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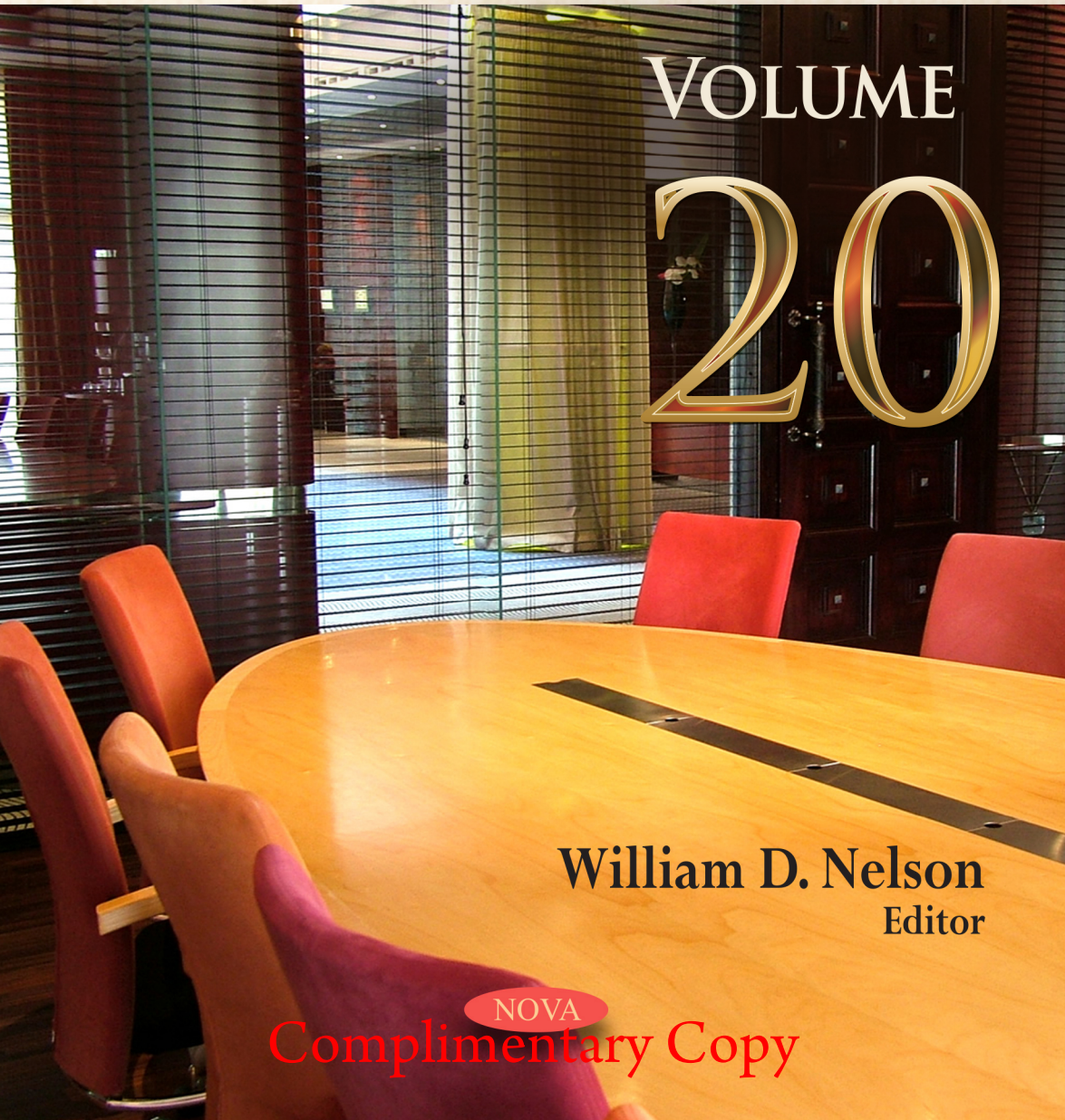

Volume 20

William D. Nelson
Editor

Advances in Business and Management

This is a numbered series focused on the latest research in business and management.

Advances in Business and Management

Advances in Business and Management. Volume 19
William D. Nelson (Editor)
2022. ISBN: 978-1-68507-834-8 (Hardcover)
2022. ISBN: 978-1-68507-877-5 (eBook)

Advances in Business and Management. Volume 18
William D. Nelson (Editor)
2021. ISBN: 978-1-68507-173-8 (Hardcover)
2021. ISBN: 978-1-68507-200-1 (eBook)

Advances in Business and Management. Volume 17
William D. Nelson (Editor)
2019. ISBN: 978-1-53616-376-6 (Hardcover)
2019. ISBN: 978-1-53616-377-3 (eBook)

Advances in Business and Management. Volume 16
William D. Nelson (Editor)
2019. ISBN: 978-1-53615-573-0 (Hardcover)
2021. ISBN: 978-1-53615-574-7 (eBook)

Advances in Business and Management. Volume 15
William D. Nelson (Editor)
2018. ISBN: 978-1-53614-188-7 (Hardcover)
2018. ISBN: 978-1-53614-189-4 (eBook)

Advances in Business and Management. Volume 14
William D. Nelson (Editor)
2018. ISBN: 978-1-53612-615-0 (Hardcover)
2021. ISBN: 978-1-53612-616-7 (eBook)

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Volume 20

nova
science publishers
www.novapublishers.com

Library of Congress Cataloging-in-Publication Data

ISBN: 979-8-88697-509-3
ISSN: 2159-9335

Published by Nova Science Publishers, Inc. † New York

Contents

Preface

This volume contains eight selected chapters covering recent advances in business and management. The First Chapter is a comparative empirical analysis of financial entropy from the perspective of asset management. The Second Chapter asks how to balance innovation and regulation in regard to SMEs and FinTech in the European Union. The Third Chapter provides a study of how interest rates effect consumption in the United Kingdom. The Fourth Chapter utilizes the Simus-Iosa method to perform a sensitivity analysis via lineal programming to support stakeholders in the decision process. The Fifth Chapter provides a systematic approach to substantiating chain management structures in business. The Sixth Chapter is a guide to implementing knowledge management in financial institutions which provides a flowchart for practice. The Seventh Chapter reviews the effects of competitive resources and capabilities as a driver toward sustained competitive advantage among manufacturing MSMEs in emerging markets. The Eighth and final Chapter displays the application of random walks to Bayesian classification and business decision making.

Chapter 1 - This chapter seeks to demonstrate the self-care mechanisms for the individual and society that the present capitalist economic system offers as an affordable solution. Social care systems can draw inspiration from what we are discussing, just as private people can use the authors' findings to their advantage. This chapter aims to bring order to a complex system of investment decision-making that can then be used as a decision-support tool to help all concerned thrive. The chapter proves that a portfolio based on nature's entropy is self-sustaining, since the criteria taken into account in its design give it the same system properties as the other systems that constitute our world. The universal conception of systems theory allows for interdisciplinary transformation. Using a pattern similar to the ordering of nature, the chapter would like to demonstrate the inherent self-sustaining power of this pattern within asset management.

The chapter reports on an empirical survey covering 984 investment portfolios and 1148 investment elements and concentrates on three main research issues: investor decision-making, diversification mismatches, and recommendations for sustainable asset management. Based on the methodology, 6-6 investment portfolios per individual were constructed. The portfolios sought diversification and return divergences in the short term of a semester (three months) and a long term of a 10-year interval. The key questions of the research focus on when, why, and what: When is the winning formula really the winning formula? Why is the winning formula – by how much and for how long? What is the explanation for the winning formula and what strategies make it sustainable? Interesting conclusions can be drawn from the research by contrasting the long- and short-term primary results of behavioral finance. The demonstrated sustainability-based portfolio management can serve as a guideline for the development of individual and institutional actors in financial culture. Raising financial awareness and self-management to a higher level needs to be coupled with a behavioral understanding of utility, which is also illuminated by the behavioral and outcome focus of the current chapter.

Chapter 2 - The growth of technological innovations in financial services, frequently denoted as ‘FinTech’ or ‘digital finance’, is causing concern for regulators internationally, including within the European Union (EU). As the overwhelmingly most prevalent form of business in the EU, SMEs are focal to the emergence of innovative FinTech products, services, and processes. By concentrating on FinTech activity within the EU, the chapter addresses the regulatory factors which must be considered when SMEs are the catalysts for unprecedented developments in finance.

The chapter argues that the fluid nature of FinTech innovation infers that regulation should respond in a flexible manner. In light of the contribution of SMEs to FinTech, the efficacy of certain regulatory initiatives could be understood best by evaluating their suitability for SMEs.

The chapter profiles the current features of FinTech activity in the EU and describes the characteristics of SME digitalisation. The chapter explains how SME innovation and start-up growth dynamics can be integral to FinTech’s ongoing rise. The chapter critically evaluates the degree to which contemporary developments in FinTech could be represented as being genuinely disruptive innovation, as the term is defined in existing literature. Innovations introduced by SME firms are more likely to be assimilated into market practices and gradually adopted by incumbent financial institutions. The types of technologies associated with FinTech are at relatively nascent

stages of development. Significant expansion is expected, and regulation will need to respond accordingly.

The chapter considers the various regulatory approaches which are utilised within the EU, ranging from examples such as sandboxes, innovation hubs and accelerators. By focusing on the importance of such regulatory mechanisms for SMEs, the chapter contends that a combined and complementary use of regulatory innovations can be highly suitable for the varied and dynamic forms of SME and start-up innovation in FinTech.

Chapter 3 - The aim of this study is to model the effects of interest rates on consumption within the UK economy to allow for a clearer understanding of the relationship between these two variables at hand and how this relates to the current economic literature. This paper also explores the causal effects of other independent variables on consumption and whether they have a significant impact or not. This topic is addressed by using a range of economic models, using Stata and EViews, to explore the full relationship of the variables at hand and how they impact consumption.

This paper provides an understanding of the timing and the effectiveness of changes in the interest rate that influences consumption. A greater understanding of the relationship between these two variables can be very important to the use of the monetary policy that the UK government uses within their economy.

Chapter 4 - Sensitivity analysis, a fundamental technique in MCDM process has received little attention from scholars and researchers, opinion that is shared by other academics as can be confirmed by examining the literature on MCDM. Even if there are a fair number of papers, very few propose improvements to the method. The same procedure devised decades ago is still used today as no new developments have been recorded. This work draws attention on the shortcomings of the current system and refers to papers that support the authors' claim and that provide a deeper analysis of some of them. For this reason, the authors believe that there is a need for a new paradigm in performing sensitivity analysis. Consequently, it proposes a new methodology that tries to overcome those drawbacks; it is illustrated with an example and the corresponding discussion. This methodology is innovative since it addresses sensitivity analysis in a way never tackled before, since it is entirely different to the present method, not only in the process and data management but especially in the wealth of the reporting.

Chapter 5 - The purpose of the article is to substantiate theoretical and methodological prerequisites for the introduction of a systematic approach to the development of the enterprise and chain management system in business,

the components of which are interrelated goals, objectives, principles, approaches, methods and functions.

Methods of classification, synthesis, analysis, induction and deduction are chosen as research methods, and binary matrices which are formed on basis of classification attributes of objects and its dichotomies used as a research tool.

The article develops the structure of the enterprise and chain management system in business; substantiates the content of goals, objectives, principles, approaches, methods and functions of enterprise and chain management in business; proposes the system of codes of components of system of this type; creates prerequisites for the formation of the integrated concept of chain management in statics and dynamics.

The implementation of obtained results will reduce the likelihood of contradictions in chains by coordinating the content of management systems of its links, create prerequisites for elimination the lost profits of chains of different type, reducing the time and cost of preparing and implementing management decisions, responding in the timely manner to unique demands of end consumers.

The originality of the research is confirmed by the substantiation of choice and use of actual qualitative attributes of management objects and its dichotomies, which allow to obtain 2^x variants of these objects and assign its binary codes processed using computer software for management activities.

Chapter 6 - The authors developed a framework for implementing knowledge management in financial institutions using a positivist and exploratory approach through qualitative research with 27 professionals in the field. The proposal is innovative due to the lack of structures that combine performance measures, KM pillars, KM processes, critical factors in the implementation and the suggestion of each of the factors according to the maturity level of KM Implementation. A flowchart is proposed for the practical application of the knowledge constructed. FIGCIF supports improvement: in acquiring knowledge resulting from academic work, in increasing tacit knowledge, in formulating instructions and normative manuals to improve understanding and use, in selecting information systems to have the ability to deliver information by through its set of rules and interaction between processes and in the defense of financial investments, aiming to generate confidence in the adoption of KM in banking institutions.

Chapter 7 - Micro, Small, and Medium Enterprises are the game changers in the industrial scenario, as they are the significant sources of employment and growth in an emerging economy. Studies based on the resource-based view are abundant in the context of developed countries but less in emerging

markets such as India. The present research extends the literature addressing the importance of resources and capabilities among manufacturing MSMEs in India, how they turn out to be competitive resources, and the abilities necessary for achieving superior firm performance, which acts as a driver toward the sustained competitive advantage of Indian manufacturing MSMEs. Therefore, the proposed model benefits policymakers and owners, especially micro and small, to develop a positive attitude on developing sustained competitive advantage among manufacturing MSMEs in India.

Chapter 8 - Many decision-making scenarios can be viewed as classification problems. Classification decisions are pervasive and occur in many business situations. In many applications, classification problems do not occur in individually but in groups where several classification problems need to be solved. Examples of these include student admissions at colleges, whether or not to extend job offers to applicants, the effectiveness of advertising channels, and determining if COVID patients should be hospitalized. With any form of classification, however, there are unavoidable inaccuracies arising in different forms, especially when multiple classification tasks need to be performed. Since typical classifiers are not free from errors, classification errors tend to accumulate, and having frequent mis-classifications are often unacceptable. Moreover, in unsupervised learning situations, there are typically no pre-determined ground truth classes; in such a situation the ground truth class is determined by the view of the majority of classifiers. In this chapter, the authors examine the situation of multiple classifications within the Naïve Bayes framework, where the ground truth is determined by the decision of most classifiers, and where there are finite resources requiring decisions to be made within a limited budget. Here, the authors represent the classification tasks as a one-dimension random walk process and perform a probabilistic analysis of the situation. The authors find that by raising the budget, the probability of error in classification can be controlled, and the extent of the reduction can be quantified. These results can be beneficially deployed in a variety of business decision-making situations in measuring and enhancing the quality of decisions.

Chapter 1

Financial Entropy from an Asset Management View: A Comparative Empirical Analysis

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Abstract

This chapter seeks to demonstrate the self-care mechanisms for the individual and society that the present capitalist economic system offers as an affordable solution. Social care systems can draw inspiration from what we are discussing, just as private people can use our findings to their advantage. This chapter aims to bring order to a complex system of investment decision-making that can then be used as a decision-support tool to help all concerned thrive. The chapter proves that a portfolio based on nature's entropy is self-sustaining, since the criteria taken into account in its design give it the same system properties as the other systems that constitute our world. The universal conception of systems theory allows for interdisciplinary transformation. Using a pattern similar to the ordering of nature, the chapter would like to demonstrate the inherent self-sustaining power of this pattern within asset management.

The chapter reports on an empirical survey covering 984 investment portfolios and 1148 investment elements and concentrates on three main research issues: investor decision-making, diversification mismatches, and recommendations for sustainable asset management. Based on the methodology, 6-6 investment portfolios per individual were constructed. The portfolios sought diversification and return divergences in the short term of a semester (three months) and a long term of a 10-year interval.

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In: Advances in Business and Management. Volume 20
Editor: William D. Nelson
ISBN: 979-8-88697-489-8

The key questions of the research focus on when, why, and what: When is the winning formula really the winning formula? Why is the winning formula – by how much and for how long? What is the explanation for the winning formula and what strategies make it sustainable? Interesting conclusions can be drawn from the research by contrasting the long- and short-term primary results of behavioral finance. The demonstrated sustainability-based portfolio management can serve as a guideline for the development of individual and institutional actors in financial culture. Raising financial awareness and self-management to a higher level needs to be coupled with a behavioral understanding of utility, which is also illuminated by the behavioral and outcome focus of the current chapter.

Keywords: behavioral finance, financial culture, portfolio management, self-sufficiency, sustainable wealth management

Introduction

Portfolio management is a chaotic system of complex decision-making processes (Pagdin and Hardy, 2018) that requires an interdisciplinary approach from both chaos- and systems sciences. Its sub-discipline – sustainable asset management – is concerned with ensuring a permanent, consistent return on the asset for its manager, without any particular energy input or significant intervention. Both active (markets outperform) and passive (benchmarking markets) strategies can be used to approach asset management sustainability (Hayes, 2019), but the diversification solutions that dominated for decades are no longer satisfactory in today's rapidly changing investment environment (Carlson, 2019).

In the field of portfolio management, money flows from actively managed funds to passively managed funds (Lovas-Romvary, 2018). Some argue this form of portfolio management is now threatening capitalism (Foxman, 2017). Capital finds better returns in less turbulent, less disturbed investment strategies based on good foundations fundamentals. Good construction saves time and energy and is not satisfied only with time- and energy-intensive strategies constantly followed by markets and exchange rates. The ordination does not need any intervention to be passively profitable, as demonstrated by the success of 'lazy' in name passive portfolio strategies (Green, 2019).

Fixed income portfolio theories (Browne, 1999) are currently in wide use and they typically employ a dividend-paying equity diversification strategy (Miller, 2006) to maintain a permanent income portfolio (Bolder, 2015). The

discipline of portfolio management is designed to enhance security without risking returns by applying the theoretical and practical tools of optimization (Pfaff, 2013). The evolution of financial culture has already led to a growing focus on financial freedom (Kiyosaki and Lechter, 2000), where people like to decide for themselves how their capital grows.

Two major 'schools' of thought on investor behavior can be distinguished: one emphasizes the importance of diversification (Swensen, 2009), and the other focuses on the fact of focusing (Hagstrom, 2001). Both are proven ways to accumulate wealth, as shown by the endowment management of US universities (Ruby, 2021) and the strategies of the world's wealthiest investors (Israelsen, 2010). Investors and their market perceptions present a composite picture of shifting paradigms, from the rational investor (Fama, 1970) to the behavioral approach (Kahneman and Tversky, 1979).

Behavioral economics emphasizes the importance of choice-making, in that choice making can nudge us in a more favorable direction without restricting our freedom of choice (Thaler and Sunstein, 2011). Moreover, the decision maker's activity is made significantly easier if the framework within which he makes his decisions is made tangible and transparent (Kennon et al. 2005). The ordering methods of fuzzy logic (set-based simplifying) thinking play an important role in a decision preparation process (Borgulya, 1995), which is now being demonstrated as a systematic principle in the field of diversification risk mitigation (Tobin, 1977) and the investment area. The used research methodology offers four types of models as alternative portfolio construction strategies, taking into account the same fund symmetry, setting a decision framework, while offering sufficient alternatives to make satisfactory investment decisions.

The word entropy in this chapter means orderliness, but it should be noted that there is controversy in the literature about the concept. The chapter considers that the formulation of the order is a matter of perspective. What is order? It depends on the set of rules; on what we take as a basis for our point of view. If we take linearity as a basis, then chaotic dynamics seem to be out of order. If we think the other way round, then geometric regularity seems odd. To Euclid, a forest may seem disorderly, just as the forest may seem disorderly to the Greek geometric lines and measured angles.

The chapter seeks to adapt the patterns of nature and therefore accepts it in its complexity. Its immeasurability and its order are incomprehensible to our human imperfection. The chaotic order, the apparent confusion, the tangle of unknowable systems, their networked interconnections, and the exact immeasurability of the forces acting on us are called order because they are

the rules of the game of called life. In this chapter, we label entropy as the strange, inexplicable, self-exciting process that lurks in the tangle as a divine creative force, and as a pattern that instils an ordering principle into our otherwise imperfect world. This has led to synthesizing entropy as the equivalent of self-organization in systems theory, as a kind of invisible orderliness whose detection the chapter traces in the field of wealth management.

The chapter aims to demonstrate and measure this orderliness as the order of the self-exciting process, the order of the self-maintaining system, the order of the entropy of nature, and the order of the complex system of investment decision-making. Particular attention will be paid to the demonstration of orderliness as a result of divergent judgements based on own decisions. To this end, a conflicting empirical analysis is used to find discrepancies within an underlying symmetry regime defined in terms of the use of the model employed.

Myth or Reality?

Financial Entropy

Entropy is a somewhat broader concept, often contradictorily defined in the cross-disciplinary literature, and which, in its original meaning, really means disorder. Entropy is not a directly measurable physical quantity. Its application helps to formulate the laws of thermodynamics, but it is no more than a useful mathematical construct. When the concept was first conceived, it applied to closed systems, but nowadays the concept of entropy is widely used and is far from being a measure of disorder as first formulated by Clausius (1867).

Order and disorder are merely a matter of perspective; what is order in closed systems can be understood as disorder in open systems. In the same way, for those for whom chaos is the starting point, artificial regularity may appear as a messy, disorderly condition. In the context of entropy, ‘perfect internal disorder’ is often taken to describe thermodynamic equilibrium. Yet the concept of thermodynamics is so far removed from everyday thinking that the use of the term in physics and chemistry has caused much confusion and misunderstanding.

The conventional definition of entropy as “changes in order” has experienced a shift recently. The words “order” and “disorder” have

transformed into “spread” and “dispersion.” Indeed, the interpretation of entropy as internal disorder is only valid for closed systems. However, in open systems, the more stable the state of a system, the higher its entropy (Baumann, 2013). The constancy in the dynamical process of an open system is itself a complex evolutionary stage of fluctuation, continuous motion, and flux. Nothing is certain but the change itself; entropy is thus a state of being condemned to perpetual wandering.

In open systems, chaotic processes prevail and confusion is the normal state. The more confused and chaotic a system is, the more self-organizing it is, and the more it strives for ‘perfection’. A seemingly contradictory, illogical conclusion, but one that has its own set of rules. Imperfect disorder is a complex dynamic process, which can still be called the steady state of open systems. It is a state rather than a moment. A state of continuous change, in which self-organizing patterns may continuously emerge, seemingly revealing order within the deterministic framework of classical entropy.

The total entropy of open systems may also be reduced by the flow of entropy due to exchange with the environment, in the process of which the system may move towards a more ordered state (Stefanescu, 1996). Schrödinger (1944) proposed that this effect explains the structure of living systems during their evolution, thus calling the encoded pattern the selection criterion for useful information. Information and entropy, or orderliness and disorder, are related (Fulop, 2001). They appear and disappear in each other’s systems. Self-regulation, decentralized operation, reproducibility, information stored and transmitted in encoded form – these could all be characteristics of life on earth, although they have been pointed out as features of the evolution of cryptocurrencies, blockchain technologies and money, among others (Mero, 2004).

The principle of utility selection – given enough information – is also reflected in the complex, open system of investment decision making in portfolio management as a scientific underpinning tool to simplify diversification. Kirchner and Zunckel (2011) argue that entropy is the better tool to capture risk reduction in financial economics through diversification. It is an additional risk mitigation tool to be considered alongside diversification and dynamic management (Ormos and Zibriczky, 2014).

Research on entropy in finance has gone as far as to state that entropy as a measure of uncertainty justifies the effect of diversification (Dionisio et al. 2007). Entropy is not an anomaly, it is not a measure of chaos, and it is not a driving force, since in open systems we are looking at both dynamic states and static moments (Lambert, 2002). Entropy controls both equilibrium and

disequilibrium (Grandy, 2009). Critics of the terminology argue that entropy is not a measure of 'disorder' or 'chaos', but rather a measure of energy diffusion or dispersion across multiple microstates. The thermal law of entropy implies that evolution disperses all the energy needed for life on this planet, while on the other hand self-organization (evolution) means the creation of ever-larger islands of order at the expense of ever-larger seas of disorder (Abou-Rahme, 1997). In the chapter conception of the 'entropy' of portfolio management, the complex field of static structures (diversification dispersion) and the dynamic processes (portfolio management) will both be explored; and both will be examined simultaneously to capture the overall attribute of entropy.

Interpreted in terms of open, dynamical systems, the concept of entropy within this chapter can only be understood as a momentary flash of constancy, which reveals a current "order" in an otherwise chaotic complex system of dynamical processes. The more constant the state of a system, Baumann says – in the present case if we take a basic model that we consider constant, then the fluctuation around this will represent the rest of the operation. In this case, the flash of the dynamical process causes a momentary entropy of the current pattern. In this sense, "order" is supposed to emerge. Order and disorder are, in the view of the chapter, a matter of perspective. What do we call order? Is order man-made linearity or nature-made morphogenetics? If we look around us in nature, we rarely see a right triangle, a perfect body, or even a straight line, which is a very unusual and rare phenomenon in the natural structure of our world.

If we want to adopt a pattern from nature to our research, we take its order and orderliness as our basic interpretation. To some people, the sight of buildings blending into the landscape seems "out of place," disturbing the harmonious conformity of the environment, which is ordered in its way. From a geological perspective, it is the order of nature that is more dominant. In the long term, the chapter considers that fractal geometry is a more sustainable form of appearance for our planet, rather than the sustainability of the appearance of a building. Let us face it, man can create a momentary order in his environment, but in the end, no building will remain standing (in shape) as long as the (appearance) line of a ridge. The environment is ordered in a non-linear way; therefore, this chapter believes that we should then consider it as order.

Take the case of a drinking glass: if you look at it, you see a neat and tidy thing, while the condition of the silicon crystal from which the glass is made can maintain this artificial order for a very time. Glass is an amorphous

material, where the base crystal is forced into a distorted construction, but that is only a momentary state of the silicon crystal over its millions of years of existence – until the glass breaks. A drinking glass thousands of years old is not a very realistic lifetime assumption. Thereby, looking at it, the true ordered state of the crystal can be imagined as some sort of dust or rock-forming element. This ground state, its maximum orderliness, however beautiful our crystal glass may be, is only a momentary state of being seen as an actual representation of the uninterrupted dynamic processes in it.

An important question, and also a question of perspective, is what we consider to be the ordered state of a crystal molecule? "It" is conveniently apart from this amorphous-glass form; its natural order would be greater otherwise, and so it is its true entropy. Not approaching this concept in its state, but rather in its existence. Is it actual order or long-term orderliness? Is it a momentary formation or long-term sustainability? There is a difference between dynamic order and static order, namely in terms of sustainability (Donaldson, 2011). A closed system may be a current state, but not necessarily a sustainable one; it must eventually become an open system, or evolve into, or become part of one. In the understanding of the chapter, the definition of entropy employed earlier applies only to closed systems. Yet unsurprisingly, when looking at their opposite, open systems, we have to come to the opposite conclusion: entropy is the degree of orderliness. In the chapter, we will use the term in this sense. The generalist approach suggests that entropy is not disorder, nor it is a matter of perspective. The other perspective may be exactly order, as has been recently confirmed, among others.

There are many different explanations for the definition of entropy, but the concept of environmental entropy was introduced into economics by Nicolas Georgescu-Roegen when he stated that "low environmental entropy is as scarce as Ricardo land" (1971). Anyone who adapts Roegen from this point onwards correctly identifies the scarcity of natural resources, but this does not determinately imply the fact of destruction and total exhaustion; matter is not lost but transformed. It is organized. On the one hand, it is self-organizing, but on the other hand, it can also produce a networked dynamic effect. Such a logical conclusion of entropy implies implicit and erroneous conclusions, namely that energy and material burdens come from an immutable eternal source until it has been proven that by using self-sustaining mechanisms, humans should never have to fear the scarcity of resources or the limitations of nature (Mayumi, 2018).

Entropy refers to the (dynamic, occasionally renewed) constraints imposed by nature, the kind of arrangement (orderliness) that the natural

system around us follows, and which thereby determines our room to operateeuver by allowing us appropriate freedom of choice. Entropy can grow rapidly when there is an unequal distribution of ordered and disordered structures in space because this causes movements and flows (which produce the classical thermal energy through friction and collisions). The high orderliness and self-sustaining mechanisms inherent in life can also be seen from a thermodynamic point of view as a driving force toward a faster increase in entropy (Rockenbauer, 2019). Every natural process moves in the direction of increasing entropy – Ilya Prigogine was awarded the Nobel Prize in Chemistry for this finding. Defeating entropy in the classical sense has also been demonstrated by control programs and mechanisms that capture, transform, and store energy entering the open system (Polanyi, 1958).

Entropy theories of decay (Rifkin, 1982), disintegration (Wark, 1966), and heat death (Perrot, 1998) must be consistently, categorically, and collectively rejected after all consideration since they are all based on previously discovered findings that apply only to closed systems. However, only in the rarest of cases can we speak of a perfectly closed system in our universe. But in open systems – such as the ones explored in this chapter – it is the orderliness that would cause order in a closed system. Heat death is only a thermodynamic concept, which can be a possible state of any (closed) system, but it is by no means necessary, nor is such a state necessarily final.

According to the Gaia hypothesis (Lovelock, 1990), the Earth is a self-sustaining system, not a set of rules drifting towards disintegration, at least not deterministically. From geology studies, we learned about the frozen planet theory (Kirschvink, 1992), which states that the Earth was once in a state of complete freezing, a heat death, so to speak (life somehow survived). This can be seen as the endpoint of a system, the limit to which it can go; it can be identified as one of its possible outcomes, all of which can be acknowledged, yet let us assume that it is not necessarily heading in that direction. The Earth is either warming or cooling (how humanity contributes to this is another matter). Those ice caps are either melting or growing. Sometimes there are none, and sometimes they cover the whole planet. It is a natural process, a process of fluctuating between limits: it either cools or warms. It would be odd if it were exactly constant, equal temperatures, in an orbiting, rotating, dynamic system; that would be extraordinary. We know well that ice ages and warmings alternate; that this is the framework of nature's system; that life must be able to survive in it; that this is the coded pattern of "striving for life" that we must see in the demonstration of self-preserving mechanisms. Heat

death may be one possible state of a system, but it is no more than this static point.

There are also systems moving on attractors, which have been shown to have no periodic changes. The system never repeats itself; it behaves chaotically. Chaotic dynamics refers to random motion on fractals. Therefore, this type of motion is characterized by a particular duality, being influenced on the one hand by the macro-level determinism manifested in the structural nature of the attractor, and on the other hand, by the micro-level randomness that is present in the successive steps of the trajectory (Barnsley, 1988). The coexistence of determinism and chance; coded pattern and chaotic trajectory; information and entropy are the characteristics of open systems.

According to General Systems Theory, a system creates its components, organizes a network, and in the process is constantly transformed, destroyed and renewed. Varela et al. (1974) speak of autopoiesis, from the Greek concepts of auto- (self) and poiesis (creation, production, generation). This is more than autonomy because autopoietic systems also create their components – self-organizing mechanisms. Autopoiesis does not make an autonomous system closed. It is not independent of its environment (Gyorgy, 2001). In addition, this competition of self-organization does not take place with other systems, but between successive states of the same system (Kaufman, 2002).

> Physicists are already having a great deal of trouble measuring the degree of order in water, which forms a crystal structure under constant energy dissipation as it turns to ice. And then this thermodynamic entropy fails miserably if we try to apply it to the emergence of amino acids, microorganisms, self-reproducing plants and animals, complex information systems like the brain, as a measure of the shift in the ratio between form and formlessness. The second law certainly applies to these evolving islands of order, but the important laws, the laws of the creator, are to be found elsewhere. Nature creates patterns. Some are spatially ordered, others disordered in time, and others the reverse. Some patterns are fractal, others involve steady or oscillating states (Gleick, 1999)

Understanding systems in terms of their dynamics already requires thinking in terms of open systems, with their complex and opaque interconnections, which are in a state of perpetual change, constantly maintained.

To maintain a state in an open system, it is possible to maintain it in a flow equilibrium, in entropy equilibrium, and the question of sustainability is therefore of great importance in a dynamic approach. There are no such things

as infinite natural resources, nor infinite growth, so we must strive for the best possible solutions within our finite limits if we are to take the word sustainability seriously. Where these limits are, what the limits to growth are, and the room to maneuver between them is what entropy shows us. “Entropy enables the understanding and mathematical theory of irreversible phenomena, which can simplify their discussion and make natural limits measurable and quantifiable” (Martinas and Huller, 2012).

The portfolio management procedure synthesized in this chapter consists not only of a constraint model but also of a methodology, which can be applied, presumably successfully, to stakeholders interested in the issue of self-care. For the scientific synthesis, the chapter considered it important to reveal not only a static model but also a dynamic procedure, which then leaves room to maneuver according to the investor’s attitude, to react to new and new conditions dictated by changing market conditions. The pattern of nature’s distribution can serve as a basis for the pursuit of growth, which is of particular importance in the field of investment. Economic systems, like thermodynamic systems, are characterized by disorder; thus, entropy characterizes both. In modern studies, non-equilibrium thermodynamics is most often used to study dissipative (non-static) economic structures (Kiss and Kiss, 2014). John Bryant (2011) considers thermodynamic temperature in economics as a kind of trading value index, while Saslow (1999) argues that economic entropy corresponds to the changes in the economy, to the degree of economic variation, that determines the internal state of the economic system and its complex system of interconnections with the external world.

To simplify the complexity of decision-making, the chapter will explore mechanisms that offer applicable solutions in the field of self-care in economics, even in the absence of specific expertise, skills, or time. The hypothesis is that there must be sufficient order in the complex system of investment decision making to make satisfactory decisions, whatever the objective to be served. In this chapter, the underlying Rolling Nuts symmetry provides the order, which, when you think about it, is difficult to maintain. For example, if you create a portfolio of four elements with one stock or one currency element, it will be at a different value or exchange rate in the next moment. The symmetry in a masterfully constructed portfolio is immediately damaged as soon as the investment occurs. Order – the basic model – is immediately broken and begins to shift out of proportion with the original design. Disorder sets in, which can be controlled by re-flashing Rolling Nuts symmetry to rebalance the portfolio, injecting actual order into the portfolio lifecycle.

In this chapter, the symmetry of the research model represents the "order," in this sense the maximum entropy at the moment, from which it deviates ever so slightly, as around an equilibrium state, or falling with decreasing entropy in the mainstream conception. Open systems are entropy-balance states. This chapter argues that entropy is at its highest when the symmetry of a research model is maintained. This orderliness disrupts the constant negative process of "disorder." The high degree of orderliness inherent in life can also be seen from a thermodynamic point of view as a driving force towards a faster increase in entropy; thus, a higher degree of orderliness increases entropy. Recent research has confirmed – or at least argued for – that self-organization processes in open systems reduce entropy in the classical sense, i.e., as if natural "self-organization" produces disorder when it is only striving for its long-term sustainable state. Open systems are dynamical processes, oscillating around an optimal state, where they go to the extremes and then back to the "middle" and further to the other extreme limit, or within this limit of the space of motion, seemingly in a state of confusion. It is quite difficult to define order in this movement. It could be the optimum point itself, which defines the extremes of the oscillation. Fluctuate all you want, but I will tell you within what limits! A creative force that provides a coded pattern for the limits of self-organization while leaving us free to choose the paths we take.

The divine creation model not only predicts the entropy principle but the entropy principle points directly to creation. That is, if all things are now in disorder, they must have originally been in a state of high order. The Catholic Encyclopedia (1993), on the other hand, defines the word chaos as a "primordial state, pre-creation existence." Ancient order? A question of point of view. The word chaos can also be interpreted as confusion, or, on the contrary, as a conception of something ordered in its particular way. Disorder is a dynamic process in which we may find static order, but entropy research has now concluded that entropy is not a measurable physical concept, but rather a definition to model the dynamic process of "being." Perpetual deterioration is posited as the antipole of high order orderliness, while we can see that in our "being" it is the more determinate rather than the state of perfection. We were perfect only at the moment of Creation (we, all of us, the organisms of our present physical world). Perfection is not a sustainable state; it can only be a moment instead. It is a rare moment – "a state of disorder." From a divine perspective, it is order, but allow me from my imperfect human perspective to consider the perfect moment as "extraordinary."

The order of humanity is a state of continuous existence. It is an imperfect state, an entropy fluctuation, where the "right" state seems so slight that we

rather take chaos as the basis. This is the irreverent justification for the conception of entropy in this chapter – to consider continued existence as order, and to think how irrelevant the moment of perfection seems. It is an unattainable illusion on which it is almost pointless to waste resources since it can only be maintained by forces beyond us. Let us rather call our obligatory imperfection order, then, let this be the starting point for design when we play with the rules of the game of the determined, orderly state of our existence. In such a conception, entropy is "order" itself, which is constrained within a well-determined framework in the chapter by specifying the symmetry of a portfolio basis. It is assumed that the emergence of an interdisciplinary pattern in the dynamic processes of portfolio management will have an excitatory effect on the system, generating even greater orderliness in the processes.

This chapter considers entropy as the order that sets the (imperfect, unfair, unequal, some would say disordered, sub-optimal, seemingly unsustainable) rules of the parlor game called life. With such rules of the game, "equality" or perfection may seem like a strange, ordered moment. The position of the chapter is that entropy is the order, the basis on which the rules of the board game called life are laid down (Dinga et al., 2021). It has its own set of rules; its inescapable nonlinear dynamic regularities that define our existence in the classical sense of entropy (decay). However, the (classical) decline of entropy observed in self-organizing processes has only occurred during the phase transition (Popovic, 2014), and overall, self-organizing, self-perpetuating mechanisms enhance the concept thus conceived – they bring about a temporary order. In the chapter conception, (classical) disorder is the basis; it is reduced when it is perfected; when it becomes a self-exciting process. Thus entropy becomes order, the actual moment of a never-ending state of uninterrupted disorder, which determines and orders the life processes, whether we want it to or not. This is a higher degree of orderliness, which is attained at most only in the moment.

So let us take advantage of its ever-emerging momentary "order" and play by its rules. The complex rules of the game can be grasped with the right simplifications of human rationality so that we can have a somewhat self-sustaining say in the contest called life through our decision alternatives. Order may be a matter of perspective, but it also expresses the truly specific perspective of the chapter, which considers the infinitely complex entropy of nature as order in the all-quantifying world of asset management, to make it visible and also to draw attention to the correctness and legitimacy of other interpretations. Order and disorder can coexist, and they can even emerge in each other's systems. In this chapter, we take natural ordering as a model,

which may seem disorderly in the practice of asset management, but this entropy may as an emergent pattern, set in motion self-sustaining processes, which this chapter attempts to demonstrate and analyze measurably and comparatively. Behavioral finance is an area currently under research, and the chapter would like to provide a complementary model to enable us to become masters of our behavior, as managers of a system with a sufficient number of alternative options to make satisfactory decisions.

Ultimately, the chapter looks for order and orderliness in the complex system of investment decision-making that can serve as a model to follow for the multitude of variations in asset management. This pattern is taken from the fractal world of nature, which may therefore seem disorderly, unusual, and strange. Since it is an infinitely complex natural pattern, it can only be approached heuristically. By reducing its complexity into a manageable pattern, this chapter attempts to capture and demonstrate the self-sustaining power of natural ordering in the returns of investment portfolio distributions. The entropy of nature is the order of this research, of which self-sustaining nature is the focus of this chapter. A self-sustaining investment portfolio, in the asset management sense, is a living being that we have the power to create and, through its buoyant systemic processes, can serve our interests from then on. Self-preservation is a basic system property that we can even influence and control in artificially created systems such as investment portfolios. The synthesis of different disciplines has led to the hypothesis of the self-sustaining portfolio, which has not been stated or established by anyone.

Methodology

Comparative Empirical Analyses

The methodology of the chapter is based on the Rolling Nuts portfolio allocation structure, which establishes the prevailing sustainability and directing principle of nature in asset management (Cziraki, 2021). The natural orderer pattern behind all physics causes sustainability in its area of occurrence (Kreiner, 2005), so it became necessary to condense it into an applicable methodology. Previous research acknowledges three distributions of the basic model. These have now been supplemented by four alternative interpretations that can be considered definitive. In this sense, a seven-element

version of the original symmetry scheme can be added to the existing four- and five-element portfolios.

In the current chapter, this model solution could be used in addition to the existing ones. Based on the chapter research methodology, four-, five-, and seven-element portfolios have been created (Figure 1) with different groups of higher education students (Bachelor, MA and postgraduate). The methodology retains the freedom of choice of investment elements, where it examines not only the returns but also the rationale for the investment decision and the range of conclusions that can be drawn from the evaluation.

In addition to the four portfolio distributions of the Rolling Nuts model system, two benchmark portfolios (P4 and P5) are projected as benchmarks, where the assumption of equal distribution of the selected elements can be compared with the results of the focused models. From the formed six portfolios, three have different degrees of focus (RN 4 and RN√ 3 with one focus, RN 5 with two), while the other three represent an equally distributed structure (with four, five and seven elements), allowing a comparison of the degree of dominance against the permanent distributions. Whether the smaller, the larger or the two-focus solution is more appropriate (dominant behavior), or whether an equal distribution of elements (permanent) produces better results, is one of the basic questions of the chapter.

The evaluation of the results also waded into the detection of differences in the number of elements by comparing two structures with four elements, three with five elements, and one with seven elements. This methodology can determine whether the appropriate solution lies in fewer, some, or many elements. Of course, a much larger number of elements could have been used, as it is not uncommon in real life for a portfolio to consist of up to 100 elements, but here the phenomenon of over-diversification (Statman, 2002) arises, which is the negative impact on returns of over-excluding risk. In our case, four, five, and seven elements can already be considered as significant deviations, relative to each other, and if not driven by representativeness on the spectrum of numbers, they may rather suggest expedient solutions by evaluating the results caused by the deviations of a few but well-focused number of elements. The study of the portfolios of a symmetry system can be seen reflected in the chapter, where multiple interpretations of the system are given, where a basic diamond structure is interpreted in four different ways. Differences within the symmetry system can be detected in this way, complemented by the empirical choices, over a wide range of data sets and different investment periods.

The chapter research methodology not only examines returns and compares them with benchmarks, but also looks at the human factors behind decision-making as an element of financial culture to measure investment behavior. The analysis in the field of behavioral investing considers the choice (justification) of investment components, the choice of portfolio focus, the range of lessons learned, and the inclusion of birthdays as a specific marker of human factors. The research participants tracked the performance of their chosen elements in a Microsoft Excel 2016 spreadsheet over a period of one semester (three months) (September–December 2020), supplemented by 10-year projected returns (2010-2020) of the same elements. Just as for the quarterly analysis, a minimum of one date per week was included in the analysis, for the 10-year period, each participant was allowed to work with values current on their birthday. This allowed a little personal attachment to be smuggled into the research alongside the long and short term analysis, and also excluded the potential bias arising from the seasonality of markets (for example, always working with exchange rates on 1 January, reflecting only the exchange rates prevailing at that time).

In addition to analyzing the differences in diversification, the methodology can also be used to analyze the size of the item count and to detect differences in the degree of focus/dominance. For item selection, a focus group approach was used, whereby some groups were given full freedom of choice, while restrictions were applied to other groups to show, for example, the beneficial effect of international diversification (Bugar and Maurer, 2002). Overall, the chapter methodology aims to determine which alternative to behavioral decision making is more appropriate and in which time horizon.

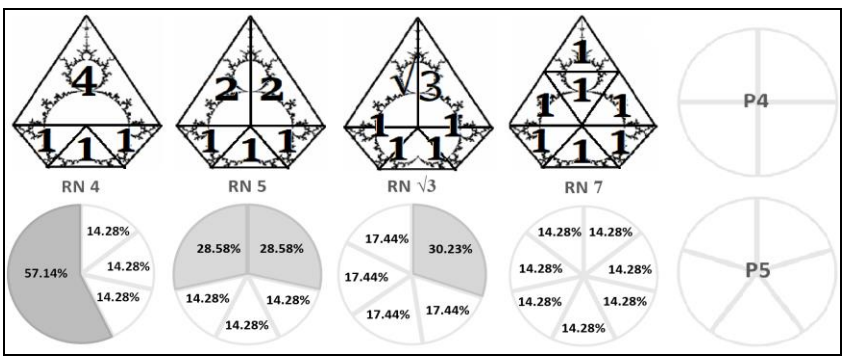


Figure 1. The Rolling Nuts (RN) and benchmark (P) distributions of the methodology used.

The chapter brings together 164 validated evaluable test completions received, including 92 long-term empirical evaluations and 72 short-term data sets. The short-term analyses were examined over three different semesters so that the results from three different periods can be compared, where short-term vs. long-term clashes are considered. The examined actual short-term periods were September–December 2020, January-April 2021, and September-December 2021 with three three-month time intervals. This was also necessary for the research to eliminate the anomaly of comparing only a given short-term investment spectrum with a given longer-term investment period. The more such short-term analyses are paired with long-term evaluations, the closer it can come to understanding the differences in investment diversification, based on comparisons of the formulae analyzed themselves.

The chapter includes three different short-term time horizons used to take several periods as a basis while comparing the results of investment decisions with the longer-term (10 years) strategic investment horizon. Short- and long-term analyses of the same selected elements were conducted to see the differences between the passive and active effects of an investment strategy across multiple platforms: justification, return, winning portfolio, focus groups and lessons learned. The research sample of the chapter represents a total of 984 investment portfolios and 1148 investment elements combined.

Outcome and Evaluation

The Investment Targets

The scope of the results is the dual of returns and investor behavior, where the yields are compared in the long and short term, while the behavior can be inferred from several factors by summarizing the chapter. First and foremost, it is useful to clarify the composition of the sample studied, in terms of the separation of the selected elements by investment category. This will provide an answer to the reasons for the size of the returns shown later, while at the same time allowing us to see the preferences of investment decision making when it is based on free choice. Figure 2 illustrates the distribution of the more than one thousand investment items examined in the research across asset classes.

The sample analyzed predominantly covers equity-type investments (64.82%), with commodities (13.87%) as the second most common choice,

and a set of preferences for foreign exchange-type (10.66%) and index tracking (10.36%). The analysis includes only four asset classes, of which equity-type investments lead the way; so, the sample analyzed will overwhelmingly reflect the 10-year and three-month performance of domestic and international stock markets. A further conclusion from the composition of the chapter sample is that the choice of items has been made in the shadow of a COVID epidemic – in the middle of it, currently, autumn 2020, and spring and autumn 2021 results are included in the three-month analysis. However, the researchers see returns in the equity, foreign exchange and commodity instruments, with a predominant focus on the former. The current economic and political situation influences our decision-making, yet what can be filtered from the categorization of our asset selection is that we are not afraid to take risks to achieve returns, even if we make our investment decisions in an unpredictable, turbulent, uncertain present and future. Of course, people do not handle their money as easily, but the research gave us an answer to the question: In what would you invest your spare money? Let us examine the deeper reasons behind the choice of predominantly equity-type investments.

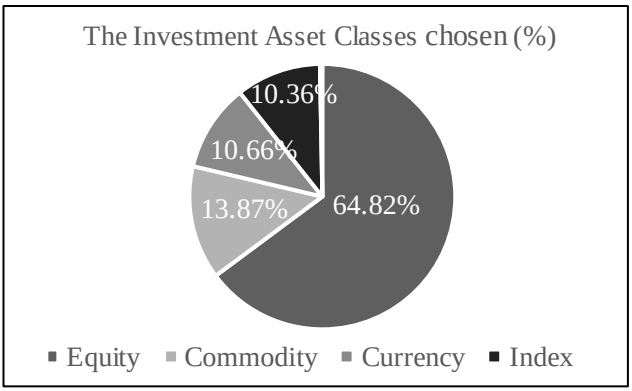


Figure 2. Distribution of the research sample across investment asset classes (%).

Justification of Investment Decision

Having looked at the sample analyzed, the first of the chapter's findings is to examine the reasons behind investment decision-making as an element of financial culture. In the individual justification, the research participants were asked to state in why they chose the current investment item, why they focused

on that particular item, and why they selected those items in a portfolio. Based on the responses received, seven distinct groups of reasons can be distinguished as follows, in order of frequency of occurrence:

1. Actuality,
2. Personal preference,
3. Industry/sector,
4. Diversification,
5. Stability,
6. Curiosity and
7. Importance of return

The justification behind investment decisions can be reduced to three distinct clusters, as the set of groups that most determine behavior, within can be identified an interesting subjective-objective – (sub)subjective levels (Figure 3).

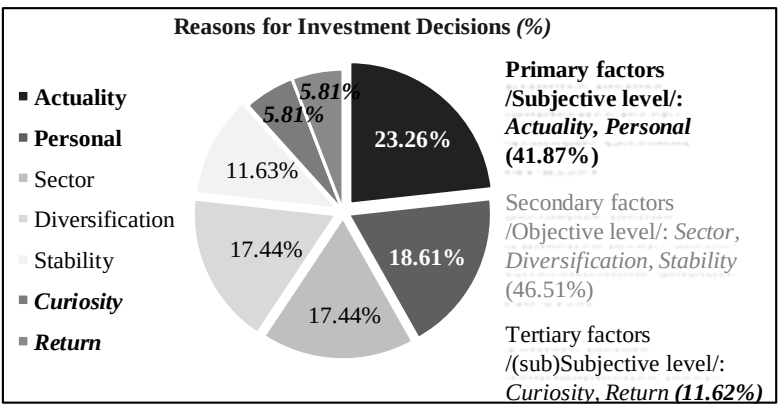


Figure 3. The justifications for investment decisions (%).

Before clustering the investment decisions, the categories that distinguish each justification should be identified, first by identifying the *actuality* that is most often cited as a justification. This category includes all the justifications that were formulated with the adjective "trendy," "hip," and "topical." This is the category of sexy, cool, trendy investments, which justified the choice of investment item in 23.26% of cases. The reason of actuality draws attention to the behavior orientation of human decision-making, topical (heard, read, picked up, advertised, now on the rise. . .) information also means the ability

to direct human attention, at the same time as the appearance of awareness. Actuality is indeed a human factor, as it is subjective to what we attribute to timeliness or rather it is the investor's focus on a relatively short time horizon. The short-term investment mindset is a characteristic of the behavioral investor (Gordon, 2010) and as such, a human factor. It was also the main investment rationale for this research based on the biggest argument of actuality.

A related but distinct set of responses falls into the category of *personal* justification as the second most common preference. Here, responses that demonstrated a personal attachment to the investment product, preferences such as brand loyalty, "I/family have the same," "we use this," "favorite product/service" or "I like this" were included. The personal justification emerges as a further subjective aspect in the analysis, again reflective of the behavioral investor, here reflecting the importance of emotionally based decisions (Taffler and Tuckett, 2010). The justification of actuality and personal attachment as two subjective factors form the first cluster of decision making, which as a major reason is found in 41.87% of the investment decisions underlying the research.

The secondary factors that follow the first cluster reflect the objective level of decisions, where they include *sector*/industry, *diversification* and the need for *stability* in an investment. The high belief in industries may occur because, without precise, accurate company knowledge, a booming industry can be chosen as an investment target, eliminating our information gaps, which also stem from human limited rationality. This way of thinking – that the industry is the third most important reason – is closer to systems theory, whereby it first could be defined as a large set of decisions to further narrow down and make decisions that are more satisfactory. Choosing to invest by sector reflects a more conscious attitude, assuming a certain knowledge of how each industry operates and how systems are organized. Systems thinking is also reflected in the next aspect, which is equally influential, namely the intention to diversify investments (17.44%).

Risk aversion – as the main tool of portfolio construction – justifies the high percentage of diversification (Chen et al., 2007). When asked why one chooses these elements as a system, a common answer is that it is precisely for risk aversion (so that they are more comfortable including riskier elements, out of curiosity, to be organized as a system in addition to the element they consider safe). At this level of reasoning, the importance of risk exclusion and safety is already apparent, which leads to the next group of reasons for the decision, namely stability. This is a well-defined objective set of responses,

which 11.63% of the respondents mentioned as a specific reason for their decision as an expectation of an investment. Long-established, broad market players with a high market capitalization, dominant market players, or those who attractively project stability have been included in this category. As secondary factors at the objective level, sector, diversification, and stability together account for 46.51% of the investment rationale, after which two additional factors emerge as another subjective decision level. This is the (sub)subjective set of decisions that can be formulated as cluster 3, with the two categories of *curiosity* and *return* on investment with equal shares (5.81%).

In the final categorization of justifications, the research represents another set of decisions influenced by human factors, with equal proportions of curiosity (randomness, random, test) and return (yield, profitability) playing a decisive role in the choice of investment. The reason for curiosity can also be explained by the nature of the research, where one can test the practical (albeit hypothetical, but actual) returns of the items chosen without stakes, depending on real market situations. Seen in this way, the choice of elements can easily be justified as a test, and as curiosity, although a small range of decisions is a distinct category of analysis.

The most surprising conclusion is reached after the categorization of the choice of elements, where the return on investment is the last criterion. The result of this research is in stark contrast to the rational investor hypothesis that has prevailed for decades, where the investor always makes his decisions in the context of return versus risk (safety). Returns do not seem to drive investment decisions, and the current research chapter shows that they are the least influential, whereas an investor would be expected to make decisions in the hope of future returns. This result could be interpreted to mean that risk aversion (diversification) rather than profit maximization (return) plays the main role in decision making so that return is much less (equally or not) important than having our money in a (what we perceive to be) good/safe place. This, in turn, implies a longer-term mindset, where security is much more important than actuality or the expected return that can be achieved and grasped. Investors, on the other hand, tend to have a more short-sighted mindset. So it is not by chance – although surprising – that the role of the return expectation highlighted in the research as the ultimate reason (as a conscious behavior), making you believe in behavioral investing.

The research discussed in this chapter shows that investors are more behavioral than return-oriented, where human factors and intuition take precedence above speculation (calculation, rationality). Nevertheless, the

highest subjective level of investment decisions is followed by an objective level of decision-making, which together determines 88% of the factors influencing behavior. An interesting conclusion is that at the bottom there is a further *(sub) subjective level*, which in total is still 11.62% of the decision factors. Only here does the issue of yield/return expectation appear. Thus, the subjective levels (53.49%) are in the majority overall among the factors influencing investment decisions, forming a sandwich around the middle set of objective judgements (Figure 4). The research suggests that investment decision-making is a *rather subjective* matter.

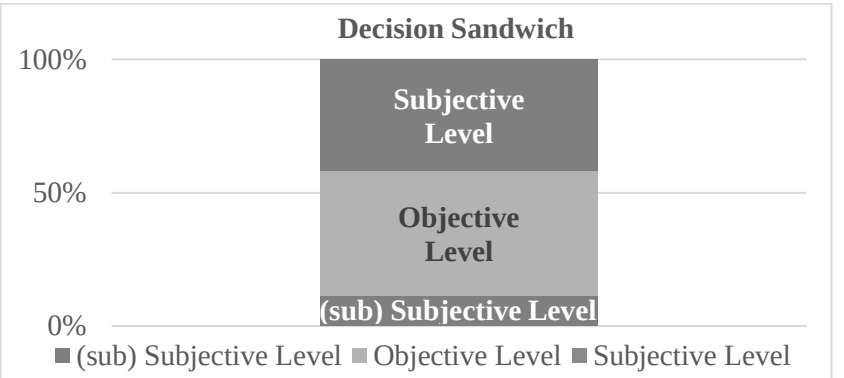


Figure 4. The Investment Decision Sandwich (%).

The Winner

Which portfolio is the winning portfolio? This is a major question in this chapter. A comparison between six different diversifications was completed. The comparison examined the which, who, and why of the winning distribution. Since research participants could decide on their investment mix and focus themselves, completely different or evenly matched results could have been expected. Yet this was not the case at the end of the analysis. Decisive and dominant results concerning the winning formula among the six portfolios were obtained instead. One of the most striking results of the chapter is that the long and short-term analyses showed a *surprising similarity* in terms of winning portfolios (Figure 5). By counting the number of winning portfolios, the differences in long- and short-term diversification strategies can be inferred to determine which of the equal or focused distributions triumphed.

Each research participant formed portfolios and decided on the focuses individually. The following will examine which formula was the winner. The 164 winning portfolios in the study led to conclusive results that reflect similarity over time.

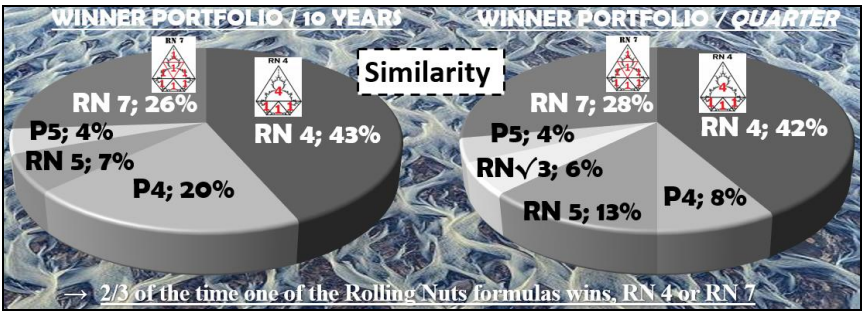


Figure 5. The percentage of winner portfolios.

This chapter constructs six differently diversified portfolios, including three equally distributed (four, five and seven elements) and three differently focused (four and five elements) palettes. Each research participant chose different investment elements and decided individually on the focus setting. Birthdays were included as an individual characteristic in the analysis. The inclusion of these two factors excluded the presence of similarities that could bias the sample. With these conditions, the research investigated which portfolio came out as the winning portfolio for each of the semesters and of the same element-based 10-years investment period. Over the long term, five portfolio distributions emerge as winners and one of the participants in the chapter was not represented at all (RN √3).

Surprisingly, the long-run analysis shows similarities with the short-run results for the winning portfolios, as *RN 4 and RN 7 portfolios emerged as winners in two-thirds of the cases* over the interval studied. Next to them, the permanently allocated four-item portfolio (P4, 20%), the two-focus Rolling Nuts (RN 5, 7%) and the five-item benchmark (P5, 4%) portfolios were the winners. In the short term, all six portfolios were winners, of which Rolling Nuts with four elements (RN 4) was the most profitable, as it was the best distribution 42% of the time. This is a decisive result in itself, namely that the portfolio with the highest proportion of focus (and the fewest elements) over the short three-month horizon was the winner.

The second most frequently occurring winning portfolio was the seven-element equally distributed version (RN 7), which became the allocation responsible for the highest return 28% of the time. The RN 4 and RN 7 portfolios thus proved to be the overall winners two-thirds of the time, while the remaining one-third of the time was shared by the other four distributions. Of these, benchmark 5 was also the least responsible for the highest return (only in one case). The investment items were mainly chosen for the short term by the participants, so the similarity of the long-term analysis did not yield the expected results in the survey. The symmetry system was found to be scalable in determining the winning portfolio; the results of the chapter research confirm that the RN 4 or RN 7 model is responsible for the highest returns in two-thirds of the cases. These are just snapshots, both three months and 10-years investment periods, the different birthdays and also the different investments would allow for a lot of variation, yet there is a similarity in terms of the winners and their proportions – already in terms of the final returns for the periods.

The scalability of the sample analyzed is also demonstrated in the data set used as a survey. This confirms the results of a previous study on a smaller sample where almost half as many (81) samples also show similarities in the distribution of winning portfolios and a two-thirds dominance of the two winning RN 4 and RN 7 portfolios (Cziraki, 2022). Performing the analysis on a larger data set confirmed the same conclusion. The analysis performed leads to the same results even with fewer samples than when performed with many elements; thus, the sample is scalable (in terms of the number of sampling elements included in the analysis). In addition, there is a further short-term analysis of the methodology based on an even smaller sample size, covering a two-month interval at the time of the COVID-19 outbreak (02–04/2020). Although this is based on only 14 processed cases representing only a single three-month interval in the short term, the two-thirds dominance of the twice-winning Rolling Nuts portfolio can already be detected here (Cziraki, 2020).

As proof of scalability, results similar to the initial result are obtained by expanding the number of test items for the winning portfolios. These portfolios may be more detailed but proportionally reflect the symmetry and similarity obtained in the small number of items comparison. An additional limitation of the research is that it only considered the final winner of a single selected period, which could be a different player over the period or over a longer or shorter time horizon. In any case, let us mention the absolute winner, the

Rolling Nuts 4 portfolio, which showed a dominant occurrence over both long (43%) and short (42%) time horizons.

Of the portfolios included in the chapter, the RN 4 is the distribution with the largest focus, with one element represented in 4/7 proportion (57.14%) next to the other three equally distributed components. It could be argued that this is risky, as the performance of the focus element of our choice will have a large impact on the performance of our portfolio. The other portfolios are at most half as dominant in something and many of them are evenly distributed, so this is where we would expect to see fierce competition in terms of the degree of diversification. However, in the case of the winning portfolio analysis, the portfolio with the largest focus emerged as the winner, even though in many cases the focus decision was made on a gut feeling or driven by the curiosity factor. Few elements have a high focus, yet this proved to be the most profitable, so focusing did not prove to be risky at all as this distribution came out as the best return performer in both the long and short term.

It is therefore worth highlighting an element and putting more emphasis on it, rather than trying to keep the elements as close as possible to each other and thus fine-tune the diversification. Diversification is a risk-averse tool, but while excluding risk, one should not forget about sufficient returns, so if both are to be considered at the same time, the best tool recommended by this research is the RN 4 distribution symmetry.

In the analysis of the winning portfolio, few elements with a high focus (RN 4) and many elements, equally distributed (RN 7), prove to be a viable solution in both the short and long term but to draw deeper conclusions, let us look at the specifics in terms of returns achieved.

Yield

In terms of the profitability examined, the winning portfolios of the largest growth and their share are identified. The next phase of the chapter will demonstrate how much each distribution outperformed the other in terms of percentage returns. Figure 6 plots the results against the worst return for both the short and long term. The similarity is also apparent here when looking at the order of the two intervals in terms of yield.

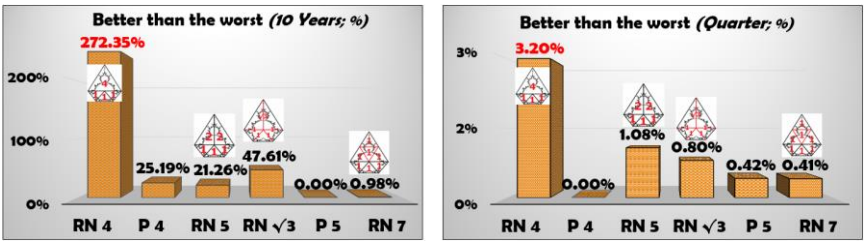


Figure 6. Portfolio return differences by worst performance (%).

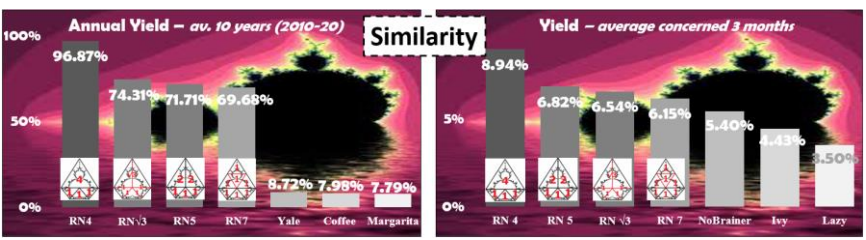
The RN 4 portfolio was responsible for the highest returns in both the short and long term, followed in order by the five-element Rolling Nuts distributions (RN 5 and RN √3). In the long term, the benchmark 4 portfolio is also not negligible, but overall the equally distributed portfolios underperformed the focal structures. These P5, P4 and RN 7 distributions clearly underperformed the focused palettes in terms of returns in the short term and only the few-element distribution showed anything approaching results in the long term. The permanent distributions were responsible for the lowest returns for all distances, so the return results confirmed the importance of focusing. The performance of the RN 4 portfolio is also outstanding.

Although this portfolio has been an outstanding winner so far, this does not indicate that it is a good performer in terms of returns. The previous analysis examined which structure gave the highest return for which portfolio. Nevertheless, conclusions about profitability can be made by reviewing the overall returns. The performance of the Rolling Nuts 4 portfolio is also noteworthy here. RN 4 achieved a 3.2% better return than the worst diversification in the analysis over just three months (that would be an annualized outperformance of 12.8%). The short-term performance of the RN 5 and RN √3 portfolios also shows a surplus of around 1% compared to the worst performance, which in any case does not refute the success of the methodology used.

Over the long term, the performance of RN 4 is even more significant, outperforming the worst (in this case P5) distribution by 272.35%, which would represent an extra return of 27.23% over a year. How we diversify makes a difference because a simple decision at the beginning of the term can multiply our returns. Moreover, the chapter is all about passive investment strategies, where we do not actively manage portfolios during maturity. With active management, these return ratios can undoubtedly change, but the research has confirmed the prominent performance of one of the portfolios

included in the analysis. The portfolios that are not focus-excluded may have results that are close to each other.

From these portfolios, we can conclude that the fewer elements are responsible for the higher returns over the long term studied. The RN 7 portfolios were the most recent winners, consistently ranking second, but when the average return results are aggregated, this distribution does not seem to be a viable solution. While it may be true that this is one of the best diversification strategies (given the winner) with the elements chosen, if we look strictly at returns, we could only find better solutions for investments almost everywhere. While the seven-element portfolio was a winner in many cases, its average return did not appear as high over any of the periods analyzed. This suggests that if it emerges as a winning formula, then a choice of focus will almost certainly enhance this return. There is not much difference between the results of the portfolios without focus, which shows that if we allocate our elements equally, almost no matter how many elements we include, we can expect almost identical returns. By contrast, portfolios with a focus clearly stand out from the field, providing evidence to support this branch of the portfolio management school. Outstanding among these is also the performance of the RN 4 portfolio, which far outperforms the other allocations in both the long and short term. As this distribution has also been a winner with a case rate above 40% and is now showing the best returns, it is worth paying more attention to in the future.



Source: Empirical analysis and Lazy Portfolio (2022).

Figure 7. Annual and three months average return on research portfolios and market participants (%).

In terms of returns, the chapter has so far looked at the percentage differences in performance relative to each other. Let us now turn to the evolution of average (annualized) returns for the 984 portfolios included in the research in Figure 7. The order is in line with the profitability already discussed, so the similarity is equally apparent over time. Averaging the long-

term analysis, we find that the return-winning RN 4 portfolio would have provided an annualized return of 96.87% over the 10-year period, while the next RN √3 would have produced 74.31%, followed closely by RN 5 with an average annualized return of 71.71%.

By putting these returns in a real-world context, they can be compared to the returns achieved by market participants over the same time horizon. The comparison is made with portfolios that are similarly diversified and passively managed compared to the portfolios used in the chapter analysis. We could use any of these types of lazy portfolios as a benchmark – Figure 7 highlights six of these – but to extract the data, it almost does not matter which real market player is the benchmark. The picture remains the same. The 10-year graph of the long-term analysis includes as benchmarks the Yale University portfolio – six items; 30%/20%/15% – (The Yale Investments Office, 2022), the Coffeehouse – seven items; focus 40%, rest 10% – (Schultheis, 2013) and the Margaritaville – three items equally divided – (Burns, 2017) portfolio. What the figure displays is no mistake. Averaging the 10-year performance of the portfolios in the research achieves a value of almost 10-times higher performance than the performance of real market participants. The main reason for this is that the research participants made their investment decisions topically, while the real players were faced with investment decisions in real time. It is therefore in no way authoritative, but only an illustrative representation of the returns achieved.

Nevertheless, what this result proves is that the behavioral investor can easily outperform the investment strategies of large, expert asset managers by listening to their intuition. The data obtained from the short-term analysis can also be used to establish annual returns by extrapolating quarterly results to an annual level (assuming that every quarter would look like this). The research uses data for three quarterly periods and the average returns for these short-term periods are shown in the statement. The returns of the real market participants next to them in the figure show the average results for the same 3-3 months so that they can be worked with real market data for more accurate representativeness. Their diversification is also similar to the chapter sample, representing the No Brainer – four elements equally distributed – (Bernstein, 2017), the Ivy – five elements equally distributed – (Faber-Richardson, 2009) and the Lazy – six elements; 30%/20%/15% – (Swensen, 2005) portfolios.

In the short term, the Rolling Nuts portfolios outperform active market participants in a comparison based on real-time data, with an overall return of 6.15–8.94%. Not a bad performance in three months, especially considering the results of inexperienced novices in the field of investment research. In the

short term, the behavioral *principle of taking a conviction position* (Siegel and Scanlan, 2014) is also *confirmed,* inducing more successful investments than professional investment principles. Second, the success of the research model has already been demonstrated at several levels in the short term and a dominant order has been established among them.

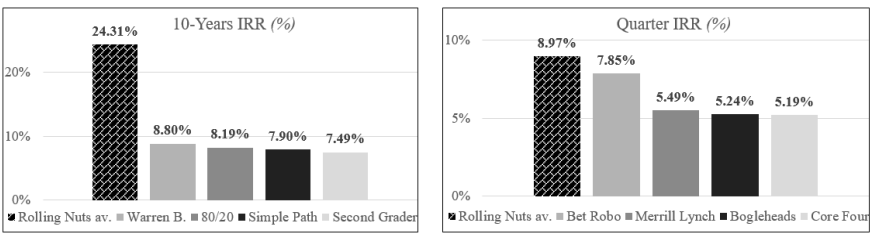
In Figure 7 of the yield statement, a *similarity* between the short- and long-term investment analysis data can be observed and in fact, the same dominance can be seen on the left and right sides of the figure. If, in strict theory, we play with the calculation of extrapolating the short-term results to annual returns – since the RN 4 portfolio outperformed the best performer in the short-term benchmark by 3.5% – this would imply an annualized excess return of 14%. And this annual return, if multiplied by 10 years of the long-term part of the comparison, would result in a 140% outperformance. That would be even more than the 96.87% of the long-term winning return. In terms of ratios, a similarity in the return calculation can be discovered, demonstrating the scalability of the sample and methodology used. Indeed, it should not be the case that the aggregated results of a random 10-year and random 3-3-month period should produce the same order of returns. What we would like to know is which formula is better for the short and long term. The same result and the same dominance in the values of the research return have been observed. The sample proves to be scalable; clear and dominant conclusions within the sample are apparent.

The return projection shows passive investment strategies, even for the three-month interval, as it only had to make a diversification decision and test the assumptions at a specific selected point in time. The more often an investor checks his investments, the more often he makes (often wrong) decisions, and an example of this elimination of the short-term mindset can be seen in the implementation of passive strategies, in full resemblance to the conscious lazy behavior of real market participants. A limitation of the research is that of course many of these 10 (or more) years of data could be lined up side by side to get closer results. In any case, a clear order can be established between the different interpretations of the model underlying the methodology, which was one of the objectives of the chapter research.

Summing up the average of all 656 Rolling Nuts portfolios in this chapter into one number (although it is not a fortuitous thing) can express the internal rate of return (IRR) of the investments. Figure 8 compares the results with the best performing peers in the period, where the quarterly results are the average of the 3-3-month results given, so caveats must be made about the representativeness of the short-term statement. However, over the 10-year

horizon, the Rolling Nuts dominance seen in returns is also evident, outperforming the Best Performers by a factor of three (24.31%). The most successful real market asset managers have an average IRR of around 8%, in order: The Warren Buffett – 90%/10% – (Rodriguez, 2021), the Stocks/Bonds 80/20, the JL Collins Simple Path to Wealth – 75%/25% – (Collins, 2016), and the Paul Farrell Second Grader's Starter (60%/30%/10%) Portfolio.

What the best performer real market portfolios over a 10-year period have in common is that they are composed of two to three components and have a strong focus. In terms of the number of elements, they are a little different from the Rolling Nuts portfolios (a minimum of four elements). At the same time, they demonstrate the importance of focus. The best performer portfolios confirm the empirical evidence from this chapter that "rather" fewer elements and a significant focus is the profitable approach for this passive form of asset management. The IRR calculation compares the average of all four models of the Rolling Nuts formula against the best market benchmarks so that all the occurring versions of the symmetry system can be compressed into one number to show the outperformance of the natural ordering forces in asset management. The excess of the average return from the Rolling Nuts pattern is a surprising result, as it deals with professional asset managers, as opposed to a behavior-oriented (subjective-objective decisions) set of investors.



Source: Empirical analysis and Lazy Portfolio (2022).

Figure 8. Rolling Nuts average versus best performer Internal Rate of Return (IRR).

Focus Groups

The chapter worked with three distinct focus groups of nearly equal size to address aspects of financial culture, such as whether free investment decisions have a demonstrable impact and the role of financial education in subsequent portfolio returns. The first focus group was constrained in the choice of investment elements by stipulating that diversification should be on an

international basis. This is a form of diversification, alongside the triad of asset class, time horizon and industry found in the literature, and it seeks to mitigate risk based on geographical exposure (Wang and McLee, 2011). The second focus group was allowed a completely free choice of items, while the third group was distinguished as a completion with non-economics students. By juxtaposing the average portfolio returns of each focus group with the annual average, some interesting conclusions arise regarding financial culture and investment element choice (Figure 9).

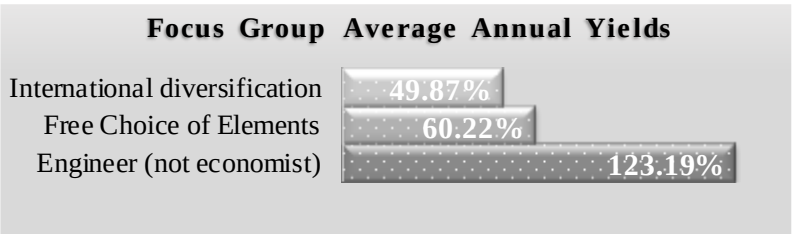


Figure 9. Average annual portfolio returns of focus groups (%).

The statement is based on the 10-year analysis data averaged over the year to separate the sample of 92 people into three nearly equal, well-defined focus groups. The international diversification focus group has reached the lowest average return, with an annualized profit of 49.87%, which includes the returns of 32 main portfolios analyzed. This is not a bad performance in itself, but allowing freedom of choice could further improve this figure to 60.22%, compared to the average annual return of the 30-person focus groups in this analysis. While the acquisition of financial literacy is a legitimate hypothesis that would increase future financial success, the converse was confirmed in the research; that if our vision is not clouded by financial insight, we can double our returns by simple behavioral choice (123.19%).

The third focus group of 30 students, which consisted mainly of engineering and computer science students who had not acquired a deep knowledge of finance because of their studies, exemplifies this behavior. The interests of non-economists (IT) may determine their investment decisions. Compared to other focus groups, they tend to focus on emerging high-tech industries that seem to have yielded higher returns over the last 10 years. In essence, focus group 3 also made a free choice of investment elements, but they clearly did not make these choices as financial professionals but relied even more on their intuition, habits, and preferences listed as reasons for their

decisions. Their vision did not put their investments through a financial lens, yet the result was much higher (double) returns compared to the other focus groups. *In all cases, the behavior-oriented conduct of free element selection outperforms international diversification*, but this can be seen in the focus group results in a distinct way.

It is not worth drawing any deeper conclusions from the data, but rather that this result is due to the fact that the industries chosen have been on an upward trend over the last 10 years, and that those who invested in such industries received higher returns than those who simply spread their risk geographically. Nevertheless, it is an interesting element of the financial culture to observe how the preferences determine the investment decisions and how these manifest themselves in concrete results in terms of returns.

Lessons Learned

The chapter specifically addressed the scope of lessons learned individually as a human factor in financial culture. In the circular process of portfolio management, equal attention is given to the set of lessons learned that can be fed back to improve subsequent decision-making. The current research can distinguish between the consequences of short-term outcomes and the lessons of long-term value, as the investment time horizon has a crucial influence on individual goals, expectations and their fulfilment. Similar findings were drawn for the time horizons analyzed. Only the order was slightly different for each reason (Figure 10).

If we wanted to, we could assume similarity here, but since we are considering a human factor based on a survey, we cannot do so based on less exact results. In addition, by the very nature of the evaluation, it is not advisable to draw a parallel between short- and long-term conclusions, as different lessons for a shorter and a longer period have been drawn. The human factor elements of the chapter are illustrated by the consequence evaluation, measuring the feedback morphology of financial culture that is captured in individuals after the analysis is completed. Nevertheless, a comparison of the lessons learned can also lead to important conclusions regarding the improvement of the methodology used, its future perspective and the scope of possible mistakes and lessons learned.

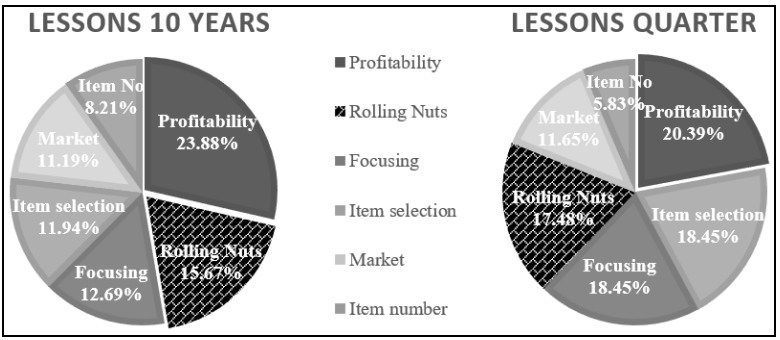


Figure 10. Scope of the lessons learned (%).

Among the lessons learned in six categories, the main lesson learned in the two periods (above 20%) was *profitability* according to the respondents. This implies that the respondents are convinced of the profitability of the methodology and passive asset management as a result of their own choice and research. This is where the financial literacy approach can be seen, and how such research can influence an individual's subsequent inclination towards this form of self-care.

The main lesson (error, report, observation, suggestion. . .) is that this is a profitable thing to do and a change in the individual's attitude appears. Individuals can use this as feedback and conclude further decision situations in their lives. The other four circles of lessons were all inferred in roughly the same way, so there is not much difference between them. Let us look at what they cover. *Rolling Nuts*, as a lesson learned, means that the researcher judged it to perform better than the benchmarks and specifically states this (or some form of it) as the recommended form of diversification. The recommendation of Rolling Nuts symmetry over the longer term was found to be the second most important lesson (15.76%), but this picture is deceptive as it occurred in a higher percentage of the short-term graph (17.48%), only here, other arguments were lined up in favor of it. Therefore, the results should be viewed as a percentage of the total, not in order.

Overall, the second most important conclusion is that the pattern used in the methodology is a recommendable diversification strategy for the future, both in the short and long term. *Focusing* was the third most important conclusion for both periods analyzed, which in its category means that the researcher sees the focus (whether well-chosen or not) as the main culprit for his results. This suggests that the right or wrong focus is the most responsible for the returns achieved. Hence, the lesson for the future is to focus on a well-

placed choice of investment within the selected items. This argument also included the research participants' belief in the fact of focus versus equal allocation, reinforcing the importance of highlighting one element for subsequent success.

A further conclusion was the cause for *item selection*, which also suggested that correct/incorrect item selection was the reason for the results achieved. This also implies that when the participant sees success in better element choice, he or she does not criticize any of the diversification strategies but sees all of them as equally and passively profitable, saying that better elements would have yielded better average returns. Here, they see the lesson of individual choice as an indirect confirmation of the correctness of the methodology used, finding nothing wrong with it for the future. The fifth most common argument, but still above 10%, is that *the market* (sector/stock market) is the cause, with external factors being responsible for the results or causing the change in returns rather than, say, our decisions or how we diversify. This set of lessons implies that one sticks to one's chosen elements and considers portfolio allocations to be successful (passively profitable), and sees actuality as the cause of each outcome rather than the other. Perhaps the strongest attitude here is that neither the choice nor the methodology is subject to criticism, the individual sees their success and is aware that the market's influence is primarily in the actual price of the investments.

Finally, the lessons learned are completed by the rationale for the *number of items*, which is the least but most noticeable conclusion. Under this category, more or fewer elements are explicitly recommended for more successful asset management. The chapter does not distinguish here between the time horizons, the combination of elements, and the recommended number of elements. These could be the subject of a deeper study. However, as a lesson, the number of elements suggests that there is indeed a suitable number of elements for a given investment strategy and that the completer also determines the desirability of having more/fewer elements for his/her elements to increase the returns of his/her choices.

In the evaluation of the data, it was possible to find that seven elements were recommended for the long term, as well as four elements for the long term, but this depends on the composition of the investment basket and is not a specific feature of the methodology. Recommending more or fewer investment elements, on the other hand, also means that no distinction is made between an equal distribution and focusing behavior. The research is also limited at this point, since with the same elements there may be a period where four, five, or even seven elements emerge as winners and the research does

not look at an infinite number of all periods, but only at arbitrarily selected time-points.

Based on the *lessons of the lessons*, three main conclusions can be drawn from the perspective of confirming the research objectives. In order, these are:

1. Passive asset management is profitable (a viable strategy)
2. The Rolling Nuts formula is recommendable (sustainable pattern)
3. The importance of focused diversification (as opposed to permanent allocation)

Conclusion

The chapter examined the rationale for investment decisions, portfolio returns, and the range of lessons learned to measure the mixed elements of financial culture and to identify detectable differences in investor behavior. In terms of investment decision making, subjective factors are the main drivers of our decisions, followed by a further objective level of decision making, and then another subjective level completes the decision palette, with the least important factor being the return of investment. The chapter thus refuted the rational investor hypothesis (Markowitz, 1952) and argued for behavioral investor deportment (Howard, 2014).

In terms of portfolio returns, the decisive result was that in two-thirds of the cases, the two formulas of the Rolling Nuts model (RN 4 and RN 7) emerged as the winning portfolios from the combination of the chosen elements (both short and long term), which makes these two the most recommendable of the six portfolio distributions analyzed. It is noteworthy that the RN 4 model outperforms in terms of returns and winning portfolios in comparison within its symmetry framework.

Of all the models used in this chapter, this one uses the fewest elements, suggesting that the simplest of the correct simplifications is the one to choose, in the same way that nature seeks only satisfactory order rather than building up excessive complexity. The long- and short-term profitability of the methodological formula is confirmed by the demonstration of double-digit annual returns, outperforming real market participants. All this was achieved without any prior stock market training. In terms of portfolio returns, focusing rather than equal allocation is the more efficient way to go. In addition, fewer elements tend to produce higher returns than more elements. All results

showed a *similarity* in the time horizons analyzed, which confirms the scalability of the research formula used.

The most recent Nobel Prize winner in physics was awarded for demonstrating the scalability of systems that make up the universe (Parisi, 2021), and the same scalability (independence of scale) has now been demonstrated in the field of investment by showing that self-sustaining portfolio systems work. The chapter has also demonstrated the universality of the Rolling Nuts symmetry system as a successful self-sustaining investment system based on nature's growth pattern. Through focus group research, the chapter demonstrated that free choice has positive, demonstrable power, which supports the principle of "taking a convictional position" of the behavioral investor and its success. According to this evidence, intuition-based investment decision-making is in some cases (not always) more expedient than rational decision-making based on excessive analysis.

The chapter has made it possible to measure financial literacy in a number of aspects (justification, returns, lessons learned, focus groups), which makes the symmetry model system used as a methodology suitable for future competence development. The research has demonstrated the passive profitability power of the capital market and its practical exploitation, which could pave the way for sustainable asset management, organizational social responsibility, sustainability of pension and other benefit systems, and self-care at the individual and organizational levels. The limitations of the research include, firstly, that the sample of investors included in the study consisted of university students – young, inexperienced participants with no qualifications are over-represented – and, therefore, the generalizability of the results is limited. A further limiting factor in the judgement of the results is that past returns are no guarantee of future returns, so it is more a question of what would have happened if we had invested in such and such a way in the past periods analyzed, and that we tested selected time points in the analysis.

An important prerequisite for General Systems Theory is the synthesis and cooperation of different disciplines and the existence of appropriate model concepts that are general enough to be transferable from one sphere to another. The model explored in this chapter is synthesized as an innovation of such an interdisciplinary critical systems heuristic (Ulrich, 1983), for which alternative concepts are offered in the methodology.

In conclusion, the chapter aimed to put a model on the table of science that can be used safely as a self-care solution, be it for private pension savings, institutional asset management, or financial and organizational sustainability. The successful application of a good model requires that it be easily adaptable

and offer alternatives, which is the only way to make it widely applicable. By being universal, the pattern identified can serve not only as a guideline for portfolio diversification but also as a management procedure offering a sufficient number of alternatives for investment decisions. We can discover a system in portfolio allocations, and we have found evidence of the effective application of a systematic mechanism in the area of asset management. A system of financial sustainability, self-care, passive income and self-sustainability has unfolded before us.

The chapter aims to summarize and provide evidence for a complex whole that frames and systematizes a comprehensive decision-making system of dynamic and strategic portfolio management procedures. Order unfolds before our eyes through the application of the natural orderliness discussed in this chapter in the area of asset management, which we can now safely call proven *financial entropy*.

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Chapter 2

SMEs and FinTech in the European Union: How to Balance Innovation and Regulation?

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Abstract

The growth of technological innovations in financial services – frequently denoted as 'FinTech' or 'digital finance' – is causing concern for regulators internationally, including within the European Union (EU). As the overwhelmingly most prevalent form of business in the EU, SMEs are focal to the emergence of innovative FinTech products, services, and processes. By concentrating on FinTech activity within the EU, the chapter addresses the regulatory factors which must be considered when SMEs are the catalysts for unprecedented developments in finance.

The chapter argues that the fluid nature of FinTech innovation infers that regulation should respond in a flexible manner. In light of the contribution of SMEs to FinTech, the efficacy of certain regulatory initiatives could be understood best by evaluating their suitability for SMEs.

The chapter profiles the current features of FinTech activity in the EU and describes the characteristics of SME digitalisation. The chapter explains how SME innovation and start-up growth dynamics can be integral to FinTech's ongoing rise. The chapter critically evaluates the degree to which contemporary developments in FinTech could be represented as being genuinely disruptive innovation, as the term is defined in existing literature. Innovations introduced by SME firms are more likely to be assimilated into market practices and gradually adopted

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In: Advances in Business and Management. Volume 20
Editor: William D. Nelson
ISBN: 979-8-88697-489-8

by incumbent financial institutions. The types of technologies associated with FinTech are at relatively nascent stages of development. Significant expansion is expected, and regulation will need to respond accordingly.

The chapter considers the various regulatory approaches which are utilised within the EU, ranging from examples such as sandboxes, innovation hubs and accelerators. By focusing on the importance of such regulatory mechanisms for SMEs, the chapter contends that a combined and complementary use of regulatory innovations can be highly suitable for the varied and dynamic forms of SME and start-up innovation in FinTech.

Introduction

It may appear counter-intuitive to suggest that the innovation of small- and medium-sized enterprises (SMEs) in digital technologies should be responded to with enhanced forms of regulation. After all, SME innovation can generate significant economic benefits, can yield greater choice for customers, and can prompt healthy competition within sectors such as finance. However, there are conspicuous challenges which certain innovations are raising, especially in determining the implications for regulators, markets and the wider public. The growth of technological innovations in financial services – frequently denoted as 'FinTech' or 'digital finance' – is one such area which is causing concern for regulators internationally, including within the European Union (EU). As the overwhelmingly most prevalent form of business in the EU, SMEs are focal to the emergence of FinTech products, services, and processes.

By concentrating on FinTech activity within the EU, the chapter addresses the regulatory factors which must be considered when SMEs are catalysts for unprecedented technological developments in finance. SME innovation can be manifested quite differently in FinTech. While technologies may first be introduced through the exuberant dynamics of start-up growth, it may require the extensive resources and market power of incumbent financial institutions and large firms to eventually bring these applications to fruition. Furthermore, there are doubts over the legal effects of particular technologies. The fluid nature of FinTech innovation infers that regulation should respond in a flexible manner.

This chapter argues that flexible regulation is essential, not only to act in tandem with the pace of innovation, but also to adapt to the varying types of firms and institutions which are trialing technologies for use in finance. As there are distinct interactions between SME innovation in FinTech and new

regulatory approaches, the chapter avoids a blinkered perspective of telling the story of typical innovative growth patterns of SMEs, or of simply listing the forms of regulation which are applied in respect of Fintech.

By reference to available data and to empirical studies, Part 2 of the chapter profiles the current features of FinTech activity in the EU and describes the characteristics of SME digitalisation. There are evident opportunities for SMEs to represent the galvanic forces of FinTech innovation. However, there remain patent challenges for FinTech firms, notably related to funding limitations and to the most effective use of resources.

As recognised in Part 3 of the chapter, SME growth possesses distinctive traits. Due to the growth in innovative technologies, start-up growth could be perceived as being 'disruptive' to established practices in finance. The disruption at issue in FinTech could be notional. It may not radically affect market incumbents by displacing existing financial institutions from traditional positions of dominance. Instead, specific technologies are more likely to be gradually assimilated into practices and business models. However, this does not diminish the profound consequences for the provision and use of financial services.

Part 4 of the chapter acknowledges the crucial role of regulation. There is a need to instill clarity for FinTech activities which are becoming defined by their inherent regulatory quandaries. Yet, FinTech regulation must simultaneously be capable of adjusting to the diffuse evolution of an array of technological applications. Regulatory techniques, such as sandboxes, innovation hubs and accelerators, are familiar approaches within the EU. In light of the contribution of SMEs to FinTech innovation, the most telling insights about regulatory initiatives could be garnered by evaluating their suitability for SMEs.

Digitalisation of SMEs: The EU Context

This part of the chapter sets out the current patterns of FinTech within the EU, especially by contemplating how FinTech can be defined, the frequency of EU activity compared to global levels, and the degree to which investment and adoption of advanced technologies are lagging in the EU. It will be emphasised that there are evident opportunities for sustained SME growth through the development of technological innovations in finance. On the other hand, there are challenges – centred on funding and resource management – which can continue to hinder SME–led FinTech innovation.

Current Patterns in FinTech

For an interdisciplinary text and to draw the parameters of what the chapter is portraying, it may be helpful to first provide examples of definitions for FinTech, FinTech firms, and SMEs as understood in an EU setting. One of the most regularly referenced definitions of FinTech is proffered by the Financial Stability Board (FSB), which regards FinTech as "technologically enabled innovation in financial services that could result in new business models, applications, processes or products with an associated material effect on financial markets and institutions and the provision of financial services" (FSB, 2022a). Relatively more recent definitions gravitate towards the purportedly revolutionary promise of the technologies. For instance, Bank for International Settlements (BIS) research construes FinTech in terms of "digital technologies that have the potential to transform the provision of financial services spurring the development of new – or modify existing – business models, applications, processes, and products." These technologies are considered as "the ongoing wave of new" digital financial services (Feyen et al. 2021). A similar definition is expressed in empirical studies produced by the World Bank (World Bank, 2022: World Bank Group Global Market Survey: Digital Technology and the Future of Finance).

As elaborated on in section 3.2 below, the types of technologies which are being carried on the crest of the FinTech wave seem to be continually evolving in their characteristics and uses. Is it possible to neatly decipher the typical features of firms and businesses responsible for instigating such apparently pioneering innovations in finance? To refer to the BIS and World Bank examples, a FinTech firm is simply identified as one that specialises in offering digital financial services to consumers, or which enables other providers to offer digital finance services (Feyen et al. 2021). In addition to being a specialist, the World Bank definition specifies that a FinTech firm is "a new entrant in the financial sector" (World Bank, 2022: World Bank Group Global Market Survey: Digital Technology and the Future of Finance).

As will be argued over the course of the chapter, an array of market players – including incumbent financial institutions and big tech corporations – are capable of flexibly providing digital financial services. It is a reason for why regulation ought to respond in kind by exhibiting a flexible approach towards promoting innovation, while safeguarding financial stability and the integrity of market rules. However, the impact of SMEs, as the predominant form of business in the EU, cannot be underestimated.

For this EU-based analysis, an SME is defined in accordance with the European Commission's Recommendation 2003/361/EC, whereby SMEs include enterprises which employ fewer than 250 persons, and which have an annual turnover not exceeding €50 million and/or an annual balance sheet total value not exceeding €43 million. Within this categorisation, a small enterprise employs fewer than 50 persons and has an annual turnover and/or annual balance sheet total value of no more than €10 million. A micro-enterprise employs less than 10 persons and has an annual turnover and/or annual balance sheet total of less than €2 million. At the time of writing, the preponderance of SMEs is epitomised by the somewhat staggering fact that SMEs constitute approximately 99.8% of all active business in the EU, providing employment for around 83 million people (European Commission, 2022a).

FinTech activity, and digitalisation generally, within the EU is a mixed picture. As exemplified by the World Bank findings, one of the highest concentrations of FinTech activity in Europe is within the jurisdiction which has most recently left the EU. Aside from the United Kingdom, there are significant proportions of FinTech-related activity in Ireland, Finland, Sweden and Estonia (World Bank, 2022: Global Patterns of Fintech Activity and Enabling Factors, Figure 3. Aggregate Fintech Activity Index, p. 24). Even when taking into account the disparities between individual countries, studies consistently reveal that European FinTech broadly is more subdued than the rate at which FinTech is developing in North America. As conceded by the World Bank study, further research can be guided by more granular data (World Bank, 2022: Global Patterns of FinTech Activity and Enabling Factors, p. 57). Attaining coherent data concerning FinTech can occasionally be hampered by uncertainties as to how FinTech activities can even be accurately measured or categorised. To a large extent, the complexity emanates from the expanding and multi-faceted nature of technological innovations.

The European Banking Authority (EBA) has sought to delineate four primary 'clusters' of FinTech activities. The first area of activity relates to credit, deposit and capital raising services. The second cluster is based on payments, clearing and settlement services. The third cluster pertains to investment and investment management services (relating particularly to securities). The fourth cluster encompasses other finance-related activities (such as compliance with know-your-customer or due diligence requirements). As demonstrated in reports from the European Systemic Risk Board (ESRB) (grounded on data from the European Central Bank (ECB) and the Cambridge Centre for Alternative Finance), the proportions recorded for

each respective cluster within the euro area (the EU states which use the euro as currency) are rather even. Firms specialising in the first cluster of FinTech activities amount to 27% of the overall distribution, the second cluster represents 30%, the third cluster corresponds to 20%, and 23% of firms are engaged in fourth cluster activities (Beck et al. 2022, Chart 5, p. 19).

The ambiguities in classifying FinTech activities may undermine efforts to precisely gauge the level to which FinTech has gained traction. Research findings on FinTech are not appreciably altered by empirical studies on wider digitalisation – or, more specifically, the adoption of advanced digital technologies – among EU firms. Since the COVID-19 pandemic, the advent of increased remote working and the prevalence of online communication and transactions, it could be anticipated that a substantial shift occurred in digitalisation of business practices. Findings produced by a European Investment Bank (EIB) survey indicate that about 46% of surveyed firms actively became more digitalised as a consequence of the pandemic. This finding is sharply tempered by a finding that up to 26% of surveyed firms decided not to invest in digitalisation (EIB, 2022, pp. 15 – 16). Furthermore, approximately 20% of firms which are 'non-digital', or which are not significantly digitalised in their practices or business models, reported that digitalisation was not a strategic priority and that it did not warrant any investment plans (EIB, 2022, p. 20).

As illustrated by the EIB findings, the most likely firms to invest in digitalisation are businesses that are already engaged in using advanced or innovative technologies. Because of a managerial focus on nurturing digital skills, there is also a higher probability of these firms providing training to staff. The EIB survey findings reinforce the outcomes of other empirical studies by disclosing the varying trends of digitalisation across EU states, and by assessing that European activity lags behind developments in the US in particular (EIB, 2022, pp. 14 – 18). Other survey findings since the pandemic show that some 75% of US digital innovators are prepared to invest further in technologies in the next five years. This compares to 61% of equivalent European innovators, as access to finance is reported as a major barrier by EU SMEs (Delanote et al. 2022, Figure 4, p. 150). Along with unequal patterns internationally, there are persisting contrasts between individual firms in their willingness and their ability to integrate digital technologies within business activities. The incentives and obstacles for SME digitalisation, and for the adoption of FinTech, are encapsulated by the differences between digital 'adopters', 'natives', and non-digital firms.

Opportunities and Challenges

The vacillation of non-digital firms in diverting funds towards advanced technologies can be quite understandable. For businesses that are more accustomed to technologies, there are two characterisations which have been attached to firms: being either a digital 'adopter' or a 'native'. An adopter is a firm which did not originally have a background in the provision of products, services or processes by technological means, or a firm whose business model is not completely dependent on digital technologies. Adopters can eventually act as enthusiastic proponents of innovations. A digital native can be distinguished from an adopter if the *raison d'etre* of a native is influenced by certain technologies, or if the firm's activities are inextricably associated with technological applications. As summarised by the EIB, a digital adopter is principally concerned with incremental improvements by gradually integrating technology within its business activities. A digital native is more inclined to aim towards scaling up and establishing a market foothold (EIB, 2020).

In light of the technological advancements of recent years, there should be ample opportunities for firms to trial and to implement digital technologies. Making a success of the venture is an altogether different matter. Considering the untested nature of many technologies and issues surrounding economies of scale, SMEs who are intent on digitalisation may find that collaboration, sectoral clusters or hubs, and multi-partner coordination can yield long-term benefits (EIB, 2020). The concept of 'ecosystems' of complementary linkages between multiple SMEs – directed towards activities that are oriented towards fresh innovations and digital technologies – is much more than an idyllic aspiration. The advantages of cooperation between networks of firms and sectors have obviously long been expressed by academics (going back to scholars such as Alfred Marshall and Michael Porter) and industry leaders (Germany's *Mittelstand* being a famous practical example of cross-sectoral collaboration).

When applied to contemporary scenarios, an ecosystem has been defined as "a set of actors with varying degrees of multilateral, nongeneric complementarities that are not fully hierarchically controlled" (Jacobides et al. 2018). The problem which arises – not only in respect of firms who are engaged in FinTech-based activities – is that such intricate support structures do not emerge spontaneously (Jacobides et al. 2018, p. 2263). There can inevitably be a lengthy wait for external political assistance and for sector-driven initiatives if any form of ecosystem is to become embedded.

Until ecosystems are commonplace, there are two distinct challenges – among others – which SMEs can experience when embarking on digitalised innovation. For the purposes of this chapter, the challenges for FinTech SME firms which merit analysis are, firstly, funding, and, secondly, resource management. As discussed in Part 4 of this chapter, these challenges can also decisively affect the choice of regulatory mechanisms which are made available to FinTech firms.

FinTech SME firms are generally reliant on intangible assets, including software, technical expertise of staff, and any applicable intellectual property or patent rights. When SMEs are unable to pledge physical assets as collateral, it lessens the probability of obtaining loans from financial institutions. As evinced in previous World Bank findings, up to 80% of secured loans require collateral through real property, such as buildings, equipment, stock-in-trade, and receivables (World Bank, 2022: FinTech and SME Finance: Expanding Responsible Access, p. 6). Informational asymmetries are heightened when there is an absence of assets over which secured charges can be taken. Banks' creditworthiness assessments must revolve around profiles of a firm's future projections and history (if any). Banks can be justifiably risk averse in extending credit to start-up firms whose business models are primarily focused on technologies which are not sufficiently mature for widespread market adoption. For this reason, banks could favour lending to digital adopters, instead of digital natives, since borrowings could be bundled with other existing (and perhaps secured) loans (EIB, 2020, p. 12).

SMEs that can be classified as digital natives will regularly resort to retained earnings as a key source of funding (ECB, 2022, p. 87). The inability to acquire bank financing may lead these FinTech firms towards other FinTech providers as lending platforms (see Eça et al. 2022). It could be asserted that a virtuous cycle is generated by these interlinkages, which should accordingly promote the growth of FinTech. On the other hand, the vacuum created by an inability to source bank funding can amplify the types of systemic risks and regulatory concerns arising from interlinkages, as further described in section 4.2 of the chapter. Considering the difficulties in finding bank credit and the idiosyncrasies of FinTech firms, it becomes clear that diverse, but specialised, modes of financing are paramount to these SMEs (Anderton et al. 2020, p. 43).

Commensurate with the slower pace of FinTech activity in Europe, there is still a glaring gap between the size of the European market for private equity and venture capital investment and that of the US, though private equity and venture capital have expanded in Europe. The situation has not changed dramatically since the COVID-19 pandemic (see Baba et al. 2020, and

Cornelli et al. 2021). Accounting for merely 10% of global investment, the present European venture capital market is regarded as comprised of small funds, exhibiting a scarcity of late-stage investment in business ventures, and drifting away from institutional investors, such as pension funds (Aghion et al. 2022, p. 37). Ambitious EU policy agendas, such as Capital Markets Union, are striving to spark some impetus in alternative funding for businesses. As of now, the circumspect viewpoint could be that cultivating capital markets is a decades-long undertaking, rather than something which can be realised over a period of years (as admitted by Haskel and Westlake, 2018, pp. 164 – 166, on the transition to equity investment in intangible capital).

As well as financing constraints, FinTech firms' reliance on intangible assets results in an onus being placed on resource management. If SMEs do not possess physical assets, intangible capital can envelop a multitude of possible examples. Even the term itself conveys how investment in intangible assets is notoriously difficult to accurately measure (Corrado and Hulten, 2010). To frame the challenge in practical terms, the management of an SME, which has invested considerably in intangible assets of digitalisation and advanced technologies, will need to utilise its limited resources in as strategic a fashion as possible. The objective of an SME is essentially to gain a competitive advantage in a financial services market in flux. It can be a question of survival for an SME when there are numerous other new entrants, with new technological applications, looking to achieve a similar advantage.

Managerial outlook and governance procedures are seen as increasingly vital for explaining why entire countries are performing more strongly in information communications technology, not just for explaining discrepancies in the productivity of individual firms (ECB, 2020, pp. 131 – 132). As motivated as the management of an SME could be, there are daunting resource-based challenges which are perennially encountered by small-scale businesses. These challenges range from shortcomings in skills and talent, poor IT infrastructure and inadequate processes for data handling, and problems in detecting bias or privacy vulnerabilities in advanced technologies (Tomada, 2022). Rather than being a by-product of the technologies, the difficulties are chiefly rooted in the inherent challenges of running an SME. As noted from the outset of section 2.1 of this chapter, FinTech firms are specialising in specific services towards individual customers. The limitations of FinTech firms are highlighted when adjudged against big tech providers' focus "on developing and/or exploiting digital technologies for non-financial usage, on a massive scale" (Beck et al. 2022, p. 24).

As FinTech firms must have recourse to a restricted pool of resources relative to other SMEs (especially non-digital firms) and to big tech firms and corporations, it could be contended that FinTech is almost tailormade for resource-based views of strategic management theory. As articulated in Jay Barney's seminal work (Barney, 1991), resource-based views provide scope for rationalising how SMEs can thrive in competitive markets by exploiting intangible assets. Barney considered a firm's resources and capabilities as being effectively bundles of tangible and intangible assets, including management skills, organisational processes, and informational knowledge (Barney et al. 2001). It is a perspective which should resonate with how a modern FinTech start-up or SME provider operates. By identifying core elements by which firm resources can be characterised (through value, rareness, (imperfect) imitability, and the likelihood for substitutability), Barney sought to elucidate the meaning of sustained competitive advantage, by which competing firms are precluded from replicating the benefits of another firm's use of resources. Over time, Barney's work also indicated the central roles of ownership, management and governance in developing a firm's resources, particularly in how processes can vary across the life cycle of a firm, whether it is a start-up, a growing business, or a mature firm (Barney et al. 2011).

It stands to reason how academics want to search for a tidy theoretical framework by which FinTech firms' innovative practices can be explicated. The pragmatic criticism levelled at resource-based views by Birger Wernerfelt is as relevant today in intimating that there is "a rich taxonomy of markets and substantial technical and empirical knowledge about market structures," but that "[i]n contrast, 'resources' remain an amorphous heap to most of us" (Wernerfelt, 1995, p. 172). Critiques of resource-based views have claimed that the reasoning is closer to a heuristic, or to guiding principles, rather than a fully-fledged theory. In addition to the vague means by which a firm's resources could be defined, an attempt to ascertain the value of a firm's resources is a subjective endeavour. The bearing of intangible assets on business performance and output will vary from firm to firm. For all of the supposedly transformative qualities of technologies, it should be cautioned that "[m]erely imagining value does not create and capture it" and that "firms will need all kinds of resources to help turn their ideas into reality" (Kraaijenbrink et al. 2010, p. 364).

The reality for numerous SMEs is that specialising and competing within innovative FinTech markets is not an assurance of sustained success. If anything, it is only quite a unique circle of firms which do reach the heights

of the truly sustained advantage envisaged by resource-based view theorists. The label of 'superstar' firms is used to refer to the phenomenon of where a cadre of young firms, active for less than six years, achieve the top 10% of average productivity growth for all firms of the same age (ECB, 2022b, p. 42). The ideal is that it could be such firms who can occupy lead positions within ecosystems of FinTech innovation involving networks of SMEs. Unfortunately, in practice, it can often be the case that the success stories of innovation, by virtue of intangible capital, become responsible for skewing market dynamics and giving rise to monopolies.

'Disruptive Innovation' in FinTech

As analysed in this part of the chapter, FinTech underscores questions as to how 'disruptive' the examples of technological innovation in finance are to existing markets and to incumbents. This chapter recognises that digitalisation and novel technologies are capable of drastically changing financial services. The changes are felt by FinTech firms as market entrants, by existing financial institutions, by big tech companies providing FinTech services, by customers of FinTech applications, and, indeed, by regulatory authorities within the EU and beyond. However, by questioning whether FinTech innovations through start-up and SME growth could truly be regarded as definitively disruptive to market practices, the chapter assesses the implications of innovation by giving an overview of the types of technologies which are presently being introduced to financial services. It will be argued that the legal and regulatory repercussions of these specific instances of FinTech innovations are as pronounced as any transformation of market practices.

Growth Dynamics and the Effects of SME Innovation

As inferred by resource-based views, the growth of SMEs and FinTech firms does not have to be exclusively attributable to first mover advantages. Rather than a FinTech firm being the original instigator of a technological innovation, the use to which a firm puts its (often limited and intangible) resources is the pivotal factor in ensuring survival and profitable growth. From an economic perspective, the growth dynamics of market entrants can be accompanied by the exit of other firms as a characteristic of a healthy and functioning economy.

The Schumpeterian view of ‘creative destruction’ as “the essential fact of capitalism” is being constantly reappraised to account for more contemporary waves of innovations and to analyse the possible fallout from the COVID-19 pandemic. For instance, creative destruction has more recently been described as “the process by which new innovations continually emerge and render existing technologies obsolete, new firms continually arrive to compete with existing firms, and new jobs and activities arise and replace existing jobs and activities” (Aghion et al. 2021).

By contributing to contestability in market competition and to cycles of business entries and exits, start-up businesses have conventionally demonstrated ‘up-or-out’ patterns (Haltiwanger, 2012; Aghion et al. 2021). SMEs are capable of either showing dramatic upsurges, or of struggling to emerge from a valley of death in the early years after establishment (Storey, 1991). Although corresponding rates of business births and deaths are a sombre, but indelible, feature of economies, it is a recurring empirical question as to whether the intensity of start-up innovation during its glorious initial peak can be more radical and more substantial than that of large firms (Aghion et al. 2021, p. 9). As summarised below in section 3.2 in relation to types of technologies, the significance of an innovation may be determined by whether it is a legitimately ‘frontier’ development and not imitative of prior market developments. Economies of scale are also formative to how SME innovation accelerates. As few SMEs have the wherewithal to invest in dedicated research and development units, ‘knowledge spillover’ enables products, processes and expertise to be steadily shared across networks of firms (Audretsch and Keilbach, 2006).

SME growth and innovation are not in doubt, but, when applied to modern FinTech, does this mean that the innovative activities of start-ups and small-scale firms can always be deemed to be ‘disruptive’? It is a phrase which may be commonly linked to heretofore unknown technologies. However, the precise nature of disruptive innovation can be elusive to define and, somewhat unsurprisingly, it is subject to regular misinterpretation. As a theory most famously associated with Clayton Christensen, a succinct description of disruptive innovation is that it is “a process whereby a smaller company with fewer resources is able to successfully challenge established incumbent businesses” (Christensen et al. 2015, p. 46). The deceptive simplicity of this idea is what can lead observers to readily include all forms of new products, services or business models within a sweeping meaning of disruptive innovation.

As explored since the most prominent texts on disruptive innovation (see especially Bower and Christensen, 1995, and Christensen, 1997), the process relates to incumbent firms opting to concentrate on an existing customer base and, in so doing, to ignore fringe groups of customers. Market entrants begin to target this segment of customers, by offering products and services which may initially appear inferior, or less costly, to those of incumbents. By reference to a classic example of the hard disk drive industry, Christensen's work depicts how the products provided by entrants progressively expand across the market. The complacency of incumbents brings about a loss of their pre-eminence in the market. The paradox of disruptive innovation is evocatively synopsised as "a natural-but-ultimately pathological devotion to an existing customer base and a sensible-but-detrimental abandonment of certain market segments" (Christensen et al. 2018, p. 1062).

The theory of disruptive innovation is based on more specific scenarios, or chains of events, than just the emergence of new, bright, shiny, and very unfamiliar processes. As a result, the theory has been criticised for being unable to adapt to varying examples of innovations, including within IT (Markides, 2006). As with many theoretical perspectives – including resource-based views – there is a sense that disruptive innovation, as defined by Christensen and others, is probably best comprehended only when the innovation has already happened. In essence, disruptive innovation theories are weakened by being more suited towards "post hoc analysis of successful cases rather than making predictions" (Si and Chen, 2020, p. 16). Nonetheless, the erosion of Christensen's formulation of disruptive innovation has not prevented other commentators from revisiting its central principles when analysing FinTech.

In her use of disruptive innovation as a framework relevant to FinTech, Iris Chiu considers that it is a process entailing "the creation of new markets and value networks that eventually disrupt existing markets and value networks, displacing established market leaders and alliances" (Chiu, 2016, p. 56). For Chiu, there are three integral components to her conception of disruptive innovation: genuine change, substitutive potential, and structural impact. The outcome of this model of innovation is for "a form of stealthy but dominant substitution" (Chiu, 2016, p. 67). For a theoretical outlook which is criticised for not being predictive enough, the way by which FinTech innovations can almost insidiously permeate through markets, and through established practices, is arguably the most perceptive sense of the kind of disruptive innovation that should be expected.

The competitive advantage which may once be enjoyed by FinTech firms could eventually be undercut as their business models "gradually converge" towards banks and incumbent institutions (Navaretti et al. 2017, p. 9). Competitive instincts may succumb to straightforward, but gradual-paced, assimilation of technological innovations. To begin with, market efficiency can be enhanced by new entrants, before there is a strengthening of the resilience of markets that are "able to play the game" (Navaretti et al. 2017, p. 11). The use of technological innovations by financial institutions for regulatory purposes (such as compliance with reporting requirements), or 'RegTech', is an apt instance of how emergent techniques can be incorporated within present practices.

In the European Commission's 2020 Digital Finance Strategy, RegTech is defined as "a sub-set of FinTech that focuses on technologies that may facilitate the delivery of regulatory requirements more efficiently and effectively than existing capabilities" (European Commission, 2020). Through efficient and cost-effective use of technologies for somewhat mundane, or traditional, functions, RegTech could be the most logical progression from the exhilarating vibrancy of start-up and SME innovation. It may not connote the same exciting qualities as SME innovation involving nascent technologies, but RegTech may be even more transformative in the long run for financial institutions (Arner et al. 2017, and Batista and Ringe, 2021). As analysed in Cambridge Centre for Alternative Finance research, "significant adoption of RegTech is a longer-term proposition that often develops over a more extended time-frame…," but which could be longer lasting, "due to its potential to help regulators adapt to a changing marketplace" (Cambridge Centre for Alternative Finance, 2019, p. 33).

Supervisory authorities, such as the ECB, can become equally adept at integrating technological applications in the performance of their responsibilities. As defined in the Commission's Digital Finance Strategy, 'SupTech' is "a sub-set of FinTech that uses of innovative technology to support supervision" by helping "supervisory authorities to digitise reporting and regulatory processes" (European Commission, 2020). Other than practically changing institutional execution of reporting, compliance and due diligence obligations, RegTech and SupTech give glimpses of additional options for regulation. RegTech and SupTech can demand specialised regulatory responses, whether it is by introducing express legislative requirements, facilitating sectoral standards or codes of conduct, or a combination of these approaches (McCarthy, 2022a).

The adoption of technologies is one blatant means by which ostensibly 'disruptive' innovations are subsumed within current market practices. Instead of displacing incumbents from positions of market dominance, financial institutions could "partner with the new entrants, buy them up partially or totally, or decide to fight them" (Vives, 2017, p. 103). There are certainly merits to mentorship regimes that allow banks to collaborate with FinTech firms. Within the EU, a mentorship regime could be most feasibly operated at Member State level with an institution such as the ECB or the European Securities and Markets Authority (ESMA) assuming an overarching coordination role (see especially the proposal of Enriques and Ringe, 2020). Moreover, in surpassing the challenges noted in section 2.2, partnerships between banks and SMEs may boost the likelihood of funding for FinTech activities. Research has shown that venture capital financing for early-stage FinTech firms increases after mergers and acquisitions involving large banks, whereas there is less probability of funding after a merger and acquisition with a big tech company (Cornelli et al. 2021).

If SME innovation can have more benign effects when aligned with traditional banks, a less benevolent attitude is taken by big tech companies or superstar firms towards the rapid growth of start-ups and small-scale providers. 'Killer acquisitions' of smaller firms can remove any trace of competition and can dissuade subsequent market entrants (Cunningham et al. 2021). The vulnerabilities of competition and antitrust laws and policies have been exposed in many jurisdictions, including the US, as large corporations (or 'TechFins') gained powerful market shares over the past two decades (Philippon, 2019). The continued rise of Google, Amazon, Facebook (now within the Meta platform), Apple and Microsoft can swiftly dampen the ambitions of the most wildly optimistic of FinTech entrants (see Aghion et al. 2021). The sink-or-swim battle for start-up growth and SME innovation may be even more intensified in the modern financial services market. In achieving prominence, digital finance platforms can acquire smaller FinTech firms and impede regional networks or ecosystems (Arner et al. 2022). The concentration of vast amounts of data within platforms can be harnessed to consolidate market share against potential newcomers. In turn, myriad concerns are raised about the control exerted by platforms over customers' data and privacy.

Although theories of disruptive innovation can have dubious predictive purposes, perhaps it is ironically worth appraising what the future may look like for financial services in the aftermath of the latest wave of FinTech innovations. As surmised by the FSB, there are three main scenarios (FSB,

2022b). Firstly, there could be a higher proportion of FinTech firms entering financial services, taking some of the market share of incumbents. Secondly, there could be fewer large incumbents in financial services, due to mergers as much as due to losses of market share. Thirdly, there could be increased incursions by big tech entrants, which may also culminate in partnerships with incumbent financial institutions (given the analysis above, a situation which would offer little room for emergent FinTech start-ups).

An analogous set of three scenarios, developing up to 2030, is discerned in ESRB research (Beck et al. 2022). Firstly, incumbents could continue to dominate, while FinTech firms specialise in niche markets. This scenario is more redolent of the 'pure' theoretical conception of disruptive innovation. However, it should be borne in mind that incumbents are not disregarding technological innovations whatsoever, as evinced by the adoption of RegTech and SupTech. Secondly, incumbents could retrench and conservatively maintain their foothold for certain banking activities, but big tech corporations begin to encroach on the wider financial services market. Thirdly, the financial services world could be utterly remoulded by the introduction of central bank digital currencies (CBDCs), something which would require a convincing level of public acceptance in order to be viable.

Irrespective of the projections for the future of financial services, the talk of radical changes in banking implies that present-day FinTech innovations must be decidedly unique and that the technologies themselves are emphatically ground-breaking.

Types of Technologies

The contemporary development of FinTech may not be equivalent to how disruptive innovation is understood in theoretical terms. However, regardless of how it is labelled, digitalisation and technologies are leading to stark changes in financial services generally. At some point, most research reports, empirical studies, academic commentary, and other work on FinTech, consider a primary question, such as 'Is this time different?' (Beck et al. 2022), or what is special about current technological innovations in finance?

Mainly because of a focus on telecommunications and IT, there is a burgeoning of financial services which are cheaper and conveniently accessible for customers. The drawback is that there can be a proliferation of risks to financial stability arising from innovative services (Beck et al. 2022, p. 12). For academics like Saule Omarova, there are five categories by which

FinTech is "visibly changing the way financial services are delivered and financial transactions are conducted" (Omarova, 2020, p. 87). The scale and scope of technological developments have expanded finance. Services are being made faster. Decision-making is arguably becoming more 'techno-centric', thus raising apprehension over customers' trust in services. There is a consequent impact on transparency and governance within financial institutions. The innately borderless quality of FinTech may be transcending jurisdictional legal frameworks, but it is also blurring the degree to which law can become applicable.

Since the COVID-19 pandemic, there are manifest drivers for the further growth of FinTech and for further digitalisation of financial services. As noted by the FSB, there are supply incentives, including financial institutions' existing digital infrastructure, robust business lines and wide client networks, which are being matched by boundless customer demand for more flexible and efficient services (FSB, 2022b). Although the trends in FinTech usage predated the pandemic, there is no longer the same impression of FinTech being a niche economic concern, albeit a fast-growing one. As reflected in the terms used by the European Commission in its 2020 Strategy, the relatively narrow connotations of FinTech, as largely relating to 'financial technology', have been supplanted by 'digital finance' or 'digital finance services'. The more expansive phraseology signals that there is now a far broader spectrum of financial activities to which SME innovations are contributing.

Even referring to FinTech as an economic concern – disruptive or otherwise – presents its own questions. As with any economic activity, the expectation is that there should be some quantifiable element of output. However, there remains a paradox, as voiced by the economist Robert Solow in the late 1980s, that technical advancements are not being mirrored in productivity figures. During this apparently heady era of innovation in spectacular forms of advanced technology, there is a continuing productivity puzzle as to why increased investment in digital technologies is not demonstrably yielding increased productivity (Aghion et al. 2021, pp. 41–42). Empirical research (through the MICROPROD project) on EU firm-level data affirms that there is little statistical evidence of productivity gains, despite indications that the pace of investment in digital technologies has increased.

A factor which is pinpointed to explain this paradox is that it is simply too early to tell the economic value of certain technologies such as artificial intelligence (AI). There can be mismeasurement of the productivity of digital technologies and a failure to account for the lags in firms' ability to gather information about, and to implement, these technologies (Veugelers and

Warzynski, 2022). Although firms may innovate through experimentation and adoption of technologies, the presence of the usual top-performing firms can distort the levels to which productivity can be measured uniformly across sectors. In other words, it is the most successful of innovative firms which are found to be most engaged in quantifiably productive investment in digital technologies, thereby bolstering their market shares and accentuating 'winner-takes-all' growth dynamics (Le Mouel, 2022).

Assuming that empirical studies will need to bide time before digital technologies' impact on productivity can be witnessed, research can only continue to surmise whether there is a FinTech innovation which could prove to have the status of a General Purpose Technology (GPT) (for example, see Bresnahan and Trajtenberg, 1995) and which could be as authentically transformative to business and society as electricity. As some consolation for those keenly monitoring the momentum of FinTech's development, it is accepted that it can take lengthy periods of time for the substantive effects of a GPT on economic productivity to be revealed. For all of the discourse around FinTech in recent years, "the productivity paradox is not much of a paradox from a historical perspective," though "the particular nature of the current technological revolution has made the mismeasurement hypothesis salient…" (Anderton et al. 2020, p. 41).

If there is one innovation which attracts much of the speculation about its potential as a GPT, it is AI. As essentially the automated and algorithm-based performance of functions that would otherwise be completed by humans, settling on a satisfactory definition of AI is becoming all the more arduous when there is an emerging abundance of variations of machine learning (ML) and advanced data analytics. AI should not be conflated with 'data science' (Petralia et al. 2019, fn. 45, p. 59). For its application in finance, AI can be tailored towards more discrete uses. A training process for an AI programme will necessitate the inputting vast quantities of varied data to establish an algorithmic model. Following this learning stage, the model can then be used for diagnostic and predictive purposes.

Algorithmic models and systems could be used for the preparation of reports on prospective borrowers' creditworthiness following the submission of loan applications. Depending on the specific kinds of data which are fed to an AI model, trepidation over bias and discrimination in algorithmic decision-making cannot be easily dismissed (Buiten, 2019). Legal and regulatory attention is being especially devoted to ensuring 'explainability' of opaque algorithmic processes, the complexities of which may not even be fully grasped by financial institutions and the FinTech firms which are utilising

these systems (as examples, see Buckley et al. 2021, and Lin, 2019). At the time of writing, the European Commission's proposed Regulation for harmonised rules on AI (COM/2021/206 final) is a bold manoeuvre in striving to intervene to construct a framework of rules and standards around this technology, even though it has invited controversy over certain omissions to its scope.

Despite conjecture as to AI's promise for future economic productivity (for example, see Aghion et al. 2021), it remains to be seen whether the widespread use of AI across the financial sector will transpire quickly. As highlighted above, a confined circle of superstar firms could reap the benefits of AI to achieve monopoly dominance. Furthermore, the advanced, or 'frontier', nature of AI signifies that it is a specialised testing ground for private companies. As of yet, here is little spillover of knowledge or expertise to the public (Korinek, Schindler and Stiglitz, 2021). From the SME vantage, only a limited portion of European businesses are able to adopt AI applications. Indeed, EIB research estimates that only one-third of SMEs are using cloud computing or any variation of AI (EIB, 2020, p. 46). The implementation of AI among the preponderance of businesses has not been aided by low rates of equity investment in AI within the EU, relative to China and the US (EIB, 2020).

As with AI, the intrinsic features of blockchain and distributed ledger technology (DLT) enable these technologies to effect comprehensive changes to financial services. As the technology underpinning cryptocurrencies such as Bitcoin (see Böhme et al. 2015), blockchain allows for transactions to be executed, validated and verifiably recorded through networks of participants. In light of the volatile price fluctuations – and perhaps shady overtones – of cryptocurrencies, there is an irony that DLT, as a permissioned form of blockchain system, can be applied to efficiently conduct significant amounts of large transactions between central banking authorities, financial authorities, and customers. Through automated 'smart contract' programming, transactions can trigger entries on a ledger (or blocks on a chain), which must be approved by network participants.

The concept of DLT and blockchain is an elegantly simple one, but there are profound legal issues which can cloud the use of these technologies (Zetzsche et al. 2018). Do network participants have legally enforceable proprietary interests over recorded entries? In the event of a cyber-attack, the hacking of a DLT system and the theft of funds, can participants have recourse through contractual rights? Smart contracts are fundamentally instances of coding and are not orthodox examples of the contractual arrangements which

are studied by generations of undergraduate students of business law (that is, a contract consisting of an offer, acceptance, consideration, and an intention to create legal relations) (Raskin, 2017; Werbach and Cornell, 2017; Wheeler, 2017; Brownsword, 2019).

As a measure of the EU's commitment to construct an applicable regulatory framework for DLT innovations, Regulation (EU) 2022/858 provides for a pilot regime for financial market infrastructures (FMIs) which are using DLT systems for securities transactions. The pilot regime has the objective of affording space for supervised experimentation of DLT. It is primarily designed to assist incumbent operators, rather than start-up SMEs. Nonetheless, it is an important first step towards regulatory recognition of technologies which could be foundational to several aspects of financial services in future (McCarthy, 2022b).

The final example of technologies to be noted in this part of the chapter may not seem as futuristic as AI or DLT. However, the use of application programming interfaces (APIs), data portals, and portable devices for financial services (extending to what is referred to as the 'Internet of Things') are areas in which there are arguably the most momentous changes on an everyday basis for financial institutions, FinTech firms and customers. As EU legislation transposed to national laws, Articles 66 and 67 of the second Payment Services Directive (PSD2) (Directive (EU) 2015/2366) provide for third party access (for payment initiation services and account information services) to the bank accounts of customers, once the consent of bank customers is expressly given. Payment service providers can access data regarding customers' accounts through APIs, which are essentially interoperable bridges for the exchange of data. The FSB has provided a more fulsome definition of APIs as "a set of rules and specifications followed by software programmes to communicate with each other, and an interface between different software programmes that facilitates their interaction" (FSB, 2022b).

Such 'open banking' measures are grounded in the availability of high volumes of data (see the characteristics of big data as identified in EBA, 2020), which can be processed expediently for transactions, increasingly with the use of phones and other portable devices. Open banking can debilitate the dominance of incumbent financial institutions by granting more extensive leeway to FinTech firms as payment service providers. Through rights of access to accounts for payment transactions, an SME does not have to try to directly compete with a bank. There is no longer the need to "wrench the customer completely away from the incumbent" (Feyen et al. 2021, p. 17). The levelling of a financial services field can favour smaller firms, eliminate

the monopolies of regional or local banks, reduce bank revenues, and alter banks' strategies for processing customer data or safeguarding privacy. Open banking can also serve to stimulate further assimilation of technologies into existing practices. Banks are developing in-house technologies, investing in RegTech applications, and, in some circumstances, collaborating in partnerships with FinTech firms (Baba et al. 2020).

Innovations based around open banking and APIs are positive factors for SME growth and market competition. For AI and DLT, it is early days. The rates of adoption are embryonic, but SME innovation around these technologies appears inevitable. When evaluating the effects for financial stability, increased interlinkages across the financial sector can increase systemic risks and the potential transmission of shocks which threaten the stability of the sector. The risks are heightened when large or expanding digital platforms enter the lending market. SME growth would be impaired by the presence of these entrants. An evolution from open banking – involving plain access to bank accounts – to a broader 'open finance' – involving interconnected accounts between banks, digital platforms, and payment service providers – could be a regulatory disaster-in-waiting. The evolution of technologies and applications therefore reveals not only the convoluted breadth of digital finance, but also regulatory problems which are becoming tougher to avoid.

Regulatory Approaches

SMEs can be instrumental to renewed innovation and to maintaining the ongoing growth of digital technologies in finance. However, as indicated above, the potential for latent systemic risks is exacerbated by a plethora of interlinkages across financial services. Regulation does not have to disproportionately interfere with, or stifle, FinTech markets. As will be demonstrated in this part of the chapter, there are regulatory approaches and techniques which can be flexible, but which provide legal clarity. These approaches to FinTech regulation can also benefit long-term SME innovation.

From Sandboxes to Hubs to Accelerators

Several regulatory innovations have become closely associated with the rise of FinTech innovations. Sandboxes, innovation hubs, and accelerators are now

fundamental elements of flexible regulatory approaches within EU Member States and – as epitomised by recent legislative initiatives – in the EU's efforts to devise common standards.

In taking a scientific view of its functions, a regulatory sandbox refers to "a controlled, time-bound, live testing environment, which may feature regulatory waivers at regulators' discretion" (World Bank, 2020a). As well as the similarities to clinical trial settings, another interpretation of sandboxes – which may be consistent with the sanctuary-like connotations of the term – is of "safe spaces in which FinTech start-ups and other innovative enterprises can develop and test their innovations without being subject to the full extent of financial regulation" (Buckley et al. 2020, p. 56).

As an indication of regulators proactively adapting their stances to new forms of innovation, academic commentators have argued that "the regulatory sandbox deserves to be lauded as an inspired feat of regulatory inventiveness, providing holding space for disruptive technologically-driven innovation to be tested at a micro level under the benign watch of a financial regulator" (Ahern, 2021, p. 404). By enabling products to be tested with real customers and without the same rigorous requirements which apply to regulated firms, the end results of sandboxes are just as important for regulatory authorities as the participating firms. Regulatory strategies can be trialed, understanding of new technologies can be gleaned, and training grounds for future regulation can be formed (Allen, 2019).

A typical eligibility criterion for entry to a sandbox is that an applicant should demonstrate that its product, service or process is genuinely innovative, or that it cannot be likened to any existing application in the market (see ESAs, 2018, and World Bank, 2020a). Even though innovation is at the forefront of the design of most sandboxes, ascertaining what innovation is in any given case is not a simple exercise. A subjective evaluation of what is 'innovative' will need to be undertaken by the authority overseeing a sandbox. This assessment will usually be based on information furnished by the applicant (ESAs, 2018, para. 60). It would not be harsh to question whether many regulators have sufficient expertise, skills or familiarity with differing kinds of technologies to make judgment calls as to the true measure of an application's innovation (Allen, 2019, pp. 624–625).

Sandboxes provide participants with trialing periods which generally range from six months to two years (World Bank, 2020a, p. 22). At one level, the time frame for protected experimentation can be a welcome haven in which innovative ideas can be progressed and realised. The danger is that a lengthy period of sandbox testing could lead to risks of regulatory capture where the

relationship with regulatory authorities becomes overly close and can influence decision-making (Allen, 2019, Chiu, 2017, and Tsang, 2019). As reiterated below in section 4.2, FinTech firms could also be ill-prepared for the realities of market competition following an exit from the insulated comforts of a sandbox.

If a sandbox is a comparably more formal route within regulatory approaches which are characteristically lenient, an innovation hub is a less intensive initiative of 'cautious permissiveness' (Zetzsche et al. 2017). A hub – or an innovation office or lab, depending on the jurisdiction – "can provide a dedicated point of contact where firms can raise inquiries with competent authorities on fintech-related issues or seek nonbinding guidance on regulatory and supervisory expectations, including licensing requirements" (World Bank, 2020a, Appendix 2). As a relatively *laissez-faire* option, the capacity for non-binding guidance is rudimentary to an innovation hub. This guidance largely pertains to the conformity of products, services or business models with licensing and regulatory requirements (ESAs, 2018). Both descriptions give the impression that FinTech firms are learning and benefiting from the advice of specialist teams within designated units – almost akin to sophisticated call centres – of regulatory authorities or central banks. In practice, as with sandboxes, regulators are learning just as much about technological innovations and, most importantly, the technologies' compliance with existing legal frameworks. In effect, hubs constitute 'information exchange regimes' between FinTech firms and regulatory authorities (Mansilla-Fernández, 2017).

Sandboxes and hubs are methods by which regulators are taking graduated steps towards addressing concerns surrounding FinTech innovations. Accelerators are examples of where private firms take the initiative to engage in testing through collaboration with other sectoral groups and with central banking authorities. Accelerators are predominantly funded and run from within the private sector. Once plans are set in motion to trial certain applications, regulators and central banks could formulate programmes to sponsor testing and, in so doing, to build cooperative links with the most innovative firms in the private sector (Mansilla-Fernandez, 2017). As FinTech activity gradually becomes more concentrated within jurisdictions, two distinct categories of accelerator are materialising. 'Industry' accelerators are exclusively private-led initiatives. 'Regulatory' accelerators are when regulatory and supervisory authorities engage in structured collaborative programmes, which can be suited to established or late-stage firms within

more mature FinTech markets (for example, see World Bank, 2020b, pp. 38–39, Table 3).

Across the EU, innovation hubs are highly prevalent since the creation of the first hub in Luxembourg in 2014. Sandboxes are increasingly being adopted by individual states, whether as mechanisms with general eligibility requirements, or with a focus on promoting innovation, or by being dedicated to particular types of technologies (for examples of studies charting the establishment of hubs and sandboxes, see ESAs, 2018; Cambridge Centre for Alternative Finance, 2019; and World Bank, 2020a). The rate of usage of accelerators is reliant on the state of financial services markets within jurisdictions and the degree to which central banks are prepared to engage in coordinated collaboration with private firms (with exemplary programmes being launched by the Bank of England and Banque de France). As a means of deepening knowledge and expertise across the EU, the European Forum of Innovation Facilitators is a joint platform for supervisory authorities to meet regularly and to share experiences arising from the regulatory treatment of FinTech (EFIF, 2022). The EU Digital Finance Platform (not to be confused with big tech platforms that are engaged in lending services) provides an updated database of innovation facilitators (primarily sandboxes and hubs) (European Commission, 2022b).

The prospect of further implementation of sandboxes in EU Member States is advanced by the Commission's proposed Regulation on harmonised rules on AI. Title V of the legislative proposal provides for measures in support of innovation, comprising of AI regulatory sandboxes. Small-scale providers and start-ups are to be afforded priority access to the AI sandboxes. Although start-ups are not explicitly defined in the original proposal, small-scale providers are deemed to be the equivalent of micro or small enterprises within the Commission's Recommendation 2003/361/EC, as referred to above in this chapter. The proposal makes provision for organising "specific awareness raising activities" relating to the proposed Regulation which are "tailored to the needs of small-scale providers and users" (Article 55(1)(b)) Where appropriate, there should be a "dedicated channel for communication" with small-scale providers and users and innovators to provide guidance in respect of queries about implementation (Article 55(1)(c)). The fees for assessing the conformity of certain AI systems are to be reduced in proportion to the size of small-scale providers, when taking into account their specific interests and needs (Article 55(2)).

The fact that the EU's primary legislative effort to address AI regulation gives such considerable attention to small firms has been noted by

commentators (Tomada, 2022, p. 64). In combination with the pilot regime for DLT FMIs, the AI Regulation proposal illustrates a drive towards placing regulatory approaches to trialling and testing innovations within a standardised EU framework. It also signifies that the efficacy of these regulatory approaches can be determined by their suitability for SME interests.

Suitability for SMEs

In light of the challenges confronting SMEs that are described in section 2.2 above, there are significant ancillary benefits which are linked to forms of FinTech regulation. For example, research findings have disclosed that participants in regulatory sandboxes have attained a 15% average increase in the capital raised following entry. It should be cautioned that these results were in the context of a relatively small sample size of FinTech firms (Cornelli et al. 2020). Although the findings on market competition can vary between jurisdictions, statistics based on the UK Financial Conduct Authority (FCA)'s sandbox show that 40% of start-ups who participated in the first cohort of sandbox testing attracted investment either during or after the duration of the trialing (World Bank, 2020a, p. 36, and FCA, 2017).

A sandbox can attest to the credibility of a FinTech firm which is testing genuine innovations. This can consequently draw investors' attention, especially for venture capital and private capital, given that creditworthiness can be more arduous to demonstrate when applying for bank funding. However, irrespective of the advantages of regulatory supports in increasing the possibilities for financing, there are grave risks for firms after exiting sandboxes. After enjoying a sandbox's protection from the scathing winds of vociferous market competition, there is evidence to show that a substantial proportion of young firms are no longer operational, or are insolvent, or are acquired, after participating in previous cohorts of the FCA's sandbox (Buckley et al. 2020, p. 57). In all, there remains a need for concrete evidence as to how successful, or not, sandboxes are in facilitating the market entry of innovative new firms (World Bank, 2020a, p. 31).

As referred to in section 4.1 in relation to accelerators, sponsorship of private sector-led initiatives can be especially suitable in jurisdictions where FinTech activity is already well established. Nonetheless, the presence of appropriate regulatory initiatives can encourage increased partnerships between incumbent banks and FinTech firms or start-ups (see Allen, 2019, p. 591). To reiterate an argument from the prior parts of the chapter, the

innovations which are being harnessed by FinTech firms do not have to be categorically 'disruptive'. Accelerators, sandboxes, and innovation hubs are helping FinTech firms in receiving recognition for their business models and in fostering closer collaborative links with existing financial institutions.

A key premise of this chapter is that an amalgamation of regulatory approaches can strike the balance between setting conditions for SME innovation and for guaranteeing clarity about applicable regulatory frameworks. There is no one example of a regulatory technique which can be a magic formula. Research findings do point towards innovation hubs as being the main sources of support for more FinTech firms than sandboxes and accelerators combined (World Bank, 2020a, p. 31). There is a highly persuasive argument to be made that "[w]hile sandboxes tend to attract the headlines and attention," hubs are responsible for "the real work" of facilitating innovation in "virtually all jurisdictions, where it does occur…" (Buckley et al. 2020, p. 59). As elaborated on through advocacy for regulatory ecosystems for FinTech, Buckley et al. assert that sandboxes do not operate as effectively without there being wider supports for start-ups, including hubs (Buckley et al. 2020). Just as interconnected networks are conducive to business innovation, broader webs of regulatory options can be especially conducive to diverse SMEs within the EU and in jurisdictions internationally (considering the frequency of SMEs relative to all other businesses).

The importance of a balance between innovation and regulation can be explained by an SME's desire to be assured that there are incentives to continue to experiment with fresh innovations, while also being comfortable in the knowledge that its activities are not contrary to relevant laws and regulation. By their very format, regulatory approaches such as sandboxes and hubs are geared towards finding some feasible balance. As expressed by Chris Brummer and Yesha Yadav, "[s]andboxes and innovation hubs can provide rules simplicity and financial innovation" by offering "a relaxed compliance regime for innovators" and rationalising regulation "when experimentation shows certain rules to be unnecessary." However, for Brummer and Yadav, markets can be exposed to harmful risks from these regulatory approaches, thus exemplifying an innovation 'trilemma', based on three angles of market integrity, regulation and innovation (Brummer and Yadav, 2019, p. 295).

A comparable trade-off – in respect of policies relating to digital transformation in finance – is evaluated by the World Bank, in the form of a pyramid bordered by concerns of stability/integrity, privacy/consumer protection, and efficiency/competition (World Bank, 2022, Fintech and the Digital Transformation of Financial Services: Implications for Market

Structure and Public Policy, Figure 12, p. 37). As regulatory approaches are calibrated towards safeguarding innovation and maintaining legal certainty, there are wider risks to the integrity and stability of financial service markets that could be posed by discretionary, or very 'light-touch', attitudes to regulation.

As reflected in Hilary Allen's analysis of regulatory sandboxes, experience of principles-based regulation can be used to inform the design of sandboxes and other approaches. Yet, this does not have to be an endorsement of a broader normative argument favouring principles-based financial regulation over strict rules-based approaches (Allen, 2019, p. 583). Principles-based regulation in finance can conceivably allow for flexible, but measured and pragmatic, case-by-case assessments, which can be steered by guiding standards (for example, see Black, 2012, and Black, 2015).

A principles-based approach should seem highly apposite to FinTech regulation. However, in view of the systemic risks that can surface from FinTech innovations, there is still scope for sandboxes and other regulatory modes to be enhanced by additional layers of rigour, by objective procedural requirements, and by structured methods of collecting accurate data on the outcomes of sandbox testing for FinTech firms and start-ups following their exit from the sandboxes (McCarthy, 2023). These improvements can be as straightforward as ensuring more definite eligibility criteria for prospective entrants. The criteria could be stated in a manner that does not unduly deter SME firms' appetite for engaging with sandboxes, but which also reduces fears about lax procedures being abused by risk-intensive firms and activities.

A balancing act is obviously not an easy thing to accomplish, particularly in the EU. As Deirdre Ahern admits, there is an apparent regulatory lag within the EU, even though the position is far from static, because the EU is "in the early stage of a transitional phase where the regulatory perimeter for FinTech is being clarified" (Ahern, 2021, p. 399). Moreover, for sandboxes specifically, these regulatory approaches "have to incorporate a certain amount of latitude – of necessity, much has to come down to common sense exercise of discretion and judgement…" (Ahern, 2021, p. 422). If there are problems in finding a balance or a trade-off between innovation and regulation and in being cognisant of the impact on market stability, the formation of a common approach across the EU is itself "a more delicate exercise than would usually be the case" (Ahern, 2021, p. 422). Nonetheless, as evinced by the provisions for sandboxes within the proposed AI Regulation and by the establishment of the pilot regime for DLT FMIs, there could be signs of progress towards convergence. These developments are along the lines of

'guided' frameworks, such as sandboxes operated at Member State level, but which are subject to coordination or oversight from central EU agencies (Ringe and Ruof, 2020).

In comprehending the potential for systemic risks, it should be admitted that SMEs, as FinTech firms, are capable of contributing to a 'disaggregated', or fragmented, financial system. Due to the sheer numbers of SMEs, differing in size from micro to the largest of the medium firms, there is a disparate kaleidoscope of FinTech-related activities which firms can engage in. As particularly demonstrated through open banking and payment service providers' links to banks and other providers, webs of interlinkages can soon become pervasive across financial markets.

The cumulative risks arising from interconnections between FinTech SMEs can endanger the stability of the financial 'system', as regarded by Steven Schwarcz as consisting of components which add to overall market functions. For Schwarcz, law's role (and, indeed, that of regulation) is to correct market failures that impair the ability of firms and markets to perform their functions (Schwarcz, 2016a, p. 1469). As articulated by Schwarcz in other writings, chaos theory can also be instructive in realising that the more complex a system is in its dynamism, the more likely, or deterministic, it is that market failures will occur (Schwarcz, 2016b, p. 45). Amidst technological innovations and other instances of change, the present-day financial system generally is "a dynamic and complex ecosystem" (Awrey and Judge, 2020).

As outlined in Part 3 of this chapter, SMEs are certainly playing their part in this dynamism, and the complexity is being furthered by the interdependencies across FinTech activities. However, do these processes of change need to be greeted with a foreboding of some imminent systemic collapse? Emilios Avgouleas reckons that finance in its entirety is "nothing more than a long chain of innovations leading to development of novel financial products and processes used to improve allocation of capital and risk management" (Avgouleas, 2015, p. 660). If the evolution of finance is as historically natural a process as envisioned by Avgouleas, these sequences of innovations deserve to be facilitated and not hindered.

Certainty and simplicity of regulation can be complementary to innovation. As argued in this chapter, a combined approach could be most effective for SMEs, involving sandboxes, hubs and accelerators. Instead of fixating on SMEs as the harbingers of systemic failures, the most ominous challenge for regulators in future years could be from increased 'platformisation' of digital finance, characterised by dominant market actors with access to vast quantities of customer data (Arner et al. 2022). It is to be

seen whether the EU's plans for a Digital Markets Act and a Digital Services Act will adequately place restraints around big tech platforms who are best positioned to exploit monopolistic opportunities. Even when it is not quite definitively 'disruptive', SME innovation in FinTech should not be alarming for regulators. There may yet be bigger concerns to monitor.

Conclusion

This chapter has argued that regulatory approaches towards FinTech should be flexibly constructed, so as to adapt to the flexible and multi-faceted nature of technological innovations in financial services. This flexibility can be particularly suited to the features of SME and start-up innovation in FinTech.

The chapter began by setting out patterns of digitalisation and FinTech activity within the EU. The fluid development of FinTech innovations was described, while recognising that the rate of FinTech growth in the EU has not been the same as international counterparts. The current state of FinTech presents opportunities and challenges for SMEs. As trends towards digitalisation have become even more ingrained following the COVID-19 pandemic, the contribution of SMEs to FinTech could be enhanced through collaboration and interlinked business networks or ecosystems. However, compared to other SMEs, FinTech firms experience difficulties in obtaining funding and in effective management of resources.

The chapter proceeded to explain how SME innovation and start-up growth dynamics can be integral to FinTech's ongoing rise. Although technologies in financial services are regularly labelled as being disruptive, the chapter critically evaluated the degree to which contemporary developments in FinTech could be represented as being genuinely disruptive innovation, as the term is defined in existing literature. Instead, the innovations which are originally introduced by SME firms are far more likely to be assimilated into market practices and gradually adopted by incumbent financial institutions. There is also the probability that SME-led innovations are eventually used by certain firms and platforms to consolidate their escalating dominance.

When assessing the types of technologies associated with FinTech, the chapter appraised that financial services markets in the EU, and internationally, are in the midst of profound changes arising from digitalisation and FinTech. However, the extent of adoption for some advanced technologies remains nascent (particularly among SMEs). The

impact on economic productivity is not yet being borne out. Notable aspects of FinTech are therefore at early phases of development, but it signifies that expansion is expected in future years and that regulation will need to be able to respond accordingly.

The chapter considered the various regulatory approaches which are utilised within the EU, ranging from examples such as sandboxes, innovation hubs and accelerators. The chapter identified the characteristics of each of these approaches and their respective merits and weaknesses. By focusing on the importance of such regulatory mechanisms for SMEs, the chapter contended that a combined and complementary use of regulatory innovations can be highly suitable for the varied and dynamic forms of SME and start-up innovation which are becoming manifest in FinTech.

There are potential systemic risks for financial stability which arise from interconnections in the activities of innovative SME firms. Although there are undoubted difficulties in settling upon uniform EU rules and standards, systemic risks can be addressed by a prudently balanced outlook to applying differing forms of regulation where appropriate. By flexibly using sandboxes, hubs and accelerators, FinTech regulation can avoid a pitfall of being preoccupied with one method. It can also enable regulation to adjust to other possible issues in future which are beyond concerns relating to SMEs as FinTech firms. There are specific concerns involving large digital finance platforms with data-based monopolies.

The promise and optimism of innovation should not be unduly obstructed or reacted to with regulatory panic. Innovations and technological advancements are consistently refining financial services, thereby producing economic and societal benefits. SMEs are essential to the fabric of such innovation, but the manner by which FinTech has developed has led to an interwoven and complex fabric in a time of digital transformation in finance.

As someone who lived during a truly revolutionary era, William Wordsworth once described ‘hopes’ in terms of “a spider’s web adorning / In a strait and treacherous pass” (‘Hopes, what are they?’). The preponderance of SMEs across the EU means that there is always a substantive scale to SME growth,, but interlinkages of activities and business networks are astonishing facets of the modern growth of FinTech. Anxieties over ‘treacheries’ resulting from systemic risks do require an emphasis on suitable regulation. Yet, regulation needs to be balanced with an acknowledgement that the intricacies of innovation are what propel the future progress of financial services in the interests of customers, market institutions and wider economies. It is a balance which the EU – and jurisdictions across the world – will continue to struggle

to accomplish, for as long as finance is being shaped by technological innovations.

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Chapter 3

How Do Interest Rates Effect Consumption in the UK?

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Abstract

The aim of this study is to model the effects of interest rates on consumption within the UK economy to allow for a clearer understanding of the relationship between these two variables at hand and how this relates to the current economic literature. This paper also explores the causal effects of other independent variables on consumption and whether they have a significant impact or not. This topic is addressed by using a range of economic models, using Stata and EViews, to explore the full relationship of the variables at hand and how they impact consumption.

This paper provides an understanding of the timing and the effectiveness of changes in the interest rate that influences consumption. A greater understanding of the relationship between these two variables can be very important to the use of the monetary policy that the UK government uses within their economy.

Keywords: consumption, interest rates, macroeconomics, time-series

JEL Classification: C01, C12, C32, E20, E40

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In: Advances in Business and Management. Volume 20
Editor: William D. Nelson
ISBN: 979-8-88697-489-8

Abbreviations

AHP	Average House Price
CONS	Total Consumption Expenditure
DGS	Durable Goods Consumption
GDP	Gross Domestic Product
GNI	Gross National Income
INF	Inflation Rate
NDG	Non-Durable Goods Consumption
RIR	Real Interest Rate
TBD	Total Bank Deposits
UNR	Unemployment Rate
RIRT	Lagged Real Interest Rate.

Introduction

The central concern in macroeconomics is the effect of interest rates on consumption.

Consumption is defined as the total expenditure of goods and services in an economy over a particular time period. Consumption is impacted by many factors, with the main being income. When income decreases, it is expected that consumption will decrease and vice versa, through the marginal propensity to consume.

The movement of money within the economy is depicted through the circular flow model. Movements of money within the economy occur between firms and households.

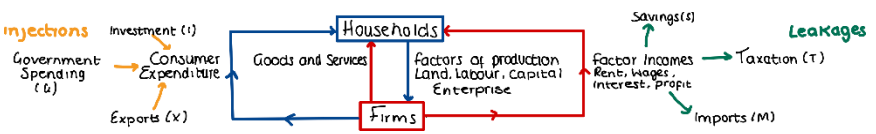

Figure 1. Circular flow of income.

From the circular flow model, we can infer several things:

1. If $I + G + X > S + T + M$ then economic growth increases.
2. If $I + G + X < S + T + M$ then economic growth decreases.

3. If $I + G + X = S + T + M$ then economic growth is stationary, therefore in economic equilibrium.
4. Aggregate demand is the total expenditure on all goods and services within the economy, within a particular period.
5. The growth of the economy is calculated by measuring GDP.

The circular flow model aids the understanding of how consumption changes due to influences on consumer demand. Consumer demand can be altered through the implementation of fiscal and monetary policies within the economy. The monetary policy uses the influence of interest rates to control the money available in the economy and promote sustainable economic growth. This is commonly used by the central bank, in this case, The Bank of England. Interest rates are the amount that is charged when you borrow money. This is also known as the reward of saving and the cost of borrowing. The consumer must decide between two decisions: spending or saving which is largely influenced by the interest rate. When The Bank of England sets the interest rate high, saving is encouraged, and there is a high return for saving your money. On the other hand, when the interest rate drops, the incentive to save decreases, leads to a rise in the consumption level in the economy.

As stated previously, the government uses a range, often a mixture, of monetary and fiscal policies in the economy to influence consumer demand. By influencing this demand, the policies can control GDP, high demand creates a higher output increasing GDP, and therefore influence the growth rate. The aims of these policies are to maintain a steady growth rate and attempt to keep the inflation rate to a target of 2%.

Research Objectives

This study will investigate the impact of interest rates on consumption and other variables that have influence over, as suggested by previous empirical studies and theories.

The objective of this study includes:

- To determine whether interest rates influence the consumption level in the United Kingdom or not. This is completed by testing against this hypothesis:

  - H_0: $\beta_1 \geq 0$ There is no inverse relationship between the real interest rate and the level of consumption in the UK.
  - H_0: $\beta_1 < 0$ There is an inverse relationship between the real interest rate and the level of consumption in the UK.
- To determine to what magnitude to which the effect takes place and
- To determine if there are any other variables that affect the level of consumption in the United Kingdom.

Contributions

The central concern in macroeconomics is the effect of interest rates on consumption. This is because the government utilities the monetary policy in order to control aggregate demand and influence consumption. This study will widen the knowledge regarding the effects of the interest rates on consumption, which can be useful when deciding which polices will be implement in the UK economy to control aggregate demand.

This paper looks at the different variables that also influence consumption. This contributes to current literature regarding this topic. Most of the previous work is theoretical, based in common economic knowledge. This study will look at empirical analysis of these variables and provide numerical results based on past data in the UK.

Structure of Research

Firstly, this paper will look at previous literature relating to the study, providing an overview of how this links to the study at hand. The second section of this paper will focus on econometric methodology, explaining why it has been chosen and why it is appropriate for this type of study. The third is the results of econometric modelling, explaining these findings and how it relates to previous work. Next, the conclusion, overall summarising the findings from this study and whether they confirm or deny previous literature findings. Finally, suggestions for further studies. These are statements that future researchers should consider before conducting further research on this topic as this can improve their findings.

Literature Review

Consumption is defined as the value of goods and services bought by a household. As it is the main component for calculating GDP, it is a very strong indicator for measuring growth.

The Keynesian view on consumption was established in the first consumption function he produced in 1936 with Keynes's General Theory of Employment and Investment. The consumption function was defined as follows:

$$C = \alpha + \beta Y$$

where C=consumption, α = autonomous consumption, β= marginal propensity to consume and Y= disposable income.

This equation shows that the Keynesian consumption function is built on the relationship between disposable income and consumption.

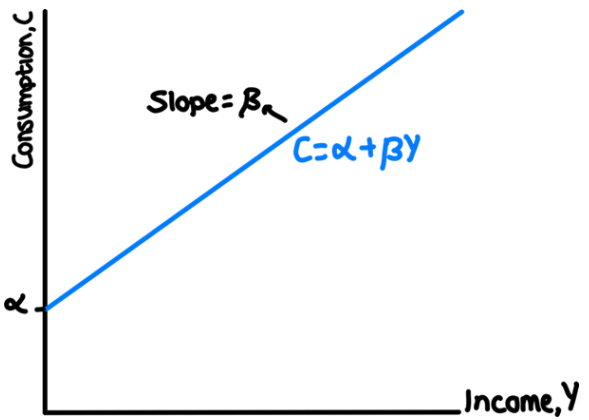

Figure 2. Consumption function.

Figure 2 is the graphical representation of the consumption function. Consumption has a positive relationship with income: as disposable income rises. Keynes says that if income rises by 1, consumption will also rise but by less than 1. This is because the elasticity of consumption with respect to disposable income is positive but less than 1. The slope of the curve is known as the marginal propensity to consume, β, this shows how changes in current disposable income led to changes in current consumption. MPC has a value of

less than one as all additional income that is earned by the consumer is consumed. When β takes a high value, current consumption is more sensitive to current disposable income, when β is low, consumption smoothing has a greater effect. Consumption smoothing is where consumers optimise their standards of living by implementing a balance between spending at different stages in their lives.

In Keynes's theories, he suggests that β decreases overtime meaning that consumption will eventually slow down when disposable income reaches a high amount. This view is challenged by Simon Kuznets (1976), his theory shows that the relationship between consumption and disposable income is stable from decade to decade, there is a constant relationship between these two variables. The Keynesian view of consumption suggests that income is the main component of consumption instead of interest rates. There are also suggestions that say that a change in disposable income will immediately cause a change in consumption without a time-lag.

These views are challenged and criticised by other economists.

First is Fisher (1957), he argues that current consumption depends solely on the present value of lifetime income this is because consumers try achieving smooth consumption. The timing of income is irrelevant, consumers can borrow and lend between periods. For example, a consumer learns that future income will increase. They can spread the extra consumption over both periods by borrowing in the current period. If they face liquidity constraints, they may not be able to increase current consumption. Suggesting that consumption may behave in the Keynesian theory but forward thinking and rational.

Next is Modigliani (1950) who modelled the life-cycle hypotheses, whereby income varies systematically over phases of the consumers life cycle. Lifetime resources are defined by the following equation:

$$w + RY$$

where w = initial wealth, R = number of years until retirement and Y = annual income. As income varies over a consumer's lifetime, a consumer will choose a level of consumption that obtains smooth consumption over the course of their lifetime.

In order to achieve smooth consumption, a consumers lifetime resources are divided equally over time using either of these equations:

$c = \frac{w+RY}{T}$ or $c = \alpha w + \beta RY$ where: T=lifetime in years, $\beta = \frac{R}{T}$, marginal propensity to consume from income and $\alpha = \frac{R}{T}$, marginal propensity to consume from wealth.

The life-cycle consumption function is as follows:

$$average\ propensity\ to\ consume = \frac{c}{y}\ or\ \alpha * \frac{w}{y} + \beta.$$

Income varies more than wealth across households, which means that higher-income households have a lover APC. Overtime, aggregate wealth, and income grow together meaning APC remains stable.

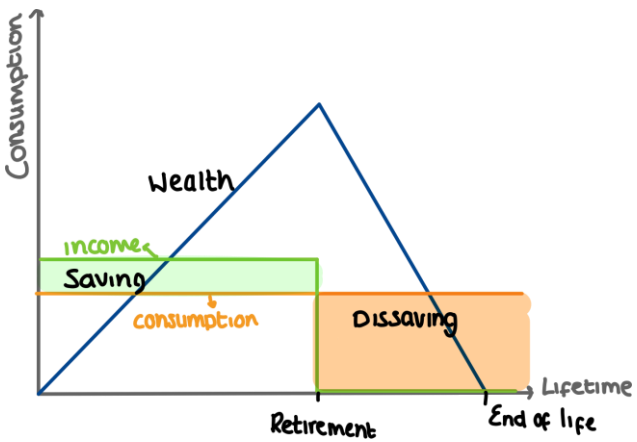

Figure 3. Life-cycle hypothesis.

The life-cycle hypothesis highlights the importance of wealth in explaining consumption within the economy rather than income as it is used in all the consumption equations and income is not. Therefore, this is a contradiction to Keynes's view that income is the main component of consumption.

The suggestion that APC remains stable overtime is supported by the Permanent Income Hypothesis which was developed by Friedman (1957).

This theory implies that $APC = \frac{C}{Y} = \alpha \frac{Y^P}{Y}$.

This means that higher income households have a higher transitory income. Over the long-run period, income variation is due to a variation in permenant income, overall leading to an APC that is stable. The PIH concept states that consumers use saving and borrowing to smooth consumption in response to transitionary changes to income according to the following equation:

$$Y = Y^P + Y^T$$

$$Y^P = Permanent\ Income \begin{pmatrix} average\ income\ expected \\ to\ persist\ into\ the\ future \end{pmatrix}$$

$$Y^T = Transitionary\ Income \begin{pmatrix} temporary\ deviations \\ from\ average\ income \end{pmatrix}$$

$$\alpha = Fraction\ of\ permenant\ income\ that\ is\ consumed\ per\ year$$

The permanent income hypothesis implies the level of spending done by the consumer is consistent with long-term and permanent level of income that a household expects. This theory suggests that consumption is determined by future expected income and current income also. Friedman believes that consumers are rational and forward-thinking in nature. This means that consumers make decisions based on their preferences rather than their level of income. This also means that Friedman believes that transitory income will not cause a change in the consumer's level of consumption. This contradicts Keynes's theory of consumption as he states that any change in a consumer's level of income, whether that is permanent or temporary income, will lead to a change in the consumption level.

Dusenbury (1949) developed the Relative Income Hypothesis whereby, consumption behaviour is impacted by individuals' income compared to others, rather than absolute income. This challenges the theory of expected consumption behaviour which suggests that as income falls, consumption should fall as a result. Most theories, including Keynes, say that a reduction in income leads to a direct and immediate impact on consumption, there is no time-lag. However, the relative income hypothesis argues that as income changes, there is little change in the consumption level as the consumer would

have adapted to the new level of consumption. This theory puts forward the argument that consumption is based on previous consumption levels rather than previous income, there is a level of irrational behaviour that interferes with an individual's ability to adjust their consumption levels.

Interest rates are the amount that is charged when you borrow money. This is also known as the reward of saving and the cost of borrowing. They play an important role in some of the models of the entire economy. According to general economic theory, the expected effect on consumption when the interest rate rises, it becomes more appealing to save as the reward has now increased and borrowing money has become more expensive. This leads to a fall in the level of consumption in the economy. This information can be used in monetary policies within the economy. The monetary policy uses the influence of interest rates to control the money available in the economy and promote sustainable economic growth. This is commonly used by the central bank, in this case, The Bank of England.

A change in the interest rate is represented by a change in the budget constraint. When the budget constraint crosses the point (y_1,y_2) a household can afford this no matter what the interest rate. A change in the interest rate will change the steepness of the curve, it will become steeper when interest rates increase. A change in prices in an economy can have both income and substitution effects. When interest rates rise, present goods become more expensive relative to future goods. Households will substitute away from present goods towards future goods which means they will save more and consume less; this is known as the substitution effect.

During the income effect, a rise in interest rates can either help or hurt a household. This all depends on if the household is initially borrowing or saving. If the household is initially saving, an increase in the interest rate will cause an increase in the savings rate. If the household is borrowing, a rise in the interest rate will damage the household as they will now be paying more interest on top of their loans. Another way a change in interest rates can affect consumption is through the wealth effect. This is where consumers decide to consume more when the value of their assets increase. Consumers choose to spend more due to an increase in financial security and confidence. An example of this is when the value of a consumer's house rises, consumers feel richer even if their income has remained fixed.

The wealth effect reflects the psychological effects of an increase in wealth. It is argued that income and wealth effects have a more significant effect on lower income households, compared to high income households, as they have a larger marginal propensity to consume. This means that a small change in their wealth will lead to a large change in the amount that they consume.

Angus Deaton says that the effect of interest rates on saving has always been an issue in the political economy. If interest rates influence saving, then there is a direct effect on monetary and fiscal policy and economic performance. Monetary policy is the control of the interest rate that the central bank or government uses to influence how much money is in an economy and the cost of borrowing. This affects the rate of which prices are rising which is known as the inflation rate. The government and central bank have an inflation target of 2%.

The fiscal policy involves the control of the rate of taxation and level of government spending in the economy. Deaton states that when there is taxation of capital income it leads to a decrease in the real interest rate which distorts saving.

There are other factors that also influence consumption in the economy.

Unemployment rate, when someone is unemployed, they will not be earning any income. Due to the income effect, it is suggested that any change in income levels will lead to a direct change in consumption.

Theoretically speaking, when the level of taxation increases, specifically income tax, consumers have less disposable income to spend, therefore, leading to a fall in aggregate consumption. If VAT increases, goods become more expensive, consumers can buy less with their money which means their overall consumption decreases. Another type of tax that consumers can endure is income tax, which is where tax is taken deducted from their overall income. A reduction in a person's income will lead to a direct fall in consumption according to Keynes's view of consumption.

The coronavirus pandemic hit the economy unexpectedly and caused a large shift in the way people consume and save. Consumers were forced to save during lockdown periods. They were unable to spend their money in ways they used to as they had to remain at home. All shops were closed apart from supermarkets, restaurants and pubs were also closed, everything expect essential shops were closed. This dramatically reduced the current consumption in the economy. This can explain results that deviate from current theories and empirical analysis on the subject.

Econometric Methodology

Overview

The econometric modelling that will be used is Ordinary Least Squares (OLS) regression in Stata. This modern type of economic modelling has been chosen as it produces results of the highest accuracy and are unbiased.

There are 7 assumptions associated with the ordinary least squares model. If all these assumptions hold to be true, the OLS regression produces estimates of the highest accuracy that are unbiased.

Five OLS regressions will be performed throughout the research, and robust regression used to eliminate heteroscedasticity. These are presented below.

Regression 1:

$$C_t = \beta_0 + \beta_1 r_t + \beta_2 r_{t-1} + \beta_3 i_t + \beta_3 g_t + \varepsilon_t.$$

Real interest rate (r_t), lagged real interest rate (r_{t-1}), inflation rate (i_t) and gross domestic product (g_t) are regressed on the consumption rate (C_t), from the period 1960-2020, to initially test the impact of interest rates and lagged interest rates on consumption. β_{0-3} are the coefficients of the variables that are estimated during the OLS regression. ε_t is the error term in the regression model.

Regression 2: The unemployment rate (u_t) has been added to Regression 1. To estimate the extent to which the unemployment rate effects consumption in the UK economy.

$$C_t = \beta_0 + \beta_1 r_t + \beta_2 r_{t-1} + \beta_3 i_t + \beta_3 g_t + \beta_4 u_t + \varepsilon_t.$$

Regression 3: Gross national income (n_t), average house price (h_t) and total bank deposits, (b_t) have been added to the equation above to investigate the effects that wealth and income has on consumption.

$$C_t = \beta_0 + \beta_1 r_t + \beta_2 r_{t-1} + \beta_3 i_t + \beta_3 g_t + \beta_4 u_t + \beta_5 n_t + \beta_6 h_t + \beta_7 b_t + \varepsilon_t.$$

Regression 4: Real interest rate (r_t) and lagged real interest rate (r_{t-1}) on durable goods (D_t) from a period 1960-2020.

$$D_t = \beta_0 + \beta_1 r_t + \beta_2 r_{t-1} + \varepsilon_t.$$

This regression is to investigate the effects of the interest rate and lagged interest rate on the different types of consumption in an economy.

Regression 5: Real interest rate (r_t) and lagged real interest rate (r_{t-1}) on non-durable goods (N_t) from a period 1960-2020.

$$N_t = \beta_0 + \beta_1 r_t + \beta_2 r_{t-1} + \varepsilon_t.$$

This is to investigate the effects of the interest rate and lagged interest rate on the different types of consumption in an economy.

Throughout this research the following hypothesis will be tested:

H_0: $\beta_1 \geq 0$ There is no inverse relationship between the real interest rate and the level of consumption in the UK.

H_0: $\beta_1 < 0$ There is an inverse relationship between the real interest rate and the level of consumption in the UK.

Data

Secondary, quantitative time-series data will be used for this research. This data has been collected through online websites like ONS, Bank of England, UK Government, and other reputable sources. This type of data is used as it is readily available to the public and has a large amount of historical data, enabling the highest accuracy of results. A summary of these variables and their notations can be found in the Appendix under Data Description.

There are many variables that have missing data or do not begin from the same time period, which is the main reason why they have not been included in the model. There were many other dependent variables that were considered to be used in the model, however, they were discarded through the lack of data and historical data availability. These included: Transitory Income, Oil and Gas Prices, Average Utility Spending, Gold Price and FSTE 100. Even though these variables do influence consumption, they cannot be used as the data was not available to the public or there were not enough data points to use within

the OLS regression analysis. This limits the number of wealth variables used in the model.

Some of the variables used within the model have a very small data set when compared to other data sets of the variables. A two-period model was considered in the study, however, due to the lack of data available they could not be involved in other time period models which limits the ability to compare the results found with each other and how these influence consumption over time.

EViews unit root testing only allows for up to 2nd difference testing. Some of the variables that undergo unit root testing require this further than the 2nd difference, however, this is not possible to do so using the current software. Therefore, this makes the unit root test statistically insignificant.

Real Interest Rate was lagged in order to investigate the lagged effects of interests on consumption in the UK. This investigation is taking place to confirm or contradict Keynes's view of consumption which states that consumption is immediately impacted by a change in the interest rate without any time lags.

Results and Data Analysis

Deterministic Trends

The data for each variable is placed into a straight-line graph, to determine whether they have an underlying deterministic trend or not. These trends can be removed by taking the 1st difference of the variables at hand. This will be completed using EViews. The results for each straight-line graph can be seen in full in the appendix that has been attached at the end of this paper.

Average House Price, Consumption, Durable Goods Consumption, Gross Domestic Product, Gross National Income, Non-Durable Goods Consumption and Total Bank Deposits all have an upward deterministic trend. This shows that the unit root test of the 1st difference must be conducted without the time trend to confirm or contradict the findings from the unit root test on the level variable.

Inflation, Real Interest Rate and Unemployment Rate do not have any trend within their data. This shows that the unit root test of the 1st difference must be conducted with the time trend to confirm or contradict the findings from the unit root on the level variable.

ADF Unit Root Testing

Unit root testing is to be completed before performing any regression analysis of the variables. This test, completed in EViews, is required to confirm that there are no variables (independent or dependant) that are not stationary at their level, and stationary in their 1st difference.

A time-series variable is stationary if:

- The variance of the variable is constant over time, and
- The mean of the variable is constant over time.

The Augmented Dicky-Fuller unit root test was completed to check if any of the variables that going to be used in the regression modelling are stationary or not.

Table 2. Augmented Dicky-Fuller unit root tests for all variables

ADF Test Statistic						
Variable	Levels	k lag	1st Difference	k lag	2nd Difference	k lag
AHP	-1.657*	0	-3.934**	0	n/a	n/a
CONS	-3.001*	1	-2.640*	10	-1863*	10
DGS	-3.545*	3	-5.934**	0	n/a	n/a
GDP	-2.649*	0	-8.544**	0	n/a	n/a
GNI	-2.531*	1	-1.916*	10	-3.098**	9
INF	-2.195*	0	-7.549**	0	n/a	n/a
NDG	-2.129*	1	-4.157**	0	n/a	n/a
RIR	-2.757*	0	-8.045**	0	n/a	n/a
TBD	-8.222**	0	-10.760**	0	-3.130*	0
UNR	-2.816*	1	-3.414*	0	-6.461**	0

* Indicates a p-value greater than the significance level of 5%.
** Indicates a p-value smaller than the significance level of 5%.

These results were tested against this hypothesis analysis for the level variables:

H_0: The level variable has a unit root
H_1: The level variable does not have a unit root
The hypothesis test for the 1st difference of the variables is as follows:

H_0: The 1st difference variable has a unit root

$H_{1:}$ The 1st difference variable does not have a unit root

The hypothesis test for the 2nd difference of the variables is as follows:

$H_{0:}$ The 2nd difference variable has a unit root
$H_{1:}$ The 2nd difference variable does not have a unit root

Six variables, AHP (Average House Price), DGS (Durable Goods Consumption), GDP (Gross Domestic Product), INF (Inflation Rate), NDG (Non-Durable Goods Consumption) and RIR (Real Interest Rate), have a unit root which means they are not a stationary variable at level. By stating that they have a unit root, this suggests that the null hypothesis cannot be rejected, it must be accepted. This is supported by the p-value (0.749, 0.051, 0.261, 0.210, 0.501, 0.072) for each value being greater than the significance level of 5%. Evidence that the test statistic for each variable is also greater than critical values at all levels of significance confirms the suggestion that that the null hypothesis is accepted. In order to confirm or deny that these variables have a unit root at their level, a unit root test in their 1st difference is required. In the 1st difference, evidence suggests that the null hypothesis is to be rejected and the alternative is accepted. The test statistic is smaller than the critical values at all levels of significance, supporting this suggestion. The p-value (0.005, 0.05, 0.000, 0.000, 0.000) for each variable is also smaller than the significance level of 5%. This means that these variables are an I(1) variable. By being and I(1) variable, they have a linear trend with no quadratic trend. As the unit root rest of the 1st difference confirms that each variable is not a stationary variable, there is no requirement to perform a unit root test for the 2nd difference.

The next variables, GNI and UNR require a 2nd difference unit root test in order to determine that they are not stationary at level with a unit root. The level unit root suggests that the null hypothesis must be accepted. Evidence witnessed in the unit root test supports this suggestion. The test statistic for each variable is greater than the critical value at each level of significance, with the p-value (0.313, 0.064) also being greater than the significance level of 5%. Therefore, confirming that the null hypothesis is rejected, the Unemployment Rate and Gross National Income have a unit root. In order to confirm or deny that UNR and GNI have a unit root at its level, a unit root test in their 1st difference is required. In the 1st difference, evidence suggests that the null hypothesis is to be accepted. The test statistic is greater than the critical values at all levels of significance, supporting this suggestion. The p-value

(0.322 0.061) for each variable is also greater than the significance level of 5%. As the null hypothesis is also accepted in the 1st difference unit root test, a unit root test using the 2nd difference is required to confirm that Unemployment Rate is not stationary. UNR and GNI are stationary in the 2nd difference. This is because the null hypothesis is rejected due to the reported p-value (0.000, 0.000) being smaller than the 5% significance level. The test statistic is also smaller than critical values at all levels of significance. Making Unemployment Rate and Gross National Income an I(2) variable.

Consumption has a unit root which means it is not a stationary variable at level. By stating that they have a unit root, this suggests that the null hypothesis cannot be rejected, it must be accepted. This is supported by the p-value (0.139) being greater than the significance level of 5%. Evidence that the test statistic for CON is also greater than critical values at all levels of significance confirms the suggestion that the null hypothesis is accepted. To confirm or deny that CON has a unit root at their level, a unit root test in their 1st difference is required. In the 1st difference, evidence suggests that the null hypothesis is to be accepted. The test statistic is greater than the critical values at all levels of significance, supporting this suggestion. The p-value (0.092) for Consumption is also greater than the significance level of 5%. As the null hypothesis is also accepted in the 1st difference unit root test, a unit root test using the 2nd difference is required to confirm that these variables are not stationary. CON is not stationary in the 2nd difference either as the null hypothesis is accepted due to the test statistic is also greater than critical values at all levels of significance. The reported p-value (0.347) being greater than the 5% significance level. To prove that Consumption is not a stationary variable, unit root testing will need to be performed further than the 2nd difference which cannot be completed with EViews itself.

The ADF unit root tests results for TBD suggest that the null hypothesis is rejected and therefore, the alternative hypothesis is accepted. This means that TBD does not have a unit root in its first different. This is supported by the test statistic being smaller than the critical value at all levels of significance. This means that Total Bank Deposits does not have a unit root at its level. A 1st difference unit root test was then conducted to confirm these findings. The results concluded the same; reject the null hypothesis is rejected. The test statistic is smaller than all levels of critical value. TBD is also stationary in the 2nd difference unit root test and the alternative hypothesis is accepted. However, it is noted that the reported p-values (0.000, 0.000 0.000) are smaller than the 5% significance level, this makes the model for ADF unit root insignificant. This could possibly be due to the small number of data

points for Total Bank Deposits as it would be difficult for EViews to produce results for this test. When there is more data available, this test should be run again in order to test the stationarity of TBD that is statistically significant.

Phillips-Perron Unit Root Test

Phillips-Perron unit root test accounts for autocorrelation and heteroskedasticity within the errors which is why it is also completed along with ADF unit root testing, also confirming the results found above.

Table 3. Phillips-Perron unit root tests for all variables

Phillips-Perron test statistic						
Variable	Levels	k lag	1st Difference	t lag	2nd Difference	t lag
AHP	-1.888*	3	-3.925**	2	n/a	n/a
CONS	-2.593*	5	-7.213**	5	n/a	n/a
DGS	-2.366*	9	-8.134**	5	n/a	n/a
GDP	-2.645**	5	-8.543**	0	n/a	n/a
GNI	-2.366*	9	-8.134**	5	n/a	n/a
INF	-2.265*	8	-11.09**	37	n/a	n/a
NDG	-1.542*	4	-3.876**	9	n/a	n/a
RIR	-2.715*	1	-8.658**	6	n/a	n/a
TBD	-7.292**	1	-10.200**	1	n/a	n/a
UNR	-1.893*	3	-3.323*	4	-7.596**	10

* Indicates a p-value greater than the significance level of 5%.
** Indicates a p-value smaller than the significance level of 5%.

The results were then analysed against the same hypothesis testing as seen with the ADF unit root tests.

Eight variables, AHP, CONS, DGS, GDP, GNI, NDG, and RIR, have a unit root which means they are not a stationary variable at level. By stating that they have a unit root, this suggests that the null hypothesis cannot be rejected, supported by the p-value (0.694, 0.288, 0.487, 0.261, 0.393, 0.186, 0.795, 0.079) for each value being greater than the significance level of 5%. Evidence that the test statistic for each variable is also greater than critical values at all levels of significance confirms the suggestion that that the null hypothesis is accepted. To confirm or deny that these variables have a unit root at their level, a unit root test in their 1st difference is required. In the 1st difference, evidence suggests that the null hypothesis is to be rejected and the

alternative is accepted. The test statistic is smaller than the critical values at all levels of significance, supporting this suggestion. The p-value (0.005, 0.000, 0.000, 0.000, 0.000, 0.000, 0.005, 0.000) for each variable is also smaller than the significance level of 5%. This means that these variables are an I(1) variable. By being and I(1) variable, they have a linear trend with no quadratic trend. As the unit root rest of the 1st difference confirms that each variable is not a stationary variable, there is no requirement to perform a unit root test for the 2nd difference.

TBD Phillips-Perron unit root test suggest the alternative hypothesis is accepted. This means that TBD does not have a unit root in its first difference. This is supported by the test statistic being smaller than the critical value at all levels of significance. This means that Total Bank Deposits does not have a unit root at its level. A 1st difference unit root test was then conducted to confirm these findings. The results concluded the same; reject the null hypothesis is rejected. The test statistic is smaller than all levels of critical value. TBD is also stationary in the 2nd difference unit root test and the alternative hypothesis is accepted. However, it is noted that the reported p-values (0.000, 0.000 0.000) are smaller than the 5% significance level, this makes the model for ADF unit root insignificant. This could possibly be due to the small number of data points for Total Bank Deposits as it would be difficult for EViews to produce results for this test. When there is more data available, this test should be run again to test the stationarity of TBD that is statistically significant.

Granger Causality

Granger causality is used when it is known that two variables are related, and it determines whether one time-series variable is useful in forecasting another. The casual relationships between consumption and all the independent variables were analysed through the approach of Granger Causality. A lot of the current literature on this subject often explains the correlation between consumption and the dependent variables, rather than the variables that cause the consumption level to change, this paper studies the relationship further by running granger causality tests.

Block Granger Causality

The Block Granger causality test equation is as follows:

Unrestricted Granger causality:

$$CON = \alpha_0 + \sum_{i=1}^{p=2} \alpha\, CON_{t-1} + \sum_{i=1}^{p=2} b_j AHP_{t-j} + \sum_{i=1}^{p=2} b_j GNI_{t-j} + \sum_{i=1}^{p=2} b_j INF_{t-j} + \sum_{i=1}^{p=2} b_j RIR_{t-j} + \sum_{i=1}^{p=2} b_j UNR_{t-j} + v_t$$

Restricted Granger causality:

$$CON = \alpha_0 + \sum_{i=1}^{p=2} \alpha\, CON_{t-1} + v_t$$

Table 4. Block Granger causality test for AHP, GNI, INF, RIR and UNR on CON

Dependent Variable: CON	Chi-sq	df	Prob
Independent Variables:			
AHP	12.279	2	0.002**
GNI	12.379	2	0.002**
INF	11.271	2	0.004**
RIR	1.689	2	0.429*
UNR	15.774	2	0.000**
ALL	106.615	10	0.000**

* Indicates a p-value greater than the significance level of 5%.
** Indicates a p-value smaller than the significance level of 5%.

Average House Price

The null hypothesis for this Granger causality test is as follows:

H_0: $\sum_{i=1}^{p=2} b_j = 0$ (AHP does not Granger cause CON)
H_1: $\sum_{i=1}^{p=2} b_j \neq 0$ (AHP does Granger cause CON)

The reported p-value (0.002) for AHP is smaller than the significance level of 5%. This suggests that the null hypothesis is rejected, the alternative hypothesis is accepted, meaning that the lagged AHP terms are equal to zero. Therefore, showing the Average House Price does Granger cause Consumption.

Gross National Income

The null hypothesis for this Granger causality test is as follows:

H_0: $\sum_{i=1}^{p=2} b_j = 0$ (GNI does not Granger cause CON)
H_1: $\sum_{i=1}^{p=2} b_j \neq 0$ (GNI does Granger cause CON)

The alternative hypothesis is accepted due to the reported p-value (0.002) for GNI is smaller than the significance level of 5%. The lagged terms of GNI are equal to zero. GNI does not Granger cause CON.

Inflation Rate

The null hypothesis for this Granger causality test is as follows:

H_0: $\sum_{i=1}^{p=2} b_j = 0$ (INF does not Granger cause CON)
H_1: $\sum_{i=1}^{p=2} b_j \neq 0$ (INF does Granger cause CON)

The reported p-value (0.004) for INF is smaller than the significance level of 5%. This suggests that the null hypothesis is rejected, the alternative hypothesis is accepted, meaning that the lagged INF terms are equal to zero. Therefore, showing the Inflation Rate does Granger cause Consumption.

Real Interest Rate

The null hypothesis for this Granger causality test is as follows:

H_0: $\sum_{i=1}^{p=2} b_j = 0$ (RIR does not Granger cause CON)
H_1: $\sum_{i=1}^{p=2} b_j \neq 0$ (RIR does Granger cause CON)

RIR does not Granger cause CON. This is because the alternative hypothesis is rejected, and the null hypothesis is accepted. This is supported by the reported p-value (0.429) is larger than the 5% significance level. Therefore, this means that the lagged RIR terms are not equal to zero.

Unemployment Rate

The null hypothesis for this Granger causality test is as follows:

H_0: $\sum_{i=1}^{p=2} b_j = 0$ (UNR does not Granger cause CON)
H_1: $\sum_{i=1}^{p=2} b_j \neq 0$ (UNR does Granger cause CON)

The alternative hypothesis is accepted due to the reported p-value (0.000) for UNR is smaller than the significance level of 5%. The lagged terms of UNR are equal to zero. UNR does not Granger cause CON.

All:

The null hypothesis for this Granger causality test is as follows:

H_0: $\sum_{i=1}^{p=2} b_j = 0$ (ALL does not Granger cause CON)
H_1: $\sum_{i=1}^{p=2} b_j \neq 0$ (ALL does Granger cause CON)

All variables in this model do not Granger cause CON. This is because the alternative hypothesis is accepted, and the null hypothesis is rejected. This is supported by the reported p-value (0.000) is smaller than the 5% significance level. Therefore, this means that the lagged ALL terms are equal to zero. This means that all these variables in the model do Granger cause CON together.

Block Granger Causality was attempted with all independent variables, however, EViews produced an error stating that there are "Insufficient number of observations to estimate 21 coefficients per equation in VAR." This is due to a small data size within some of the variables in the model. To correct this error these variables were removed, and a Pairwise Granger causality test was performed between each independent variable and consumption. These results can be seen below:

Table 5. Pairwise Granger causality test for NDG, DGS, GDP AND TBD on CON

Null Hypothesis	F-Statistic	Prob
NDG does not Granger Cause CON	1.158	0.349
CON does not Granger Cause NDG	2.734	0.109
DGS does not Granger Cause CON	1.158	0.349
CON does not Granger Cause DGS	2.734	0.109
GDP does not Granger Cause CON	N/A	N/A
CON does not Granger Cause GDP	N/A	N/A
TBD does not Granger Cause CON	N/A	N/A
CON does not Granger Cause TBD	N/A	N/A

Non-Durable Goods Consumption

The null hypothesis for this Granger causality test is as follows:

H_0: $\sum_{i=1}^{p=2} b_j = 0$ (NDG does not Granger cause CON or CON does not Granger cause NDG)

H_1: $\sum_{i=1}^{p=2} b_j \neq 0$ (NDG does Granger cause CON or CON does Granger cause NDG)

These results show that the variables NDG and CON do not Granger Cause each other, and the null hypothesis cannot be rejected. Since the probability for both tests (0.349, 0.109) are larger than the level of significance that is 5%.

Durable Goods Consumption

The null hypothesis for this Granger causality test is as follows:

H_0: $\sum_{i=1}^{p=2} b_j = 0$ (DGS does not Granger cause CON or CON does not Granger cause DGS)

H_1: $\sum_{i=1}^{p=2} b_j \neq 0$ (DGS does Granger cause CON or CON does Granger cause NDG)

The reported p-values (0.349, 0.109), which are larger than the 5% significance level suggest that the null hypothesis is accepted. This means that DGS and CON do not Granger cause one another.

Gross Domestic Products and Total Bank Deposits

The null hypothesis for this Granger causality test is as follows:

H_0: $\sum_{i=1}^{p=2} b_j = 0$ (GDP does not Granger cause CON or CON does not Granger cause GDP)

H_1: $\sum_{i=1}^{p=2} b_j \neq 0$ (GDP does Granger cause CON or CON does Granger cause GDP)

H_0: $\sum_{i=1}^{p=2} b_j = 0$ (TBD does not Granger cause CON or CON does not Granger cause TBD)

H_1: $\sum_{i=1}^{p=2} b_j \neq 0$ (TBD does Granger cause CON or CON does Granger cause TBD)

Due to an insignificant number of data points, the Granger causality tests were not able to produce results. This means the study can neither confirm or deny that granger causality exists between GDP and CON and TBD and CON. Therefore, when further data is available, these tests should be re-run in the same manner. This will ensure that there are enough data points available to conduct this test, producing statistically accurate results that conclusions can be drawn from.

OLS Regression

Table 6. OLS regression results for a number of models, time period 1960-2020

Variables	Constant	RIR	RIRT	INF	GDP	UNR	GNI	AHP	TBD
Constant	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
CON - Model 1	-849651.284*	-6560.211*	-3532.039**	-5668.075*	1.1352*	xxx	xxx	xxx	xxx
CON - Model 2	-1133317.951*	-7561.031*	-4241.428**	90.002**	1.240*	-17772.178*	xxx	xxx	xxx
CON - Model 3	-378149.351*	-5510.938**	8864.760**	-15543.291**	0.172*	-15894.713**	0.902*	0.208*	-0.013*
DGS- Model 4	90750.466*	-3582.635**	-3466.238**	xxx	xxx	xxx	xxx	xxx	xxx
NDG - Model 5	204167.649*	-8765.357**	-8282.438**	xxx	xxx	xxx	xxx	xxx	xxx

* Indicates a p-value smaller than 0.05.
** Indicates p-values greater than. 0.05.

Model 1, real interest rate, lagged real interest rate, inflation rate and gross domestic product are regressed on the consumption rate. When the regression results are placed into Regression 1 it takes the form:

$$C_t = -849651.284 - 6560.211r_t + -3532.039r_{t-1} - 5668.075i_t + 1.1352g_t$$

From this equation it can be inferred that there is an inverse relationship between all the variables and consumption, apart from GDP which has a positive relationship. The coefficient for the lagged real interest rate is -3532.039, showing that a 1% increase in the lagged real interest rate leads to a fall in the consumption rate of £3532.04. A 1% increase in the real interest rate will lead to a £6560.21 decrease in consumption. As this decrease is larger

than the lagged real interest rate, this supports the suggestion that there is no time lag between a change in the interest rate and the change in the level of consumption. Mankiw and Campbell (1989) completed a very similar regression with consumption and the lagged real interest rate. They found that the lagged variable does not have influence over the consumption level and this assumption was rejected. It is important to note that the p-value for the lagged real interest rate is greater than the 5% significance level, therefore making this coefficient insignificant, hence it will not be used to determine the effects that interest rate has on the consumption level in the UK. It is observed that as the inflation rate also has an inverse relationship with consumption. An increase in the inflation rate will cause consumption to fall by £5668.08. This is in line with current theory, as common understanding is that as inflation rises, prices rise, consumption will therefore fall, which is consistent with the regression results found. However, this all depends on the price elasticity of the good/service in question.

The Model 2, real interest rate, lagged real interest rate, inflation rate and gross domestic product are regressed on the consumption rate with the addition of the unemployment rate. Placing the regression results into Regression 2 gives the equation the form of:

$$C_t = -1133317.951r_t - 7561.031r_{t-1} + 90.002i_t + 1.240g_t - 17772.178u_t + \varepsilon_t.$$

When a person is unemployed, they will not be earning any income, this means their total income falls. This model shows that as unemployment rises, consumption will fall by £17772.18. This empirical evidence supports the ideas of Keynes who states that the level of consumption will change no matter the timing of this income change. This coefficient has not caused the impact of interest rates on consumption to change. Real interest Rate remains the larger impactor on consumption compared to lagged interest rate, therefore, confirming the results found previously that state there is no lagged effect on consumption from the interest rate.

Model 3 is a regression with the same variables used in both Model 1 and Model 2 with the addition of GNI, AHP and NDG. These variables have been added to the regression to investigate the effects of a consumer's income and wealth on their consumption.

With the regression coefficients added, the equation for Regression 3 is as follows:

$$C_t = -378149.351 + -5510.938r_t + 8864.760\, r_{t-1} - 15543.291i_t + 0.172g_t - 15894.713u_t + 0.902n_t + 0.208h_t - 0.013b_t.$$

The coefficients for the variables that have been used in both previous models are consistent with previous findings, they all have a negative correlation with the dependant variable, and all have a p-value smaller than a significance level of 5% making the coefficients statistically significant. This does not apply of the lagged real interest rate, it has a coefficient is 8864.780, an 1% increase in the lagged real interest rate leads to an increase in consumption by that amount. This contradicts previous findings and those findings of Campbell and Mankiw that state there is no time lag present between real interest rate and consumption. Even though this result is contradictory to previous findings, this can be discarded as the coefficient has the p-value is less than 0.05, it is statistically insignificant and should not be used within the model. GNI and AHP both have a positive correlation with consumption and are both statistically significant. These regression results support the theories produced by Fisher (1957) and Friedman (1957), which suggest consumption depends solely on income, regardless of timing, and wealth is also a determining variable for consumption. These results also confirm the consumption function, created by Keynes. He states as income rises consumption will follow. The coefficient correlation for GNI is positive, an increased income leads to an increase in consumption, therefore supporting the Keynesian consumption function.

Model 4 is the regression of real interest rate and lagged real interest rate on durable goods consumption. By adding in the regression results into Regression 4, the equation takes the form:

$$D_t = 90750.466 + -3582.635r_t - 3466.238\, r_{t-1}.$$

Both the real interest rate and lagged interest rate have a negative correlation with durable goods, which confirms the findings in Model 1. As durable goods are expensive in nature, they are long-term goods that aren't necessary. The regression results show that there is a larger correlation coefficient between RIR and CON, compared to RIRT and CON. Mankiw suggests that durable goods are very sensitive to the real interest rate which is

supported by the empirical evidence found in the regression results. Contradictory to this, it is found that the coefficients for both real interest rate and lagged interest rate is statistically insignificant and the p-values are smaller than the 5% significance level.

Model 5 is based on Model 4, but durable good consumption has been substituted for non-durable good consumption. Adding the coefficient results into Regression 4 gives the equation the form.

$$N_t = 204167.649 - 8765.357r_t - 8282.438r_{t-1}.$$

The findings are very similar to those found for the regression of durable goods; however, the coefficients are roughly 2.5 times larger. Lagged real interest rate has a smaller impact on the consumption of non-durable goods compared to the real interest rate. This will discard the assumption that the interest rate has a time lag when impacting consumption. These results show that the consumption of non-durables is very sensitive to changes in the interest rate compared to the typical studies that state that they are more sensitive to changes in income. Again, it is noted that the coefficients for this regression are statistically insignificant and the significance level of 5% is smaller than the p-values for each coefficient.

Conclusion

The aim of this study is to model the effects of interest rates on consumption within the UK economy to allow for a clearer understanding of the relationship between these two variables at hand and how this relates to the current economic literature. The results from the study meet all the research objectives that were set out at the start of this paper. It is found that Real Interest Rates have a significant inverse relationship with Consumption. This means that the null hypothesis is rejected, and the alternative hypothesis is accepted.

The empirical analysis of the econometric regression models suggests that there is a significant inverse correlation relationship between Consumption and Real Interest Rates in the United Kingdom. It is noted that lagged Real Interest Rate has a smaller correlation relationship with Consumption compared to Real Interest Rate. This empirical evidence supports the Keynesian view of the consumption function (1936), which states a change in

interest rate leads to an immediate response in the level of consumption. The overall findings from this study contradict the thoughts of.

This study suggests that the monetary policy is an ineffective way of using interest rates as a way of promoting consumption. This is because the Granger Causality confirms that there is no cause or relationship between these two variables. However, the OLS regression analysis shows that there is a correlation relationship between Real Interest Rates and Consumption. This means that a change in the Real Interest Rate will lead to a change in the Consumption level. The monetary policy is useful for influencing Consumption rather than directly causing a change. As it is used to control aggregate demand, the government should use the fiscal policy in conjunction with the Bank of England in order to fully control the consumption level in the United Kingdom. The fiscal policy is the implementation of taxation rates and government spending to influence aggregate demand. This policy mix is useful in influencing consumption as this is a component of aggregate demand. This would require further study to confirm or deny that a policy mix is useful for controlling aggregate demand.

Suggestion for Further Studies

As there is a data availability issue at hand, further research should wait until more data is available in order to conduct deeper research. This would ensure that the results produced from this study will be of the highest accuracy and cover a large time period. This further research would be able to confirm or contradict previous findings with more confidence and truly show the effects of independent variables on consumption.

The next suggestion for further studies is to add more independent variables in order to fully explore all the factors that influence consumption. Researchers could include variables that were considered to be included but had to be discarded due to data availability, this includes Transitory Income, Oil and Gas Prices, Average Utility Spending, Gold Price and FSTE 100. These variables can investigate the impact of necessary consumption and wealth on consumption in further detail, for example, Gold Price is a variable for wealth. By using this variable, it enables further research into the wealth effects on consumption.

This paper only covers the impact of interest rates on consumption in the UK. It is suggested that further studies look beyond the United Kingdom and branch this investigation to other countries around the world. By doing this it

would enable researchers to compare the results found to those in the UK and investigate whether interest rates affect consumption in the same nature. Researchers could then dive into this topic further by investigating these effects in less developed economies. The analysis of less developed countries would highlight the impact of the Human Development Index (HDI) on consumption, which also relates to the question, do all economies no matter their maturity react to changes in the interest rate and consumption of the same nature? It is noted that this research of different economies should use the same data range as the United Kingdom to allow for direct and accurate comparisons.

The study suggests that interest rates only have a correlation coefficient with consumption rather than a cause and correlation. A policy mix of monetary and fiscal policy can be used by the UK government in order to control aggregate demand and influence consumption to its full potential. The suggestion for further studies is to gather information on variables such as Government Spending and Taxation Rate. The same econometric models and analysis, that is conducted in this paper, should be used to fully explore the effects of taxation and government spending on the consumption level. These variables should be added to the regression models used in this paper in order to test the suggestion of a policy mix.

Acknowledgments

I would first like to thank my supervisor Aleks Vasilev for his support and guidance through the completion of my independent study. Without this help, this study would have been very difficult to produce.

Secondly, I would like to thank all my lecturers that have taught me during my time at the University of Lincoln. They have widened my knowledge of Economics as a whole, which has been highly utilised through the research.

Thirdly, to my family and friends, thank you for all your encouragement and support during this time. This has inspired me to keep going and produce something I feel proud of.

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Appendix

Deterministic Trends

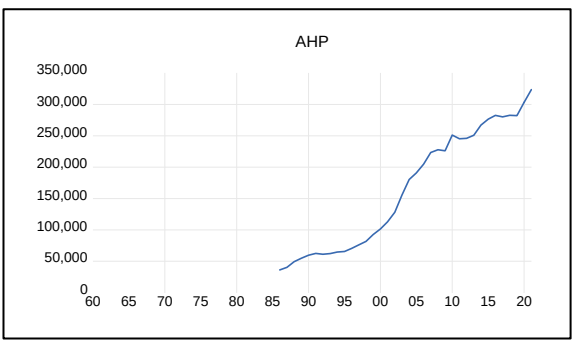

Figure 1. Annual average house price for UK, time period 1987-2021.

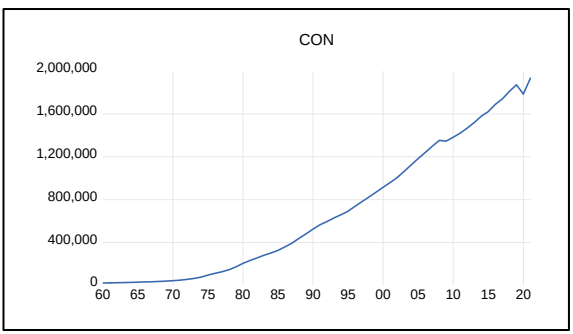

Figure 2. Annual consumption expenditure for UK, time period 1960-2021.

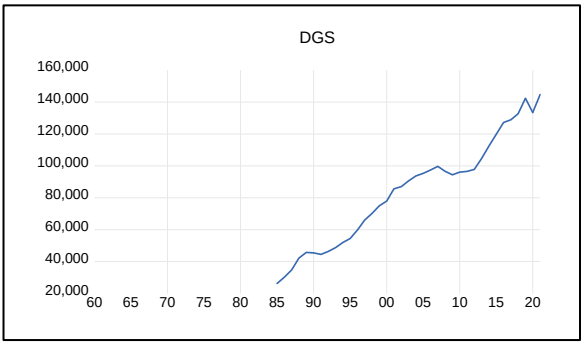

Figure 3. Annual durable goods consumption for UK, time period 1985-2021.

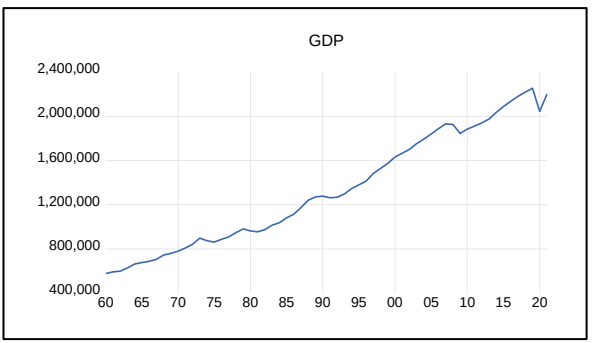

Figure 4. Annual gross domestic product for UK, time period 1960-2021.

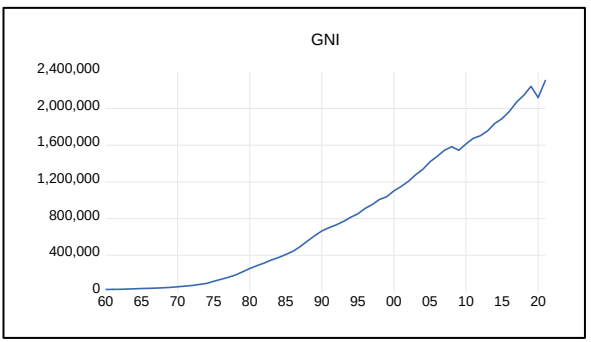

Figure 5. Annual gross national income for UK, time period 1960-2021.

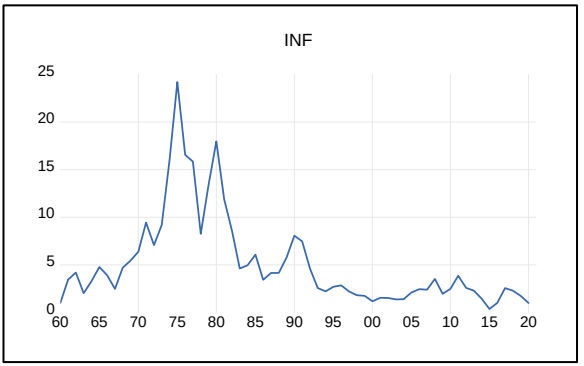

Figure 6. Annual inflation rate for UK, time period 1069-2021.

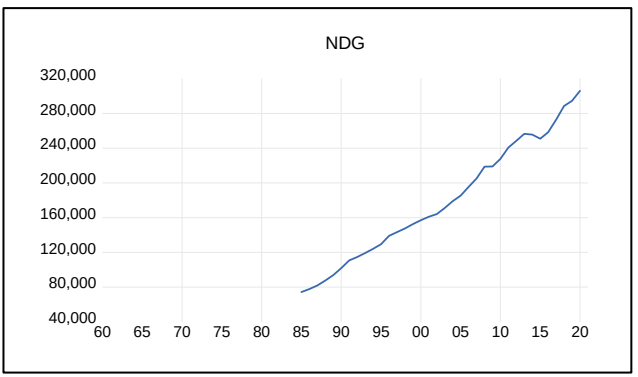

Figure 7. Annual non-durable goods consumption for UK, time period 1985-2021.

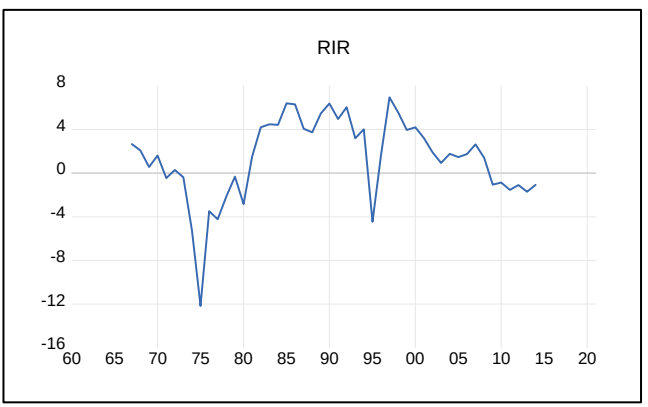

Figure 8. Annual real interest rate for UK, time period 1965-2021.

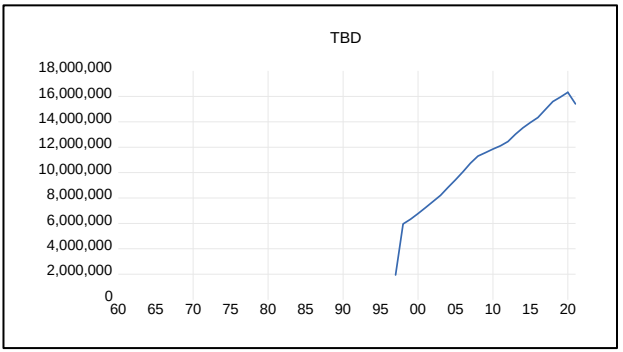

Figure 9. Annual total bank deposits for UK, time period 1996-2021.

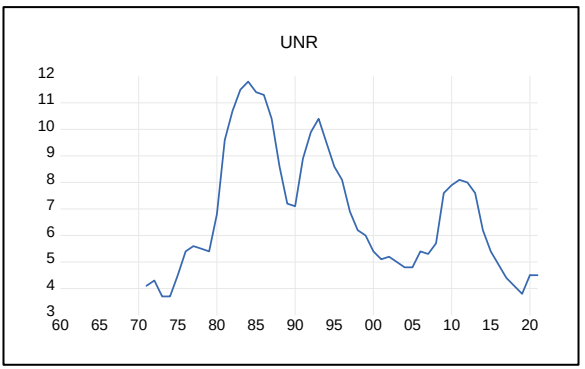

Figure 10. Annual unemployment rate for UK, time period 1971-2021.

Descriptive Statistics

Table 1. Descriptive statistics for all variables in the model, time period varying start-2020

Variable |	Obs	Mean	Std. dev.	Min	Max
	+				
INF |	61	5.090183	4.858125	.3680468	24.20729
RIR |	48	1.388493	3.7051	-12.16741	6.936658
	+				

Variable |	Obs	Mean	Std. dev.	Min	Max
DGS |	37	83686.73	33530.36	26287	144768
GNI |	62	823230	724750.2	26353	2305142
GDP |	62	1337457	520587.8	576144	2255283
	+				
UNR |	51	6.8	2.373015	3.7	11.8
NDG |	36	179259.2	68530.3	74410	305946
CON |	62	689039.9	617872.9	21383	1935664
AHP |	36	164476.4	95729.88	36276	323595
TBD |	25	1.10e+07	3720691	1936330	1.63e+07

Granger Causality Test

VAR Granger Causality/Block Exogeneity Wald Tests
Date: 05/08/22 Time: 12:31
Sample: 1997 2014
Included observations: 16

Dependent variable: CON01

Excluded	Chi-sq	df	Prob.
AHP	12.27862	2	0.0022
GNI	12.37894	2	0.0021
INF	11.27100	2	0.0036
RIR	1.689142	2	0.4297
UNR	15.77392	2	0.0004
All	107.6147	10	0.0000

Figure 11. Block Granger causality test for AHP, GNI, INF, RIR and UNR on CON, time period 1997-2014.

Pairwise Granger Causality Tests
Date: 05/08/22 Time: 12:44
Sample: 1997 2014
Lags: 2

Null Hypothesis:	Obs	F-Statistic	Prob.
DGS does not Granger Cause CON01	16	1.15799	0.3496
CON01 does not Granger Cause DGS		2.73411	0.1087

Figure 12. Pairwise Granger causality test for DGS on CON, time period 1997-2014.

Pairwise Granger Causality Tests
Date: 05/08/22 Time: 14:22
Sample: 1997 2014
Lags: 2

Null Hypothesis:	Obs	F-Statistic	Prob.
GDP does not Granger Cause CON01	16	NA	NA
CON01 does not Granger Cause GDP		NA	NA

Figure 13. Pairwise Granger causality test for GDP on CON, time period 1997-2014.

Pairwise Granger Causality Tests
Date: 05/08/22 Time: 14:24
Sample: 1997 2014
Lags: 2

Null Hypothesis:	Obs	F-Statistic	Prob.
NDG does not Granger Cause CON01	16	1.15799	0.3496
CON01 does not Granger Cause NDG		2.73411	0.1087

Figure 14. Pairwise Granger causality test for NDG on CON, time period 1997-2014.

Pairwise Granger Causality Tests
Date: 05/08/22 Time: 14:25
Sample: 1997 2014
Lags: 2

Null Hypothesis:	Obs	F-Statistic	Prob.
TBD does not Granger Cause CON01	16	NA	NA
CON01 does not Granger Cause TBD		NA	NA

Figure 15. Pairwise Granger causality test for TBD on CON, time period 1997-2014.

Unit Root Testing

Null Hypothesis: AHP has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-1.657831	0.7485
Test critical values:	1% level	-4.243644	
	5% level	-3.544284	
	10% level	-3.204699	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(AHP)
Method: Least Squares
Date: 05/09/22 Time: 12:35
Sample (adjusted): 1987 2021
Included observations: 35 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
AHP(-1)	-0.117035	0.070595	-1.657831	0.1071
C	-25629.40	17420.28	-1.471239	0.1510
@TREND("1960")	1194.451	641.4069	1.862236	0.0718

R-squared	0.111866	Mean dependent var	8209.114
Adjusted R-squared	0.056357	S.D. dependent var	8467.868
S.E. of regression	8225.795	Akaike info criterion	20.94975
Sum squared resid	2.17E+09	Schwarz criterion	21.08307
Log likelihood	-363.6207	Hannan-Quinn criter.	20.99577
F-statistic	2.015294	Durbin-Watson stat	1.345265
Prob(F-statistic)	0.149850		

Figure 16. ADF unit root test for AHP at level, time period 1987-2021.

Null Hypothesis: D(AHP) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-3.934207	0.0047
Test critical values:	1% level	-3.639407	
	5% level	-2.951125	
	10% level	-2.614300	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(AHP,2)
Method: Least Squares
Date: 05/09/22 Time: 12:35
Sample (adjusted): 1988 2021
Included observations: 34 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(AHP(-1))	-0.680023	0.172849	-3.934207	0.0004
C	5816.754	1962.698	2.963652	0.0057

R-squared	0.326003	Mean dependent var	476.5294
Adjusted R-squared	0.304941	S.D. dependent var	9915.023
S.E. of regression	8266.174	Akaike info criterion	20.93475
Sum squared resid	2.19E+09	Schwarz criterion	21.02454
Log likelihood	-353.8908	Hannan-Quinn criter.	20.96537
F-statistic	15.47798	Durbin-Watson stat	1.997202
Prob(F-statistic)	0.000421		

Figure 17. ADF unit root test for AHP at 1st difference, time period 1988-2021.

Null Hypothesis: AHP has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 3 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-1.888177	0.6393
Test critical values:	1% level	-4.243644	
	5% level	-3.544284	
	10% level	-3.204699	

*MacKinnon (1996) one-sided p-values.

Residual variance (no correction)	61863950
HAC corrected variance (Bartlett kernel)	1.02E+08

Phillips-Perron Test Equation
Dependent Variable: D(AHP)
Method: Least Squares
Date: 05/09/22 Time: 12:37
Sample (adjusted): 1987 2021
Included observations: 35 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
AHP(-1)	-0.117035	0.070595	-1.657831	0.1071
C	-25629.40	17420.28	-1.471239	0.1510
@TREND("1960")	1194.451	641.4069	1.862236	0.0718

R-squared	0.111866	Mean dependent var	8209.114
Adjusted R-squared	0.056357	S.D. dependent var	8467.868
S.E. of regression	8225.795	Akaike info criterion	20.94975
Sum squared resid	2.17E+09	Schwarz criterion	21.08307
Log likelihood	-363.6207	Hannan-Quinn criter.	20.99577
F-statistic	2.015294	Durbin-Watson stat	1.345265
Prob(F-statistic)	0.149850		

Figure 18. Phillips-Perron unit root test for AHP at level, time period 1987-2021.

Null Hypothesis: D(AHP) has a unit root
Exogenous: Constant
Bandwidth: 2 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-3.924963	0.0048
Test critical values:	1% level	-3.639407	
	5% level	-2.951125	
	10% level	-2.614300	

*MacKinnon (1996) one-sided p-values.

Residual variance (no correction)	64310247
HAC corrected variance (Bartlett kernel)	63637085

Phillips-Perron Test Equation
Dependent Variable: D(AHP,2)
Method: Least Squares
Date: 05/09/22 Time: 12:38
Sample (adjusted): 1988 2021
Included observations: 34 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(AHP(-1))	-0.680023	0.172849	-3.934207	0.0004
C	5816.754	1962.698	2.963652	0.0057

R-squared	0.326003	Mean dependent var	476.5294
Adjusted R-squared	0.304941	S.D. dependent var	9915.023
S.E. of regression	8266.174	Akaike info criterion	20.93475
Sum squared resid	2.19E+09	Schwarz criterion	21.02454
Log likelihood	-353.8908	Hannan-Quinn criter.	20.96537
F-statistic	15.47798	Durbin-Watson stat	1.997202
Prob(F-statistic)	0.000421		

Figure 19. Phillips-Perron unit root test for AHP at level, time period 1987-2021.

Null Hypothesis: CON01 has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 1 (Automatic - based on SIC, maxlag=10)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-3.008116	0.1387
Test critical values:	1% level	-4.118444	
	5% level	-3.486509	
	10% level	-3.171541	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(CON01)
Method: Least Squares
Date: 05/09/22 Time: 12:39
Sample (adjusted): 1962 2021
Included observations: 60 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
CON01(-1)	-0.063329	0.021053	-3.008116	0.0039
D(CON01(-1))	-0.489338	0.136432	-3.586673	0.0007
C	-19578.20	9733.227	-2.011481	0.0491
@TREND("1960")	3456.844	754.2312	4.583268	0.0000

R-squared	0.480775	Mean dependent var	31883.42
Adjusted R-squared	0.452960	S.D. dependent var	29502.96
S.E. of regression	21821.03	Akaike info criterion	22.88348
Sum squared resid	2.67E+10	Schwarz criterion	23.02310
Log likelihood	-682.5043	Hannan-Quinn criter.	22.93809
F-statistic	17.28437	Durbin-Watson stat	1.967174
Prob(F-statistic)	0.000000		

Figure 20. ADF unit root test for CON at level, time period 1962-2021.

Null Hypothesis: D(CON01) has a unit root
Exogenous: Constant
Lag Length: 10 (Automatic - based on SIC, maxlag=10)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.640248	0.0919
Test critical values:	1% level	-3.568308	
	5% level	-2.921175	
	10% level	-2.598551	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(CON01,2)
Method: Least Squares
Date: 05/09/22 Time: 12:40
Sample (adjusted): 1972 2021
Included observations: 50 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(CON01(-1))	-0.503130	0.190562	-2.640248	0.0120
D(CON01(-1),2)	-1.071532	0.201096	-5.328463	0.0000
D(CON01(-2),2)	-0.761037	0.308478	-2.467071	0.0182
D(CON01(-3),2)	-0.679085	0.335675	-2.023044	0.0501
D(CON01(-4),2)	-1.170066	0.328441	-3.562486	0.0010
D(CON01(-5),2)	-0.994824	0.342402	-2.905431	0.0061
D(CON01(-6),2)	-1.134086	0.325567	-3.483419	0.0013
D(CON01(-7),2)	-1.091349	0.328046	-3.326814	0.0020
D(CON01(-8),2)	-1.036352	0.335006	-3.093533	0.0037
D(CON01(-9),2)	-1.082724	0.323262	-3.349373	0.0018
D(CON01(-10),2)	-1.539402	0.308492	-4.990085	0.0000
C	28107.42	7287.775	3.856790	0.0004

R-squared	0.821070	Mean dependent var	2853.440
Adjusted R-squared	0.769274	S.D. dependent var	41382.11
S.E. of regression	19877.47	Akaike info criterion	22.83812
Sum squared resid	1.50E+10	Schwarz criterion	23.29701
Log likelihood	-558.9531	Hannan-Quinn criter.	23.01287
F-statistic	15.85209	Durbin-Watson stat	1.199554
Prob(F-statistic)	0.000000		

Figure 21. ADF unit root test for CON at 1st difference, time period 1972-2021.

Null Hypothesis: D(CON01,2) has a unit root
Exogenous: Constant
Lag Length: 10 (Automatic - based on SIC, maxlag=10)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-1.862719	0.3467
Test critical values:	1% level	-3.571310	
	5% level	-2.922449	
	10% level	-2.599224	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(CON01,3)
Method: Least Squares
Date: 05/09/22 Time: 12:41
Sample (adjusted): 1973 2021
Included observations: 49 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(CON01(-1),2)	-4.146580	2.226090	-1.862719	0.0705
D(CON01(-1),3)	2.147165	2.137458	1.004541	0.3216
D(CON01(-2),3)	1.569917	2.003715	0.783503	0.4383
D(CON01(-3),3)	0.954356	1.853462	0.514905	0.6097
D(CON01(-4),3)	0.242924	1.660695	0.146279	0.8845
D(CON01(-5),3)	-0.091903	1.434113	-0.064083	0.9492
D(CON01(-6),3)	-0.428442	1.205219	-0.355489	0.7242
D(CON01(-7),3)	-0.784883	0.993524	-0.789999	0.4346
D(CON01(-8),3)	-1.067748	0.776963	-1.374259	0.1776
D(CON01(-9),3)	-1.321149	0.559584	-2.360948	0.0236
D(CON01(-10),3)	-1.790515	0.317282	-5.643290	0.0000
C	4021.566	3064.334	1.312379	0.1975

R-squared	0.948706	Mean dependent var	4744.959
Adjusted R-squared	0.933457	S.D. dependent var	62242.79
S.E. of regression	16056.11	Akaike info criterion	22.41446
Sum squared resid	9.54E+09	Schwarz criterion	22.87776
Log likelihood	-537.1543	Hannan-Quinn criter.	22.59024
F-statistic	62.21257	Durbin-Watson stat	1.614011
Prob(F-statistic)	0.000000		

Figure 22. ADF unit root test for CON at 2nd difference, time period 1973-2021.

Null Hypothesis: CON01 has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 5 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-2.593452	0.2847
Test critical values:	1% level	-4.115684	
	5% level	-3.485218	
	10% level	-3.170793	

*MacKinnon (1996) one-sided p-values.

Residual variance (no correction)	5.41E+08
HAC corrected variance (Bartlett kernel)	2.06E+08

Phillips-Perron Test Equation
Dependent Variable: D(CON01)
Method: Least Squares
Date: 05/09/22 Time: 12:41
Sample (adjusted): 1961 2021
Included observations: 61 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
CON01(-1)	-0.042446	0.021302	-1.992625	0.0510
C	-12938.37	9701.305	-1.333673	0.1875
@TREND("1960")	2345.156	721.7414	3.249302	0.0019

R-squared	0.369055	Mean dependent var	31381.66
Adjusted R-squared	0.347298	S.D. dependent var	29517.37
S.E. of regression	23847.08	Akaike info criterion	23.04464
Sum squared resid	3.30E+10	Schwarz criterion	23.14845
Log likelihood	-699.8615	Hannan-Quinn criter.	23.08533
F-statistic	16.96279	Durbin-Watson stat	2.459673
Prob(F-statistic)	0.000002		

Figure 23. Phillips-Perron unit root test for CON at level, time period 1961-2021.

Null Hypothesis: D(CON01) has a unit root
Exogenous: Constant
Bandwidth: 5 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-7.213388	0.0000
Test critical values:	1% level	-3.544063	
	5% level	-2.910860	
	10% level	-2.593090	

*MacKinnon (1996) one-sided p-values.

Residual variance (no correction)	8.52E+08
HAC corrected variance (Bartlett kernel)	1.53E+09

Phillips-Perron Test Equation
Dependent Variable: D(CON01,2)
Method: Least Squares
Date: 05/09/22 Time: 12:42
Sample (adjusted): 1962 2021
Included observations: 60 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(CON01(-1))	-0.924477	0.151502	-6.102064	0.0000
C	29660.39	5880.609	5.043762	0.0000

R-squared	0.390981	Mean dependent var	2448.117
Adjusted R-squared	0.380481	S.D. dependent var	37724.37
S.E. of regression	29692.67	Akaike info criterion	23.46795
Sum squared resid	5.11E+10	Schwarz criterion	23.53776
Log likelihood	-702.0386	Hannan-Quinn criter.	23.49526
F-statistic	37.23519	Durbin-Watson stat	1.760227
Prob(F-statistic)	0.000000		

Figure 24. Phillips-Perron unit root test for CON At 1st difference, time period 1962-2021.

Null Hypothesis: DGS has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 3 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-3.544528	0.0509
Test critical values:	1% level	-4.262735	
	5% level	-3.552973	
	10% level	-3.209642	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(DGS)
Method: Least Squares
Date: 05/09/22 Time: 12:44
Sample (adjusted): 1989 2021
Included observations: 33 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
DGS(-1)	-0.463519	0.130770	-3.544528	0.0015
D(DGS(-1))	0.000916	0.167728	0.005464	0.9957
D(DGS(-2))	0.452087	0.231790	1.950412	0.0616
D(DGS(-3))	0.581708	0.270256	2.152430	0.0405
C	-23923.87	7438.679	-3.216145	0.0034
@TREND("1960")	1417.658	393.0251	3.607042	0.0012

R-squared	0.387565	Mean dependent var	3109.364
Adjusted R-squared	0.274151	S.D. dependent var	3903.758
S.E. of regression	3325.876	Akaike info criterion	19.21982
Sum squared resid	2.99E+08	Schwarz criterion	19.49191
Log likelihood	-311.1270	Hannan-Quinn criter.	19.31137
F-statistic	3.417258	Durbin-Watson stat	1.997297
Prob(F-statistic)	0.016068		

Figure 25. ADF unit root test for DGS at level, time period 1989-2021.

Null Hypothesis: D(DGS) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-5.934482	0.0000
Test critical values:	1% level	-3.632900	
	5% level	-2.948404	
	10% level	-2.612874	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(DGS,2)
Method: Least Squares
Date: 05/09/22 Time: 12:45
Sample (adjusted): 1987 2021
Included observations: 35 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(DGS(-1))	-1.101906	0.185679	-5.934482	0.0000
C	3585.756	870.9161	4.117223	0.0002

R-squared	0.516257	Mean dependent var	211.0571
Adjusted R-squared	0.501598	S.D. dependent var	5527.764
S.E. of regression	3902.467	Akaike info criterion	19.43205
Sum squared resid	5.03E+08	Schwarz criterion	19.52093
Log likelihood	-338.0609	Hannan-Quinn criter.	19.46273
F-statistic	35.21807	Durbin-Watson stat	1.866730
Prob(F-statistic)	0.000001		

Figure 26. ADF unit root test for DGS at 1st difference, time period 1987-2021.

Null Hypothesis: DGS has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 3 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-2.177843	0.4870
Test critical values:	1% level	-4.234972	
	5% level	-3.540328	
	10% level	-3.202445	

*MacKinnon (1996) one-sided p-values.

Residual variance (no correction)	12709432
HAC corrected variance (Bartlett kernel)	16999898

Phillips-Perron Test Equation
Dependent Variable: D(DGS)
Method: Least Squares
Date: 05/09/22 Time: 12:48
Sample (adjusted): 1986 2021
Included observations: 36 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
DGS(-1)	-0.207230	0.110454	-1.876162	0.0695
C	-7731.546	6086.411	-1.270297	0.2129
@TREND("1960")	643.9880	339.2054	1.898519	0.0664

R-squared	0.098511	Mean dependent var	3291.139
Adjusted R-squared	0.043875	S.D. dependent var	3808.028
S.E. of regression	3723.551	Akaike info criterion	19.36240
Sum squared resid	4.58E+08	Schwarz criterion	19.49436
Log likelihood	-345.5232	Hannan-Quinn criter.	19.40846
F-statistic	1.803051	Durbin-Watson stat	1.874305
Prob(F-statistic)	0.180654		

Figure 27. Phillips-Perron unit root test for DGS at level, time period 1986-2021.

Null Hypothesis: D(DGS) has a unit root
Exogenous: Constant
Bandwidth: 3 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-6.035312	0.0000
Test critical values:	1% level	-3.632900	
	5% level	-2.948404	
	10% level	-2.612874	

*MacKinnon (1996) one-sided p-values.

Residual variance (no correction)	14359006
HAC corrected variance (Bartlett kernel)	18674649

Phillips-Perron Test Equation
Dependent Variable: D(DGS,2)
Method: Least Squares
Date: 05/09/22 Time: 12:51
Sample (adjusted): 1987 2021
Included observations: 35 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(DGS(-1))	-1.101906	0.185679	-5.934482	0.0000
C	3585.756	870.9161	4.117223	0.0002

R-squared	0.516257	Mean dependent var	211.0571
Adjusted R-squared	0.501598	S.D. dependent var	5527.764
S.E. of regression	3902.467	Akaike info criterion	19.43205
Sum squared resid	5.03E+08	Schwarz criterion	19.52093
Log likelihood	-338.0609	Hannan-Quinn criter.	19.46273
F-statistic	35.21807	Durbin-Watson stat	1.866730
Prob(F-statistic)	0.000001		

Figure 28. Phillips-Perron unit root test for DGS at 1st difference, time period 1987-2021.

Null Hypothesis: GDP has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=10)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.649212	0.2610
Test critical values:	1% level	-4.115684	
	5% level	-3.485218	
	10% level	-3.170793	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(GDP)
Method: Least Squares
Date: 05/09/22 Time: 12:51
Sample (adjusted): 1961 2021
Included observations: 61 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
GDP(-1)	-0.192992	0.072849	-2.649212	0.0104
C	105838.1	33540.53	3.155527	0.0025
@TREND("1960")	5682.332	2104.294	2.700351	0.0091

R-squared	0.112077	Mean dependent var	26595.56
Adjusted R-squared	0.081459	S.D. dependent var	42626.50
S.E. of regression	40853.46	Akaike info criterion	24.12130
Sum squared resid	9.68E+10	Schwarz criterion	24.22511
Log likelihood	-732.6997	Hannan-Quinn criter.	24.16199
F-statistic	3.660506	Durbin-Watson stat	2.052818
Prob(F-statistic)	0.031833		

Figure 29. ADF unit root test for GDP at level, time period 1961-2021.

Null Hypothesis: D(GDP) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=10)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-8.543941	0.0000
Test critical values:	1% level	-3.544063	
	5% level	-2.910860	
	10% level	-2.593090	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(GDP,2)
Method: Least Squares
Date: 05/09/22 Time: 12:52
Sample (adjusted): 1962 2021
Included observations: 60 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(GDP(-1))	-1.194430	0.139798	-8.543941	0.0000
C	31546.14	6481.775	4.866899	0.0000

R-squared	0.557248	Mean dependent var	2281.317
Adjusted R-squared	0.549615	S.D. dependent var	63514.20
S.E. of regression	42624.86	Akaike info criterion	24.19103
Sum squared resid	1.05E+11	Schwarz criterion	24.26084
Log likelihood	-723.7308	Hannan-Quinn criter.	24.21834
F-statistic	72.99892	Durbin-Watson stat	1.933307
Prob(F-statistic)	0.000000		

Figure 30. ADF unit root test for GDP at 1st difference, time period 1962-2021.

Null Hypothesis: GDP has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 0 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-2.649212	0.2610
Test critical values:	1% level	-4.115684	
	5% level	-3.485218	
	10% level	-3.170793	

*MacKinnon (1996) one-sided p-values.

Residual variance (no correction)	1.59E+09
HAC corrected variance (Bartlett kernel)	1.59E+09

Phillips-Perron Test Equation
Dependent Variable: D(GDP)
Method: Least Squares
Date: 05/09/22 Time: 12:53
Sample (adjusted): 1961 2021
Included observations: 61 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
GDP(-1)	-0.192992	0.072849	-2.649212	0.0104
C	105838.1	33540.53	3.155527	0.0025
@TREND("1960")	5682.332	2104.294	2.700351	0.0091

R-squared	0.112077	Mean dependent var	26595.56
Adjusted R-squared	0.081459	S.D. dependent var	42626.50
S.E. of regression	40853.46	Akaike info criterion	24.12130
Sum squared resid	9.68E+10	Schwarz criterion	24.22511
Log likelihood	-732.6997	Hannan-Quinn criter.	24.16199
F-statistic	3.660506	Durbin-Watson stat	2.052818
Prob(F-statistic)	0.031833		

Figure 31. Phillips-Perron unit root test for GDP at level, time period 1961-2021.

Null Hypothesis: D(GDP) has a unit root
Exogenous: Constant
Bandwidth: 2 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-8.543256	0.0000
Test critical values:	1% level	-3.544063	
	5% level	-2.910860	
	10% level	-2.593090	

*MacKinnon (1996) one-sided p-values.

Residual variance (no correction)	1.76E+09
HAC corrected variance (Bartlett kernel)	1.76E+09

Phillips-Perron Test Equation
Dependent Variable: D(GDP,2)
Method: Least Squares
Date: 05/09/22 Time: 12:54
Sample (adjusted): 1962 2021
Included observations: 60 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(GDP(-1))	-1.194430	0.139798	-8.543941	0.0000
C	31546.14	6481.775	4.866899	0.0000

R-squared	0.557248	Mean dependent var	2281.317
Adjusted R-squared	0.549615	S.D. dependent var	63514.20
S.E. of regression	42624.86	Akaike info criterion	24.19103
Sum squared resid	1.05E+11	Schwarz criterion	24.26084
Log likelihood	-723.7308	Hannan-Quinn criter.	24.21834
F-statistic	72.99892	Durbin-Watson stat	1.933307
Prob(F-statistic)	0.000000		

Figure 32. Phillips-Perron unit root test for GDP at 1st difference, time period 1962-2021.

Null Hypothesis: GNI has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 1 (Automatic - based on SIC, maxlag=10)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.530766	0.3128
Test critical values:	1% level	-4.118444	
	5% level	-3.486509	
	10% level	-3.171541	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(GNI)
Method: Least Squares
Date: 05/09/22 Time: 12:55
Sample (adjusted): 1962 2021
Included observations: 60 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
GNI(-1)	-0.066547	0.026295	-2.530766	0.0142
D(GNI(-1))	-0.488272	0.131744	-3.706215	0.0005
C	-22945.56	13844.42	-1.657387	0.1030
@TREND("1960")	4188.808	1082.238	3.870506	0.0003

R-squared	0.427563	Mean dependent var	37950.82
Adjusted R-squared	0.396896	S.D. dependent var	39516.07
S.E. of regression	30688.07	Akaike info criterion	23.56548
Sum squared resid	5.27E+10	Schwarz criterion	23.70510
Log likelihood	-702.9643	Hannan-Quinn criter.	23.62009
F-statistic	13.94244	Durbin-Watson stat	1.946694
Prob(F-statistic)	0.000001		

Figure 33. ADF unit root test for GNI at level, time period 1962-2021.

Null Hypothesis: D(GNI) has a unit root
Exogenous: Constant
Lag Length: 10 (Automatic - based on SIC, maxlag=10)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-1.916323	0.3224
Test critical values:	1% level	-3.568308	
	5% level	-2.921175	
	10% level	-2.598551	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(GNI,2)
Method: Least Squares
Date: 05/09/22 Time: 12:56
Sample (adjusted): 1972 2021
Included observations: 50 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(GNI(-1))	-0.430090	0.224435	-1.916323	0.0629
D(GNI(-1),2)	-0.952800	0.220382	-4.323403	0.0001
D(GNI(-2),2)	-0.802877	0.281531	-2.851827	0.0070
D(GNI(-3),2)	-0.565991	0.291601	-1.940975	0.0597
D(GNI(-4),2)	-0.774583	0.301478	-2.569289	0.0142
D(GNI(-5),2)	-0.775679	0.295015	-2.629287	0.0123
D(GNI(-6),2)	-1.035291	0.289243	-3.579313	0.0010
D(GNI(-7),2)	-0.665573	0.287716	-2.313298	0.0262
D(GNI(-8),2)	-0.763551	0.284338	-2.685365	0.0107
D(GNI(-9),2)	-0.972416	0.258389	-3.763375	0.0006
D(GNI(-10),2)	-1.452845	0.219861	-6.608016	0.0000
C	29007.40	9496.629	3.054495	0.0041

R-squared	0.846968	Mean dependent var	3594.460
Adjusted R-squared	0.802669	S.D. dependent var	59654.13
S.E. of regression	26499.52	Akaike info criterion	23.41320
Sum squared resid	2.67E+10	Schwarz criterion	23.87209
Log likelihood	-573.3301	Hannan-Quinn criter.	23.58795
F-statistic	19.11945	Durbin-Watson stat	1.733349
Prob(F-statistic)	0.000000		

Figure 34. ADF unit root test for GNI at 1st difference, time period 1972-2021.

Null Hypothesis: D(GNI,2) has a unit root
Exogenous: Constant
Lag Length: 9 (Automatic - based on SIC, maxlag=10)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-7.102743	0.0000
Test critical values:	1% level	-3.568308	
	5% level	-2.921175	
	10% level	-2.598551	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(GNI,3)
Method: Least Squares
Date: 05/09/22 Time: 12:57
Sample (adjusted): 1972 2021
Included observations: 50 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(GNI(-1),2)	-11.72374	1.650594	-7.102743	0.0000
D(GNI(-1),3)	9.405076	1.609215	5.844510	0.0000
D(GNI(-2),3)	8.274023	1.498536	5.521404	0.0000
D(GNI(-3),3)	7.418074	1.362247	5.445471	0.0000
D(GNI(-4),3)	6.379329	1.195317	5.336933	0.0000
D(GNI(-5),3)	5.388984	1.021277	5.276713	0.0000
D(GNI(-6),3)	4.179324	0.840255	4.973878	0.0000
D(GNI(-7),3)	3.389756	0.649655	5.217780	0.0000
D(GNI(-8),3)	2.534188	0.430778	5.882820	0.0000
D(GNI(-9),3)	1.496627	0.226038	6.621122	0.0000
C	12744.34	4405.467	2.892846	0.0062

R-squared	0.931114	Mean dependent var	6191.700
Adjusted R-squared	0.913451	S.D. dependent var	93110.57
S.E. of regression	27392.36	Akaike info criterion	23.46545
Sum squared resid	2.93E+10	Schwarz criterion	23.88610
Log likelihood	-575.6364	Hannan-Quinn criter.	23.62564
F-statistic	52.71549	Durbin-Watson stat	1.672608
Prob(F-statistic)	0.000000		

Figure 35. ADF unit root tests for GNI at 2nd difference, time period 1972-2021.

Null Hypothesis: GNI has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 9 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-2.365762	0.3933
Test critical values:	1% level	-4.115684	
	5% level	-3.485218	
	10% level	-3.170793	

*MacKinnon (1996) one-sided p-values.

Residual variance (no correction)	1.08E+09
HAC corrected variance (Bartlett kernel)	2.59E+08

Phillips-Perron Test Equation
Dependent Variable: D(GNI)
Method: Least Squares
Date: 05/09/22 Time: 13:13
Sample (adjusted): 1961 2021
Included observations: 61 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
GNI(-1)	-0.047979	0.027103	-1.770271	0.0819
C	-16621.78	13917.65	-1.194295	0.2372
@TREND("1960")	2977.786	1076.073	2.767272	0.0076

R-squared	0.293458	Mean dependent var	37357.20
Adjusted R-squared	0.269095	S.D. dependent var	39458.71
S.E. of regression	33734.44	Akaike info criterion	23.73836
Sum squared resid	6.60E+10	Schwarz criterion	23.84217
Log likelihood	-721.0198	Hannan-Quinn criter.	23.77904
F-statistic	12.04498	Durbin-Watson stat	2.537141
Prob(F-statistic)	0.000042		

Figure 36. Phillips-Perron unit root test for GNI at level, time period 1961-2021.

Null Hypothesis: D(GNI) has a unit root
Exogenous: Constant
Bandwidth: 5 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-8.133928	0.0000
Test critical values:	1% level	-3.544063	
	5% level	-2.910860	
	10% level	-2.593090	

*MacKinnon (1996) one-sided p-values.

Residual variance (no correction)	1.53E+09
HAC corrected variance (Bartlett kernel)	2.91E+09

Phillips-Perron Test Equation
Dependent Variable: D(GNI,2)
Method: Least Squares
Date: 05/09/22 Time: 13:14
Sample (adjusted): 1962 2021
Included observations: 60 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(GNI(-1))	-1.081297	0.149388	-7.238172	0.0000
C	40785.80	7312.873	5.577261	0.0000

R-squared	0.474596	Mean dependent var	3078.767
Adjusted R-squared	0.465537	S.D. dependent var	54377.70
S.E. of regression	39753.90	Akaike info criterion	24.05157
Sum squared resid	9.17E+10	Schwarz criterion	24.12138
Log likelihood	-719.5471	Hannan-Quinn criter.	24.07888
F-statistic	52.39114	Durbin-Watson stat	1.761932
Prob(F-statistic)	0.000000		

Figure 37. Phillips-Perron unit root tests for GNI at 1st difference, time period 1962-2021.

Null Hypothesis: INF has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=10)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.195209	0.2101
Test critical values:	1% level	-3.544063	
	5% level	-2.910860	
	10% level	-2.593090	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(INF)
Method: Least Squares
Date: 05/06/22 Time: 16:16
Sample (adjusted): 1961 2020
Included observations: 60 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
INF(-1)	-0.153465	0.069909	-2.195209	0.0322
C	0.791420	0.493971	1.602160	0.1146

R-squared	0.076712	Mean dependent var	-0.000235
Adjusted R-squared	0.060793	S.D. dependent var	2.698112
S.E. of regression	2.614813	Akaike info criterion	4.793028
Sum squared resid	396.5604	Schwarz criterion	4.862839
Log likelihood	-141.7908	Hannan-Quinn criter.	4.820335
F-statistic	4.818944	Durbin-Watson stat	1.839853
Prob(F-statistic)	0.032164		

Figure 38. ADF unit root test for INF at level, time period 1961-2020.

Null Hypothesis: D(INF) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=10)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-7.548575	0.0000
Test critical values:	1% level	-4.121303	
	5% level	-3.487845	
	10% level	-3.172314	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(INF,2)
Method: Least Squares
Date: 05/06/22 Time: 16:25
Sample (adjusted): 1962 2020
Included observations: 59 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(INF(-1))	-1.003603	0.132953	-7.548575	0.0000
C	0.279448	0.744074	0.375565	0.7087
@TREND("1960")	-0.010357	0.021051	-0.491995	0.6246

R-squared	0.504430	Mean dependent var	-0.054111
Adjusted R-squared	0.486731	S.D. dependent var	3.829910
S.E. of regression	2.743856	Akaike info criterion	4.906115
Sum squared resid	421.6097	Schwarz criterion	5.011752
Log likelihood	-141.7304	Hannan-Quinn criter.	4.947351
F-statistic	28.50054	Durbin-Watson stat	2.005557
Prob(F-statistic)	0.000000		

Figure 39. ADF unit root test for INF at 1st difference, time period 1962-2020.

Null Hypothesis: INF has a unit root
Exogenous: Constant
Bandwidth: 8 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-2.265693	0.1863
Test critical values:	1% level	-3.544063	
	5% level	-2.910860	
	10% level	-2.593090	

*MacKinnon (1996) one-sided p-values.

Residual variance (no correction)	6.609341
HAC corrected variance (Bartlett kernel)	7.099991

Phillips-Perron Test Equation
Dependent Variable: D(INF)
Method: Least Squares
Date: 05/06/22 Time: 16:26
Sample (adjusted): 1961 2020
Included observations: 60 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
INF(-1)	-0.153465	0.069909	-2.195209	0.0322
C	0.791420	0.493971	1.602160	0.1146

R-squared	0.076712	Mean dependent var	-0.000235
Adjusted R-squared	0.060793	S.D. dependent var	2.698112
S.E. of regression	2.614813	Akaike info criterion	4.793028
Sum squared resid	396.5604	Schwarz criterion	4.862839
Log likelihood	-141.7908	Hannan-Quinn criter.	4.820335
F-statistic	4.818944	Durbin-Watson stat	1.839853
Prob(F-statistic)	0.032164		

Figure 40. Phillips-Perron unit root test for INF at level, time period 1961-2020.

Null Hypothesis: D(INF) has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 37 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-11.09107	0.0000
Test critical values:	1% level	-4.121303	
	5% level	-3.487845	
	10% level	-3.172314	

*MacKinnon (1996) one-sided p-values.

Residual variance (no correction)	7.145927
HAC corrected variance (Bartlett kernel)	1.075363

Phillips-Perron Test Equation
Dependent Variable: D(INF,2)
Method: Least Squares
Date: 05/06/22 Time: 16:28
Sample (adjusted): 1962 2020
Included observations: 59 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(INF(-1))	-1.003603	0.132953	-7.548575	0.0000
C	0.279448	0.744074	0.375565	0.7087
@TREND("1960")	-0.010357	0.021051	-0.491995	0.6246

R-squared	0.504430	Mean dependent var	-0.054111
Adjusted R-squared	0.486731	S.D. dependent var	3.829910
S.E. of regression	2.743856	Akaike info criterion	4.906115
Sum squared resid	421.6097	Schwarz criterion	5.011752
Log likelihood	-141.7304	Hannan-Quinn criter.	4.947351
F-statistic	28.50054	Durbin-Watson stat	2.005557
Prob(F-statistic)	0.000000		

Figure 41. Phillips-Perron unit root test for INF at 1st difference, time period 1962-2020.

Null Hypothesis: NDG has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 1 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.148556	0.5016
Test critical values:	1% level	-4.252879	
	5% level	-3.548490	
	10% level	-3.207094	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(NDG)
Method: Least Squares
Date: 05/09/22 Time: 13:16
Sample (adjusted): 1987 2020
Included observations: 34 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
NDG(-1)	-0.250215	0.116457	-2.148556	0.0399
D(NDG(-1))	0.379055	0.177656	2.133650	0.0412
C	-24161.96	12392.82	-1.949674	0.0606
@TREND("1960")	1680.703	748.2084	2.246303	0.0322

R-squared	0.232384	Mean dependent var	6709.235
Adjusted R-squared	0.155623	S.D. dependent var	4219.042
S.E. of regression	3876.877	Akaike info criterion	19.47358
Sum squared resid	4.51E+08	Schwarz criterion	19.65315
Log likelihood	-327.0508	Hannan-Quinn criter.	19.53482
F-statistic	3.027355	Durbin-Watson stat	1.846824
Prob(F-statistic)	0.044758		

Figure 42. ADF unit root test for NDG at level, time period 1987-2020.

Null Hypothesis: D(NDG) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.156742	0.0026
Test critical values:	1% level	-3.639407	
	5% level	-2.951125	
	10% level	-2.614300	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(NDG,2)
Method: Least Squares
Date: 05/09/22 Time: 13:18
Sample (adjusted): 1987 2020
Included observations: 34 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(NDG(-1))	-0.713161	0.171567	-4.156742	0.0002
C	4852.765	1315.123	3.689970	0.0008

R-squared	0.350630	Mean dependent var	237.0588
Adjusted R-squared	0.330337	S.D. dependent var	5020.919
S.E. of regression	4108.766	Akaike info criterion	19.53666
Sum squared resid	5.40E+08	Schwarz criterion	19.62644
Log likelihood	-330.1231	Hannan-Quinn criter.	19.56728
F-statistic	17.27850	Durbin-Watson stat	1.844649
Prob(F-statistic)	0.000225		

Figure 43. ADF unit root test for NDG at 1st difference, time period 1987-2020.

Null Hypothesis: NDG has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 4 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-1.541299	0.7954
Test critical values:	1% level	-4.243644	
	5% level	-3.544284	
	10% level	-3.204699	

*MacKinnon (1996) one-sided p-values.

Residual variance (no correction)	14838162
HAC corrected variance (Bartlett kernel)	15748117

Phillips-Perron Test Equation
Dependent Variable: D(NDG)
Method: Least Squares
Date: 05/09/22 Time: 13:19
Sample (adjusted): 1986 2020
Included observations: 35 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
NDG(-1)	-0.162679	0.110317	-1.474652	0.1501
C	-14362.32	11410.37	-1.258707	0.2172
@TREND("1960")	1152.338	709.9739	1.623071	0.1144

R-squared	0.131411	Mean dependent var	6615.314
Adjusted R-squared	0.077125	S.D. dependent var	4193.509
S.E. of regression	4028.553	Akaike info criterion	19.52202
Sum squared resid	5.19E+08	Schwarz criterion	19.65533
Log likelihood	-338.6353	Hannan-Quinn criter.	19.56804
F-statistic	2.420688	Durbin-Watson stat	1.376109
Prob(F-statistic)	0.104961		

Figure 44. Phillips-Perron unit root tests for NDG at 1st difference, time period 1986-2020.

Null Hypothesis: D(NDG) has a unit root
Exogenous: Constant
Bandwidth: 9 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-3.875782	0.0055
Test critical values:	1% level	-3.639407	
	5% level	-2.951125	
	10% level	-2.614300	

*MacKinnon (1996) one-sided p-values.

Residual variance (no correction)	15888901
HAC corrected variance (Bartlett kernel)	7523274.

Phillips-Perron Test Equation
Dependent Variable: D(NDG,2)
Method: Least Squares
Date: 05/09/22 Time: 13:20
Sample (adjusted): 1987 2020
Included observations: 34 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(NDG(-1))	-0.713161	0.171567	-4.156742	0.0002
C	4852.765	1315.123	3.689970	0.0008

R-squared	0.350630	Mean dependent var	237.0588
Adjusted R-squared	0.330337	S.D. dependent var	5020.919
S.E. of regression	4108.766	Akaike info criterion	19.53666
Sum squared resid	5.40E+08	Schwarz criterion	19.62644
Log likelihood	-330.1231	Hannan-Quinn criter.	19.56728
F-statistic	17.27850	Durbin-Watson stat	1.844649
Prob(F-statistic)	0.000225		

Figure 45. Phillips-Perron unit root test for NDG at 1st difference, time period 1987 2020.

Null Hypothesis: RIR has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.756766	0.0724
Test critical values:	1% level	-3.577723	
	5% level	-2.925169	
	10% level	-2.600658	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(RIR)
Method: Least Squares
Date: 05/06/22 Time: 17:07
Sample (adjusted): 1968 2014
Included observations: 47 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
RIR(-1)	-0.292981	0.106277	-2.756766	0.0084
C	0.375557	0.418775	0.896800	0.3746

R-squared	0.144483	Mean dependent var	-0.033003
Adjusted R-squared	0.125471	S.D. dependent var	2.871353
S.E. of regression	2.685181	Akaike info criterion	4.854995
Sum squared resid	324.4589	Schwarz criterion	4.933724
Log likelihood	-112.0924	Hannan-Quinn criter.	4.884621
F-statistic	7.599759	Durbin-Watson stat	2.071151
Prob(F-statistic)	0.008402		

Figure 46. ADF unit root tests for RIR at level, time period 1968-2014.

Null Hypothesis: D(RIR) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-8.045234	0.0000
Test critical values:	1% level	-4.170583	
	5% level	-3.510740	
	10% level	-3.185512	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(RIR,2)
Method: Least Squares
Date: 05/06/22 Time: 17:07
Sample (adjusted): 1969 2014
Included observations: 46 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(RIR(-1))	-1.199833	0.149136	-8.045234	0.0000
C	0.151875	1.101385	0.137895	0.8910
@TREND("1960")	-0.007298	0.032237	-0.226394	0.8220

R-squared	0.600997	Mean dependent var	-0.021193
Adjusted R-squared	0.582438	S.D. dependent var	4.485413
S.E. of regression	2.898430	Akaike info criterion	5.029209
Sum squared resid	361.2384	Schwarz criterion	5.148468
Log likelihood	-112.6718	Hannan-Quinn criter.	5.073884
F-statistic	32.38426	Durbin-Watson stat	2.057971
Prob(F-statistic)	0.000000		

Figure 47. ADF unit root test for RIR at 1st difference, time period 1969-2014.

Null Hypothesis: RIR has a unit root
Exogenous: Constant
Bandwidth: 1 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-2.715414	0.0790
Test critical values:	1% level	-3.577723	
	5% level	-2.925169	
	10% level	-2.600658	

*MacKinnon (1996) one-sided p-values.

Residual variance (no correction)	6.903380
HAC corrected variance (Bartlett kernel)	6.637270

Phillips-Perron Test Equation
Dependent Variable: D(RIR)
Method: Least Squares
Date: 05/06/22 Time: 17:09
Sample (adjusted): 1968 2014
Included observations: 47 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
RIR(-1)	-0.292981	0.106277	-2.756766	0.0084
C	0.375557	0.418775	0.896800	0.3746

R-squared	0.144483	Mean dependent var	-0.033003
Adjusted R-squared	0.125471	S.D. dependent var	2.871353
S.E. of regression	2.685181	Akaike info criterion	4.854995
Sum squared resid	324.4589	Schwarz criterion	4.933724
Log likelihood	-112.0924	Hannan-Quinn criter.	4.884621
F-statistic	7.599759	Durbin-Watson stat	2.071151
Prob(F-statistic)	0.008402		

Figure 48. Phillips-Perron unit root test for RIR at level, time period 1968-2014.

Null Hypothesis: D(RIR) has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 6 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-8.657774	0.0000
Test critical values:	1% level	-4.170583	
	5% level	-3.510740	
	10% level	-3.185512	

*MacKinnon (1996) one-sided p-values.

Residual variance (no correction)	7.853009
HAC corrected variance (Bartlett kernel)	4.754890

Phillips-Perron Test Equation
Dependent Variable: D(RIR,2)
Method: Least Squares
Date: 05/06/22 Time: 17:09
Sample (adjusted): 1969 2014
Included observations: 46 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(RIR(-1))	-1.199833	0.149136	-8.045234	0.0000
C	0.151875	1.101385	0.137895	0.8910
@TREND("1960")	-0.007298	0.032237	-0.226394	0.8220

R-squared	0.600997	Mean dependent var	-0.021193
Adjusted R-squared	0.582438	S.D. dependent var	4.485413
S.E. of regression	2.898430	Akaike info criterion	5.029209
Sum squared resid	361.2384	Schwarz criterion	5.148468
Log likelihood	-112.6718	Hannan-Quinn criter.	5.073884
F-statistic	32.38426	Durbin-Watson stat	2.057971
Prob(F-statistic)	0.000000		

Figure 49. Phillips-Perron unit root test for RIR at 1st difference, time period 1969-2014.

Null Hypothesis: TBD has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=5)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-8.221891	0.0000
Test critical values:	1% level	-4.394309	
	5% level	-3.612199	
	10% level	-3.243079	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(TBD)
Method: Least Squares
Date: 05/09/22 Time: 13:21
Sample (adjusted): 1998 2021
Included observations: 24 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
TBD(-1)	-0.863466	0.105020	-8.221891	0.0000
C	-9390895.	1609098.	-5.836123	0.0000
@TREND("1960")	390153.5	54714.74	7.130684	0.0000

R-squared	0.811416	Mean dependent var	561636.3
Adjusted R-squared	0.793456	S.D. dependent var	798127.0
S.E. of regression	362725.7	Akaike info criterion	28.55715
Sum squared resid	2.76E+12	Schwarz criterion	28.70441
Log likelihood	-339.6858	Hannan-Quinn criter.	28.59622
F-statistic	45.17821	Durbin-Watson stat	0.893431
Prob(F-statistic)	0.000000		

Figure 50. ADF unit root test for TBD at level, time period 1998-2021.

Null Hypothesis: D(TBD) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=5)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-10.76060	0.0000
Test critical values:	1% level	-3.752946	
	5% level	-2.998064	
	10% level	-2.638752	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(TBD,2)
Method: Least Squares
Date: 05/09/22 Time: 13:22
Sample (adjusted): 1999 2021
Included observations: 23 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(TBD(-1))	-0.986361	0.091664	-10.76060	0.0000
C	402848.7	88406.10	4.556797	0.0002

R-squared	0.846481	Mean dependent var	-214225.5
Adjusted R-squared	0.839170	S.D. dependent var	804620.4
S.E. of regression	322681.8	Akaike info criterion	28.28966
Sum squared resid	2.19E+12	Schwarz criterion	28.38840
Log likelihood	-323.3311	Hannan-Quinn criter.	28.31449
F-statistic	115.7905	Durbin-Watson stat	0.917119
Prob(F-statistic)	0.000000		

Figure 51. ADF unit root test for TBD at 1st difference, time period 1999-2021.

Null Hypothesis: TBD has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 2 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-7.291641	0.0000
Test critical values:	1% level	-4.394309	
	5% level	-3.612199	
	10% level	-3.243079	

*MacKinnon (1996) one-sided p-values.

Residual variance (no correction)	1.15E+11
HAC corrected variance (Bartlett kernel)	1.65E+11

Phillips-Perron Test Equation
Dependent Variable: D(TBD)
Method: Least Squares
Date: 05/09/22 Time: 13:23
Sample (adjusted): 1998 2021
Included observations: 24 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
TBD(-1)	-0.863466	0.105020	-8.221891	0.0000
C	-9390895.	1609098.	-5.836123	0.0000
@TREND("1960")	390153.5	54714.74	7.130684	0.0000

R-squared	0.811416	Mean dependent var	561636.3
Adjusted R-squared	0.793456	S.D. dependent var	798127.0
S.E. of regression	362725.7	Akaike info criterion	28.55715
Sum squared resid	2.76E+12	Schwarz criterion	28.70441
Log likelihood	-339.6858	Hannan-Quinn criter.	28.59622
F-statistic	45.17821	Durbin-Watson stat	0.893431
Prob(F-statistic)	0.000000		

Figure 52. Phillips-Perron unit root test for TBD at level, time period 1998-2021.

Null Hypothesis: D(TBD) has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 0 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-0.768254	0.9536
Test critical values:	1% level	-4.440739	
	5% level	-3.632896	
	10% level	-3.254671	

*MacKinnon (1996) one-sided p-values.

Residual variance (no correction)	67609.99
HAC corrected variance (Bartlett kernel)	67609.99

Phillips-Perron Test Equation
Dependent Variable: D(TBD,2)
Method: Least Squares
Date: 05/06/22 Time: 17:13
Sample (adjusted): 1999 2020
Included observations: 22 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(TBD(-1))	-0.324297	0.422122	-0.768254	0.4518
C	-419.6879	519.1711	-0.808381	0.4289
@TREND("1960")	11.76160	9.554927	1.230946	0.2334

R-squared	0.117168	Mean dependent var	56.46361
Adjusted R-squared	0.024239	S.D. dependent var	283.2489
S.E. of regression	279.7950	Akaike info criterion	14.23212
Sum squared resid	1487420.	Schwarz criterion	14.38089
Log likelihood	-153.5533	Hannan-Quinn criter.	14.26716
F-statistic	1.260829	Durbin-Watson stat	1.433657
Prob(F-statistic)	0.306083		

Figure 53. Phillips-Perron unit root test for TBD at 1st difference, time period 1999-2020.

Null Hypothesis: D(TBD,2) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=5)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-3.130315	0.1252
Test critical values:	1% level	-4.467895	
	5% level	-3.644963	
	10% level	-3.261452	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(TBD,3)
Method: Least Squares
Date: 05/08/22 Time: 09:03
Sample (adjusted): 2000 2020
Included observations: 21 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(TBD(-1),2)	-1.260561	0.402695	-3.130315	0.0058
C	-609.0354	523.5963	-1.163177	0.2599
@TREND("1960")	13.44583	10.39570	1.293403	0.2122

R-squared	0.389771	Mean dependent var	55.56176
Adjusted R-squared	0.321968	S.D. dependent var	350.3255
S.E. of regression	288.4676	Akaike info criterion	14.29861
Sum squared resid	1497844.	Schwarz criterion	14.44782
Log likelihood	-147.1354	Hannan-Quinn criter.	14.33099
F-statistic	5.748557	Durbin-Watson stat	1.447231
Prob(F-statistic)	0.011734		

Figure 54. ADF unit root test for TBD at 2nd difference, time period 2000-2020.

Null Hypothesis: D(TBD) has a unit root
Exogenous: Constant
Bandwidth: 1 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-10.20088	0.0000
Test critical values:	1% level	-3.752946	
	5% level	-2.998064	
	10% level	-2.638752	

*MacKinnon (1996) one-sided p-values.

Residual variance (no correction)	9.51E+10
HAC corrected variance (Bartlett kernel)	1.09E+11

Phillips-Perron Test Equation
Dependent Variable: D(TBD,2)
Method: Least Squares
Date: 05/09/22 Time: 13:23
Sample (adjusted): 1999 2021
Included observations: 23 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(TBD(-1))	-0.986361	0.091664	-10.76060	0.0000
C	402848.7	88406.10	4.556797	0.0002

R-squared	0.846481	Mean dependent var	-214225.5
Adjusted R-squared	0.839170	S.D. dependent var	804620.4
S.E. of regression	322681.8	Akaike info criterion	28.28966
Sum squared resid	2.19E+12	Schwarz criterion	28.38840
Log likelihood	-323.3311	Hannan-Quinn criter.	28.31449
F-statistic	115.7905	Durbin-Watson stat	0.917119
Prob(F-statistic)	0.000000		

Figure 55. Phillips-Perron unit root test for TBD at 1st difference, time period 1999-2021.

Null Hypothesis: D(TBD,2) has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 0 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-3.130315	0.1252
Test critical values:	1% level	-4.467895	
	5% level	-3.644963	
	10% level	-3.261452	

*MacKinnon (1996) one-sided p-values.

Residual variance (no correction)	71325.91
HAC corrected variance (Bartlett kernel)	71325.91

Phillips-Perron Test Equation
Dependent Variable: D(TBD,3)
Method: Least Squares
Date: 05/08/22 Time: 09:04
Sample (adjusted): 2000 2020
Included observations: 21 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(TBD(-1),2)	-1.260561	0.402695	-3.130315	0.0058
C	-609.0354	523.5963	-1.163177	0.2599
@TREND("1960")	13.44583	10.39570	1.293403	0.2122

R-squared	0.389771	Mean dependent var	55.56176
Adjusted R-squared	0.321968	S.D. dependent var	350.3255
S.E. of regression	288.4676	Akaike info criterion	14.29861
Sum squared resid	1497844.	Schwarz criterion	14.44782
Log likelihood	-147.1354	Hannan-Quinn criter.	14.33099
F-statistic	5.748557	Durbin-Watson stat	1.447231
Prob(F-statistic)	0.011734		

Figure 56. Phillips-Perron unit root test for TBD at 2nd difference, time period 2000-2020.

Null Hypothesis: UNR has a unit root
Exogenous: Constant
Lag Length: 1 (Automatic - based on SIC, maxlag=10)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.815293	0.0636
Test critical values:	1% level	-3.574446	
	5% level	-2.923780	
	10% level	-2.599925	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(UNR)
Method: Least Squares
Date: 05/06/22 Time: 17:13
Sample (adjusted): 1973 2020
Included observations: 48 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
UNR(-1)	-0.119733	0.042529	-2.815293	0.0072
D(UNR(-1))	0.653342	0.114183	5.721873	0.0000
C	0.840644	0.311480	2.698873	0.0098

R-squared	0.442613	Mean dependent var	0.004167
Adjusted R-squared	0.417840	S.D. dependent var	0.885812
S.E. of regression	0.675869	Akaike info criterion	2.114828
Sum squared resid	20.55598	Schwarz criterion	2.231778
Log likelihood	-47.75587	Hannan-Quinn criter.	2.159023
F-statistic	17.86691	Durbin-Watson stat	1.754899
Prob(F-statistic)	0.000002		

Figure 57. ADF unit root test for UNR at level, time period 1973-2020.

Null Hypothesis: D(UNR) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=10)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-3.413857	0.0614
Test critical values:	1% level	-4.161144	
	5% level	-3.506374	
	10% level	-3.183002	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(UNR,2)
Method: Least Squares
Date: 05/06/22 Time: 17:14
Sample (adjusted): 1973 2020
Included observations: 48 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(UNR(-1))	-0.426636	0.124972	-3.413857	0.0014
C	0.165812	0.305428	0.542884	0.5899
@TREND("1960")	-0.004330	0.007859	-0.551037	0.5843

R-squared	0.207045	Mean dependent var	0.010417
Adjusted R-squared	0.171803	S.D. dependent var	0.802719
S.E. of regression	0.730517	Akaike info criterion	2.270333
Sum squared resid	24.01447	Schwarz criterion	2.387283
Log likelihood	-51.48799	Hannan-Quinn criter.	2.314528
F-statistic	5.874882	Durbin-Watson stat	1.608074
Prob(F-statistic)	0.005409		

Figure 58. ADF unit root test for UNR at 1st difference, time period 1973-2020.

Null Hypothesis: UNR has a unit root
Exogenous: Constant
Bandwidth: 3 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-1.892559	0.3330
Test critical values:	1% level	-3.571310	
	5% level	-2.922449	
	10% level	-2.599224	

*MacKinnon (1996) one-sided p-values.

Residual variance (no correction)	0.724727
HAC corrected variance (Bartlett kernel)	1.503048

Phillips-Perron Test Equation
Dependent Variable: D(UNR)
Method: Least Squares
Date: 05/06/22 Time: 17:15
Sample (adjusted): 1972 2020
Included observations: 49 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
UNR(-1)	-0.072067	0.052846	-1.363708	0.1792
C	0.504983	0.384897	1.311997	0.1959

R-squared	0.038062	Mean dependent var	0.008163
Adjusted R-squared	0.017595	S.D. dependent var	0.876983
S.E. of regression	0.869233	Akaike info criterion	2.597549
Sum squared resid	35.51161	Schwarz criterion	2.674766
Log likelihood	-61.63995	Hannan-Quinn criter.	2.626845
F-statistic	1.859701	Durbin-Watson stat	0.797732
Prob(F-statistic)	0.179156		

Figure 59. Phillips-Perron unit root test for UNR at level, time period 1972-2020.

Null Hypothesis: D(UNR) has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 4 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-3.328956	0.0738
Test critical values:	1% level	-4.161144	
	5% level	-3.506374	
	10% level	-3.183002	

*MacKinnon (1996) one-sided p-values.

Residual variance (no correction)	0.500302
HAC corrected variance (Bartlett kernel)	0.465178

Phillips-Perron Test Equation
Dependent Variable: D(UNR,2)
Method: Least Squares
Date: 05/06/22 Time: 17:15
Sample (adjusted): 1973 2020
Included observations: 48 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(UNR(-1))	-0.426636	0.124972	-3.413857	0.0014
C	0.165812	0.305428	0.542884	0.5899
@TREND("1960")	-0.004330	0.007859	-0.551037	0.5843

R-squared	0.207045	Mean dependent var	0.010417
Adjusted R-squared	0.171803	S.D. dependent var	0.802719
S.E. of regression	0.730517	Akaike info criterion	2.270333
Sum squared resid	24.01447	Schwarz criterion	2.387283
Log likelihood	-51.48799	Hannan-Quinn criter.	2.314528
F-statistic	5.874882	Durbin-Watson stat	1.608074
Prob(F-statistic)	0.005409		

Figure 60. Phillips-Perron unit root test for UNR at 1st difference, time period 1973-2020.

Null Hypothesis: D(UNR,2) has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 10 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-7.596406	0.0000
Test critical values:	1% level	-4.165756	
	5% level	-3.508508	
	10% level	-3.184230	

*MacKinnon (1996) one-sided p-values.

Residual variance (no correction)	0.629809
HAC corrected variance (Bartlett kernel)	0.169799

Phillips-Perron Test Equation
Dependent Variable: D(UNR,3)
Method: Least Squares
Date: 05/08/22 Time: 09:05
Sample (adjusted): 1974 2020
Included observations: 47 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(UNR(-1),2)	-0.979362	0.151569	-6.461492	0.0000
C	0.018281	0.347580	0.052595	0.9583
@TREND("1960")	0.000259	0.008820	0.029411	0.9767

R-squared	0.486905	Mean dependent var	0.038298
Adjusted R-squared	0.463582	S.D. dependent var	1.119890
S.E. of regression	0.820214	Akaike info criterion	2.503198
Sum squared resid	29.60101	Schwarz criterion	2.621292
Log likelihood	-55.82514	Hannan-Quinn criter.	2.547637
F-statistic	20.87703	Durbin-Watson stat	1.913323
Prob(F-statistic)	0.000000		

Figure 61. Phillips-Perron unit root test for UNR at 2nd difference, time period 1974-2020.

Null Hypothesis: D(UNR,2) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=10)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-6.461492	0.0000
Test critical values:	1% level	-4.165756	
	5% level	-3.508508	
	10% level	-3.184230	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(UNR,3)
Method: Least Squares
Date: 05/08/22 Time: 09:09
Sample (adjusted): 1974 2020
Included observations: 47 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(UNR(-1),2)	-0.979362	0.151569	-6.461492	0.0000
C	0.018281	0.347580	0.052595	0.9583
@TREND("1960")	0.000259	0.008820	0.029411	0.9767

R-squared	0.486905	Mean dependent var	0.038298
Adjusted R-squared	0.463582	S.D. dependent var	1.119890
S.E. of regression	0.820214	Akaike info criterion	2.503198
Sum squared resid	29.60101	Schwarz criterion	2.621292
Log likelihood	-55.82514	Hannan-Quinn criter.	2.547637
F-statistic	20.87703	Durbin-Watson stat	1.913323
Prob(F-statistic)	0.000000		

Figure 62. ADF unit root test for UNR at 2nd difference, time period 1974-2020.

Regression Analysis

Table 2. OLS regression analysis, regression of RIR, RIRT, INF and GDP on CON, time period 1960-2020

	(1)
	regression_1
VARIABLES	CON
RIR	-6,560.211*
	(3,622.602)
RIRT	-3,532.039
	(3,283.357)
INF	-5,668.075*
	(3,116.229)
GDP	1.152***
	(0.031)
Constant	-849,651.284***
	(60,328.346)
Observations	47
R-squared	0.988

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

Table 3. OLS regression analysis, regression of RIR, RIRT, INF, GDP and UNR on CON, time period 1960-2020

	(1)
	regression_2
VARIABLES	CON
RIR	-7,561.031**
	(3,079.914)
RIRT	-4,241.428*
	(2,126.529)
INF	90.002
	(2,848.717)

	(1)
	regression_2
VARIABLES	CON
GDP	1.240***
	(0.039)
UNR	17,772.178***
	(3,603.348)
Constant	-1133317.951***
	(90,466.596)
Observations	44
R-squared	0.994

Robust standard errors in parentheses.
*** p < 0.01, ** p < 0.05, * p < 0.1.

Table 4. OLS regression analysis, regression of RIR, RIRT, INF, GDP, UNR, GNI, AHP and TBD on CON, time period 1960-2020

	(1)
	regression_3
VARIABLES	CON
RIR	-5,510.938
	(3,881.359)
RIRT	8,864.760*
	(4,834.436)
INF	-15,543.291*
	(7,163.814)
GDP	0.172
	(0.258)
UNR	15,894.713
	(8,774.802)
GNI	0.902***
	(0.122)
AHP	0.208
	(0.219)
TBD	-0.013

Table 4. (Continued)

	(1)
	regression_3
VARIABLES	CON
	(0.009)
Constant	-378,149.351
	(329,628.131)
Observations	18
R-squared	0.999

Robust standard errors in parentheses.
*** p < 0.01, ** p < 0.05, * p < 0.1.

Table 5. OLS regression analysis, regression of RIR and RIRT on DGS, time period 1985-2020

	(1)
	regression_4
VARIABLES	DGS
RIR	-3,582.635
	(2,469.888)
RIRT	-3,466.238
	(2,654.218)
Constant	90,750.466***
	(5,340.647)
Observations	30
R-squared	0.522

Robust standard errors in parentheses.
*** p < 0.01, ** p < 0.05, * p < 0.1.

Table 6. OLS regression analysis, regression of RIR and RIRT on NDG, time period 1985-2020

	(1)
	regression_5
VARIABLES	NDG
RIRT	-8,282.438

	(1)
	regression_5
VARIABLES	NDG
	(5,612.776)
RIR	-8,765.357
	(5,167.551)
Constant	204,167.649***
	(11,530.457)
Observations	30
R-squared	0.645

Robust standard errors in parentheses.
*** p < 0.01, ** p < 0.05, * p < 0.1.

Data Definitions

List of Tables and Figures

Chapter 4

Sensitivity Analysis Using Lineal Programming Shadow Prices to Support Stakeholders in the Decision Process – The SIMUS-IOSA Method

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Abstract

Sensitivity analysis, a fundamental technique in MCDM process has received little attention from scholars and researchers, opinion that is shared by other academics as can be confirmed by examining the literature on MCDM. Even if there are a fair number of papers, very few propose improvements to the method. The same procedure devised decades ago is still used today as no new developments have been recorded. This work draws attention on the shortcomings of the current system and refers to papers that support our claim and that provide a deeper analysis of some of them. For this reason, we believe that there is a need for a new paradigm in performing sensitivity analysis. Consequently, it proposes a new methodology that tries to overcome those drawbacks; it is illustrated with an example and the corresponding discussion. This methodology is innovative since it addresses sensitivity analysis in a way never tackled before, since it is entirely different to the present method, not only in the process and data management but especially in the wealth of the reporting.

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In: Advances in Business and Management. Volume 20
Editor: William D. Nelson
ISBN: 979-8-88697-489-8

Introduction

Sensitivity analysis (SA) is defined as finding the effect or impact on the output due to changes in the input/s. This is a broad definition and does not reveal the depth of the association in this cause-effect relationship.

SA is a fundamental part of the MCDM process mainly due to the uncertainty of performance values and criteria relative importance, however, it is also significant on its own because it permits an insight view of the process, allowing for drawing a series of conclusions concerning data and result, as is analyzed later, and for revealing unforeseen aspects that were not even considered at the beginning of the MCDM process. However, research on sensitivity analysis for deterministic MCDM models is rather limited (Triantaphyllou 2000) and received little attention (Ishizaka 2013).

At present, it is believed that SA is not properly addressed in two counts: Quality of information inputted and the way information is processed. Consequently, measures taken upon results given by SA are not only misleading but also without too much value for the stakeholders.

This paper is organized as follows: In a first section the objective is detailed. A second section deals with aspects that we understand must be considered in SA. A third section addresses the shortcomings of the present-day method for SA. A fourth section suggests an innovative procedure to deal with those shortcomings, and the fifth section proposes, develops and analyze an example using this procedure.

Objective

The objective of this paper is to propose a different approach for SA, grounded on reliable input and that provides quantified and relevant information to stakeholders.

We believe that this procedure is a real contribution to the advancement and significance of Operations Research and in the decision process, because at present, SA is performed as was designed decades ago and then, no significant improvements have taken place. The proposed methodology, innovative in conception and in the kind of data employed, has no relation with the actual process, especially because it is based on objective information and delivers graphical results, which increment the worth of SA as a control tool.

In this approach all criteria that affect a solution are identified and simultaneously considered, and also assigned a value regarding their relative importance. The purpose is to have a SA that delivers accurate and especially useful information to stakeholders for them to take correct decisions.

Aspects to be Considered in Performing a Sensitivity Analysis

The authors consider that the following aspects must be taken into account:

Methodology Used

The methodology must contemplate the diverse features in real-world scenarios, such as influence of uncertain data, multiple scenarios, especial demands and constraints, existent relationships between alternatives as well for criteria, etc. (DTLR 2000) backs up this issue when it expresses that the MCDM must include criteria that are of the concern of all stakeholders, while Barba–Romero et al. (1997), state that it is necessary to verify that no criterion has been forgotten permitting alternatives discrimination. This is the most immediate concept to consider when modelling, making sure that all relevant aspects of the decision problem reflect as criteria, as Barzilai (2010) reports on modelling and its mathematical foundation. The modelling of a certain scenario is essential and if not properly performed the results of a SA may be meaningless.

There is a need for the project analyst to understand and assess the effect of market forces in appraising investment projects (Savvides, 1990). This set of issues inherent to a particular scenario, is what we call the scenario environs.

Consequently, it is necessary to design an initial decision matrix that replicates as much as possible the real scenario.

Elements that Intervene in the Computation of Strength or Robustness of the Solution or Output

The methodology must use every criterion that is relevant to the result. Accordingly, these criteria need to be properly and unquestionably identified.

Ways in Which the Best Solution and the Ranking (Output) Reacts to Variations of Selected Criteria (Input)

The methodology must give the DM enough quantitative data to evaluate different actions to take, based on his/her experience and knowledge. When a result is known, subjective decisions from the DM are very important and essential, and they have to be supported by reliable data furnished by MCDM method.

How Sensible an Output is to Variations of Critical Criteria

The importance of this subject is paramount. The DM must examine the different criteria that conform the solution, and examine if their allowable variation ranges allow for a reasonable stability of the output. Naturally, the larger the allowed variation the stronger the output.

What Information Do Stakeholders Need?

In the pre-analysis, the DM must have prior information concerning each stakeholder wishes or demands, and assuming that most possibly these claims will be in conflict, since the request from a stakeholder may collide or intrude into other stakeholder claim, for instance, a demand for a higher limit from the engineering department for working capital or operating cost, may reduce the return limit from the financial department.

Learning about stakeholders' needs is an activity that must be performed prior to designing the initial decision matrix, and it is a very important task for the DM; without this information the initial decision matrix will be incomplete, and then, of relative usefulness.

In the post-analysis, after the result is known, the DM must examine how the solution found conforms those demands.

How Can We Determine the Impact that the Variations of Exogenous Parameters May Have in the Performance of the Selected Alternative, as Well as the Potential Risk Produced by Each One?

For sure, the stakeholders will be interested in knowing the robustness of a solution and the potential changes in the ranking, but possibly much more concerned, in learning about the strength of the solution due to the effect of changes in some unknown parameters, when the project it is in operation, and how it will influence the company business, or the project performance. That is, they will be attentive on how the best alternative will perform in the future when subject to the impacts of parameters on which the stakeholders have no

control, for instance, the international price fluctuation of an item manufactured, and to be exported by the company.

Shortcomings of the Present-Day Procedure in SA

The most common technique for performing SA (Bosque-Sendra 2004) is the progressive increasing of weights of a chosen criterion. Further, the DM observes which is the value of the accumulated increase of this criterion that produces a change in the ranking, or substitution of the best alternative for another. The robustness of the solution is examined considering the criticality of this criterion, which is related with the allowable range of variation of the weight; the smaller the range the larger the criticality of the criterion. Naturally, a criterion with zero range is critical, since a small variation can produce a change in the ranking.

The actual procedure is grounded on these assumptions:

1. Action

Once a solution obtained by any method is known, the DM selects the criterion with the highest weight.

Drawback

This process does not have any mathematical support, it is only intuitive (Triantaphyllou 2000) since the highest weight is not related with criteria relative importance.

Trintaphyllou also mentions the work of Winston (1991) page 754, who stated that this policy may not always be true, and in some instances the criterion with the lowest weight may be the most critical; this is mathematically demonstrated in Munier et al. (2019).

Weights are elicited from personal preferences and therefore, highly subjective, and may be unfair, for instance, in the case when a criterion outcome affects thousands of people, a fact which is inherent to large projects, the DM is making a decision that may impact positively or negatively thousands of people without even consulting them.

In so doing these 'weights' computation violates *'Arrow' Impossibility Theorem'*, Arrow (1963) or paradox, that demonstrates that no voting system can convert the preferences of individuals into a community-wide ranking, while also meeting certain reasonable criteria with three or more discrete options to choose (Köksalan et al. 2013).

2. Action

The DM presumes that these subjective 'weights' are adequate to evaluate alternatives.

Drawback

This is incorrect, because they have been elicited without considering the attributes of each criterion, which is due to the dispersion of its values. This very important fact is also mentioned by Choo et al. (1999), when expressing that 'the achievement levels of the optimal alternative are not necessarily related to the criteria wrights nor the criteria importance.' Unfortunately, this condition is ignored by most MCDM methods that use weights.

As a matter of fact, these 'weights' are not even that, because they are trade-offs between criteria (Belton et al. 2001), (Franco et al. 2010), (Munda 2008.).

Consequently, they do not possess the necessary quantity of information for evaluating alternatives. This assert is grounded on the Information Theory Theorem (Shannon 1948), which demonstrates that the information contained in a series of values depends on its entropy, which in turn, is contingent to the dispersion or discrimination of those values. The entropy is instead a reflex of the genuine importance of the criteria (Triantaphyllou 2000). Subjectivity and objectivity in MCDM are straightforward analyzed in Buchanan et al. (1998).

In addition, these weights have different interpretations and implications, and there is no consensus on their meaning (Choo et al. 1999), and usually authors do not mathematically define their meaning; therefore, they are considered only heuristic, Noghin (2001), and thus, without the benefit of an axiom or a mathematical reasoning. In addition, criteria weights assume mutual independence of preferences (DTLR 2000), which is difficult to accept, considering the DM potential biases in measuring changes (Belton et al. 2001), (Cinelli et al. 2014), (Zeleny 2011), (Zardhari et al. 2015).

For the above, the use of these weights does not have any advantage nor effect in performing SA.

3. Action

The DM selects one criterion and keeps the other constant.

Drawback

This procedure violates a fundamental principle in Systems Theory, and MCDM is a system (Saaty 1980), (Zeleny 2011), which establishes that all

elements in the system are interrelated, therefore, changing one of them, directly or indirectly, affects the others.

For this reason, many researchers reject this procedure, and instead suggest that the variation of all criteria should be considered simultaneously (Pianosi et al., 2016), as well as their range of variation. In addition, Wang et al. (2008) demonstrate that the simultaneous procedure produces changes in the ranking, also known as rank reversal, which is not to be confused with rank reversal that happens when alternatives are added, deleted or have the same performance values (Triantaphyllou 2001).

The same conclusion is shared by DTLT (2000), when they state that disaggregation is good for thinking but not to take a decision.

4. Action

The DM, normally using a graphic aid, progressively increases the value of the weight of the chosen criterion and stops when he sees that the best alternative is overtaken by another alternative.

Drawback

This procedure does not take into account that the range of allowable variation for each criterion, in plus and minus, changes with every increase or decrease, that is, it is not constant, consequently, the break point, i.e., when one alternative is superseded by another, perhaps is not as shown in the graphic. This means that the change of the original ranking of alternatives may not accurately reflect the impact of increasing criteria weights.

5. Action

As mentioned, the DM selects only one criterion for change.

Drawback

In so doing he ignores that there could be, and usually are, more criteria that conforms the solution, not only one. Consequently, whatever could be the breaking point, it does not represent the effect of all criteria and then, steering to misleading information.

6. Action

Determining robustness of the solution. This consists in examining the range of variation of the selected criterion. If this range is large, it is assumed that the corresponding selected alternative is strong or robust, since it does not

change for small variations of the criterion. If it is small, or even null, then the criterion is considered critical, since a small variation can cause a rank reversal in the ranking (Zavadskas et al. 2012).

Drawback
Since the DM is considering only one criterion, he does not realize that the selected alternative can also be highly sensitive to another, and this is not shown.

7. Action
Normally, it is considered a variation in only one sense, for instance, increasing the criterion importance, by increasing its weight.

Drawback
In fact, it is also necessary to consider how the output varies when one criterion calls for maximization while another could call for minimization. In this case, an increase in the first will increment the output, while a decrease in the second will decrement the output. Obviously, the output will be affected by the combination of these two criteria.

Proposing a New Methodology for SA

Linear Programming (LP) (Kantorovich, 1939), is the inequalities-based technique used in this paper to build an initial matrix incorporating most of the elements present in a scenario. This is a fundamental step for the DM to be able to replicate reality as much as possible. LP is explained in Khotari (2009), as well as in many books describing the LP matrix.

The Simplex algorithm (Dantzig 1948), for finding the best alternative and ranking, is central to this process, as well as the necessary software *'Solver'* (Fylstra 2018), which is used in this proposed methodology. This is used by SIMUS (Sequential Interactive Method for Urban Systems) (Munier 2011) to extract data for performing SA.

This data is processed by IOSA (Input-Output Sensitivity Analysis), a part of SIMUS (Munier et al. 2019), that produces quantitative performance curves for SA that allow the DM and stakeholders to extract valuable information.

LP uses no weights and no subjectivity in the process, however, the latter is fully and necessary exerted by the DM as a post-result analysis, and where

he/she is able to apply his/her experience and knowledge, to propose changes based on the strength or robustness of the solution. However, due to limitations in LP because it is constrained to one objective, the SIMUS method was developed to defuse this serious drawback, and then it can consider multi-objective problems.

The SIMUS/IOSA software (Lliso et al., 2014), introduces some innovations that allow for representing reality more accurately, especially in complex scenarios, as well as performing more reliable SA. At the same time, it produces paramount and quantitative information to stakeholders such as comparison between different alternatives and computation of risks. These innovations are:

- Determining and taking advantage of the synergy between the primal and dual problems of LP, to build a graphic performance function of each objective using the IOSA algorithm,
- Revealing ways for accurately selecting the criteria that conform a solution,
- Using a mathematically computed marginal value of each criterion to determine the corresponding growth/decline of the objective function, by considering simultaneously all criteria, and producing composite performance curves for each objective (a completely new goal, a new concept, very useful for stakeholders). This is important since the objective function is a measure of the method performance (Jansen et al., 1997).

To analyze the sensitivity of the best alternative (output), i.e., to examine how changes in the criteria (input) affect the output (best solution and ranking), the DM loads into IOSA the data related to the intervening criteria and indicate the intervals he/she wants for each criterion variation. IOSA produces a composite performance curve for each objective, which illustrates the response of the output to variations due to several inputs considered simultaneously. This performance curve is also suitable to examine the influence of simultaneous variations from inputs due to exogenous factors, which the entity can't control, and allowing for the determination of risk values, derived from their potential actions.

The composite curve is similar to the utility function, concept developed by Kenney et al. (1976) in the Multi-Attribute Utility Theory, which was expanded and explained amongst others, by Dyer et al. (2005) and Cox (2015). We also refer to Dyer et al. (1992), who added that in most MCDM methods,

the user need not to be aware that there is a value function. However, the determination of such a function is an essential issue in the SA method proposed here.

This concept is also supported by DTLR (2000) when asserting that criteria express in many ways that options create value and suggests building a consequence table for each option.

The proposed technique involves:

1. Action

Starting with a matrix that has the ability of modelling most of the features of the scenario.

Even when this initial matrix is similar to those used in all other MCDM methods, since it contains alternatives and criteria, it is formed by inequalities, with a left term called *'Left Hand Side'*(LHS), which includes the performance values, that is, the values that show the contribution of each alternative to each criterion. The right term is called *'Right Hand Side'* (RHS) and has values indicating the availability of resources, contingent to each criterion, or limits imposed for whatever reasons, or a formula that indicates the relation and dependency with other RHS values.

Both sides are linked by mathematical symbols such as '<' for maximization, '>' for minimization and '=' for equalization.

2. Action

When completed, this initial matrix is worked out using the Simplex algorithm. The software to process this matrix, *'Solver'*, is an Excel add-in. The initial decision matrix is built in Excel, and from there the Solver takes the necessary data.

However, the Simplex can only address scenarios which are mono-objective and in addition, it can't accept qualitative criteria. For this reason, a method was needed to circumvent these two drawbacks, which lead to the development of the SIMUS method, based in LP but that can work with any number of objectives, as well as any mix of quantitative and qualitative criteria. The SIMUS software allows for solving a very large array of complex problems. The result is not optimal, because it is a heuristic algorithm, however, this is not paramount since most researchers agree that there is no optimal solution in multi objective problems (Bosque-Sendra et al.).

3. Action

For SA, SIMUS approach differs from the one utilized at present.

This fundamental analysis can be performed using IOSA (Munier et al., 2019), which permits the visual examination of the evolution of the result found by SIMUS, when increasing or decreasing values.

4. Action

Neither LP nor SIMUS use weights for criteria, however, because LP is an iterative method, the relative importance of each criterion changes at each iteration. Consequently, at each step, criteria relative significance is computed as a ratio between each RHS and the corresponding performance value that pertains to the new alternative that enters in the solution. This relative importance is then used to select the alternative that is eliminated from the solution, in order to keep the problem dimensions constant.

5. Action

The SA process starts with the scores for each alternative that are given by the primal problem as well as the ranking of alternatives.

The DM, based on these scores, choses the best alternative and then work with the objectives that conform it. In turn, each objective is dependent of a number of criteria that define it and it is shown in the data provided by the dual problem. In this way, the DM knows with certainty, which, out of may be dozens of criteria, are those that conform the solution. Consequently, he must work with this set of criteria.

The dual problem shows for each criterion its marginal value (that can refer to benefits or costs), or '*Shadow price'.* It is important to remember that the shadow price also represents the market value of those elements than do not have a market value, or 'externalities', for instance, erosion caused by logging, or depletion of aquifers, or noise, and therefore, criteria can be comparable as a function of their shadow prices.

Accordingly, each time that the RHS value of a criterion is increased or decreased, the corresponding objective increments or decrement at a constant rate, in an amount equal to the shadow price. The dual also shows for each increase/decrease, the valid interval or range of variation for each criterion. At every increment/decrement, these intervals change and this is also shown by the dual. Similar concept is expressed by Felli et al., (1997) when they propose a SA method that incorporates both the probability of a decision change and the marginal benefit of such a change into a single measure.

6. Action

When the DM uploads the pertinent data into IOSA, it is convenient to load all the criteria that conform the objective, irrelevant of their number, as well as mixing increasing and decreasing values. When solved, the software will take into account not only the shadow prices but also the variation of the valid range, at each increase or decrease of the RHS.

As a result of this process, IOSA draws two curves, one for increments and the other for decrements, that illustrate the performance of the objective under study, when the variations in plus or in minus for the several criteria are considered simultaneously.

These curves are not smooth but formed by a set of linear segments; each of them straight as long as the change of the respective RHS increases or decreases within their valid range, because shadow prices are constant within their interval. When an increase or decrease in any criteria surpasses its upper or lower limits, that criterion ceases to be significant for the objective under study and is replaced by another one. Since the new one will have a lower shadow price, the new straight line in the performance curve will have a lower slope. This is the reason by which the composite performance curve, when completed, is convex.

It can be seen that this process gets a result by considering at the same time the change in each criterion as well as the changes of the valid ranges of all the other criteria.

7. Action

The DM can use these composite performance curves for his own analysis and for informing the stakeholders, as follows:

(a) Each curve gives the evolution of the objective as a function of progressively changing the criterion RHS or right term, that establishes the limit for the corresponding resource. This informs about the benefit, the cost, or whatever other objective, and then, it is similar in concept, to a total utility curve. Therefore, it visually shows how the benefits, costs, the environment or a certain social issue, are influenced by variations of criteria, and also indicate when the ranking changes.

(b) Normally the curves show break points, materialized for a change in the slope regarding the last data, which indicates that there is reversal in the ranking, that is, when the best alternative is overcome by the second best, which now becomes the best.

(c) Each curve allows for quantitatively comparing two or more alternatives, as a function of the forecasted potential changes. That is, if the main objective is say, maximization of *'Return on Investment'*, comparing the performance curves for project A and B, will indicate which of them is more convenient.
(d) Each curve allows for quantitatively computing the potential risks associated to exogenous variables that can't be controlled, but which future performance can be statistically estimated. This is done computing the risk as a product of probability of occurrence of an exogenous parameter, which can be obtained by statistics, and the impact that it can produce, given by the different values of the performance values before and after considering the risk,

This is a new issue since no technique incorporates futures changes in the state of the world (DTLR 2000).

To this respect Keeney et al. (1976) provided sound integration of the uncertainty associated with future consequences, and it is important to realize that we are assessing the consequences of the options or alternatives, not the options by themselves (DTLR 2000).

This is the case where different parameters act with no relationships between them, for instance, prices increasing in a 2%, competition gaining a 7% share of the market and demand decreasing in 1.5%.

These parameters are normally independent from each other; however, the performance of the best alternative is affected by the simultaneous effects of them all. It is possible to know the overall risk, assuming that the respective probability of a series of variations for each parameter is known from statistics, and that the impact can be deducted as differences from the performance curve. This procedure for computing risk has been suggested by the Massachusetts Institute of Technology (MIT) and is validated by the PMBOK (Project Management Body of Knowledge) published by the Project Management Institute (PMI 2017).

8. Action

The fundamental role of the DM.

Subjectivity is considered the main culprit for differences between results using the different MCDM methods.

As can be seen in the proposed method, subjectivity is absent in the construction of the initial decision matrix and during the computation process; however, once the result is known, the DM is able to work, using the data

obtained, as well as statistics, for conducting a thorough analysis aiming at determining the robustness of the best alternative.

Figure 1. Flowchart describing the whole process.

Following this scheme, a case is proposed and solved.

Application Example

An agro-industrial firm (from now on the company), manufacturing two different fertilisers A and B, is considering exporting overseas. Both products serve the same purpose but with dissimilar chemical structure, as well as different strength and yield, and have different properties regarding soil contamination. Similar products existing in the market have fluctuating international market prices and then, products A and B are subject to the same external factors, such as competition, weather, international prices, variable demand, etc. which the company can't control. The initial data is shown in Table 1. All resources are explicit, except perhaps the first one (Benefits) where there is a limit for them. The reason is that benefits derive for considering a limit in the company investment, that affects increasing production, and thus, benefits.

The Accounting Department has concluded that 6,000,000 Euros (Criterion C1), is the most they can reasonable expect based on the available working capital. Criteria C2, C3 and C5 have also availability limits, while in C4 the value expresses the maximum contamination the company can generate in producing these products, and the RHS shows the limit imposed by environmental agencies.

Table 1. Initial decision matrix

Criteria	Product A	Product B	Product C	Resource limits (RHS)
C1 Benefits (€)	5000	4000	Max	6000
C2 Raw material (Kg)	100	160	Max	350
C3 Manpower (Number)	200	100	Max	260
C4 Environmental damage (ppm)	300	100	Min	100
C5 Equipment (Units)	1	3	Max	3

It can be seen that reality is considered, even in this elemental example, when there is a limitation of benefits due to limits in capital expenditures, and that also there are maximum limits regarding resources, as well as pondering a minimum of environmental damage. The latter appears to be contradictory,

since we are establishing a minimum of contamination when the ideal is zero, however, every anthropogenic activity produces contamination, and then, it has to be registered. Here we could also add another criterion with the maximum limit of pollution, and then framing the allowable contamination levels, between minimum and a maximum.

For the same token another criterion could be added to reflect the fact that for instance raw materials must be greater than a minimum, to make sure the company does not run out of them. Only one product is to be exported due to production restrictions linked to the company working capital, available equipment, labour, etc.

The company is interested in determining which of the two products is better for export to get the maximum benefit. The purpose of this basic example with few criteria is to illustrate the use of the proposed methodology, since the modus operandi is independent of problem size. The steps are (see Figure 1).

1. Open SIMUS and copy or electronically transfer this information into the software,
2. Initiate SIMUS. There are two options: To see the results step-by-step, or just the final output,
3. When SIMUS finishes computing it will show the screen portrayed in Figure 2.
4. From the initial decision matrix, SIMUS solves two problems simultaneously, the primal and the dual, the latter is the transpose of the former. The primal delivers the scores of each alternative (A = 1.19) and (B = 1.21), shown in the solid row. The dual delivers the shadow prices or marginal increments for each objective, depicted at right.

In this example the primal shows that product B is preferred to project A, or that $B \geq A$. However, the difference is minimal, which makes the selection more complicated.

The more significant objective function is Z1 = 7520 as shown boxed in the objectives function values column. This value is obtained by multiplying each score by the corresponding benefits, and adding up these products. The dual shows the marginal utility for each objective, thus, for objective Z1 it has two marginal values, one for criterion C3 (Manpower) (22) and the other for criterion C5 (Equipment) (600), both boxed.

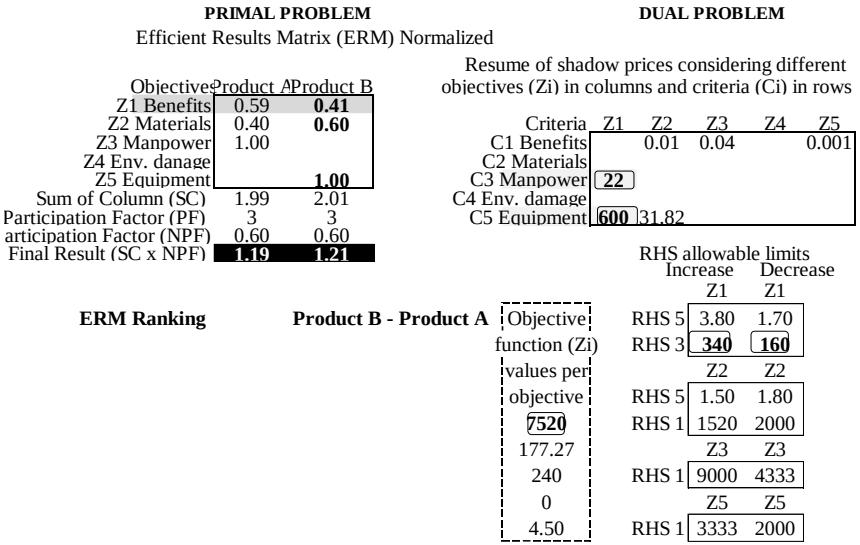

Figure 2. Scheme of the whole process.

Consequently, for each unit that criterion C3 increases, the objective function increments in 22 units. Since the resource limit for C3 is 260 (from the corresponding RHS in Table 1), an increase of one unit, that is, increasing the resource from 260 to 261, will increase the value of Z1 from 7520 to 7542. This increase has a limit given by the upper bound of the range for C3 which is 340, as shown boxed in the RHS allowable limits box. Consequently, C3 can be increased up to 260 + 340 = 600 units. Within this range the objective function Z1 will increment at a constant rate of 22 units per unit of increase of C3.

This process can be graphically visualized as a straight line since increments are constant within that interval. Figure 3 represents the evolution of the objective function for increments of 4 units at a time and starting with the initial value of 7520 found by the primal in SIMUS.

If instead of 4 units' intervals we use 50 units intervals the representation will be again a straight line as seen in Figure 4 produced by IOSA.

This straight line is then the total performance function for criterion C3 when the marginal utility is constant. If in lieu of increasing C3 the DM deceases it, there will be another total performance function with the same rate, and both starting at the same point, however, most probably, the limits of variation for decreasing will be different, as can be seen in Figure 1 where the

lower limit for C3 is 160. It means that it can decrease down to 260 – 160 = 100 units.

Increments Δ=4 for C3	0	4	8	12	16
Z values	7520	7608	7696	7787	7872

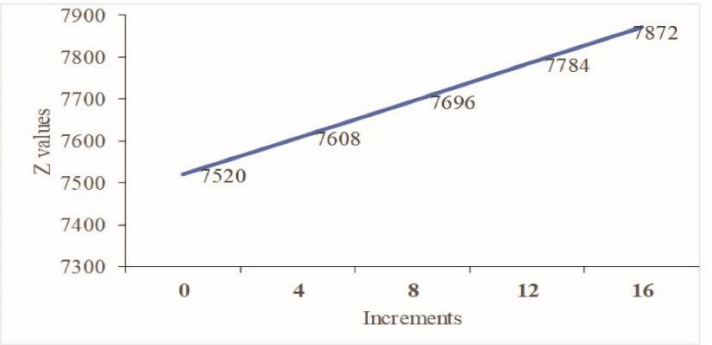

Figure 3. Evolution of the objective function for a constant shadow price.

Therefore, criterion C3 can vary from 160 to 600 always keeping the same rate, and in that interval the objective Z1 will increase uniformly.

Increment (Δ=50) for C3	0	50	100	150	200	250
Z1 values	7520	8620	9720	10820	11920	13020

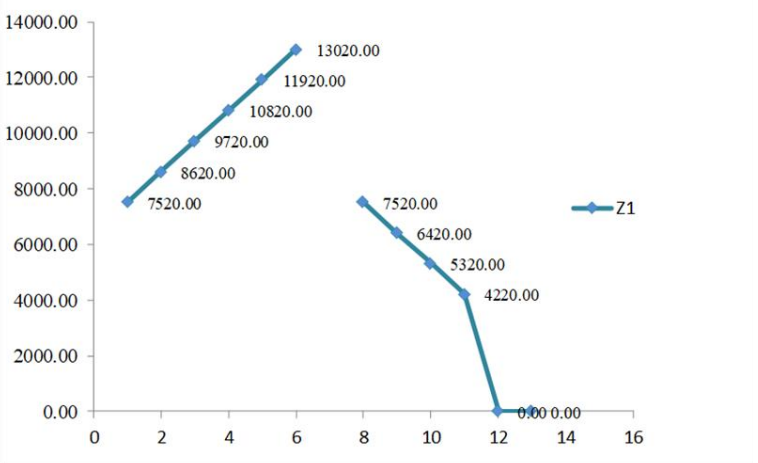

Figure 4. Evolution of the objective when the C3 criterion varies in 50 un its intervals.

It can be seen that the left total performance curve corresponding a Z1 is a straight line. If the increment would continue up to 600 units, the Z1 will reach its maximum of 15,000 units (7520 + 340 x 22) which is the highest limit. If the increment continues after this point, the criterion C3 ceases to be determinant for objective Z1 and will be replaced by another criterion with different marginal increments and different limits. In this case the performance curve will have a break and will change the slope possibly continuing to increase but at a lesser rate. That is, the performance curve is no longer straight but convex.

That is precisely what happens for decrements. After the decrement of C3 reaches the 4000 value (7520-160 x 22) the curve falls abruptly to zero indicating that beyond that point the ranking is no longer valid, since there are no other criteria that can take over to C3. Consequently, a further decrement will not have any effect in the objective function.

Notice that C3 is the criterion that represents manpower, and then the result shows that diminishing this labor to less than 100 workers, makes the project unfeasible.

The same analysis for C5 will certainly generate a different performance function because its marginal increments are different from C3. This can be seen in Figure 5.

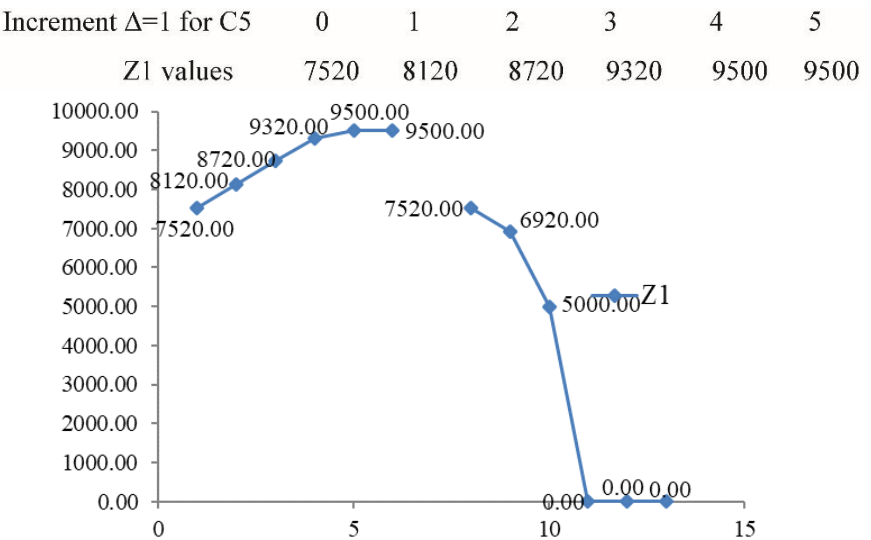

Figure 5. Evolution of the objective when the C5 criterion varies in 1unit intervals.

As seen, the performance curve at the left shows a constant increase of the objective function from 7520 to 9320, and after that there is no increase. This is due to the fact that 9320 units, which is the upper limit for C5 variation, has been reached and it does not matter how much we continue to increment it.

Since both C3 and C5 conform the subjective function Z1 it is reasonable to ask what happens when both change simultaneously. The answer is given in Figure 6.

Increment Δ = 50 for C3	0	50	100	150	200
Increment Δ = 1 for C5	0	1	2	3	4
Z1 values	7520	9220	10920	12227	13136

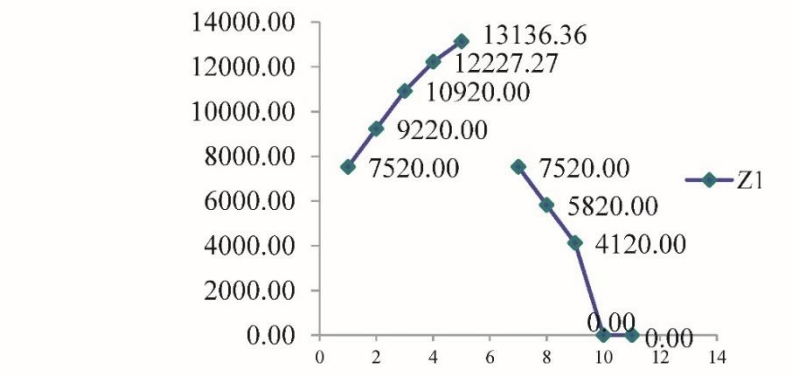

Figure 6. Evolution of the objective when criteria C3 and C5 vary at the same time.

Observe that the left performance curve now has a higher limit that the original for C3 in Figure 4, which means that its combination with C5 boosted the performance function. This confirms what was said regarding that it is not correct to use the one criterion procedure.

Uncertainty and Potential Dependency on Exogenous Factors

Assume now that the stakeholders need to know how the output (product B) will react to uncertain events, for instance, how will it be affected for a decrease of say 7% in its international price.

From statistics the DM determines that there is a 25% chance of this happening. Consequently, he needs to compute the impact of this decrease in the performance curve; he starts by modifying the value of the benefit in the initial decision matrix as a consequence of the decrease in the price.

Running again SIMUS and IOSA a new curve is drawn. The impact of the reduction in prices can be computed as the difference between the Z1 values given by SIMUS in the two cases. Say for instance that now the Z1 base value is 6885, consequently, the impact is (7520-6885)/7520 = 8.5%. The risk is then 0.25 x 0.085 = 0.02 = 2%, which appears to be acceptable.

The stakeholders might also want to know what the performance and risk would be if product A is selected. The same procedure can be done for B and then, risks compared. To help this decision, the stakeholders notice that the difference in scores between A and B is minimal, which supports the idea of doing a sensitivity analysis for A.

Discussion

The developed example illustrates in a practical way how the aspects that were enunciated in Section 2 have been met, however, because of the simplicity of the example some aspects are not incorporated. For instance, it is mentioned that all particulars pertaining to a scenario must be present in the initial decision making. In case of the existence of relationships between criteria, for instance, establishing dependence, it is readily accomplished by using additional inequalities, stating for instance:

- That project A must precede project B (A > B), or
- That projects A and B, out of many, have to be chosen (A = B), or
- That project A and B are exclusive, meaning that if A is chosen, then B must be rejected and vice versa. This can be done using a binary inequality, stating for instance that A = 1 and B = 1, but that the RHS must be equal to 1.

Regarding criteria, there are some real-world aspects that can be considered, for instance:

- Modelling the existence of correlation between pair of criteria, using the sentence ‘IF……; then…..’, or

- Considering that criteria are not independent. This is automatically done by LP, because the initial matrix is a system, or
- Taking into consideration that there is always an RHS value, that may be a resource availability, or a lower and upper limit, or limits for contamination, etc.

All of this is related to the modelling; however, we were more interested in SA.

From this point of view, the example shows how the very important parameters are considered accurately:

- The selection of the objectives that conform a solution, is given by the primal,
- The criteria that intervene in that solution, are given by the dual,
- The contribution of each criterion, is expressed by its shadow price,
- The allowable range of variation for each shadow price, is obtained the dual,
- The drawing of the objective performance curve, is automatically performed by IOSA. This curve, giving quantitative values, allows for an ample spectre of questions from the stakeholders.

Consequently, these authors believe that the proposed system give useful and especially reliable information and that is meets all the conditions specified in Section 2.

Conclusion

This paper establishes the main aspects that are to be considered in SA. After that, it identifies and elaborate the shortcomings of the present-day method used for SA and shows that the way in which it is performed nowadays, does not provide neither enough nor reliable and useful information to stakeholders. In addition, it proves that the actual procedure uses arbitrary concepts and assumptions, which may produce false results.

Aiming at getting a more realistic and documented SA, the paper proposes a completely new procedure based on Linear Programming, that allows obtaining crucial information about which criteria are significant in the

selection of the best alternative, as well as their marginal increments and range of validity.

With these elements obtained mathematically, it demonstrates how to build a performance curve for each objective, considering either individually or combined criteria. This curve has a paramount importance because allows the DM to visualize how the output reacts to variation in the inputs, and it is fundamental for quantitatively computing when a ranking change due to the combined effects of all intervening criteria, and how much the objective increases or decreases.

In addition, this curve allows for quantitatively computing the different risks that may threaten the best selection when exogenous factors, not considered in the construction of the initial matrix, because they are uncertain and do not depend on the promoter, vary simultaneously and in different directions.

A simple example is proposed, which illustrates how some of the mentioned drawbacks of the existing system are overcome. Even in its simplicity, it incorporates resources and their limits, identifies all criteria that contribute to the selection, informs on the relative importance of each criterion based on their marginal values, alert about their respective limits of variation, which change with every increase/decrease, and produces the performance curves.

In addition, risk analysis is also performed to illustrate the procedure. It is believed that this paper sheds new light on SA process.

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Chapter 5

A Systematic Approach to Substantiating Chain Management Structures in Businesses

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Abstract

The purpose of the chapter is to substantiate theoretical and methodological prerequisites for the introduction of a systematic approach to the development of the enterprise and chain management system in business, the components of which are interrelated goals, objectives, principles, approaches, methods and functions.

Methods of classification, synthesis, analysis, induction and deduction are chosen as research methods, and binary matrices which are formed on basis of classification attributes of objects and its dichotomies used as a research tool.

The chapter develops the structure of the enterprise and chain management system in business; substantiates the content of goals, objectives, principles, approaches, methods and functions of enterprise and chain management in business; proposes the system of codes of components of system of this type; creates prerequisites for the formation of the integrated concept of chain management in statics and dynamics.

The implementation of obtained results will reduce the likelihood of contradictions in chains by coordinating the content of management systems of its links, create prerequisites for elimination the lost profits of chains of different type, reducing the time and cost of preparing and implementing management decisions, responding in the timely manner to unique demands of end consumers.

In: Advances in Business and Management. Volume 20
Editor: William D. Nelson
ISBN: 979-8-88697-489-8

The originality of the research is confirmed by the substantiation of choice and use of actual qualitative attributes of management objects and its dichotomies, which allow to obtain 2^x variants of these objects and assign its binary codes processed using computer software for management activities.

Keywords: chain, system, management, goal, objective, principle, approach, method, function, matrix, binary code

Introduction

Chain management in business is an integral concept of managing linearly ordered enterprises and time-coordinated processes that form value chains (Porter, 1985); demand chains (Selen and Soliman, 2002); supply chains (Oliver and Weber, 1982), as well as novelty chains (Tyapukhin, 2021). Like any other type of management, chain management in business is a system that includes an entity (who manages?) or subject and objects (who or what is controlled by?). Moreover, in the vast majority of cases, specialists prefer to investigate first of all the objects of management, leaving the subject of management out of sight. To fulfill its mission, the subject or their combination usually uses a set of management tools, which include, for example, “concepts, principles, processes, and practices,” as well as “operations” and “tasks” (Wasson, 2005).

As management mostly belongs to scientific disciplines (Taylor, 1919), the quantity, quality and interrelationships of management tools must be justified. The methodological basis for solving this problem is a systematic approach, which assumes that “the system consists of three elements: ... components, attributes and relationships” (Blanchards and Fabrycky, 2006).

At the same time, the study of various tools for managing enterprises and chains in business from the standpoint of a systematic approach allows us to conclude that they collectively do not represent a system and, as a result, in practice sometimes provoke a very significant loss of profit. Losses of this type, as a rule, arise due to insufficiently clear structuring of tasks, powers and responsibilities of performers at various levels of organizational structures of enterprise management, as well as at the junctions between them in chains of various types. Of course, it is possible to make an amendment to the fact that management, unlike exact sciences, operates with human resources that are extremely unstable in time and difficult to combine when functioning (Islam

and Khan, 2004). Moreover, resources of this type individually or in groups, including in chains, pursue different goals, which poses a serious threat when achieving a common goal for them, for example, creating values for end consumers of products and/or services. However, this does not reduce the relevance of the above task, one of the solutions of which is presented in this article.

Literature Review

The structure of chain management in business is predetermined by the essence and content of the term "chain," which, regardless of the type of management object, is considered as:

(a) "A group of inter-connected participating companies" (Lu, 2011);
(b) "The complex network of relationships" (Chen et al., 2012);
(c) "Life cycle processes comprising physical, information, financial, and knowledge flows" (Ayers, 2001); and
(d) "The series of activities and organizations" (Waters, 2007), etc.

At same time, the chains are studied in statics (as interconnected enterprises) and in dynamics (as ordered activities or processes), that is, as systems. Therefore, in accordance with systematic approach, the author proposes to understand the chain in statics as a set of linearly ordered enterprises and relationships between them, and chain in dynamics as a set of linearly ordered processes interconnected by flows of material, information, financial and human resources. Based on the content of these chains, it is necessary to distinguish between the chain management in statics and in dynamics. In addition, it is important to note that static chains are formed at the preparation stage, and dynamic chains are used when fulfilling orders of end consumers of products and/or services.

In turn, the term "management system" is difficult to formulate unambiguously. In general, "management systems are made up of a series of interconnected elements that drive the continual improvement of a particular discipline or aspect of an organization" (Susca, 2019). As follows from this definition, the composition and structure of management system depends on type of goals and solved objectives. The most widespread systems of this type are in areas of quality management (ISO 9000:2015) and information technology (e.g., Mohanty and Deshmukh, 2000). Moreover, achieving goal

of this research in conditions where the management system is universally identified with information management systems such as ERP systems consisting of "hardware, software, database, processes, and people" (Motiwalla and Thompson, 2012) is almost impossible. It seems appropriate to take slightly different approach to substantiating and using the structure of enterprise and chain management system in business: first, the design or optimization of this system and only after that its digitalization. This is explained by the fact that the external environment actively influences the management system, constantly provoking changes in its structure, which leads to partial or complete depreciation of information technologies in the field of enterprise management and business chains and the need for their adjustments.

The components of organization are presented in sufficient detail in the literature, the list of which partially duplicates the components of enterprise management systems and/or chains in statics. For example, the components of an organization include: "people and their relationships" (for example, McAuley et al., 2007; Daft, 2008); "resources" (for example, Barney, 1991; Karmeli and Tishler, 2004), "interactions" (for example, Hatch and Schultz, 2002; Haslam et al., 2017); "processes" (e.g., Platts, 1993; Shaw et al., 2007); "activities of firms" (Siggelkow, 2002), etc.

There are the different points of view on composition and structure of enterprise management system, each of which has same disadvantages. As the example, it considers the point of view of Gutermann (2021), who believes that components of system of this type include "policy, planning, implementation and operations, performance assessment, improvement and management review." If it conducts preliminary analysis of these components, it is possible to note the following aspects:

1. The list includes following heterogeneous objects: three management functions: planning, implementation and management review; business process component: operations; management tool: policy; management objective: improvement, as well as statement of results: performance assessment;
2. This list may be clarified and supplemented. For example, motivation, control, integration, regulation, etc. can be added to management functions, regulations and motivation system, etc. to management tools; sustainability and sustainable development to management objectives, etc.;

3. The components of management system can form logical sequences and have clear relationships. For example, planning is used first, then policy, then implementation and performance assessment; and
4. The management system includes components of different levels. For example, functions, like business processes, consist of operations, and policy, in turn, is part of organization's strategy.

Without questioning the relevance and content of management system components listed above, it is necessary to note the following aspects of their substantiation and development. In particular, the authors:

(a) Arguments confirming the quantity and quality of these components are not provided;
(b) Horizontal and vertical relationships between them are not established, that is, the components proposed by the authors do not provide a systematic approach to their justification and development; and
(c) The mechanism for coordinating these components vertically or at management levels and horizontally or positions provided for by the organizational structure of enterprise management, as well as between chain links, is not specified.

Based on this, the objectives of this study include clarifying and supplementing the structure of the management system of enterprises and chains in business based on a systematic approach, as well as creating methodological prerequisites for the digitalization of components of this system and the development of management software in chains of this type.

Methodology

The methods of qualitative research based on objects classification (e.g., Bailey, 1994; Creswell, 2014) chosen as methods for solving these objectives, such as:

(a) A descriptive method that allowing substantiate and select actual qualitative attributes and their dichotomies that are adequate to the research object. Moreover, in this study, such objects are the

components of chain management system in business, as well as factors of external environment for them;

(b) A faceted method on basis of which binary matrices are formed (e.g., Warfield, 1973) containing 2^x variants of this object, where the digit "2" reflects the number of dichotomies, and x is the number of corresponding attributes.

Qualitative attributes and dichotomies of research object are selected using analysis of literary sources and/or sociological surveys of specialists familiar with this object. Usually, both methods of selecting qualitative attributes and their dichotomies are quite time-consuming. The feature of this research is the use of two-level system of actual qualitative attributes, which allowing substantiate the content of such components of enterprise and chain management in business as goals, objectives, principles, approaches, methods and functions based on systematic approach.

Results

Management as the activity involves the transfer of management object from one state to another, desired state in accordance with goal, while solving several objectives, attracting and processing necessary resources and performing required functions and/or processes (e.g., Terry and Stephen, 1982; Weihrich and Koontz, 2005; etc.). In other words, for effective management, the managers of enterprises, including as part of chains in static, needs to answer at least four questions:

(a) What creates opportunities and has negative impact on management object?
(b) What should be achieved or gained?
(c) How will this "what" achieved?
(d) By what means can this "what" achieved?

The answer to the first question is predetermined by the factors of the external and internal environment of the enterprise and/or the chain, as well as the availability of the necessary resources to use the opportunities and/or counteract their negative impact. The answer to the second question requires setting goals (Drucker, 1954), developing ideas and substantiating management principles. The last two stages provide for the formation of a

management concept (e.g., Certo and Certo, 2009). The answer to the third question presupposes the formulation of objectives and the definition of the content of management functions that form management practices (e.g., Bloom et al., 2012). Finally, the fourth question is focused on identifying approaches to solving these problems and choosing management methods that are adequate to the existing combination of factors of the external and internal environment. Together, these two stages characterize management tools (e.g., Groenendijk, 2003). The above arguments allow us to develop a hierarchy of components of the enterprise and/or chain management system in statics (Figure 1).

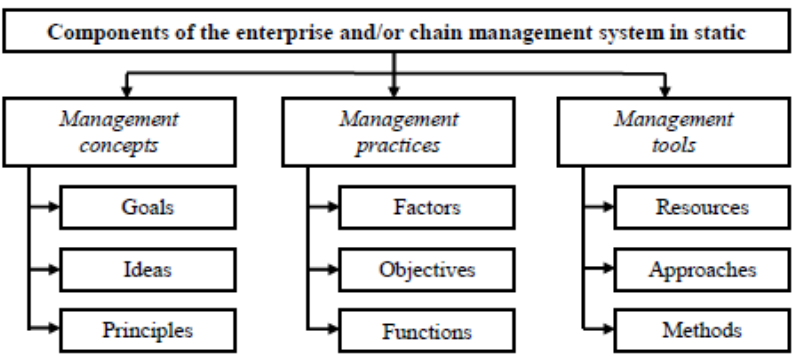

Figure 1. Classification of components of the enterprise and/or chain management system.

It follows from the content of Figure 1 that the content of management practices is predetermined by factors of the external and internal environment of the enterprise and/or chain; the content of management concepts is formed on the basis of the goals of this enterprise and/or chain; and the content of management tools depends on the quantity and quality of the resources they attract. In other words, the following logic of the formation of the components of the management system is traced:

"factors → resources → ideas → goals → principles → objectives→ approaches → methods → functions,"

These are implemented both at the stage of preparation and at the stage of fulfilling orders of end users of products and/ or services. This logic, on the one hand, makes it possible to create prerequisites for the introduction of a process approach to chain management in statics, carried out by management entities (subjects), and, on the other hand, for the formation and

implementation of design and matrix organizational structures for managing enterprises and chains of this type.

The information presented in Figure 1 can be confirmed on the basis of the combined use of previously identified relevant qualitative attributes and their dichotomies, such as: “groups of components of the enterprise and/or chain management system in statics”: prerequisites, concept, management tools and practice, as well as “stages of end- consumer order management products and/or services”: preparation and execution (Figure 2).

Stages of end consumer order management products and/or services	Groups of components of the enterprise and/or chain management system in statics			
	Prerequisites *Why?* *(00)*	Concepts *What?* *(01)*	Tools *With what?* *(10)*	Practices *How?* *(11)*
Preparation *(0)*	Factors *(000)*	Ideas, goals *(001)*	Approaches *(010)*	Objectives *(011)*
Fulfillment *(1)*	Resources *(100)*	Principles *(101)*	Methods *(110)*	Functions *(111)*

Figure 2. Classification of components of the enterprise and/or chain management system.

Features of Figure 2:

(a) Differentiation of enterprise and/or chain management components in statics by stages of order management of the end consumer of products and/or services. Moreover, if factors, ideas, goals, approaches and objectives are taken into account and developed by the entity (subject) of management and are used mostly in static chains, then resources, principles, methods and functions are implemented by management objects mainly in dynamic chains;

(b) Use of three-digit binary codes of components of enterprise and/or chain management system in statics formed by dichotomies of actual qualitative attributes used. These codes are the basis for formation of more complex codes with further substantiation of content of each of components of Figure 2.

As shown earlier, the achievement of research purpose is possible on the basis of set of actual qualitative attributes, primarily chains in business. The solution to this problem was proposed by Tyapukhin (2021), who developed the binary matrix based on such qualitative attributes and their dichotomies as:

"direction of the flow of resources": downstream (from the supplier), code "*0*," and upstream (from the consumer), code "*1*," as well as the "type of management situation": standard (typical), code "*0*," and non-standard (atypical), code "*1*." The joint use of these attributes and dichotomies allows us to justify the following objects and concepts of chain management: products and/or services (supply chain management concept); demands (demands chain management concept); novelty (novelty chain management concept); and value (value chain management concept) (Figure 3).

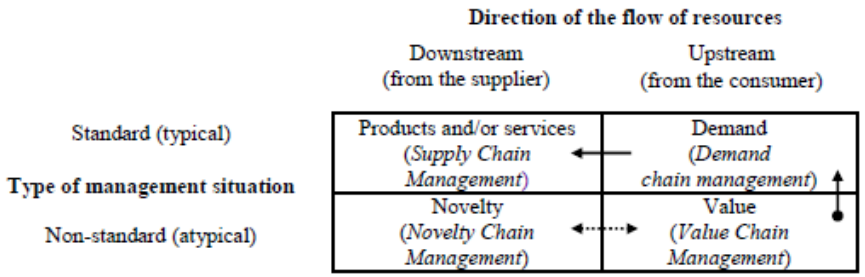

Figure 3. Classification of basic concepts and objects of chain management in business (Tyapukhin, 2021).

The information in Figure 3 allows us to make the following conclusions:

1. The priority object of chain management in business is value of end consumer of products and/or services, which can be created (a) by consumer himself; (b) by supplier of these products and/or services; (c) by supplier and end consumer jointly (Vargo and Lusch, 2008);
2. The end consumer value is divided into following basic forms: "desired value," "value prototype," "value carrier," and "perceived value." Moreover, desired and perceived value are objects of Value and Novelty Chain Management, value prototype refers to Demand Chain Management, and value carrier or products and/or services belong to competence of Supply Chain Management (Tyapukhin and Ermakova, 2022); and
3. The term "value" is ambiguous in content. According to Porter (1985), value is "the amount buyers are willing to pay for what a firm provides." Feller et al., (2006) understand by value "an experience." Lancaster (1975) believes that value is "a bundle of attributes" of products and/or services. Strydom (2005) indicates that value can

obtained through "a process of interpreting the environmental factors such as smell, touch, vision, sound, within the customer's frame of reference." The points of view listed above can be reconciled using information in Figure 4, from which it follows that sensations, impressions and experience are of interest to end consumer of products and/or services, profit and experience, as the rule, form the basis of value of chain links in business. A special role in creation of values assigned to attributes of products and/or services as the criterion for effectiveness of values in chains of this type, used when they are received/transmitted by chain links in static.

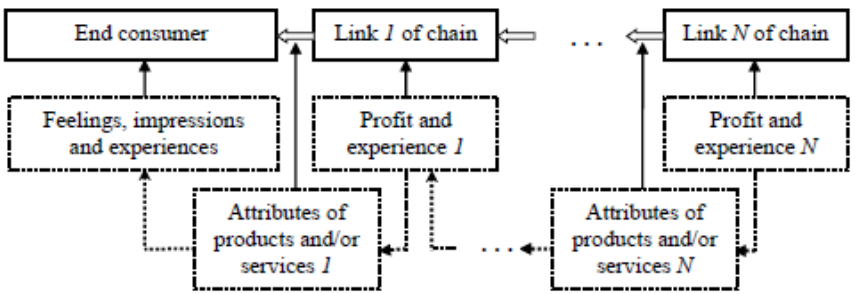

Figure 4. Transformation of value in chains of various types.

Table 1. Classification of goals and objectives of enterprise and chain management in statics

Components chains (Figure 2)	Management object (Figure 3)			
	Product and/or service (100)	*Demand (101)*	*Novelty (110)*	*Value (111)*
Goals (001)	Making the profit *(001100)*	Minimization of costs, time and lost profits when placing orders for products and/or services *(001101)*	Efficiency of creating new products and/or services *(001110)*	Matching desired and perceived value *(001111)*
Objectives (011)	Production of products and/or provision of services *(011100)*	Formation of efficient chains in statics and dynamics *(011101)*	Rational use of intellectual and resource potential *(011110)*	Creation and delivery of products and/or services *(011111)*

The information of Figure 3 makes it possible to substantiate the content of the goals and objectives of enterprises and chain links in statics, since these components extend to the enterprises included in them. As follows from Table 1, these goals and objectives apply to products and/or services,

demands, novelties and values, and each goal or objective is indicated by a six-digit code that facilitates their processing with the help of software and computer support for management activities.

It is possible to clarify the content of more structurally complex components of enterprise management system and chains in statics if use the elements of these chains presented in literary sources. These elements, among other things, substantiated by Tyapukhin (2021) on basis of such actual qualitative attributes and dichotomies as "state of the chain in time": statics and dynamics, as well as "processes performed by the chain in business": processing resources and receiving/transferring resources (Figure 5).

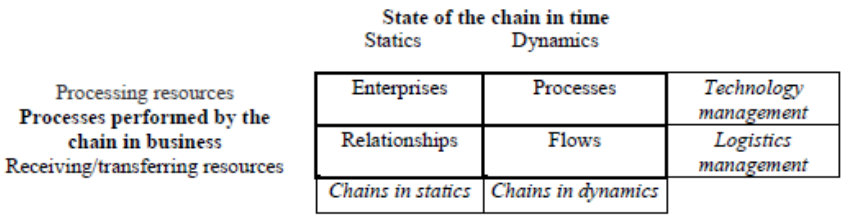

Figure 5. Classification of chain elements in business (Tyapukhin, 2021).

The features of Figure 5 are not only the isolation of chains in statics and dynamics, but also the substantiation of main types of business processes performed by chains in business, such as technological and logistics management.

Table 2. Matrix of qualitative attributes and codes that form the structure of the enterprise and chain management system in business

Components of the management system	Chains type *(0)*:				The stage of chain management *(1)*:			
	- in statics *(00)*		- in dynamics *(01)*		- fulfillment *(10)*		- preparation *(11)*	
	Chains elements (Figure 5)				Management object (Figure 3)			
	Enter-prises (000)	*Relation-ships (001)*	*Proces-ses (010)*	*Flows (011)*	*Product and/or service (100)*	*Demand (101)*	*Novelty (110)*	*Value (111)*
Goals	+	-			+	+	+	+
Objective	+	-			+	+	+	+
Principles	+	+	+	+	+	+	+	+
Functions	+	+	+	+	+		+	
Approaches	+		+		+	+	+	+
Methods	+		+		+		+	

The information presented in Figure 3 and 5 creates theoretical prerequisites for development of matrix of actual qualitative attributes and codes that form the management structure of enterprises and chains in statics, on basis of which it is possible to clarify the content of its components (Table 2).

The content of Table 2 allows us to make the following conclusions:

1. The actual (main) qualitative attributes of the first level of classification that characterize the management system of enterprises and chains in business are “type of chains,” code “0,” and “stage of chain management,” code “1.” Accordingly, their dichotomies are presented as follows: chains in statics, code “00,” chains in dynamics, code “01,” and “execution, code “10,” preparation, code “11”;
2. The relevant (main) qualitative attributes of the second level of classification characterizing the management system of enterprises and chains in statics are “elements of chains in statics and dynamics” (Figure 5) and “object of chain management in statics and dynamics” (Figure 3). Each element and object are indicated by a three-digit a code that allows you to proceed to the classification of the management system components presented in the left column of Table 2;
3. As it was shown earlier in Table 1, in order to clarify the content of the goals and objectives of enterprises as part of chains in statics, it is sufficient to focus on the objects of chain management in statics and dynamics. To substantiate the content of the management principles, a complete list of management objects and chain elements is required. To clarify the content of management functions, it is recommended to use chain elements, as well as chain management stages in business. In turn, approaches to chain management can be justified on the basis of data types of chains and chain management objects. Finally, management methods can be distinguished using both the types of chains in business and the stages of chain management; and
4. The codes of the components of the second level of the enterprise and chain management system are formed taking into account the actual qualitative attributes of the binary matrices located vertically and horizontally, each of which concerns any of the components of the first level listed in the left column of Table 2.

The most difficult variant of substantiating content of enterprise and chain management components in statics are substantiating management principles, which involves two stages. At first stage, characteristic aspects of chain management of various types with the code "*101*" are determined (Figure 2). At second stage, using these aspects, desired management principles are formed.

The joint use of chains elements (Figure 5) and management objects (Figure 3) in accordance with the recommendations of Table 2 allowing form Table 3 containing the above characteristic aspects.

Table 3. Characteristic aspects of the principles of chain management in business *(101)*

Chain elements (Figure 5)	Management object (Figure 3)			
	Product and/or service (100)	*Demand (101)*	*Novelty (110)*	*Value (111)*
Enterprises (000)	Order *(101000100)*	Virtuality *(101000101)*	Risk *(101000110)*	Variant *(101000111)*
Relationships (001)	Rhythm (clock cycle) *(101001100)*	Unification *(101001101)*	Synergy *(101001110)*	Compromise *(101001111)*
Processes (010)	Technology *(101010100)*	Digitalization *(101010101)*	Potential *(101010110)*	Structure *(101010111)*
Flows (011)	Sustainability *(101011100)*	Barriers (noise) *(101011101)*	Optimization *(101011101)*	Lost profit *(101011111)*

The logic of filling in Table 3 is as follows:

(a) The combination of element "enterprises," code "*000*" and management object "products and/or services," code "*100*," form the management aspect "order," code "*101000100*," where part of code "*101*" indicates the group according to principles of management, part of code "*000*" corresponds to element "enterprises," and part of code "100"" corresponds to object of management "products and/or services." The remaining segments of Table 3 filled in the same way. For example, the combination of element "flows," code "011" and management object "value," code "*100*," form management aspect "lost profit," code "*101011111*," which, in turn, reflects the discrepancy between desired and perceived values of end consumer of products and/or services;

(b) Since chains are divided into chains in static and dynamic, each type of chain is characterized only by its characteristic aspects; and

(c) The characteristic aspects of enterprise and chain management in statics and dynamics form logically ordered sequence corresponding to previously mentioned sequence “desired value - value prototype – value carrier - perceived value” (Figure 6).

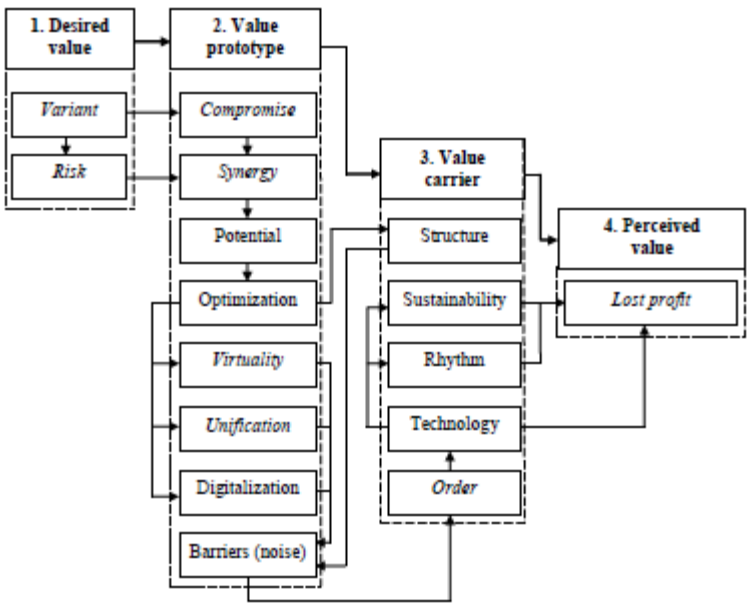

Figure 6. The sequence of taking into account aspects of chain management.

At the “desired value” stage, the characteristic aspects are: (i) the variant of the value of the end user of products and/or services, which is initially “intelligible, heterogenously experienced, co-created and potentially perishable” (Vargo and Lusch, 2008); and (ii) the risk of insufficient achievement of the goals set by the supplier. The choice of the value option by the end consumer is often accompanied by a compromise between the desired feelings, impressions, experience, and the real solvency of this consumer. Nevertheless, together with the supplier, he can achieve a synergistic effect that contributes to the maximum use of available potentials that contribute to optimizing the prototype of value and determining the structure of the order or the future carrier of value. Achieving optimal results in chains is accompanied by interaction with virtual enterprises, unification of relationships and management procedures, as well as digitalization of management objects and algorithms for their use. The characteristic aspects

listed above are designed to eliminate or reduce cross-functional barriers in various types of chains, structure demands and place an order for products and/or services desired by the end consumer. This order is carried out on the basis of a combination of technological, logistics and trade processes with ensuring their stability and compliance with the rhythm (beats) of the operations included in them. As a rule, the products and/or services created in this case do not fully ensure compliance with the desired and perceived values, which, as mentioned earlier, is accompanied by lost profits, the reduction of which may be the goal of subsequent actions by the end consumer of products and/or services and their supplier.

The information presented in Table 3 allowing substantiate the content of principles of enterprise and chain management in statics, which is possible to see in Table 4.

Table 4. Aspects, codes and principles of chain management (*101*)

Aspects	Codes	Principles of chain management
Product and/or service (100)		
Order	*101000100*	Compliance of the order with the demands of the consumer
Rhythm (clock cycle)	*101001100*	Compliance with the rhythm and clock cycle of chain management processes
Technology	*101010100*	Technology compliance with customer order parameters
Sustainability	*101011100*	Ensuring sustainability and achieving sustainable development
Demand (101)		
Virtuality	*101000101*	Formation and use of virtual chains
Unification	*101001101*	Unification of documentation and processes between adjacent links of the chain
Digitalization	*101010101*	The use of digital technologies and twins
Barriers (noise)	*101011101*	Elimination of cross-functional barriers and noise in communication processes
Novelty (110)		
Risk	*101000110*	Minimizing uncertainty and risks in chains
Synergy	*101001110*	Achieving the synergistic effect
Potential	*101010110*	Developing the potential of chain links
Optimization	*101011101*	Global optimization of chain parameters
Value (111)		
Variant	*101000111*	Minimization of the value creation life cycle of end consumers
Compromise	*101001111*	Implementation of chain management methodology by values
Structure	*101010111*	Maximum compliance of product and/or service parameters with consumer values
Lost profit	*101011111*	Minimizing lost profits in chains

As it follows from Table 4, the number of principles of enterprise and chain management in business is 16 or 2^4, which does not coincide with the

number of principles proposed, for example, by Fayol (1916) and Anderson et al., (1997), the rationale for which is mostly subjective.

It should be noted that chains in business not only differ, but also have common characteristics, therefore, the division of the principles in Table 4 by type of chains is conditional. To one degree or another, as well as in combination, they can be used outside of a specific stage of value creation for end consumers of products and/or services.

In accordance with the content of Table 2, it is possible to clarify and supplement the content of the chain management functions in business, code "111." The solution to this problem is presented in Table 5.

Table 5. Elements, codes and functions of chain management in business (*111*)

Chain elements (Figure 5)	The stage of chain management *(1)*:	
	- fulfillment *(10)*	- preparation *(11)*
Enterprises (000)	Coordination *(11100010)*	Planning *(11100011)*
Relationships (001)	Integration *(11100110)*	Motivation *(11100111)*
Processes (010)	Regulation *(11101010)*	Organization *(11101010)*
Flows (011)	Control *(11101110)*	Monitoring *(11101110)*

The content of Table 5 formed as follows:

1. The priority functions of "enterprise" chain element, code "*000*" at "preparation" management stage, code "*11*," is planning, code "*11100011*," and at "fulfillment" stage, code "*10*," such the function is "coordination," code "*11100010*." Similarly, the remaining management functions of enterprises and chains formed in statics; and
2. The code of "coordination" function: "*11100010*," formed of three parts: first part of code "*111*" corresponds to code of "function" component (Figure 2), second part of code "*000*" indicates that this function is fulfilled by enterprise, third part of code "*10*" characterizes the stage chain management "fulfillment."

Following the logic of presentation of the results presented in Table 2, it is possible to substantiate the content of management methods of enterprises and chains in business, code "*110*" (Table 6).

It follows from the contents of Table 6 that the priority methods of managing enterprises and chains in statics at the stage of management preparation are socio-psychological methods, code "1100011," aimed at interacting with end consumers of products and/ or services, each of which is a person with individual characteristics and behavior. The procedure for obtaining customer data demands and preparing for the execution of orders based on them involves the use of organizational management methods, code "1100111." When executing orders received from consumers, administrative management methods, code "1100010," are mostly implemented. Since end consumers may be limited in making decisions based on the criterion of "solvency," in the chains in dynamics, priority should be given to economic management methods, code "1100110." The codes of the management methods presented in Table 6 are formed as follows. The code "1100110" consists of three parts. The first part of the code "110" corresponds to the code of the component "methods" (Figure 2), the second part of the code "01" indicates that this function is performed by the chain in dynamics, the third part of the code "10" characterizes the stage of chain management "execution."

Table 6. Types of chain, codes and methods of chain management in business *(110)*

Type of chain	The stage of chain management *(1)*:	
	- fulfillment *(10)*	- preparation *(11)*
Chain is static *(00)*	Administrative methods *(1100010)*	Socio-psychological methods *(1100011)*
Chain in dynamics *(01)*	Economic methods *(1100110)*	Organizational methods *(1100111)*

If we use such relevant qualitative attributes and dichotomies as "type of chain": chain in statics, code "00," and "chain in dynamics," code "01," as well as "object of management of enterprises and chains in business": products and/or services, code "100," demand, code "101," novelty, code "110," and value, code "111," then it is possible to justify the approaches to managing enterprises and business chains presented in Table 7.

Table 7. Types of chain, codes and approaches to chain management *(010)*

Types of chain	Management object (Figure 3)			
	Product and/or service (100)	*Demand (101)*	*Novelty (110)*	*Value (111)*
Chain is static *(00)*	Structural approach *(01000100)*	Pragmatic approach *(01000101)*	Marketing approach *(01000110)*	Exclusive approach *(01000111)*
Chain is dynamic *(01)*	Process approach *(01001100)*	Entrepreneurial approach *(01001101)*	Innovative approach *(01001110)*	Adaptive Approach *(01001111)*

The contents of Table 7 formed as follows:

1. When organizing interaction with the end consumer of products and/or services, it is advisable to focus on an exclusive approach due to the uniqueness of the desired value, therefore, an adaptive approach should be used in the dynamics of the chain, assuming the necessary adjustment of processes and flows;
2. The creation of novelties is accompanied by the introduction of a marketing approach that takes into account the preferences of end consumers of products and/or services, which can initiate the application of innovative approach to chain management both in statics and dynamics;
3. When managing demand chains, a pragmatic approach is relevant, focused on the choice of enterprises that are able to fully meet the demands of end consumers of products and/or services. It is logical to assume that the solution to this problem should be based on an entrepreneurial approach, since the values of these enterprises can be profit; and
4. A static chain is formed as a result of structuring the demands of end consumers of products and/or services and transferring orders to enterprises – links in the business chain, which is the prerogative of a structural approach to management. When fulfilling these orders, the priority is the process approach to management, which is widely represented in the framework of total quality management of products and/or services.

The management system of enterprises and chains in business formed on basis of components proposed in this chapter is extremely complex, therefore, for its use it is advisable to develop and put into practice computer and

management software, which based on binary codes of these components formed with the help of actual qualitative attributes and their dichotomies.

Discussion

Despite the special importance of enterprise and chain management system in business, which allows the entity (subject) of management to effectively influence the objects of management, due attention is not paid to systems of this type, and the research of its main components is local. This chapter attempts to:

1. Reorient: (a) local concepts of chain management to integral concept of chain management in business; and (b) goals and objectives of chain links of various types from creating values to increasing the effectiveness of impact of subject on management objects; and
2. To create the prerequisites: (a) to introduce the systematic approach to substantiating the management structure not only of enterprises, but also of chains in statics and dynamics; (b) to develop the methodology for designing, forming and optimizing systems of this type; (c) for the full-scale implementation of binary matrices as the basis of structuring complex management objects and their digitalization, facilitating the development and implementation of computer and software management activities.

Since this chapter presents and studies for first time the problem of implementing the systematic approach to chain management in statics and dynamics, its results are largely debatable. According to author, the discussion can be fruitful on following aspects of studied problem:

(a) The classification of subjects and objects of management with the allocation and ranking of their actual qualitative attributes and dichotomies based on study of literary sources and conducting sociological surveys of specialists;
(b) The creation of more advanced terminological apparatus of chain management in business, the components of which are linked both horizontally and vertically, which allows the systematic approach to their adjustment;

(c) The development of standard business chain management modules like the Lego constructor, on basis of which computer modeling is possible not only of various types of chains that create value for end consumers of products and/or services, but also chain management systems that include goals, objectives, principles, approaches, methods and functions in one or another combination, depending on factors of external and internal environment;
(d) The creating prerequisites for transformation of typical business chain management modules into specific modules designed to be used, at least in extremely negative, stable and most favorable conditions of chain activity; and
(e) The combination of sometimes conflicting priorities aimed, on one hand, at sustainability and sustainable development of chains in business, and, on other hand, at creating values for end consumers of products and/or services, etc.

Conclusion

The current state of global and regional economies characterized by extreme instability, forcing most enterprises and chains in business to identify and use new competitive advantages, including in sphere of impact of subjects on management objects. Unfortunately, not enough attention paid to research of this problem. So, for example,

1. In well-known and widely cited definition of term "Supply Chain Management" (CSCMP, 2013), only three management functions are given: planning, coordination and collaboration, that is, other functions, such as motivation, regulation, control, etc., are clearly secondary in this type of management;
2. The most popular version is about seven principles of Supply Chain Management (Anderson et al., 1997), but the quantity, quality and interrelationships of these principles are based on subjective opinion of authors; and
3. The management approaches and management methods of various types of chains are extremely poorly presented. Apparently, at same time, the authors believe that it used only at the level of chain links in business.

This chapter presents the results based on systematic approach to management of enterprises and chains in business, allowing form horizontally and vertically ordered system of management components, each of which has binary code. These results form the theoretical and methodological basis for correcting content of local concepts of chain management in business and creating integrated concept based on it. On basis of this concept management object "chain" can be transformed into management object "network" (Lazzarini et al., 2001), the study of which is unthinkable without computer and software management activities.

Special attention is necessary to pay to the use of actual qualitative attributes of research objects and their dichotomies, which are the basis for formation of binary matrices as research tool. The author's experience of communication with editors of management journals shows that they experience some confusion at sight of matrices of this type. It is obvious that this confusion is due to partial lack of evidence of relevance of these attributes and dichotomies, that is, the scale for measuring the qualitative characteristics of research object. The development of scale of this type is extremely time-consuming and unique for each research object. As shown earlier, the solution of this problem based on study of numerous literary sources and conducting sociological surveys of specialists familiar with this object. It cannot solved alone. This chapter uses the minimum necessary set of attributes that allowing obtain new results in management of enterprises and chains in business. Similar results are possible to obtain in other areas of management of objects described by qualitative characteristics, which is what the author expects in further research.

Acknowledgments

This article was prepared in accordance with the state task of the Russian Ministry for education and science to the Institute of Economics, Ural branch of Russian Academy of Sciences for the year 2022.

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Chapter 6

How to Implement Knowledge Management in Financial Institutions? A Flowchart for Practice (FIGCIF)

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Abstract

We developed a framework for implementing knowledge management in financial institutions using a positivist and exploratory approach through qualitative research with 27 professionals in the field. The proposal is innovative due to the lack of structures that combine performance measures, KM pillars, KM processes, critical factors in the implementation and the suggestion of each of the factors according to the maturity level of KM Implementation. A flowchart is proposed for the practical application of the knowledge constructed. FIGCIF supports improvement: in acquiring knowledge resulting from academic work, in increasing tacit knowledge, in formulating instructions and normative manuals to improve understanding and use, in selecting information systems to have the ability to deliver information by through its set of rules and interaction between processes and in the defense of financial investments, aiming to generate confidence in the adoption of KM in banking institutions.

Keywords: knowledge management, implementation, banks, implementation models

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In: Advances in Business and Management. Volume 20
Editor: William D. Nelson
ISBN: 979-8-88697-489-8

Introduction

Knowledge is currently positioned as a basis of economy, utilizing technology as a tool to make different types of actions viable (De Borba et al., 2020). Therefore, the organizations that seek to find the best strategies to create, deliver and capture value for business recognize knowledge as one of the main sources of innovation and differentiation (Oztemel and Arslankaya, 2012). This relevance means that Knowledge Management (KM) has begun to occupy a central position in business models with a focus on value creation (Al-Debei and Avison, 2010). KM is recognized as a discipline which, through its own processes, serves the purpose of increasing knowledge and generating value for stakeholders (Ragab and Arisha, 2013). These stakeholders can belong to various sectors of society, especially, the banking sector.

Academic interest in banking business models has been maintained over time. Such aspects as digital transformation, increase in bad payers and image crisis have created unprecedented managerial challenges in the banking sector (Esteban-Sanchez, de la Cuesta-Gonzalez and Paredes-Gazquez, 2017). Armed with the recognized aggressivity of the sector, which seeks to reach and maintain the levels of profit that characterize them, banks invest in knowledge as an asset with the potential to furnish solid competitivity (Tan et al., 2010).

Research into KM in recent years is divided into two significant stages. In the first, the focus is the definition of KM scope and understanding of the processes. This is where we find Nonaka's (1994) contributions which, among other things, propose the cycle of knowledge encompassing actions of socialization, externalization, combination and internalization. In the second, more recent stage, knowledge is understood as an asset (Chen, Liang and Lin, 2010). Research along this line utilizes a view based on knowledge (KBV - *Knowledge Based View*), investigating the effects of KM on performance and organizational capacities.

The implementation of KM appears with different challenges, especially in the banking segment, where, compared to other sectors, the gaps in KM are even bigger (Hung, Chou and Tzeng, 2011). The literature brings together frameworks and models that promise to help in the solution for problems related to the implementation of KM. However, as frameworks tend to suffer influence from the sector to which they are destined, alternatives adapted to the implementation of KM in the banking segment are missing, those which consider its financial, technological, regulatory characteristics and, above all, the speed at which the banking sector is modified (Ferhan, Onur and Gozlu,

2010; Hung, Chou and Tzeng, 2011; Liao et al., 2012; Abbas et al., 2013; De Borba, Chaves and Oliveira, 2022).

One of the main points in this gap comes precisely from the lack of plans for practical implementation, given that the prevalent characteristic of frameworks is the high degree of theoretical abstraction. Faced with the importance of KM for the generation of value and the scarcity of artifacts specifically developed for financial institutions, the objective of this article is to propose a framework for the implementation of KM in financial institutions.

Literature Review

Knowledge Management Processes

The change in thinking caused by the increase in importance of knowledge implies a new approach to innovation in the organizational environment, as there is no longer space for the paradigm of the organization as a system for the processing of information or the solving of problems (Al Ahbabi et al., 2019). New challenges demand the acceptance of the role of creator, which companies need to assume in the face of a knowledge society. This role basically passes through four processes (Nonaka, 1994): 1) creation, 2) storage, 3) sharing and 4) application of knowledge.

The dimensions relative to the creation of knowledge accept the role of the individual and, more precisely, their commitment to the process of knowledge creation. Consequently, this creation of knowledge can be understood as a continuous dialogue between tacit and explicit knowledge (Nonaka, 1994). Explicit knowledge is that which can be codified and stored in various formats, in manuals for example, and therefore the assumption is that it can be transferred without losses (Stevens, 2010). On the other hand, tacit knowledge is more related to the experiences of an individual and their opinions, so storing it can be difficult (Grant, 2007).

The storing of knowledge is the process that will form organizational memory, whose recording will be done through physical systems formally and informally retained as values, norms and beliefs, which are associated with the organizational culture and structure (Alavi and Dorothy, 2001). Gonzalez and Martins (2017) relate five forms of knowledge storage: 1) individuals who make up the organization, 2) the culture defines the path for thinking and feeling, 3) the process of transformation of work methods, 4) the set of rules, hierarchies and attributions and 5) the environment that promotes the process

of sharing. Information technology (IT) appears as a key tool, offering support and conditions for codification, creation of directories and the creation of knowledge networks (Alavi and Leidner, 1999).

Knowledge sharing encompasses knowledge transfer or dissemination activities from one person, group or organization to another; including the tacit and explicit dimensions (Al Ahbabi et al., 2019). Knowledge sharing is sometimes identified in KM models as a process of the distribution of knowledge. In this article the option was to utilize the term "sharing" on account of its being used more frequently and to be better able to identify the set of actions that comprise it.

The process of applying knowledge has the role of applying knowledge in the sense of generating value for an organization. It is the process that will direct the knowledge captured and stored for some purpose. The application of knowledge becomes more evident when associated with decision-making processes, whether they are at operational, tactical or strategic levels (Al Ahbabi et al., 2019). The process is identified at times in the models as utilization of knowledge, but our option was to use the term 'application' as we understood that it has wider coverage and more frequent use.

Knowledge Management Implementation Frameworks

There are several KM frameworks that were developed over time by individuals and organizations. Frameworks can be classified as prescriptive or descriptive (Rubenstein-Montano et al., 2001). Those classified as prescriptive will furnish a view on the types of KM procedures, without lingering on specific details of the procedures that should be put into practice. On the other hand, the structures classified as descriptive identify relevant KM attributes because of their influence in the success or failure of KM initiatives. After a systematic literature review, we located (Chen, Liang and Lin, 2010; Lee and Lan, 2011; Wu et al., 2012; Oztemel and Arslankaya, 2012; Tsai et al., 2012; Moradi, Aghaie and Hosseini, 2013; Singh and Gupta, 2014; Martínez-Martínez, Cegarra-Navarro and García-Pérez, 2015; Allal-Chérif, Bidan and Makhlouf, 2016; An et al., 2017; De Borba and Chaves, 2021).

Faced with these findings, this article seeks to bring together the main frameworks published in the past ten years according to the parameters presented at the beginning of the chapter. The main objective is to contemplate the support offered by the frameworks created so that, on being integrated with the data and analyses obtained in the research that will be carried out, it will

be possible to prescribe a model for the implementation of KM in banks in the light of the literature and the best practices already utilized.

Maturity Models in KM

In previous sections it was explained that the implementation of KM is generally guided by an implementation structure. The set of guiding principles that seek to represent the orientations and directions on how to operate KM in companies was named as implementation framework (Wong and Aspinwall, 2004). This structure is guided by stages that can be extracted from maturity models. The models presented in this section were suggested by revisers of scientific magazines to whom the articles that preceded and collaborated with this research were submitted.

Oliveira, Caldeira and Romão (2012) conducted research with 11 Portuguese companies in order to apply a structure to classify the level of KM maturity based on the factors identified. In their article, the authors suggest that KM is an evolutionary process. The initial motivation for these sample companies was to prevent the loss of knowledge by a worker leaving or protect the knowledge in some way. However, other motivating factors were mapped: increase in efficiency, creation of unique image for clients and innovation.

It is worth highlighting here that the factors present in each of the four phases are cumulative, that is, they continue to be present and are necessary in the phases that follow. Organizations cannot manage to focus on all factors simultaneously, and empirical evidence suggests the relevance of these factors associated with the beginning of each stage, since the implementation of KM is seen as an evolutionary process (Oliveira, Caldeira and Batista Romão, 2012).

Method

The research adopted a positivist paradigm, in which the phenomenon investigated is considered independent of its observation. Faced with the general and specific objectives set out, this work was conducted by means of qualitative research. In the first phase, 27 semi-structured interviews were held with different professionals involved in the KM area or in KM activities in four different banks in the country. The interviewees were selected on a non-probabilistic, intentional basis, according to the definitions in Lancaster et al.,

(2005). Data collection was carried out through individual interviews, for which the selected participants occupied the following groups: professionals from support areas, agencies and the knowledge area or equivalent. The interviews were held during a period of 45 days, remotely, using Cisco Webex® software. In the second phase, the interviews were transcribed and analyzed by means of content analysis. Bardin's (2006) perspective was utilized for the content analysis, by bringing together a set of techniques for communications analysis. This perspective was utilized at this stage of the research in an exploratory way. Nvivo®. Software was used in order to operationalize the content analysis.

Interviewee Characteristics

The interviewees were selected from domestic banks operating in at least three Brazilian states which had adopted some type of KM initiative. Five companies from the Brazilian banking sector were then invited to participate, four of which accepted the invitation. In all, 27 professionals from different areas were interviewed. The selection of professionals was the free choice of the participating companies, with guidelines that the person chosen should work in the unit that centralized KM activities or develop some activity correlated to the object of study. The average length of time for the interviews was 57 minutes. The longest interview was 1h 22m and the shortest was 45 minutes.

In relation to their time in the company, three interviewees had been there for five years, 12 for more than 5 years and up to 10, eight more than 10 years up to 20 and four had more than 20 years of service in the company. The interviewees worked in four Brazilian states. Their level in the company was as follows: managerial (10), technical (16) and operational (1). As for their area of operation and function, it was possible to obtain perspectives from different sectors and functions, which contributed to a wider approach to the theme.

The consolidation presented served as a basis for the structuring of the framework presented and of the research instruments in such a way as to supplement and expand the existing studies. The framework was validated by a PhD professor specializing in Strategic Knowledge Management and two master's post-graduates. The validations were sent by e-mail, and the public for validation was selected on account of their intimacy with the field of research. Their suggestions were appropriated directly in the final version.

Results

To extract information about the process of knowledge creation from the interviews four questions were dealt with, which covered 1) acquisition of external knowledge 2) identification and treatment of gaps in knowledge 3) incentive for knowledge creation and 4) appropriation of knowledge generated from academic works.

In relation to incentives for knowledge creation, two specific standards were identified: incentive understood as support by the institution for participation in events and on courses, and openings for the participation of users in the demand for or co-creation of knowledge solutions (E11 and E13). As for incentive understood as user participation, open channels of communication with internal units and Wiki, with the mediation of specialists were mentioned (E4 and E5).

To extract knowledge from the interviewees regarding knowledge practices and storage, four structures were dealt with, according to the interview script: practices for an increase in tacit knowledge, knowledge conversion practices, storage routines by user initiative and the existence of storage standards and knowledge updating.

Tacit knowledge is more related to the experiences of an individual and their opinions (Grant, 2007), thus external storage is more difficult. However, it is possible to increase tacit knowledge in the individual. There was some evidence of such practices as mentoring and coaching for managerial and strategic levels, and for technical and operational levels the actions are limited to meetings and workshops (E2, E6, E10, E11, E22, E23 and E37).

The application of knowledge presented just one standard, which is mediation by a unit or group of specialists. This mediation takes place formally, when solutions are submitted to different committees, or also organically through the business schools that appropriate the knowledge generated by the practice for the application of solutions (E1, E2 and E17).

The adoption of KM is a strategy to guarantee the control of knowledge on the part of the company and everything begins with implementation. As interviewee 1 described *"(...) the knowledge was in the hands of third parties and we needed to unify it."* The minimum conditions, difficulties and facilities found presented three standards: technological solutions, company culture and support from people.

The performance measures topic was included in the script to give benefits to the framework that will be proposed, seeing that in the frameworks used as the basis of this research, there was no mention of the ways to measure KM

performance. The performance measures presented three standards: financial measures, process measures and development measures. Interviewee 1 mentions that they usually use cost reduction to evaluate using the financial perspective and they measure the use of the knowledge repository as a process measure. On the question of people development, capacities and competencies are measured on the basis of behavioral change. Reflections on people`s results can also be measured from a comparison of performance before and after the application of the knowledge. Similarly, interviewees mentioned that the worker's own perception of development serves as a measure. The presence of knowledge in internal evaluations tends to function as a measure of development and is adopted as a basis for internal promotions and behavioral evaluations (E5, E6 and E10).

Discussion

The study of KM implementation framework characterization aimed to bring together the main publications in relevant journals with a view to evaluating the direction that research has taken in the different sectors (De Borba and Chaves, 2021). In addition to the ten frameworks studied, field research was conducted in banking institutions to map the KM practices that could contribute to the structure of a descriptive framework for the sector. This field research contributed with thirty additions or alterations in the framework initially proposed.

The empirical research brought learning to the field of study and after reflection and analysis, a framework was structured, now prescriptive, for the implementation of KM in banks. The structure was named Framework for the Implementation of Knowledge Management in Financial Institutions (FIGCIF), as a result of the construction of these elements: KM pillars, processes, implementation, performance and maturity.

Academic Contributions

As for the originality dimension, the research can be classified as incremental, and regarding utility, it can be classified as scientific and practical (Corley and Gioia, 2011). The FIGCIF allows the orientation of new studies in the KM domain in financial institutions and structures it according to a maturity model,

thus permitting analysis of the implementation proposal throughout time. The FIGCIF could serve as a basis for quantitative empirical approaches that aim to assess the relevance of the factors listed in the framework and also help in research on maturity models from the perspective of the banking segment. This sector has some specificities, such as: the diversity of areas of knowledge, the intensity of knowledge, the intensity of technologies and an environment of adverse activity and constant change. The elements listed in the FIGCIF were structured according to the KM maturity model proposed by Oliveira, Caldeira and Batista Romão (2012) which, besides presenting a simplified structure, thereby making it easy to apply, concentrated its sample on service organizations. Table 1 structures the elements that compose the FIGCIF throughout the maturity stages proposed by the authors. The framework was validated by two academic specialists in the KM area.

Besides contributing to new variables and structures to compose models of academic research, such as business schools and the suitability of language, the FIGCIF innovates in suggesting performance measures applicable to different maturity levels of KM implementation.

Managerial Contributions

Using the reports collected in the environment of empirical research, it is possible to suppose that financial investment and confidence in the adoption of KM in banking institutions encounters managers and professionals who are unaware of formats of performance mediation. Consequently, this chapter presents some suggestions for forms of mediation that can be used by banks:

1) Measuring the reduced cost using a knowledge solution can be more logical than measuring the generation of revenues;
2) Comparing commercial performance before and after the application of KM activities;
3) Quantifying the new products and solutions developed;
4) Using process metrics that can reflect improvements using KM solutions and
5) Measuring staff turnover by sector as a way of justifying implementations of KM solutions individually.

The research findings, which were shown in Table 1, were organized in a flowchart to facilitate practical implementation, see Figure 1.

Table 1. The FIGCIF structuring in the maturity model

		Stages in the implementation of KM (Oliveira, et al., 2012, p. 13)[1]			
		1) Planning	2) Initiation	3) Development	4) Integration
		(*)	+1	+1+2	+1+2+3
3. Implementation		3.1 Alignment of objectives	3.3 Awareness raising	3.5 Language	3.6 Maturity
		3.2 Approximation	3.4 Project team		
1. KM Pillars	1.1 People	1.1.5 Participation	1.1.2 Culture	1.1.1 Competition	
			1.1.4 Leaders	1.1.3 Incentives	
	1.2 Processes	1.2.3 Demands	1.2.2 Capacities	1.2.1 Evaluation	1.2.6 Legality
		1.2.8 Planning	1.2.4 Strategies	1.2.7 Standardization	
		1.2.9 Routines	1.2.5 Structure		
	1.3 Technology	1.3.4 Technological solution	1.3.1 Access	1.3.2 Controls	1.3.3 IT Infrastructure
2. KM Processes	2.1 Application	2.1.5 Intensity	2.1.1 Use	2.1.3 Feedback	2.1.2 Evolution
		2.1.6 Prevention		2.1.4 Flow	2.1.7 Validation
	2.2 Storage	2.2.7 Curation	2.2.1 Filing	2.2.2 Updating	2.2.3 Autonomy
		2.2.8 Academic works	2.2.5 Conversion	2.2.4 Tacit knowledge	
				2.2.6 Content creation	
	2.3 Sharing	2.3.1 Collection and donation	2.3.4 Groups	2.3.3 Diversity	2.3.5 Integration
		2.3.2 Diffusion			2.3.6 Protection
	2.4 Creation	2.4.1 Acquisition	2.4.4 Gaps	2.4.3 Schools	2.4.6 Production
		2.4.5 Research			2.4.2 Scenarios
4. Performance measures		4.2 Human capital	4.3 Intellectual capital	4.4 Organizational capital	4.7 Matrix
		4.1 Information capital	4.5 Costs	4.6 Innovation	
		4.8 Process metrics		4.9 Result metrics	

Source: the author. * Note: the stages of maturity are cumulative, therefore the related components in the initial phases continue to be important throughout the process of implementation. In the table the ideal moment for the process to be initiated or better worked on is represented.

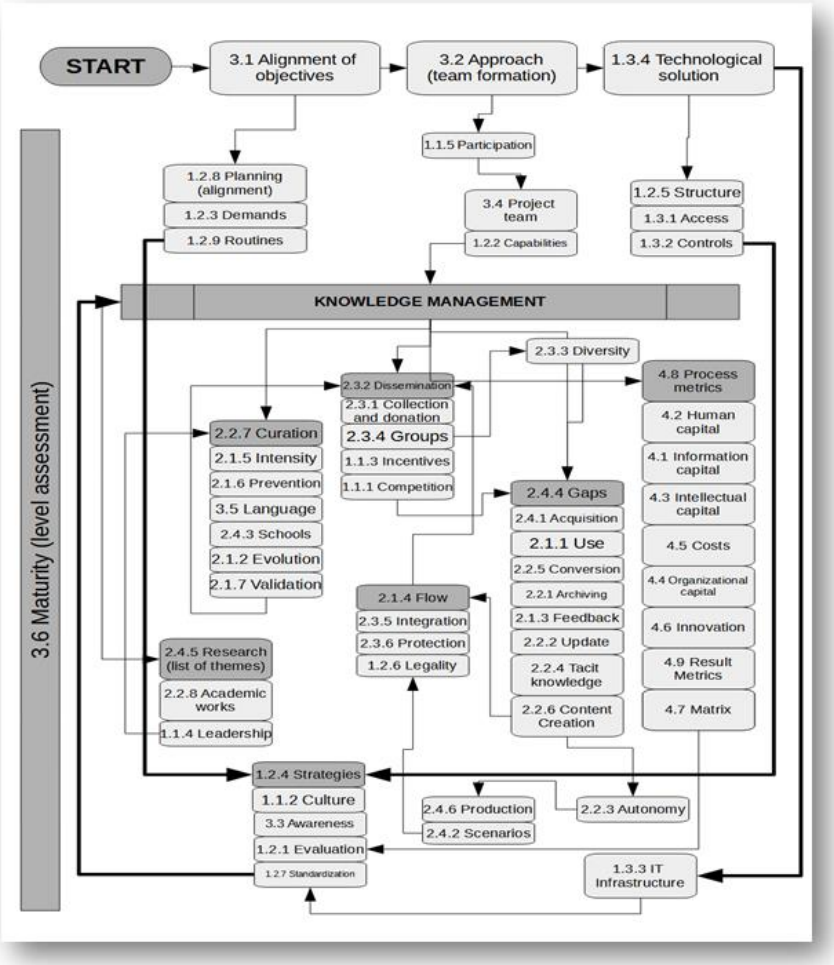

Figure 1. Flowchart for practice (FIGCIF).

Conclusion

From the perspective of the prescriptive and descriptive frameworks studied and the empirical research, it was possible to formulate a framework for the implementation of KM in banks (FIGCIF).

This chapter also presented some limitations:

1) The words utilized for the search for articles that composed the systematic literature review can be limited to the range of articles that are related to the field studied;
2) The criteria for selecting the sample articles that focused on high-impact magazines may have excluded relevant articles; and
3) The transversal sample utilized.

Considering that the implementation of KM is closely related to the models of maturity in KM, it would perhaps be interesting to research the same companies at different stages of maturity. Future research could investigate structures of KM implementation in wider or more diversely utilized samples of articles and apply the FIGCIF using interventionist approaches such as research-action or Design Science Research.

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Chapter 7

Competitive Resources and Capabilities: A Driver toward Sustained Competitive Advantage among Manufacturing MSMEs in Emerging Markets

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Abstract

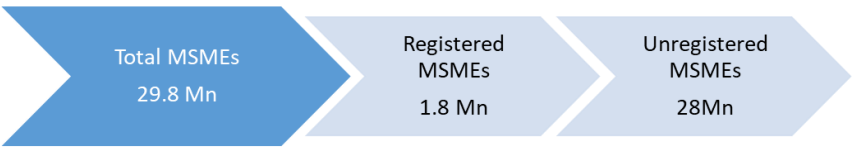
Micro, Small, and Medium Enterprises are the game changers in the industrial scenario, as they are the significant sources of employment and growth in an emerging economy. Studies based on the resource-based view are abundant in the context of developed countries but less in emerging markets such as India. The present research extends the literature addressing the importance of resources and capabilities among manufacturing MSMEs in India, how they turn out to be competitive resources, and the abilities necessary for achieving superior firm performance, which acts as a driver toward the sustained competitive advantage of Indian manufacturing MSMEs. Therefore, the proposed model benefits policymakers and owners, especially micro and small, to develop a positive attitude on developing sustained competitive advantage among manufacturing MSMEs in India.

Keywords: resources, capabilities, competitive, sustained competitive advantage, superior firm performance

In: Advances in Business and Management. Volume 20
Editor: William D. Nelson
ISBN: 979-8-88697-489-8

Introduction

While focusing on the developed economy, 99% of European economies are small and medium enterprises that contribute enormously to wealth creation. The participants of OECD countries, especially Australia, Canada, Japan, Korea, United States, where their respective Governments prioritise the growth of small and medium enterprises through well-defined policies and procedures, are the same as in Asian countries. However, when moving to East Asian countries like India, characterised by an agricultural economy, their entry into the manufacturing sector resulted in stagnant growth over the last two decades. This is because Indian Industries are dominated by Micro, Small, and Medium Enterprises sharing their role in manufacturing and service markets.



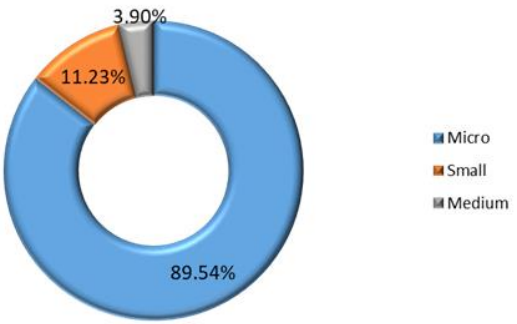
Source: MSME Annual report of Government of India 2016-17.

Figure 1. Total number of registered and unregistered MSMEs.

From Figure 1, it is clear that despite their most significant contribution of MSMEs, the concentration of unregistered MSMEs is more than registered MSMEs in India. Out of the manufacturing sector, the MSMEs contribution is only 7 per cent, and the MSMEs contributed 30.5 per cent to India's GDP out of the service sector. Manufacturing plays a vital role in the country's industrialisation and maintaining a smooth industrial climate. However, the manufacturing competencies of MSMEs need to be improved as the demand for manufactured goods should agree with global standards. While examining the entrepreneurship literature in emerging markets, abundant research on the manufacturing challenges of Indian MSMEs has been explored. Still, research shows that gaining superior performance based on competitive resources and capabilities, vital for attaining sustained competitive advantage for manufacturing MSMEs in India, is less.

The Prime Minister's Make in India Programme aimed to make India the fifth largest manufacturing country by 2020 (Federation of Indian Chamber of Commerce, 2010). However, the growth rate of manufacturing has become stagnant because of the absence of competitive factors/resources. The

Manufacturing sector's competitiveness has lost its market advantage due to low labour productivity and increased input and material cost. As a result, the contribution of India's manufacturing sector to world GDP is only 2 per cent. This denotes that India is still encountering a competitive disadvantage due to poor technology, infrastructure, and high input cost. It is also because the share of Micro enterprises marked the highest in emerging markets (same as the case of Indian MSMEs.) While in a developed economy, the percentage of small and medium enterprises is increased than large and micro enterprises. This is revealed in the following figure.



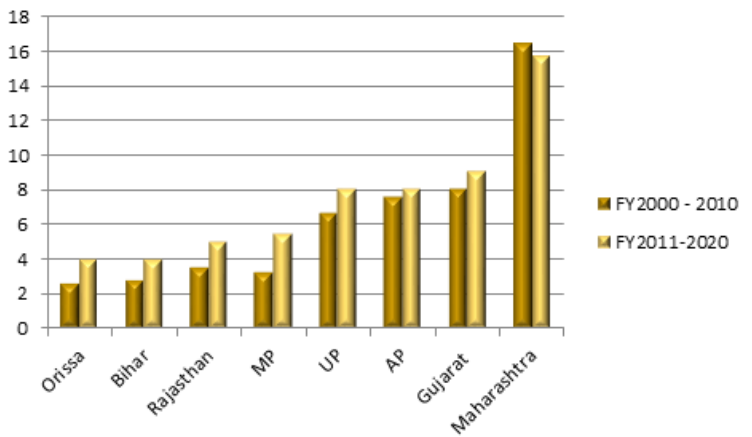
Source: MSME Annual report of Government of India 2016-17.

Figure 2. Percentage share of MSME units.

From Figure 2, it is evident that the share of micro units is enormously significant, which constitutes around 89.54 per cent, whereas the contribution of small units is only 11.23 per cent, and the medium units contribute a minimal share of 3.9 per cent. The percentage of small and medium units towards total manufacturing MSMEs is comparatively low. The figure stresses the need for uplifting micro units, and the relative contribution of small and medium enterprises, especially in the manufacturing sector, should increase. On the manufacturing side, the emerging market is highly deficient in internal resources, and strengthening the internal resource pool shall be the main focus for micro, small and medium enterprises. Therefore, the research critically emphasises internal factors like infrastructure, improved technology, research and development, quality consciousness, quality exports, intellectual property rights, and skilled human resources, which strengthens the internal resources and capabilities, which are vital for improving firm performance for developing sustained competitive advantage of micro, small and medium manufacturing firms.

Competitive Resources as a Driver Towards Sustained Competitive Advantage in Emerging Markets

The author analysed Indian Manufacturing MSMEs' resources and capabilities from a theoretical perspective, highlighting the importance of competitive resources necessary for generating superior performance. The results of several studies exhibited differences in performance among firms within similar industries. (Cubbin 1988; Hansen et al., 1989; Lewis and Thomas 1990). Some firms perform poorly in attractive sectors, while others perform well in declining industries. Resource Based View emerged as a solution to such performance differences among firms (Rumelt, 1984; Conner, 1991). Resources are regarded as predecessors in the development path of the firm. (Wernerfelt, 1984). A sustained competitive advantage is generated by a firm's unique combination of resources, which are rare and valuable and ultimately form the basis of improved performance. (Wernerfelt, 1984; Barney, 1991; Conner and Prahalad,1996; Dollinger, 1999). Successful enterprise creation is usually the result of tangible and intangible resources representing the strength and weaknesses, thereby leading to competitive advantage (Grant, 1991). Tangible resources constitute physical capital such as location, facilities, plant, and equipment where Indian small and medium enterprises lack considerably to develop manufacturing facilities as they are not aware of the latest manufacturing technologies currently available.



Source: MSME Annual report 2016-17.

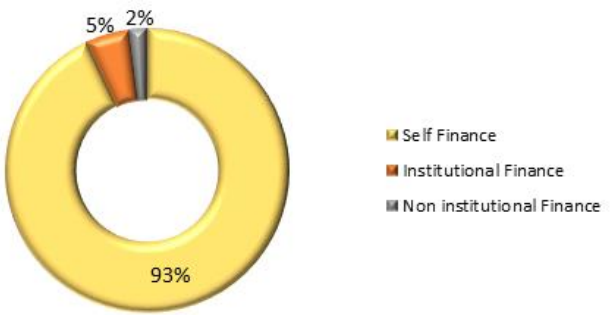
Figure 3. Percentage distribution of MSME in top 8 states.

From Figure 3, there are wide disparities among states regarding GDP contribution. Even though there is an increasing trend toward GDP contribution among the States of Uttar Pradesh, Madhya Pradesh, Bihar, and Rajasthan, their relative contribution to the country's development is low. In contrast, the States of Maharashtra, Gujarat, and Andhra Pradesh contribute significantly more to the country's development. Industrialisation to flourish in India requires more land acquisitions. There are also other issues ranging such as labour, electricity, water, etc. Land acquisitions were favourable in industry-friendly states, especially Maharashtra, Gujarat, and Tamil Nadu and such forced actions created violence in less industry-friendly states (Mukherji, 2009). Indian industry should focus more on creating transparency to ensure clearances and licenses to foster manufacturing growth. All these postulates the need to focus on physical capital as a competitive resource.

Lack of knowledge, skill, and experience possessed by entrepreneurs and workers, which are critical for small and medium enterprises to develop the capability of exporting, acts as a hindrance to SMEs survival. For small and medium enterprises to survive, the skills and experience embedded in individual entrepreneurs are critical for the firm's growth and development (Ahmed et al., 2010). The presence of entrepreneurship literature relating to entrepreneurial experiences (Ronstadt, 1988) reveals that entrepreneurial expertise leads to booming success. (Vesper, 1980). A broad recognition in the entrepreneurship literature showing the significance of the positive contribution of entrepreneurial experience to venture performance (Ronstadt, 1988) contends that prior entrepreneurial expertise can lead to success (Vesper (1980).

Similarly, a small firm's growth heavily depends on experience from similar businesses. (Chandler and Hanks, 1994). The entrepreneurs' lack of education, training and networking poses a severe challenge in most emerging markets (Gumede and Ramussen, 2002; Herrington et al., 2009). The small and medium firms' survival in India is greatly influenced by entrepreneurs' age, managerial experience, education, caste, and social community (Bates, 1990). These are called entrepreneurs' human capital, a vital intangible resource for attaining superior firm performance. The growth rate in employment in the organised manufacturing sector shows a diminishing trend because of stringent labour laws. The stability of Indian manufacturing is heavily dependent on the focus towards greater emphasis on human resource development. In 2010, the employment growth of the manufacturing sector was negative for the private sector. Human capital as an intangible resource is the investment made through education and training, leading to increased

human productivity and firm performance (Schultz, 1961). Different researchers proposed social capital from the transaction cost theory, resources dependency theory, and social network theory (Premanatne, 2002). Social capital postulates relationship two types of relationships such as external (bridging) and internal (bonding) (Adler and Kwon, 2002). Social capital as an intangible resource is vital for firm performance for small and medium enterprises in emerging markets (Roxas et al., 2017). Social capital, from the point of view of external relationships, is the relationship maintained by the firm with the institutions and players outside to improve the performance of manufacturing MSMEs. Dependency on external actors is crucial for small firms for their survival. By March 2010, around 48 per cent of MSMEs had been declared sick because of a lack of availability of working capital from institutional sources. The MSME firms can deploy such relationships to get things done for the firm. In India, the growing importance of financing for small and medium enterprises from external financing agencies poses a severe threat (Thampy, 2010).



Source: Government of India (2011).

Figure 4. Distribution of finance among different sources.

From Figure 4, it is depicted that the percentage contribution of institutional finance towards registered MSMEs is around 11.21 per cent, which is the primary cause of self-financing by MSMEs (As per the fourth All India Census,2006-2007).

It is being noted that the timely and adequate support extended to manufacturing MSMEs is primarily constrained by regulatory barriers (working paper -Centre for civil society). As a result of globalisation, customers have become cautious in their purchasing behaviour. They became highly demanding, expecting high standards in products, activities, and

operations among different business enterprises. This reflects enterprises' operational costs (Gilaninia et al., 2015). Relationship with customers helps small and medium enterprises to acquire new skills (Appiah-Adu and Singh, 1998; O'Regan, Ghobadian, and Gallear, 2005). Customer relationship ensures the firm is profitable, both in the short and long run, necessary to gain improved performance among manufacturing MSMEs in India.

This research, therefore, examines to what extent social capital explains the level of trust and relationship maintained by the Government, financial institutions, and customers, which will foster superior performance among manufacturing MSMEs in India.

Competitive Capabilities

Resources in isolation seldom contribute to firm performance, but the application of these resources in the form of capabilities is put forward by researchers (Grant, 1991; Teece, 2007). The dramatic transformation of the economy due to transportation advancements and information and communication technology due to liberalisation and globalisation pressed the need to represent small and medium enterprises in the international markets (Fujitha, 1998; Keegan and Green, 2005). The low innovation capacity of Indian small and medium enterprises is revealed through Global Innovation Index (81 out of 141 countries). Resource scarcity hinders SMEs from entering export markets (Moen, 1999).

A firm to develop the capability to export is influenced by high technological knowledge, which becomes fruitful with the help of in-house Research and Development efforts, equipped with a good number of scientists and engineers. (Romer, 1990; Jones, 1995; Abdihand Joutz, 2006). In the case of emerging markets, where there are inhibitions concerning innovation and technology, the knowledge about IP protection is emphasised least. (Thurrow, 1997). In many developing countries, the innovations in MSMEs are informal with no particular focus on Research and Development concerning investment, infrastructure, and personnel. As a result, a trademark may play a more significant role than patents which act as a competitive resource for small and medium enterprises in emerging markets. Per the report published by the Ministry of MSME, the number of units that have applied for patents is relatively low. Although innovations are a minor focus, small and medium enterprises cannot recruit such skilled personnel due to financial and infrastructural constraints. This necessitates the need for capacity-building

programmes for enhancing the skills of engineers and workers through training, which can be developed through Human resource practices. Availability of Information relating to the market and technology at the right time can impact firm performance. As part of the developmental initiative Government of India launched Digital India Programme in 2014 to transform the economy into a digitally empowered society that can foster digital empowerment among all sections of society. Digital India Programme envisages information and communication technology among Indian users, especially business units. It necessitates the development of capabilities in the form of computers, software applications, and telecommunication systems for information and knowledge sharing (Attaran, 2003). Small and Medium Enterprises are deficient in infrastructure, hamper the capability of adopting Information and Communication Technology (Ongori and Migiro 2010). Adopting information and communication technology enables ready access to information internationally (Minton, 2003; Ndubisi and Kahraman, 2005), enhancing firm performance to a greater extent.

Firm Performance Measures

The performance of manufacturing MSMEs is based on the typologies developed by Nelson and Mwwaura (1997), such as Growth in sales, financial foundation, profitability, and employee morale. Manufacturing MSMEs generate superior performance when competitive resources and capabilities are employed together.

Sustained Competitive Advantage in Emerging Markets

Sustained Competitive Advantage can be attained only when a firm outperforms its rivals. Therefore, the development of a Sustained Competitive Advantage is very much dependent on internal resources in the form of both tangible and intangible (Papula and Volna, 2013). However, in the case of an emerging market such as India, possession of resources does not make sense for manufacturing MSMEs. Still, the focus of this research is the importance of resources as competitive necessary for developing competitive capabilities. Based on the literature, competitive resources and capabilities are responsible for generating superior performance among manufacturing micro, small and

medium enterprises in India and therefore are the drivers towards sustained competitive advantage.

Conceptual Framework

Based on the literature review, a conceptual model has been worked out where competitive resources are treated, independent variables and capabilities will be treated as mediating variables and firm performance as dependent variables—in this study, manufacturing MSMEs competitive resources such as physical capital (tangible), entrepreneurs' capital, social capital, and human capital (intangible) together responsible for generating capabilities. Therefore, the summation of competitive resources and capabilities generates superior performance, necessary to achieve a sustained competitive advantage in manufacturing MSMEs in India. There are many types of research on the resource-based view and sustained competitive advantage. Still, the present study seems distinct, which involves identifying the competitive resources and capabilities meant for emerging markets such as India.

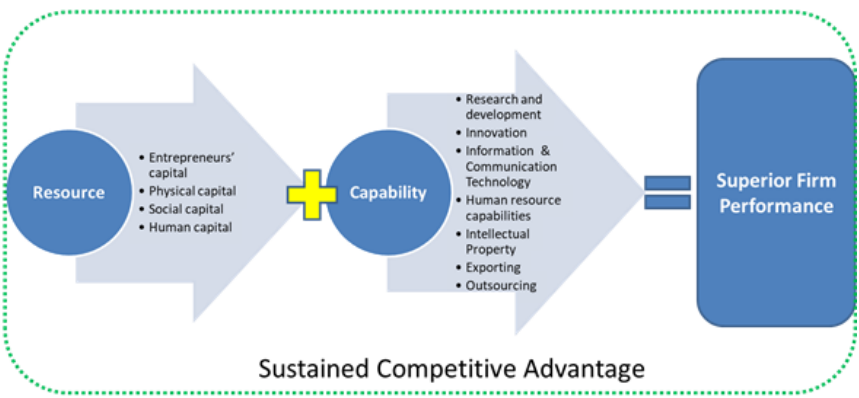


Figure 5. Conceptual model based on resource-based view.

Conclusion

As an emerging market, India should emerge as an industrially developed country, and manufacturing MSMEs have played a leading role in this regard. The research points out the MSMEs' commitment to tangible and intangible

resources, which makes the firm competitive. The proposed model highlights the importance of competitive resources and capabilities as they necessarily generate superior performance for manufacturing micro, small and medium enterprises to foster sustained competitive advantage. To create outstanding performance manufacturing MSMEs in emerging markets, India should focus inwardly on developing competitive resources and capabilities as their primary need towards uplifting the micro and small manufacturing MSMEs.

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Chapter 8

Application of Random Walks to Bayesian Classification and Business Decision Making

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Abstract

Many decision-making scenarios can be viewed as classification problems. Classification decisions are pervasive and occur in many business situations. In many applications, classification problems do not occur in individually but in groups where several classification problems need to be solved. Examples of these include student admissions at colleges, whether or not to extend job offers to applicants, the effectiveness of advertising channels, and determining if COVID patients should be hospitalized. With any form of classification, however, there are unavoidable inaccuracies arising in different forms, especially when multiple classification tasks need to be performed. Since typical classifiers are not free from errors, classification errors tend to accumulate, and having frequent misclassifications are often unacceptable. Moreover, in unsupervised learning situations, there are typically no pre-determined ground truth classes; in such a situation the

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In: Advances in Business and Management. Volume 20
Editor: William D. Nelson
ISBN: 979-8-88697-489-8

ground truth class is determined by the view of the majority of classifiers. In this chapter, we examine the situation of multiple classifications within the Naïve Bayes framework, where the ground truth is determined by the decision of most classifiers, and where there are finite resources requiring decisions to be made within a limited budget. Here, we represent the classification tasks as a one-dimension random walk process and perform a probabilistic analysis of the situation. We find that by raising the budget, the probability of error in classification can be controlled, and the extent of the reduction can be quantified. These results can be beneficially deployed in a variety of business decision-making situations in measuring and enhancing the quality of decisions.

Keywords: binary classification, naïve Bayes classifier, multiple classification, random walk, unsupervised learning

Introduction

The need to classify different kinds of entities occur frequently in everyday life [3] and a significant amount of practical decision making are related to some form of classification. The underlying entities may correspond to such objects as patients, products, cities, academic results, advertising channels, or projects. However, classification decisions are not always correct, and misclassifications frequently occur [11]. In many realistic scenarios, not one, but many classifications of similar problems are required.

Classification algorithms, whether based on automatic means or human judgment, are recognized to be imperfect with classification errors being inevitable [24]. In the most rudimentary formulation, a given entity is put into one of a discrete number of classes by a classifier. In more realistic scenarios, however, there can be many classifiers to the same entity, with multiple entities to be placed in classes, and the overall performance of the system is evaluated by placing these multiple objects into correct classes.

This multiple classification problem has received considerable attention [4, 9, 14, 20, 22] in different contexts, such as medical treatment, homeland security and crowd sourcing [1, 5, 10, 19, 21]. While most of these works propose algorithmic solutions, they do not study the relationship between the number of available classifiers and the error of classification. Exceptions to these are the studies [2, 7, 8]. In this study, we consider the multiple classification problem as studied in [7, 8] under different assumptions. Here, as in [7, 8], we assume that there is a set of M objects or problems to be

classified, and adopting the terminology there, shall be called tasks. As in [7, 8], we focus on binary classification of two classes $\{+1, -1\}$. Our aim is to develop an error bound on such a classification problem. In [7], several practical examples of this situation are highlighted. For example, in a medical consultation context, the tasks can correspond patients, and physicians are to classify the patients (i.e., recommend patient management option) as (i) proceed with invasive surgery, or (ii) adopt a course of non-invasive treatment; other examples include police surveillance operations and employee contract renewal in human resources departments. In general, different physicians have different views concerning the treatment to be adopted. In the present chapter, for concreteness we shall often use this particular medical treatment example, bearing in mind that this is actually representing a general multiple classification problem.

Whilst the same framework and problem are being adopted, there are a number of important differences between [7, 8] and the current study. Firstly, in [7, 8], it is assumed the ground truth is available and given, which in many situations is unrealistic. In the medical consultation example, there is generally no objective right treatment for the patient, and the best treatment at the time may be the view of the majority - this approach is indicated in [7, 13] as majority voting. Secondly, in [8], it is assumed that there is a budget constraint, which represents a realistic practical limitation, and classification decisions are made after the budget is exhausted. Here, the budget constraint is reflected in the number of classifiers applied, after which a classification decision is made on the basis of majority voting. Thirdly, in [7, 8], the same set of predictors or classifiers is available for every task. Here, we allow the set of available classifiers may be different for each task.

Mathematical Framework

In the present study, we shall largely follow the framework in [7]. We assume there is a set of M tasks to be classified as in [7], and a set of independent predictors (i.e., Naïve Bayes property) which assigns binary classification labels – i.e., the labels are in the set $\{\pm 1\}$. As in [7], we shall use the terms classifiers and predictors interchangeably, and also the terms classification problem and task interchangeably. For task i, a predictor will classify the task as -1 with probability $q_i > 0$, and it would classify the task to be $+1$ with probability $p_i > 0$, with $p_i + q_i = 1$. As suggested in [7], the classification process of different predictors can be viewed as a one-dimensional random

walk process, where a step to left corresponds to receiving a label of −1, while a step to the right corresponds to receiving a label of +1. More precisely, for a given task i, we let $\{Z_{ij}\}_{j>0}$ be a set of independent identically distributed random variables with $\mathbb{P}[Z_{ij} = -1] = q_j$ and $\mathbb{P}[Z_{ij} = +1] = p_j$ and let

$$X_{in} = \sum_{j=1}^{n} Z_{ij} \tag{1}$$

be the displacement from zero of the walk after n steps, where it is assumed that $X_{i0} = 0$.

In [7], it is assumed that the ground truth vector is given; while this is feasible in some situations, in many realistic unsupervised scenarios, an objective absolute ground truth label is often not available. Here, we shall assume that the ground truth is determined by the majority of classification labels – this is called majority voting in [7, 8]. The ground truth is the class that, assuming the task is classified a large number of times, the resultant majority defines the ground truth. Denote the ground truth class for task i by gi, thus gi can take on the value −1 or +1. Denote by

$$\boldsymbol{g} = \begin{pmatrix} g_1 \\ g_2 \\ \cdots \\ \cdots \\ g_M \end{pmatrix}$$

the ground truth vector of the problem. Of course, the classification error can only be determined when the ground truth labels are known; here for each task, the ground truth which corresponds to majority voting is indicated by the propensity of the walk to move in a particular direction, which is dependent on the parameters pi and qi, without which the ground truth cannot be meaningfully indicated. Thus, instead of simply assuming that the ground truth vector is given as in [7], we introduce a probabilistic factor which allows for some variations in the ground truth specification process, which is more realistic in situations where the ground truth is only estimated and not known with absolute certainty. The budget factor is introduced in [7, 8] as part of the classification framework; while we may invoke an unlimited budget, in the practical assignment of labels, we shall adopt a finite budget constraint as in [7, 8].

For task i, we assume that a fixed number of classifiers n_i are used to complete the classification task, after which majority voting determines the class; n_i is normally assumed to be odd to avoid an equal number of votes for each class being received. While the walk can take any number of steps (potentially unlimited), we assume n_i steps are taken, and n_i can thus be regarded as a constraint placed on the budget. If we assume, without loss of generality, that each classification performed invokes unit cost, then the total budget for the M tasks is $n_1 + n_2 + \ldots + n_M$. We denote by $\hat{g}_i$ the predicted class for task i, and by

$$\hat{\boldsymbol{g}} = \begin{pmatrix} \hat{g}_1 \\ \hat{g}_2 \\ \ldots \\ \ldots \\ \hat{g}_M \end{pmatrix}$$

the predicted class vector. We shall aim to determine a bound for the classification error. The following theorem enables us to determine ground truth.

Theorem 1

For any given task i,

(i) the ground truth for the task is -1 when $q_i > p_i$, and
(ii) the ground truth for the task is $+1$ when $p_i > q_i$.

Proof

From equation (1), taking expectations of both sides,

$$E(X_{in}) = \sum_{j=1}^{n} E(Z_{ij}) = \sum_{j=1}^{n}(p_i - q_i) = n(p_i - q_i)$$

As $n \to \infty$, when $q_i > p_i$, the mean displacement will drift to $-\infty$, indicating the majority of the votes are for the class -1, which completes the proof of (i). Similar argument applies to the case $q_i < p_i$, resulting in the majority of the votes are for the class $+1$.

First, we consider a task i, where $q_i > p_i$, and from Theorem I, the correct class is -1. We wish to calculate the probability that $X_{n_i} > 0$, which corresponds to a situation where the majority votes for +1, and results in misclassification.

We first determine the probability $\mathbb{P}[X_{n_i} = k]$, where $n_i \geq |k|$, and $k > 0$. We note that $\mathbb{P}[X_{n_i} = k] = 0$ if $n_i < |k|$ since the walk cannot reach position k in less than $|k|$ steps. Here for simplicity, we drop the double index and use X_{n_i} for X_{in_i}, since X_{n_i} is sufficient to indicate that the task in question is task i. The following theorem gives the property of this probability.

Theorem II

(i) For k an even integer,

$$\mathbb{P}[X_{n_i} = k] = 0.$$

(ii) For k an odd integer,

$$\mathbb{P}[X_{n_i} = k] = \binom{n_i}{\frac{n_i+k}{2}} p_i^{\frac{n_i+k}{2}} q_i^{\frac{n_i-k}{2}}. \quad (2)$$

Proof

Let U_{n_i} and V_{n_i} denote the number of positive and negative steps respectively in the first n_i steps. So we have:

$$X_{n_i} = U_{n_i} - V_{n_i}$$
$$n_i = U_{n_i} + V_{n_i}$$

Eliminating V_{n_i} in the above, we obtain:

$$2U_{n_i} = n_i + X_{n_i}$$

Since the left-hand side is an even number, this means that n_i and U_{n_i} must be both even or both odd. Since we assume that n_i is odd, thus X_{n_i} must be odd, which completes the proof of (i).

Now, from the previous equation, $X_{n_i} = k$ if and only if,

$$U_{n_i} = \frac{n_i+k}{2}$$

and U_{n_i} is a binomial random variable with parameters n_i and p_i so that (ii) follows.

Random Walk Behavior

Now, a classification error would result if k lies in the positive axis, which corresponds to a situation that the number of +1 votes outnumbers that of -1 votes. Thus, the probability of classification error for task i is:

$$\mathbb{P}[\hat{g}_i \neq g_i] = \sum_{k \in \Omega^+} \mathbb{P}[X_{n_i} = k] = \sum_{k \in \Omega^+} \binom{n_i}{\frac{n_i+k}{2}} p_i^{\frac{n_i+k}{2}} q_i^{\frac{n_i-k}{2}} \quad (3)$$

where $\Omega^+ = \{2n-1\}_{n=1}^{\frac{n_i-1}{2}}$ is the set of positive odd integers from 1 to n_i (inclusive of 1 and n_i). The probability of correct classification for task i is:

$$\mathbb{P}[\hat{g}_i = g_i] = 1 - \sum_{k \in \Omega^+} \binom{n_i}{\frac{n_i+k}{2}} p_i^{\frac{n_i+k}{2}} q_i^{\frac{n_i-k}{2}} \quad (4)$$

Since we know that for the binomial distribution, the maximum is attained at $k^* = \lfloor (n_i+1)p_i \rfloor$, thus from equation (3), we have on replacing each summand by k^*,

$$\mathbb{P}[\hat{g}_i \neq g_i] \leq \left\lceil \frac{n_i}{2} \right\rceil \binom{n_i}{\frac{n_i+\lfloor (n_i+1)p_i \rfloor}{2}} p_i^{\frac{n_i+\lfloor (n_i+1)p_i \rfloor}{2}} q_i^{\frac{n_i-\lfloor (n_i+1)p_i \rfloor}{2}} \quad (5)$$

Alternatively, approximating k^* by $n_i p_i$, and noting that $\left\lceil \frac{n_i}{2} \right\rceil = \frac{n_i+1}{2}$, since n_i is assumed odd, we obtain from equation (2) the approximate bound:

$$\mathbb{P}[\hat{g}_i \neq g_i] \lesssim \left(\frac{n_i+1}{2}\right) \binom{n_i}{\frac{n_i(1+p_i)}{2}} p_i^{\frac{n_i(1+p_i)}{2}} q_i^{\frac{n_i q_i}{2}} \quad (6)$$

We note that $\frac{1}{2}n_i(1+p_i)$ is in general not integral, so we may use the gamma function in place of the factorials. Thus, we obtain the following more general form for the above bound:

$$\mathbb{P}[\hat{g}_i \neq g_i] \lesssim \left(\frac{n_i+1}{2}\right) \frac{\Gamma(n_i+1)}{\Gamma\left(\frac{n_i(1+p_i)}{2}+1\right)\Gamma\left(\frac{n_i q_i}{2}+1\right)} p_i^{\frac{n_i(1+p_i)}{2}} q_i^{\frac{n_i q_i}{2}}$$

Using the relationship $s\Gamma(s) = \Gamma(s+1)$, and simplifying, the above becomes:

$$\mathbb{P}[\hat{g}_i \neq g_i] \lesssim \frac{\Gamma(n_i+2)}{2\Gamma\left(\frac{n_i(1+p_i)}{2}+1\right)\Gamma\left(\frac{n_i q_i}{2}+1\right)} p_i^{\frac{n_i(1+p_i)}{2}} q_i^{\frac{n_i q_i}{2}} \tag{7}$$

As in [1], we shall adopt the Naïve Bayes property that the predictors are independent, so that the, the probability of correct classification for all the tasks for which the ground truth is −1 is given by:

$$\prod_{i \in Q}\{1 - \sum_{k \in \Omega^+} \binom{n_i}{\frac{n_i+k}{2}} p_i^{\frac{n_i+k}{2}} q_i^{\frac{n_i-k}{2}}\} \tag{8}$$

where Q is the set of indexes of tasks with ground truth equal to −1.

Next, we consider a task j, where $q_j < p_j$, and from Theorem I, the correct class is now +1. We wish to calculate the probability for this situation that $X_{n_j} < 0$, which corresponds to a situation where the majority votes for −1, and therefore results in misclassification.

We shall make use of the reflection principle to determine the probability $\mathbb{P}\left[X_{n_j} = k\right]$, where $n_j \geq |k|$, and $k < 0$. By the reflection principle, we can reflect the random walk about zero and swapping p_i and q_i [Feller] in equation (2) to obtain:

$$\mathbb{P}\left[X_{n_j} = k\right] = \binom{n_j}{\frac{n_j+|k|}{2}} p_j^{\frac{n_j-|k|}{2}} q_j^{\frac{n_j+|k|}{2}} \tag{9}$$

As before, we have $\mathbb{P}\left[X_{n_j} = k\right] = 0$ when k is even. Thus, the probability of classification error for task j for this situation is (next page):

$$\mathbb{P}\left[\hat{g}_j \neq g_j\right] = \sum_{k\,\epsilon\,\Omega^-} \mathbb{P}\left[X_{n_j} = k\right] = \sum_{k\,\epsilon\,\Omega^-} \binom{n_j}{\frac{n_j+|k|}{2}} p_j^{\frac{n_j-|k|}{2}} q_j^{\frac{n_j+|k|}{2}} \quad (10)$$

where $\Omega^- = \{1-2n\}_{n=1}^{\frac{n_i-1}{2}}$ is the set of negative odd integers from -1 to -n_j (inclusive of -1 and -n_j).

Applying the same approximation as before in replacing each summand by using the value $|k^*| = \lfloor (n_i+1)q_i \rfloor$, we have from equation (10):

$$\mathbb{P}\left[\hat{g}_j \neq g_j\right] \leq \left\lceil \frac{n_j}{2} \right\rceil \binom{n_j}{\frac{n_j+\lfloor (n_j+1)q_j \rfloor}{2}} p_j^{\frac{n_j-\lfloor (n_j+1)q_j \rfloor}{2}} q_j^{\frac{n_j+\lfloor (n_j+1)q_j \rfloor}{2}} \quad (11)$$

Using a similar approximation as in equation (5) above, we obtain the approximate bound:

$$\mathbb{P}\left[\hat{g}_j \neq g_j\right] \lesssim \frac{\Gamma(n_j+2)}{2\Gamma\left(\frac{n_j(1+q_j)}{2}+1\right)\Gamma\left(\frac{n_j p_j}{2}+1\right)} p_j^{\frac{n_j p_j}{2}} q_j^{\frac{n_j(1+q_j)}{2}} \quad (12)$$

The probability of correct classification for task j is:

$$\mathbb{P}\left[\hat{g}_j = g_j\right] = 1 - \sum_{k\,\epsilon\,\Omega^-} \binom{n_j}{\frac{n_j+|k|}{2}} p_j^{\frac{n_j-|k|}{2}} q_j^{\frac{n_j+|k|}{2}} \quad (13)$$

Again, making use of the Naïve Bayes property, we have for the probability of correct classification for all the tasks for which the ground truth is +1 is given by:

$$\prod_{j\,\epsilon\,P} \{1 - \sum_{k\,\epsilon\,\Omega^-} \binom{n_j}{\frac{n_j+|k|}{2}} p_j^{\frac{n_j-|k|}{2}} q_j^{\frac{n_j+|k|}{2}} \} \quad (14)$$

where P is the set of indexes of tasks with ground truth equal to +1. Thus, we obtain the probability of correct classification for all tasks:

$$\prod_{j\,\epsilon\,P} \{1 - \sum_{k\,\epsilon\,\Omega^-} \binom{n_j}{\frac{n_j+|k|}{2}} p_j^{\frac{n_j-|k|}{2}} q_j^{\frac{n_j+|k|}{2}} \} \prod_{i\,\epsilon\,Q} \{1 - \sum_{k\,\epsilon\,\Omega^+} \binom{n_i}{\frac{n_i+k}{2}} p_i^{\frac{n_i+k}{2}} q_i^{\frac{n_i-k}{2}} \}, \quad (15)$$

and the complement of this gives the error probability $\mathbb{P}[\hat{\boldsymbol{g}} \neq \boldsymbol{g}]$. The results we have obtained so far may be summarized in the following Theorem.

Theorem III

(i) $\mathbb{P}[\hat{\boldsymbol{g}} \neq \boldsymbol{g}] = 1 - \prod_{j \in P}\{1 - \sum_{k \in \Omega^-} \binom{n_j}{\frac{n_j+|k|}{2}} p_j^{\frac{n_j-|k|}{2}} q_j^{\frac{n_j+|k|}{2}}\} \prod_{i \in Q}\{1 - \sum_{k \in \Omega^+} \binom{n_i}{\frac{n_i+k}{2}} p_i^{\frac{n_i+k}{2}} q_i^{\frac{n_i-k}{2}}\}$. (16)

(ii) For any task i with a ground truth class of −1, we have:

$$\mathbb{P}[\hat{g}_i \neq g_i] \leq \left\lceil \frac{n_i}{2} \right\rceil \binom{n_i}{\frac{n_i+\lfloor (n_i+1)p_i \rfloor}{2}} p_i^{\frac{n_i+\lfloor (n_i+1)p_i \rfloor}{2}} q_i^{\frac{n_i-\lfloor (n_i+1)p_i \rfloor}{2}} \quad (17)$$

and

$$\mathbb{P}[\hat{g}_i \neq g_i] \lesssim \frac{\Gamma(n_i+2)}{2\Gamma\left(\frac{n_i(1+p_i)}{2}+1\right)\Gamma\left(\frac{n_i q_i}{2}+1\right)} p_i^{\frac{n_i(1+p_i)}{2}} q_i^{\frac{n_i q_i}{2}} \quad (18)$$

(iii) For any task j with a ground truth class of +1, we have:

$$\mathbb{P}[\hat{g}_j \neq g_j] \leq \left\lceil \frac{n_j}{2} \right\rceil \binom{n_j}{\frac{n_j+\lfloor (n_j+1)q_j \rfloor}{2}} p_j^{\frac{n_j-\lfloor (n_j+1)q_j \rfloor}{2}} q_j^{\frac{n_j+\lfloor (n_j+1)q_j \rfloor}{2}} \quad (19)$$

and

$$\mathbb{P}[\hat{g}_j \neq g_j] \lesssim \frac{\Gamma(n_j+2)}{2\Gamma(\frac{n_j(1+q_j)}{2}+1)\Gamma(\frac{n_j p_j}{2}+1)} p_j^{\frac{n_j p_j}{2}} q_j^{\frac{n_j(1+q_j)}{2}} \quad (20)$$

Discussion and Conclusion

Both the exact and approximate errors are given in Theorem III. In Theorem III, although (i) provides the exact error, it is computationally much more

involved, requiring the evaluation of sums and products, while (ii) and (iii) are much more direct and wieldy. In practice, therefore, (ii) relating to the −1 classification, and (iii) relating to the +1 classification are sufficient for error estimation purposes.

As we have indicated above, the occurrence of errors in classification problems are inevitable and cannot be completely eliminated. The presence of false positives and false negatives can never be wholly avoided due to imperfect accuracies in the associated classification mechanisms, be they manual or automatic. In addition, in many practical situations, it is unrealistic to assume that absolute and objective ground truth classes are available. In the present chapter, the multiple classification problem is studied using the Naïve Bayes approach, where the ground truth is not given but is voted upon by the view of the majority.

Moreover, the penalty, either in terms of the cost or the delay, of misclassification is often significant and cannot be ignored. Where resources are plentiful, of course, all classifiers should be activated to arrive at a classification decision, but resource and time constraints often make this impractical, and classification decisions will have to be made within finite time bounds prior to fully exhaustive classification. We make use of a random walk model to study the situation and have derived closed-form expressions for the probability of error as well as useful error bounds as a function of the budget constraint. We also find that by appropriately increasing the budget, the probability of erroneous classification can be decreased, and the degree of the improvement can be suitably controlled and managed.

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Contents of Earlier Volumes

Advances in Business and Management. Volume 19

Advances in Business and Management. Volume 18

Advances in Business and Management. Volume 16

Index

D

E

F

G

H

I

J

K

L

M

N

O

P

Q

R

S

T

U

V

W

Y

Advances in Business and Management

Volume 20

William D. Nelson
Editor

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ISBN-13: 979-8-88697-509-3
9 798886 975093