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PRODUCTIVITY DISPERSION ACROSS COMPANIES: A Case Study of Estonia

Master Thesis

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Abstract:

Productivity growth serves as a key driver of economic advancement, but recently there has been a decline in aggregate productivity growth in many countries. Many factors may explain this trend, which includes the diminishing impact of new technologies, the delay in how we adopt new technologies, and the measurement challenges. However, we need to understand the dynamics of productivity at the firm level, as individual firms collectively shape aggregate productivity. There is growing consensus on the widening productivity disparities between firms within industries internationally. Drawing on firm-level data from Statistics Estonia covering the period 2014-2022, the study examines the characteristics of less productive firms, their catch-up rates over time, and the impact of digitalization and intangible assets on productivity dynamics. The findings reveal increasing productivity dispersion, declining catch-up rates, and technology adoption in sectors. The insights of this study contribute to understanding the dynamics of productivity and inform policy interventions to promote productivity growth in Estonia.

Keywords: Productivity, Firm Dynamics, Estonia, Digitalization, Intangible Assets, Catch-up Rates, Policy Implications.

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1 INTRODUCTION

Productivity serves as the main driver of economic growth, yet many countries have witnessed a decline in aggregate productivity growth since around 2005 compared to earlier periods (Inklaar et al., 2020). Various factors may explain this trend, including the possibility that new technologies have less potential to boost aggregate productivity growth than past innovations (Gordon, 2012). Additionally, adoption lags, that is, delayed implementation of new technologies due to the need for complementary investments in infrastructure and new management practices (Brynjolfsson et al., 2019), and measurement issues related to the IT revolution's impact on the creation of new goods (Brynjolfsson et al., 2020; Byrne and Corrado, 2020) are potential contributors.

However, it is essential to recognize that aggregate productivity growth does not provide insight into the microdynamics of individual firms. It is the dynamism and structural changes within firms that collectively drive aggregate productivity. Therefore, analyzing the productivity heterogeneity among firms becomes crucial. Beyond its impact on productivity, increasing productivity differences among firms can also lead to wage inequalities among individuals (Berlingieri et al., 2020), which may have been worsened by events like the COVID-19 crisis (OECD, 2020).

Internationally, there is a growing consensus that within-industry productivity disparities (the difference between high- and low-productivity firms) have widened in recent decades. Andrews et al. (2016) argue that this trend is due to slower productivity growth among lagging firms, while the global frontier has seen strong growth. They attribute this to the transition to digitalization and the growing importance of investments in intangible assets, which increase the costs of adopting new technologies for lagging firms (Corrado et al., 2022). However, it is not necessarily the case that lagging firms remain stagnant over several years; this is an empirical question critical to policy analysis.

Productivity dispersion can also arise from the dominance of superstar firms with high markups and barriers to outperforming their competitors (Autor et al., 2020). Low-productivity firms are related to zombie firms, which have increased (Banerjee and Hofmann, 2018). These firms, despite their low profitability, persist due to low real interest rates (Gouveia and Osterhold, 2018). Furthermore, public support, especially during economic downturns like the global financial crisis and the COVID-19 pandemic, can keep firms afloat, resulting in a loss of potential output (Caballero et al., 2008). Again, Andrews et al. (2021) examine how similar support influenced firm survival and productivity in Australia.

The purpose of the paper is to investigate the dispersion of productivity within Estonian companies, particularly focusing on less productive companies, the impact of digitalization and intangible assets on productivity dynamics, and the convergence rate of laggard companies. The study contributes to the existing literature in several ways. Firstly, it adds to the research exploring the relationship between productivity dispersion and aggregate productivity slowdown (Akcigit and Ates, 2019; Andrews et al., 2016; Comin and Hobijn, 2010; Decker et al., 2016) by providing firm-level evidence within the Estonian context. Third, it investigates the role of digitalization as a potential explanation for the declining catch-up rate of laggards and the increasing productivity dispersion. The study presents cross-sectional heterogeneity in catch-up rates by digital intensity and examines how catch-up rates have evolved over a significant time period. Furthermore, given Estonia's outlook on digitalization, the digital intensity (software usage) findings in sectors offer valuable insights for policymakers (OECD, 2020).

The analysis in this study used firm-level data from Statistics Estonia covering the period from 1995 to 2020 and survey data of IT usage in companies (Infotehnoloogia ettevõtetes) from 2014 to 2022. The dataset includes information on the financial and background characteristics of all non-financial private-sector firms in Estonia. The primary variable of interest is labor productivity, defined as the real value added per employee, with Total Factor Productivity (TFP) as a robustness check. Laggard firms are classified according to their position within the labor productivity distribution within their sector and year, with the bottom 40% firms considered laggards, following the approach of Berlingieri et al. (2020).

Consistent with previous research, industry productivity dispersion has increased over the past decades (Andrews, Criscuolo, & Gal, 2016). This increase is more pronounced in industries with a high intensity of digital and intangible assets. Although we observe a positive convergence rate among the laggard firms (bottom 40%), there is a general decline in convergence over time; further analysis reveals that this decline is particularly prominent in sectors with a high intensity of digitalization. These findings suggest the presence of barriers to the adoption and diffusion of new technologies in sectors where digitalization is crucial and quality labor. Therefore, policies that enhance firms' absorptive capacity, such as digital competence and improved access to digital infrastructure, can effectively promote productivity growth. We pay special attention to the less productive firms, as Estonia's status as one of the most innovative countries globally suggests a more significant potential for progress in this area (World Intellectual Property Organization, 2021). Corrado et al. (2021) explain that intangible assets, such as research and development (R&D), software, and branding—are often not measured accurately. These investments are treated as regular business expenses instead of long-term assets. As a result, their contribution to productivity and economic growth tends to be underestimated. For example, when a company invests in developing new software or improving its brand, this spending might not be recorded as an "asset" in traditional accounting, making it harder to capture the true value these investments add to the economy.

In addition, the study investigates the catch-up dynamics of less productive firms, sector-specific productivity trends, and the broader implications of economic policy, suggesting a customized approach to support technological advancement in Estonia.

The structure of this study is as follows. Section 1 presents the introduction. Section 2 includes a review of the literature. Section 3 presents data and methods. Section 4 presents the results. The final section concludes.

2 LITERATURE REVIEW

The evolution of productivity within different economic sectors has long been a focal point for researchers, policymakers, and industry practitioners. Despite extensive research on productivity growth mechanisms, the understanding of within-sector productivity disparities remains underexplored. There are already literature reviews that aim to bridge this gap by examining productivity differences, firm dynamics, and the phenomenon of zombie firms by exploring the dynamics of convergence and divergence between laggard and frontier firms, identifying factors such as digital adoption that influence these trends. It highlights how digital technologies and intangible assets drive productivity growth, while acknowledging the barriers that prevent laggard firms from fully realizing these advancements, which are crucial for shaping sector-specific productivity narratives and the broad implications for policy design.

Furthermore, the concept of zombie firms, inefficient yet surviving entities, adds complexity, raising significant questions about resource allocation, financial systems, and market health, especially within the Estonian context. By providing a comprehensive overview of current research and identifying gaps, this review seeks to guide future studies and support stakeholders in fostering environments conducive to high productivity and sustainable economic growth.

2.1 Previous Studies on Productivity and Firm Performance

Research into within-sector productivity differences has historically been limited. Still, interest has grown since the late 1990s, with studies like Bartelsman and Doms (2000) exploring cross-sectional productivity dispersion between firms within the same sector. However, the number of studies has increased in the last decade. The focus is on; (1) productivity differences, (2) firm dynamics.

In examining productivity differences across various studies, it becomes evident that there is a range of definitions for what constitutes frontier and laggard firms. This variation in definitions leads to multiple approaches to analyzing productivity disparities. For instance, Andrews et al. (2016) define global frontier firms as the top five percent of the productivity distribution within each two-digit industry and year and compare them with other firms. Berlingieri et al. (2020) group firms into five groups based on their productivity levels: the bottom 10th percentile, the 10th-40th percentiles, the 40th-60th percentiles, the 60th-90th percentiles, and the top 90th–100th percentiles. Firms in the bottom 10th and 10-40th percentiles are identified as laggards. This framework is applied to labor and total factor productivity (TFP), with particular attention given to frontier firms and the two lowest performing groups as laggards.

The choice of benchmark used in productivity studies can significantly affect the results.

Bartelsman et al. (2008) demonstrate that productivity growth among the least productive firms within a country may be more akin to the most productive firms within that same country, rather than those at the global frontier. The importance of the national context in the analysis of productivity cannot be underestimated. Country-level factors, such as digital infrastructure and policy environments, influence productivity growth disparities. The importance of these factors is that they can either accelerate or hinder the catch-up process of laggard firms, affecting productivity dispersion and economic growth.

In particular, Andrews et al. (2016) by focusing on a cross-country analysis among OECD countries find that the decline in productivity growth primarily arises from an expanding labor productivity gap between global frontier companies and laggard companies. This gap is not due to a deceleration in productivity growth among frontier firms, but rather to stagnation and a limited ability to adapt to best practices among laggard companies. In contrast, Van Heuvelen et al. (2018) discovered that in the Netherlands, both frontiers and laggards exhibited relatively similar development patterns over a specific period. Among countries such as the USA, Andrews et al. (2016) reveal that the market share of frontier firms, especially in sectors like computer programming and telecommunications, has increased. Meanwhile, Berlingieri et al. (2020) note that laggards, although smaller, experience higher productivity growth rates, indicating convergence towards the frontiers in countries such as Germany and France. However, this group of laggards appears to be diverse and marked by a high degree of dynamism.

Akcigit and Ates (2021) delve into the trend of declining business dynamics in the US and its implications. They suggest that reduced technological diffusion from frontier to laggard firms may contribute to the deceleration in aggregate productivity growth. Factors such as increased market concentration, rising mark-ups, lower labor share, declining firm entry rates, decreased presence of young firms, and sluggish productivity growth come into play. It is thus implied that the GDP share that goes to labor is reduced, hence a decline in labor share. Increased market concentration can lead to higher mark-ups, where companies charge more than their products' marginal cost.

Regarding potential drivers, Andrews et al. (2016) argue that a lack of pro-competitive product market reforms has heightened productivity dispersion. Additionally, Diez et al. (2018) emphasize the role of superstar firms in promoting divergence, particularly in industries characterized by "winner-takes-all" dynamics, such as ICT-intensive sectors. Calligaris et al. (2018) support this notion by highlighting more significant differences in mark-ups between frontiers and laggards in digital-intensive industries compared to other sectors. [1] [2] Mohammed (2024) observed a general reduction in mark-ups across industries, which, due to increased competition, contributes to an increase in the overall labor share of value added. He stated that improved trade openness and international integration in Estonia also positively affect labor share, particularly benefiting catching-up countries.

In addition to the factors previously discussed, some studies highlight the decline in knowledge diffusion as a contributing factor to the increase in productivity differences, as suggested by Akcigit and Ates (2021). Although theoretical papers have explored the connection between productivity dispersion and intangible assets (Aghion et al., 2019; De Ridder, 2019), empirical evidence on this topic is limited. However, Corrado et al. (2021) provide an exception, demonstrating that heightened productivity dispersion is particularly prominent in sectors characterized by a significant reliance on intangible assets. He further states that industries that heavily rely on intangible assets tend to exhibit more excellent productivity dispersion between leading (frontier) firms and lagging firms. This is because intangible-intensive companies often have the resources and capabilities to innovate and adopt new technologies more effectively, leaving behind firms that lack these assets.

This divergence can partly be attributed to scalability, with a more substantial gap between the top-performing firms and the median observed in industries where sales differences are more pronounced. The analysis by Corrado et al. (2021) reveals that dispersion at the upper end of the distribution is associated with scalability, i.e., the ability of a

[1] Winner-takes-all dynamics are fundamental in ICT-intensive sectors, as these industries often exhibit high returns to scale, network effects, and fast technological advancements, leading to a concentration of market share and productivity gains among a few frontier firms while laggard firms struggle to compete (Brynjolfsson et al., 2002; Andrews et al., 2016).

[2] Autor et al.(2021) describe superstar firms as exceptionally productive and successful companies that come to dominate their respective markets, often due to network effects, scale economies, or technological advantages. In winner-takes-all markets, once a firm gets ahead, its lead tends to become self-reinforcing, making it hard for others to catch up.

company, industry, or economy to grow or expand its production output, sales, or other relevant metrics without a corresponding increase in costs, while dispersion at the lower end is linked to factors such as digital intensity, trade openness, and venture capital[3]

In recent years, the growing gap between high-productivity firms (global frontier firms) and low-productivity firms (laggards) has raised concerns about declining business dynamism and increasing productivity dispersion. Although technological innovation often helps firms improve productivity, the strategic use of patents to block competition, as Akcigit and Ates (2019) suggested, can contribute to this widening gap. Additionally, Calvino and Criscuolo (2019) find that sectors heavily reliant on intangible assets, such as intellectual property, experience lower entry rates, further exacerbating the divide between frontier firms and laggards. This suggests that barriers to entry and limited competition may play a significant role in driving productivity dispersion, particularly in intangible-intensive sectors.

In the subsequent sections, we will provide a concise overview of the literature on firm dynamics and zombie firms, as they are interconnected with laggard firms and their potential for catching up to frontier firms.

2.2 Firm dynamics

Analyzing data from OECD countries, Berlingieri et al. (2020) find that laggard firms, on average, tend to be younger and smaller in size and a concern for aggregate resource allocation. He discusses that younger firms are quick to converge to the productivity frontier, indicating that laggards underscore future productivity. Intriguingly, a substantial body of literature presents the crucial role that startups and young firms play in fostering productivity growth (Decker et al., 2014; Haltiwanger et al., 2016) and job creation (Ayyagari et al., 2014; Barba Navaretti et al., 2014; Coad et al., 2018; Haltiwanger et al., 2013). Herein, the study by Haltiwanger et al. (2016,p.47) delves into the "significant impact of high-growth young firms on job creation, output, and productivity growth". It

[3] The paper assumes Cobb- Douglas production function at firm level with output as value added. Productivity dispersion measured as the logarithmic difference between the 90th and the 10th percentile of a multifactor productivity (MFP) within an industry.

emphasizes that while most start-ups and young firms fail or do not create jobs, a small fraction that experiences rapid growth plays a crucial role in contributing to economic development. Research supports the idea that high-growth companies, which are unequally young, contribute substantially to the growth of production and productivity, especially in the high-tech and energy-related industries. The findings also highlight the differing impact of these firms in different sectors, with some industries showing a higher share of activity attributed to high-growth firms, thus contributing to understanding the dynamics of firm growth and the pivotal role of young high-growth firms in fostering economic vitality. Similarly, findings of Ayyagari et al. (2014) in "Who creates jobs in developing countries" highlight that eventhough the fastest growing and large mature firms might have the largest employment shares, small young firms have higher propensity for job creation and young firms have higher growth rate.

Decker et al. (2014) stress that entrepreneurship is more accurately represented by young firms than by small firms. In the context of our discussion, this implies that young laggard firms possess the potential to transcend their low-productivity status and actively contribute to overall productivity growth.

Haltiwanger et al. (2016) describe the "up-or-out" dynamics associated with new firms as a vital source of productivity enhancement. To learn about their capabilities and market conditions, young firms have less time and resources; hence, these often grapple with uncertainty (as elucidated by Jovanovic, 1982). In Jovanovic s model, there are two concepts, i.e. active and passive learning. Firms naturally learn about their productivity in a way that is passive, as they learn their strengths by how they perform over time by an indeliberate process. If in the process they discover that they are efficient producers, i.e., low-cost producers, they grow, else they stagnate or exit the market. In contrast, passive learning is an active and conscious effort to understand the environment better through market research, controlled trials, and other forms of deliberate information gathering. It is a challenge for young companies in active learning as they do not have the resources to do extensive research. Firms displaying higher revealed capability tend to "move up" and achieve higher productivity levels than incumbents. Conversely, firms with lower revealed capability tend to "move out" at a higher rate than incumbents, thereby contributing to productivity growth by reallocating resources from less productive to more productive firms. A slowdown in this reallocation process can consequently impede productivity growth (Decker et al., 2014).

Furthermore, the discussion surrounding productivity gaps and business dynamism is intricately connected with the discourse on zombie firms, essentially non-profitable entities. In the following section, we will provide a concise overview of the literature from a productivity perspective, delving into the dynamics surrounding these issues.

2.3 Zombie firms

While frontier firms drive productivity with innovation and success, laggards, despite underperformance, have growth potential. In contrast, zombie firms are unresponsive and consume resources that could benefit dynamic firms. Although this study does not focus on zombie firms, their absence could free up capital and labor for efficient use. Zombies are often defined as firms receiving subsidized credit (Caballero et al., 2008) or older firms unable to cover interest payments (Adalet McGowan et al., 2018).

On an aggregate level, Banerjee and Hofmann (2018) demonstrate that a higher number of zombie firms can undermine overall economic growth in 14 countries. For instance, Italy has many zombie firms' presence in industrial sectors. The favorable banking lending practices and regulatory environments supported these firms, affecting overall productivity and economic growth. Again, a country like Japan is cited for its experience in the 1990s and 2000s. Japan's " Lost Decade" of stagnant economic growth was a result of prolonged periods of low interest rates and liquidity support that led to survival of zombie firms. This occurs because these firms use labor and capital resources that could be used more effectively by their more productive counterparts. Andrews and Petroulakis (2017) investigate the connection between zombie firms, weak banks, and their repercussions on productivity in Europe, highlighting that zombie firms are closely associated with the presence of feeble banks and subsequent declines in aggregate productivity growth. The continued existence of these firms can further stress already weak banks, furthering financial instability. These banks are posed with higher risks of default and subsequent deterioration in their balance sheets.

Caballero et al. (2008) delve into the consequences of credit flows to insolvent borrowers, or zombies. They reveal that a proliferation of zombie firms hampers the entry and investment of healthy firms, leading to lower job creation and productivity in industries with a significant share of zombie firms. Furthermore, a larger proportion of zombie companies are related to wider productivity gaps. Their research particularly focused on the phenomenon during Japan's "Lost Decade" in the 1990s.

Adalet McGowan et al. (2018) emphasize the global rise in the number of zombie firms within the OECD since the mid-2000s. Monetary policies and regulatory environments seem to be a particular pattern that promotes the survival of zombie firms. This phenomenon allocates more resources to low-productivity firms, restricting growth opportunities for more productive entities. In the case of Sweden, they observed an increase in the prevalence of zombie firms from 2007 to 2010, coinciding with the global financial crisis. Banerjee and Hofmann (2018) attribute this increase, in part, to low interest rates. In contrast, Cella (2020), using the Bisnode Serrano database, reports a decline in the share of zombie firms in Sweden from 2010 onward, a period marked by lower interest rates.

In reference to the lowest-performing firms, Bartelsman et al. (2008) proposed that monetary policy, specifically lower interest rates, might play a role in keeping low-productivity firms afloat. However, Berlingieri et al. (2020) caution against automatically categorizing laggard firms as "zombies," that is, unhealthy and unviable entities. They point out that the laggard status can arise from various factors. For instance, a firm may have experienced a temporary productivity setback, or it might still be in its early stages of development, thus not yet operating at peak efficiency.

Lastly, Nieto-Carrillo et al. (2022) highlight that an appropriate institutional framework can enhance the likelihood of zombie firms undergoing reorganization and recovery. In contrast, government interventions, such as financial support, can increase the prevalence of zombie firms if misdirected to inappropriate recipients (Chang et al., 2021).

Although the existing literature sheds light on frontier firms, laggard firms, and zombie firms separately, there is limited understanding of the dynamics and interactions among these groups, particularly within an Estonian context.

2.4 Literature on Estonian Firms

Research on Estonian companies has examined the role of digitalization and intangible assets as critical drivers of productivity growth, as seen in the work by Masso et al. (2004) and Gouveia and Osterhold (2018). These studies indicate that while Estonian companies have made strides in adopting new technologies, productivity dispersion remains a concern, especially between high-performing firms and those lagging behind. Moreover, Calvino and Criscuolo (2019) observe that Estonian sectors highly reliant on intangible assets tend to exhibit a more excellent productivity dispersion, reflecting global trends in which technological adoption is uneven between firms.

Also, a study by Azzopardi et al. (2020) delves into productivity dispersion among Estonian firms, emphasizing the importance of digital intensity and intangible assets. Examines productivity variations, the impact of digital technologies and the role of intangible assets in firm performance. Additionally, it investigates the catch-up dynamics of less productive firms, sector-specific productivity trends, and broader economic policy implications, suggesting a tailored approach to support technological advancement in Estonia.

Building on this focus on firm-level productivity, Banh et al. (2020) explored the impact of participation in the global value chain (GVC) on productivity in Estonia, using firm-level data from 2000 to 2016. They found that higher GVC participation at the industry level led to greater productivity at the industry and firm levels. However, non-frontier, small, and non-exporting firms did not benefit as much as frontier firms, large firms, and exporting firms from GVC participation.

The study by Benkovskis et al. (2024) reveals contrasting effects of Global Value Chain (GVC) participation on productivity, depending on whether firms operate upstream or downstream industries. Downstream industries, closer to the final consumer, experience a negative correlation with productivity, potentially due to factors such as increased dependence on foreign inputs, less control over production processes, or weaker innovation incentives. In contrast, upstream industries, which supply inputs for other firms, benefit from greater specialization, technological advancements, and stronger integration into global markets, resulting in improved efficiency and productivity growth. These findings highlight the importance of policies that promote the participation of GVCs to enhance aggregate productivity and potential growth in Estonia (Banh et al., 2020).

Expanding on firm dynamics, Masso et al. (2004) explored firm entry, exit, and survival analysis in Estonia from 1995–2001. Their study found high firm turnover, driven by low institutional entry barriers and the rise of the SME sector. They also observed that the high survival rates and rapid growth of new firms indicated their relatively high productivity compared to incumbents. Additionally, productivity growth during this period was primarily attributed to improvements within firms, such as adopting new production technologies and organizational changes, alongside the reallocation of production factors through the exit of low-productivity units.

Building on the analysis of firm-level productivity differences, Vahter (2006) examined labor productivity and total factor productivity (TFP) among Estonian firms from 1995 to 2002. His findings highlight that productivity variation in Estonia was more significant than in Western Europe. Despite notable firm entry and exit during the period, there was limited movement within the productivity distribution of the surviving firms. Vahter emphasizes that innovation and a less concentrated market structure were positively associated with increased firm productivity, further underlining the importance of fostering innovation and competition.

Further insights into productivity dynamics in Estonia emerge from recent research that integrates survey- and registry-based data from Statistics Estonia. This study sheds light on the labor productivity premium associated with adopting digital technologies and improving digital skills. It decomposed the productivity premium into a direct effect - benefitting firms that increase their digital intensity - and an indirect impact arising from operating in a sector with high digital intensity. The results consistently demonstrate a substantial and positive firm-level productivity premium for adopting digital technologies in various sectors, particularly manufacturing and high-automation industries (OECD, 2020a).

Building on this, OECD researchers highlight the transformative potential of digital technologies such as cloud computing, online platforms, and artificial intelligence for productivity and living standards. Despite Estonia's advanced digital foundations and e-government services, challenges remain, including declining aggregate productivity growth.

The study stresses the need for Estonia to accelerate digital adoption beyond the ICT sector and improve synergies between digital technologies, skills, and policies. It also points out the importance of improving digital user skills and management practices and fostering collaboration among industry stakeholders to fully realize the productivity potential of digital technologies (OECD, 2020b).

3 METHODOLOGY

3.1 Data

The analysis in this study uses firm-level data from the Estonian business registry. This data covers Estonia's non-financial private sector companies from 1995–2020. The final data set is an unbalanced panel of 288,362 individual firms, yielding 2,491,170 firm-year observations for the entire period. Data from Infotehnoloogia ettevõtetes (Information technology in enterprises) over 2014-2020 show that 3,000 firms have been merged annually into the Estonian business registry for analysis. Data are presented every five years to simplify analysis, focus on long-term trends, reduce annual fluctuations, align with primary policy or economic changes, and make the data easier to manage. Financial statistics contain firm-level details, such as value-added, number of employees (measured as full-time equivalent), capital stock, industry, sales, and total wages paid. All monetary values are deflated using the Consumer Price Index (CPI).

As highlighted in Tillväxtanalys (2021), there are multiple methods to measure productivity. The simplest method that does not require a capital measure is labor productivity. However, total factor productivity (TFP), which requires a capital measure and often an econometric estimation, is also considered. This study opts for labor productivity, defined as the logarithm (log) of real value added per employee, as the primary variable of interest. Additionally, TFP, as formulated by Levinsohn and Petrin (2003), built on the ideas of Olley and Pakes (1996). The main innovation of the Levinson-Petrin method lies in its use of intermediate inputs, typically subtracted out in a value-added production function, to address simultaneity problems in production function estimation. This approach is consistent with similar studies in the field (Andrews et al., 2016; Berlingieri et al., 2020), and robustness tests using TFP have yielded similar results, indicating that choosing between these productivity measures is not critical.

3.2 Variables and Measurements

The primary variable of interest is labor productivity, defined as the logarithm of the real value added per employee. Total Factor Productivity (TFP) is also used as a robustness check, based on the Levinsohn and Petrin (2003) method.

Following the classification by Berlingieri et al. (2020), firms are categorized into five productivity groups based on their position within the productivity distribution in each two-digit industry and year. These groups range from p0-10 (1st to 10th percentile) to p90-100 (90th to 100th percentile). Laggard firms are those in the bottom 40 percent of the productivity distribution (p0-40). In comparison, frontier firms are classified as those in the top 10 percent (i.e., p90–100), following the thresholds used by Berlingieri et al. (2020). These thresholds capture the most distinct productivity differences between firms, highlighting the gap between the top-performing firms that drive innovation and growth (frontier firms) and those struggling to catch up (laggard firms). The bottom 40 percent includes a significant portion of firms that are not performing and face persistent challenges, such as lower resource efficiency, outdated technologies, or weaker management practices. In contrast, the top 10 percent represents highly productive firms likely to influence industry-wide trends and set benchmarks for others. This classification provides a clear framework for studying productivity dispersion, allowing researchers to focus on policy interventions supporting laggard firms' convergence toward the frontier.

Under the methodology we analyze the catch-up rates of laggard firms with respect to frontier firms. We utilize both descriptive statistics and regression analysis to understand the dynamics of productivity growth among different firms. Mathematically, the productivity growth rate of frontier firms can be expressed as:

$$\Delta P_s F_t = PF_t - PF_{t-1} \tag{1}$$

Where PF_t refers to the productivity of frontier firms at time t, and PF_{t-1} refers to the productivity of frontier firms in the previous period $t-1$.

The productivity gap at time t, which represents the difference between the productivity of the most productive firms and the laggard firm in the industry, is given by:

$$\text{gap}_t = PF_t - P_t \tag{2}$$

Where P_t refers to the average productivity of all firms in the sector at time t. The difference $PF_t - P_t$ is the productivity gap between the frontier firms (PF_t) and the laggard firms (P_t). This gap reflects whether the productivity disparity between these groups is widening or narrowing over time and indicates changes in the ability of laggard firms to catch up with frontier firms.

The catch-up rate can be defined as

$$CR_t = \frac{\Delta P_t - \Delta PF_t}{PF_{t-1} - P_{t-1}} \tag{3}$$

Where ΔP_t and ΔPF_t represent the productivity growth rates of the laggard firms and the frontier firms, respectively, and $PF_{t-1} - P_{t-1}$ is the productivity gap in the previous period.

3.3 Model Description

We employ a baseline model to estimate the productivity growth of firms as a function of their productivity gap relative to the frontier firms and the productivity growth of the frontier firms in the same sector and year. Below, we estimate the following fixed effect model:

$$\Delta P_{ist} = \alpha + \beta_1 \text{gap}_{ist-1} + \delta \Delta P_{sFt} + \sum_k \theta_k Z_{ist-1} + \epsilon_{ist} + \delta_s + \gamma_t \tag{4}$$

Where:

- ΔP_{ist}: Productivity growth of firm i in sector s and year t.
- gap_{ist-1}: Productivity gap of the firm i relative to the frontier firms in the previous period.

- ΔP_{sFt}: Productivity growth of frontier firms in sector s and year t.

- Z_{ist-1}: Control variables (e.g., usage of customer relationship software (CRM), usage of the website (Website)) at $t-1$.

- δ_s: industry fixed effects defined as two-digit industry-classification

- γ_t: Year fixed effects

- ϵ_{ist}: Error term.

We regress ΔP_{ist} on gap_{ist-1} to estimate β_1, the convergence rate in the baseline model.

Secondly, we employ a fixed effect model that examines if the rate of productivity convergence has slowed down over time:

$$\Delta P_{ist} = \alpha + \delta \Delta P_{sFt} + \beta_1 \text{gap}_{ist-1} + \sum_j \beta_{2j} \text{gap}_{ist-1} * D_{jt} + \sum_k \theta_k z_{ist-1} + \delta_s + \gamma_t + \epsilon_{ist} \quad (5)$$

where:

- D_{jt}: Dummies for periods, that is, time-specific effects. In this model, the different periods, j, refer to 1995-2005, 2005-2015, and 2015-2020.

- β_{2j}: Parameters representing the extent to which the convergence rate differs over time.

- *gap*: the distance between the frontier and the laggard productivity.

$gap_{ist} \times D_{jt}$ is the interaction term used in the regression model to analyze how convergence rates change between periods. D_{jt} capture time-specific effects, and allow the model to assess whether there are distinct periods during which the convergence rate between firms differs significantly. This model helps to understand the dynamics of productivity growth across various time phases that might influence the rate at which less productive firms catch up to more productive ones.

4 RESULTS

This section deals with the dynamics of productivity growth and firm behavior among Estonian firms and focuses on productivity differences, entry and exit rates, and sales performance. The results provide insights into the productivity gap and catch-up rates over time by analyzing the characteristics of laggard and frontier firms. Regression analysis also explores the effect of frontier growth, IT adoption, and productivity gaps on overall productivity growth.

In addition, firms' entry and exit rates are an important indicator of the general health and stability of the business environment. Increased entry rates often reveal good market conditions, lower barriers to entry, and a dynamic entrepreneurial ecosystem that promotes innovation and competition. On the contrary, exit rates can be signs of challenges such as economic downturns, structural problems, or external shocks like the COVID-19 pandemic, which hasten firms to leave the market. The entry and exit rates provide important information on the resilience of the business landscape in Estonia and how well it has adapted to challenging times. Sales data again enrich this analysis as it focuses on economic activity trends and firm performance over time. A rise in sales often shows improved productivity, technological improvements, and successful integration into global value chains. For example, during the 1995-1999 period, sharp sales growth observed is evidence of Estonia's post-independence economic changes and its transition towards a market-centred economy. Similarly, Estonia's entry into the European Union in 2004 and its integration into global trade networks later on are seen in times of high sales growth and productivity increase.

These results provide an understanding of the factors that shape productivity and economic growth in Estonia, linking them to global historical trends like the global financial crisis and COVID-19. They highlight the role of technology use and innovation in driving productivity and emphasize the importance of policies that promote digitalization, lower entry barriers, and encourage competition. The findings underscore the interaction between firm dynamics, technological progress, and economic policies and offer critical insights to reduce the differences between laggards and frontier firms and maintain economic resilience.

Table 1: Summary statistics of Labor Productivity

Variable	Mean	Std. Dev.	Min	Max
labor productivity frontier	11.01	0.66	9.06	12.4
Catch-up rate	0.002	0.15	-0.5	0.8
Frontier growth	0.24	0.33	-1.50	1.50
Productivity gap	1.16	0.41	0.5	2.5
Observations	2,948,758			

Source: Author's calculation on Estonian data

Table 1, provides key insights into labor productivity, catch-up rates, productivity growth at the frontier, and productivity gaps.

The frontier productivity growth rate is the logarithmic difference in the labor productivity of frontier firms at time t. The catch-up rate is defined as the negative ratio of the change in the gap at time t to the gap at $t-1$ (see Equation 3). The observed productivity gap for Estonia is approximately 14%, consistent with international findings (Berlingieri et al., 2020). However, sector-specific differences and historical context could amplify this gap to 30%, necessitating targeted interventions. We refer to Equation 2 to calculate the gap between frontiers and laggards- the logarithmic difference of the labor productivity of frontier and laggard firms. In essence, 'catch-up' refers to lagging firms that are improving to reach the level of the leading ones. Equation 1 refers to frontier firms' productivity growth.

The productivity gap quantifies the difference between a firm's productivity and this leading edge, as presented in Equation 2. It signifies the disparity in efficiency and performance between frontier firms, industry leaders, and laggard firms that struggle to catch up. This gap can be linked to differences in resource allocation, technological adoption, and market dynamics, all of which play a critical role in shaping firm productivity. Understanding these disparities and the catch-up process is crucial for designing policies that encourage technological diffusion, reduce productivity gaps, and promote economic growth.

Generally, a catch-up rate of 0.002 implies that, on average, laggard firms close the pro-

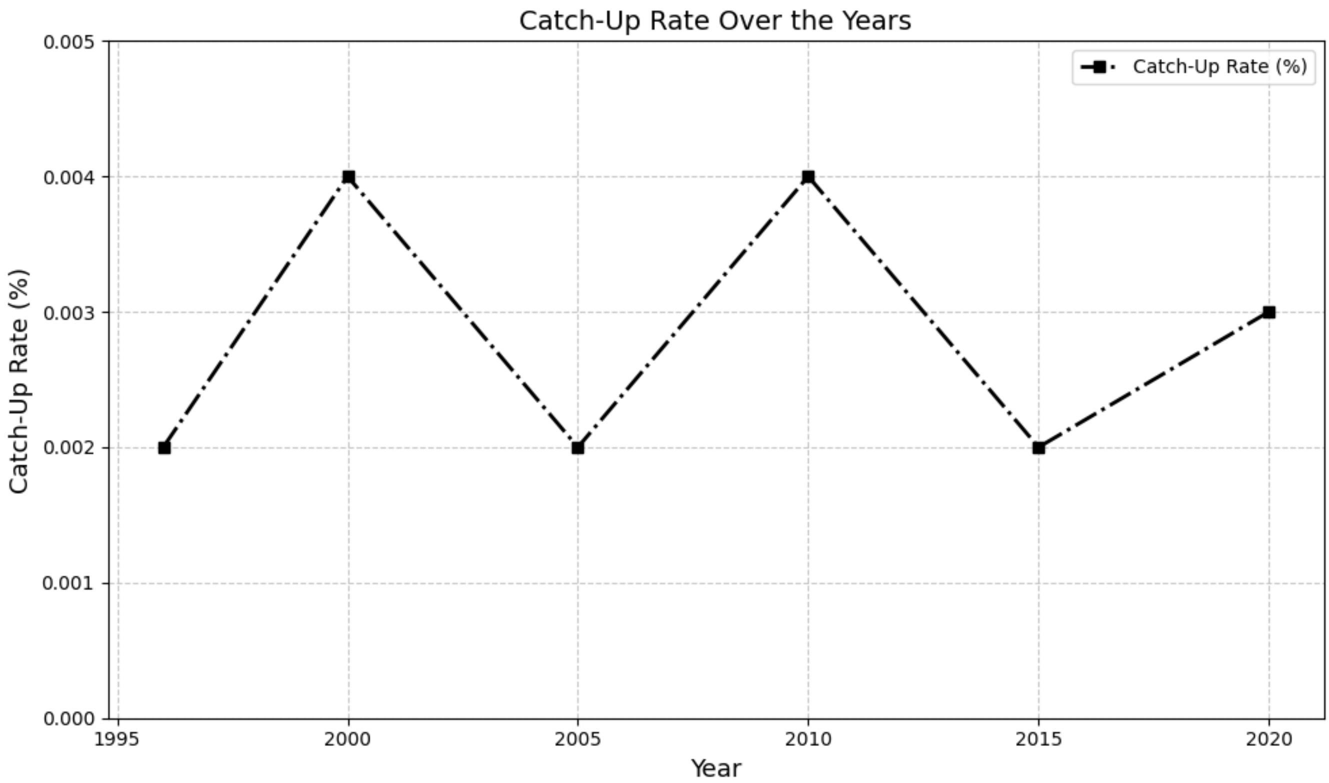

Figure 1: Catch-up rate over the years

Source: Author's calculations with Estonian Business Registry data.

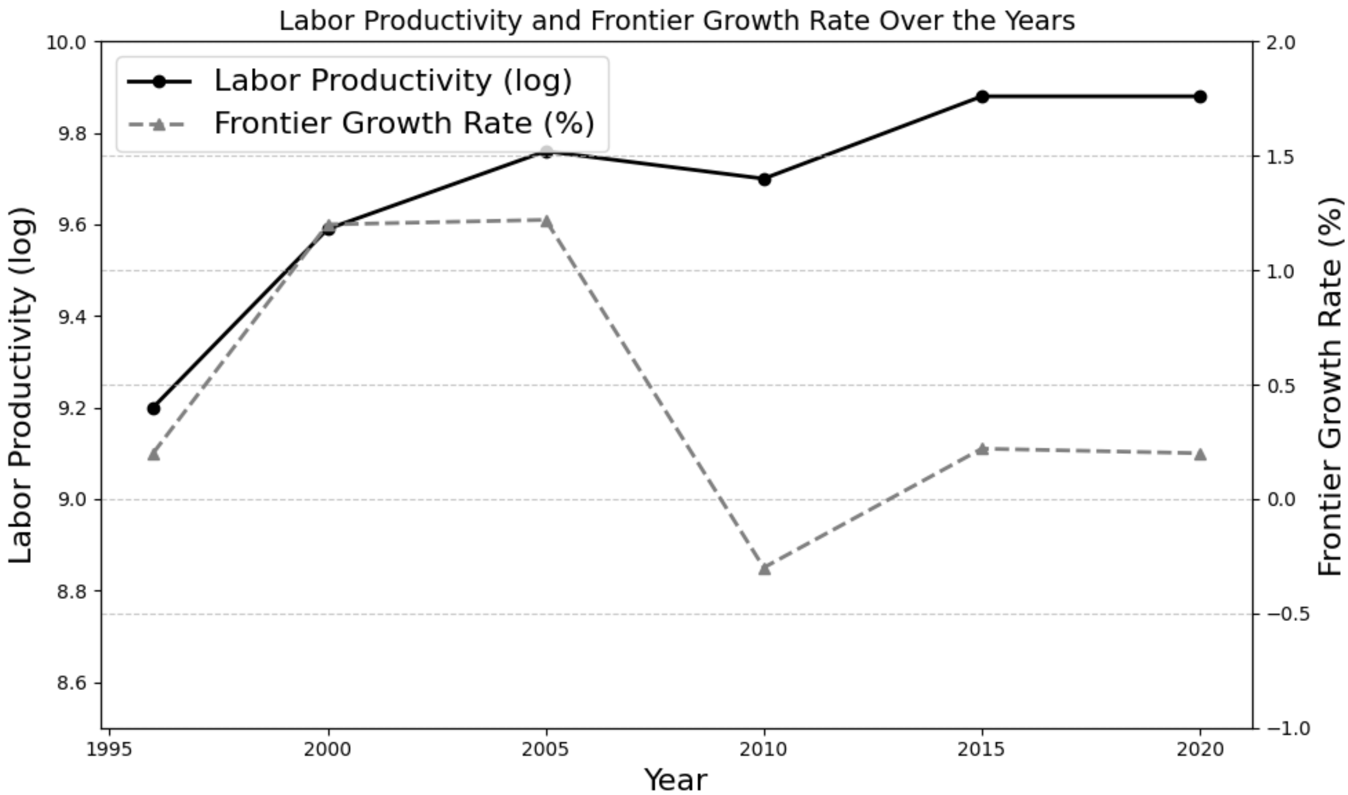

Figure 2: Comparison of Labour productivity and Frontier growth rate

Source: Author's calculations with Estonian Business Registry data.

ductivity gap with frontier firms by 0.2% per year. This indicates that laggard firms are improving their productivity relative to the frontier firms, albeit very slowly. Figure 1 shows that before period 1997, there was a lower catch-up rate, and it increased positively in 2000 with a value of 0.4%, implying that the laggards were able to close the gap between them and the frontier firms and then diverged to 2005 by 50%. After 2005, there was a positive catch-up rate, but a decrease in the frontier growth rate between 2005 − 2010 was observed. There is a significant increase in catch-up, indicating that laggards have at least been able to close the gap between them and the frontier firms before the year 2020. However, it was slow and unstable, alternating between 0.2% and 0.4%. Notable by Andrews et al. (2016), the global productivity slowdown has highlighted significant disparities between frontier and laggard firms, with laggards experiencing slower catch-up rates in recent decades.

In Figure 2, the frontier growth rate recorded positive values in most periods until 2005, gradually declined until 2010, and then increased. Vahter (2006) highlights the role of innovation and market structure in productivity differences among Estonian firms. Although his analysis predates 2005, recent trends suggest slower frontier growth due to limited movement within productivity distributions. This period matches with the global financial crisis, which had a dampening effect on productivity improvements. In contrast, the growth observed from 2010-2020 highlights the recovery enabled by increased technological adoption and favorable policy frameworks.

In addition, in Figure 3, as the year progresses, there is an increase in the mean values of labor productivity from 9.06 to 9.88, indicating an upward trend in all productivity groups. The total factor productivity (TFP), calculated using the method of Olley and Pakes (1996) for robustness, shows a trend similar to that of labor productivity.

In Table 6 in the appendix, the productivity growth rate has not been consistent, fluctuating between values of 0%, 53%, 17%, −6%, 18% seems to increase in the initial period before 2000 and finally achieve 16% growth during the period. Staehr (2004) discusses Estonia's transition to a market economy, driven by rapid liberalization, privatization, and integration into western markets, which significantly contributed to productivity growth during the 1990s and early 2000s.

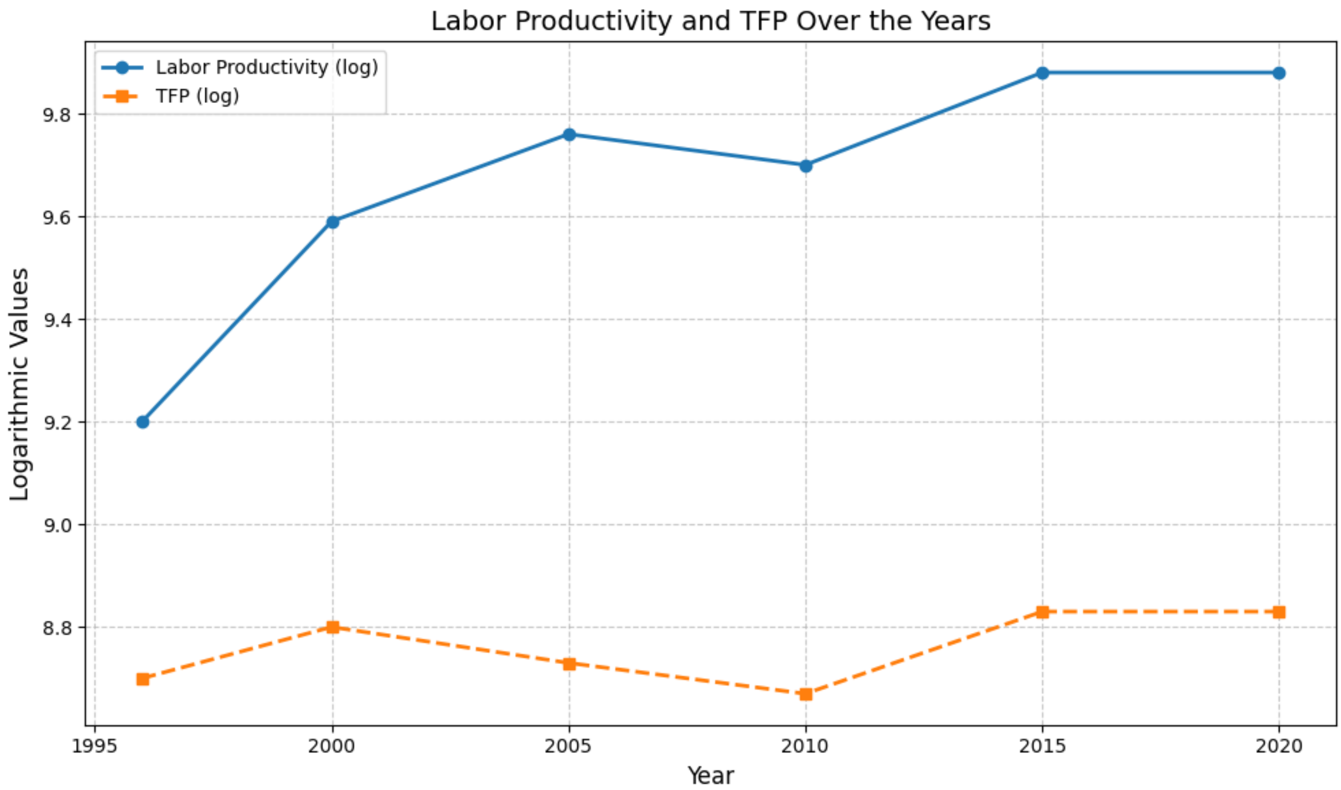

Figure 3: Comparison of Labour Productivity and TFP Over the Years

Source: Author's calculations with Estonian Business Registry data.

Labour productivity is measured as output per employee

The steady but inconsistent catch-up rate further suggests that, while laggard firms have made progress, systemic barriers continue to limit their ability to maintain convergence over time.

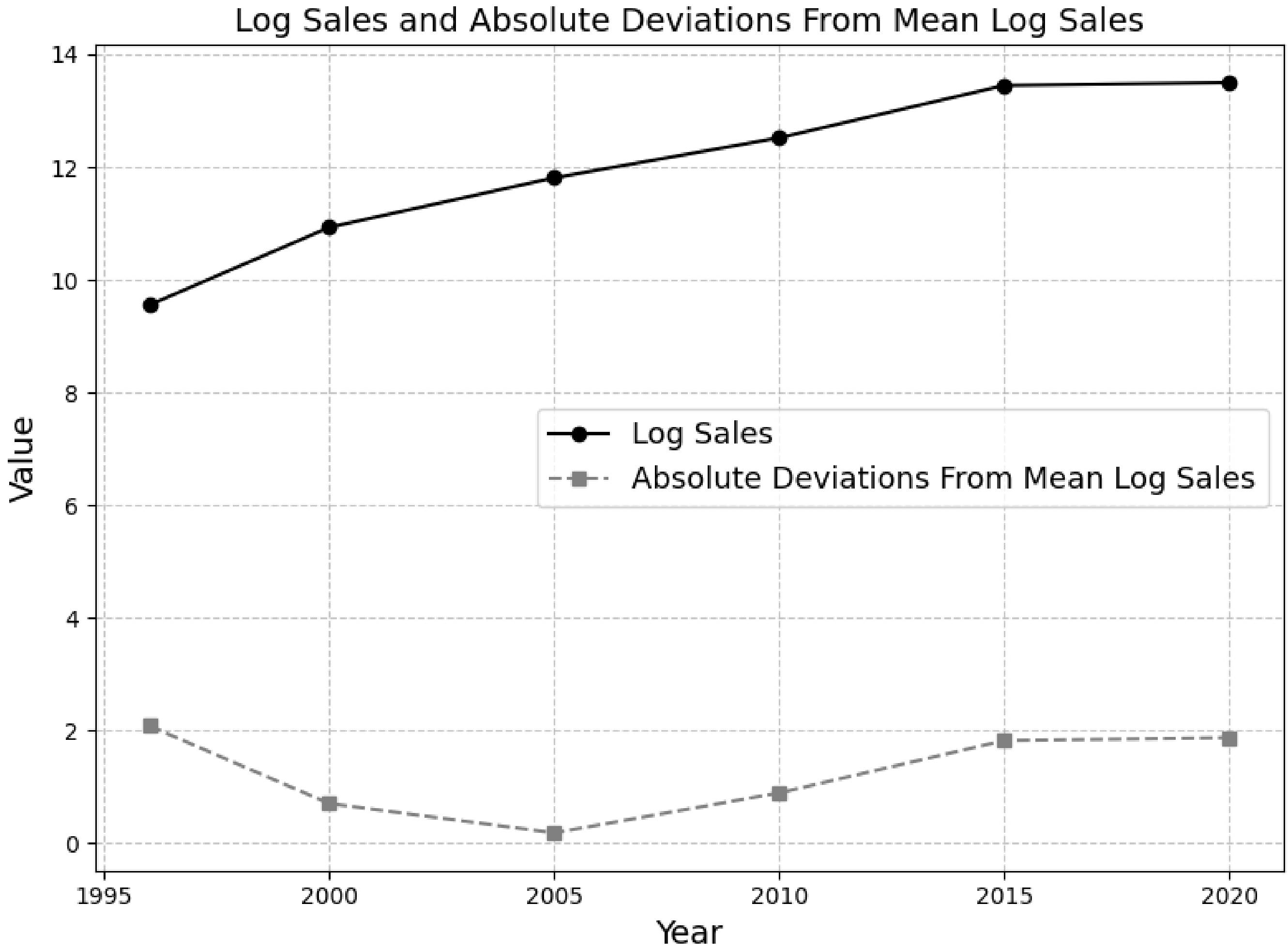

Figure 4: Graph of Average sales per company

Source: Author's calculations with Estonian Business Registry data.

Figure 4 shows a sharp increase in sales between 1995 and 2000 with an absolute deviation close to 2, increasing from below 10 to around 11 logarithmic values similar to instances after 2015. This is because around 1995-1999, after Estonia's independence from the Soviet Union in the early 1990s, the country experienced significant economic transformation due to reforms that opened the economy to international trade and investment. Adopting digital technologies and their integration into global value chains helped drive productivity growth, which likely contributed to the increase in sales during this period (IMF, 2020).

Estonia's integration into the EU single market and increased global value chain participation allowed for more robust productivity growth, mainly in the exporting sectors (OECD, 2020). Also, around 2005-2009, although the global financial crisis affected Estonia, the resilience of its digital economy helped maintain productivity levels, as reflected in sales. Although the crisis slowed growth, Estonia's involvement in global value chains continued to provide productivity gains, especially for export-oriented firms (Estonian Competitiveness Report, 2020).

Using advanced technologies such as artificial intelligence and automation in 2015-2020 and Estonia's position in global value chains probably contributed to the high mean sales. Despite international challenges such as the COVID-19 pandemic, Estonia's digital economy provided resilience and helped maintain high productivity levels (IMF, 2020; OECD, 2020).

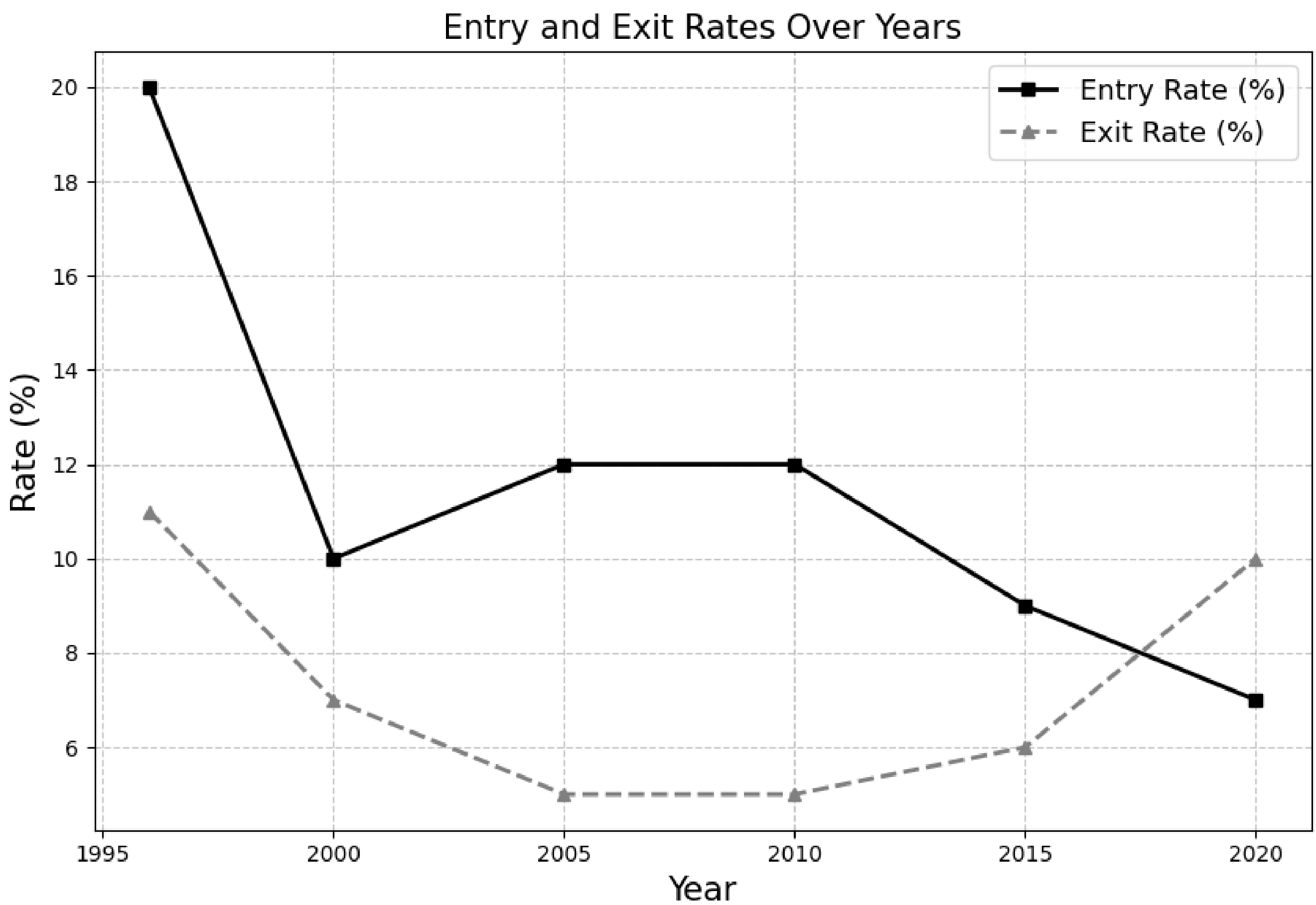

Figure 5: Firm entry and exit

Source: Author's calculations with Estonian Business Registry data.

In Figure 5, the entry and exit rates depicted reflect the evolution of Estonia's market dynamics, shaped by significant economic reforms and integration into global markets post-independence in the 1990s. High entry rates (20%) in 1995 signify the influx of new firms during rapid liberalization and preparations for EU accession (Staehr, 2004). As the economy matured, entry rates stabilized (10%-12%) between 2000-2005, reflecting reduced market turbulence and improved firm survival, supported by institutional stability and increased foreign direct investment (Masso et al., 2004). However, the global financial crisis (2008-2009) could have contributed to a slight increase in exit rates post-2005, signaling challenges in firm sustainability (Vahter, 2006). Post-2015, declining entry rates (7%) and rising exit rates (10%) indicate economic disruptions such as the COVID-19 pandemic, highlighting structural challenges in maintaining firm dynamism (OECD, 2020). These trends show the importance of fostering entrepreneurship and reducing exit barriers to sustain long-term economic growth.

Table 2: Regression of Labor Productivity Growth on Productivity Gap with IT Variables, 2014-2020

	Estimate	t-value	standard error
Productivity gap	-0.045	(-1.78)*	(0.025)*
Frontier growth	0.573	(9.08)***	(0.063)***
CRM software (dummy)	0.022	(0.085)	(0.26)
Website (dummy)	0.025	(0.036)	(0.69)
_cons	0.497	(1.83)*	(0.271)*
Observations	201076		
R-squared	0.048		
Industry FE	Yes		
Year FE	Yes		

Note: Standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Source: Author's calculations with Estonian Business Registry and IT data survey of Information Technology in Enterprises.

As shown in Table 2, the regression results provide insight into the factors influencing productivity growth. The coefficient of the productivity gap is -0.045 and indicates a negative relationship with productivity growth, significant at the 10% level. Frontier growth represents a strong positive relationship with productivity growth in all firms, with a coefficient of 0.573, significant at the level 1%. The dummy variables for CRM adoption and website usage, have positive coefficients but are not statistically significant, suggesting a limited direct impact in this context.

These results highlight the varying impact of different factors on productivity growth, with frontier growth playing a central role. In addition, the negative relationship between the productivity gap and growth highlights the importance of closing the gap between laggard firms and frontier firms to promote overall productivity growth.

Table 3: Regression of Productivity Growth Equation, 1995-2020

	Estimate	t-value	standard error
Productivity gap	-0.055	(-18.93)***	(0.003)***
Frontier growth	0.212	(39.23)***	(0.005)***
gap_period1	0.002	(6.14)***	(0.000)***
gap_period2	-0.000	(-1.59)	(0.000)
_cons	0.597	(19.03)***	(0.031)***
N	579,689		
R2	0.61		

The periods are 1995-2005, 2005-2015, 2015-2020

Note: Standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Given $\beta_1 + \beta_2^j$ as the convergence rate over period j. β_2^j is the coefficient for the productivity gap in period j. The convergence rate over a given period is expressed as follows.

$$\text{Convergence over a given period j} = \beta_1 + \beta_2^j \tag{6}$$

For the first interval, the average convergence rate is calculated as follows.

$$\beta_1 + \beta_2^1 = -0.055 + 0.002 = -0.053$$

In the next interval, the convergence rate becomes the following:

$$\beta_1 + \beta_2^2 = -0.055 - 0.002 = -0.057$$

Finally, for the subsequent interval, the rate is given by:

$$\beta_1 + \beta_2^3 = -0.055 + 0 = -0.055$$

These convergence rates indicate how the gap between laggard firms and the productivity frontier changes over time. The values suggest that intuitively convergence tends to slow down as time progresses.

From Table 2, as the productivity gap measured as the value added per employee increases by 1 unit, the productivity growth decreases by 4.5%. Using CRM software increases productivity growth by a smaller amount (0.2%). However, since the result is not statistically significant, we cannot confidently say there is any meaningful impact on productivity growth. A one-unit growth in frontier firms leads to 57.5% of productivity growth. For example, suppose that the productivity gap decreases by 1 unit (i.e., firms catch up with the frontier). In that case, we can expect an increase in productivity growth by 0.045 units, which may seem small but could have large economic implications when aggregated over many firms or sectors.

From Table 3, as the productivity gap increases by 1 unit, the productivity growth decreases by 5.5%. The average convergence rate in the different periods are -0.053, -0.057, and -0.055, indicating that the productivity gap between laggard and frontier firms is increasing as laggards fail to catch up with the leading frontiers over time. This implies that catch-up to frontier firms might weaken over time, leading to eventual divergence. In addition, the estimate 0.212 suggests that for every percentage increase in frontier growth, there is a corresponding 21.2% increase in productivity growth. This is a significant and positive effect that indicates that improvements in the productivity of frontier firms have a substantial impact on the overall productivity growth of firms.

5 DISCUSSIONS AND POLICY IMPLICATIONS

Policymakers can build on this basis by investing in education, infrastructure, and governance to improve these key drivers. In addition, baseline growth creates opportunities for laggard firms to benefit from spillover effects, promoting economic convergence through collaborative initiatives such as knowledge-sharing networks. Maintaining this growth is essential for reducing risks from external shocks and internal inefficiencies, and it requires resilient strategies like economic diversification and social safety nets. Harmonizing baseline productivity growth initiatives with national strategies for competitiveness and innovation can promote sustainable development.

The convergence in productivity growth across firms is negatively affected. Specifically, an increase of one unit in the productivity gap results in a 4.5% reduction in labor productivity growth according to Table 2 and a 5.5% reduction according to Table 3. This constant negative effect on productivity growth needs policymakers to aim at reducing the productivity gap by prioritizing policy measures that are essential for enhancing overall economic efficiency and competitiveness by facilitating greater convergence in productivity levels across firms.

Again, in Tables 2 and 3, we can observe that the growth of frontier productivity is also beneficial to the general growth of productivity. For example, an increase in the productivity of frontier firms leads to a 57.3% increase in overall productivity growth. This finding suggests the relevance of supporting firms to maintain their competitive edge, which in turn helps the broader economy through spillover effects in line with Berlingieri et al. (2020), who emphasized the convergence dynamics, where laggard firms benefit from the growth of frontier firms, specifically in countries like Germany and France. Andrews et al. (2016) highlight that frontier firms develop and implement advanced technologies and practices that other firms (laggards) can adopt to improve their productivity. Empirical findings from the OECD (2020) highlight that sectors with strong digital intensity and robust performance of frontier firms often exhibit higher aggregate productivity, supporting the regression result on the critical role of frontier growth in enhancing the broader economy. The estimate of the productivity gap is negative and statistically significant in both tables 2 and 3, indicating that the larger gaps between the frontier and the laggard firms slow the growth of productivity. The observed divergence pattern as seen in 3 could be explained by Akcigit and Ates (2021), who argue that the increase in the productivity gap is driven by a decrease in knowledge diffusion, particularly in intangible assets such as digital innovation. Accessing new technological advancements, innovations, and intangible resources necessary for productivity growth can be difficult for laggard firms, which prevents them from maintaining their catch-up rate. Similarly, Andrews et al. (2016) show that the widening productivity gaps between frontier and laggard firms are a significant barrier to aggregate productivity growth. They argue that this gap is mainly due to the inability of laggard firms to adopt best practices and technologies from frontier firms.

The slowdown in the convergence rate pinpoints the need to strengthen knowledge diffusion between frontier and laggard firms. To maintain convergence, Estonia must ensure that technological advances and best practices are shared more widely throughout the economy. Promoting innovation networks that foster the cooperation of frontier firms with laggard firms is recommended, specifically in sectors where the productivity gap is widening. Subsidies and grants should be provided to firms. This will encourage R&D in laggard firms helping these companies to acquire and adopt cutting-edge technologies that drive productivity growth.

Estonia should enact policies that focus on supporting innovation, education, and infrastructure, as well as reducing barriers to lagging firms. As observed in Figure 5, the low exit rate of Estonian firms between 2000 and 2010 could be compared to the findings that firm turnover (entry and exit) is crucial for rapid productivity growth during periods of fast economic growth (Asturias et al., 2017). Collaboration between firms and the exchange of ideas should be promoted, as well as labor market mobility. Eventhough the business environment appeared favorable for firm creation in the early 2000s, barriers to entry may have increased, limiting the number of new firms entering the market. This trend is consistent with Calvino and Criscuolo (2019), who observed that sectors reliant on intangible assets tend to see lower entry rates. Policymakers should focus on ways to lower entry barriers for new firms, primarily in sectors that have high potential for innovation and growth. For example, business registration processes could be simpler. There should be reduced bureaucracy and financial motivation for startups in high-tech and knowledge-intensive industries. Developing a dynamic entrepreneurial ecosystem will ensure that the economy continues to benefit from new entrants who can introduce creative ideas and competition, driving productivity growth.

In Figure 2, productivity growth experiences a notable decline after 2005, reflecting challenges such as crisis in the financial sector and structural inefficiencies. However, a resurgence was observed after 2010, driven by advances in digital transformation, innovation, and improved market dynamics. To sustain this upward trend, it is essential to reinforce best practices, such as promoting innovation, enhancing digital adoption, and having policies that support the diffusion of frontier technologies between firms.

To address this productivity disparity, Estonia should focus on accelerating technological diffusion and lowering the costs of digital adoption for laggard firms. Policies include offering subsidies or tax incentives for laggard firms to invest in intangible assets and digital technologies and providing access to training programs that equip firms with the skills needed to integrate these technologies successfully.

Figure 1 shows an unstable trend over the years. Still, it has improved since 1995 and is consistent with the findings of Azzopardi et al. (2020), who emphasize the role of digital intensity and intangible assets in improving the catch-up dynamics of lagging firms. Notwithstanding the initial decline, the slow and steady improvement in catch-up rates reflects the integration of IT infrastructure across various sectors, allowing laggard firms to gradually close the gap with frontier firms. However, relatively low and slow catch-up suggests that barriers to technology adoption persist, particularly in firms with lower digital capacity (OECD, 2020). This aligns with Berlingieri et al. (2020) and Haltiwanger et al. (2016), who emphasize the dynamic nature of firm growth, where laggard firms often show convergence through learning, innovation adoption, or improved resource allocation. However, convergence is not uniform, and factors such as market concentration and resource constraints play a critical role. Bartelsman et al. (2008) argue that the national context, such as policies supporting innovation and market competitiveness, significantly influences the pace and extent of convergence.

The overall productivity gap between frontier and laggard firms presents a crucial challenge to policy makers. The findings reveal that technological advances (e.g., IT integration) are critical to productivity growth. However, their adoption by laggard firms remains slow. Therefore, a policy should facilitate greater access to digital technologies and support smaller firms, as emphasized by Berlingieri et al. (2020). In addition, the need to promote a more inclusive digital transformation strategy is supported by the OECD (2020) and calls for a stronger emphasis on managerial practices, digital infrastructure, and skills development.

The analysis also confirms existing assertions in the literature that policymakers' adoption of digital technology plays an important role in both the growth of the frontier and the laggard catch-up rate, even though the result we obtained is not statistically significant. However, it also highlights prevalent challenges in reducing productivity disparities, particularly in laggard firms with minimal access to digital skills. Policies that improve the productivity of its frontier firms should be prioritized, especially in high-tech sectors. Estonia can continue to benefit from the positive externalities that frontier firms provide to the rest of the economy, including knowledge spillovers and technological advancements.

However, the use of CRM software showed a positive but statistically insignificant association with productivity growth in the regression table 2, suggesting that the use of this specific technology may not yet be driving meaningful productivity improvements in Estonia. This result aligns with the broader literature that suggests that digital adoption alone is not enough: firms must have complementary skills and processes in place to take advantage of digital technologies (Corrado et al., 2021). The use of IT and digital technologies has been widely studied, with works like Masso et al. (2004) and the OECD (2020) identifying positive productivity growth for firms using digital technologies, mainly in digital-intensive sectors.

The results of this research present an issue that policymakers should address concerning increasing productivity growth for low-performing firms. Tillväxtverket(2022) articulates three areas of importance in relation to: (i) increasing collaboration to promote digital front-edge competence, (ii) the need for research and education in the digital areas, and (iii) focusing on statistics and forecasts to acquire knowledge. The general results of the regression highlight the relevance of supporting frontier productivity growth and addressing productivity gaps to promote aggregate productivity improvements. Many studies, including Akcigit and Ates (2021) and Calvino and Criscuolo (2019), argue for pro-competitive reforms, policies that encourage innovation, and investments in digital infrastructure to enhance productivity spillovers and convergence. Estonian-specific studies, such as Masso et al. (2004) and OECD (2020), highlight targeted policies to support laggard firms in adopting technologies and benefiting from digital spillovers.

Studies that included software variables showed positive results, but had little overall impact, making them seem less important. In the future, more detailed research could improve these findings by looking more closely at how software affects productivity. This could help make the results more valuable and meaningful.

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Appendix

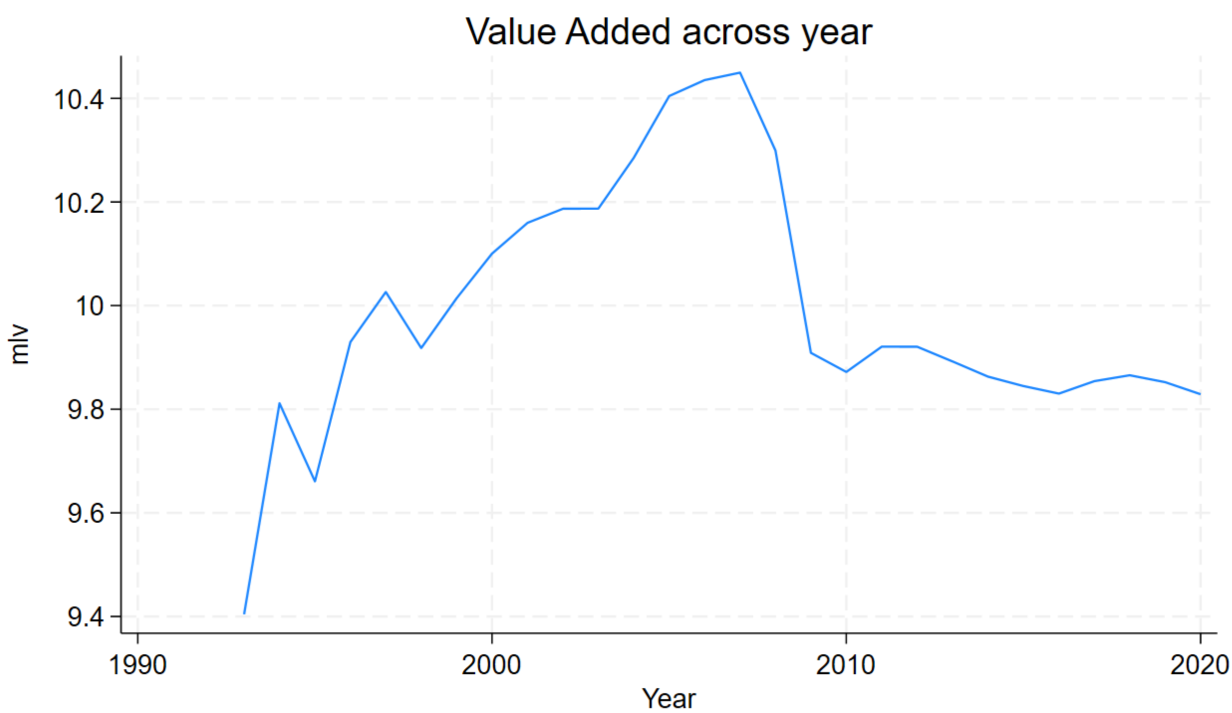
Table 4: Entry and Exit Rates by Year

Year	Entry Rate (%)	Exit Rate (%)
1996	20.0	11.0
2000	10.0	7.0
2005	12.0	5.0
2010	12.0	5.0
2015	9.0	6.0
2020	14.0	10.0

Note: The entry and exit rates are calculated using Estonian Business Registry data from 1996-2020.

Source: Author's calculations based on Estonian Business Registry data.

Figure 6: Value Added Across Years



Source: Author's calculations using Estonian Business Registry data.

Table 5: Mean Log Sales by year

Year	Mean Log Sales
1995	9.55
2000	10.93
2005	11.81
2010	12.52
2015	13.45
2020	13.47

Table 6: Summary Table for Labor Productivity

Year	Labor Productivity	Labor Productivity Growth	TFP	Catch-up Rate	Frontier Growth Rate
1995	9.06	0.00	8.63	-0.01	0.20
2000	9.59	0.53	8.80	0.004	1.02
2005	9.76	0.17	8.73	0.002	0.22
2010	9.70	-0.06	8.67	0.004	-0.30
2015	9.88	0.18	8.83	0.002	0.25
2020	9.88	0.17	8.83	0.003	0.25
Total	9.73	0.16	8.73	0.002	0.24

Note: All mean values are logarithmic. TFP (Total Factor Productivity) is used as a robustness check.

Resümee

Tootlikkuse hajuvus üle ettevõtete Eesti näitel

Tootlikkuse kasv on majandusarengu võtmetegur, kuid viimastel aastatel on paljudes riikides täheldatud kogutootlikkuse kasvu langust. Seda trendi võivad selgitada mitmed tegurid, sealhulgas uute tehnoloogiate mõju vähenemine ja viivitused uute tehnoloogiate kasutusele võtmisega, aga samuti tootlikkuse ja tehnoloogiliste muutuste mõjude mõõtmisega seotud väljakutsed. Siiski on tootlikkuse dünaamika mõistmine ettevõtte tasandil ülioluline, kuna üksikud ettevõtted kujundavad samal ajal ka majanduse kogutootlikkust. Rahvusvaheliselt on üha suurem üksmeel selles, et tootlikkuse erinevused ettevõtete vahel majandusharudes kasvavad. Käesolevas magistritöös uuritakse kasutades Äriregistri ettevõttetaseme andmeid aastatest 1995-2022 seda, mis iseloomustab konkreetses majandusharus teistest vähem tootlikke ettevõtete, kas ja kuivõrd madala tootlikkusega ettevõtete tootlikkuse tase aja jooksul konvergeerub kõrgema tootlikkusega tasemega ettevõtetega ning milline on digitaliseerimise ja immateriaalsete varade mõju tootlikkuse dünaamikale. Tulemused näitavad tootlikkuse hajuvuse suurenemist aja jooksul, tootlikkuse konvergeerumise määra langust ja olulisi takistusi uute tehnoloogiate kasutusele võtus sektorites, mis sõltuvad digitaliseerimisest ja immateriaalsetest varadest (Caballero, Hoshi, & Kashyap, 2008). Käesoleva uuringu tulemused aitavad mõista tootlikkuse dünaamikat ja kujundada poliitikameetmeid, mis on suunatud tootlikkuse kasvu edendamisele Eestis.

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