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Advancing Trending Statistical Techniques to Examine Growth and Variability in Scottish Sustainable Business Enterprises

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Abstract

Purpose: This study aims to explore the growth and variability of enterprises in four key Scottish industrial sectors between 2008 and 2021, emphasizing the importance of sustainable business practices in today's evolving economic landscape.

Design/methodology/approach: The research employs a quantitative and testing approach, using advanced statistical methods by ORANGE data mining, namely Compound Annual Growth Rate (CAGR), Mean, Standard Deviation (SD), Coefficient of Variation (CoV), Root Mean Square Error (RMSE), and Average Growth Rate (AGR). Data from sectors like Electronics, Information Technology, Information and communication technology (ICT), and Telecommunications form the basis of this analysis.

Findings: The study reveals varied growth patterns across sectors. Information Technology displayed a steady growth (CAGR of 1.03%), while the Electronics sector exhibited more variability (Coefficient of Variation of 5.79%). These findings highlight the differing dynamics and stability of enterprises in the context of economic and technological changes.

Research limitations/implications: The analysis is limited to Scottish enterprises and may not reflect trends in other geographical contexts. Further research expands to compare with global trends, or utilize machine learning-based analysis for regression and future probabilistic forecasts.

Practical implications: The insights are valuable for business strategists and policymakers, aiding in informed decision-making and strategic planning for sustainable business development.

Social implications: The study contributes to understanding the sustainability of business practices, which is critical in the current socio-economic climate.

Originality/value: This paper enriches the discourse in business administration by integrating modern statistical analyses, offering a novel perspective on the management of sustainable enterprises during significant global economic shifts.

Keywords: Sustainable Enterprise Management, Business Administration, Statistical Analysis, Scottish Industries, Growth.
JEL classification: C1, C25, C46, D8, R11

1. Introduction and Literature Review

This section lays the groundwork for a nuanced appreciation of the intricate patterns of growth within sustainable business enterprises. It opens with a broad-stroke overview of the enterprise growth landscape, emphasizing its crucial place in the tapestry of the global economy. Delving deeper, the literature review navigates through a rich tapestry of scholarly work, casting light on the multifaceted nature of enterprise development. Special attention is paid to the themes of sustainability and economic variability, with a nod to how cutting-edge statistical methodologies play into the domain of business analysis. A diverse array of studies is brought into the conversation, weaving a narrative that ties the expansion of enterprises to wider economic forces and the march of technological progress. Moving forward, this section brings to the fore the unique contributions of the current study, spotlighting its innovative elements and the substantial value it contributes to the realms of Business Administration and Sustainable Enterprise Management. Merging a foundational introduction with a review of pertinent literature, the discourse culminates in a clear articulation of this research's originality. This fusion not only primes the reader for a more granular exploration of the growth dynamics within the Scottish enterprise context but also places the study as a significant stepping stone in the evolving journey of academic inquiry

1.1 Overview of Enterprise Dynamics in Modern Economies

The dynamics of enterprise growth and sustainability engage in a major role in the field of modern economics (Gunessee & Lane, 2023; Hands, 2021). This behavior is increasingly relevant in a current trend marked by rapid technological improvements, shifting market demands, and growing concerns over environmental and social impacts. Enterprises which range from small startups to large multinational corporations are the engines moving economic growth, innovative approaches, and employment (Ali, et al., 2022; S. Wu, et al., 2023; Xie, et al., 2023). The enterprises' ability of adapting and evolving is extremely important for economic resilience and improvement and hence sustainably grows in the face of global challenges and opportunities. (Kumar & Paramanik, 2023; Noman, et al., 2023). Sustainable enterprises hold a significant social responsibility towards economic viability. It is globally known that operational frameworks and company strategic plannings are both increasingly adopting the all-incorporating approach as a major rule. These enterprises also represent an incremental understanding in the capacity of striking a balance between economic goals and social or environmental issues which is a necessary condition for long-term success rates.

Data-driven decision-making and the introduction of digital technologies are also changing the face of enterprise growth (Martin, et al., 2023). Herewith, analyzing and forecasting enterprise performance and trends requires the application of sophisticated statistical features (Gao, et al., 2023; C. Wu, et al., 2023). These techniques provide fully detailed methodologies of consumer preferences in addition to operational effectiveness of market dynamics by empowering businesses to innovate and successfully compete any field of interest. The use of these methods in business administration is indicative of a divergence from theoretical practices and convergence in the direction of empirical methods. Small and

medium-sized businesses (SMEs) are frequently facing particular challenges in resource allocation in the scalability of market accessing and hence SMEs should take special note of this evolution. By leveraging data and adopting sustainable practices, SMEs can not only enhance the competitiveness but also contribute to the goals of economic sustainability in an overall criteria.

1.2 Literature Survey on Enterprise Growth and Sustainability

The recent research advancements in business administration and sustainable enterprise management have focused on the integration of improved statistical methods and new approaches to assess enterprise growth and risk management. A highlight was made on the significance of digital transformation in enterprise development by the work of (Ren & Wang, 2023) involved within sustainability in which an XGBoost model was utilized for classification of enterprises based on digitization levels. Adding up, enterprise credit risk assessment was redefined by (Song, et al., 2024) in neural networks through the development of a multi-structure cascaded graph neural network framework. The integration of graph learning methods enhanced enterprise representation by benefitting small and medium-sized enterprises. Investment attractiveness and risk in industries were both examined by the work in (Vertakova, et al., 2022) as the paper had proposed a multiplicative methodology that accounts for both quantifiable and obscure indicators. The role of entrepreneurial traits in business sustainability was also underscored by the authors of (Wei, et al., 2023) as the research had revealed a direct impact of the entrepreneur courage quotient on sustainable enterprise growth. The work presented in (Hansen, et al., 2009) had scrutinized the influence of government support on overall enterprise performance as a significant finding detected the effects on firm dynamics from state sector interactions in Vietnam. The impact of mobile money on SMEs' performance in Somalia was explored by (Mohamed, 2023) as the experiment indicated a substantial enhancement in business growth due to improved financial access. Lastly, the default risk of SMEs had been assessed through a stacking model in the work of (Chi, et al., 2023) of which the authors had emphasized the critical role of macroeconomic features in risk assessment. These studies collectively acknowledge the need for improved statistical feature methodologies to analyze enterprise growth and inevitably offering a wider scope that addresses the challenges and opportunities in sustainable business management.

Moreover, to further understand growth analysis, it is advised to conduct testing-based calculations that boosts the conclusions (Wong, Chew & Sikorski, 2001; Wong, Manzur & Chew, 2003). This paper is to utilize the t-test that is based on T-statistic and P-value to test the growth rate analysis provided further on (Yu, et al., 2022).

1.3 Novelty and Significance of Current Research

The current paper is distinguished by incorporating advanced applications of modern analysis and techniques that would analyze the growth and variability of enterprises which are linked to Scottish industries. This domain is relatively unexplored in the cited existing literature in the previous subsection. A uniquely integrated methodologies of advanced statistical metrics is presented by shedding spotlights on the dynamics of sustainable enterprise development in a specific regional context. Its novelty lies in

the comprehensive temporal one decade span of analysis of which it provides a deeper understanding of long-term trends and patterns in enterprise growth. The research also contributes to the discourse on sustainable business practices as it correlates statistical findings with broader economic and technological transformations. This approach not only bridges a gap in empirical studies focusing on Scottish industries but also offers valuable insights for policy-makers and business strategists globally. Herewith, the study stands out for its methodological robustness in a regional specificity of practical relevance which makes a notable contribution to administrative methods in enterprises' management.

2. Open Government Data

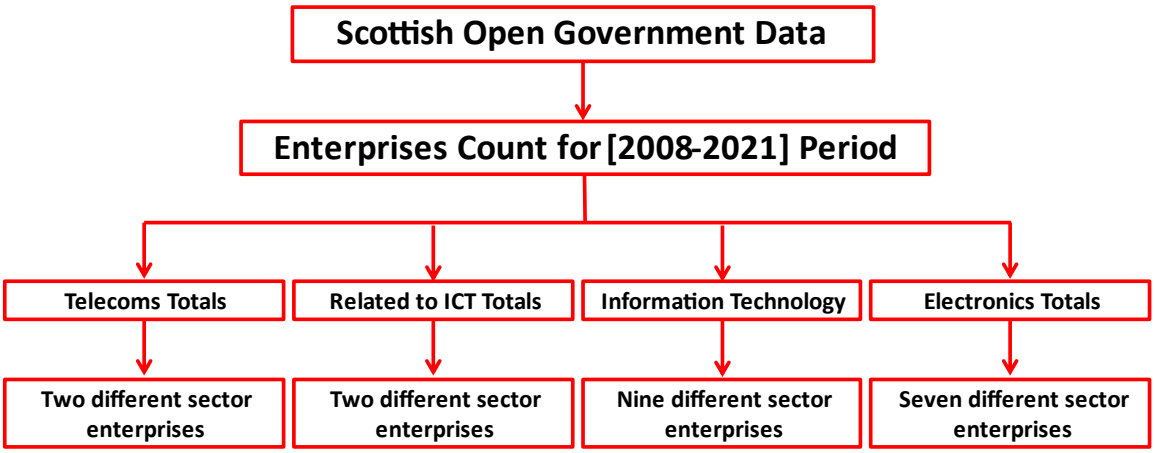
In pursuing transparent and accessible data for authentic research, this study harnessed open government data by specifically drawing from the online resource at https://statistics.gov.scot. This portal is managed by the Scottish government and directly serves as a rich repository of official statistics which aggregates data from diverse sources including the Scottish government, national records of Scotland, publicly funded healthcare system in Scotland, and transportation records of Scotland. The decision to utilize this open data source is underpinned by its broad coverage and reliability as this research needs a wealth of information and organizational datasets for statistical purposes. This approach aligns with the growing trend of leveraging open data for empirical research to ensure data transparency and replicability of findings for other academic research proposals. The site has an extensively wide database for different operating sectors. For that, the analysis of enterprise growth and sustainability is completed by leveraging some selected datasets from the available dynamical behavior of Scottish enterprises.

The work of (Karamanou, et al., 2023) has simplified the utilization of such data in creating integrated statistical indicators. Herewith, the previous work has inspired the comprehensive concept of using the aforementioned open government data in this present research. In addition to that, (Karamanou, et al., 2022) had demonstrated the practical applications of open data in predictive analytics. These articles reinforce the legitimacy and robustness of the data used in this study in addition to showcasing the potential of open government data in generating meaningful and actionable trust-worthy insights of enterprise growth in Scotland. The present study thereby contributes to the field of business administration and sustainable enterprise management with a statistics-analyzing data-driven approach. For that, Figure 1 provides an organized classification chart of enterprises in a systematic segmentation of four key sectors: Electronics, Information Technology (IT), Information and Communication Technologies (ICT), and Telecommunications. Each of these four sectors has its respective sub-categories. This chart analyzes a structured breakdown of the various industry segments which are explored in the current study.

The Electronics sector is the first category that has a seven-range of sub-sectors as follows: the manufacture of communication equipment, computers and peripheral equipment, consumer electronics, electronic components, and loaded electronic boards. In addition to including segments focusing on the repair of computers and communication equipment and the wholesale of electronic and

telecommunications equipment and parts. The IT sector follows the electronics with a detailed 9 subsectors as will be presented next. It includes computer consultancy activities, computer facilities management activities, computer programming activities, data processing, hosting, and related activities which also cover web portals. The sector further extends to cover other IT and computer service activities like software publishing, publishing of computer games, and the wholesale of computers, computer peripheral equipment, and software. The third category in the chart is the ICT sector which comes before the last one. This broader category integrates elements from both the Electronics and IT sectors and hence provides an overarching view of the combined data and trends across these interrelated sectors. Lastly, the Telecommunications sector is depicted with being divided into two primary groups: wired telecommunications activities and a collective group holding wireless, satellite, and other telecommunications activities. Table 1 enlists the industrial sectors in details and abbreviations for the discussion section of this study.

Figure 1. Enterprises classification chart for evaluation purposes.



Note: This figures shows the four studied Scottish sectors for the period of 2008-2021.

Table 1. Studied sectors

Main Industrial Sector	Consists of	Abbreviation
Electronics	Manufacture of communication equipment	Electronics-1
	Manufacture of computers and peripheral equipment	Electronics-2
	Manufacture of consumer electronics	Electronics-3
	Manufacture of electronic components	Electronics-4
	Manufacture of loaded electronic boards	Electronics-5
	Repair of computers and communication equipment	Electronics-6
	Wholesale of electronic and telecoms equipment and parts	Electronics-7
Information Technology	Computer consultancy activities	IT-1
	Computer facilities management activities	IT-2
	Computer programming activities	IT-3
	Data processing, hosting and related activities; web portals	IT-4
	Other information technology and computer service activities	IT-5
	Other software publishing	IT-6
	Publishing of computer games	IT-7
	Wholesale of computers, computer peripheral equipment and software	IT-8
	For Electronics, Information Technology & Telecoms	IT-9

Information and communication technology	Other information service activities N.E.C. Reproduction of computer media & Manufacture of fiber optic cables	ICT-1 ICT-2
Telecommunications	Wired telecommunications activities Wireless, Satellite activities & Other telecommunications activities	Telecoms-1 Telecoms-2

Note: The table shows the studies sectors along with their corresponding abbreviation in the current study.

3. Statistical Features Methodology

3.1 Growth Analysis

This section delves into the statistical methodologies utilized to analyze the growth and variability of enterprises in Scottish industrial sectors. Five key statistical features form the basis of the current analysis, namely Growth Rate, Compound Annual Growth Rate (CAGR), Mean, Standard Deviation (SD), and Coefficient of Variation (CoV). Each of these statistics would provide individually unique insights to study the dynamic behavior of Scottish enterprise development in terms of management sustainability.

Equation 1 mathematically defines the Growth Rate statistical feature which is commonly used to quantify the change in the number of enterprises from year to year (Ullah & Uddin, 2021; Williams, 2020). It is essential to spot sudden trend in growth rate to understand the short-term effect on different industrial economies and this is where the significance of this metric lies within. Equation 2 on the other hand is used to calculate CAGR and hence providing a smoothed display of growth over a longer time frame (Kim & Nilsen, 2023; Park, et al., 2024). Although the Growth Rate brought insights into short-term dynamics, the further understanding of long-term growth trends of businesses is accomplished by means of CAGR which in turn reduces volatility of year-to-year fluctuations of behavior. In both equations, n corresponds to the the number of years. Progressing further, equation 3 expresses the computation of the average mathematical Mean and hence the average number of enterprises in a specified period of time (Al-Haddad, Jaber, Neranon & Al-Haddad, 2023; Al-Haddad & Jaber, 2023b, 2023c). This metric resembles a point of reference for each of the four sectors by helping in making comparisons easier. This statistic is also needed in calculating different and other statistical features. X_i in this metric refers to the corresponding number of existing enterprises when conducting the calculation. Moreover, the degree of variability or dispersion around the arithmetic mean is measured by the SD. A higher SD value in the context of enterprise growth denotes a high degree of variation in enterprise numbers which implies possible instability in a specific sector. The SD is mathematically calculated by expression 4 (Al-Haddad & Jaber, 2023a; Al-Haddad, Jaber, Al-Haddad & Al-Muslim, 2023). Finally, the CoV offers a normalized measure of dispersion in relation to the Mean and is computed as equation 5 states (Singh, et al., 2024). The CoV is particularly useful when comparing the variability of the four sectors as the average size varies because it offers a relative rather than an absolute measure of variability.

$$Growth\ Rate = \frac{Value\ in\ Current\ Year - Value\ in\ Previous\ Year}{Value\ in\ Previous\ Year} \times 100, \quad (1)$$

$$CAGR = \left(\frac{Ending\ Value}{Beginning\ Value}\right)^{\frac{1}{n}} - 1, \quad (2)$$

$$Mean = \frac{1}{N}\sum_{i=1}^{N} X_i, \tag{3}$$

$$SD = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(X_i - Mean)^2}, \tag{4}$$

$$CoV = \frac{SD}{Mean}, \tag{5}$$

where x stands for the specific enterprise number of a specific year, and n corresponds for the number of years. When these measurements are combined, extensive assessment can be conducted in terms of the stability and growth perspectives in an individual or overall point of you in each or all enterprise sectors and industries. It is also important to point out that these statistical equations are to be employed using ORANGE data mining which is an online available tool based on artificial intelligence (Alawee, et al., 2024; Demšar & Zupan, 2013; Hamzah & Fayad, 2023; Luttfi A Al-Haddad, et al., 2024; Luttfi A Al-Haddad, Jaber, Luttfi A Al-Haddad & Mahdi, 2024; Mohammed, et al., 2023).

3.2 Testing Analysis

The paired sample t-test and the Root Mean Squared Error (RMSE) are two major tools to be used in the evaluation and testing of the produced growth rate data. These two values can also be used to forecast the next coming years in terms of growth rates, average growth rates, and other evaluation metrics of the statistical datasets. By relying on the SD value of the difference between an exact and predicted value, the sample t-test and RMSE can assess and test the presented methodology accordingly. The equations that represent the paired sample t-test and RMSE depending on the Orange software, respectively, are elaborated below:

$$RMSE = \sqrt{\frac{1}{m}\sum_{i=1}^{m}(x_i - y_i)^2} \times 100, \tag{6}$$

$$t = \frac{d}{\frac{SD}{\sqrt{n}}}, \tag{7}$$

where x is the original value of the average growth rate, y is the forecasted value depending on the t-test, and d stands for the distance of which the growth rate differs.

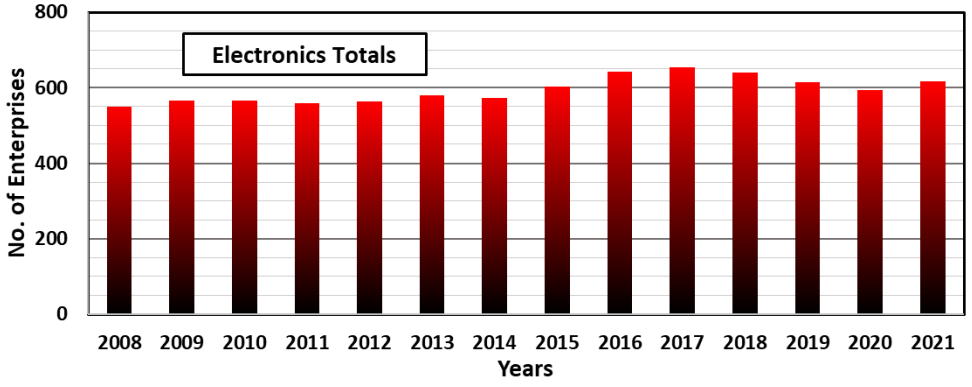
4. Results and Discussion

4.1 Visual Representation

In this subsection, a close examination to the changing numbers of enterprises within various sectors through variant depictions is illustrated in Figures 2, 3, 4, and 5. The annual changings and shifts in enterprise numbers are presented in these depictions in terms of the four previously stated sectors during a span of 14 years. Each figure corresponds to a specific aspect of growth and change in which a rich developmental visualization is offered by the data of each sector.

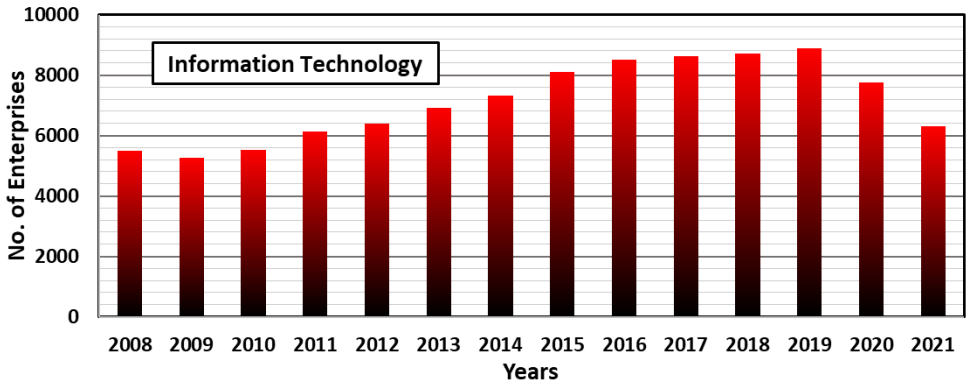
In terms of discussing the illustrations, Figure 2 captures the evolution of enterprises within the first sector with an initial count of 550 in 2008 gradually ascended to 654 by the year of 2017 which then marginally retracted to 618 by the close of 2021. Regardless of the fluctuations, such progression suggests an overall robustness in this specific sector. Specifically speaking, the interval from 2015 to 2017 was particularly marked by pronounced growth that hints at a period of significant industry expansion. In contrast, Figure 3 delineates a more transparent ascent in the IT sector while enterprise numbers are swelling from 5496 to an apex of 8886 in the year of 2019 which later receded to 6298 by 2021. This suggests a potential reflection of market maturation or the repercussions of broader economic developments. The span from 2011 to 2019 was especially characterized by vigorous growth that indicates an economic jump in sectorial investment and innovation. Figure 4 on the other hand, reveals more erratic patterns in the number of ICT-related enterprises' numbers which began with 221 enterprises in two thousand and eight then dipped to 129 by two thousand and ten only to climb back to 223 in the year of 2019. By 2021, the number of enterprises has diminished to 189 in total which underscores a sector beset by high considerable instability. Lastly, Figure 5 illustrates the Telecom sector's trajectory, exhibiting steady expansion from 278 enterprises in 2008 to an almost doubled number by the year of 2019 then again followed by a slight downturn to 406 in 2021, which reflects the sector's overall enduring growth despite recent marginal downturns. It is clearly notable that IT and Telecom sectors show substantial and consistent growth. Electronics and ICT on the other hand, exhibit more fluctuating patterns. These differences highlight the distinct market dynamics and external influences shaping each sector in the discussed Scottish management methodologies. The recent declines across all sectors could be attributed to market shifts and technological advancement or broader economic challenges that warrants further investigation into the specific causes and implications of these trends.

Figure 2. Electronics-related enterprises' number growing throughout the period of 14 years.



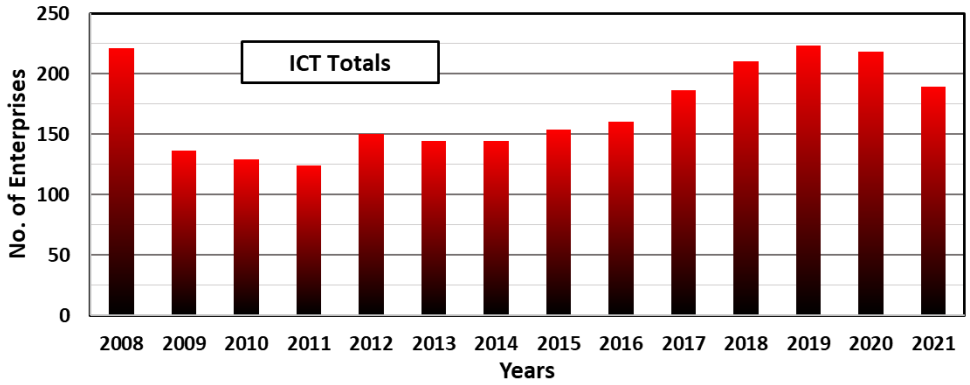
Note: This figure shows the number-year distribution of electronic SMEs.

Figure 3. Enterprises' number growing throughout a period of 14 years in IT-related sectors.



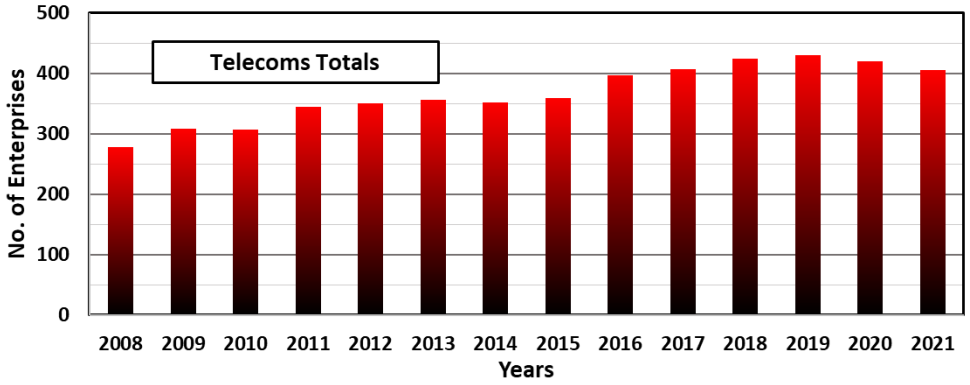
Note: This figure shows the number-year distribution of information technology SMEs.

Figure 4. ICT-related enterprises' growth numbers throughout a span of 14 years.



Note: This figure shows the number-year distribution of ICT SMEs.

Figure 5. ICT-related enterprises' number growing throughout the period of 14 years.



Note: This figure shows the number-year distribution of Telecommunication SMEs.

4.2 Statistical Approach

The clustering behavior in terms of radial visualization is elaborated in Figure 6. It is worth mentioning that the mean is slightly indicational as it was only instrumental in calculating other statistical features. The cluster also tends to move in the CAGR and average growth rate measures which indicates their prevalence in presenting the behaviors. Furthermore, Table 2 elaborates on the numerical results of the four main features utilized in this study. Consequently, the free visualization of all the five features which includes all the four industrial sectors is presented in Figure 7. The average growth rate is where the data mostly fluctuates and hence it is expected that it will give better indicational results.

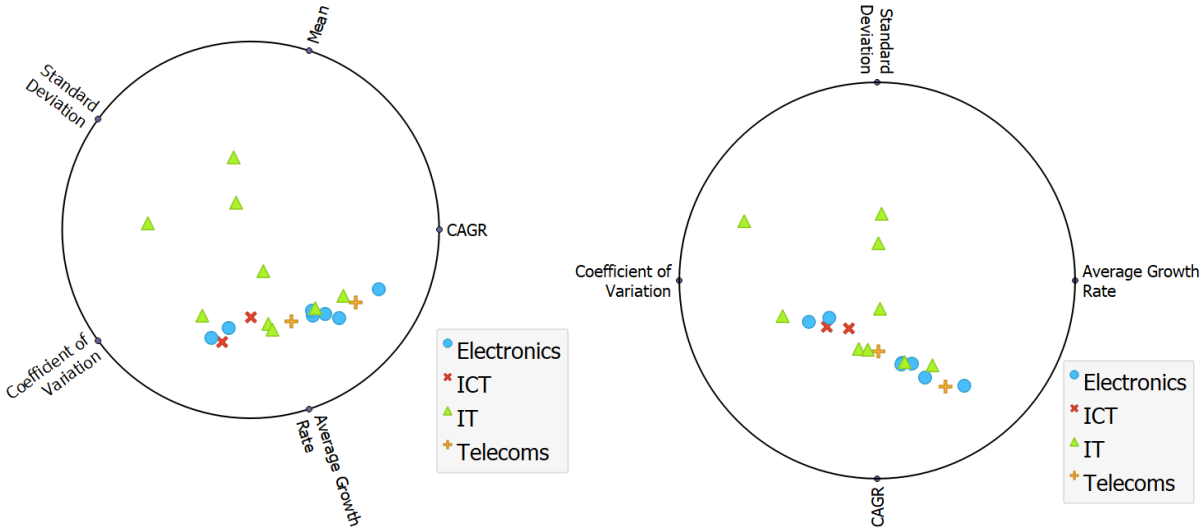
Figure 8 presents a detailed quantitative analysis of various subsectors within the Electronics, IT, ICT, and Telecoms domains. The CAGR, CoV, and Average Growth Rate are computed for each subsector to evaluate their performance over the 14-year period. In the Electronics sector, subsectors such as the manufacture of communication equipment (Electronics-1) and computers and peripheral equipment (Electronics-2) have experienced negative CAGRs of -0.0371 and -0.0344, respectively, with corresponding average growth rates indicating a contraction. Conversely, the repair of computers and communication equipment (Electronics-6) stands out with a positive CAGR of 0.0555 and an impressive average growth rate of 5.89, suggesting a robust expansion within this subsector. The IT sector exhibits a diverse range of growth patterns. IT subsectors related to computer consultancy activities (IT-1) and computer programming activities (IT-3) show positive growth, with CAGRs of 0.0202 and 0.0429, respectively. Notably, the computer facilities management activities and publishing of computer games (IT 2 and 7) subsectors display significant growth rate, with the highest CAGRs of 0.1202 and 0.1246, and average growth rates of 14.30 and 16.88, the most rapidly expanding areas within IT.

The ICT-related subsectors, other information service activities (ICT-1) and reproduction of computer media & manufacture of fiber optic cables (ICT-2), have shown a slight contraction with negative CAGRs. However, ICT-2's average growth rate of 1.46 suggests a resilience not immediately apparent from the CAGR alone. Moreover, In Telecommunications, the wired telecommunications activities (Telecoms-1) subsector has seen a substantial increase with a CAGR of 0.0902 and a robust average growth rate of 9.96. The wireless and satellite activities subsector (Telecoms-2) exhibited lower CAGR of 0.0191, while maintaining a positive growth trend. This assessment, facilitated by the statistical features, provides a clear and empirical understanding of the growth trends within each subsector. It allows for a comprehensive evaluation of their economic performance, revealing the heterogeneity within and between these vital industry sectors. The use of passive voice in this description underscores the objective and unbiased nature of the analysis, adhering to academic standards.

Upon examining the results captured in Figure 8 and the corresponding data, it was observed that the IT sector exhibited the most pronounced fluctuations throughout the 14-year period. This sector, particularly characterized by subsectors IT-2 and IT-7, demonstrated the highest CAGRs which indicates rapid expansion phases. However, it also faced significant downturns, as evidenced by subsectors IT-5 and IT-8, which showed some of the steepest declines in Average Growth Rates. The

stark contrasts within the IT sector's subsectors underscore its susceptibility to rapid changes, likely driven by technological innovations and market demand shifts. This variability suggests that the IT sector, while presenting opportunities for significant growth, also faces greater risks and impacts from economic cycles and technological disruption compared to the Electronics, ICT, and Telecommunications sectors.

Figure 6. Radial visualization of the resulted features data in terms of including mean and not including it with all the four industrial sectors.



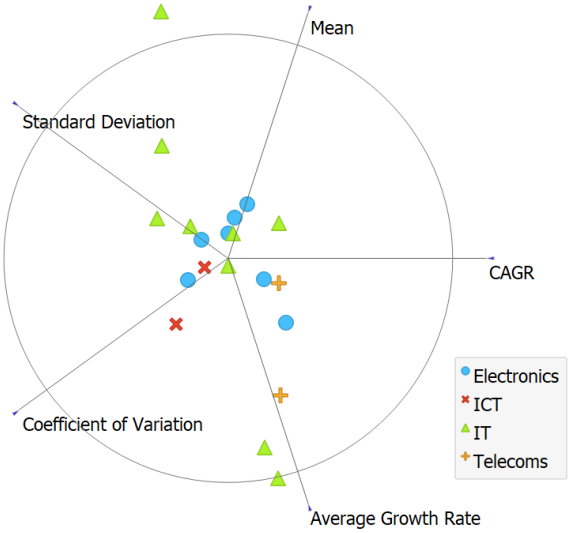
Note: This figure depicts the radial visualization of the four calculated features for the four sectors of businesses.

Table 2. Numerical results of the adopted methodology.

Abbreviation	CAGR	SD	CoV	Growth Rate
Electronics-1	-0.0371	10.7775	0.1585	-2.6351
Electronics-2	-0.0344	7.4362	0.1994	-2.3063
Electronics-3	-0.0135	3.3249	0.1103	-0.8487
Electronics-4	0.0079	4.2562	0.1105	1.1433
Electronics-5	-0.0219	2.3110	0.0986	-1.8318
Electronics-6	0.0555	49.715	0.1898	5.8908
Electronics-7	-0.0190	8.7089	0.0637	-1.8682
IT-1	0.0202	1104.1053	0.2536	2.7109
IT-2	0.1202	13.7993	0.5018	14.3007
IT-3	0.0429	363.6761	0.2632	6.3226
IT-4	0.0221	22.8016	0.1049	2.5008
IT-5	-0.0516	177.6561	0.1817	-4.9130
IT-6	-0.0099	11.3805	0.1101	-0.5707
IT-7	0.1245	5.7856	0.5011	16.8837
IT-8	-0.0394	12.9224	0.1570	-3.8364
IT-9	0.0113	1369.0616	0.1692	1.4298
ICT-1	-0.0118	35.2211	0.2164	0.1468
ICT-2	-0.0139	2.2822	0.2904	1.4579
Telecoms-1	0.0902	27.7493	0.3976	9.9570
Telecoms-2	0.0191	23.8738	0.0799	2.0422

Note: The table shows the resulted numbers of the four statistical analysis metrics for the abbreviations of the sector-based proposals.

Figure 7. Free visualization of the resulted features data in terms of all five statistics in all the four industrial sectors.

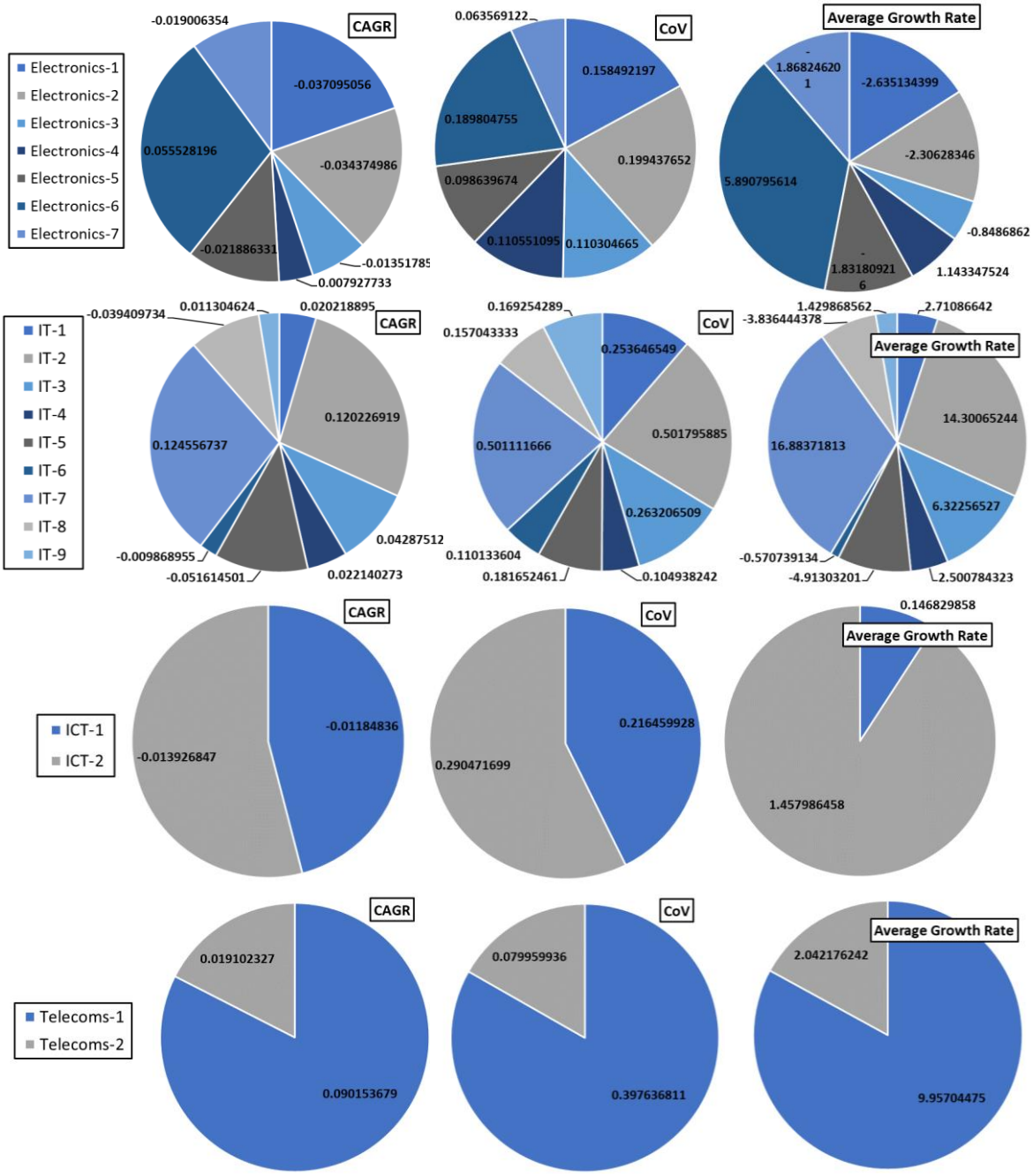


Note: This figure shows the five calculated features for the same four sectors.

In terms of visualizing the advanced tool for statistical analysis and computing, the flow of the adopted methodology for statistics is presented in Figure 9. The program is based upon embedded algorithms in each orange with each having its own work. First, the arrangement of the columns is in order where the categories and distributed. Then and secondly, the data of each category is subdivided into groups as specified previously. Finally, the statistics of each group are calculated and then presented in an embedded table where the readings can be displayed and interoperated.

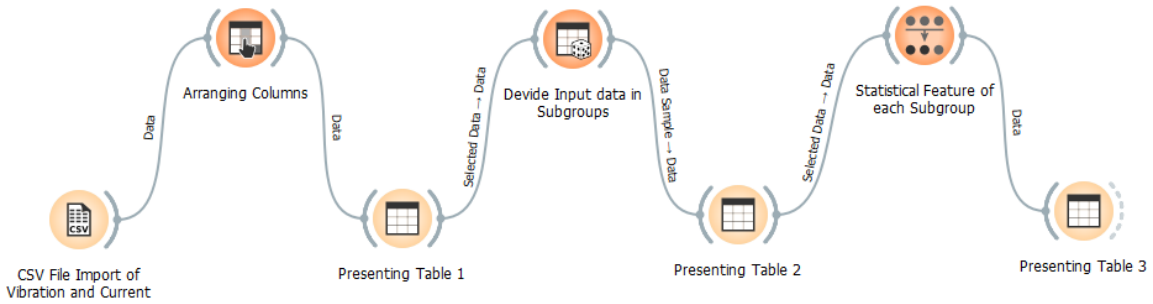
Looking ahead, the future trajectory of Scottish enterprise growth appears to be closely tied to the evolving global technological landscape and economic climate. Given the historical data and trends observed, sectors that are adaptable and poised to capitalize on digital transformation and innovation—such as Information Technology and Telecommunications—are expected to continue to expand, albeit with potential fluctuations as new technologies emerge and market conditions shift. However, external factors such as geopolitical developments, environmental policies, and global economic trends will also play critical roles. As Scotland positions itself at the forefront of sustainable and technologically advanced economies, the enterprises within its borders are anticipated to reflect this progression, harnessing opportunities for growth in a future that increasingly values resilience, sustainability, and innovation.

Figure 8. Statistical features results of all four sectors.



Note: This figure shows the calculated statistics for each of the chosen four economic Scottish sectors.

Figure 9. Statistical features results of all four sectors.

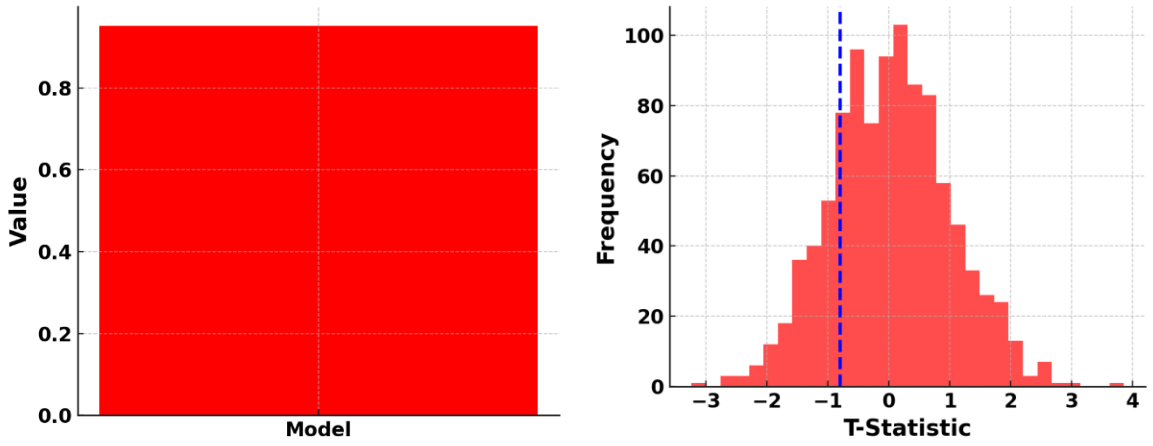


Note: This figure depicts the circle-flow diagram in order to calculate the statistics of the study.

4.3 Testing Results and Discussion

The resulted RMSE value of 0.951% indicates a high degree of accuracy in the model's predictions, suggesting it is a reliable tool that forecasts growth rates of SMEs. This precision in results is particularly valuable for stakeholders making financial, investment, and policy decisions based on expected growth in various sectors. Moreover, the t-test results of -0.798 t-statistic and p-value of 0.435 reinforce the model's validity as depicted in Figure 10. The high p-value suggests that the discrepancies between the model's predictions and actual growth rates are not statistically significant which implies that the model's forecasts are effectively indistinguishable from real outcomes at the usual significance levels.

Figure 10. Testing results.



Note: This figures shows the t-static results along with their p-values in terms of frequency and value.

The results of entire forecasts are enlisted in Table 3 that corresponds for each sector of the tested dataset. The results are highly indicative of the superiority of better smooth growing results in the IT, ICT, and Telecoms sectors due to their low values of RMSE. The slightly higher values of t-test and RMSE in the electronics section are a slight indication of the hard market change and hence and harder the prediction of the trending growth rate amongst the different years these sectors grow.

Table 3. *2021 Forecasts in terms of T-test results along with their RMSE values.*

Abbreviation	Growth Rate	T-Statistic	P-Value	RMSE
Electronics-1	-2.6351	-0.798	0.435	0.035
Electronics-2	-2.3063	-0.3	0.768	0.016
Electronics-3	-0.8487	0.25	0.805	0.011
Electronics-4	1.1433	0.155	0.878	0.007
Electronics-5	-1.8318	-0.27	0.789	0.012
Electronics-6	5.8908	0.21333	0.842	0.009
Electronics-7	-1.8682	-0.29	0.775	0.013
IT-1	2.7109	0.21	0.834	0.009
IT-2	14.3007	-0.24	0.812	0.011
IT-3	6.3226	0.16	0.873	0.007
IT-4	2.5008	0.099	0.929	0.004
IT-5	-4.9130	0.154	0.882	0.007
IT-6	-0.5707	-0.02	0.984	0.001
IT-7	16.8837	0.13	0.897	0.006
IT-8	-3.8364	0.091	0.929	0.004
IT-9	1.4299	0.112	0.912	0.005
ICT-1	0.1468	0.0655	0.948	0.0033
ICT-2	1.4579	0.0451	0.964	0.0021
Telecoms-1	9.9570	0.07	0.944	0.0039
Telecoms-2	2.0422	0.065	0.948	0.0037

Note: The table shows the t test results of the previously calculated statistical metrics for the same abbreviations of the chosen four sectors.

5. Conclusion

This paper undertook an analysis of the growth dynamics of Scottish enterprises over a period spanning from 2008 to 2021. The primary motivation of this study was to understand the economic resilience and variability of Scottish industries within an evolving global context as it focused on sustainable business practices. Given the increasing importance of sustainability in business, this paper addressed the crucial need to assess how Scottish enterprises have adapted and thrived amid economic and technological changes. Herewith, the central problem addressed revolves around the need for comprehensive, data-driven insights into sector-specific growth patterns and their implications for policy and strategy. The study aimed to illuminate the complex interplay between economic forces and technological advancements in Scottish industries with a focus on sustainable practices. By employing three statistical measures—namely the CAGR, CoV, and Average Growth Rate—the study quantified the expansion and contraction patterns within key sectors of the Scottish economy. For instance, the Electronics-related enterprises displayed resilience with a notable CAGR of 0.0079 and an average growth rate of 1.14, while certain IT subsectors, specifically IT-2 and IT-7, demonstrated substantial growth rates, with CAGRs of 12.02% and 12.46%, respectively. However, this rapid growth was contrasted by other IT subsectors that encountered declines evidenced by the CoV points to highly-induced variability within this sector. In addition to that, the t-test analysis, in terms of both t-statistic and p-value, had brought great insights into the analysis and demonstrated the dependability of the results.

The findings revealed a relatively volatile nature of sectoral growth, shaped by technological advancements, policy decisions, and market forces. These insights are vital for academics in the field of business administration and economic development, as well as for practitioners involved in strategic planning and policy-making. This study made significant contributions to the literature by providing robust statistical analysis and employing data-driven methodologies as tools to dissect and understand growth patterns within the Scottish economic landscape. The innovative use of specific statistical techniques offers a novel perspective that enhances the general understanding of how such tools can guide strategic decisions in a rapidly evolving economic environment.

The limitations of the current study include its focus solely on Scottish enterprises, which may not be generalizable to other geographical contexts. Further research could expand to include comparative studies with global trends or employ machine learning techniques for more predictive analyses. The conclusions drawn herein underscore the importance of robust statistical analysis in navigating the complex landscape of economic development and in laying the groundwork for continued research into the factors driving enterprise success in Scotland and any country of choice.

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