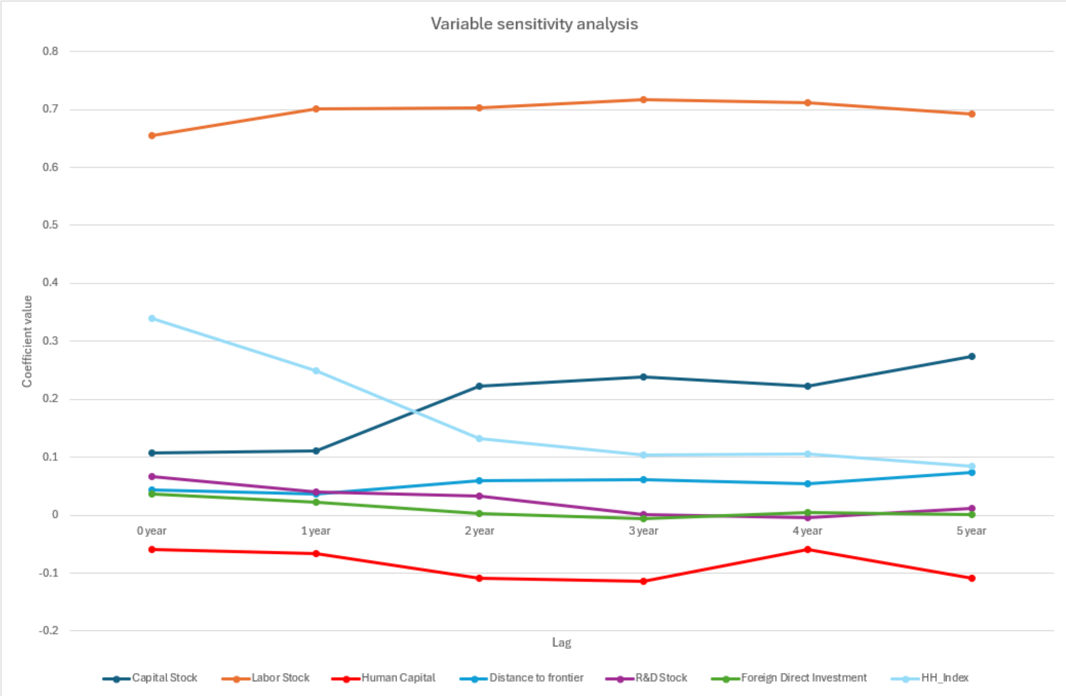


Figure C.1: Visual representation of coefficient values obtained through sensitivity analysis with respect to lag

This sensitivity exercise reveals important dynamics about timing and persistence. First, the human-capital coefficient is negative and significant at every lag, growing in magnitude from about –0.06 at lag zero to –0.12, but it's significance drops from ($p < 0.05$ to $p < 0.1$). That indicates that long term influence of Human Capital is smaller. R&D stock and FDI inflows behave similarly: both show a small but significant boost to growth in year zero (R&D at +0.06, FDI at +0.04) and still a modest gain in year one, but thereafter their coefficients collapse to near zero. In effect, these investments spur innovation and capital formation that pay off within the first couple of years, but they do not generate enduring growth perspectives unless fresh investments keep coming. That on the other hand can be seen in the literature. Howitt and Mayer-Foulkes also argues that constant investments in R&D are essentially to avoid the divergence from tech-frontier country (Howitt & Mayer-Foulkes, 2005).
Another rather suprising effect can be seen in Herfindahl-Hirschman Index. While it's significance remained it's size decreased a lot. When no lag was introduced size of it's coefficient was second biggest however next lags made the variable smaller. That again indicates the importance of the Index but rather in the short term. Concentration of markets can attract new capital, but according to U-shaped theory it should be around the high value added activities. Lastly not including the government education spending in the model decreased R^2 - meaning that indeed a variable has input to the model and should be considered in further parts of the thesis.

Another comparison that need to be made is between the model from table 4.3 and the 0 year lag results from the sensitivity table. What can be observed is that distance to frontier variable became positive when one period was dropped. According to the theories variable should remain positive no matter what periods are taken into considerations. However period 1994 till 1999 was a period of huge economic changes especially in the post soviet countries (not that far from the tech frontier), that is why it's influence could be smaller than expected (Piatkowski, 2019).

Lastly, the increasing values of R^2 point out that when lag is included the model predicts the variance of the dependent variable better. That is why it was decided that for the next models lag of 5 years is the best choice for the next part of the thesis.

C.2. Country comparison further analysis

C.2.1. R&D puzzle

In the graph 4.5 it can be observed that the pace of growth for Korea is declining but when compared to the increase in the graph describing increase in the R&D investments it can be seen that the dynamic is opposite. This can confirm the statement that high-income countries can have ”diminishing” returns from investment in technologies. Especially if they are concentrated in small number of companies, in some ways preventing the natural creative destruction process that accelerate the growth (Aghion & Bircan, 2017). Overall, the model’s counterintuitive prediction (of small influence of R&D) may well apply to advanced economies: large, monopolistic firms in high-income countries have the resources to pour vast sums into R&D, but their dominant market positions and internal incentives can lead to wasteful or misdirected spending - and this inefficiencies can lead to the smaller size of the coefficient related to the R&D spending in the models that try to find it’s relation to growth. That is also somewhat related to the X-inefficiencies theory - where companies that are not pressured to perform at it’s best, tend to misallocate resources (Leibenstein, 1966).

Furthermore both countries can benefit from the findings in this comparison - first of all it is quite clear that Poland is not the most innovative country. It needs to boost the innovation output because it is at risk at diverging and stagnating at the levels that are far from it’s potential (also shown in the CTFP from above). That follows from the models output from the precious chapter. Where the model without the lagged values and model endogenous, in R&D showed positive relation to GDP growth - meaning that more investment in R&D translates to the bigger GDP growth. That indicates that if Poland can indeed increase it’s spending in order to secure more economic growth. South Korea on the other hand despite being recognized as one of the innovation frontier need to definitely work on the efficiency in the resource allocation (especially R&D expenditure) (Leibenstein, 1966).

D Code

D.1. Data interpolation

```

valid_countries <- long_data %>%
  # Pivot all columns except Country.Name and Year into long format
  pivot_longer(
    cols = -c(Country.Name, Year),
    names_to = "Series",
    values_to = "Value"
  ) %>%
  # For each country and series, count non-missing values
  group_by(Country.Name, Series) %>%
  summarise(count = sum(!is.na(Value)), .groups = "drop_last") %>%
  # For each country, check if all series have at least 5 non-missing values
  summarise(all_series_valid = all(count >= 5), .groups = "drop") %>%
  filter(all_series_valid) %>%
  pull(Country.Name)

# Filter the long_data to keep only valid countries
long_data <- long_data %>%
  filter(Country.Name %in% valid_countries)

dt <- as.data.table(long_data)

# Identify the columns to interpolate (all except Country.Name and Year)
cols <- setdiff(names(dt), c("Country.Name", "Year"))

# Set the key for proper grouping and ordering by Country.Name and Year
setkey(dt, Country.Name, Year)

# For each country, apply interpolation and constant filling for each variable in cols
dt[, (cols) := lapply(.SD, function(x) {
  # First, perform linear interpolation (internal gaps)
  x_int <- na.approx(x, x = Year, na.rm = FALSE)
  # Then, fill leading NAs using last observation carried forward
  x_filled <- na.locf(x_int, na.rm = FALSE)
  # Finally, fill trailing NAs using backward filling (locf from last)
  na.locf(x_filled, na.rm = FALSE, fromLast = TRUE)
}), by = Country.Name, .SDcols = cols]

# Convert back to a data.frame
df_interpolated <- as.data.frame(dt)

#depriciation rate
delta <- 0.05
df_interpolated <- df_interpolated %>%
  arrange(Country.Name, Year) %>%
  group_by(Country.Name) %>%
  mutate(
```

```
    I_RD = r_and_d_spend/100 * rgdpna,
    RD = {
      k     <- numeric(length(I_RD))
      k[1] <- I_RD[1] / delta
      for(i in 2:length(k)) {
        k[i] <- (1 - delta)*k[i-1] + I_RD[i]
      }
      k
    }
  ) %>%
  ungroup()
```

D.2. Growth rates definition

```
df1  <- df_interpolated %>%
  filter(Year %in% 1994:2019) %>%
  group_by(Year) %>%
  mutate(frontier_ctfp = max(ctfp, na.rm = TRUE)) %>%
  ungroup()

new_data <- df1 %>%
  filter(Year %in% c(1994, 1999, 2004, 2009, 2014, 2019)) %>%
  group_by(Country.Name) %>%
  arrange(Year, .by_group = TRUE) %>%
  mutate(rgdp_ln = log(rgdpna) - log(dplyr::lag(rgdpna, 1)))%>%
  mutate(K_ln = log(rnna)- log(dplyr::lag(rnna,1)))%>%
  mutate(ctfp_ln = log(ctfp)- log(dplyr::lag(ctfp,1)))%>%
  mutate(HC_lag = dplyr::lag(hc,1))%>%
  mutate(L_ln = log(emp*1000000)- log(dplyr::lag(emp,1)*1000000))%>%
  mutate(RD_ln = log(dplyr::lag(RD,1))- log(dplyr::lag(RD,2)))%>%
  mutate(GOV_edu_ln = log(dplyr::lag(gov_edu_spend,1)*dplyr::lag(rgdpna,1))- (log(dplyr::lag(
      gov_edu_spend,2)*dplyr::lag(rgdpna,2))))%>%
  mutate(FDI_ln = log(dplyr::lag(FDI,1))- log(dplyr::lag(FDI,2)))%>%
  mutate(HH_lag=dplyr::lag(HH_index,1))%>%
  mutate(distance_to_frontier_lag = dplyr::lag(frontier_ctfp,1)/dplyr::lag(ctfp,1))%>%
  ungroup()

my_cols <- c("Country.Name", "Year","rgdp_ln", "K_ln", "L_ln",
              "HC_lag", "HH_lag", "RD_ln", "GOV_edu_ln","FDI_ln","distance_to_frontier_lag" )

df_filtered <- new_data %>%
  filter (Year %in% c(2004, 2009, 2014, 2019)) %>%
  select(all_of(my_cols))
```

D.3. Panel regression

```
# --- Define Panel Data Structure ------------------------------------------
pdata <- pdata.frame(df_filtered, index = c("Country.Name", "Year"), drop.index = TRUE)
#Multicollinearity test
#Fit linear model
model <- lm(rgdp_ln ~ K_ln + L_ln + HC_lag + HH_lag + RD_ln +
                     GOV_edu_ln + FDI_ln + distance_to_frontier_lag,
            data = pdata)

#Compute Variance Inflation Factors (VIFs)
vif_vals <- vif(model)
print(vif_vals)

#Compute Tolerance = 1/VIF
tol_vals <- 1 / vif_vals
print(tol_vals)

# --- Define model_structure ------------------------------------------
model_1_formula <- rgdp_ln ~
  K_ln +
  L_ln

model_2_formula <- rgdp_ln ~
  K_ln +
```

```
  L_ln +
  HC_lag +
  distance_to_frontier_lag

model_3_formula <- rgdp_ln ~
  K_ln +
  L_ln +
  HC_lag +
  HH_lag +
  RD_ln+
  GOV_edu_ln+
  FDI_ln +
  distance_to_frontier_lag

# --- Fit Panel Model  ----------------------------
model_fem_1 <- plm(
  formula = model_1_formula,
  data    = pdata,
  model   = "within"
)
model_fem_2 <- plm(
  formula = model_2_formula,
  data    = pdata,
  model   = "within"
)
model_fem_3 <- plm(
  formula = model_3_formula,
  data    = pdata,
  model   = "within"
)

# --- Display summary of models ----------------------------------------------------

# Present the model results using stargazer
stargazer(model_fem_1, type = "text")
stargazer(model_fem_2, type = "text")
stargazer(model_fem_3, type = "text")

# --- Diagnostic Tests ----------------------------------------------------
# Breusch-Pagan Test for Heteroskedasticity - random effect model
print("Breusch-Pagan␣Test:")
bp_test <- bptest(model_fem_3, studentize = FALSE)
print(bp_test)

# Breusch-Godfrey/Wooldridge Test for Serial Correlation
print("Breusch-Godfrey/Wooldridge␣Test:")
bg_test <- pbgtest(model_fem_3)
print(bg_test)

# --- Driscoll-Kraay Standard Errors --------------------------------------
# Driscoll-Kraay handles cross-sectional dependence, heteroskedasticity, serial correlation
dk_se <- vcovSCC(model_fem_3, type = "HC0", maxlag = 2)

# --- Obtain robust coefficient test results using Driscoll-Kraay
robust_results_dk <- coeftest(model_fem_3, vcov = dk_se)
print("Coefficient␣test␣with␣Driscoll-Kraay␣robust␣standard␣errors:")
print(robust_results_dk)
```

D.4. Real GDP prediction using Model Endogenous

```
#PREDICT ΔlnY ------------------------------------------

#Specify coefficients (including intercept)
beta0 <- 0.33    # intercept from model endogenous
fe_coefs <- list(
  beta1 = 0.292,   # Δ(K_ln)
  beta2 = 0.679,   # Δ(L_ln)
  beta3 = -0.108,  # HC_lag
  beta4 = 0.070,   # distance_to_frontier_lag
  beta5 = 0.010,   # Δ(RD_ln)
```

```
  beta6 = -0.033,  # Δ(GOV_edu_ln)
  beta7 = 0.002,   # Δ(FDI_ln)
  beta8 = 0.105    # HH_lag
)

#Filter for Poland and compute the predicted -fiveyear -logchange
df_poland <- df_filtered %>%
  filter(Country.Name == "Poland") %>%
  arrange(Year) %>%
  mutate(
    pred_delta_ln = beta0 +
                    fe_coefs$beta1 * K_ln +
                    fe_coefs$beta2 * L_ln +
                    fe_coefs$beta3 * HC_lag +
                    fe_coefs$beta4 * distance_to_frontier_lag +
                    fe_coefs$beta5 * RD_ln +
                    fe_coefs$beta6 * GOV_edu_ln +
                    fe_coefs$beta7 * FDI_ln +
                    fe_coefs$beta8 * HH_lag
  )

#Reconstruct -loglevels and levels of GDP
df_poland <- df_poland %>%
  # lnY0: log of actual GDP in the base year - 1999
  mutate(lnY0 = log(574419.5)) %>%
  # cumulative sum of predicted -fiveyear -logchanges
  mutate(cum_delta = cumsum(pred_delta_ln)) %>%
  # predicted -loglevel in each period
  mutate(lnY_pred = lnY0 + cum_delta) %>%
  # -backtransform to levels
  mutate(Y_pred = exp(lnY_pred))
```

D.5. Country comparison

```
df_gdp_pc_cagr5 <- pwt_data %>%
  # Filter from 1956 for Korea, 1986 for Poland by country code
  filter(
    (countrycode == "KOR" & year >= 1956) |
    (countrycode == "POL" & year >= 1986)
  ) %>%
  select(countrycode, country, year, rgdpna, emp, ctfp, hc) %>%
  arrange(countrycode, year) %>%
  # Compute GDP per capita
  mutate(gdp_pc = rgdpna / emp) %>%
  group_by(countrycode) %>%
  # Compute 5-year lag and 5-year CAGR
  mutate(
    gdp_pc_lag5    = dplyr::lag(gdp_pc, 5),
    CAGR5_gdp_pc   = if_else(
      !is.na(gdp_pc) & !is.na(gdp_pc_lag5) & gdp_pc_lag5 > 0,
      ((gdp_pc / gdp_pc_lag5)^(1/5) - 1) * 100,
      NA_real_
    )
  ) %>%
  mutate(
    tfp_pc_lag5    = dplyr::lag(ctfp, 5),
    CAGR5_ctfp   = if_else(
      !is.na(ctfp) & !is.na(tfp_pc_lag5) & tfp_pc_lag5 > 0,
      ((ctfp / tfp_pc_lag5)^(1/5) - 1) * 100,
      NA_real_
    )
  ) %>%
  ungroup() %>%
  # Restrict to the plotting window by year and code
  filter(
    (countrycode == "KOR" & year >= 1963) |
    (countrycode == "POL" & year >= 1993)
  ) %>%
  # Align ’Polands years back by 30 for direct comparison
  mutate(
```

```
    year_aligned = if_else(countrycode == "POL", year - 30, year),
    country      = if_else(countrycode == "KOR",
                           "South␣Korea",
                           "Poland")
  )
  # Fit the two regressions
mod_pol <- lm(hc ~ year, data = df_gdp_pc_cagr5, subset = countrycode=="POL")
mod_kor <- lm(hc ~ year, data = df_gdp_pc_cagr5, subset = countrycode=="KOR")

# Extract the coefficients
coef_pol <- coef(mod_pol)    # a -length2 vector: (Intercept) and Year
coef_kor <- coef(mod_kor)
```

D.6. Poland stagnation

```
x <- 1214221.5

Poland_stagnation <- pwt_data %>%
  # Filter from 1956 for Korea, 1986 for Poland by country code
  filter(
    (countrycode == "POL" & year >= 1980)
  ) %>%
  select(countrycode, country, year, rgdpna, pop) %>%
  arrange(countrycode, year) %>%
  mutate(gdp_pc = rgdpna / pop) %>%
  arrange(year) %>%
  # compute 7-year CAGR:  (gdp_t / gdp_{t-7})^(1/7) - 1
  mutate(growth7 = ((gdp_pc / dplyr::lag(gdp_pc,7))^(1/7) - 1)) %>%
  ungroup()

Poland_stagnation_sim <- pwt_data%>%
  # Filter from 1956 for Korea, 1986 for Poland by country code
  filter(
    (countrycode == "POL" & year >= 1980)
  ) %>%
  select(countrycode, country, year, rgdpna, pop) %>%
  arrange(countrycode, year) %>%
    add_row(
    countrycode = "POL",
    country = "Poland",
    year = 2020,
    rgdpna = x*1.025,
    pop = 37.88777,
    )%>%
  add_row(
    countrycode = "POL",
    country = "Poland",
    year = 2021,
    rgdpna = x*(1.025)^2,
    pop = 37.88777,
    )%>%
    add_row(
    countrycode = "POL",
    country = "Poland",
    year = 2022,
    rgdpna = x*(1.025)^3,
    pop = 37.88777,
    )%>%
      add_row(
    countrycode = "POL",
    country = "Poland",
    year = 2023,
    rgdpna = x*(1.025)^4,
    pop = 37.88777,
    )%>%
  add_row(
    countrycode = "POL",
    country = "Poland",
    year = 2024,
    rgdpna = x*(1.025)^5,
```

```
    pop = 37.88777,
    )%>%
    add_row(
    countrycode = "POL",
    country = "Poland",
    year = 2025,
    rgdpna = x*(1.025)^6,
    pop = 37.88777,
    )%>%
    mutate(gdp_pc = rgdpna / pop) %>%
  arrange(year) %>%
  # compute 5-year CAGR:  (gdp_t / gdp_{t-7})^(1/7) - 1
  mutate(growth5 = ((gdp_pc / dplyr::lag(gdp_pc,5))^(1/5) - 1)) %>%
  ungroup()
```