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Contents

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The Use of the Principle of Sharing and Mutuality in Covering Risks (in the Modern World)

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ABSTRACT

Purpose:
Operational risks appear as the main threats of the modern world. Mistakes made by employees, an imperfect information systems or changes in the law can cause losses that businesses today are not even able to estimate. Therefore, in the face of widespread the asymmetry of information, it becomes crucial to find such forms of financing losses, where the transmission of this information will not cause any concern. Such a form of insurance is based on the principle of mutuality.

Design/methodology/approach:
The research was based on a review of the literature in the area of asymmetric information and verification of research in the identification of key risk categories.

Findings:
Many researchers, including Nobel Prize winners, have identified the problem associated with a lack or asymmetry of information. But today, this issue leads to critical risks for businesses. This phenomenon is a subject of disclosure in the form of various categories of operational risk.

Research limitations/implications: Mutuality-based insurance is therefore a path based on solutions of the past (primary forms of insurance), but at the same time is seen as a response to the lack of adaptation of insurance products to the actual needs of clients. Consequently, the agency theory (principal-agent dependency) commonly used in modern times is being replaced by the idea of a sharing economy.

Originality/value:
The study addresses a complex area of the modern economy. Companies run their business and they want to have adequate insurance products to cover possible losses, including operational risks. Today, the insurance market is not ready to build appropriate products. Only insurance based on mutuality and the realization of the sharing economy can allow the preparation of adequate insurance products.

1. Introduction

The key elements of the modern world economy and individual enterprises are, on the one hand, systemic risks (pandemic, war) and, on the other hand, events related to the organisation and resulting in its characteristics, it means operational risks (mistakes of employees, improper procedures). In many cases, operational risks appear to be as difficult to mitigate and as important to a company's operations as systemic risks. The aim of this article is to show that the easiest and most effective (and perhaps the cheapest) forms of covering losses caused by such operational risk are solutions based on the sharing economy and mutual insurance.

On these days, almost 30% of the insurance premium goes to insurance companies based on the idea of mutuality. The remaining part of the insurance premium is collected by organizations (insurance companies) which base their activity on commercial principles. Analytical work on the effectiveness of the application of these solutions was carried out by comparing the financial results of profit-oriented insurance companies and those based on the principle

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of mutuality (territorial scope of the analysis: Europe). A special place in the analytical dimension is also occupied by information on the results of entities based on pure mutuality and operating in the area of agriculture (mutual fund).

The category 'systemic risk' was introduced by the Organisation for Economic Co-operation and Development (OECD). As noticed Systemic risk refers to "the risk or probability of a collapse of an entire system, as opposed to individual parts or components, and arises from the dependence (correlation) between most or all of these parts" (Kaufman& Scott, 2003). An appropriate categorization of these events are situations that (Renn, 2016): (1) are by global nature in their potential effects, (2) have complex and closely related to causes resulted in a high degree of comprehensive nature, (3) are non-linear in their cause-effect relationships, and (4) have stochastic regularity with respect to their effects.

Operational risk - is the risk of errors occurring in transactions carried out, the risk of losses resulting from inadequate or unreliable internal processes, people and technical systems or from external events. The probability of occurrence ranges from small losses that occur daily, for example due to errors in routine processes that result in business interruption (Moosa, 2007). But it can fail with IT systems or a damage to infrastructure or unauthorized or fraudulent acts by employees or external parties. All these cases can affect any type of organisation and any area of the economy.

When we analyze standard terms and conditions of property insurance or liability insurance contracts, we find exclusions referring to such phenomena. An exemplary catalogue of exclusions includes war, terrorism, nuclear contamination and damages resulting from erroneous advertising or data loss.

2. Review of Literature

2.1 Theoretical Review

A lack of effective insurance products offered to cover the consequences of these events is due to information asymmetry, i.e., mainly to insufficient information on the part of insurance companies. Information asymmetry occurs to the both sides of the implementation of the contract: before the conclusion of the transaction - including insurance - (*ex-ante* phase) and after it (*ex post* phase) (Figure 1). In the *ex-ante* phase, the problem of adverse selection is directly related to asymmetry, while in the *ex-post* phase, is directly related tothe moral hazard (Stiglitz&Weiss, 1981).

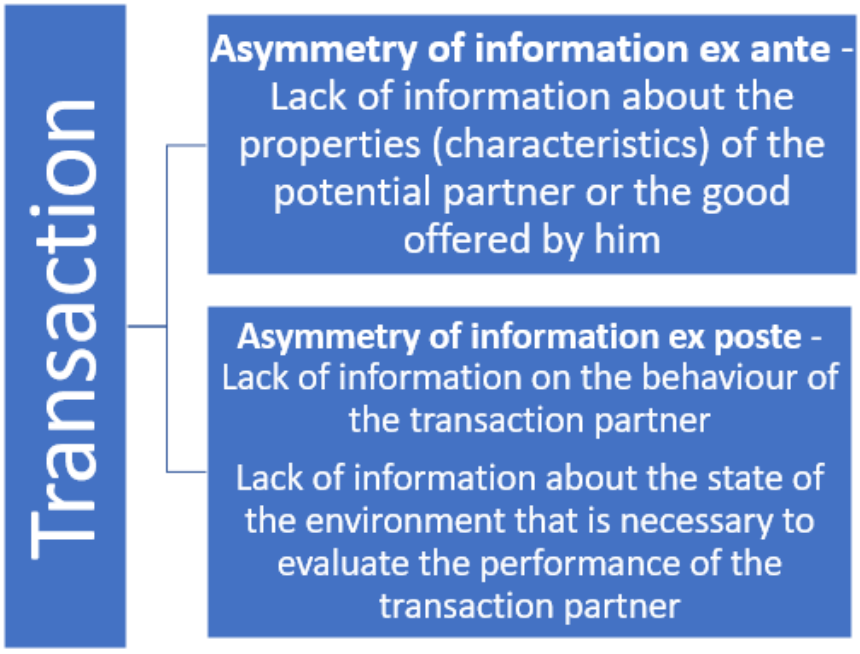

Figure 1. Phases of information asymmetry
Source: own work

Threats of information asymmetry further contribute to uncertainty, noted as “neither ignorance nor complete and perfect information but partial knowledge” (Knight, 1935, p. 199). We can identify a significant level of information asymmetry in the area of corporate operational risk, which in turn causes difficulties in finding appropriate insurance cover (which could be an instrument for risk mitigation).

In relation to the phenomena described above, a lack of insurance protection may result, in terms of systemic risk, primarily from the need to bear full responsibility for the financial consequences relating to many entities. Insurance companies are ready to cover the consequences of the systemic risk, but by building solutions with limited liability: using maximum liability limits, introducing index-based insurance and lump-sum liability, or by implementing the so-called microinsurance (Doff, 2015, p. 49).

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Based on the definition of operational risk, we can divide this risk into two main types (Figure 2). Type one corresponds to the risk of a loss due to the firm's operating system, i.e., a failure in a transaction or investment, either due to an error in the back office (or production) process or due to legal considerations. Type two corresponds to the risk of a loss due to incentives, including both fraud and mismanagement (Jarrow, 2008). Both types of operational risk losses occur with repeated regularity, and they can be small and safe or huge and catastrophic.

Figure 2. The scope of operational risk
Source: own work

With respect to operational risks, the lack of insurance coverage is primarily due to the behavior of the employees of the insured entity and the management of such entity itself. The choice of these two operational risks is due to the great difficulty in obtaining a source of loss funding through an adequate insurance contract. The lack of attention to specific procedures regarding the functioning of an enterprise (e.g. protection against fraud or errors in access to computer systems) means that it is not possible to correctly quote an insurance premium and determine appropriate behavior in the event of a loss. Therefore, insurance contracts also introduce limits of liability and enforce appropriate behavior after a loss that has been realized.

The objective pursued by a commercial organization is to maximize the value of the company and this can be achieved by increasing product prices, maximizing returns on investment activity, reducing costs, restructuring employment, etc. Such activities can drive the growth of the enterprise but can also be in conflict with the interests of clients. The problem of business development is today closely linked to technological progress, new devices, with its startling in the different areas of activity. However, these new devices, technology are closely associated with a man and his/her autonomy, desire to reduce efforts or costs. So, a technology, and as a result operational activities, are designed to bring benefits to a specific recipient. Yet, if these benefits an objective on their own, they can lead to the implementation of operational risks. Therefore, in the field of economics, it becomes important to explore a combination of the interests of the owner and the client, thus eliminating the existence of opposing pressure groups. Such examples can also be found in the area of insurance (Trynchuk et al., 2019).

2.2 Previous studies

Nevertheless, the operational risk nature features are becoming increasingly important among the most frequently indicated risks to enterprises. In a recurring survey conducted worldwide by Aon PLC, among the 10 most frequently indicated risks in 2021, as many as six can be categorized as operational risks (Figure 3). Amongst these can be identified: cyber-attacks/data breach, commodity price risk/scarcity of materials, damage to reputation/brand, regulatory/legislative changes, supply chain or distribution failure, failure to innovate/meet client needs. It is therefore worth considering the characteristics of operational risks and to what extent insurance covers the consequences of such events.

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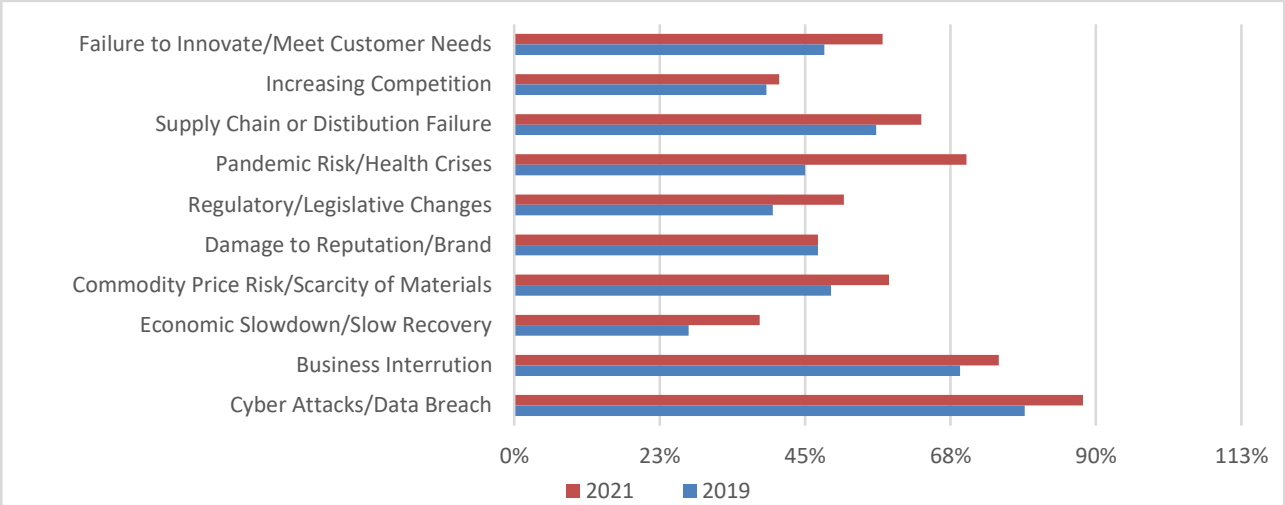

Figure 3. Reported Readiness for Top 10 Risks
Source: AON (2021), Global Risk Management Survey 2021

As indicated by the Aon PLC (2021) study, the greatest level of risk is experienced from Cyber Attacks/Data Breach since 2019. This area of risk was ranked as the 25th greatest risk to the modern world in a similar study conducted in 2009, but in 2017 it was ranked the 5th and now as the first one. It shows how operational risks dominate the risks. At the same time, the referenced study details that different perceptions of individual threats exist in the different parts of the world. Cyber Attacks/Data Breach is ranked 9th in Latin America and 4th in Europe. However, it already ranked 2nd in Asia Pacific and Middle East and Africa and 1st in North America.
Some of the most spectacular events in terms of operational risk in the financial sector are summarized below.

- Barings Bank (1995) went into insolvency due to the fraud of its dealer Nick Leeson and lack of separation of functions and supervision, loss amount US$1 billion (Stein, 2000)
- Daiwa Bank (1995) in the US with a loss of USD 1.1 billion (Aronson, 2003)
- Bank of America failed system integration USD 225 million (Farrell, 2010)
- Salomon Brothers IT systems conversion resulted in incorrect account balances of USD 303 million (Sims &Brinkman, 2002)
- a scandal in New York involving illegal business practices by insurance broker Marsh that rigged prices by submitting false bids to create the illusion of competition, charging multi-million-dollar fees for referring clients to selected firms (Cummins& Doherty, 2006)

3. Methodology

In order to build the necessary coverage for operational risk, it is necessary to define insurance product designs that simultaneously cover the consequences of operational and systemic risk for those at risk and ensure the security and sustainability of operations for the insurance company. Due to this effect, the authors have turned to the traditional approach to insurance, i.e. they have analyzed possible sources of funding and identified the optimal use of mutual insurance.

3.1 Insurance Mutuality - description of the variables under study

Vaughan, in defining a mutual insurer, specifies that it is owned by the policyholder (as opposed to a joint stock company) (Vaughan& Vaughan, 2008, p. 77). Studies for the World Bank define mutual insurers as those in which clients own the organisation and the financial benefits of mutual insurance arise from lower premiums (Kassim, 2012, pp. 21-22). While developing this understanding - a mutual insurer is an undertaking in which:
1) the members are both the insurer and the policyholders,
2) the members, either through contributions or liabilities, participate in the creation of a fund from which all damages are paid and liabilities covered,
3) profits are shared among the members and losses are covered by them in proportion to their participation in the fund [1] (Conflict, 1942, pp. 689-693).
In this respect, we can identify the benefits of mutual insurance on the basis of agency theory [2].

[1]Such a principle is called pay-as-you-go, participatory or non-final premium - the actual amount of the premium is only determined after the outcome of the insurer has been determined.
[2]The first attempts to explain the coexistence of commercial and mutual insurance on the basis of agency theory were made by Mayers and Smith (1981,1986) and Fama and Jensen (1983). This theory of the functioning of the firm is categorised as one of the strands of contemporary enterprise theory known as new institutional economics. (See more (Williamson, 1963, pp. 1033-1037))

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The agency theory was first presented by M.C. Jensen and W.H. Meckling in 1976. (Eisenhardt, 1989, p. 58). The key concept of agency theory is the agency relationship. It is defined as a contract whereby, one or more persons (the principal) use the services of another person (the agent) to perform some action, to fulfil a task. This action involves the delegation of authority and thus a certain degree of decision-making autonomy to the agent. (Jensen & Meckling, 1976).

An important aspect of this theory is the occurrence of so-called agency costs which are the costs associated with the reduction and resolution of conflicts that occur between interest groups plus the value of the service (production) capacity lost as a result of the inability to eliminate these conflicts from the activities of organization (Birkmaier & Laster, 1999).[3]

As a part of this strand, a theory of organizational forms has been proposed according to which, in a market process, the organizational form that guarantees the minimization of costs, including agency costs, will prevail (Fama & Jensen, 1983). It is a theory that has formed the basis for considering the coexistence of insurance companies based on the principle of mutuality and commercial companies. In insurance companies, the relevant agency relationships may involve three groups of stockholders - owners, managers, policyholders (Janowicz-Lomott, 2016) (Figure 4).

	Managers	**Owners**	**Clients**
commercial insurer	management	shareholders	policyholders
mutual insurer	management	member = policyholder	

Figure 4. Links between owner, client and manager in different forms of insurance activity
Source: Mayers& Smith(2000)

In the diagram presented above, two agency relationships (contracts) can be found: owner-management, owner-client relevant to explaining the strengths and weaknesses of both organizational forms of insurance companies.

The first type of relationship 'owner(principal) - management (agent)' is the primary agency relationship for the theory. It is believed that the resolution of conflicts of interest along this line is easier in the commercial companies. An important mechanism for external supervision is the capital market verifying the performance of managers, but also a properly structured system of information and financial incentives (Janowicz-Lomott,2016).

The second type generating agency costs occurs on the 'owner-client' line. In a mutual company, the combined interest of owner and client eliminates the existence of opposing pressure groups. In this respect, therefore, insurance mutuality is a response to the existing pressures identified in the previous section. This idea can be directly applied to build appropriate insurance solutions covering operational risks.

3.2 Insurance Mutuality and Information Asymmetry - enlargement of the study area

A natural solution to the problem of information asymmetry, not only in insurance, is to invest resources in monitoring activities and using the information obtained in this way. A full observation of policyholders and activities undertaken by them is either impossible or costly, and in the case of operational risk, this involves overcoming the reluctance to fully invigilate the company, including a disclosure of strategic information. Other solutions are therefore being sought, including an analysis of the benefits of specific organizational forms of insurance companies.
Mutual insurance, as described in the previous section, in theory shows an advantage over commercial insurances in terms of addressing information asymmetries, and both *ex-ante* (called adverse selection) and *ex-post* (moral hazard) asymmetries.

Smith and Stutzer (1990, pp. 493-510) formulated a theory of the coexistence of different organizational structures in the insurance markets as an effect of the existence of adverse selection in that market. They based their concept on an analysis of two types of insurance contracts - one characteristic for insurance companies based on the idea of mutuality (premium settled after the insurance period) and the other for commercial companies (fixed premium,

[3]One of the earliest descriptions of the impact of the separation of ownership and management (hence the thesis of agency costs) is contained in "An Inquiry into The Nature and Causes of The Wealth of Nation" by Adam Smith: *"The directors of such companies, however, being the managers rather of other people's money than of their own, it cannot well be expected, that they should watch over it with the same anxious vigilance with which the partners in a private copartnery frequently watch over their own. Like the stewards of a rich man, they are apt to consider attention to small matters as not for their master's honour, and very easily give themselves a dispensation from having it. Negligence and profusion, therefore, must always prevail, more or less, in the management of the affairs of such a company"* (Smith, 1904).

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determined before the conclusion of the contract) [4]. In their considerations, Smith and Stutzer conclude that a mutual insurance company will be chosen by lower-risk policyholders in terms of a single business line (type of insurance).The mutual insurer should be linked to a lower-risk policyholder (an entity with lower expected losses) (Smith & Stutzer, 1990, pp. 508-509).

The above theoretical considerations are also confirmed by analytical studies conducted by many authors (O'Donnell, 1936, p. 663;Bainbridge, 1952, p. 190 ff.);Smith& Stutzer, 1990, pp. 507-508; (Lamm-Tennant & Starks, 1993, pp. 29-32;Mayers& Smith, 2002, pp. 117-124). Policyholders, knowing their risk, 'signal' their lower-than-average risk, as it were, by choosing insurers based on the principle of mutuality. Most often, this is related with the fact that the risk of the insurance activity in commercial insurance is shared between policyholders and shareholders (responding in the case of a badly inadequate insurance fund), while in the case of mutual insurance it is actually only between policyholders, so when the risk of policyholder is higher, the latter will choose the commercial company. This situation is even referred to as the free-rider problem[5] or even the seizure of shareholders' capital (Laux & Muermann, 2010, pp. 333-354). The selection of 'better' risks and their supervision in mutual insurance is even called 'risk depreciation' (Xi et all, 2021).

The problem of ex-post asymmetry, i.e. moral hazard, is also one of the key issues raised in connection with the issue of mutual insurance. In the literature, the effect of mutuality on limiting moral hazard is even pointed out as one of the immanent features of insurance mutuality (Sangowski, 2001;Rejda, 1998;Vaughan& Vaughan, 2008). In 1995, B. D. Smith and M. J. Stutzer attempted to theoretically prove the beneficial effect of mutual insurance on reducing moral hazard. For the purpose of doing so, they based a model of gambling on the assumption that the probability of loss can be reduced at the expense of the effort (workload) involved in reducing gambling. In doing so, they demonstrated that a participation contract (associated with a non-final premium) is the optimal method for encouraging policyholders to make efforts to reduce moral hazard losses, as it ties policyholders to the ultimate outcome of the insurer (Smith, Stutzer, 1995).

Certainly, in formal terms, the analyses conducted by Smith and Stutzer (1990,1995) concerned the effect of participation contracts on the ability to reduce the impact of adverse selection and moral hazard. However, since these contracts have been commonly used by insurers basing their operations on the idea of mutuality they have therefore been adopted as a conceptual explanation for the coexistence of both organizational forms in the insurance markets (Lamm-Tennant& Starks, 1993, pp. 29-46;Ligon& Thistle, 2005, pp. 529-556;MacMinn&Ren, 2011, pp. 101-111). They also provide theoretical evidence to support the words that 'moral hazard and adverse selection can have interesting consequences for the choice of ownership structure' (Winton, 1993, p. 509).

The theoretical concepts analyzed for the advantage of mutual over commercial insurance under conditions of information asymmetry are part of the considerations on the design of insurance cover for operational risk. Mutuality-based mechanisms linked to other management instruments of operational risk can become a solution to the lack of adequate insurance cover for entrepreneurs.

4. Mutuality in the insurance market and the concept for covering operational risk

Practice shows that mutual insurances can fulfill the role of a traditional insurer[6] but also, thanks to the development of new technologies, they can become a tool for creating informal communities securing the interests of entrepreneurs, in both cases: developing and developed countries.

Mutual insurers in Europe account for about one third of the global mutual insurance market. In 2020, they collected about 33% of the global insurance premium in Europe, in life insurance 25.7% and in non-life insurance 42.8%. In 2015 and 2016, for the first time since 2008 (ICMIF, 2022), there was an admittedly slight decline in the premium collected by mutual insurers (Figure 5).

[4]Participation contracts, as mentioned earlier, are not the only determinant of a particular organizational structure. Participation policies may also be offered by commercial insurance companies, but the scale of this activity is not as widespread as in the case of mutual insurers.

[5]The free-rider problem refers to a phenomenon that has been known for a long time. The free-rider issue refers to the efficiency of resource allocation in goods markets characterized by very high costs of excluding someone from their consumption. This allows economists to define a free-rider as one who uses goods or services to an extent that exceeds a share of the latter related to the cost of producing them. This problem generally referred to public goods. See more (Galor, 2010, pp. 63-78).

[6]can be mentioned, inter alia, mutual insurance associations or cooperative insurers, but also other forms permitted by the law. See more (Janowicz-Lomott & Sliwinski, 2017).

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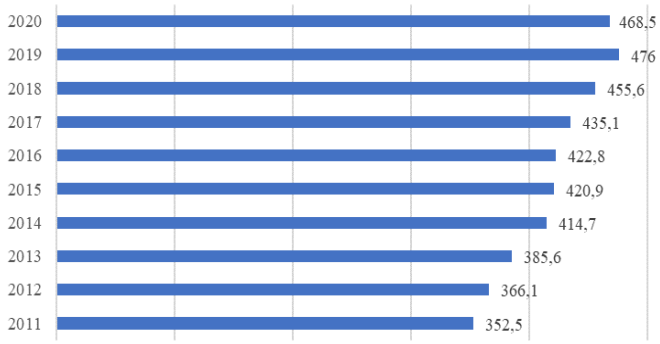

Figure 5. Mutual and cooperative premium income in Europe (EUR billions).
Source: Own elaboration based on International Cooperative and Mutual Insurance Federation reports

The growth of premium in the overall insurance market in Europe between 2010 and 2020 was approx. 14% when, at that time, the dynamics of mutual insurance was close to 32%.

Both the theoretical considerations in the literature and the widespread presence of mutual insurance companies on the insurance market allow us to draw conclusions about a possible new role of insurance mutuality. It will involve offering insurance cover when it is today inadequate to the needs of the client. However, a problem that has been signaled for some time by those who study social enterprises (which include mutual insurance associations) is a kind of informal commercialization of social enterprises, which in practice modify their mission and 'tilt' towards a market enterprise (Płonka, 2013). Due to the fact that these enterprises, having been economically successful, decide to further market expansion and emphasize the economic aspect at the expense of social functions. This thesis is also supported by the results of studies conducted in Poland, which indicate that the place occupied by mutual insurance associations in the field of social economy, is more similar to the field occupied by the business sector with a high degree of socialization (e.g. pursuing the corporate social responsibility model) than the social economy sector (Płonka, 2013). This phenomenon is extremely characteristic of large mutuals, especially the universal mutual insurance associations where, due to the number and variety of entities involved, social ties disappear.

The solution to this problem could be the sharing economy which is understood as the sharing of assets, resources, time, skills or capital, without transferring ownership. However, it is equally enabling services based on shared resources. In the case of operational risk and search for sources of loss coverage, it is the search for economic mechanisms that will allow the resources of all entities involved in building a community of danger, i.e. a group of entities facing the same risk that define an event as a risk.

The entities that decide to join the sharing economy often reject available, perhaps even cost-optimal solutions, in favour of what they believe to be higher values. This might be sustainability, popular in the recent years, or corporate social responsibility. However, in the case of operational risk management, it is the search for a solution that does not breach trade secret, while at the same time creating a sustainable source of funding for the consequences of events. The objective, therefore, is to move away from the need to fill out very elaborate and insightful insurance applications in favour of trust between the participants in such an undertaking.

In the case of insurance mutuality, it is worth highlighting the historically well-established, but still present today, informal insurance groups. They are formed and function mainly through direct acquaintance between policyholders. Such groups exist everywhere but are particularly popular in developing countries (mainly rural areas) where credit or insurance markets are underdeveloped. The body of literature often points to their development as a part of stabilizing operations of homestead, but also as health, accident, funeral benefit equivalents or short-term unemployment assistance in Asia, Africa, Central America or the Middle East.[7]

Modern technologies (mainly the internet) and social media are fostering the creation of groups of friends, which can be called co-insurance pools (so-called peer-to-peer, P2P insurance). There is a dynamic development of online platforms (start-ups for P2P insurance) financed as a rule by private individuals or venture capitals (Swiss Re, 2016). Formally, they are not insurance companies, but a specialized form of intermediation - they enable the organisation of many small groups whose members offer each other insurance cover (e.g., Friendsurance in Germany, Guevara and Inspool in the UK, in Peere in France, Lemonade and Insure APeer in the USA, Broodfond in the Netherlands, Peers Mutual Protection and Tong Ju Bao in China, Wesura in Venezuela) (MacDonald, 2015; Uys, 2014; Huckstep, 2015; Swiss Re, 2016). Thanks to the mutual direct contact (such small groups on platforms are mostly formed by people who previously have known each other), it is easier to eliminate high-risk individuals, more mutual trust. Most platforms allow for almost automatic loss adjustment, so that some of them also cover small losses, usually excluded from insurance cover due to very high settlement costs. Unused premiums are refunded to group members, or

[7]Instead of many, see (Morduch, 1999) (De Weerdt'a, Dercon, 2006) (Bloch et al., 2007) and the publications cited therein.

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allocated to other purposes designated by the group (e.g. charity). Groups structured in this way have the characteristics of small mutual insurance associations. Platforms often cooperate with insurers or reinsurers who take over part of the insurance cover (guaranteeing a certain level of benefits) or assist in the administration of policies.

However, the use of informal communities can create additional risks. In the case of operational risk, we are talking about the pooling of professional entities, entrepreneurs. The cover offered in this way may raise doubts about its stability and certainty. On the other hand, the creation of informal communities may cause a reaction from the authorities - in fact, in Europe, an insurance community - an insurance company should have a specific formal organization, capital equipment and, above all, authorization to conduct insurance activity. In some member states, these requirements are limited for small communities (so-called small insurance companies). Although in this area, we can also observe some deviations. The example of 'mutual fund' communities with an insurance character in agriculture can be mentioned here. These have been formally excluded from insurance market regulation, although by offering insurance (or quasi-insurance) cover they can be accredited and regulated by special internal laws of the member states rather than by the rules of insurance law (Janowicz-Lomott & Łyskawa, 2014).

5. Conclusion and Recommendations

The increasing frequency of loss events, which are both systemic and operational risks, is forcing the financial sector to seek new solutions. The solution has been, is now and will be in the future insurance products. However, the asymmetry of information inherent in the functioning of the insurance sector means that a solution is increasingly sought that exploits the relationship and trust between the entities, rather than just the contractual provisions and consequent economic calculation. Mutuality-based insurance is therefore a path based on solutions of the past (primary forms of insurance), but at the same time is seen as a response to the lack of adaptation of insurance products to the actual needs of clients. Consequently, the agency theory (principal-agent dependency) commonly used in modern times is being replaced by the idea of a sharing economy. Modern tools of communication between members of the community facilitate the development of new solutions. Nevertheless, these solutions are often ahead of the legal solutions operating in the countries or economic areas concerned (e.g. the EU). It is therefore necessary to shape new regulations in such a way that they do not limit the creation of what can cover the most difficult risks; in this case, operational risks.

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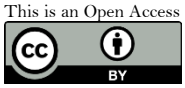

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Banking Sector Race to Efficiency during the COVID-19 Pandemic Crisis in Croatia: Does the Size Matter?

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ABSTRACT

Purpose:
The consolidation of the banking market in Croatia is characterized by a decreasing number of banks, especially small banks. The inability to remain in the market is often the result of the inability to maintain sustainable efficiency over time. Therefore, the main aim of the study was to determine whether small banks can successfully participate in the efficiency race with large banks. Furthermore, it was essential to clarify whether the efficiency gap arises from technical or scale efficiency. Finally, we also analyse how the COVID-19 pandemic crisis has affected efficiency and the difference between large, medium, and small banks.

Design/methodology/approach:
The efficiency development of the Croatian banking sector over eight years is examined using the Malmquist - DEA performance measure under the assumption of variable returns to scale (BCC model) and using the input-oriented DEA model. We use the intermediary approach for defining input and output variables, and the study covers the period from 2013 to 2020. Data are taken from ORBIS database.

Findings:
Banks in Croatia increased their total factor productivity by 2.2% on average, mainly due to an increase in technological change (1.93%), implying innovation and new banking services. Moreover, the COVID-19 pandemic crisis has further accelerated the race for efficiency. Indeed, the results show that the improvement in efficiency was more remarkable than the average of the period studied, especially in terms of technical efficiency (1% in 2020 compared to the mean of the period of 0.28%), but also due to technological efficiency (2.02% in 2020 compared to the mean of the period of 1.93%). Finally, the COVID-19 pandemic crisis affected efficiency in different ways with respect to the size of banks. Large banks improved their total factor productivity by 7.19%, small banks by 2.64%, and medium-sized banks reduced it by 1.38%. In addition, large banks achieved efficiency improvements due to technological change, while small banks focused on both technical (1.70%) and technological (0.98%) efficiency improvements.

Research limitations/implications:
One of the limitations of the paper was that during period some takeovers were conducted in Croatian banking sector and therefore some banks were omitted from sample. Additionally, ORBIS database does not cover some data that could be better as indicators of outputs. Therefore, future research on this topic could include other input-output variables such as assets/labor and revenue (income). Our results suggest that innovation in the delivery of banking services is critical to maintaining the race for efficiency. Therefore, our results may lead managers to focus on technological change in the long run, but especially in times of crisis. Managers of small banks should focus on both managerial and technological improvements.

Originality/value:
This study primarily makes an empirical contribution to the topic of efficiency in the banking sector. We have analysed the impact of the COVID -19 pandemic crisis on banking

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efficiency, with particular attention to the size effect, which, to our knowledge, has not yet been thoroughly studied. Future research could build on this study by taking into accountother input-output variables and sample of CEE countries.

1. Introduction

Over the last 20 years, many transition countries have undergone privatization and restructuring of the banking sector. The privatization process has been characterized primarily by the acquisition of domestic banks by foreign banks, resulting in a more competitive market, technological advances, better risk management, and generally higher efficiency. New standards for market-oriented banking practices were introduced. A similar process took place in Croatia. However, many banks also failed during this period. In general, after peaking at 61 in 1997, the number of banks has steadily declined to 23 in 2021, with a sharp decrease in the number of small banks after the financial crisis and pandemics (16 in 2008 and 12 in 2021). Thus, most of the failed banks were small banks that could not cope with the higher standards of the central bank and the financial crises, resulting in lower profitability. On the other hand, the market leaders, i.e., the big banks, dominated the market throughout the period, with a market share of more than 40% (44% in 2021) for the two biggest banks and 80% (80.1% in 2021) for the five biggest banks. Thus, the market has become increasingly concentrated, virtually neglecting the importance of small banks.

The questions that arise from this are- Why small banks couldn't keep their place in the market and was the pandemic a major factor? Can small banks maintain their efficiency at the level of large banks? Are large banks more efficient than small banks?

The theory generally explains the higher efficiency levels of large banks in terms of economies of scale and scope. Economies of scale imply that the firm's resources are used more efficiently to produce multiple units of the same service package. Economies of scope indicate that some resources are used more efficiently to deliver numerous services rather than just one. In particular, large banks are generally more efficient than small banks because of the growth in scale that leads to cost savings. Namely, fixed costs are spread across a larger number of services (Rose and Hudgins, 2010). Studies such as Hughes et al., 2001, Jemrić and Vujčić (2002), Drake and Hall (2003), Hasan and Marton (2003) confirm the theory that large banks are more efficient.

However, some studies suggest that the average cost curve in the banking sector is roughly U-shaped. Costs decrease with size up to a certain value of total assets, and unit costs increase beyond that value. These results suggest that medium-sized banks have higher scale efficiency than large and small banks (Berger et al., 1987; Stimpertand Laux, 2011). In addition, Tariq and Arfeen (2012) find that banks benefit from economies of scale as their size increases. Still, larger banks begin to experience scale disadvantages, and then very large banks start to share economies of scale again.

Moreover, Rose and Hudgings (2010) conclude that there is evidence of at least moderate economies of scale in banking and that most studies find weak or no evidence of economies of scope. Even more recent studies such as Benito (2008), Almumani (2013), Karray and Chichti (2013), Řepková (2014) do not confirm the thesis that larger banks are more efficient than small banks. Finally, Andries andUrsu (2016) show that large banks were more sensitive to cost efficiency than small banks during the financial crisis. On the other hand, large banks were less affected by the crisis regarding profit efficiency.

Regarding the COVID-19 crisis, Carletti et al. (2020) point to mid-sized banks and emphasize that they will suffer because they will not manage the cost efficiencies and IT investments that are critical in the new environment. In addition, digitalization will receive a substantial boost, and new entrants will challenge banks. This means that banks will have to increase their efficiency. Similarly, Marcu (2021) also states that banking innovations and digital strategies are essential factors. More specifically, the banking system has continuously adapted to customer expectations and the need to reduce costs while the pandemic accelerated digitalization in the banking sector. In this sense, digitalization can be considered as an important driver of cost-efficiency. The question is whether small and medium-sized banks can follow the investment volume of IT. In terms of bank size, Korzeband Niedziółka (2020) use a sample of 13 Polish banks to show that the largest banks are the most resilient to the impact of the pandemic. Likewise, Bernardelli et al. (2021) show that large retail banks were less affected than medium-sized banks with relatively rich corporate portfolios. Moreover, Demirgüç-Kunt, A. et al. (2021) found that larger banks experienced larger declines in their stock returns, reflecting their larger expected role in coping with the crisis. This implies that large banks were forced to be more efficient to maintain profitability stability for their stakeholders. Finally, concerning the COVID-19 crisis, Dissanayake and Wu (2021) found that countries with efficient banking institutions could lend significantly more to businesses and households during the crisis. Moreover, these countries are associated with better output growth after the pandemic. Crucial efficiency aspects are generally lower bank overhead costs and net interest margins.Finally, the banking sector is an important channel for financing investment, especially in bank-oriented financial systems. Increasing the efficiency of the banking sector thus contributes to economic growth and prosperity (Hashem, 2016), which seems particularly important in times of crisis and post-crisis.

Therefore, there is no consensus on the relationship between bank size and efficiency. Moreover, the literature on pandemics and their impact on the banking system is still developing, so this paper attempts to contribute by

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analyzing the effect of COVID-19 pandemic on the banking sector efficiency in Croatia. Also, the results regarding the size importance vary depending on the countries in the sample, the period studied, the measurement of efficiency, and the methodology used. Empirical studies for Central and Eastern European countries (CEE) are rare. Therefore, there is a need to investigate this issue further. Thus, this paper examines bank size as an explanatory variable for efficiency with a special aspect of the COVID-19 effects.

Hence, the objective of this paper is to analyze the total factor productivity change of Croatian banks for the period 2013-2020. Namely, in order to estimate different kinds of efficiencies, i.e. technological changes and technical efficiency changes, the Malmquist – DEA index, based on an input oriented BCC model, was chosen for this analysis. Additionally, the goal is to determine the existence of a size effect in the Croatian banking sector and whether it is due to technical or scale efficiency. The final aim is to capture the time dimension of efficiency development in small, medium, and large banks, with a special focus on total factor productivity changes in the time of pandemic COVID-19.

Malmquist DEA index is applied in the analysis of the Croatian banking sector in order to investigate total factor productivity changes. Jemrić and Vujčić (2002) used the panel data in measuring the efficiency of Croatian banks, but they applied just a number of individual cross-section analyses. DEA analysis has a stationary character and delivers a snapshot of providers and their efficiency, while Malmquist DEA index provides more reliable evidence of their performance by tracking the performance of each provider through sequence periods. Therefore, calculating the Malmquist DEA index on panel data resolves the major weakness of DEA (Sun, 2011).

The rest of the paper is organized as follows. The next section presents conceptual comparative framework of banking efficiency and literature review of empirical results on size effects on bank efficiency. The third section explains the methodology and the data sample, while the fourth section discloses and discusses the empirical results and provides an economic interpretation of the results. The last section is the conclusion, which summarizes the study results and provides suggestions for future research.

2. Review of Literature

2.1 Conceptual comparative framework of banking efficiency

Banks are a very important factor for the whole economy, especially in bank-oriented financial systems. Indeed, the banking sector transfers funds and finances investments, thereby increasing the efficiency of the whole economy and contributing to economic growth. In this sense, the efficiency of the banking sector is very important (Alber et al., 2019).

According to Mokhtar et al. (2016), the concept of efficiency measurement was first discussed by Farrell (1957), who divided it into technical efficiency (TE) and allocative efficiency (AE), with further subdivision into cost and profit efficiency. A market participant is said to be technically efficient if it is able to produce the maximum amount of output with a given set of inputs or use fewer inputs to achieve a given level of output. An efficient bank can achieve a maximum value of one compared to an inefficient bank. In addition, a producer is said to be allocative efficient if it can use inputs at an optimal ratio given input prices and production technologies. A participant is cost efficient if he is able to produce a given output without wasting resources, i.e., at minimum cost. Similarly, it is considered profit efficient if it is able to maximise the profit from the allocated inputs and outputs (Mokhtar et al., 2016).

There are two general methods for measuring efficiency - the parametric and nonparametric approaches. The parametric approach allows for noise in the measurement of inefficiency, but requires the specification of the production functional form. The nonparametric approach, on the other hand, is simple, easy to calculate, and does not require specification of functional form. However, it has the disadvantage that all deviations from the best-practise frontier are attributed to inefficiency. Common parametric methods are the Stochastic Frontier Approach (SFA), Thick Frontier Approach (TFA), and Distribution Free Approach (DFA), while nonparametric techniques are Free Disposal Hull Analysis (FDH) and Data Envelopment Analysis (DEA) (Mokhtar et al., 2016). Most studies use either nonparametric or parametric techniques in their respective studies on banking efficiency.

With respect to the banking sector efficiency, there are two main approaches used in the banking theory literature: the intermediation approach and the production approach. The production approach assumes that financial institutions act as producers of services, i.e., banks use physical inputs such as labour and capital to provide deposits and loans. The intermediation approach views banks as intermediaries between savers and borrowers. More specifically, banks are viewed as financial intermediaries that use labour and deposits and convert them into loans and other profitable assets. The intermediation approach is suitable for banks where most activities consist of converting large deposits and other funds into loans and investments and is more appropriate for evaluating financial institutions as a whole, while the production approach is more appropriate for evaluating the efficiency of bank branches (Mokhtar et al., 2016; Alber et al., 2019).

2.2 Previous studies

The relationship between the size of a bank and its efficiency is relatively well represented in the economics literature, with Rose and Hudgings (2010) providing detailed explanations. They point to the greater efficiency of large banks resulting from economies of scale and scope. However, previous and recent empirical studies disagree on the relationship between bank size and efficiency. On the one hand, many studies confirm that larger banks are generally more efficient than small banks due to economies of scale and scope (Hughes et al., 2001). Moreover, there seems to be

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a strong relationship between bank size and technical and scale efficiency, as evidenced by the study of Drake and Hall (2003) for the banking sector in Japan. On the other hand, some recent studies have confirmed the opinion of a U-shaped average cost function (Stimpertand Laux, 2011; KarrayandChichti, 2013; Řepková, 2014).

The empirical literature confirming the importance of banks' size for their efficiency mainly relies on economies of scale and scope in its explanations (Hughes et al., 2001, Drake and Hall, 2003). Hasan andMarton (2003), who examined the performance and efficiency of the banking sector in Hungary for the period 1993-1998 found, among other things, that there was an inverse relationship between size and inefficiency, i.e., that larger institutions were relatively more efficient. Drake et al. (2006), who studied the impact of macroeconomic and regulatory factors on bank efficiency in Hong Kong, found a very strong relationship between size and efficiency in terms of pure technical efficiency. Namely, the largest banks performed better than smaller banks. They also confirmed the importance of environmental factors in significantly altering the relationship between size and technical efficiency.

Andrieş and Cocriş (2010) used both the DEA and the SFA method and analyzed the efficiency of the main banks in Romania, the Czech Republic, and Hungary for period 2000-2006. Their results showed that bank size, annual inflation rate, degree of banking reform and interest rate liberalization, and ownership form are the most important determinants of efficiency. Kristo (2013) used cost efficiency indicators based on the SFA methodology to understand the efficiency of the Albanian banking system. The author concluded that the largest banks seem to be more efficient than the smaller banks. However, some papers find no differences between efficiency when bank size is considered. For example, Fernando and Nimal (2014), analyzing the technical efficiency of the banking sector in Sri Lanka for the period 2007-2011, concluded that there were no significant differences in efficiency between small and larger banks. They also concluded that although most large banks operate with increasing returns to scale, and small banks operate with decreasing returns to scale, this difference does not exist.

Recent studies do not support the existence of the size effect over time. Moreover, some studies suggest that efficiency depends on a particular environment and that small banks seem to be more efficient under certain circumstances. First, using the sample of Spanish commercial, savings, and cooperative banks for the period 1970-2006, Benito (2008) finds that the relationship between size and growth is not stable over time but changes depending on the competitive environment of banks. However, he concludes that larger banks have grown at the same rate or faster than smaller banks and that the size distribution of Spanish banks will become more skewed, and concentration will tend to increase in the coming years. Second, Kwan (2006) examined the cost efficiency of commercial banks in Hong Kong using the SFA method. The results showed that the average large bank was less efficient than the average small bank, i.e., there is a positive correlation between bank size and inefficiency. It is assumed that the size effect is related to the difference in portfolio composition.

In addition, Staub et al. (2010) studied cost, technical, and allocative efficiency for Brazilian banks using cost data from 2000 to 2007 and DEA methodology. Their results showed that size is not critical for economic efficiency. However, the results also showed that micro banks are the most efficient in terms of allocative efficiency, confirming the niche market hypothesis, which states that small banks have cost advantages to operate in niche markets. The statistical results were not significant. Also, size was not a significant determinant of technical efficiency.

Moreover, Almumani (2013) measured the relative efficiency of banks in Saudi Arabia for the period 2007-2011 using a basic DEA methodology. Interestingly, the results showed that the relative efficiency of smaller banks is significantly better than that of medium and larger banks. Besides that, banks with higher capital adequacy ratios were less efficient. Banks with higher capital ratios are less risky and manage safer and lower-yielding portfolios, which may explain the results.

Also, using a panel of 402 commercial banks from 15 developing countries over the period 2000-2003, Karrayand Chichti (2013) have shown that inefficiency in all banks is mainly due to pure technical inefficiency, while high levels of scale inefficiency also characterize the largest banks. Their results are contrary to the basic theoretical assumptions. The explanation is that small banks are more focused on non-interest activities, which can be explained by better specialization and/or by offering differentiated services to their customers.

Řepková (2014) analyzed the efficiency of the Czech banking sector using panel data from 2003 to 2012. Using DEA window analysis based on an input-oriented model, the author's results interestingly showed that large banks were less efficient than other banks. The explanation was that large banks have excess deposits on their balance sheets and inadequate operating size.

Finally, some work points to the importance of distinguishing between cost and profit efficiency. Andries and Ursu (2016) studied the impact of the financial crisis on efficiency, taking into account, among other factors, bank size. Their study based on 783 commercial banks from the EU during 2004-2010 showed that the impact of the crisis on cost inefficiency was higher for large banks, which were more affected by the global financial crisis. On the other hand, large banks were less affected by the crisis regarding profit efficiency.

It is impossible to draw a definite conclusion about the analyzed relationship from the present literature review, especially for transition countries. Although some researchers address this issue, most neglect the detailed technical and scale efficiency analysis. For example, Drake et al. (2006) do not analyze the relationship between size and scale efficiency. Moreover, the previous studies do not recommend which business segment and what should be improved in less efficient banks in terms of their size. Furthermore, this research also considers additional factors regarding the

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effects of pandemic COVID-19. We also examine the importance of the size effect over a longer time horizon, covering the period before and during the COVID-19 crisis.

3. Data and Methodology

Efficiency is defined as the ratio used for production factors, i.e. inputs and outputs, where the provider is efficient if it produces, for a given level of input variables, a greater amount of output variables or if it uses, for a certain amount of output, fewer input variables (Ozcan, 2008). In order to investigate total factor productivity changes of Croatian banks, due to data availability, the intermediary approach for defining input and output variables was selected. In addition, Mokhtar et al. (2006) found that the intermediation approach is the most commonly used approach to determine the appropriate input and output variables. Therefore, values for all selected variables were taken for 17 banks from the Orbis database, for the period 2013-2020. More precisely, as in paper of Jemrić and Vujčić (2002),fixed assets, total customer deposit, and the number of employees present input variables, while loans and other securities present output variables. Descriptive statistics for the data set are presented in Table 1.

Table 1: Descriptive statistics of the selected input and output variables, 2013-2020

Variables		Minimum	Maximum	Average
Inputs	Fixed Assets	762,228.3782	345,632,994.4	53,065,290.51
	Total customer deposits	95,350,799.97	15,615,121,458	2,303,141,251
	Number of employees	67	6,274	1,161.617647
Outputs	Loans, EUR	51,281,380,49	11,161,355,023	1,975,338,434
	Other securities	5,800,549.165	1,878,988,504	410,955,659.9

Source: Orbis database, 2022

With the aim of setting the efficiency frontier using the aforementioned presented variables, different statistical and mathematical approaches can be applied stressing the different ways of defining the frontier and interpreting results. While the statistical approach is based on econometric models and has the characteristics of stochasticity (randomness), the mathematical approach is based on the models known as linear programming and is deterministic by nature (Worthington, 2004).In order to evaluate relative efficiency, data envelopment analysis (DEA) is the most commonly used tool of mathematical linear programming. Its advantage in regards to DFA or SFA (which present statistical tools), is the fact that it doesn't require specific functions of providing services, where the non-parametric bases of multiple input and output variables present the base for the formulation of production (Gardijan and Koić, 2012). Furthermore, the DEA approach is confirmed by Trivedi et al. (2016), who replicate the DEA approach of efficiency measurement for financial institutions. Finally, in order to implement the selected DEA approach, it is necessary to choose the appropriate DEA model. Namely, DEA models differ according to scale and orientation. As managers have higher control over the input than over output variables, input oriented DEA model was chosen. Furthermore, according to the literature review, discussing the existence of economies of scale and scope, the BBC model was chosen, assuming variable returns to scale.

Furthermore, in order to avoid the stationary character of basic DEA models, i.e. to quantify the evolution of efficiency over a period of time, DEA window analysis and Malmquist DEA index can be used. While DEA window analysis evaluates the performance of decision-making units over time, treating them as s different entities in each analyzed period, the Malmquist DEA index provides an opportunity to compare the bank's performance from one period to another (Sanchez–Ortiz, 2021). Moreover, Malmquist DEA index can analyze different drivers of total factor productivity change. Namely, on the one side, it measures the changes in technical efficiency presenting how the decision-making units have managed to catch up to the relative frontier. On the other side, it measures the change in technology presenting changes in the position of the whole relative frontier (Prior, 2006). As the idea of the paper is to find out whether the identified changes from one period to another are due to pure efficiency improvement, technological changes in service delivery, or are the consequence of both these changes, the Malmquist DEA index is chosen in this study.

4. Empirical Results and Discussion

As we explained in the previous section, in order to evaluate change in relative technical efficiency over time, Table 2 presents total factor productivity change (TFPCH), i.e. the results of the Malmquist DEA index and its components. Namely, the mentioned measure is decomposed into technical efficiency changes (EFFCH) and technological changes (TECHCH).

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Table 2: Total factor productivity change and its components for banks in the Croatian bank system, 2013-2020

Banks	EFFCH	TECHCH	TFPCH
ADDIKO BANK D.D. ZAGREB	1.0067	0.9654	0.9719
AGRAM BANKA D.D. ZAGREB	1.0000	1.0223	1.0223
BANKA KOVANICA D.D. VARAZDIN	1.0132	1.0286	1.0422
CROATIA BANKA D.D.	1.0018	1.0757	1.0780
ERSTE & STEIERMARKISCHE BANK D.D.	1.0000	1.0775	1.0775
HRVATSKA POSTANSKA BANK D.D.	1.0000	1.0779	1.0779
IMEX BANKA D.D.	0.9869	1.0176	1.0022
ISTARSKA KREDITNA BANK UMAG D.D.	1.0010	1.0191	1.0155
J&T BANKA D.D.	1.0146	1.0744	1.0905
KARLOVACKA BANKA D.D.	0.9998	1.0013	1.0022
KENTBANK D.D.	0.9800	0.9917	0.9713
PARTNER BANKA D.D.	0.9914	1.0129	1.0043
PODRAVSKA BANKA	1.0160	1.0151	1.0325
PRIVREDNA BANKA ZAGREB D.D	1.0237	0.9712	0.9929
RAIFFEISENBANK AUSTRIA D.D.	1.0128	1.0457	1.0606
SBERBANK D.D.	1.0000	0.9403	0.9403
ZAGREBACKA BANKA D.D.	1.0000	0.9921	0.9921
Mean	1.0028	1.0193	1.0220

Source: Orbis database, 2022

If the values of those components are greater than one, they indicate progress, while the value lower than one indicates regress (a value equal to one presents no change). The total factor productivity changes analysis was conducted using computer software Frontier Analyst Banxia.

Over the analyzed period, the total factor productivity change of Croatian banks is found to be at 1.0220, which presents an increase in productivity of 2.2%. The aforementioned change in productivity arises from both, an increase in technical efficiency (EFFCH=1.0028) and a slightly higher increase in technological change (TECHC=1.0193). During the analyzed period, the highest productivity increase, more specifically 9.05%, occurred in J&T Banka d.d (TFPCH=1.0905) which is associated with an increase in technical efficiency, representing a catch-up effect, but it is also associated with technological change in service delivery referring to innovation, according to which this bank shifted an efficient frontier to a higher level. Contrary, Sberbank d.d. experienced the most significant decline of 5.97% (FTPCH=0.9403), linked entirely to a decline in technological change.

With the aim to analyze aggregate total factor productivity change over time, Table 3 presents aggregate mean productivity change for each year.

Table 3: Total factor productivity change over the period 2013-2020, for Croatian banks

	EFFCH		**TECHCH**		**TFPCH**	
Year	Mean	% change	Mean	% change	Mean	% change
2014	1.0075	0.75%	0.9877	-1.23%	0.9977	-0.23%
2015	0.9914	-0.86%	1.0492	4.92%	1.0385	3.85%
2016	1.0144	1.44%	1.0963	9.63%	1.1109	11.09%
2017	0.9882	-1.18%	1.0253	2.53%	1.0133	1.33%
2018	1.0039	0.39%	1.0220	2.20%	1.0260	2.60%
2019	1.0042	0.42%	0.9346	-6.54%	0.9378	-6.22%
2020	1.0100	1.00%	1.0202	2.02%	1.0300	3.00%
Mean	1.0028	0.28%	1.0193	1.93%	1.0220	2.20%

Source: Orbis database, 2022

According to the results presented in Table 3, total factor productivity on average increased by 2.20% over the analyzed period. This is mostly the result of an increase in technological change by 1.93%, while the technical efficiency increased by 0.28%. In other words, the presented increase was driven mostly due to innovation in the process of providing bank services to their clients who shift the relative efficiency frontier to a higher level. Although the most significant increase in total factor productivity occurred in 2016 (11.09%) it is important to stress an increase in total factor productivity in 2020 during the time of the pandemic. Namely, in 2020 total factor productivity increased by 3%, due to an increase in technical efficiency representing managerial efficiency (1%) but mostly due to

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an increase in technological change (2.02%). With these results, an increase in total factor productivity change in 2020 is larger than the average increase of productivity in the whole analyzed period, especially in terms of technical efficiency (1% in 2020 compared to the mean of the period of 0.28%), but also due to technological efficiency (2.02% in 2020 compared to the mean of the period of 1.93%). It can be concluded, that the COVID-19 crisis has further accelerated the race for efficiency.

In order to analyze total factor productivity change in the time of pandemic COVID-19 according to bank size, all banks for the sample are grouped into three categories, small (10 banks), medium (3 banks), and large ones (4 banks), and their aggregate values of Malmquist DEA index and its components are presented in Table 4.

Table 4: Total factor productivity change in the pandemic (2019-2020), for Croatian banks grouped according to their size

	EFFCH		TECHCH		TFPCH	
Banks	Mean	% change	Mean	% change	Mean	% change
Large	1.0000	0.00%	1.0719	7.19%	1.0719	7.19%
Medium	1.0000	0.00%	0.9862	-1.38%	0.9862	-1.38%
Small	1.0170	1.70%	1.0098	0.98%	1.0264	2.64%

Source: Orbis Database, 2022

As can be observed from the table, large banks improved their total factor productivity by 7.19%, small banks by 2.64%, and medium-sized banks reduced it by 1.38%. Furthermore, large banks achieved efficiency improvements due to technological change which was probably mainly driven by the process of digitalization which large banks were able to conduct due to high investment in IT. On the other hand, the total factor productivity of medium banks decreased which confirms Carletti et al. (2020) who questioned IT investment possibilities of mid-size banks. Finally, small banks focused on both technical (1.70%) and technological (0.98%) efficiency improvements, which positively contributed to the productivity change. Results suggest that small banks can improve their efficiency, primarily through management improvements, but also through technological innovations. They adapted to customer expectations and the need to reduce costs by accelerating digitalization. Yet, their progress is significantly lower compared to large banks. As Hashem (2016) points out that profitable banks are, among others, those that have more efficient internal management, this implies that small banks need to further improve their technical efficiency.

Finally, in order to analyze more deeply the bank's size effect during a pandemic, Table 5 shows values of overall technical efficiency (OTE, calculated using the CCR input oriented model), pure technical efficiency (PTE, calculated using the BCC input oriented model) and scale efficiency (SE, calculated as a ratio of overall to pure technical efficiency).

Table 5: Overall, technical and scale efficiency of Croatian banks in 2020

Banks	OTE	PTE	SE
ADDIKO BANK D.D. ZAGREB	0.918	1	0.918
AGRAM BANKA D.D. ZAGREB	1	1	1
BANKA KOVANICA D.D. VARAZDIN	1	1	1
CROATIA BANKA D.D.	1	1	1
ERSTE & STEIERMARKISCHE BANK D.D.	1	1	1
HRVATSKA POSTANSKA BANK D.D.	1	1	1
IMEX BANKA D.D.	0.84	0.9	0.933
ISTARSKA KREDITNA BANK UMAG D.D.	0.827	0.848	0.975
J&T BANKA D.D.	1	1	1
KARLOVACKA BANKA D.D.	0.852	0.906	0.940
KENTBANK D.D.	0.865	0.866	0.999
PARTNER BANKA D.D.	0.88	0.939	0.937
PODRAVSKA BANKA	0.887	0.946	0.938
PRIVREDNA BANKA ZAGREB D.D	1	1	1
RAIFFEISENBANK AUSTRIA D.D.	0.917	1	0.917
SBERBANK D.D.	1	1	1
ZAGREBACKA BANKA D.D.	1	1	1
Mean	0.940	0.965	0.974
Large	0.979	1	0.979
Medium	0.973	1	0.973
Small	0.915	0.941	0.972

Source: Orbis database, 2022

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According to results presented in Table 5, Croatian banks did not operate on the scale fit to their capacities, i.e. they were not successful in delivering their services at optimal scale. Namely, those having an efficiency score equal to 1 are relatively efficient ones and form the efficiency frontier, while those having an efficient score lower than 1 are relatively inefficient in relation to the banks on the frontier. While the large and medium banks are on average pure technical efficient, small banks are overall technically inefficient due to both – managerial inefficiency and scale inefficiency. Although according to Table 4 small banks on average increased their technical efficiency in 2020 (EFFCH=1.0170) they still didn't catch up relative efficiency frontier set up by large and medium banks.

In summary, both managerial and technological improvements are needed for small banks to maintain their efficiency, especially in the area of innovative banking services and in times of crisis. In addition, small banks should strive to channel deposits into profitable investments and benefit from economies of scale by increasing the size of the bank.

5. Conclusion and Recommendations

The aim of this paper was to analyse the total factor productivity change of Croatian banks for the period 2013-2020, using Malmquist – DEA index, based on an input oriented BCC model. Additionally, the goal was also to determine the influence of the COVID-19 pandemic crisis on bank efficiency, with special regards to size effect. Malmquist DEA index in comparison to DEA analysis, that has a stationary character and delivers a snapshot of providers and their efficiency, provides more reliable evidence by tracking the performance of each provider through sequence periods.

Our results revealed that total factor productivity change of Croatian banks has increased by 2.2%, both due to an increase in technical efficiency (EFFCH=1.0028) and a slightly higher increase in technological change (TECHC=1.0193). The presented increase was driven mostly due to innovation in the process of providing bank services. With regards to the effects of COVID-19 pandemic crisis in 2020, total factor productivity increased by 3%, due to an increase in technical efficiency representing managerial efficiency (1%) but mostly due to an increase in technological change (2.02%). With these results, an increase in total factor productivity change in 2020 is larger than the average increase of productivity in the whole analysed period, especially in terms of technical efficiency. It can be concluded, that the COVID-19 pandemic crisis has further accelerated the race for efficiency.

We also confirmed size effect. Namely, both large and small banks increased their efficiency. Still, progress of small banks is significantly lower compared to large banks. Large banks, due to greater capability of investment in IT, mainly regarding digitalization, achieved efficiency improvements due to technological change. Small banks improved their efficiency, primarily through management improvements, but also through technological innovations. Total factor productivity of medium banks decreased which confirms questionable IT investment possibilities of mid-size banks.

Finally, size effect was also confirmed during COVID-19 pandemic crisis. In comparison to large and medium banks, which are on average pure technical efficient, small banks are overall technically inefficient due to both – managerial inefficiency and scale inefficiency. Even though they have increased their technical efficiency in 2020, they still didn't catch up relative efficiency frontier set up by large and medium banks.

Our results indicate that small banks are still able to stay in the market and that they manage to maintain sustainable efficiency over time. Yet, in the context of competition, stakeholder expectations, and the recent crisis, the challenges to efficiency have never been greater. We conclude that small banks should focus on both managerial and technological improvements. More specifically, innovation in the delivery of banking services is critical to maintain the race for efficiency, especially in times of crisis. In addition, bank managers of small banks should seek to channel deposits into profitable investments and benefit from economies of scale through bank growth. Finally, it is important for policymakers to maintain a competitive banking sector, as competition promotes efficiency and productivity growth, while a concentrated industry leads to inefficiencies and neglects technological progress.

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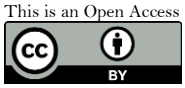

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High and Low Credit Risk in SME Portfolios: Evidence from Regulatory Risk Grade Dissemination

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ABSTRACT

Purpose:
SME sector credit risk has received attention in research from several dimensions of the financial system. SME sector's funding is mainly supplied by financial institutions and SME sector is both diversified and large sector in both well developed and less developed economies. Specific research on assessing SME as Financial Institution's (FI's) individual counterparties and SMEs as portfolios have developed from a theoretical and empirical perspective. To supplement current research on the area, we approach SME risk from perspective of FIs own risk assessments and compare it to how SME risk rating and measurement compares to other counterparties.

Design/methodology/approach:
We use published risk rating data from large financial institutions in Europe including globally operating FIs and compare shares of credits in different risk grades and overall portfolio risks within an institution's own risk classification system and risk measurement system. The data consists of 89 comparable portfolios with over 25 million credits.

Findings:
Our results show that comparison to households and large corporates originates from higher default rate estimates for SME, which shows as smaller share of credits in the investment grade. SME risk is further raised as even within speculative grades SME's receives higher default estimates in comparison to households and large corporates. An equally notable finding is that the other relevant parameter for risk calculation, loss given default (LGD), does not differ between SME's and other counterparties. A part of SME credits is found to be in a low-risk regime in portfolio credit risk estimation.

Research limitations/implications:
Coverage and detail of data restricts to a specified geographical coverage and aggregated data on SME-companies is not as exact as unit level data. The data represents mostly European institutions as it is collected from institutions which have a head quarter in Europe and are applying Basel regulation in a single rule book environment for banking regulation. In a global scope there may be differences between jurisdictions or between geographical areas. Data published by institutions is an aggregated data on a rating grade level a and not on a unit level data that institutions have for their exact calculations. Comparison methods for SME sector are selected accordingly so that methods apply to class level instead of unit level data.

Originality/value:
Higher capital requirements for SME's may restrict the price and availability of finance. According to our results there can be separated a low-risk SME finance without higher capital requirements compared to peers. Results may also be used to support counterparty level default risk model results showing higher risk for SME's which can be seen in smaller shares of investment grade credits and in a higher default rate for speculative grade credits.

1. Introduction

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To what extend do the financial institutions (FIs) separate Small and Medium-size Enterprise (SME) risk from risks in households and corporates and how FIs differentiate between low and high credit risk within SME has high impact in a regulatory environment. There has been suggestion of high excess in capital requirement for small business, and the excess has been evaluated to be 45% by Bams et al. (2019). Risk classification and parameter estimation of SME in comparison to other counterparties is an important link in assessing the SME finance in the economy as it is connected to the prices of credits and the capitalization of banks. A coherent approach from risk parameters to capital requirements also serves IFRS 9 expected credit loss analysis which have similarities with capital requirement calculation models for larger institutions as noted for example by Frykström et al. (2018).

SME sector's credit risk has received attention in research of several sides of financial system. A counter sector to SME corporates on financing is to a large extend the financial sector. SME sector's funding is mainly supplied by financial institutions and the sector is both diversified and a large sector in both well developed and less developed economies. Specific research on assessing SMEs both as (FI) individual counterparties and SMEs as portfolios has developed from a theoretical and empirical perspective. To supplement current research on the area we approach SME risk from the perspective of FIs own risk assessments and compare how SME risk rating and risk parameter estimates compares to other counterparties.

A question that rises from FI specific risk measurement and risk classification is that how SME credits are rated in comparison to other counterparties. This question is relevant primarily for FIs with internal rating based (IRB) approach where ratings and risk parameters are part of prudential calculation. FI's own risk assessments for various portfolios are combined with regulatory defined portfolio risk factors in a capital requirement calculation for IRB institutions.

We use published risk rating data from 25 large European financial institutions including globally operating FIs and compare shares of credits in different risk grades and overall portfolio risks within institution's own risk classification system and risk measurement system. The division of SME credit risk to banks and the division within bank to portfolios are considered. The sizes of SME portfolios in banks reflect bank's differentiating position to serve SME sectors need for finance. Instead of sectoral or systemic view, regional aspect may be more important in the financing decisions made by smaller banks.

The paper proceeds as follows. Chapter 2 presents a literature review and chapter 3 derives the credit portfolio risk measurement methodology in Basel regulation and describes the data. In chapter 4 results are presented and discussed. Conclusions are in chapter 5.

2. Literature review

Research on SME counterparties of FI's have a large literature both on the portfolio level risk and on the counterparty level of risk. On portfolio level, the capital requirement of SMEs in comparison to predicted portfolio risk has been studied intensively.

Research on the default prediction on counterparty portfolio have been classified by Ciampiet al. (2021). They found five major lines of research: one that focuses on cause-and-effect relationships between default prediction modelling, bank lending activities, and firm-bank relationships, mainly by analysing SME default prediction from the bank perspective. The second class focuses on the exploration of the prediction potential of numerous quantitative and qualitative variables and the third class explores the potential of innovation-related variables in predicting SME default. The fourth class analyses the critical variables for small company success and the fifth class focuses on the empirical validation of the seminal theoretical failure prediction model of Argenti (1976) and the development of SME default prediction models based on longitudinal data. Figini et al. (2011) have studied a model selection between different model classes. The need to specify separate default models to SME and large corporates was noted by Altman et al. (2013). In a large study for SME firms in Europe by Filipe et al. (2016) support was found for the use of financial indicators and firm size as a default prediction factor.

The main features of capital requirement calculations for IRB institutions are parameter estimation for credit risk parameters, use of asset correlations with sensitivities to parameters and exposure class and in case of SME, application of support factor in the end. While there is a high regulatory capital requirement perspective in IRB calculation, also the use in economic capital framework of an institution also has an important role as described by Elizade & Repullo (2007). Introduction to IRB parameters and formulas are given for example by Hibbeln (2010). An analytical treatment of defaults in credit portfolio is based on three parameters: probability of default (PD), a loss given default (LGD) and a credit exposure at default (EAD). In PD estimation for firms, accounting variables have an important role, and a firm's size has recognized effects. Gupta et al. (2018) show that micro firms differ in default risk by having higher default rates. Properties of portfolio losses can be described with expected loss (EL) = PD x LGD x EAD and unexpected loss (UL) that considers default correlations. Calculation of UL requires an additional factor in calculation, that is an asset correlation ρ. Asset correlation could be classified also as a portfolio specific risk parameter or exposure specific risk parameter.

Higher capital requirement's connection to the capital costs and supply of finance has several aspects as evaluated by Baker et al. (2015) and increasing capital requirement decisions have been noted to have reducing effects in supply of higher risk corporate credits as shown by De Jongheet al. (2020). There are various elements of risk sensitivity in capital requirements. The capital requirements on level of FI are composed of several requirements. Requirements build through different risk areas, where credit risk is one of the areas and SME credit portfolios are part of credit risk. The resulting capital requirements have been studied and reservations to preparation VaR 99,9% loss scenario has been questioned right from the start of Basel II period as Varsanyi Z (2006) and in conjunction with a financial crisis peaking in 2008 for example by Kiema et al. (2013). A high cumulation of non-performing loans after a financial

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crisis have been studied in detail, for the Spain Gila-Gourgoura et al. (2017) identified both institution-based and macroeconomic factors explaining the level of cumulation. In a level of SME lending, a proportional or an absolute excess in capital requirements compared to through tail risk have been suggested in several studies.

Often research on capital requirement for SME firms captures asset correlations as the part of capital requirements which results in overestimation of risk. Bams et al. (2019) argue that there is a disproportionality in asset correlations favouring large corporates in the cost of SME funding price. Asset correlation does not affect the expected loss of a portfolio and order of portfolio risks could differ in EL and UL. Dietsch et al. (2016) suggests that 0,7169 SME supporting factor generally corrects the disproportionality. Only the credit size limit for support, that is a credit size not exceeding 1,5 M€, leaves out some balancing effects so that without this limit the UL would be in line with loss data. Filipe et al (2016) evaluate co-movements and sensitivity to systematic factors for SME firms in several countries and with several firm features. They find that within SME the smaller companies are more exposed to systematic factors than the larger ones as was suggested by Filipe et al. (2016).

3. Methodology

3.1. Asymptotic single risk factor framework for IRB model

In the Basel regime UL is estimated though asymptotic single risk factor (ASRF) framework. Loss estimation is based on 99,9% Value-at-Risk. ASRF formulas treatment of defaults has its foundation in the limit where the value of a firm's liabilities exceeds value of the firm's assets. In the default model of Merton, a default of a firm occurs if value of liabilities exceeds value of assets of a firm. Asset prices are drivers for defaults with given loan sizes and in case of two firms, dependence can be modeled through asset correlations. Further assumption is that assets are correlated though one or several systematic risk factors. A single systematic risk factor assumption on defaults gives an asymptotic formula

$$UL = VaR_{0.999}^{(ASRF)}(\bar{L}) =$$

$$\sum_{i=1}^{n} \mathrm{w_i E}\left(\widetilde{\mathrm{LGD_i}}|\tilde{x} = \Phi^{-1}(0.999)\right)\Phi\left(-\frac{\Phi^{-1}(\mathrm{PD}) + \sqrt{\rho}\Phi^{-1}(0.999)}{\sqrt{1-\rho}}\right) \times 1.06$$

In IRB modifications EL is subtracted from (2), LGD is downturn estimate, PD reflects one year default horizon and as there is a maturity correction. Scaling factor of 1.06 is included to maintain overall level of capital requirements as equal to preceding Basel 1 regulation (Hibbeln, 2010).

Under Basel internal model regulation, risk parameters are linked with capital requirements. If a financial institution applies IRB method in calculation of capital requirements. In IRB method financial institution uses its own estimates of PD, EAD and LGD while EL and UL are calculated with given formulas. One form of IRB uses a standard LGD instead of own estimate.

FIs publish results on parameters, results of prudential calculation as risk weighted assets (RWA) that is a combining calculation factor for banks using IRB method and banks using standardized method. In standardized method RWA is predefined number separating the required capital so that for example exposures in retail secured with real estate are given RWA of 35% and unsecured corporates receive a 100% RWA. In IRB method RWA is calculated by multiplying the UL by 1250. The basis of 1250 multiplier is an initial Basel regulation rule of reserving 8% capital on FIs exposures to cover the losses. SME exposures are given a support factor to RWA to compensate higher capital requirements otherwise calculated to SME's.

3.2. Asset correlations

Correlation formulas in regulation are specific for exposure classes. For large corporates, SME and part of the retail exposures the increase of PD decreases the correlation, which reflects an assumption that with higher PD levels idiosyncratic risk is given more weight and systematic risk, dependence on other counterparties, is given less weight. In the literature main alternative methods for using IRB formula are portfolio models. In portfolio models all parameters can in principle be estimated from internal data and results can be very different to IRB formula where structure is specified and only EAD, and LGD are based on internal estimates. The regulatory models are calibrated to well diversified portfolios with two parameters: a level of confidence and a set of asset correlations. the portfolios used in IRB calibration were not published and distribution is unknown. Calibration refers to data on large international banks Calibration of IRB formula was introduced in BIS (2004) and calibration has not changed since.

3.3. Basel III regulation changes to parameters and loss estimation

Basel II regulation that largely started in 2005, introduced a risk sensitive capital requirement calculation. Capital requirements were aimed to be risk sensitive and at the centre of this aim was the option to use institutions internal credit ratings along with own risk estimates and new regulation, which replaced the first Basel accord that had started at 1981. Basel II regulation was modified with packages increasing preparations for liquidity risk and with targeted rules for securitizations and certain parts of market risk between 2010 and 2013. Preparations for Basel III started in 2015 (Vousinas, 2015) and the enhanced framework was published in 2018. Implementation varies by region, in the European Union regulation started in phases during period 2019 and 2025. In credit risk area regulation aims at increasing sensitivity of standardized method of credit risk and to selectively restricts use of results from internal model approach to reduce variability between FIs model outputs (Durango-Gutiérrez et al., 2021). The use of external ratings will have more detailed rules and use is complemented by the new approach to counterparties without

external rating. Standardized method will for the first time make direct use of loan-to-value (LTV) for real estate secured loans as risk weight vary according to LTV classes. For portfolios of large corporates and institutions advanced IRB approach will no longer be available. PD floors are introduced as a new floor for corporates and for two groups in retail. The use of LGD floors within retail will be extended. Output floor for internal models will be applied to the ratio of results from a new standardized approach.

Initial calibrations of asset correlations will not be changed, and the only exception comes from an increase of asset correlations between financial institutions as a consequence of financial turbulence starting in 2008. Some features of Basel III implementation in the EU do reflect that reliance on the model is limited as some floors that were planned to be temporary in the start of Basel II regime will be continued even in Basel III.

3.4 Regulatory portfolio size limits: SME retail threshold

The SME limit applied in regulation is based on a turnover limit of 50 million euros of a firm and on credit size. SME supporting factor has an upper limit of 1,5 million euros in exposures. SME retail threshold is a concept of regulation which aims at dividing exposures to firms into two segments: retail and corporates. Corporates as regulatory defined portfolio is again split into two: one including large number of diversified and small exposures (corporate SME portfolio) and other one including the largest ones (Large Corporate Portfolio). Emphasis in this research is in the SME retail threshold for which banks using IRB are required to define. Regulation requires retail exposures to be smaller than 1 million euros and that banks should genuinely treat these firms less individually. Therefore, if the bank for example has more detailed credit evaluation or decision process for firm exposures above 100 000 euros, this might be a candidate for banks specific SME retail limit. In all cases the limit can be 1 million euros at highest. The exposures with immovable property as collateral (later, IP secured) may be decreased from exposure, and IP secured is its own portfolio with its own asset correlation. This exception is purely a prudential calculation rule for individual exposures and defines cases where firms with exposures above the bank specific retail SME threshold may have exposures in retail that are above the threshold. In corporate exposures, non-SME practically means large corporates, and in retail non-SME practically means households.

3.5 Grade level data from Pillar 3 reports

The data was collected from reports of 25 European institutions published in 2019 and 2020 and referring to end of year date previous year, so that end of year 2018 and 2019 data was used. Each institution is represented only once. There are total of 89 portfolios as summarized in table 1. In terms of the number of credits covered, the data has a macro level view to banking, while a number of institutions and portfolios are smaller and the analysis requires a micro level view with relatively small sample data.

Table 1: Summary of the portfolios in the data

Exposure class	Number of exposures	Number of portfolios
Corporate Large	189 474	21
Corporate SME	564 953	25
IP Secured non-SME	7 655 354	10
IP Secured SME	452 578	11
Retail Other non-SME	15 475 249	10
Retail Other SME	2 453 125	12
Sum	26 790 733	89

The publications of Pillar 3 data follow a standard content as in BCBS (2015) but are not in standard format. FIs follow requirements on minimum information to be reported, but the format is not specified, and requirements also leave room for interpretations. Some reports are in Excel spreadsheets and the accuracy of reported numbers varies. Regulation requires that observed default rates used as data for PD estimates "must have a meaningful distribution of exposures across its credit risk rating grades with no excessive concentrations on either its obligor grades" and that these default rates "must have a minimum of seven obligor grades for non-defaulted obligors and one for defaulted obligors". Estimates presented at given year in Pillar 3 report are based on long run data. Parameters are representative of long run history based on the banks own data and possibly external data. Especially the EL in lower risk grades is reported with relative low accuracy. Maturity has very little variation from 2,5 years in reports, which is a standard estimate for retail.

At least two approaches would enable increased time coverage on portfolio risk but from different perspectives. One option is to consider the time-varying features of the risk parameters and the other is to increase number of years where Pillar 3 reports are collected. First one is methodologically straightforward to approach as in bank sector time-variability of parameters is well recognized and unified methods may be applied. The other one, increasing years of Pillar 3 reports, would be complex due to model changes, exposure roll-outs and bank specific risk level changes. Time-varying features are evident only in PD parameter.

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4. Research Results and Discussion

There are two main approaches to PD estimation. One is a two-phased approach starting from risk assessment of a credit to a grade and in the second phase being an estimation of PD to this grade considering all the aspects of PD estimation including long-term estimation and cyclicality considerations. The other approach is a direct estimation approach where individual credit's PD is estimated, and the grade consists of all credits having a PD in the range of a grade. Grade level inferences on input of grades to the UL estimate is equally applicable to both approaches. However, in the description of how, for example the credits to highest risk grade, end up to this grade term could either be that credits are classified to the grade or that credits receive an estimate of this class. We use the term classification to grade describing both two-phased and direct PD -estimation.

All EL and UL calculations are based on grade level PD and LGD data and UL uses the asset correlation of class. The trace from risk estimation to end results stays as straightforward and is based on portfolio risk parametrization. The UL is primarily presented without SME supporting factors reflecting the result of credit portfolio risk estimation. In picture a comparisons of risk measures between SME and non-SME in three comparable exposure classes shows that the SME unexpected loss level is higher than loss for the peer counterparties in corporate exposures and in IP secured. A deviation to smaller risk in SME is observed in other retail for some institutions while some institutions have even multiple SME risks compared to households.

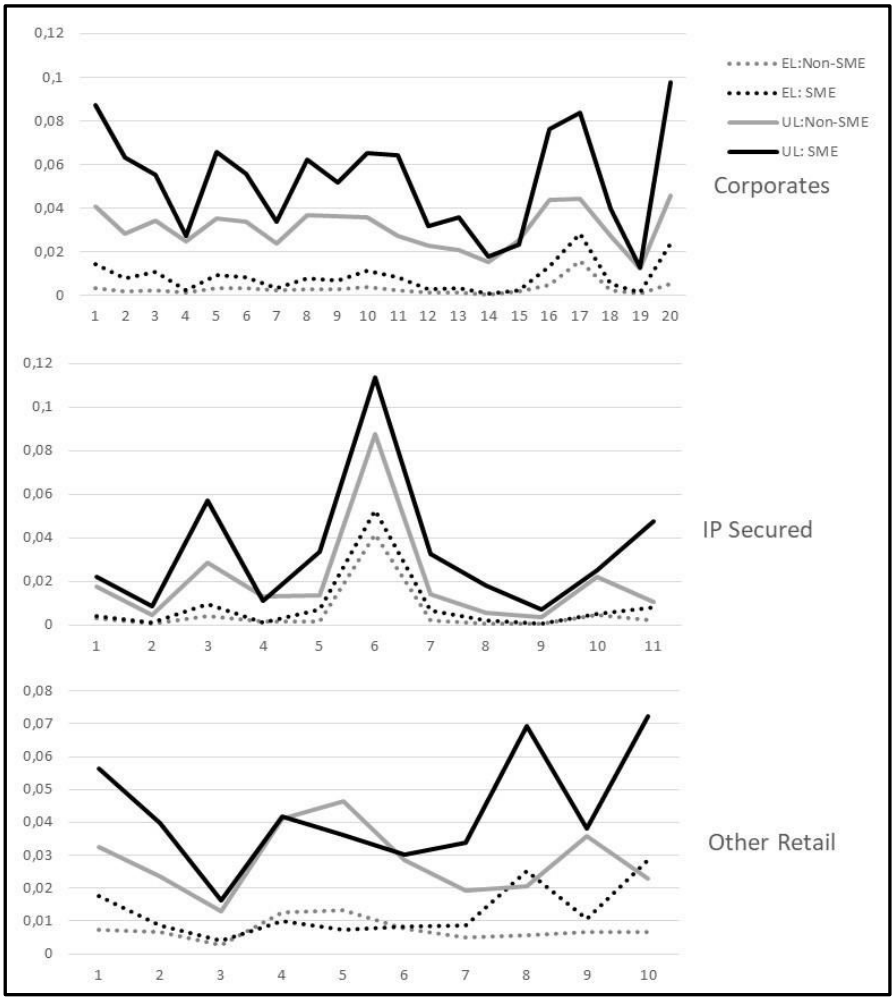

Figure 1 Comparison of unexpected and expected loss between SME and non-SME in banks

The deciles in table 2 show that the first two grade levels constitute the majority for large corporates with 60% accumulation and in IP secured with 58% accumulation. In parentheses is a credit count weighted average decile, which shows that specially for corporates the average credit size is higher in lowest risk grades. This shows clearly in grade one. In grade one, the non-SME large corporates have the highest difference in average deciles: + 0,15. Higher risk class estimations for SME are justified based on research as corporate size and accounting measures have impact on the default risk for companies. For large corporates the higher average credit size in low default risk grades indicates also that credit size is at its highest in lower risk grades.

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Table 2: Average deciles of credit exposure (credit count) for six exposure classes						
Grade	**Corporate Large**	**Corporate SME**	**IP Secured non-SME**	**IP Secured SME**	**Retail Other non-SME**	**Retail Other SME**
1	0.46 (0.31)	0.26 (0.23)	0.47 (0.49)	0.25 (0.26)	0.39 (0.34)	0.17 (0.16)
2	0.58 (0.41)	0.34 (0.3)	0.60 (0.63)	0.37 (0.38)	0.47 (0.42)	0.25 (0.24)
3	0.79 (0.58)	0.54 (0.45)	0.72 (0.72)	0.48 (0.5)	0.51 (0.48)	0.39 (0.37)
4	0.87 (0.66)	0.61 (0.54)	0.78 (0.79)	0.58 (0.59)	0.62 (0.54)	0.52 (0.5)
5	0.98 (0.84)	0.87 (0.81)	0.93 (0.93)	0.72 (0.73)	0.86 (0.81)	0.8 (0.74)
6	1,00 (0.96)	0.99 (0.97)	0.97 (0.97)	0.89 (0.89)	0.96 (0.95)	0.99 (0.96)
7	1,00 (1.00)	1,00 (1.00)	1,00 (1.00)	1,00 (1.00)	1,00 (1.00)	1,00 (1.00)

Tests in table 3 verify that pairwise differences are significant for PD, EL and UL for corporates and IP Secured credits both in t-test and Wilcoxon rank test. For other credits the difference in PD and UL are significant at 0.05 level. for LGD parameters the differences are not significant in any of the three exposure classes.

Table 3: Comparison tests on risk measures - all risk grades included				
Exposure class	**Risk measure**	**t-test**	**Wicoxon**	**Correlation**
Corporates	UL	-6.14 [0.0000]	2 [0.0000]	0.91 [0.0000]
	EL	-4.97 [0.0001]	0 [0.0000]	0.84 [0.0000]
	PD	-5.14 [0.0001]	0 [0.0000]	0.82 [0.0000]
	LGD	0.64 [0.527]	123 [0.5217]	0.83 [0.0000]
IP Secured	UL	-3.71 [0.004]	1 [0.002]	0.92 [0.0000]
	EL	-3.1 [0.0112]	1 [0.002]	0.98 [0.0000]
	PD	-2.21 [0.051]	1 [0.002]	0.99 [0.0000]
	LGD	-1.44 [0.1789]	15 [0.2213]	0.48 [0.1326]
Other	UL	-2.34 [0.0437]	5 [0.0195]	0.01 [0.9749]
	EL	-1.92 [0.0866]	11 [0.1055]	-0.09 [0.7969]
	PD	-2.31 [0.0457]	10 [0.084]	0.2 [0.5737]
	LGD	-0.71 [0.4906]	20 [0.4922]	0.36 [0.302]

SME portfolios are not among the low-risk portfolios of banks. Rank of SME portfolios is presented in table 4. Corporate SME was in 11 cases the portfolio with highest UL and in most cases among the three portfolios with highest risk. The immovable property secured SME portfolios were also in few cases among the highest risk portfolios while also in having in some banks a relatively low portfolio risk. Other SME within retail was again a higher risk portfolio as it had highest portfolio risk for some banks in most cases it was classified at least to highest half of portfolio risks.

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Table 4: Rank of portfolio UL lowest to highest			
Number of reported portfolios in institution	**of which Corporate SME**	**of which IP Secured SME**	**of which Retail Other SME**
4	4	-	-
5	2,4,5,5,5,5,5,5	4,5	-
6	5,5,6	6	4,6
7	5,5	2,7	6
8	6,7,8,8	4,4,5	4,6,7,8
9	8,9,9	4,5,6	6,9
10	8,8	2,5	9,10

To focus on a low risk in SME, a more general risk definitions to risk grades may be applied to data. Terminology and default levels for rating agencies give several options for the reclassification of grades. An interesting part of the rating grades are the two lowest risk grades, which may be mapped to term "Investment grade" based on observed default levels in Moody's data. Moody's and Standard and Poors definitions are those applied by Livingston et al. (2021) and mapping is reported in table 5.

Table 5: Mapping of PD grades of portfolios to rating definitions				
Grade	**PD**	**Moody's and S&P**		
1	0.00 to <0.15	A	Investment grade	Highest quality
2	0.15 to <0.25	BBB	Investment grade	High quality
3	0.25 to <0.50	BBB-	Speculative grade	Likely to fulfil obligations
4	0.50 to <0.75	BB	Speculative grade	Likely to fulfil obligations
5	0.75 to <2.50	BB-	Speculative grade	High risk
6	2.50 to <10.00	B	Speculative grade	High risk
7	10.00 to <100.00	CCC	Speculative grade	Vulnerability to default

The contributions of the investment grade and the speculative grade to RWA are in table 6. Lowest UL and RWA is in IP secures non-SME credits while the share of investment grade is higher in other exposure classes. Lowest risk weight in IP secured are due to the lowest asset correlation of all exposure classes. For SME the contribution to RWA from investment grade to does not exceed 7% in any exposure class.

Table 6: Contribution to portfolio RWA from investment and speculative grades						
	Corporate Large	**Corporate SME**	**IP Secured non-SME**	**IP Secured SME**	**Retail Other non-SME**	**Retail Other SME**
Portfolio RWA	36.7	62.6	25.1	42.9	35.5	54.3
- incl. SME support factor		47.7		32.7		41.4
of which investment grade	23.3%	7,0 %	7.4%	3.3%	13.2%	4.1%
of which speculative grade	76.7%	93,0 %	92.6%	96.7%	86.8%	95.9%

Within the investment grade there are mainly differences to higher in risk in SME in comparison to other exposures according to comparisons in table 7. In corporate exposures the difference, especially in EL is very small, partly balanced by lower LGD in SME. In speculative grade for corporate exposures the EL ratio of 58% is narrowed to 77% through asset correlation that decreases though PD.

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Table 7: Risk measure comparisons between SME and Non-SME for two ratings classes					
Exposure class	**Risk measure**	**Rating**	**Non-SME**	**SME**	**Ratio to SME**
Corporates	UL	Investment	0.014	0.015	94.8%
		speculative	0.05	0.065	76.9%
	EL	Investment	0,000	0,000	89.9%
		speculative	0.006	0.011	58.4%
	PD %	Investment	0.113	0.130	87.4%
		speculative	1.659	2.803	59.2%
	LGD %	Investment	38.213	36.527	104.6%
		speculative	39.226	38.500	101.9%
IP Secured	UL	Investment	0.003	0.005	72.8%
		speculative	0.028	0.036	76.7%
	EL	Investment	0.000	0.000	69.9%
		speculative	0.008	0.009	80.7%
	PD %	Investment	0.112	0.148	75.8%
		speculative	3.552	4.856	73.1%
	LGD %	Investment	15.455	17.896	86.4%
		speculative	16.913	18.537	91.2%
Other	UL	Investment	0.010	0.013	75.1%
		speculative	0.041	0.049	83.8%
	EL	Investment	0.000	0.001	69.1%
		speculative	0.012	0.015	82.6%
	PD %	Investment	0.109	0.138	78.6%
		speculative	2.946	3.152	93.5%
	LGD %	Investment	47.523	51.011	93.2%
		speculative	40.015	46.025	86.9%

The pairwise tests in table 8 on UL show that for corporates and for other exposures differences are not significant, but for IP Secured there is a 0,0389 significance in the test. The EL of corporates is also significant, but in this case to the direction of lower UL for SME. As the EL figures are very small ratios, this may reflect the varying direction of differences in PD and LGD without having effect on UL.

Table 8: Comparison tests on risk measures - investment grade				
Exposure class	**Risk measure**	**t-test**	**Wilcoxon**	**Correlation**
Corporates	UL	-0.86	83	0.66
		[0.4026]	[0.4304]	[0.0014]
	EL	5.23	203	0.4
		[0.0000]	[0.0000]	[0.0794]
	PD	-2.07	52	0.43
		[0.0518]	[0.0484]	[0.059]
	LGD	1.27	118	0.76
		[0.2211]	[0.3652]	[0.0001]
IP Secured	UL	-2.47	5	0.44
		[0.0389]	[0.0391]	[0.2379]
	EL	-2.56	4	0.45
		[0.0335]	[0.0273]	[0.228]
	PD	-4.16	0	0.75
		[0.0032]	[0.0039]	[0.0188]
	LGD	-1.52	10	0.52
		[0.1661]	[0.2936]	[0.1507]
Other	UL	-1.55	12	0.13
		[0.1561]	[0.1309]	[0.7293]
	EL	-1.74	8	0.08

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		[0.1153]	[0.0488]	[0.822]
	PD	-4.68 [0.0012]	0 [0.002]	0.7 [0.0251]
	LGD	-0.41 [0.6944]	24 [0.7695]	0.14 [0.7096]

As a summary on the results, on a portfolio level, SME portfolios show higher risk in comparison to large companies. In comparison to large companies, SME has a higher share of credits in a weaker category of speculative grades and even within speculative grade the SME risk is higher. In retail exposure classes IP secured and other retail, the SME risk is also higher than for other counterparties in retail, which generally are the households. Interestingly, the presence of collateral in IP secured does not balance out the higher risk of SME counterparties, while the role of the collateral is important as studied by Berger et al. (2011).

5. Conclusions

We find that SME portfolios are among the riskiest portfolios of the banks within all portfolios of institutions and in comparison to similar credit types to households or to bigger companies. Higher risk of SME portfolios supports findings on previous research. The output of SME risk is dampened by the SME supporting factor applied to the result. The higher portfolio loss risk, expected and unexpected, rises from higher PD estimates which leads to classification of SME counterparties and credits to higher risk grades. With findings on PD parameter, results complement the current research by stating the importance of PD estimation as a main factor behind higher capital requirements. For the investment grade credits, the difference in loss estimates is not generally higher for SME and within this lowest credit risk class is also a substantial share of SME counterparties. Risk level comparison identifies a low-risk part of SME credit portfolio and this finding may affect how to measure risk for SME portfolios in comparison to other sectors. Another contribution with this finding is a support for SME rating models which differentiate between low and high-risk SMEs. The speculative grades are the source of portfolio differences both with higher share of SME credits and with higher average risk estimates.

Reforms on Basel regulation may restrict the amount of information available through Pillar 3 as there are floors affecting the result on capital requirement calculation. Even the current data dissemination practice resulted in limited availability of comparable information from institutions. Introduced floors could affect lower risk parts of SME portfolios which were identified within investment risk categories based on data of almost 90 portfolios.

For the research on capital requirements concerning SME's, an important finding is that institutions assess SME as higher default risk counterparties than peers and this results in higher capital requirements. Future research on credit risk of SME firms may enlighten how separation of low-risk and high-risk SME counterparties effects various dimensions of credit risk measurement. For future research these dimensions are potentially in separated estimation of expected loss and unexpected loss estimation for SME credit portfolios. Also, for the research on SME finance, a risk separation may be an important factor defining both access to finance and pricing of finance.

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Monetary Conditions Index and Economic Activity in Dollarized Zimbabwe

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ABSTRACT

Purpose:
Zimbabwe has experienced a chronic inflationary crisis whose roots can be traced back to 1997. Various macroeconomic instruments have been suggested to stabilize the country's prices and foster economic growth but evidence on how they interplay to influence policy is lacking. This study developed a monetary conditions index (MCI) for Zimbabwe during the 10-year dollarization period, 2009 to 2018, and measured its correlation with economic activity. The aim of the MCI is to inform monetary policy making in Zimbabwe.

Design/methodology/approach:
Using monthly time series data, the MCI series from 2009 to 2018 was calculated using real interest rates and exchange rates. The relationship between the MCI, GDP, inflation, money supply and private sector credit was analysed using the Auto Regressive Distributed Lag (ARDL) model for the long-term relationship and Granger causality for the short term.

Findings:
Results showed MCI weights of 1:1.54 implying that exchange rates dominate the interest rate in Zimbabwe's monetary policy. A long run relationship between the MCI and economic variables was statistically significant while short term relationships were established for private sector credit, GDP, and foreign interest rates.

Research implications:
The study concludes that the MCI is a useful indicator of the central bank's monetary policy position for economic analysts while the central bank can also adopt it for inflation and growth targeting.

Originality/value:
Unlike previous research which has proffered monetary solutions based on specific variables, this study took into consideration the interplay between interest rates and exchange rates in determining economic activity in Zimbabwe. The constructed MCI captured the interplay between these two key variables and the study established its relationship with economic activity. On this basis, the study recommends the adoption of the MCI in guiding monetary policy in Zimbabwe.

1. Introduction

Zimbabwe has faced a chronic inflationary crisis since year 1997 when its currency crashed(Southall, 2020). Inflation peaked at 231 million% in the year 2008 (Njokwe, 2016) coinciding with negative GDP growth rates (Masiyandima et al., 2018). Although the country's economy stabilized in 2009 after dollarization, it faced a liquidity crunch (Mugari and Olutola, 2021) and deflation (Saungweme and Odhiambo, 2021) from 2012. After reintroducing a local currency in 2016, inflation soon spiralled as the foreign exchange rate deteriorated since the local currency was rushed before meeting the requisite fundamentals such as sufficient US$ reserves to defend the currency (Makena, 2020; Saungweme and Odhiambo, 2021). By mid-2019, inflation had breached triple figures at 230% and the central bank ceased publishing the economic statistic to contain inflationary expectations from economic agents (Maumbe and Chikoko, 2022).

The inflationary problem seems related to monetary policy and exchange rate challenges which can be explained within the Mundel-Flemming model. The model posits that a country can only simultaneously implement at most two of the following: monetary policy independence, free capital mobility and a fixed exchange rate. This has been

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popularised as the financial policy trilemma or the impossibility trinity (Aizenman, 2019). Before 2009, the policy trilemma implied that Zimbabwe focused on monetary policy independence and exchange rate stability as the economy was relatively closed. After experiencing a hyperinflationary environment between 2007 and 2008 (Strike et al., 2021), Zimbabwe dollarised its economy to restore financial stability (Chidakwa and Munhupedzi, 2017). Dollarisation refers to the adoption of another country's currency such as US$, Euro and Renminbi (Lyzun et al., 2019).Monetary policy and exchange rate policies became officially unavailable as policy tools since dollarisation effectively removed the possibility of money printing by the central bank.

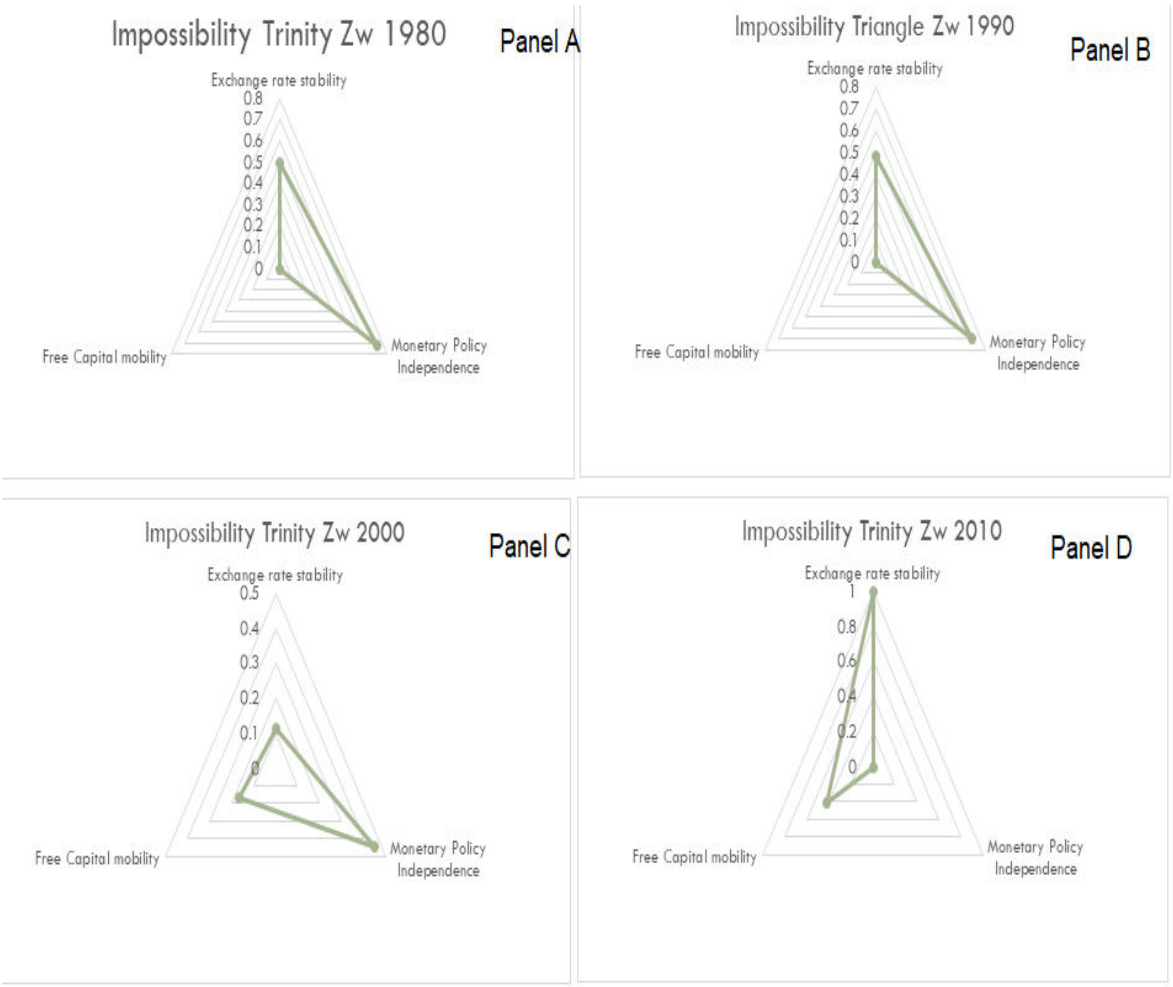

Figure 1: Impossibility Trinity: Zimbabwe characterization
Source: RBZ data (RBZ, 2021)

Figure 1 shows the degree to which the Zimbabwean government had control of monetary policy, exchange rate and capital mobility since 1990. Panel A to C show that the Zimbabwean government had total control over monetary policy for three decades from independence in 1980 until 2009 when the economy dollarized. Panel D refers to the period 2010 to 2016 when Zimbabwe had very little monetary policy control due to dollarisation. Zimbabwe had a fixed exchange rate for two decades as shown in panels A and B, but floated it in 2000 as shown in panel C. When the economy dollarized in 2009, it fixed its currency to the adopted US dollar as shown in panel D.

The country earned most of its US dollars in circulation from raw material exports mostly from mining (Sanderson et al., 2021; Muzurura, 2019; Chirwa and Kader, 2018). Other sources included foreign capital inflows, developmental aid and migrant remittances. The exporting of raw materials generated low export earnings and the accumulation of foreign currency reserves was lower than demand for imports which led to the depletion of the reserves. The depletion was exacerbated by unregulated capital outflows and unchecked money laundering activities that saw a number of foreign and domestic residents shipping money, mostly in form of cash, out of the country. The US dollar appreciated relative to other currencies especially the South African Rand which compromised the competitiveness of Zimbabwean exports (Pasara and Garidzirai, 2020). The South African Rand was a key component of the multi-currency regime especially for smaller denominations and coins that served for change purposes for small transactions. The South African Rand was gradually rejected for local transactions leaving the stronger US$ as the preferred currency amongst the basket of officially accepted currencies as shown in figure 2.

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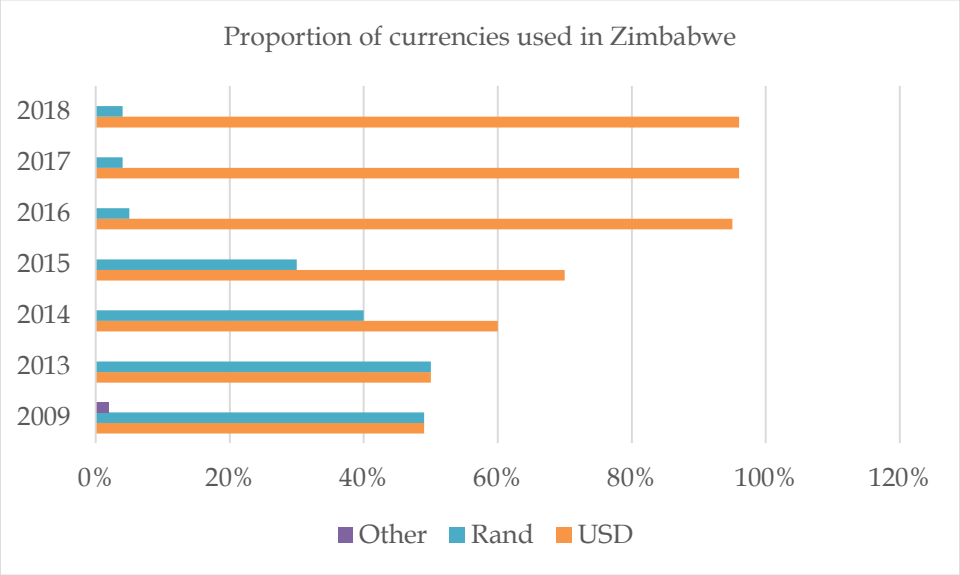

Figure 2: Composition of Foreign Currency Reserves in Zimbabwe 2009 to 2018
Source: (Mandeya, 2017; RBZ, 2021)

To deal with change for large notes, the central bank introduced 1, 5, 10, 25, and 50 cents token coins pegged at par to the US$. The central bank later on added a two-dollar token called bond notes and started to issue their electronic equivalents beginning in September 2016 thereby ushering in a new way of gaining monetary policy independence. By 2018, substantial monetary policy autonomy was gained through electronic money supply growth. As the electronic money balances grew, they began attracting an exchange rate with the US$ on the parallel market which eventually forced Government to abandon the fixed exchange rate that was one to one with the US$. In February 2019, dollarisation officially ended.

Against this background, this study investigates whether a Monetary Conditions Index (MCI) for Zimbabwe can be developed and used as a monetary policy tool in pursuit of economic growth. The MCI is a univariate measure of the effects of interest rates and exchange rates on economic performance (Eika et al., 1996). The correlation between MCI and economic activity helps to inform whether the MCI can be used as a monetary policy tool to influence the level of economic activity in a dollarised economy in which the Central Bank lacks monetary policy control.

Monetary conditions refer to a combination of financial variables that influence monetary policy (Costa, 2000; Osborne-Kinch and Holton, 2010). The rationale of the MCI is that monetary policy pressurizes the economy through interest rate and exchange rate leading to inflation(Lattie, 2000). An increase in the MCI resembles the loosening of monetary conditions and thus inflationary pressure and vice versa is true. MCI considers the impact of the exchange rate on small open economies like Zimbabwe. The combination of interest rate and exchange rate in its calculation ensures that the two variables can be targeted to loosen or tighten monetary policy to stimulate the economy.

2. Literature Review

The MCI is an empirical construct developed by aggregating interest rates and exchange rates into a single index for use in guiding monetary policy. The two components are weighted in comparison to a given initial state to reflect their importance on national output as informed by econometric evidence on the determinants of aggregate demand (Ericsson et al., 1997). The index is grounded in Monetarist and Keynesian schools of thought on the role of interest rate, exchange rate, and government spending in stimulating economic activity. The MCI has been established as a monetary policy anchor useful for tracking inflation and economic growth by central banks of countries such as Canada and New Zealand (Mohseni et al., 2019; Ericsson et al., 1998). An increase in the MCI implies loose monetary conditions and the vice versa is true (Osborne-Kinch and Holton, 2010) for an indirectly quoted exchange rate where the local unit is the base currency.

Previous MCI studies have shown that the interest rate and exchange rate channels need to be jointly evaluated when studying monetary policy and changes to the monetary conditions (Qayyum, 2002). Amador et al. (2020) have shown that policies that do not simultaneously address interest rate and exchange rate channels affect capital flows. Consequently, the central bank would need foreign currency reserves to maintain financial stability which can be unsustainable (Amador et al., 2020; Cavoli et al., 2019). Some variants of the MCI add changes in credit and money supply to the two traditional variables(Kannan et al., 2007). Another variant of the MCI considers asset prices leading to an alternative term called the financial conditions index (Zheng and Yu, 2014).

DOI: 10.25103/ijbesar.152.04

The Bank of Canada used the MCI by determining its optimal growth path, using interest and exchange rates predicted by a quarterly projection model. The projection model also estimates output and inflation simultaneously. It also has a monetary response function that determines the optimal inflation path towards the central bank's inflation target. The model thus estimates interest and exchange rate paths consistent with the inflation target. The major factor guiding the Bank of Canada regarding this is that under a flexible exchange rate regime, monetary policy arrangements have their influence through both interest rates and the exchange rate. The current study uses the MCI to capture the degree of tightening or easing of monetary policy and as a monetary policy target.

The MCI has been adopted by other economies such as Sweden and Norway to guide monetary policy (Eika et al., 1996) but yet to be examined for Zimbabwe whose exchange rate has become a key parameter in its output and prices. The index closest to the MCI to have been calculated for Zimbabwe was the Macro-Financial Conditions Index (MFCI) estimated by Machirinani et al. (2020). An MFCIs aggregates several macroeconomic and financial indicators weighted by their regression coefficients (Kapetanios et al., 2018).

Machirinani et al. (2020) found that a declining MFCI indicating improved financial stability is negatively related to GDP growth in Zimbabwe. Other variables found influencing growth include inflation, interest and debt. The inclusion of monetary variables such as interest rate and debt which have short and long run granger causality relationships makes their piecemeal consideration as monetary policy instruments complex. Previous researchers on Zimbabwean monetary policy have proffered monetary interventions based on specific variables ignoring this interaction. For instance, Saungweme and Odhiambo (2021) found public debt as the most important tool in managing inflation and economic performance in Zimbabwe. They thus argue for the government to focus on public debt in order to control inflation and economic growth without considering the interplay between public debt, resultant interest rates and exchange rates.

On the other hand, Madesha et al. (2013) discovered the effect that the exchange rate has on inflation in Zimbabwe and proffered recommendations involving support measures that the government could consider without factoring the interplay with interest rates. Researchers like Makena (2020) managed to establish that the exchange rate influences Zimbabwe's inflation but they have no meaningful solution since it depends on the performance of the US$/Rand exchange rate. Makena (2020) acknowledges that the country needs to attract domestic and foreign capital without emphasizing the importance of the interest rate in attracting the funds or its interplay with the exchange rate as captured by the MCI. The present is conducted cognizant of the interplay between interest rates and the exchange rate as captured by the MCI. Such an insight has been lacking in prior studies attempting to proffer evidence-based solutions to the chronic economic challenges facing Zimbabwe which will be attempted in this paper.

3. Methodology

Monthly data between 2009 and 2018 were collected from government and international organizations as shown in table 1. Data relating to taxation was obtained from ZIMRA. Foreign interest rate data was obtained from international institutions namely the IMF, World Bank, and Trading Economics. Inflation data was obtained from ZIMSTAT. While the rest of the data was obtained from the Zimbabwean central bank (RBZ). Data analysis was performed using E-Views 11.

Table 1: Data Sources

Variable	Calculation	Data Source
Interest rate	As published by central bank	Reserve Bank of Zimbabwe (RBZ)
Real Exchange rate	As published by RBZ using the South African Rand (ZAR), the currency of the largest neighbouring trading partner of Zimbabwe.	RBZ
Inflation	Monthly CPI as published by ZIMSTAT	Zimbabwe National Statistical Agency,ZIMSTAT
GDP	estimated from monthly value added tax	Zimbabwe Revenue Authority (ZIMRA)
Money supply	M3 as published by RBZ	Reserve Bank of Zimbabwe (RBZ)
Foreign interest rate	As published by secondary sources	IMF, World Bank, Trading Economics
Tax	As published by ZIMRA	ZIMRA
Private sector credit	As published by RBZ	RBZ

The MCI for each month (t) was computed using a formulation developed by Kannan et al. (2007) which aggregates the real interest rate (r) weighted by w_r and the real exchange rate (e) weighted by w_e as shown in equation (1):

$$MCI_t = w_r(r_t - r_{2009m03}) + w_e(e_t - e_{2009m03}) \quad (1)$$

DOI: 10.25103/ijbesar.152.04

The third month of year 2009 was the base period. The real exchange rate was obtained using equation (2):

$$e_t = E_t . \frac{P_t}{P_t^*} \quad (2)$$

where E_t is the nominal exchange rate, p_t is the overall price level for Zimbabwe; p* refers to the general price level for South Africa[1].

$$w_r + w_e = 1 \quad (3)$$

Freedman and Luxton (2009) argued that inflationary pressure depends on the output gap and that monetary policy affects output through interest rate and exchange rate. The weights,$w_r$and w_e were thus obtained from coefficients of the real exchange rate and interest rate in equation (4) which estimates the output gap:

$$GDPGap_t = \propto + \propto_1 interest\ rate + \propto_2 real\ exchange\ rate + \propto_3 Money\ supply + \propto_4 Domestic\ inflation + + \propto_5 foreign\ interest\ rate + \propto_6 Tax + U_t \quad (4)$$

4. Results

4.1 Development of the Monetary Conditions index

Equation (4) was regressed using the ordinary least squares regression to estimate coefficients for use as weights in the calculation of the MCI. Table 2 shows OLS estimates of the coefficients.

Table 2: Regression of GDP gap on real interest rate and real exchange rate

Variable	Coefficient	Std. Error	t-statistic	p-value
Real Interest rate	-0.300***	0.094	-3.181	0.001
Real exchange rate	0.463**	0.194	2.390	0.019
Constant	-5.286***	1.108	-4.773	0.000
Money supply	0.111	0.081	1.380	0.171
Inflation	-0.003	0.024	-0.130	0.897
Foreign interest rate	0.038**	0.017	2.212	0.029
Tax	0.476***	0.122	3.905	0.000
Observations				190
R-squared				0.220
Adjusted R-squared				0.175
F-statistic		4.808	p-value	0.000
Durbin-Watson stat				1.277

The ratio of the MCI weights was calculated as in equation (5):

$$Ratio = real\ interest\ rate\ coefficient / real\ exchange\ rate\ coefficient \quad (5)$$
$$= 0.300/0.463$$
$$= 65/100$$
$$= 1{:}100/65$$
$$= 1{:}1.54$$

This ratio indicates that, a percentage rise in interest rate is met by a 1.54% decline in the real exchange rate. From, equation (3), $w_r$and $w_e$add up to 1 so that:

$$w_r = 1/2.54 = 0.394$$

and

$$w_e = 1.54/2.54 = 0.606$$

[1] Real Exchange rate is based on South African Rand (ZAR), the currency of the largest neighbouring trading partner of Zimbabwe. RBZ calculates the monthly real exchange rate

DOI: 10.25103/ijbesar.152.04

Substituting these weights into equation (1) gives equation (6):

$$MCI_t = 0.394(r_t - r_{2009m03}) + 0.606(e_t - e_{2009m03}) \qquad (6)$$

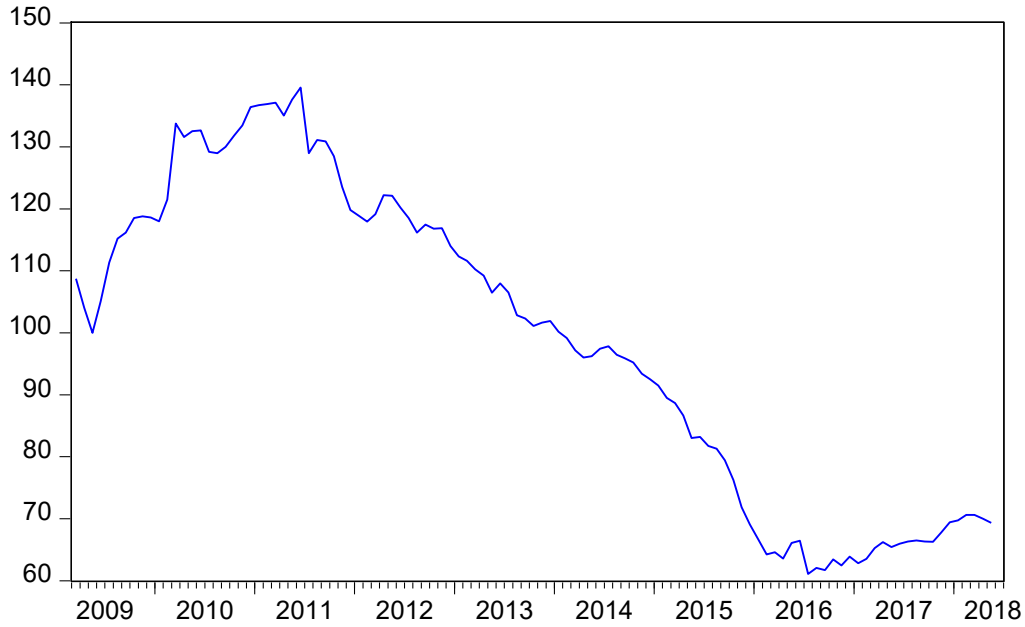

Figure 3: Monetary Conditions Indices for Zimbabwe, 2009 to 2018
Source: Calculated by Researcher using RBZ and other data

The MCI series resulting from equation (6) is plotted in figure 3. The series shows that the monetary conditions index loosened from 2009 but began tightening in 2011. It then loosened in 2016 before marginally tightening until 2018. The correlation matrix shown in appendix 1 indicates that there is a negative association between monetary conditions index and output growth. Loose monetary conditions are associated with increasing GDP and tight monetary conditions are associated with declining GDP.

4.2 Descriptive statistics

Descriptive statistics are presented in table 3. The data consisted of 109 monthly observations during the period of dollarisation in Zimbabwe. The MCI index ranges between 1.936 and 2.094. Its skewness lies between -1 and +1 expected of a normally distributed variable. The kurtosis value is also within the expected values of normality between -2 and +2. The GDP of Zimbabwe ranged between US$8.686 billion and US$9.901 billion with a mean of US$9.093 billion. The skewness statistic is greater than 1 implying positively skewed data and the kurtosis of more than 2 implies heavier tails than expected of a normal distribution. The same skewness pattern is noted for variables CRP and M3. Comparable conclusions can also be drawn for kurtosis values of CRP, FIR, M3 and CPI. Removing extreme values and data transformation can result in better distribution of data towards normality. The data was log transformed to reduce the effects of size of values given that some variables were observable in billions while some like the MCI were only single digits.

Table 3: Descriptive statistics

Parameter	GDP	MCI	CRP	FIR	M3	CPI
Mean	9.093	2.012	6.378	13.634	6.528	101.829
Median	9.086	2.011	6.537	13.510	6.585	102.219
Maximum	9.901	2.094	6.576	15.400	6.909	106.594
Minimum	8.686	1.936	5.138	12.740	5.602	92.016
Std. Dev.	0.167	0.050	0.319	0.692	0.263	3.796
Skewness	2.094	-0.131	-2.135	0.710	-1.402	-0.919
Kurtosis	12.433	1.778	6.988	2.570	5.090	2.981
Jarque-Bera	483.779	7.094	155.051	9.987	55.561	15.337
Probability	0.000	0.029	0.000	0.007	0.000	0.000

DOI: 10.25103/ijbesar.152.04

Sum	991.110	219.356	695.229	1486.055	711.601	11099.34
Sum Sq. Dev.	3.028	0.264	10.961	51.720	7.451	1555.995
Observations	109	109	109	109	109	109

4.3 Stationarity

Time series data is usually non-stationary leading to spurious regression results and a very high R^2. A stationary variable is one whose mean and variance are constant overtime. Stationarity and order of integration were determined using the augmented Dickey-Fuller (ADF) unit root test. If a variable was not stationary at its initial level, I(0), first order differencing I(1) was conducted to make it stationary.

Table 4: Augmented Dickey Fuller (ADF) Unit root test results

Variable	Level		First difference		Order of integration
	Intercept	Intercept and Trend	Intercept	Intercept and trend	
Log GDP	-3.459 ** (0.009)	-5.337*** (0.000)	-16.181*** (0.000)	-16.160*** (0.000)	I(0)
Log MCI	-0.156 (0.944)	-2.812 (0.193)	-8.733*** (0.000)	-8.897*** (0.000)	I(1)
Log CRP	-15.624*** (0.000)	-9.926*** (0.000)	-4.514 ** (0.000)	-5.974 *** (0.000)	I(0)
Log FIR	-0.744 (0.835)	-0.880 (0.958)	-11.971*** (0.000)	-12.116*** (0.000)	I(1)
Log M3	-9.768*** (0.000)	-9.242*** (0.000)	-8.356*** (0.000)	-9.482*** (0.000)	I(0)
Log CPI	-0.686 (0.850)	-1.167 (0.917)	-7.249*** (0.000)	-7.199*** (0.000)	I(1)

P-values in parentheses; *, **, and *** represents significance at 10%, 5% and 1% level of significance respectively.

Table 4 shows the stationarity results using the ADF test while appendix A2 presents results of a Philips-Perron test. Logarithms of GDP, CRP, and M3 were stationary in levels while logarithms of MCI, FIR, and CPI were integrated of the first order.

4.4 Long run relationship

The ARDL model was used to analyse long run relationships among I(0) and I(1) variables. Table 5 shows that the null hypothesis of no relationship between MCI and economic growth is rejected at the 5% level of statistical significance.

Table 5: Relationship between MCI and GDP growth

F-Bounds Test			Null Hypothesis: No levels relationship	
Test Statistic	Value	Signif.	I(0)	I(1)
F-statistic	3.336379	10%	2.37	3.2
K	3	5%	2.79	3.67
		2.5%	3.15	4.08
		1%	3.65	4.66
Actual Sample Size	107		Finite Sample: n=80	
		10%	2.474	3.312
		5%	2.92	3.838
		1%	3.908	5.044

4.5 Granger causality

The causality test developed by Engle and Granger (1987)was used to evaluate for short run causal relationships between the MCI and output represented GDP. The model is as follows:

$$MCI_t = \alpha_0 + \sum_{i=1}^{t} \alpha_{1i} MCI_{t-i} + \sum_{i=1}^{t} \alpha_{2i} GDP_{t-i} + e_t \quad (7)$$

$$GDP_t = \beta_0 + \sum_{i=1}^{t} \beta_{1i} GDP_{t-i} + \sum_{i=1}^{t} \beta_{2i} MCI_{t-i} + \varepsilon_t \quad (8)$$

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where MCI is the monetary conditions index, GDP is the gross domestic product, where $e_t$and ε_t represent white noise. The statistical significance of parameters α_{2i} and $\beta_{2i}$are used to evaluate the null hypothesis that GDP granger causes MCI and vice versa respectively.

Table 6: Granger Causality Test between MCI and GDP and other variables

Hypothesis	Observations	F-Statistic	P-Values
MCI does not cause GDP**	107	3.49905	0.0339
GDP does not cause MCI		1.43984	0.2417
CRP does not cause GDP	107	0.00883	0.9912
GDP does not cause CRP		1.36094	0.2610
FIR does not cause GDP	107	1.67487	0.1924
GDP does not cause FIR		0.11844	0.8884
M3 does not cause GDP*	107	2.50151	0.0870
GDP does not cause M3		1.15936	0.3178
CPI does not cause GDP	107	1.09256	0.3392
GDP does not cause CPI		0.27892	0.7572
CRP does not cause MCI***	109	5.75999	0.0042
MCI does not cause CRP		0.18538	0.8311
FIR does not cause MCI	109	1.29513	0.2782
MCI does not cause FIR***		6.05875	0.0032

*, **, and *** represents significance at 10%, 5% and 1% level of significance respectively.

Table 6 shows the granger causality results between MCI and GDP and other variables. It shows that MCI granger causes GDP statistically significant at the 5% level but GDP does not granger cause MCI. This result is important in that it implies that the MCI can be used to guide monetary policy that supports economic growth.

The correlation matrix showed a negative relationship meaning that tightening the monetary conditions discourages economic activity. The other variable that MCI granger causes is FIR statistically significant at the 1% level, but FIR does not granger cause MCI. This result suggests that South Africa, Zimbabwe's main trading partner, might use its interest rates to react to policy changes in Zimbabwe to protect its own economy. CRP granger causes MCI statistically significant at the 1% level, but MCI does not granger cause CRP. This result suggests that private sector credit influences monetary policy in Zimbabwe. The table also shows that M3 granger causes GDP for Zimbabwe, statistically significant at the 10% level. This means that optimal money supply growth can be used to support economic growth, and when taken in conjunction with the earlier finding, M3 needs to be informed by the MCI.

4.6 Diagnostic tests

Tests for serial correlation were conducted using the Breusch-Godfrey Serial Correlation LM Test. As shown in Appendix A3, there was no evidence of serial correlation. The test for the null hypothesis of homoscedasticity, showed the models did not suffer from the problem of heteroscedasticity as shown in Appendix A4.

5. Discussion

This study successfully developed an MCI for Zimbabwe. It went on to show that the index has a long run corelation with GDP, private sector credit, foreign interest rate, money supply and inflation. Furthermore, the study showed that the MCI granger causes economic growth and foreign interest rate while private sector credit granger causes the MCI. The MCI weights ratio of 1:1.54 (alternative expression 0.649:1) established in this study is smaller than the 1.9:1 established by Knedlik (2006) for South Africa. These two ratios mean that the Zimbabwean MCI is dominated by the exchange rate while that of South Africa is dominated by interest rate. The MCI series (figure 3) rose sharply between 2009 and 2011. This upward trend dovetails with the loosening monetary and fiscal conditions that existed as the government sought to boost an economy from recession. The tightening of monetary policy since 2011 is in line with the cash budgeting approach implemented to curb government spending within its means. The Zimbabwean MCI weights are comparative to other small economies with double digit billion-dollar GDP figures such as Jamaica and Croatia that have ratios of 0.019:1 and 0.649:1 respectively (Lattie, 2000; Benazić, 2012). South African weights on the other hand are comparative to triple digit billion-dollar GDP economies such as Romania with ratio of 1.5:1 and 3:1 for Czech Republic (Nucu and Anton, 2018).

The current study established that the MCI is well connected with economic growth in Zimbabwe and has causal relationship with economic variables such as GDP, private sector credit and foreign interest rate. This result supports

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the finding that the Zimbabwean MFCI has a long run relationship with GDP growth, CPI, Interest and Leverage ratio established by Machirinani et al. (2020). This means that the MCI can be used as an indicator of the central bank's monetary policy stance by economic analysts (Hong, 2017). The Zimbabwean central bank can also use the MCI for targeting the inflation and GDP output gap. Countries such as Canada, New Zealand, Norway and Sweden have used the MCI as an operational target (Ericsson et al., 1998; Eika et al., 1996). Canada determines the optimal MCI path such that when the actual MCI is above the target, the market views this as monetary conditions tightening and vice versa and it makes the necessary adjustments (Ericsson et al., 1998). Most recently constructed MCIs include Turkey, Hungary, Poland, Romania, Czech Republic, and India. Akdeniz (2021) calculated an MCI for Turkey and showed that when weights were properly adjusted over time, it closely predicted the developments of the country's economic fluctuations. Nucu and Anton (2018) showed that the MCI of Hungary, Poland, Romania, Czech Republic were able to track the economies monetary tightening. Sharma et al. (2021) recently developed an MCI for India and also established that it tracked monetary conditions well if properly adjusted for changes in weights over time. The MCI was also discovered to estimate GDP growth and inflation.

Observations similar to the present study have been made for Sub Saharan African economies such as Nigeria and South Africa. Yaaba (2013) established that similar to the present study, the exchange rate dominates the Nigerian MCI and that the MCI is consistent with economic output for the country. In contrast, Sharma et al. (2021) and Knedlik (2006) found that the interest rate dominates the Indian and South African MCI respectively, but also that there were certain differences between the MCI and monetary policy targets in the latter. The explanation of the differences was that the model used for calculating the MCI was a bit simplistic as it did not consider other key economic fundamentals such as technology, regulations and fiscal policy. This suggests that future studies may consider multiple variables in estimating the MCI. The current paper, however, has shown that the MCI constructed with interest rates and exchange rates is sufficient to guide monetary policy.

The current study finds private sector credit to have a causal effect on the MCI. This is in consistence with previous studies like Machirinani et al. (2020) who found the MCI was negatively related to banking sector leverage ratio in Zimbabwe. Guillaumin and Vallet (2017) also found bank credit negatively related to MCI but positively related to economic growth in Switzerland. More recently, Sharma et al. (2021) found monetary conditions tightening such as increases in interest rates and real exchange rates linked to increase in bank credit in India. While the current study found the relationship using Granger causality, there are previous studies which incorporated credit in the MCI (Guillaumin and Vallet, 2017; Sharma et al., 2021; Nucu and Anton, 2018; Kannan et al., 2007; Yaaba, 2013). The argument was to address the simplicity of the two factor MCI as highlighted above. Kannan et al. (2007) found bank credit offsetting the effect of real interest rate and real exchange rate on aggregate demand for India. Yaaba (2013) on the other hand found interest rate offsetting both variables. These two studies seem to suggest that for exchange rate dominated MCIs, credit reinforces exchange rate but countering interest rates. On the other hand, for interest rate dominated MCIs, it counters both interest and exchange rates.

Although this study has shown that the MCI components can be managed to target output growth in Zimbabwe, previous studies suggest that the interest rate and exchange rate components can be used to specifically target inflation. Knedlik (2006) showed that the MCI for South Africa is useful in targeting inflation through these components. Sharma et al. (2021) showed that monetary tightening through raising interest rates and exchange rate was negatively related to inflation in India. (Machirinani et al., 2020) showed that the MFCI components including interest rates have a bidirectional causal relationship with inflation. Since Zimbabwe has a recurring problem with inflation, further research is required to explore the effectiveness of the MCI in informing inflation targeting especially in the post dollarized economy. The period of analysis was easier to analyse because Zimbabwe was using the US dollar. Under the current economic environment that would be a challenge since the economy uses two exchange rates namely the official rate controlled by the central bank and used for government transactions and the parallel rate used by private individuals and businesses. The choice of interest rate and exchange rate used has a bearing on the MCI values as well as its relationship with output (Ericsson et al., 1998). Future research is thus needed to examine which particular exchange rate or hybrid is more appropriate. In addition to that, Kavila and Le Roux (2016) and Makena (2020) find major trading partner exchange rate and inflation affecting Zimbabwe's inflation. This means that future researchers may need to consider more than two variables to derive weights for the MCI components.

6. Conclusion and policy recommendations

This study aimed at developing an MCI for Zimbabwe and evaluating if it can be of any use as an indicator of the central bank's monetary policy stance. The paper successfully developed the MCI and showed that the exchange rate dominates interest rates in determining output in Zimbabwe. The paper also showed that the MCI is related to economic growth and other variables such as private sector credit and foreign interest rates. The study therefore concludes that the MCI is a tool that Zimbabwe could use as a monetary policy anchor for monitoring inflation and stimulate or curtail economic activity in line with desired levels.

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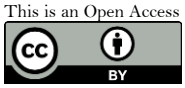

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Appendices

A1: Correlation Matrix

	Log GDP	Log MCI	Log M3	Log FIR	Log CRP	Log CPI
Log GDP	1.000000					
Log MCI	-0.538220	1.000000				
Log M3	0.619629	-0.597755	1.000000			
Log FIR	0.271627	-0.248912	-0.083770	1.000000		
Log CRP	0.499188	-0.405603	0.944197	-0.355012	1.000000	
Log CPI	0.449286	-0.288850	0.793265	-0.482901	0.891031	1.000000

A2: Phillip-Perron Unit root test results

Variable	Level		First difference		Order of Integration
	Intercept	Intercept and Trend	Intercept	Intercept and trend	
Log GDP	-3.236** (0.018)	-5.494*** (0.000)	-16.969*** (0.000)	-17.044 *** (0.000)	I(0)
Log MCI	-0.314 (0.923)	-2.804 (0.195)	-8.729*** (0.000)	-8.868*** (0.000)	I(1)
Log CRP	-17.053*** (0.000)	-10.873 *** (0.000)	-4.248 ** (0.000)	-6.156 *** (0.000)	I(0)
Log FIR	-0.616 (0.867)	-0.695 (0.974)	-11.928*** (0.000)	-12.115*** (0.000)	I(1)
Log M3	-8.740 *** (0.000)	-10.624 *** (0.000)	-8.527 *** (0.000)	-9.696 *** (0.000)	I(0)
Log CPI	-1.139 (0.699)	-1.658 (0.769)	-7.433*** (0.000)	-7.485*** (0.000)	I(1)

A3: Test for Serial correlation

F-statistic	**0.683058**	**Prob. F(2,97)**	**0.5075**
Obs*R-squared	1.486024	Prob. Chi-Square(2)	0.4757

A4: Test for heteroscedasticity

F-statistic	**1.188528**	**Prob. F(7,99)**	**0.3164**
Obs*R-squared	8.294911	Prob. Chi-Square(7)	0.3073
Scaled explained SS	84.23537	Prob. Chi-Square(7)	0.0000

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Unemployment and Foreign Direct Investment Nexus: Empirical Evidence from Ghana

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ABSTRACT

Purpose:
The paper examines the effect of foreign direct investment on unemployment in Ghana.

Design/methodology/approach:
The paper uses annual data spanning from 1990 to 2020 and employed the Autoregressive Distributed Lag (ARDL) estimation technique.

Findings:
The paper found that unemployment has a long-run relationship with foreign direct investment, gross domestic product, export and gross capital formation. Foreign direct investment and GDP has a negative long-run relationship with unemployment. On the contrary, export of goods and services positively relate to unemployment in the long-run devoid of gender. Lastly, we also found a mediating effect of GDP on FDI in reducing unemployment rate in Ghana.

Research limitations/implications:
The finding that export of goods and services relate positively with unemployment in the long run does not necessarily imply that Ghana should stop exporting goods and services in order to solve unemployment challenges in the country. Rather we should adopt the attitude of adding value to our raw products before exporting. And to reduce unemployment in the country, government should adopt incentivized tax policies to foreign investors to attract more FDI inflows into the economy.

Originality/value:
Not only does the present paper extend to more recent data, but it is also the first of its kind to the best of our knowledge in studying the nexus between FDI and unemployment rate in Ghana and also bringing to bear the gender dynamics of such relationship.

1. Introduction

With varied levels of development in their economic, political, and social systems, labor unemployment is one of the most significant issues that nation states throughout the globe are currently dealing with, particularly in light of the COVID-19 epidemic. History has it that almost all countries around the world have faced the problem of unemployment at one time or the other (Angela et al., 2013; ILO, 2020). Following the Great Depression, the unemployment issue first emerged in North America in 1929, where 4.3 million people were made unemployed in a matter of one year. This continued to the western countries soon after the World War II (Overy, 2020). Given this as a global challenge, the United Nations Agenda 2030 for sustainable development acknowledged the need for all nations to achieve full and productive employment and decent work for all and equal work of equal value. According to the World Bank, current unemployment rate in Sub-Saharan Africa (SSA) is above the world unemployment rate of 6.6%, and compared to other SSA countries, Ghana has a relatively low average of 4.7% unemployment rate (World Bank, 2022). Though this figure appears low, unemployment rate has grown by 11.37% between 2017 and 2021.

Several economic theories and studies have tried to explain the concept of unemployment, its determinants and consequences and how to reduce it. Whiles the Classical and Neo-Classical theories recognise only voluntary and frictional unemployment, the modern theories argued that unemployment is as a result of imperfections in the labour market (Felbermayr et al., 2011) as cited in Mustafa and Azizun (2020). The study of the relationship between unemployment and foreign direct investment (FDI) is so an important topic in the economic literature and to policy decision makers, more especially in Sub-Saharan Africa where FDI inflows hit a record high of USD83 billion in 2021 and USD 2.6 billion to Ghana in the same year (World Investment Report, 2022). More so, it is hypothesised that

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FDI will increase government investment spending through increases in state tax-revenue, seasonal unemployment stabilization, and the generation of intensive-labour projects which are characterised by the use of contemporary technology and therefore the creation and diversity of new work prospects (Mustafa and Azizun, 2020). Several governments in Ghana since independence have tried reducing unemployment challenges in the country at one time or the other by focusing on economic growth and assuming that higher economic growth will lead to higher employment rate. The question that arises is how does FDI inflow affect the situation of unemployment in the country, more especially in the period of Ghana beyond aid?

In responding to the question, the current study seeks to explore empirically the relationship between unemployment rate and FDI in Ghana. This study is unique and important as it is the first of its kind to the best our knowledge in studying the nexus between FDI and unemployment rate in Ghana and also bringing to bear the gender dynamics of such relationship. Results of the study will only not help government and policy decision makers but will also help contribute to the debate from Ghana's perspective in fashioning out policies toward reducing unemployment by the African Continental Free Trade Agreement (AfCFTA).

2. Review of Literature

Foreign direct investment's contribution to the successes of economies of nations cannot be overemphasised, more especially to those with less developed financial markets. It is believed by many economists and policy practitioners to have the tendency of reducing unemployment, widening the frontiers of business prospects and elevating the income levels of people of receiving nations.

Mukit (2020) examined if macroeconomic variables substantially affect unemployment in the long run by using annual data starting from 1991 to 2018. Applying the vector autoregression and Johansen cointegration models for its cointegration test, the study concluded that inflation, gross domestic product, population growth, foreign direct investment and foreign debt affect the unemployment level of the Bangladesh economy. Dijan and Senad (2017) analysed the effect of FDI on unemployment rate in west Balkan countries from 2000 to 2014. Using OLS regression, the study revealed no positive impact of FDI on unemployment. Similarly, Mehmet and Tahir (2013) examined the unemployment impact of FDI in seven developing countries. The study applied panel cointegration and panel causality test on yearly data from 1981 to 2009 and conclude that FDI positively affect unemployment in the long run. The causality test however only shows a relationship from FDI to unemployment in the long run. Using panel data analysis techniques and data from 1994 to 2014, Kunofiwa (2018) investigated the employment impact of FDI in the BRICS. The findings revealed that high levels of economic expansion, financial development and human capital are necessary conditions in BRICS for FDI's to positively affect employment generation. In their study, Hisarciklilar et al. (2014) examined the contribution of FDI in employment creation in Turkey from 2000 to 2008 at a sectoral level. Using a panel data analysis, the study found a positive but weak relationship between employment and FDI. Johnny et al. (2018) investigated the unemployment impact of FDI in Nigeria for the period 1980 to 2015. Using OLS and cointegration test, the study posed a negative and insignificant impact of FDI on unemployment and a positive but significant effect of capital formation on unemployment. Similarly, Irpan et al. (2018) explored the unemployment impact of FDI in Malaysia using a 32-year annual data for its analysis. Adopting the ARDL model technique, the study observed GDP, FDI and number of foreign workers to significantly affect and reduce unemployment rate in Malaysia.

Mkombe et al. (2021) studied the youth unemployment impact of FDI in Southern African Development Community (SADC) region for the period 1994 to 2017. Applying the Feasible Generalized Least Squares (FGLS) technique, the study revealed an insignificant negative effect of FDI on youth unemployment in the SADC region. Khan et al. (2022) explored the effect of FDI on employment creation in Pakistan from 1900 to 2019. Using the ARDL bound test approach; the study found that increases in FDI, industrialization and gross capital formation increases the opportunities for people to be employed both in the short and long-run. From the above review, it is clear that the pool of studies has failed to give a clear-cut answer on the exact effect of foreign direct investment on unemployment rate. Also, the effect of foreign direct investment on unemployment differs from country to country and therefore results from such studies cannot be used to generalize and therefore the need to conduct a study using Ghana as case study. It is also worthwhile to mention that for the past two decades, Ghana is the second largest recipient of FDI in West Africa after Nigeria (Bekoe and Abdul Rahaman, 2021) and therefore choosing Ghana for this kind of study cannot be underestimated.

3. Methodology

The section explores the various statistical tools and packages used for data analysis. We started by conducting a basic descriptive analysis of the variables under consideration. Secondly, the study checked for the presence of unit roots of the time series data such that none of the variables is stationary of order two (Giles, 2013). The study applied the Phillips-Perron (PP) (Phillips, 1991) and Augmented-Dicky-Fuller (ADF) (Dickey & Fuller, 1979) tests for its unit root test. The null hypothesis of ADF and PP is that the series are non-stationary and therefore has unit root. If the critical value at a significant level of 5% is less than the t- statistic, the null hypothesis is rejected in favour of the alternative and concludes that the series are stationary. Having investigated the unit roots and confirming that the variables are integrated, the next step is to determine whether the variables have a long-term relationship. We can then proceed to use the autoregressive distributive lag (ARDL) model once the cointegration between the variables has been established. The bound test's null hypothesis is that there is no long-run association between the series being examined. The decision rule for the bound test is that the null hypothesis is rejected in favour of the alternative if the calculated F-statistic exceeds the critical value of the upper bound I (1). If the F-value on the other hand is lower than

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the critical value of the lower bound I (0), the null hypothesis of no cointegration among the variables is accepted. After the bound test verified the long-term association, we used the ARDL model to get the long and short-term estimates. The functional form of the model to be estimated is thus presented as:

$$UEMP = f(FDI, CRED, GCF, GDP, EXP, INF) \quad (1)$$

where the UEMP is unemployment rate, FDI is foreign direct investment, CRED is the domestic credit to private sector, GDP is the gross domestic product, GCF is gross capital formation, EXP is export and INF is the inflation rate. Data is sourced for these variables spanning from 1990 to 2020 for analysis. Equation 1 can be expressed in linear form as follows:

$$UEMP_t = \alpha_0 + \alpha_1 FDI_t + \alpha_2 CRED_t + \alpha_3 GCF_t + \alpha_4 GDP_t + \alpha_5 EXP_t + \alpha_6 INF_t + \varepsilon_t (2)$$

For the ARDL model to be applied, the variables must be stationary at either its levels, I (0), its first difference, I (1), or a mixture of both. The ARDL is used because of its inherent ability to handle different levels of integration and also the ability to simultaneously estimate the short and long-run coefficients (Işık, 2013) makes it superior to traditional models like the Johansen cointegration (Johansen, 1991) and Engle and Granger (Engle & Granger, 1987). The ARDL model also provides reliable results for small sample size (Khan et al., 2019) and lastly, the trouble of endogeneity is also resolved by incorporating lags into the model (Asteriou et al., 2020; Khan et al., 2019). The ARDL model as used in the current study is therefore specified as follows:

$$\Delta UEMP_t = \beta_0 + \beta_1 UEMP_{t-1} + \beta_2 FDI_{t-1} + \beta_3 CRED_{t-1} + \beta_4 GCF_{t-1} + \beta_5 GDP_{t-1} + \beta_6 EXP_{t-1} + \beta_7 INF_{t-1} + \sum_{j=1}^{k} \gamma_1 \Delta UEMP_{t-j} + \sum_{j=1}^{r} \gamma_2 \Delta FDI_{t-j} + \sum_{j=1}^{r} \gamma_3 \Delta CRED_{t-j} + \sum_{j=1}^{r} \gamma_4 \Delta GCF_{t-j} + \sum_{j=1}^{r} \gamma_5 \Delta GDP_{t-j} + \sum_{j=1}^{r} \gamma_6 \Delta EXP_{t-j} + \sum_{j=1}^{r} \gamma_7 \Delta INF_{t-j} + \mu_t (3)$$

Where β_0 is the intercept term while β_1 to β_7 denotes the long-run coefficients and γ_1 to γ_7 are the short run coefficients, k reports the lag for unemployment rates, r represents lags of the regressors, μ_t report the error residuals and Δ represent the difference operator. However, if there is cointegration or long-run association between the variables after the bounds test, both short-run and long-run relationships would be specified. Therefore, the error correction model (ECM) is adopted to specify the long-run relationship as specified in equation (4) below:

$$\Delta UEMP_t = \sum_{j=1}^{k} \gamma_1 \Delta UEMP_{t-j} + \sum_{j=1}^{r} \gamma_2 \Delta FDI_{t-j} + \sum_{j=1}^{r} \gamma_3 \Delta CRED_{t-j} + \sum_{j=1}^{r} \gamma_4 \Delta GCF_{t-j} + \sum_{j=1}^{r} \gamma_5 \Delta GDP_{t-j} + \sum_{j=1}^{r} \gamma_6 \Delta EXP_{t-j} + \sum_{j=1}^{r} \gamma_7 \Delta INF_{t-j} + \varphi ECM_{t-1} + \mu_t (4)$$

Where ϕ which is the coefficient of the lagged error correction term (ECM), is used to determine the speed of adjustment of the parameter in the long-run, and it is expected to be negative and significant. ECM is the error correction term which accounts for the long run representation in the specified model (Darko, 2016). After estimating the short and long-run coefficients, some diagnostic and stability test will be conducted to ensure that the model is free from serial correlation, heteroskedasticity and also stable.

4. Results and Discussions

4.1 Stationarity Test

Regression analysis with non-stationary series produces spurious outcomes which cannot be used for analysis, forecasting or policymaking (Bashar, 2015; Emeka and Aham, 2016), thus the Augmented Dickey-Fuller (ADF) and the Phillips-Perron (PP) tests was employed to test the unit roots.

Table 1: Results of Unit root test (ADF and PP)

Level Form					First Differenced			
	ADF		PP		ADF		PP	
Variable	Intercept	Prob	Intercept	Prob	Intercept	Prob	Intercept	Prob
UNEMP	-2.2199	0.2039	-3.1216	0.0356**	-3.4360	0.0177**	-3.4427	0.0175**
FDI	-2.7209	0.0823*	-2.7519	0.0774*	-4.4474	0.0015***	-4.3031	0.0021***
GDP	-3.1550	0.0331**	-3.1435	0.0339**	-6.1623	0.0000***	-7.5402	0.0000***
INF	-3.8669	0.0062***	-3.8669	0.0062***	-5.4166	0.0002***	-18.7997	0.0001***
EXP	-2.5099	0.1232	-2.4812	0.1299	-5.6556	0.0001***	-5.6556	0.0001***
GCF	-2.9804	0.0487**	-2.7612	0.076*	-5.0885	0.0003***	-5.2715	0.0002***
CRED	-1.7518	0.3961	-1.7510	0.3965	-6.6258	0.0000***	-6.4908	0.0000***

Source: Author's construct, 2022.

Table 1 present results of the unit root test and indicate that when intercept is considered, all variables were stationary at levels except unemployment rate (UNEMP), export of goods and services (EXP) and domestic credit to private sector (CRED) but become stationary after first differencing. This shows that only I (0) and I(1) series are present. Hence the Autoregressive Distributed Lag (ARDL) method is appropriate.

4.2 Bounds Test for Cointegration

After determining if the series is stationary, we perform the bound test for cointegration. The prognosis for testing the existence of long-run relationship is anchored by the bounds-test for cointegration. This is required when using the ARDL model. Table 2 present the bound test result for cointegration.

Table 2: Results of Bounds Test for Cointegration

F-bounds Test				
H_o: No long-run relationship				
Test Statistic	Value	Sig	I(0)	I(1)
F-Stat	9.1618	10%	2.03	3.13
K	7	5%	2.32	3.50
		2.5%	2.60	3.84
		1%	2.96	4.26

Source: Author's construct, 2022.

The F-statistic value of 9.1618 as shown in Table 2 exceed the upper bound value, I (1) at 5% significant level and therefore the null hypothesis of no long-run relationship is rejected in favour of the alternative that there is a long-run joint cointegration. Having established the presence of long-run relationship between unemployment and the covariates using the bound test for cointegration, the ARDL framework was employed to estimate the long-run coefficients. Results from Table 3 revealed that unemployment has a long-run relationship with foreign direct investment (FDI), gross domestic product (GDP), export (EXP), gross capital formation (GCF) and interaction of GDP and FDI. The coefficient of FDI is negative and significant at 5%, indicating the presence of a negative long-run relationship between foreign direct investment and unemployment. A unit increase in FDI reduces unemployment in Ghana by 39.7% holding all other variables constant. This result is expected as FDI is expected to boost government investment expenditure and therefore creating job opportunities, leading to reduction in unemployment rate. This finding is congruous with the results of Hamidah et al. (2016) and Mehmet and Tahir (2013) who found negative long-run association between FDI and unemployment in Malaysia and Thailand respectively. By gender, we found a negative but significant long-run correlation between FDI and Male unemployment rate. A unit increase in FDI reduces male unemployment rate by 77.3% all else constant. FDI appears to promote female unemployment though not statistically significant. Similarly, gross domestic product (GDP) is found to negatively influence unemployment in the long run. Impliedly, a unit increase in GDP will reduce unemployment rate in Ghana by 25% and with male unemployment rate by 32.6% holding all other variables constant. This result conforms to Tegep et al. (2019) finding that GDP and provincial minimum wage reduces unemployment rate in Indonesia. It also supports the Okun's law which states that a 1 percentage point decrease in unemployment rate will results to a 3 percent rise in GDP.

Table 3: Results of long-run effect of FDI on Unemployment rate

Levels Equation Case 3: No Trend and Unrestricted Constant			
Variable	Female Coefficient	Male Coefficient	Pooled Coefficient
FDI	0.148387	-0.772581***	-0.397348**
	(-0.355059)	(0.250195)	(-0.152531)
GDP	-0.159291	-0.325901***	-0.250003***
	(-0.156856)	(0.085052)	(-0.080613)
CRED	0.139272	0.443265*	0.272679
	(-0.520341)	(0.235935)	(-0.254607)
EXP	2.405586**	1.056595***	1.528402***
	(-0.874461)	(0.287437)	(-0.334721)
GCF	0.861	1.758154**	1.211932***
	(1.232165)	(0.72623)	(-0.401931)
INF	0.513586**	0.122588	0.33632***

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	(0.229147)	(0.109634)	(-0.088254)
GDP_FDI	0.009577	0.045306**	0.029998**
	(0.023634)	(0.016583)	(-0.010897)

Note: Numbers in parenthesis represents standard errors.

Source: Author's construct, 2022.

Also, export of goods and services (EXP), Gross capital formation (GCF) and inflation (INF) are found in the long run to positively influence unemployment rate. Thus, increases in export by one unit, increases unemployment rate by 1.53 units. This has the same distributional effect on gender. Economic theory tells us that trade can help boost employment, but with a caveat. This depends on whether the country involved in export has a comparative advantage in producing the exported goods. This implies that, countries with comparative disadvantage in producing exported goods are more likely to lose their labour force, thereby increasing unemployment. Perhaps Ghana could be exporting goods it has comparative disadvantage[1] in and therefore increasing export will lead to increasing unemployment all else remain constant. This result is at variant to the study of Mustafa and Azizun (2020) who found export to negatively influence unemployment in the Middle East and North Africa and that of Dritsakis and Stamatiou (2018) study which report a bidirectional and inverse relationship between unemployment rate and export in fifteen old EU Members. The coefficient of inflation (INF) is positive and significant for the pooled and female unemployed, suggesting that inflation has a positive long-run correlation with unemployment. A 1% increase in inflation, increases unemployment by 33.6% holding all other variables constant. This result contradicts the studies by Arslan and Zaman (2014) and Mustafa and Azizun (2020) who found inflation to have negative impact on unemployment in Turkey and Middle East and North Africa respectively. Finally, the coefficient of the interacting variable (GDP_FDI) is significant, suggesting that FDI affect unemployment rate at different levels of economic growth. In fact, increases in FDI inflows will continue to decrease unemployment rate if growth rate in Ghana remains within a threshold of 13.2[2] percent all things being equal.

4.3 Short-run Dynamics

The ARDL has three components: the error-correction term (ECT), the short-run and the long-run. From Table 4, ETC (CointEq) has a negative coefficient and it is significant at 1% level. This is expected as it confirms the existence of a long-run relationship among variables as earlier on established. The error-correction term can be interpreted to mean that fluctuations in unemployment (that is above or below its equilibrium level) are adjusted at a speed of 34.4% to ensure long-run convergence to equilibrium. The short-run estimates revealed a negative and significant association between FDI and unemployment. A one percent increase in FDI will reduce unemployment in the short run by 3.7% holding other variables constant. Similarly, gross capital formation (GCF) negatively affects unemployment in the short run. The coefficient suggests that a 1% increase in capital investment reduces unemployment rate by 10.8 and 10.7% respectively for the pooled and female category. This result is expected and conforms to the studies of Limosani and Monteforte (2017) and Boianovsky (2015) who made the case that capital growth boosts production capacity, thereby generation more jobs and lowering the unemployment rate in the country. The one-lagged period of GCF also presented a mixed (positive and negative) significant impact on unemployment for the female and male categories. In a similar vein, one-lagged period for FDI and GDP presents a negative significant effect on unemployment. Finally, though the interaction variable does not significantly affect unemployment in the short-run, its one-lagged period positively and significantly affects unemployment for the pooled and male categories.

Table 4: Short Run Effects of FDI on Unemployment in Ghana

ARDL Error Correction Regression

Case 3: No Trend and Unrestricted Constant

Variable	Female Coefficient	Male Coefficient	Pooled Coefficient
C	1.9575***	3.1440***	2.6389***
	(-0.1971)	(0.3132)	(0.2384)
D(FDI)	-0.1012***	0.0510**	-0.0369*
	(0.0270)	(0.0209)	(0.0202)
D(FDI(-1))		-0.1076***	-0.0693***
		(0.0290)	(0.0208)

[1]More especially where most of our exported goods like Cocoa, Gold among others does not receive value addition before its export. As a result, potential jobs that will have been created along the value chain are being exported, thereby creating more unemployment in the country.

[2]UNEMP = 0.03GDP*FDI-0.3973FDI

DOI: 10.25103/ijbesar.152.05

D(GDP)	-0.0228**	0.0036	-0.0081
	(0.0094)	(0.0089)	(0.0085)
D(GDP(-1))	-0.0165***	-0.0669***	-0.0368***
	(0.0043)	(0.0100)	(0.0083)
D(CRED)	0.1017		0.0210
	(0.0802)		(0.0669)
D(EXP)	0.0027	0.0318	-0.0278
	(0.0636)	(0.0627)	(0.0543)
D(EXP(-1))	0.2418***	0.2217***	0.2643***
	(0.0651)	(0.0593)	(0.0584)
D(GCF)	-0.1069*	-0.0712	-0.1083**
	(0.0559)	(0.0580)	(0.0470)
D(GCF(-1))	-0.1138**	0.1669**	
	(0.0517)	(0.0648)	
D(INF)		-0.1261***	
		(0.0166)	
D(INF(-1))		-0.0636***	
		(0.0139)	
D(GDP_FDI)	0.0001	-0.0040***	-0.0014
	(0.0012)	(0.0012)	(0.0011)
D(GDP_FDI(-1))		0.0071***	0.0031***
		(0.0014)	(0.0010)
CointEq(-1)*	-0.1896***	-0.4403***	-0.3435***
	(0.0189)	(0.0436)	(0.0308)
Observation	29	29	29
R-squared	0.9162	0.9468	0.9379
S.E. of regression	0.0487	0.0396	0.0400
F-statistic	19.6910	20.5451	23.3295
Prob(F-statistic)	0.0000***	0.0000***	0.0000***

Source: Author's construct, 2022.

4.4 Residual and Stability Diagnosis

Having estimated the short and long-run effects of the covariates on the dependent variable, the residual and stability diagnosis was conducted and the result is presented in Table 5. The study has employed the Jarque-Bera test for normality, Breusch-Pagan residual test for heteroskedasticity and the serial correlation LM test for serial correlation.

Table 5: Residual and Stability Tests Results

Method	**F-Statistic**	**Prob**
Serial correlation	2.2108	F (2,8) = 0.1720
Heteroscedasticity	1.146	F (18,10) = 0.4268
Normality (Jarque-Bera)	0.2476	0.8836, Normal
CUSUM	Within 5% critical region	Stable
CUSUMSQ	Within 5% critical region	Stable

Source: Author's construct, 2022.

The probability values of the F-statistic in all scenarios are all more than the 5% level of significance, showing that there is neither a serial correlation nor a heteroskedasticity, and so the no serial correlation and heteroskedasticity null hypothesis is accepted. Last but not the least; the study used the cumulative sum of recursive residuals (CUSUM) and the cumulative sum of the square recursive residual (CUSUMSQ) test to check for parameter stability. Figures 1,

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2 and 3 in the appendix report results of the CUSUM and CUSUMSQ for the pooled, female and male categories respectively. As can be observed from the graphs, all the blue lines fall inside the red lines' borders, suggesting that the models employed in the study are stable.

5. Conclusion and Recommendations

This study explored the nexus between foreign direct investment and unemployment rate in Ghana. Annual data was sourced from the World Bank Development indicators' website spanning from 1990 to 2020 and used for analysis. Using the ARDL bound test of cointegration to examine the long-run relationship, the study revealed that unemployment has a long-run relationship with foreign direct investment, gross domestic product, export and gross capital formation. The increasing flow of foreign direct investment into the economy of Ghana helps reduce unemployment rate both in the long and short run. When disaggregated by gender, males unemployed appear to benefit from such inflows. As expected, growth in GDP negatively affect unemployment rate in the long run. This could be explained by the fact that expansion of the economy provides avenues for job creation and therefore unemployment rate is reduced. The coefficient of export is positive and significant for all categories, indicating that export of goods and services in the long-run increases unemployment rate irrespective of gender. The result also shows that gross capital formation negatively affects unemployment rate in the short-run for the pooled and female categories. Whiles this may be refreshing, capital formation tends to promote unemployment in the long-run. Finally, the mediating effect of GDP on FDI negatively affects unemployment rate in the long run. Thus, increases in FDI inflows will continue to reduce unemployment rate if growth rate in Ghana remained within a threshold of 13.2 percent. Based on the afore mentioned conclusions, the study recommends that beyond government flagship programs of introducing the Nation Builders Corps (NABCO) and Planting for Food and Jobs (PFJ) to reduce youth unemployment in Ghana, government should implement incentive-based tax policies to foreign investors to attract more FDI inflows into the economy. Policy makers should formulate and repackage existing policies that is geared towards growing the economy as growth in GDP has the tendency of reducing both short and long-run unemployment. For instance, the government planting for food and jobs program be repackage by making its operations more transparent and apolitical. Government should also encourage and facilitate new and existing entrepreneurs who want to delve into small-scale industry business to acquire capital at much lower rate to enable them expand their businesses. This will facilitate the creation of new job avenues. Finally, it is recommended that government should formulate policies to reduce (if not possible to stop) the exportation of raw commodities such as cocoa, timber, gold among others without value addition. This will help create more job avenues along the value chain, thereby reducing unemployment rate in the long run.

The study was not without limitations. First, institutional factors such as level of democracy, legal framework and corruption were not considered in the study. These are key takeaways for foreign investors and therefore influence the amount of investment they commit to a given country. Also, whiles we found FDI to reduce unemployment in Ghana, the study could not account for the gender differentials in its reduction. Future studies should consider addressing this and extending the analysis to include other African countries.

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Appendix

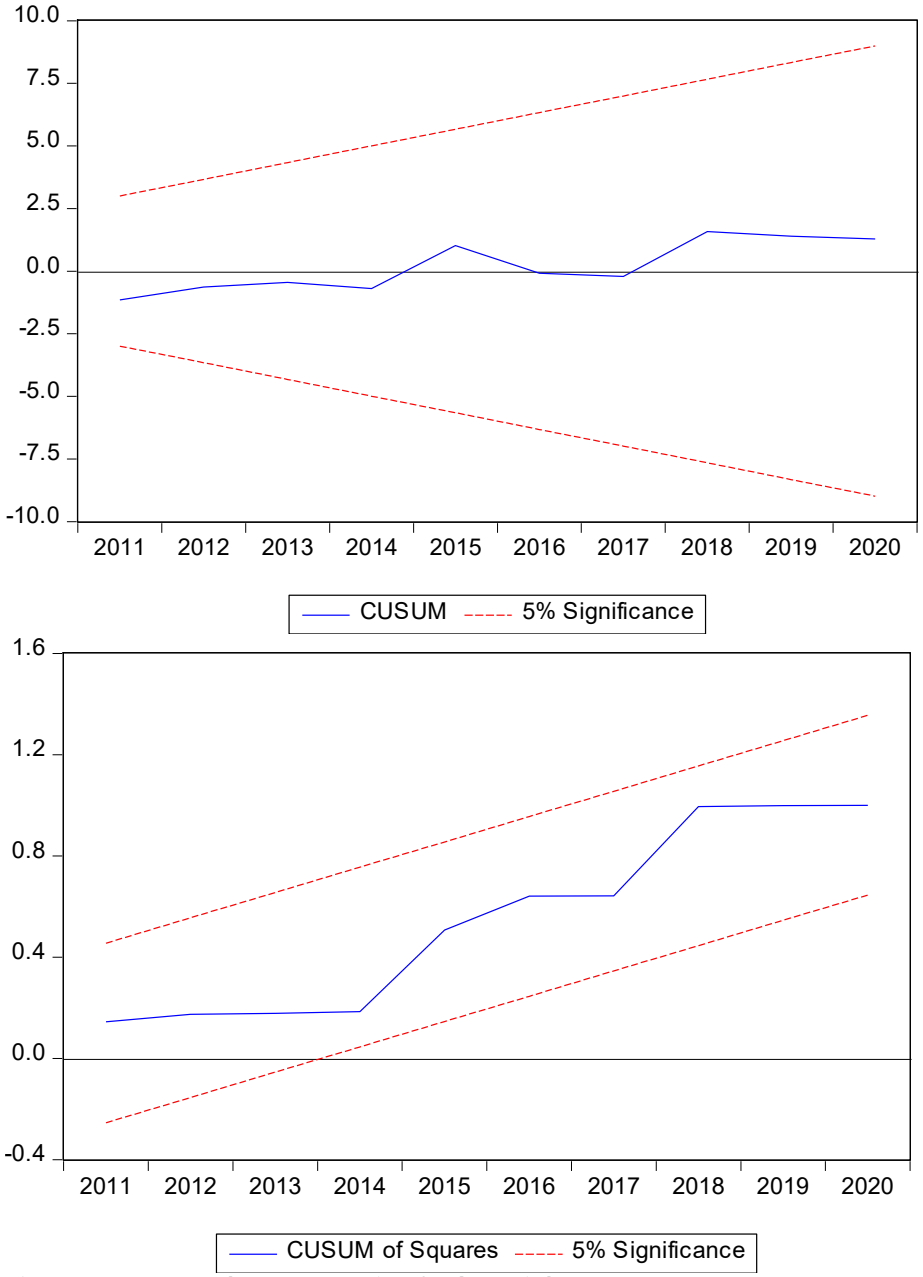

Figure 1: CUSUM and CUSUMSQ plots for the pooled category

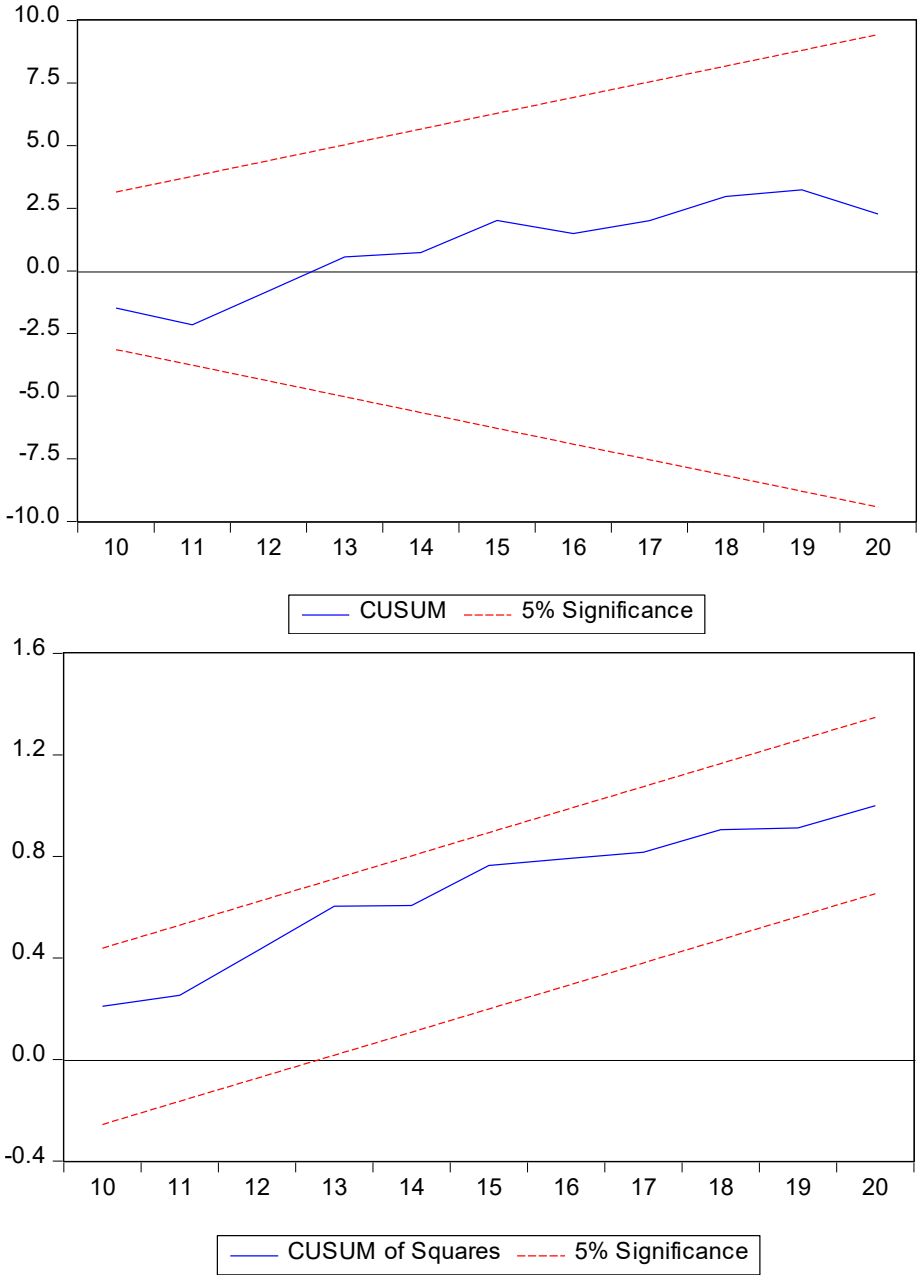

Figure 2: CUSUM and CUSUMSQ plots for the Female category

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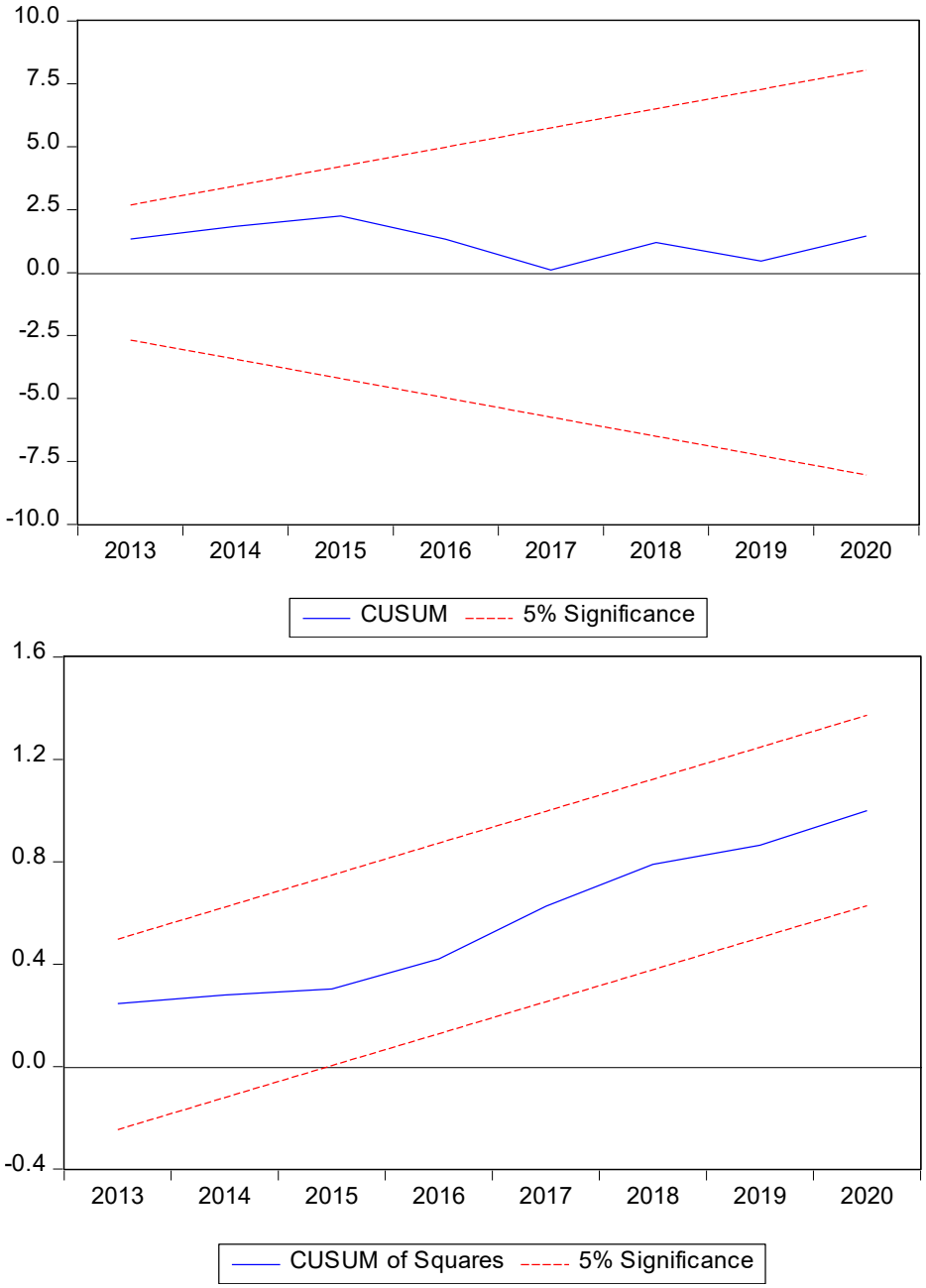

Figure 3: CUSUM and CUSUMSQ plots for the Male category

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Reframing the High-Technology Landscape in Greece: Empirical Evidence and Policy Aspects

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ABSTRACT

Purpose:
The major purpose of the paper is to explore, identify and highlight the general and specialized (sector-specific) long-term technology trends following the evolution of technology-intensive sectors in Greece during the last years. In a similar vein, sectoral differentiations have been identified and highlighted (e.g. evolution, growth, size distribution, industrial dynamics) as an analytical dimension of innovative activity across the high-technology sectoral domain.

Design/methodology/approach:
The paper methodology consists of a systematic review of primary data collected through the Eurostat/SBS database and the SME Performance Review 2022, as one of the major tools the European Commission uses to monitor and assess countries' progress in implementing the Small Business Act (SBA). The methodological approach of the paper involves the mapping of sector-specific trends in terms of technology-intensive categories, size classes and underlying sectoral characteristics and dynamics trends.

Findings:
The exploration of detailed and long-term data within the landscape of technology-intensive sectors in Greece, provides a clearer picture for the upward and downward trends, the sector-specific differentiations and the upcoming challenges. High-tech enterprises constitute a considerably important part of the country's productive base with gradually increasing trends in all relevant categories. This is further motivated by the development of start-ups and spin-offs in several fields of higher technological specialization ('deep tech').

Research limitations/implications:
It is widely accepted that aggregated technology growth is a long-term and multi-level process within an economy. Further research regarding the actual and potential spillover effects of technology sectors across the wider economy constitutes an important area of further research. The paper provides a multi-dimensional analytical framework to identify sector-based technological and industrial underlying dynamics and understand long-term sectoral characteristics and trends within the high-tech industry evolution in Greece.

Originality/value:
The paper provides an analytical approach to explore the underlying industrial dynamic trends within the technology-intensive sectors in Greece. The exploration of detailed and long-term data within the landscape of technology-intensive sectors in Greece provides an overall view of the underlying technology-intensive sectors' dynamics, the sector-specific differentiations, the upcoming challenges and the innovation policy implications.

1. Introduction

Emerging technologies constitute one of the major mechanisms transforming economies in several different dimensions. In this context, high technology is connected to new science-based activities, novel technology-based processes and products, high technology new ventures (e.g. start-ups, spin-offs) as well as new technology-based emerging sectors (e.g. semiconductors, robotics, nanotechnology, biotechnology, Artificial Intelligence and machine learning).

A large part of high-technology sectors is following an upward trend during the last years in Greece. This, in turn, interacts and reinforces multiplier effects in several interlinked sectors and economic activities providing an enhanced maturity to critical aspects of the national innovation system (e.g. VC funds' investments). With the increasing recognition that explaining high-technology sectors' growth indispensably requires taking into account the

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broader time framework and the sector-specific features, the present paper aims to shed some light on the dominant long-term trends driving the emerging technology growth prospects.

Based on recently published empirical data, the paper sets out to build an analytical framework in order to explain the expansion of technology-based ecosystem in Greece. Nevertheless, it seems that some aspects are not equally developed throughout the last years. Remarkably, differentiations are observed between sectors and sub-sectors. In the long-run for instance, high-tech enterprises in the knowledge-intensive services sectors are revealing a pathway of growth consistency while the high-tech sub-category in the manufacturing sector is characterized, in several sub-sectors, by a slower (or even occasionally declining) trend.

Last but not least, the crucial role of technology and innovation policy is highlighted in congruence to the major challenges emerging next to the sustainable and robust growth of the technology-intensive industries in the country. In light of the above, a framework for the formulation of a new technology and innovation policy is needed to enhance the contribution of high-technology sectors in many complementary critical aspects (e.g. job-intensity, value added appropriation, spillovers, strategic alliances and interconnection to international value chains, technology embeddedness) related to economic transformation processes (e.g. interlinkages with economy-wide sectors).

2. Review of Literature

Technology-intensive sectors bring a transformative potential in several science-based and technology-oriented sectors. In tandem, technology-based sectors might potentially pave the way for major transformations within traditional sectors through the deployment of new processes, products, services and business models. Similarly, innovation is considered a major mechanism of economic growth and competitiveness of business firms and economies (Schumpeter, 1911; Romer, 1990). Entrepreneurship might play a decisive role for economic growth (Acs, 2006), especially when it is based on innovative ventures, high-growth firms and technological knowledge (Colombelli et al., 2013).

Meanwhile, appropriated and evidence-based government policy on entrepreneurial activity constitutes and integral part of a conducive business environment (Minniti, 2008). According to Audretsch et al. (2020), innovative start-ups can create new industries and enhance considerable economic and societal impacts. Consequently, start-ups hold a central role in technology and innovation policy agendas (through several programmes and supporting schemes) during the last years (Autio et al., 2014).

Unsurprisingly, a wide array of policy initiatives aiming to support the growth of technology-intensive sectors has been implemented worldwide. Nevertheless, differentiated features characterize different sectors and technologies; policy tools that worked at one sector might not be equally efficient to another one. Thus, the type and the extent of the policy tools vary significantly and thus, the empirical data call for specialized approaches to enrich the design of targeted and holistic innovation policies.

Government-designed schemes and measures supporting technology-based entrepreneurship include a wide range of different tools, which involves R&D subsidies, tax allowances, counselling services and training (Autio et al., 2007). The major rationale of government interventions in these fields includes the need to mitigate technology and market risk and uncertainty, to provide enriched financial resources and to accelerate scale-up growth of technology-intensive companies. Moreover, the relationship between institutions and innovation constitutes a growing field of research (Rodrik et al., 2004). As a result, institutional conditions and institutional quality are inextricably interlinked to a business environment conducive to innovation (Sharma et al., 2022).

Research results derived from empirical studies provide evidence to clearly understand innovation processes by taking into account internal and contextual factors (Becheikh et al., 2006). The present paper contributes to the existing research by focusing on the technology-intensive sectors' underlying growth trends in Greece. As an empirical study, the paper illustrates the long-term patterns across the different sectors composing the high-technology landscape. In a similar vein, sectoral differentiations have been identified and highlighted as an analytical dimension of innovative activity. Based on the empirical data, differentiated trends provide an evidence for the formulation of a favourable policy environment for technology growth and innovation both in terms of early-stage, start-up but also scale-up phases.

3. Methodology

The main purpose of the present paper is to unearth, identify and highlight the general and specialized (sector-specific) technology trends following the evolution of technology-intensive sectors in Greece during the last years. The paper involves a systematic review of primary data collected through the Eurostat/SBS database and the SME Performance Review 2022, as one of the major tools the European Commission used to monitor and assess countries' progress in implementing the Small Business Act (SBA).

The methodological approach of the paper involves the mapping of sector-specific trends in terms of technology-intensive categories and size classes along with underlying sectoral characteristics and dynamic trends. These dimensions, in turn, are analyzed in congruence to different sector-specific parameters related to the number of enterprises, employment rates and value added. In that respect, there are two main objectives: i) to identify underlying trends across sectors in common dimensions; ii) to explore differentiations between sectors; and iii) to highlight critical aspects which would contribute to foster and formulate a multi-level innovation policy for the technology-intensive sectors in the country.

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4. High-technology sectors in Greece – findings

The exploration of detailed and long-term data within the landscape of technology-intensive sectors in Greece provides an overall view for the underlying technology-intensive sectors' dynamics, the sector-specific differentiations, the upcoming challenges and the innovation policy implications.

4.1. Knowledge-intensity in manufacturing industries – number of enterprises

A critical issue related to business, sector and economy-wide growth is that of knowledge-intensity. As it is illustrated in Table 1, the number of high-technology enterprises is a relatively small part of the manufacturing sector during the period 2008-2022. In tandem, the number of high-technology enterprises is relatively stagnant. Similarly, in the sub-category *Medium-high-technology*, the number of enterprises reaches a relatively higher percentage in relation to the total number of enterprises in the manufacturing sector but it is still remaining a small part.

Table 1: Knowledge-intensity in manufacturing industries - number of enterprises

Manufacturing industries	***2008***	***2009***	***2010***	***2011***	***2012***	***2013***	***2014***	***2015***
High-technology	628	534	508	532	441	363	592	525
Medium-high-technology	5,932	5,751	5,500	5,314	4,375	3,665	4,926	4,649
Medium-low-technology	24,861	23,512	22,396	21,906	18,907	16,517	19,714	18,051
Low-technology	53,442	53,629	50,799	46,194	40,746	37,073	40,732	38,493
Total manufacturing	**84,863**	**83,426**	**79,203**	**73,946**	**64,469**	**57,618**	**65,964**	**61,718**
Manufacturing industries	***2016***	***2017***	***2018***	***2019***	***2020***	***2021***	***2022***	-
High-technology	531	503	515	536	536	544	557	-
Medium-high-technology	4,567	4,393	4,423	4,427	4,457	4,536	4,647	-
Medium-low-technology	17,979	16,640	16,522	16,492	16,596	16,960	17,436	-
Low-technology	38,664	35,703	35,458	35,420	35,693	36,419	37,392	-
Total manufacturing	**61,741**	**57,239**	**56,918**	**56,875**	**57,282**	**58,459**	**60,032**	-

Source: SME Performance Review 2022·Eurostat/SBS database.

Similarly, the overall view of the long-term trend is illustrated in the Figure 1. As it is depicted, the major part of the manufacturing sector remains concentrated within the categories *Low technology* and *Medium-low technology*. This trend, in turn, constitutes a major feature of the Greek economy affecting its wider growth path during the last decades.

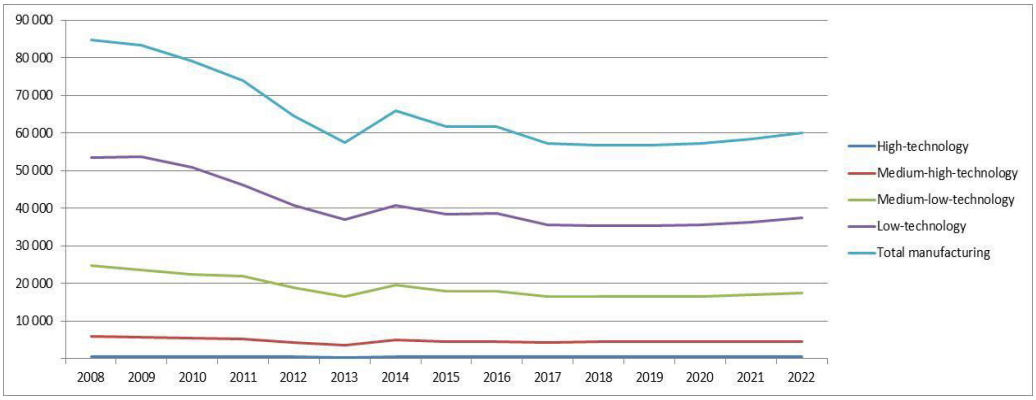

Figure 1 Knowledge-intensity in manufacturing industries - number of enterprises

Source: SME Performance Review 2022·Eurostat/SBS database.

4.2. Knowledge-intensive services – number of enterprises

The picture in the services sector is slightly different. The sub-category *High-tech*is a relatively large part –in contrast to the manufacturing industries- within the category *Knowledge-intensive services*. Moreover, the number of enterprises

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within the sub-category *High-tech* is consistently increasing, especially since 2014. Nevertheless, the major part of the enterprises in the services sector as a whole is concentrated within the category *Less knowledge-intensive services* (Table 2).

Table 2: Knowledge-intensive services - number of enterprises

	2008	***2009***	***2010***	***2011***	***2012***	***2013***	***2014***	***2015***
Knowledge-intensive services, of which	**139,727**	**141,833**	**137,749**	**132,553**	**128,860**	**122,337**	**186,686**	**176,627**
Market services	121,525	123,726	120,601	115,678	112,057	105,505	157,685	148,183
High-tech	13,538	13,434	12,705	12,442	12,283	12,355	24,651	24,287
Other	4,664	4,673	4,443	4,433	4,520	4,477	4,350	4,157
Less knowledge-intensive services, of which	**496,090**	**483,774**	**472,634**	**442,553**	**438,066**	**426,188**	**481,124**	**460,109**
Market services	495,736	483,413	472,280	442,199	437,714	425,794	479,885	458,939
Other services	354	361	354	354	352	394	1,239	1,170
Total services	**635,817**	**625,607**	**610,383**	**575,106**	**566,926**	**548,525**	**667,810**	**636,736**
	2016	***2017***	***2018***	***2019***	***2020***	***2021***	***2022***	-
Knowledge-intensive services, of which	**175,815**	**157,583**	**155,715**	**158,636**	**155,844**	**163,737**	**170,747**	
Market services	149,205	134,498	132,601	134,543	132,148	139,416	145,639	
High-tech	22,494	19,180	19,181	20,127	19,790	20,293	20,951	
Other	4,116	3,905	3,933	3,966	3,906	4,028	4,157	
Less knowledge-intensive services, of which	**462,118**	**426,513**	**419,683**	**423,039**	**411,377**	**401,955**	**419,093**	
Market services	460,958	425,396	418,565	421,925	410,226	400,828	417,968	
Other services	1,160	1,117	1,118	1,114	1,151	1,127	1,125	
Total services	**637,933**	**584,096**	**575,398**	**581,675**	**567,221**	**565,692**	**589,840**	

Source: SME Performance Review 2022·Eurostat/SBS database.

In congruence to the data presented in the Table 2, the Figure 2 illustrates the general trends and the share of *High-tech* within the *Knowledge-intensive services* during the last years. Indicatively, the comparison between two different periods (2008 and 2022) illustrates clearly an upward trend of *High-tech category* within the *Knowledge-intensive services.*

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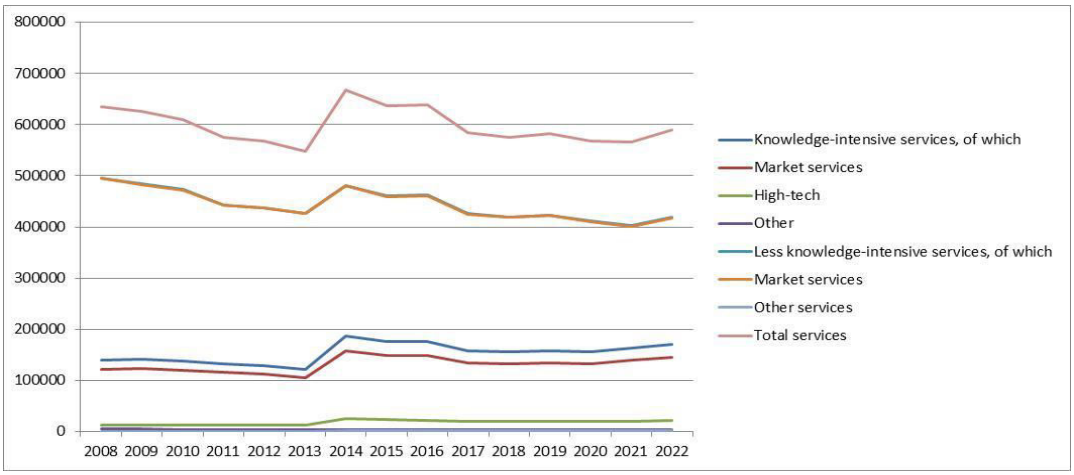

Figure 2 Knowledge-intensity in services - number of enterprises

Source: SME Performance Review 2022·Eurostat/SBS database.

4.3. Knowledge-intensity in manufacturing and services – employment

Unsurprisingly, the major part of the employment for the manufacturing sector is concentrated in *Low-technology* and *Medium-low technology* (Table 3). The aggregate level of employment in the *High-technology* sector reaches approximately 5,000 employees in the year 2021 (Manufacturing), while the total employment in the manufacturing sector is 289,207 employees for the same year.

Table 3: Knowledge-intensity in manufacturing industries – employment

Manufacturing industries	***2008***	***2009***	***2010***	***2011***	***2012***	***2013***	***2014***	***2015***
High-technology	7,272	6,774	6,595	5,463	5,249	6,483	5,549	6,111
Medium-high-technology	41,688	40,616	38,327	35,069	31,177	28,624	27,112	25,386
Medium-low-technology	105,456	102,860	93,882	82,222	75,342	68,568	67,843	59,414
Low-technology	192,853	173,198	164,537	150,320	138,977	123,596	156,845	145,408
Total manufacturing	**347,269**	**323,448**	**303,341**	**273,074**	**250,745**	**227,271**	**257,349**	**236,319**
Manufacturing industries	***2016***	***2017***	***2018***	***2019***	***2020***	***2021***	***2022***	-
High-technology	5,717	6,200	5,657	5,192	4,991	5,005	5,053	-
Medium-high-technology	25,397	26,701	29,362	28,729	28,783	29,602	30,592	-
Medium-low-technology	63,216	62,198	67,556	66,206	68,003	70,814	74,053	-
Low-technology	157,261	156,359	170,933	171,593	176,831	183,786	191,823	-
Total manufacturing	**251,591**	**251,458**	**273,508**	**271,720**	**278,608**	**289,207**	**301,521**	-

Source: SME Performance Review 2022·Eurostat/SBS database.

Additionally, the employment in the manufacturing sector has been dramatically decreased since 2008 (347,269) while in the same year the *High-technology* sub-category reported 7,272 employees. Following the data presented in the Table 3, the Figure 3 clearly illustrates the long-term trends in the employment dimension. The aggregate level of employment is slowly bouncing back during the last years, notwithstanding the stagnant and sluggish growth in the *High-technology* sub-category.

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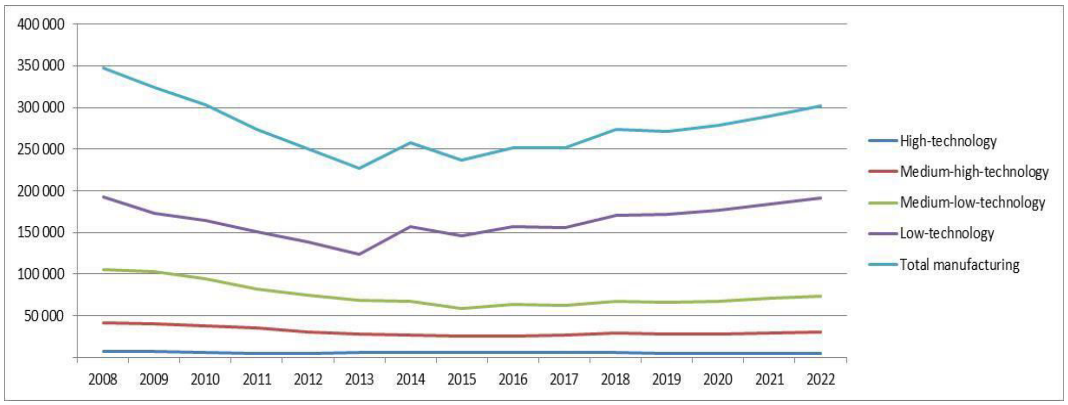

Figure 3 Knowledge-intensity in manufacturing industries – employment

Source: SME Performance Review 2022·Eurostat/SBS database.

The trends are also slightly different in the services sector. As the Table 4 illustrates, *High-tech* sub-category follows a constant and upward trend during the last years (48,235 employees in 2008 and 58,276 in 2022). Besides the upcoming trends and perspectives, the share of high-tech employment within the total employment in the services sector is relatively higher in contrast to the respective share in the manufacturing sector.

Table 4: Knowledge-intensive services – employment

	2008	***2009***	***2010***	***2011***	***2012***	***2013***	***2014***	***2015***
Knowledge-intensive services, of which	**305,307**	**321,471**	**300,193**	**304,745**	**275,645**	**260,547**	**332,808**	**286,072**
Market services	229,355	246,701	226,791	242,472	212,464	198,626	261,988	221,865
High-tech	48,235	48,336	46,428	38,710	41,028	41,296	56,433	51,069
Other	27,717	26,434	26,974	23,563	22,153	20,625	14,387	13,138
Less knowledge-intensive services, of which	**1,397,736**	**1,368,049**	**1,321, 274**	**1,246,218**	**1,166,878**	**1,146,709**	**1,233,766**	**1,134,658**
Market services	1,395,706	1,366,076	1,319,853	1,244,279	1,165,130	1,143,067	1,228,765	1,128,391
Other services	2,030	1,973	1,421	1,939	1,748	3,642	5,001	6,267
Total services	**1,703,043**	**1,689,520**	**1,621,467**	**1,550,963**	**1,442,523**	**1,407,256**	**1,566,574**	**1,420,730**
	2016	***2017***	***2018***	***2019***	***2020***	***2021***	***2022***	-
Knowledge-intensive services, of which	**319,399**	**285,368**	**302,196**	**302,776**	**292,362**	**311,074**	**330,113**	
Market services	253,172	221,587	234,655	235,956	226,761	243,311	258,215	
High-tech	53,714	51,445	54,065	54,739	53,496	55,007	58,276	
Other	12,513	12,336	13,476	12,081	12,105	12,756	13,622	
Less knowledge-intensive services, of which	**1,281,918**	**1,276,964**	**1,400,735**	**1,450,513**	**1,368,494**	**1,316,361**	**1,407,041**	
Market services	1,275,503	1,270,105	1,393,549	1,442,672	1,360,764	1,308,958	1,399,534	
Other services	6,415	6,859	7,186	7,841	7,730	7,403	7,507	
Total services	**1,601,317**	**1,562,332**	**1,702,931**	**1,753,289**	**1,660,856**	**1,627,435**	**1,737,154**	

Source: SME Performance Review 2022·Eurostat/SBS database.

Figure 4 illustrates the relatively slow but gradually upward trends in terms of employment within the *High-tech* sub-category. The aggregate employment in the services sector reaches 1.737,154 employees in 2022. Similarly,the employment level in the *Knowledge-intensive services* reaches 330,113 employees (2022).

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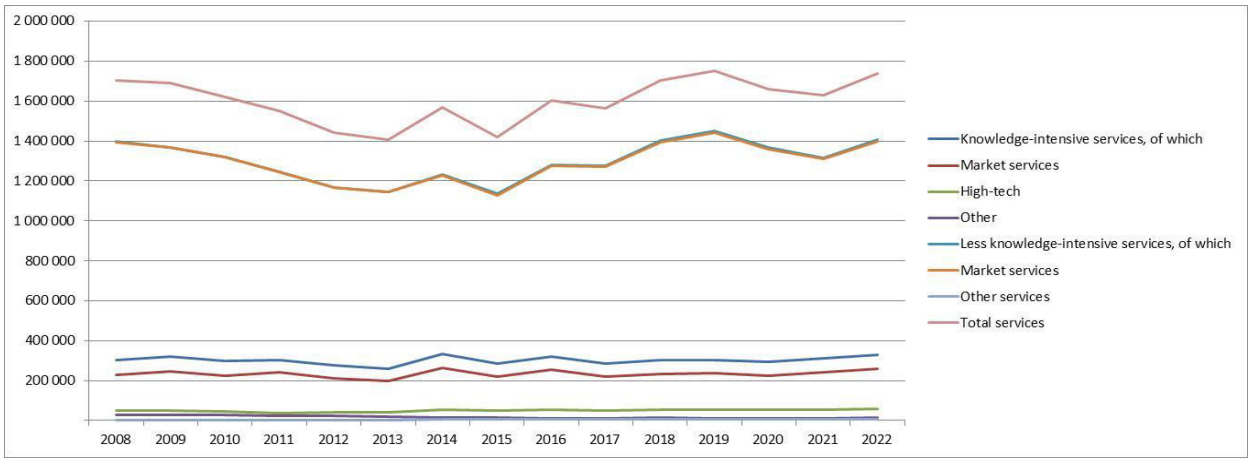

Figure 4 Knowledge-intensive services – employment

Source: SME Performance Review 2022·Eurostat/SBS database.

4.4. Value added at factor costs in manufacturing and services

Value added is a crucial parameter for the detailed understanding of relevant sectors' trends. Figure 5 illustrates the major trends in manufacturing industries under the dimension of value added (at factor costs). The exploration of the detailed data depicts some major findings. More specifically, it is evident that the different sector groups (based on knowledge-intensity) are following a similar pattern of long term decrease and gradual increase (in the last two years). However, the aggregate level of total value added produced is lower in each category.

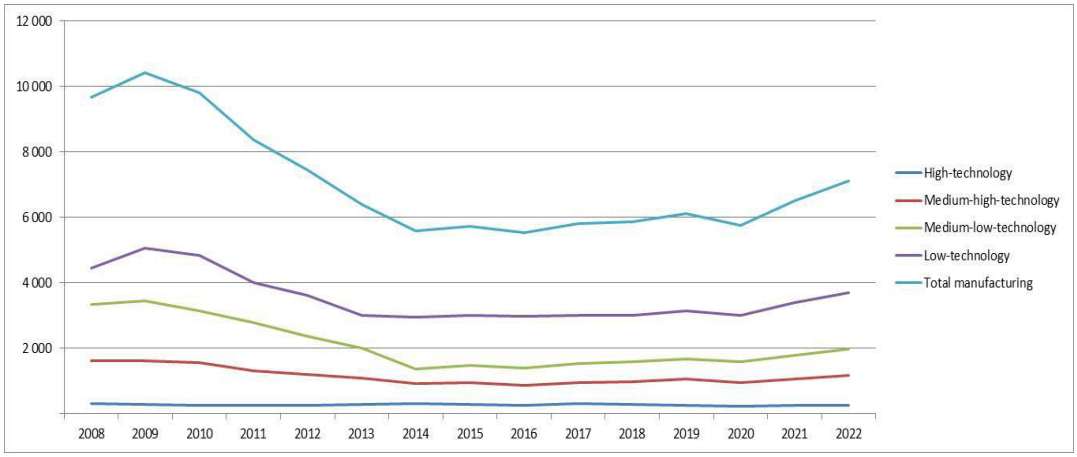

Figure 5 Knowledge-intensity in manufacturing industries – value added at factor costs

Source: SME Performance Review 2022·Eurostat/SBS database.

Figure 6 illustrates the major trends into the services sector under the perspective of value added at factor costs. More analytically, the data reveals that value added in the *Less knowledge-intensive* services such as *Market services* has been increased at a faster pace in comparison to *Knowledge-intensive services* and *High-tech* sector group of enterprises.

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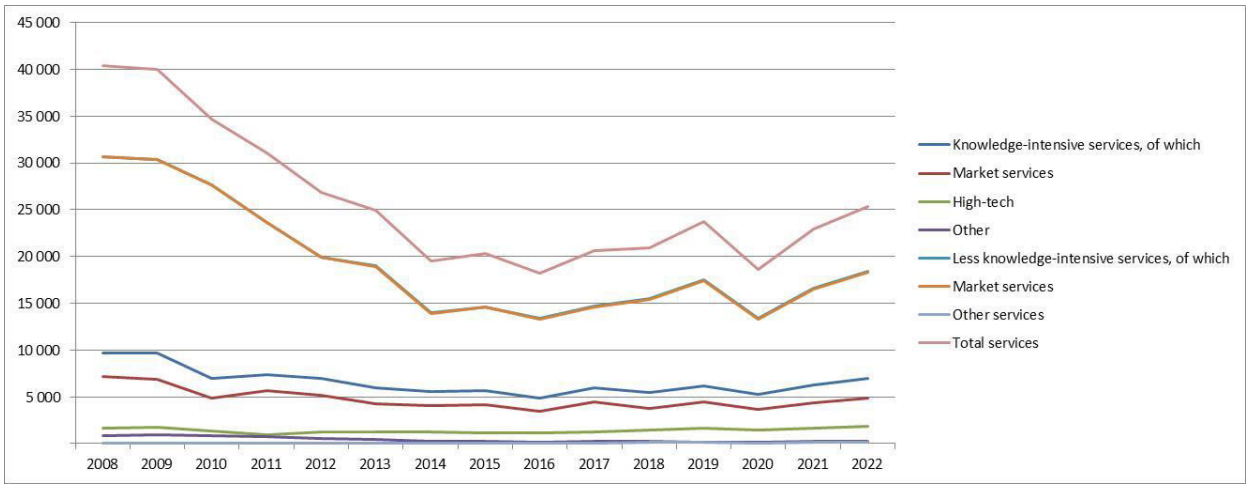

Figure 6 Knowledge-intensive services – value added at factor costs

Source: SME Performance Review 2022·Eurostat/SBS database.

4.5. High-tech manufacturing sectors (C21 and C26)

Based on NACE rev.2 classification system, the high-technology domain in the manufacturing industry is composed by two technology-intensive sectors (2-digit industries): *Basic pharmaceutical products and pharmaceutical preparations* (C21) and *Manufacture of computer, electronic and optical products* (C26). Figure 7 illustrates the general trends based on the size classes of enterprises for the sector *Basic pharmaceutical products and pharmaceutical preparations* (C21 – NACE rev.2). The major activity in the sector is diachronically concentrated in the size classes 10-49 and 50-249 employees. However, during the last years (since 2010 approximately) there is an upward trend in the size class 0-9 employees (micro companies) depicting the emergence of new start-ups and spin-off enterprises mostly specialised in technology niche markets and cutting-edge technology areas (e.g. biotechnology, medical technology, genetic engineering). Besides the number of enterprises, the major part of the employment is concentrated in medium and large companies. In the size class of enterprises with more than 250 employees for instance, the total number of employees is 6,555 (2022) and the number of employees for the size class 50-249 is 1,667 employees (2022). Conversely, within the size class 0-9 there are 160 employees while in the size class 10-49 the respective number is 540.

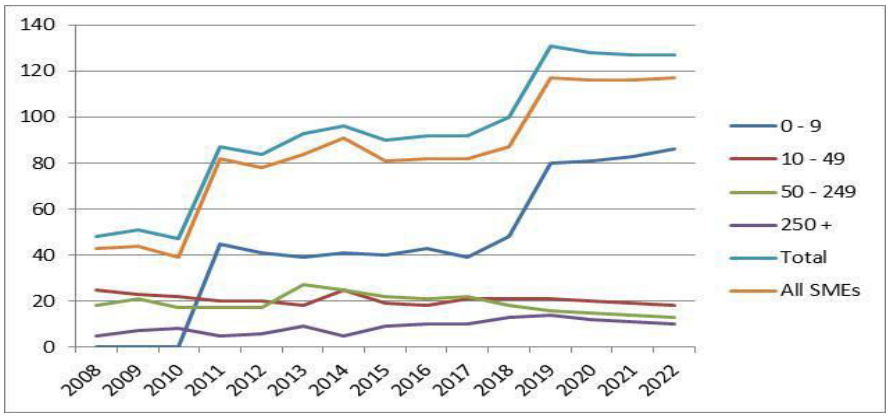

Figure 7 Manufacture of basic pharmaceutical products and pharmaceutical preparations (C21) – number of enterprises

Source: SME Performance Review 2022·Eurostat/SBS database.

Accordingly, the major part of the value added for the sector *Basic pharmaceutical products and pharmaceutical preparations* is concentrated in larger firms. The current estimation for the year 2022 reaches 585 million euros in the sub-category with more than 250 employees. The estimation for the size class 50-249 is 124 million euros while the aggregate value added for the size class 10-49 employees is 25 million euros.

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The anatomy of the sector *Manufacture of computer, electronic and optical products* (C26 – NACE rev. 2) is rather different. As the Figure 8 illustrates, the larger number of enterprises is largely concentrated into the size class 0-9 employees (399 companies in 2022 out of total 441) while the size class 10-49 employees depicts 36 enterprises (2022).

According to the employment level, the size class 50-249 depicts 1,000 employees (2022) while in the size class 0-9 employees the respective number is 913 for the same year; and 773 employees for the size class 10-49. It should be mentioned that there is a dramatic decrease of employment in the size class 0-9 employees (from 2,528 employees in 2008 to 913 in 2022).

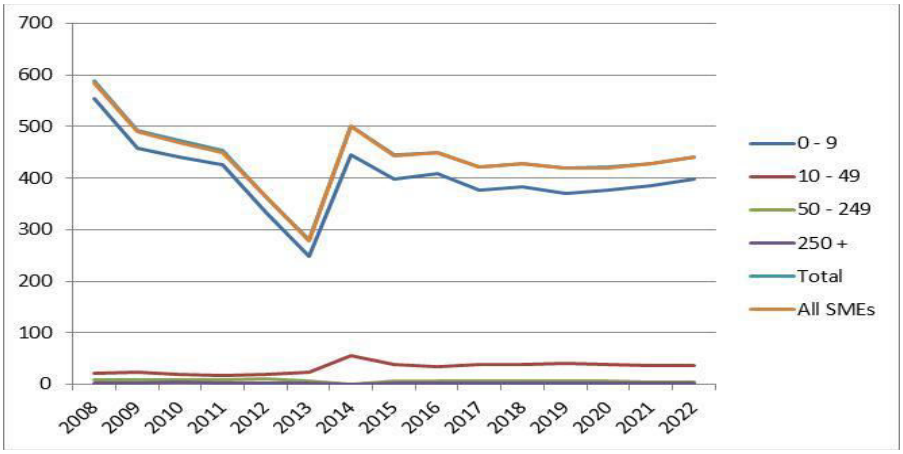

Figure 8 Manufacture of computer, electronic and optical products (C26) – number of enterprises

Source: SME Performance Review 2022·Eurostat/SBS database.

Examining the valued added (for the sector *Manufacture of computer, electronic and optical products*), the latter is distributed across the different size classes as follows: 23 million euros in the size class 0-9 employees; 48 million euros in the size class 10-49 employees; 46 million euros in the size class 50-249 employees; and 44 million euros for enterprises with more than 250 employees.

4.6. Knowledge intensive services - high-tech sectors (J61 and J62)

Regarding the sector of *Telecommunications* (J61), it is evident that a rapid surge is taking place since 2013 with reference to the number of enterprises, especially within the size class 0-9 employees (Figure 9). The size class of enterprises with 10-49 employees is following with an upward trend, since the aggregate number of enterprises (SMEs) increased from 97 (2008) to 1,418 (2022). As regards the number of employees in the sector *Telecommunications* and the size class 0-9 employees, 209 employees has been reported for the year 2008, while in 2022, the total number of employees is 3,420. Regarding the size class 10-49 employees, 664 employees have been reported in 2008 and the total number of employees is 1,859 in the year 2022. The value added increased during the same period within the size class 0-9 employees (from 6 million euros in 2008 to 70 million euros in 2022).

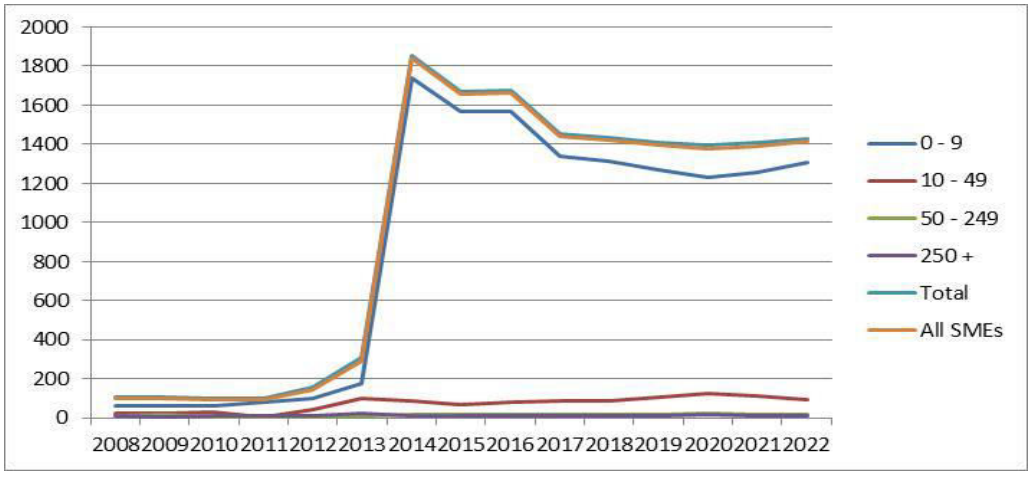

Figure 9 High-tech services: sector of Telecommunications (J61) - number of enterprises

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Source: SME Performance Review 2022·Eurostat/SBS database.

By examining the number of enterprises (Figure 10), it is also evident that within the sector of *Computer programming, consultancy and related activities (J62)*, a surge is under progress since 2013, especially within the size class 0-9 employees. The aggregate number of enterprises (SMEs) increased from 5,403 (2008) to 7,527 (2022).

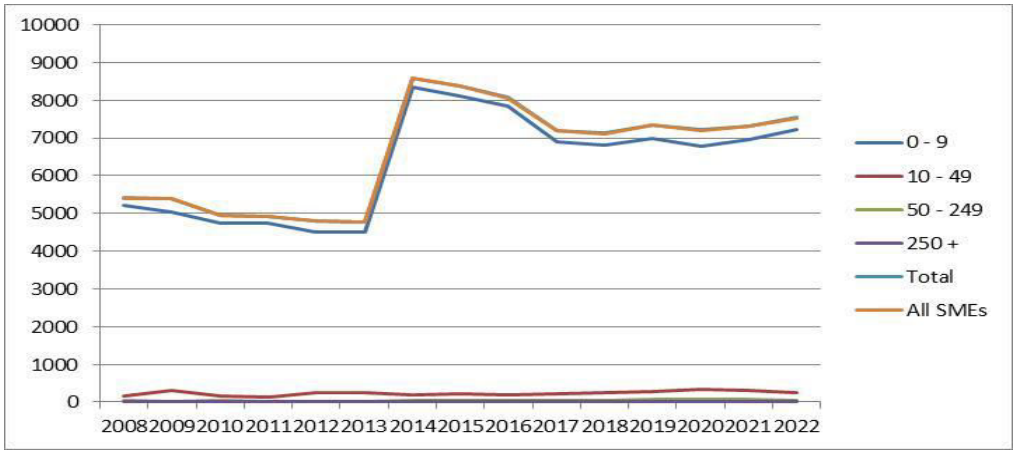

Figure 10 High-tech services: sector of Computer programming, consultancy and related activities (J62) - number of enterprises

Source: SME Performance Review 2022·Eurostat/SBS database.

As regards the number of employees in the sector *Computer programming, consultancy and related activities* and the size class 0-9 employees, 8,016 employees has been reported in the year 2008, while in 2022, the total number of employees is 11,516. Regarding the size class 10-49 employees, 3,498 employees have been reported in 2008 and the total number of employees is 5,417 in the year 2022. The value added increased during the same period in the size class 0-9 employees (from 228 million euros in 2008 to 278 million euros in 2022). Value added is also increased in the size classes 10-49 employees (from 117 million euros in 2008 to 285 million euros in 2022) and 50-249 employees (from 174 million euros in 2008 to 275 million euros in 2022) during the same period.

5. Conclusion and Recommendations

Remarkably, it should be noted that during the last years there is an increasing investment activity across several technology-intensive and start-ups in Greece. According to Foundation/EIT Digital 2021/2022 Venture Financing Report the total number of startups funded during 2021 is about 70 which is 30% more than last year, while the total investments secured by them exceed €500 million (Foundation/EIT Digital, 2022). Regarding the amounts that companies request from the funds, there is a significant increase in the area of €100,000 - €200,000 and €400,000 - €500,000.

Based on the report findings, the trend reflects a new wave of start-ups and technology-based companies. It should be noted that many of these enterprises are focusing on B2B markets while there is an intensified activity in emerging markets such as Life Sciences, Retail and AgriTech. Accordingly, based on Endeavor Greece (2022), Greek startups posted a funding record in 2021, raising more than $1 billion in a year. According to Endeavor Greece, in 2020 the Greek startups succeeded in raising 455€ millions, an amount that was 71% higher than the 266€ millions invested in the Greek ecosystem in 2019 (Endeavor Greece, 2021). However, during 2022 is expected start-ups showing a 20%-40% of slowdown due to the wider economic downturn and funding challenges.

The emergence of various schemes of Venture Capital financing during the last years across the country and the deployment of state-backed VC mechanisms (e.g. EquiFund - co-financed by the EU and national funds, as well as funding from the European Investment Fund), has created a conducive environment for technology-based companies. Especially in the early stages, the growth of technology-intensive companies is often constrained by the lack of financial resources (Alperovych et al., 2020). Subsequently, the design and deployment of venture capital programmes can contribute at the sustainable growth of technology-intensive activities.

Nevertheless, the present empirical analysis provides evidence for several complementary aspects of the evolution of high-technology sectors in Greece. Firstly, high-tech enterprises constitute a considerably important part of the country's productive base with gradually increasing trends in all relevant categories (e.g. number of enterprises, number of employees and value added). Noticeably, although there are fluctuations over time (for the period 2008-2021), with sub-periods where a downward trend is observed in sectors and categories (e.g. number of companies), during the last years a consolidation seems to be taking place. This is motivated, *inter alia*, by the development of start-ups and spin-offs in several fields of higher technological specialisation ('deep tech'), such as the wider domain of

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hardware and embedded systems, Artificial Intelligence systems, microelectronics and optical products, life sciences, biotechnology, pharmaceutical products, genetic engineering and medical technology. However, high-tech enterprises and start-ups still constitute a small part of the overall production structure (in terms of number of enterprises, number of employees and value added). Subsequently, low-tech and medium-low-tech enterprises constitute the largest part of economic activity (e.g. number of enterprises, value added), especially in the manufacturing sector.

Secondly, it is evident that there are some stark asymmetries and differentiations among sectors, such as *Basic pharmaceutical products and pharmaceutical preparations* (C21) and *Manufacture of computer, electronic and optical products* (C26) in terms of concentration, size classes' shares and overall contribution to value added and employment. Meanwhile, the data illustrate that the *High-tech* sector in services is growing at a faster pace, especially in sectors such as *Telecommunications* (J61) and *Computer programming, consultancy and related activities* (J62). In view of this, it should be noted that the growth trend in the manufacturing sector is relatively sluggish (e.g. number of enterprises) both at the level of *High-technology* and *Medium-high technology groups*. The decreasing trend of *High-technology*and *Medium-high technology groups in the manufacturing sector* is being reflected (for the period 2008-2022) at the number of enterprises, the employment and the value added dimensions. Although the high-tech domain depicts an aggregated upward trend during the last years, as it has been illustrated, some critical sectors and sub-sectors are not following suit.

Evidently, it seems that the evolution of high-tech sectors is a long, complex and multi-level process. The multiplier effects from the emergence of technology-intensive sectors involve a wide range of challenges related to scaling-up of activities, formulation and integration to wider value chains and fostering important aspects relevant to the wider technology and economic impact (e.g. value added). It is also worth noting that the critical aspects are not limited to the number of new technology-based enterprises and start-ups; the critical long-term dimensions involve value added, employment as well as technology exploitation and economic impact at local and regional level. As Marques & Morgan (2021) clearly illustrate, innovation is a crucial parameter for long-term economic growth but not always sufficient to generate development. Therefore, emphasis on local knowledge, technology embeddedness and value added appropriation within the local and regional economies constitute integral elements of revisited technology and innovation policies.

Consequently, the data retrieved illustrate that the long-term, continuous and sustainable high-tech growth environment necessitates pro-active, large scale, holistic and targeted technology and innovation policy measures. Furthermore, a wide and long-term spectrum of policy tools needs to be also combined with specialized approaches across sectors. The growth trend in one sector is not always following established patterns in different sectors. Accordingly, each sector carries differentiated features. As Pisano (2006) illustrates, what might works in one sector might not be suitable for another. As a result, one size does not fit all, when it is necessary to efficiently deal with profound uncertainty and high risks (Pisano, 2006).

Parenthetically, based on the data analyzed, it should be mentioned that the potential growth paths of technology sectors in Greece could be multiple and diversified. Three dominant pathways for the growth of technology sectors in the country could be summarized in the following complementary options: i) scale up growth in rapid developing sub-sectors; ii) niche markets growth and integration within international value chains; iii) open innovation and strategic cross-sectoral coupling.

First of all, consolidation constitutes a critical stage following the early stages of technology-based companies. While several dynamic and upward trends have been identified in different technology-intensive sub-sectors in Greece, the formulation of critical mass, the achievement of spillovers across interconnected sectors (e.g. biotechnology and pharmaceuticals; advanced software, embedded systems and semi-conductors; Artificial Intelligence and mobile applications) and the enhancement of scale-up growth of high-tech companies will further accelerate rapid expansion of technology-based sub-sectors. The need to streamline and enrich funding and investment environment through the establishment of funding tools oriented towards the whole innovation value chain (e.g. pre-seed, seed capital, VCs, scale-up capital), remains a prerequisite for strengthening the technology base while it will provide long-term growth and scale opportunities. In view of this, complementary resources and policy tools are needed. For example, business accelerators have rapidly emerged as crucial dimensions within the entrepreneurial ecosystem to support spin-offs and start-ups scaling up processes (Livieratos & Siemos, 2021).

Secondly, the long-term growth of technology-based sectors and companies has always been inextricably interlinked with the need for specialization in niche markets and the formulation of strategic positioning within international value chains. The integration of high-tech companies in wider value chains through the production of specialized technology-based intermediate products or services, which are critical to a high-end output, is usually a major strategic choice to efficiently entering new markets and to achieve sustainable technology and business growth. Aligning to innovation networks for building up innovative products or services and providing part of the final offering remains an efficient growth path for developing new technology partnerships. For example, acquisitions of start-ups by incumbents constitute a major trend within the technology-based markets. The past few years, several high-tech companies have been acquired by large international technology companies or by other VC-backed companies across the country.

Thirdly, the strategic coupling between high-tech and technology intensive-sectors with traditional production and industrial activities constitutes a crucial field of potential growth. For example, the technological adaptation of agro-food firms in the emerging digital requirements remains a potential technology application domain with

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innovation perspective. Nevertheless, the limited digitalisation of agro-food firms in Greece, especially regarding more advanced digital tools, formulates an unexploited economic landscape (Ioannidis et al., 2022). Thus, technology diffusion across critical value chains could be a promising growth path for technology-based firms.

In this context, the type of interventions should involve supply-side and demand-side measures. For example, R&D subsidies, tax cuts and allowances, innovation hubs, state-backed VCs and collaborative schemes are always major part of the technology and innovation policy agenda. Nevertheless, the mobilization of demand (e.g. R&D procurements, large-scale projects in critical complementary domains) constitutes a crucial policy tool to enhance technology development and innovation through "mission-oriented" initiatives (Mazzucato, 2021).

Building on this approach, it should be noted that policy measures needed across the value chain from technology development, pre-seed and seed stages to scale-up phases. It is worth noting also that the shortage in capital may occur in several later stages of growth (Alperovych et al., 2020). Consequently, the formulation of an integrated funding environment providing adequate access to capital not only across the early stages but also throughout the growth stages (scale-up capital), constitutes a crucial element for national innovation systems.

The design and deployment of various collaborative partnerships and open innovation approaches through different methods and channels constitute also crucial dimensions for the growth of innovative SMEs (Vanhaverbeke, 2017). A largepart of technology-based companies in Greece is getting in on the action for B2B markets. As a result, open innovation approaches (both in terms of strategic and policy design) would provide opportunities for knowledge spillovers, economies of scale, increasing returns and new innovation strategies for SMEs (Livieratos et al., 2022).

In that respect, it should be mentioned that due to their complexity and scale needed, technology-based opportunities are usually accelerated through various schemes of collaboration. The open innovation approach has provided a prompt response to business challenges while the adoption of "open innovation strategies" constitutes an important innovation management concept in several technology-intensive sectors, such as biotechnology industry (Kunz, 2022). More recently, as Chesbrough illustrated, Covid-19 has prompted a wide variety of open and collaborative initiatives (e.g. vaccines) (Chesbrough, 2020). According to Chesbrough & Bogers (2014), open innovation is defined as a distributed innovation process involving knowledge flows across organizational boundaries. In that prism, open innovation approach could provide insightful lessons for innovation policy domain in terms of designing new programmes to encourage interdisciplinary research and collaborative innovation projects as well as accelerated commercialization of science-based business opportunities.

The next field of research to be explored includes a more detailed exploration of issues related to policy design regarding special focus areas. For example, the pandemic has highlighted the promise of new technologies tackling wider social challenges related to human health. Biotechnology industry has exhibited high growth rates in terms of research achievements, scientific discoveries and science-based business activities (Angelakis & Galanakis, 2017). Similarly, climate change constitutes one of the major challenges human societies are facing and, thus, it is inextricably connected to the ability to develop new "green technologies" and renewable energy systems characterized by high technology readiness level and high level of techno-economic effectiveness while being able to address a wide range of uncertainties (Sakki et al., 2022). Consequently, based on the rapidly growing science-based business activities in Greece (e.g. start-ups, spin-offs), more research is necessaryin order to identify promising technology areas, business environment bottlenecks, sector-based specialized needs, and to discover new technology-based business and investment opportunities.

Last but not least, a holistic framework for the formulation of a new technology and innovation policy is needed to enhance the contribution of high-technology sectors in major aspects (e.g. employment and value added) and economic transformation processes (e.g. interlinkages with economy-wide sectors, such as agro-food and manufacturing). The major contribution of technology-intensive sectors into the economy is not limited at the number of enterprises and the share of employment. It is also related to the value added in economic terms but also in terms of technology accumulation, human capital, cross-sectoral spillovers and wider economic and industrial transformation. The major challenge for the technology sector involves both its sustainable growth but also the enhanced embeddedness and value added appropriation within the economic and national innovation system.

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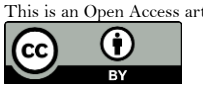

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The Impact of the COVID-19 Pandemic on the Expenditures of Hellenic Supermarket Customers Spending Clusters: An Econometric Analysis

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ABSTRACT

Purpose:
Given the severity and the length of the crisis caused by the COVID-19 pandemic, information on the financial impact of the pandemic becomes useful to enterprises who wish to arm themselves with strategies and policies, designed to combat the effects of similar crises. Such information is particularly useful to grocery retailers, who may need to know the effects of the pandemic on spending behaviour of different spending power classes of consumers. To that end, the study explores the configuration of (supermarket) consumer spending in Greece in relation to the number of: a) reported COVID-19 infections; b) admissions in hospital intensive care units, and: c) number of COVID-19 reported deaths, for the period between February the 26th, 2020 to April 30th, 2021.

Design/methodology/approach:
Methodologically, the paper focuses on an econometric analysis of daily spending reactions of six distinct spending clusters of consumers of Greek nation -wide supermarket chain, measured against official numbers of COVID-19 related metrics in Greece during the period of February 2020- April 2021. The data used, emerged from daily sales records of a national chain of supermarkets in Greece, consisting of 60 stores. Proven econometric causality techniques were used to analyse the data by applying Hsiao's Optimizing Procedure via the "Stepwise Granger Causality", for the statistical tests of possible interactions between variables.

Findings:
The study found a phenomenal effect of the number of reported COVID-19 related deaths on consumers' supermarket spending in Greece. The study revealed the statistically significant effects of the COVID-19 variables on the 6 buyers' clusters. These statistically significant effects have a diachronic behaviour which is varied in relation to the covid variables. The findings indicate that the biggest fluctuations in daily consumer reactions (on reported COVID-19 related variables) occurred in lower spending clusters of consumers, diminished over a period of about 15 days. The study also revealed that consumers' spending reaction on infection case is minimal compared to that of reported deaths, signalling a relative apathy to the number of reported infection cases.

Research limitations/implications:
One basic constraint was the lack of spending data over a longer period of time which would have included the entire pandemic era. Ideally the researchers would prefer to compare customer spending data of several supermarket chains, yet the availability of such data was scarce. The findings also imply that lower spending clusters react more intensively to COVID-19 outcomes and as such marketing efforts to serve these target markets may need to be customized.

Originality/value:
The interpretation of the results reveals that the level of panic that drives reactionary spending appears to be lower in higher spending consumers. This study contributes to theory by appreciating the Greek supermarket customers' psychological reaction to COVID-19 related variables, by not relying on self-reported data. Although the study was not designed to reveal the reasons for this occurrence, the results demonstrated variability

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in the reaction of customer clusters as outcomes of severely negative COVID -19 related reports. The data used were objective and the adopted analysis method was appropriate to the purpose of the study. The paper further suggests that future research could build on this study by: (a) examining causality of variability of customer spending during various phases of the pandemic by applying non-linear and possibly chaotic causality tests on daily data; and (b) identifying the exact threshold of change in consumers' spending patterns on specific product categories, as influenced by reports of COVID-19 related factors.

1. Introductions & purpose of study

The COVID-19 pandemic has so far devastated families, lives, businesses, communities, markets, sectors and economies. According to Congressional Research Service Report: R46270 (2021),the COVID-19 pandemic reduced global economic growth by 3.2% in 2020 and although some signs of gradual recovery were evident in the subsequent years, several advanced economies are estimated to underperform until 2024 due to this pandemic. The cost of human life has also been devastating. The World Health Organization (2022) reported 509,531,232 confirmed cases of COVID-19, including 6,230,357 deaths, by the 28thof April 2022 (i.e. see: https://covid19.who.int). The numbers of reported deaths notably seemed to affect the cognitive and affective state of consumers, and as such, merited empirical investigation. According to Jackson et al (2021: R46270), the COVID-19 pandemic has negatively affected global economic growth, caused a global rise an unemployment and shrank global trade by 5.3% in 2020. Beyond causing a health crisis, the pandemic also severely impacted the spending levels of individuals, as changes in degrees of spending were found to be associated with changes in consumer behavior (Di Grosta et al., 2021).

Given the severity and the length of the crisis, any information on the financial impact of the COVID-19 pandemic is always useful for enterprises, who wish to arm themselves with strategies and policies designed to combat the effects of similar crises. Such information is particularly useful to grocery retailers, who need to know the effects of the pandemic on different income classes of consumers. To that end, an exploration of the configuration of consumer spending in relation to the number of reported number of patients with COVID-19 in intensive care units in hospitals, number if infection cases and COVID-19 attributed deaths, was performed in Greece. The aim of this study is to test the effect of COVID-19 related reported effects (variables) on supermarket spending. We identified spending data of 6 clusters of supermarket levels of spending by Greek customers of a national chain of supermarkets in Greece, during the period of the Corona virus pandemic. There were concerns that the reported number of casualties attributable to COVID-19 infections influenced the psychological motives of customers towards their supermarket spending. Therefore, we were interested to explore real, measurable, long and short term COVID-19 related effects on spending, and in particular how the reported numbers of COVID-19 related deaths affected supermarket spending of consumers in Greece.

2. Framework and conceptualization

Fluctuations on consumer spending due to COVID-19 has been noted is various countries. Chronopoulos et al.(2021) investigated consumer spending in GB between January 1st to April 7th, 2020, the period of the early stages of the outbreak and the pandemic. Their work observed fluctuations of consumer spending after measures related announcements by the British prime minister of that era. Especially in terms of the product category of groceries, consumer spending increased after the World Health Organization announcement declaring the situation to be a pandemic, and after one week of the first lockdown in the UK. Chronopoulos et al.(2021) attribute this result to media reports about stockpiling, leading to *normal* panic behaviour. Overall, their study indicated that over the entire study period consumer spending varied across product categories, UK nations, consumer income levels, gender and age.

Other studies conducted in the US and China, explored consumer spending during the COVID-19 pandemic, revealing very interesting findings. Chen et al (2020) investigated consumer spending in 214 cities in China during the period of January1st to April 14th, 2020, by using daily transaction data on various product categories including among others, groceries and necessities. Their work revealed a dramatic decrease in spending in all sectors during the first 3 months of the pandemic and pointed out that offline consumer spending declined by about 32% on average in China, and regions hit most by the pandemic (i.e. Wuhan) suffered from a reduction in consumer spending as high as 70%. Similarly, Dunn et al (2020) utilized daily transaction data to map the phenomenon of declining consumer spending across several product and service sectors during this pandemic, in the US. They termed this exploration as an estimation of pandemic *effect* (the effect of the pandemic on consumer spending), which they examined in the US by using card payments data. Their study revealed a decline of US consumer spending after the mitigation measures were set in place, by 27.8% with the food/drink service, accommodation, and gas stations being hit the hardest. They also observed that the food and beverage/ groceries sector experienced about 100% increase in sales followed by a dip to below expectations for the month of March 2020. In the US the causal effects of the *pandemic shock* on consumer spending were investigated by Fink and Tillman (2022) who explored how pandemic fatalities affected household

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spending and found that the pandemic shock has a negative effect on household spending. They explained this phenomenon by arguing that driven by fear household voluntarily restrain consumption, especially as household might be expecting an alteration of their future income which motivates them to adjust their spending. Their findings indicated the lower income households bared the consumption burden during the pandemic due to job uncertainty and social distancing and that spending radically declined when bad news was announced (i.e. national emergency). They also found that the surprise increase of the difference of the realized versus expected deaths lead to a sharp drop in spending, and the pandemic shock increased inequalities of household spending during the period of April - October 2020.

Some of the results of the Fink and Tillman (2022) on the pandemic shock, eco work conducted by Di Crosta et al. (2021) on the psychological factors that affected household consumption/spending during this pandemic. Earlier literature suggested that fear affects consumer psychology during crises (Cannito et al., 2020) as well as consumers' disposition towards spending (i.e. see Baker et al, 2020 on Stockpiling during the pandemic). Di Crosta et al (2021) demonstrated that consumer purchase of necessities was predicted by anxiety and Covid-19 related fear, where as consumer behaviour towards non necessities was predicted by depression, although spending on necessities increased in the first week of the lock down. They recommended the further exploration of consumer behaviour at different phases of the COVID-19 pandemic based on actual spending. Our present study attempts to address the research recommendations of Di Crosta et al (2021) by utilizing actual (daily measurements) of consumer spending as a consequence to factors that may affect consumer psychology such as reported infections, deaths and ICU admissions due to this pandemic in Greece. A snapshot of the numbers of the COVID-19 attributable deaths in Greece is presented in Appendix A.

3. Methodological approach

Over the years, the framework for exploring, formulating, measuring, calibrating and finally implementing economic policy measures based on econometric models has evolved. The catalyst was the work of Christopher Sims (1980) who criticized the utilization of large-scale econometric models with too many equations and constraints, arguing in favor of using a simple equation or a model consisting of a few stochastic equations. In attempting to explore the causality of COVID-19 effects to (supermarket) spending, we consider standardized causality techniques based on the works of Sims (1980) and Hsiao (1979).

Based on the above literature, the framework for the formulation of economic policy for two stationary economic variables $\{y_t\}$ and $\{x_t\}$, with endogenous variability could be presented as follows:

- Statistical test for possible diachronic interactions (Granger) between the two variables: announced number of covid-19 related deaths and supermarket spending.
- Formulation and quantification of this interaction. The quantification of the interactions is usually based on the estimation of an autoregressive system of equations with each of the two variables as endogenous and the formulation consists in the specification of the diachronic interactions and the corresponding variance decompositions. The specification of the interactions between the variables $\{y_t\}$ and $\{x_t\}$involves a descriptive approach on how each variable affects the other.
- In Figure 1 seen below, we present the diachronic effect of variable $\{x_t\}$(deaths) on the variability of $\{y_t\}$ (spending), as well as the basic descriptive measures of this effect. These measures include the mean, variance, length and height of the effect as well as the respective decimals.

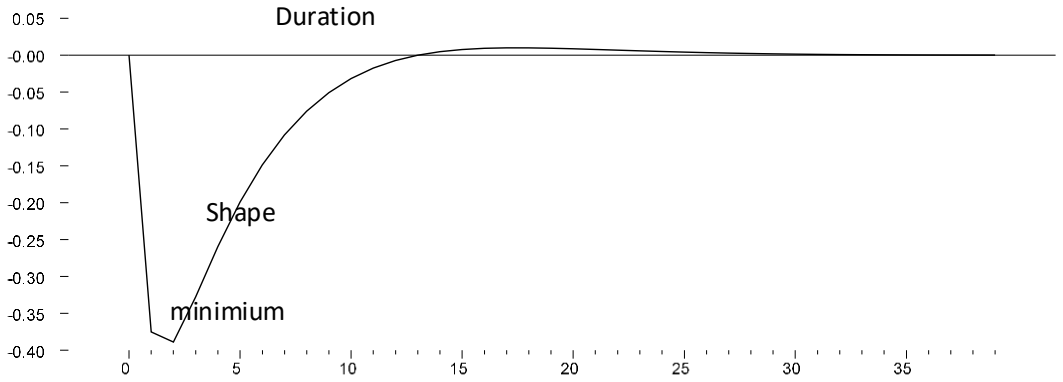

Figure 1. Presentation of a diachronic effect of $\{y_t\}$ on $\{x_t\}$

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We define the 5 clusters of outcomes on the basis of their total annual supermarket spending during the period 26/February/2020- 30/April/2021. These categories follow:

1. Cluster 1= 100-2000 euros
2. Cluster 2= 2001 – 4000
3. Cluster 3= 4001-6000
4. Cluster 4= 6001-8000
5. Cluster 5= 8001- 10000
6. Cluster 6= 10001- 15667.57

3.1 The research design

In this section the method applied to the investigation of the possible feedback effect between supermarket spending and announced COVID-19 related deaths is the standard method of Hiao (1979). The approach of this investigation is econometric, rather than opinion-polled customer self-reported spending, and was based on real sales figures of a nationally wide supermarket chain in Greece, consisting of 60 stores, rather than self-reported data. The supermarket chain begun its operations in 1980 in Crete and currently sustains stores in the entire vicinity of Greece. Various techniques have been proposed in the literature for the performance of statistical tests used to detect the existence of dynamic Granger interactions between two variables. In this paper we followed Hsiao's Optimizing Procedure or the "Stepwise Granger Causality", for the statistical tests of possible interactions between variables. This adoption of this method is justified by the literature, as this is an effective method in detecting the appropriate feedback effect between the considered variables (i.e. see: Granger, 1986; Christiano & Eichnbaum, 1987; Johansen, 1998). For each of the two variables and this method proposes the following procedure (three step procedure):

3.1.1 Control of Granger causality: Step 1

1. We estimate the autoregressive equations for s=1,2

$$(x_t) = \sum_{s=1}^{M} \alpha_s x_{1,t-s} + u_{1t} \quad t = 1,2,3,..T \ (1)$$

where M is the arbitrarily defined maximum number of the terms of the polynomial. In this paper, the maximum length has been set at 14, as we believe that a ten-day lag length is sufficient to include every relevant information on the interaction of the variables (as per the Hsiao, 1979 method). The optimal order of time lags can be determined by minimizing the Forecast Prediction Error, henceforth FPE(M,0):

$$MinFPE(M^*,0) = \frac{T+m+1}{T-m-1}\frac{SSE}{T} (2)$$

$$SSE = \sum_{t=1+M*}^{T} u_{1t}^2 \quad (3)$$

2. For the pair of variables of our model, we estimate the regression: $x_t = \sum_{s=1}^{M^*_i} a_s\, x_{1,t-s} + \sum_{r=1}^{N} b_r y_{1,t-r} + u_{2t}$

and we minimize the $FPE^M(M^*,n^*)$(4)

Where $i \neq j$ and n run from 0 to M. Then we choose n such that the FPE is minimized. Also, M_j^* is the optimal order of x_t selected in step (1).

According to the "Stepwise Granger causality test", the variable y_t causes in the Granger sense the variability of x_t if $FPE^{y,x}(M^*,n^*)$ is lower than $FPE^y(M^*,0)$
or $FPE^{y,x}(M^*,n^*)/FPE^y(M^*,0)<1$.

We followed exactly the same steps from (1) with y_t as the dependent variable and x_t as the independent, in order to define the optimal order of the polynomial (4).

3. After the determination of the optimal orders of M_i^* and n_i^* for $i > 1.2$in the previous steps, a VAR can be estimated:

$$\begin{pmatrix} x_t \\ y_t \end{pmatrix} = \begin{pmatrix} A(L) & B(L) \\ C(L) & D(L) \end{pmatrix} \begin{pmatrix} x_t \\ y_t \end{pmatrix} + \begin{pmatrix} u_t \\ \varepsilon_t \end{pmatrix} \quad (5)$$

DOI: 10.25103/ijbesar.152.07

where A(L), B(L), C(L) and D(L) represent the lag polynomials fitted in step (2) above; They are shown as follows:

$$\left.\begin{aligned} A(L) &= \left(a_1 L + a_2 L^2 + \cdots + a_{Mi} L^{M_1^*}\right) \\ B(L) &= \left(b_1 L + b_2 L^2 + \cdots + b_{ni} L^{n_1^*}\right) \\ C(L) &= \left(c_1 L + c_2 L^2 + \cdots + a_{Mj} L^{M_2^*}\right) \\ D(L) &= \left(d_1 L + d_2 L^2 + \cdots + d_{ni} L^{n_1^*}\right) \end{aligned}\right\} \qquad (6)$$

Then the full – information maximum likelihood method (FIML) is used in estimating (5).

3.1.2 Quantification of the interactions between variables: Step 2

The system of equations (5) is estimated using the Generalized Least Squares method. The utilization of data series with different temporal aggregation is very likely to distort the possibility for an effective application of the test described above. This distortion can be stronger if the true interaction between the variables x_t and y_t is realized at a level of high disaggregation. For instance, we can imagine a case of two monthly time series that do not have a causal relationship, however if aggregated at a quarterly level, some form of causality, appears.

Given the fact that quite often, when trying to formulate dynamic interactions between economic variables, data at higher aggregation level are used in lieu of lower, simply because of lack of availability at the desired level. Therefore, there is a high probability that we may end up *detecting* false or non-existent dynamic interactions between the economic variables under investigation.

Given $Z = X\beta + E$ (7)

where Z is the matrix of endogenous variables $\left(x'_t\ y'_t\right)$ and X the matrix of the explanatory variables, as defined in (5) and (6).

If $E = \begin{bmatrix} u_t \\ \varepsilon_t \end{bmatrix}$ then $\sum \begin{bmatrix} \sigma_{11} & \sigma_{22} \\ \sigma_{21} & \sigma_{12} \end{bmatrix}$ and $V = \sum \otimes I_T$ (8)

or

$$V^{-1} = \sum \otimes {I_T}^{-1} \qquad (9)$$

and the Generalized Least Squares estimation function will be:

$$\hat{\beta} = [x' V^{-1} x]^{-1} x' V^{-1} Z \qquad (10)$$

$$V\left(\hat{\beta}\right) = (x' V^{-1} x)^{-1} \qquad (11)$$

3.1.3 Representation of diachronic interactions: Step 3

The representation of the dynamic interactions between variables $\{y_t\}$ and $\{x_t\}$ can be expressed in two ways, either in the form of impulse response functions or via the procedure of variance decompositions. In the case of impulse response functions, the results show the way the interactions between the variables $\{y_t\}$ and $\{x_t\}$ are spread over a time dimension. In the case of variance decomposition analysis, the variance of a variable is broken into the part due to its own internal variability and the percentage due to the causal diachronic interactions with other variables.

4. The findings of the study

In this study we used daily data during the period February 2020-April 2021. The data were made available by supermarket chain and the official site of the Hellenic Ministry of Health. A graphical representation of the diachronic co-variability of the total spending and the number of deaths is presented in figure 2. This figure demonstrates the power of the diachronic co-viability between these 2 variables. The blue line reflects the supermarket spending during the period Feb/20- Apr/21 and the black line reflects the official number of announced deaths due to Covid-19. In this figure we observe the linear correlation between these two variables, specifically the negative interaction of consumer spending and the announcement of deaths. Also, we observe a peak in spending due to the Christmas/holiday season while the numbers of deaths begun to decline. In addition, for the period Oct-Nov/2020 – April 2021, we notice a phenomenal effect of the announcement of deaths on supermarket spending which we tested by applying the Granger causality test method using the approach of Hsiao (1979).

DOI: 10.25103/ijbesar.152.07

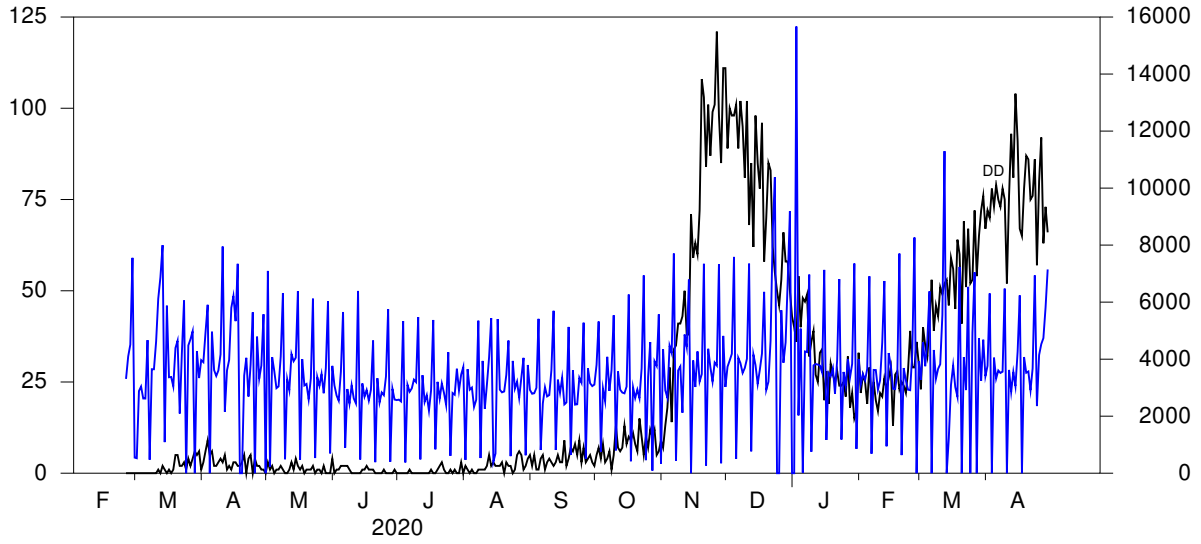

Figure 2. Co-variability between supermarket total spending and Covid-19 related deaths' announcements.

Before applying the causality tests in the supermarket spending data and Covid-19 data set, we investigated the order of integration using the Augmented Dickey Fuller test (ADF) for unit roots (see table 1).

Table 1: ADF test results at levels

	ADF(0)	ADF(1)	ADF(2)	ADF(3)	ADF(4)
Variable					
Cluster 1	-23.1467	-16.1283	-11.2314	-7.86966	-6.66474
Cluster 2	-20.8661	-14.2959	-11.5605	-10.0434	-9.01559
Cluster 3	-24.298	-16.4374	-12.4692	-10.1566	-8.54282
Cluster 4	-21.2029	-15.2209	-12.9163	-11.5194	-10.2196
Cluster 5	-26.3399	-16.2978	-12.258	-9.74952	-7.3791
Cluster 1	-21.8411	-15.5987	-12.787	-10.6767	-9.72488
Total Consumption	-26.9733	-17.9757	-13.5564	-10.4007	-8.29584
Covid-CASES	-4.53388	-3.83302	-2.71976	-2.14949	-1.63451
Covid Deaths	-2.70905	-1.53883	-0.97476	-0.8808	-0.67583
Covid METH	2.562742	1.168468	0.404625	-0.18113	-0.6602

Table 2: ADF test results at first differences

	ADF(0)	ADF(1)	ADF(2)	ADF(3)	ADF(4)
Variables					
Covid-CASES	-25.7272	-14.4505	-10.8972	-9.6127	-9.51275
Covid Deaths	-23.8675	-15.5726	-11.1621	-8.36651	-7.37323
CovidMETH	-16.6848	-9.87127	-8.98986	-9.34969	-7.11977

Table 1 reports the ADF test of the null hypothesis of non stationarity (H0). The number of lags in the ADF egressions is determined on the basis of the Akaike Information Criterion (AIC). The 5% critical value of the ADF test is −3.36.

Table 2 reports the results of the application of the Hsiao causality method and specifically the arithmetic application of formula 13. The numbers in the cells of Table 2 correspond to the ratios:

The numbers in the cells of Table 1 correspond to the ratios:

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$$FPE^{y}(m^{*},0)/FPE^{x}(m^{*},n^{*}) \quad (12)$$

where

$$FPE^{y}(m^{*},0)=\frac{T+m^{*}+1}{T-m^{*}-1}\frac{SSE_1}{T}\,FPE^{y}(m^{*},n^{*})=\frac{T+(m^{*}+n^{*})+1}{T-(m^{*}+n^{*})-1}\frac{SSE_2}{T} \quad (13)$$

$$SSE_1=\sum_{t=1+M}^{T}\hat{u}_{1t}^{2}\;SSE_2=\sum_{t=1+M}^{T}\hat{u}_{2t}^{2} \quad (14)$$

$$x_i-\sum_{s=1}^{m^{*}}\hat{a}_s\,x_{i,t-s}=\hat{u}_{1t}x_i-\sum_{s=1}^{m^{*}}\hat{a}_s\,x_{i,t-s}-\sum_{r=1}^{n^{*}}\hat{b}_r x_{j,t-r}=\hat{u}_{2t} \quad (15)$$

As long as the ratios (12) are greater than 1, we accept that variable $\{x_t\}$ affects in a Granger sense the formulation of the variability of variable$\{y_t\}$.

As long as the ratios (13) are greater than 1, we accept that variable $\{x_t\}$ affects in a Granger sense the formulation of the variability of variable $\{y_t\}$.

Table3. Direct Granger-causality test between Covid Variables and the different clusters of consumption

	LINEAR CAUSALITY					
	Manipulated Variable					
Controlled Variable	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6
Covid-CASES	1.00542	1.00542	1.00542	1.00542	1.16307	1.06307
Covid Deaths	1.02024	1.0024	1.0024	1.2024	1.14500	1.06400
Covid Intensive Care Units	1.9990	2.9990	1.9990	1.93930	1.99815	0.99815

Source: Our Results

Based on the results of Table 3, we can see that there is a causality of announced COVID-19 related deaths on supermarket spending. Using the method of Hsiao (1979) we detect the direct causality of all Covid related variables to the supermarket spending of each cluster of buyers. In Figures 3a-c we can see a diachronic effect between 2 variables. As the graph lines 3a, 3b, 3c, flatten, there is a standard decrease without osculation and cycles. In 3a we can see the effect of 1% of change in the number of COVID-19 infection cases on the 6 buyers' clusters. In 3b we can see the effect of 1% of change in the number of COVID-19 intensive care unit patients, on the 6 buyers' clusters. In 3c we can see the effect of 1% of change in the number of covid-19announced deaths on the 6 buyers' clusters. Finally, in 3d we can see a comparison of the dynamic effects of the of the COVID-19 variables (Cases, Deaths and number of patients in Intensive Care Units) on the six consumption clusters.

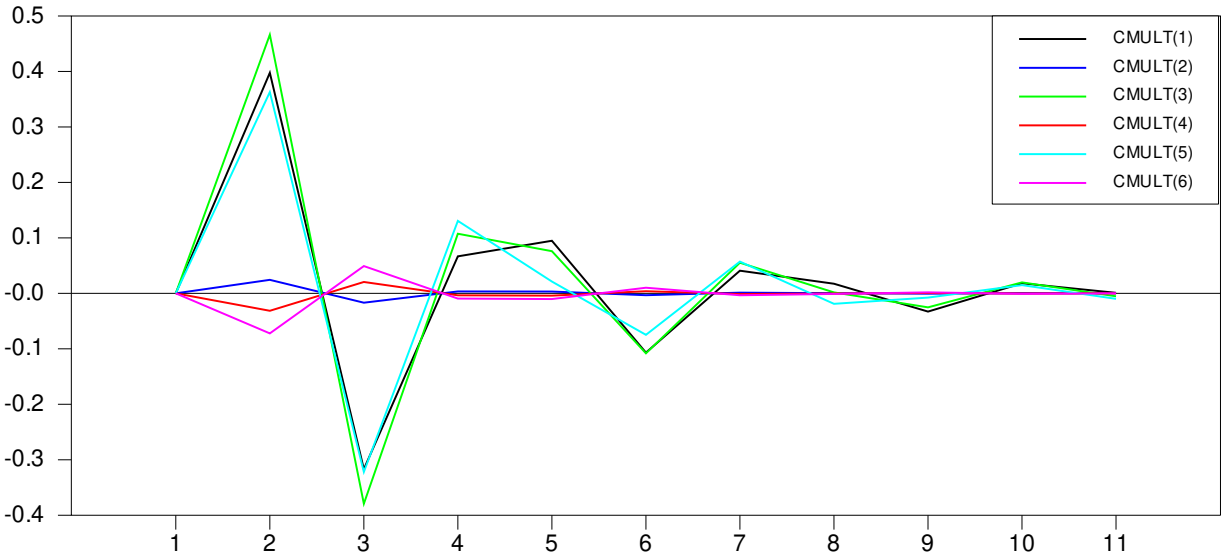

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Figure 3a. The Dynamic Effects of the Announcement of the Number of Covid-19 Infection Cases on the Six Supermarket Spending Clusters

Note: the colored lines in figures 3a, 3b, 3c and 3d mean the following: black=cluster 1, blue=cluster 2, green= cluster 3, red=cluster 4, turquoise= cluster 5 and pink= cluster 6.

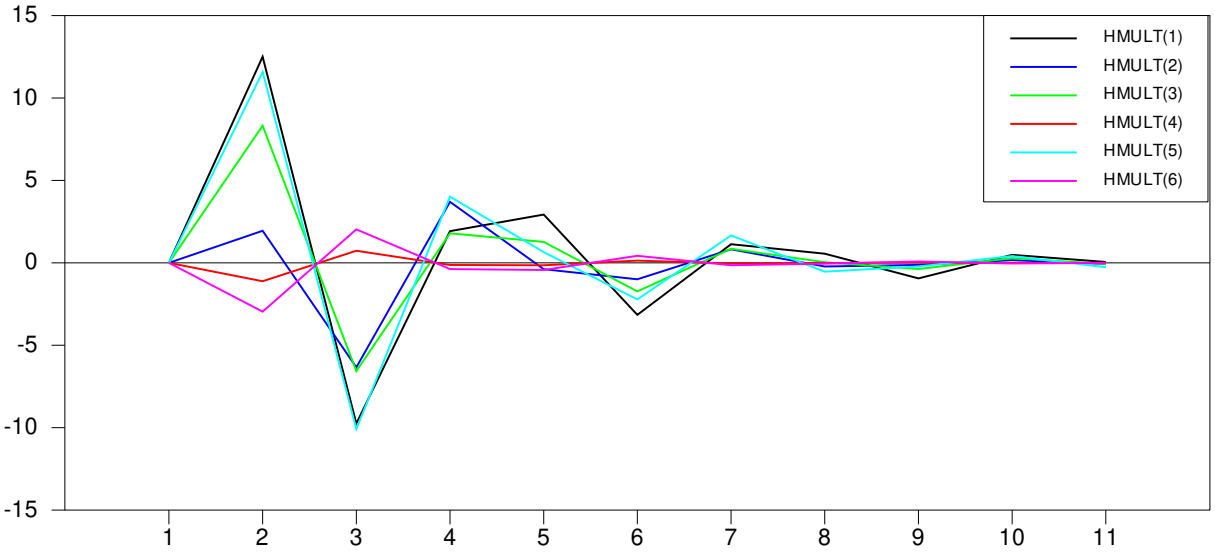

Figure 3b. The Dynamic Effects of the of the Number of Covid-Intensive Care Units on the six consumption Clusters

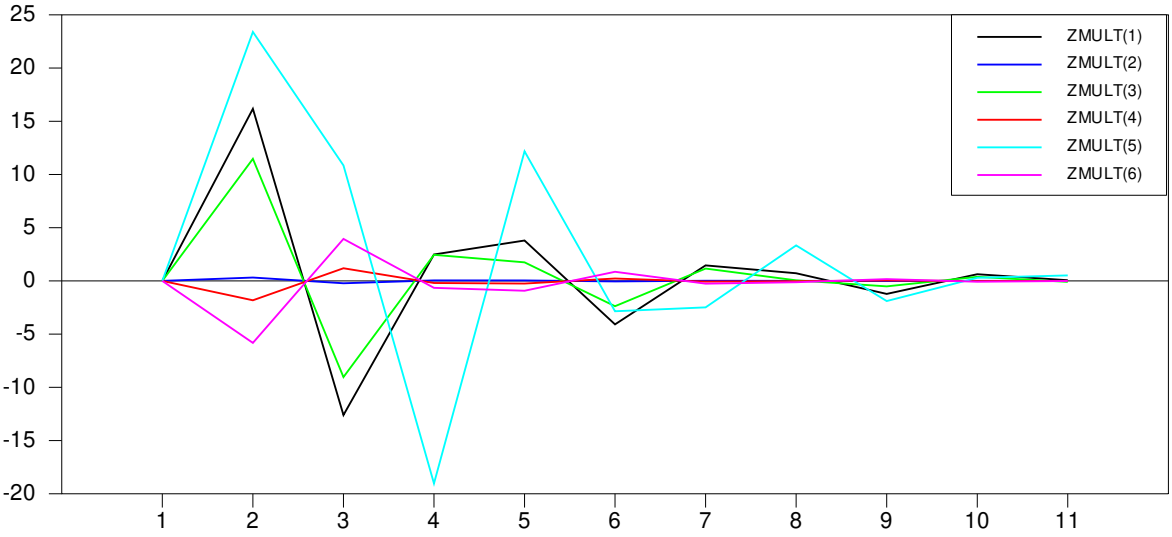

Figure 3c. The Dynamic Effects of the of the Number of Covid-Deaths on the six consumption Clusters

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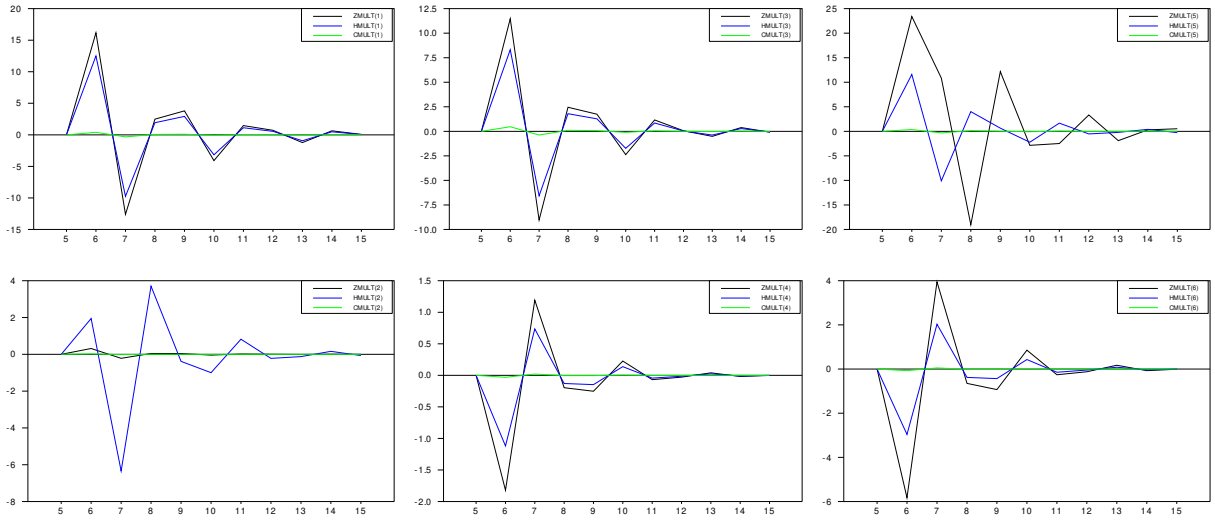

Figure 3d: A Comparison of The Dynamic Effects of the of the Covid Variables (Cases, Deaths and Intensive Care Units) on the six consumption Clusters (green = cases blue=intensive care, black deaths) clusters 1, 2,…6

According to the above estimations, we confirm the statistically significant effects of the Covid variables on the 6 buyers' clusters. These statistically significant effects have a diachronic behavior which varied in relation to the Covid variables. More specifically, the most prominent effect is the one attributed to the number of reported deaths followed by the number of COVID-19 patients admitted to intensive care units and finally by the number of the announced COVID-19 infection cases. The effects of these COVID-19 related variables appear to last for a period of 15 days.

Another finding of the study is related with the shape of the diachronic effects of the Covid variables on the 6 buyers' clusters. These effects are not straight lines, but they follow cyclical patterns which mirror the nature of the data. These data show that the convergence of the effects, includes information which can be used to comprehend the characteristics of the effects of COVID-19 on consumer spending in Greece. For example, as seen in figure 3c, following the reported number of deaths attributable to COVID-19, the 5th cluster of buyers demonstrate an increase in spending which starts to decrease on day 3, and on day 4 it plumets to about 20% lower spending that the average spending of the period. Also, cluster 5 demonstrates the highest reaction to the reported number of deaths compared to clusters 4 and 6. Furthermore, the data indicate that the number of reported deaths impacts consumption spending more than reported infection cases and reported number of patients admitted to intensive care due to COVID-19.

Figure 3d demonstrates unexpected effects of some Covid variables on Greek consumer spending. In principle the number of reported infection cases was expected to bare impact on consumer spending, however the results indicate that consumer spending reaction on infection cases is minimal compared to that of reported deaths, leading us to wonder about the apathy of Greek consumers to such information. Furthermore, clusters 1 and 2 demonstrate similar reactions to the 3 Covid variables. Cluster 3 demonstrated they highest reaction on consumer spending due to reported deaths than any of the other clusters. This cluster is also sensitive to reported number of patients admitted to intensive care units. The results of cluster 4 are rather surprising, as they indicate a reverse of the effects of Covid variables on consumer spending going a lead on the variable of reported number of patients admitted to intensive care units. The most prominent observation regarding the results of clusters 4 and 5 is the fact that number of reported deaths and intensive care unit admitted patients, do not lead consumers to increase their purchases for the first 6 days following the announcements. This data suggest that lower spending clusters (reflecting lower income consumer groups) appear to fear the reported outcomes of COVID-19 pandemic leading them to spending reaction which are not replicated by high income consumer groups. As such, the level of panic that drives reactionary spending appears to be lower in higher income consumers, who tend to normalize their spending after day 12 according to the standard reaction of the entire market.

5. Conclusion

The current study offers insight into the spending behaviors of a number of Hellenic-consumer spending clusters during the early periods of the COVID-19 pandemic. The analyses conducted (based on the application using the RATS software) revealed that after a certain period following the reports of the numbers of infections, deaths, and

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ICU admissions due to COVID-19, spending normalizes, leading to stable convergence after 13 days. We observed that on average, the number of reported deaths affect spending sensitivity more than the number of infections and the numberCOVID-19 patients in ICUs (except in the case of cluster 4). Also, we found that the number of reported deaths of cluster 3 shows a high variability and in cluster 4 the intensive care unit admitted patients appears to affect spending, more dramatically than other Covid related variables. Although it was not part of the purpose of this study, we are interested to discover why spending patterns of the clusters vary. The submitted literature revealed several psychological factors that affect consumer spending in such circumstances (i.e. fear) however we have no evidence about their effect on the specific population. Clearly as shown in this study lower spending clusters react more intensively to COVID-19 outcomes. This finding is consisted with other studies presented in the literature however our work was not designed to reveal the reasons for this occurrence.

The outputs of the study bare implications for both business practice and research. The reasons that cause the variability in the spending patterns of the clusters could be explored to provide answers to retailers' questions on how to best manage supply of goods during crises. Methodologically speaking we recognize the need to conduct non-linear and possibly chaotic causality tests on daily data per: sector, county, country, continent, income class, urban versus rural populations, online versus physical shopping of the populations under study. Such results can be useful for entire grocery retail supply chains and individual grocery stores as well. Also, we signal the need to examine threshold info in relation to specific *types of products* on spending distributions. This means we could examine the exact threshold of change in consumers' spending patterns on specific product categories, as influenced by reports of COVID-19 related factors (i.e. deaths infections, ICU admissions). Finally future studies on this phenomenon conducted in Greece, could replicate the approach of Ng et al (2022), in exploring how psychological traits of Hellenic consumers affected their supermarket spending during the COVID-19 pandemic. Such work could aid grocery retailers better predict the composition of the product portfolia critically affected by reported crises outcomes, aiding them in better managing pricing and just in time delivery of such product classes. The study revealed time lags pertinent to specialty logistics management, including promotional and pricing policy decisions for supermarket and grocery retailers. Thus, the study identifies opportunities for inventory and warehouse management decisions of supermarket related items producers. Finally, we suggest that the study identifies time related opportunities for social media advertising campaign strategists, related to reactionary messages to reported numbers of covid related variables.

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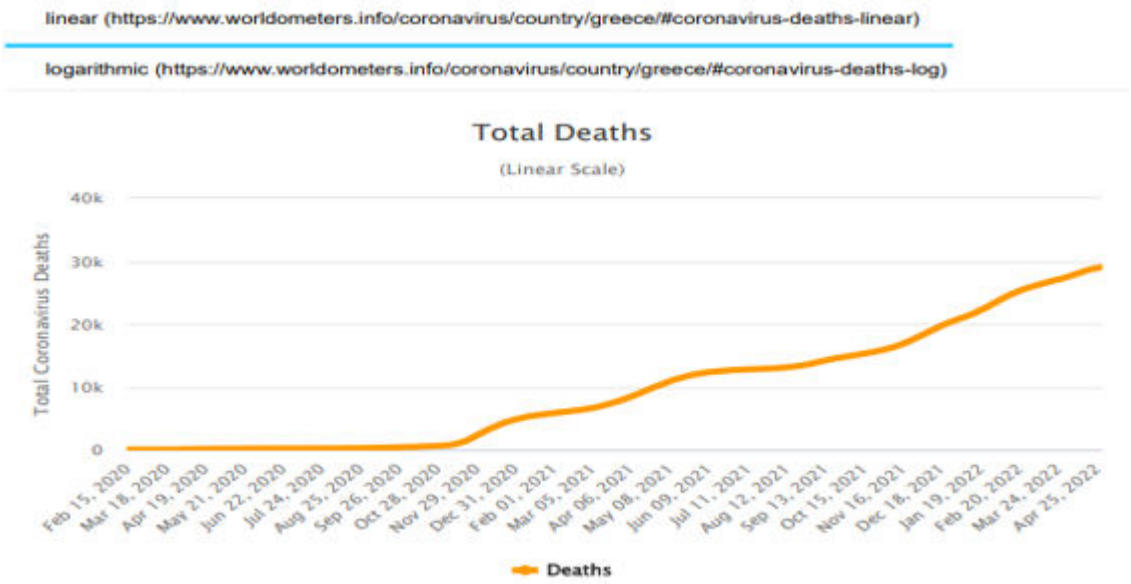
Appendix

Appendix A: Total number of Coronavirus deaths in Greece



Source: https://www.worldometers.info/coronavirus/country/greece, accessed April 29, 2022.

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