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Human Capital and Economic Growth in North African Countries: The Role of Institutional Quality

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Abstract: This paper aims to study the association between institutional quality, human capital, and economic growth in 4 North African countries, namely, Tunisia, Morocco, Algeria, and Egypt. Annual panel over the 2000-2021 period are examined using the System GMM. The result show that institutional quality and human capital can fuel economic growth. Interestingly, institutional quality and human capital have a significant positive interactive impact on the economic growth of North African countries. Policy implications of these results are that careful attention should be paid to co-development policies to improve the institutional quality and the human capital in these countries. Policies should also deliberate economic growth policies to maintain sustainable economic growth.

Keywords: Institutional quality, human capital, economic growth.

1. Introduction

In contemporary theories of growth, the development of human capital and the quality of institutions are identified as important factors of economic growth. Furthermore, the existence of good quality institutions is an important precondition for human capital to contribute significantly to economic growth, as human and social capital exert a direct positive effect on productivity. Furthermore, the role of institutional quality in the link between human development and growth is still unresolved, as China has experienced special economic growth without having high-quality political and economic institutions, the so-called “China Paradox”.

Consequently, this study explores the effect of institutional quality and human capital on economic growth in the North African countries. Unfortunately, empirical analysis on the impact of the interaction of institutional quality and human capital on GDP growth of these countries are very limited. Also, we examine the related growth effects of institutions and human capital. In fact, we study whether institutional quality can be a positive moderator for the effects of human capital on economic growth in the region. According to Tang and Zhang (2016), human capital stands for the absorptive capacity of host countries, as in the spirit of the endogenous growth theories. Moreover, in the context of the Millennium Declaration era, the World Bank has been carrying out human capital projects in Africa to help the African countries to develop their human capital. The World Bank (2018) recognized that human capital development plays a key role in ending extreme poverty and strengthening social inclusion. This requires investment in nutrition, health services, quality education, skills acquisition and access to jobs.

This paper then contributes to the related literature in three main aspects. First, to the best of the authors’ knowledge, this is the first study to examine the moderating role of economic freedom, an indicator of the quality of economic institutions, in the human capital-economic growth nexus in North African countries. Second, the findings of this paper have important policy implications for the North African countries as human capital and institutional quality are two of the most important determinants of economic growth. To achieve this, it is necessary not only to improve the quality of institutions, but also to increase the level of human capital. Third, compared to previous studies, this paper uses a more advanced dynamic panel econometric technique that formally addresses the countries’ specific effects and simultaneity bias. This method is based on the generalized method of moments (GMM) estimator, which has a number of advantages over the cross-section estimator.

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This paper studies the role of institutional quality on human development–growth nexus in the north African countries. We aim to address the following research question: Do institutional quality (economic freedom) matter in the human development-growth nexus?

The remainder of this paper is structured as follows: Section 2 provides an overview of the background literature. Section 3 describes the data and the empirical methodology. The empirical results are offered in section 4 and finally section 5 presents the conclusions and comments on policy implications.

2. Literature review

2.1. Theoretical literature

In the literature on long-term growth, there is broad consensus that the accumulation of human capital and knowledge plays a crucial role in the process of economic development. Empirical evidence on the subject has shown, moreover, that one of the explanatory causes of growth gaps between countries lies in differences in terms of quantitative and qualitative endowments of human capital.

Human capital is an intangible asset that can advance skills development for worker employability and business productivity. It can grow, shrink or become useless. It is subject to different effects and comes from different origins, including, but not only, learning organized in the form of education and training. The four elements (knowledge, qualifications, skills and other personal qualities) can be united in different ways depending on the individual and the context in which they are used (Al-Tit et al. 2022).

Economists consistently confirm that human capital is a determining factor in economic growth, regardless of the state of economic situations (see Solow, 1956; Nelson and Phelps, 1966). With the appearance of new growth theories discussed by Lucas (1988), Romer (1986) and Barro (1997), human capital development has become one of the important factors for strengthening economic growth through technological advances by decreasing inequality and achieving productivity gains (Cadil et al. 2014). On the other hand, labour productivity mainly depends on the new skills and knowledge developed by the education system, which can transform the population into labour as a productive input into the production function (Barro, 1991). Additionally, employing a skilled workforce appears to be crucial to achieving high business productivity. Human capital consequently constitutes a potentially crucial determinant in enhancing economic growth.

As for Romele (2013), he showed that the development of human capital requires continuous and substantial investment in capacity building through the application of government skills development programs and improving the education level of workforce. In fact, the development of human capital positively affects the development of physical capital in the economy. Investments in human capital can also reduce income inequality in society (Heckman and Jacobs, 2010) and ensure higher labor force size and promote inclusive and sustainable economic growth (Deere and Vešovice, 2006). For his part, Lucas (1988) emphasized the essential role of human capital in economic development for developing countries.

2.2. Empirical literature

In fact, many empirical studies have shown the positive effect of human capital on economic growth. For example, Qadri and Waheed (2013) showed evidence of a positive human capital contribution in overall and sectoral production and economic growth in a cross-section of 106 countries. However, its magnitude is similar in the agricultural and industrial sectors, greater than that associated with the services sector. As for Jaiyeoba (2015), he found a positive link between human capital and economic growth in Nigeria. For his part, Pelinescu (2015) reported a positive impact of human capital on economic growth in European Union countries.

Likewise, Teixeira and Queiros (2016) showed a link between the development of human capital and economic growth in the countries of the Organization for Economic Co-operation and Development, countries in transition and Mediterranean countries. As for Fang and Chang (2016), they pointed out a positive link between human capital and long-term economic growth in 16 countries in the Asia-Pacific region. For their part, Ogundari and Awokuse (2018) examined 35 sub-Saharan African (SSA) countries and found that human capital has positive effects on economic growth, although the contribution of health is relatively larger than the impact of education. For their part, Han and Lee (2020) found that human capital contributes significantly to economic growth in Korea; it accounted for 0.5% points of economic growth over the period. They recommended that policies to improve human capital of female or elderly workers help to increase human capital growth.

As for Ogbeifun and Shobande (2022), they showed that human capital plays a vital role in economic growth for a panel of 24 OECD countries. For their part, Ali et al. (2022) pointed out that human capital has a positive and significant link with economic growth for higher-income and overall Organization of Islamic Cooperation countries (OIC). However, in lower-income OIC countries, human capital has an insignificant correlation with economic growth. More recently, Shaban and Shahbaz (2023) found that India's cultural diversity and human capital have significant effects on regional economic growth in India.

The relationship between institutions and economic growth has been the subject of much research and debate among economists. One of the most influential studies on this topic is the work of North et al. (2009) who claimed that the key to economic development is the development of inclusive institutions that limit state power and protect property, rights of individuals and businesses. They argued that inclusive institutions, such as the rule of law, constitutional limits on state power, and an independent judiciary, are necessary for economic growth because they create a stable and predictable environment in which individuals and businesses can make long-term investments. Another important contribution to this literature is the work of Acemoglu and Robinson (2012), who showed that the key to economic growth is the development of institutions that promote economic and political competition. They pointed out that institutions that provide opportunities for individuals and businesses to compete for resources and power are more likely to generate economic growth than those that concentrate power in the hands of a few people. They also maintained that institutions that promote economic and political competition are more likely to be inclusive and protect the property rights of individuals and businesses.

The definition of institutions assumed by North (1990) is the most used in institutional economics. According to North (1990), institutions are the rules of the game in a society, or more formally, they are the humanly designed constraints that determine human interactions. Consequently, institution's structure incentives in human exchanges, both in the political, economic and social domains. Furthermore, institutions have the nature of reducing uncertainty in everyday life (North, 1990). Acemoglu et al. (2005) defined institutions as a combination of three closely related concepts:

- Economic institutions: These include the factors that govern the incentive structure in society and the distribution of resources. For example, the structure of property rights, barriers to entry, all contract types.

- Political power: Economic institutions are themselves the result of collective choices by society. A society is made up of different groups with conflicting interests. The distribution of political power determines the quality of economic institutions.

- Political institutions: They are legal instruments enabling the functioning of public authorities and the State. The first of these instruments, which guarantees the national sovereignty of a country, is the constitution.

Several economists show that the quality of institutions plays a vital role in the economic performance of countries. Interested in the role of institutions in the process of economic growth, Knack and Keefer (1997) affirmed the existence of a positive relationship between the different indicators of institutional quality (political stability, bureaucracy, property rights) and economic performance. Hall and Jones (1999), argued that differences between countries in institutional development and policies adopted by governments could be a fundamental determinant of differences in productivity and capital accumulation. Furthermore, Raiser (1997) revealed forward the idea that the weakness of economic performance in the countries of the former USSR could be explicated by the poor quality of institutions through their influence on social capital.

The literature also showed several benefits of institutional quality. For example, good institutions can have an effect on improving education, reducing inequality and reducing public consumption, which could increase economic growth (Tavares and Wacziarg, 2001). Institutional quality increases the level of economic growth, particularly through their impact on investments (Busse and Hefeker, 2007). Reuveny and Li (2003) supposed that the quality of institutions plays a role in reducing income inequalities. As for Mauro (1995) and Shleifer and Vishny (1993), they emphasized the negative interaction that exists among the level of corruption and economic growth, and showed that the structure of institutions and the political process determine the level of corruption which is detrimental to economic growth.

Other economists have used history to demonstrate the impact of the quality of institutions on the current state of different economies. Engerman and Sokoloff (2002) confirmed that the former European colonial powers adopted different strategies of colonial exploitation which led to different institutional trajectories in these countries, with a more developed (Canada and United States) than the South. Acemoglu and Robinson (2008) showed that previous institutions have a long-term effect on economic performance. They also argued that the colonial origin is strongly correlated with the current economic situation through its impact on the quality of current institutions.

On the other hand, Rodrick et al. (2004) showed that institutional quality plays an important role in explaining income gaps between rich and poor countries. In the same line of thinking, Acemoglu and Robinson (2012) explained that the difference in income and living standards between rich and poor countries is based on the existence of “inclusive” political and economic institutions which, according to them, represent the key to the prosperity of nations by creating a virtuous circle of innovation and economic expansion. For their part, Méon and Sekkat (2004) indicated that improving institutional quality in MENA countries will lead to an increase in entry of foreign direct investment and exports of manufactured products and will also allow the participation of these countries in the world economy.

As for Ouedraogo et al. (2021), they analyzed economic development in Africa through the examination of the role of institutional quality in the development of human capital using a panel of 49 African countries over the 1996-2018 period. They showed that improving institutional quality encourages access to primary, secondary and higher education in general and for women. In particular, controlling corruption, government effectiveness, political stability are the main determinants that promote the development of human capital. Their results suggested that promoting these particular dimensions of institutional quality is crucial to improve human capital development in Africa.

For their part, Uddin et al. (2021) studied the effect of institutions, human capital and economic growth in a panel of 120 developing countries over the 1996-2014 period. They showed that the development of human capital and institutions have positive effects on economic growth. Remarkably, institutional quality and human capital development have a significant negative interactive impact on GDP growth in developing countries. They concluded that additional investment in human capital development would have a negative effect on economic growth in the presence of weak or dysfunctional institutions, because the additional stock tends to be diverted into socially unproductive activities. They also confirmed that the prosperity of a country presupposes the existence of solid institutions, a necessary condition to create an environment to facilitate the development of the private sector, reduce poverty and provide useful services to the population.

On the other hand, Uberti and Knutsen (2021) used panel data over the 1955-2010 period and an indicator reflecting the protection of property rights (indicator of institutional quality) to study the link between institutions, human capital and economic growth. They pointed out that property rights protection and human capital are positively associated with economic growth because it encourages investment and innovation. In countries where property rights are not clearly defined and protected, individuals and businesses are less likely to invest in long-term projects or make large purchases because they cannot be sure that their investment will be safe. This can lead to a lack of economic development and slow economic growth.

As for Abdulwahab (2023), he examined the effect of institutional quality and human capital development on economic growth for the SSA countries over the 2002-2021 period. He argued that institutional quality and human capital development have a statistically low impact on economic growth in these countries. He also recommended that various authorities should improve the quality of health care and make the education system more efficient and allocate adequate resources to productive sectors to promote economic growth.

More recently, Doré and Teixeira (2023) studied the extent to which human capital and institutional quality contribute to economic growth in Brazil, over the 1822-2019 period. They suggested that human capital (measured by years of schooling) have a positive impact on economic growth in Brazil. They also revealed that institutional quality does not have a decisive effect on economic growth in Brazil.

Taken as a whole, the effect of institutional quality and human capital on GDP growth are exposed in the literature to be mixed, whereas their influence on the North African countries is attracting increasing attention between economists and analysts. In fact, this paper is interested by similar reflexions and efforts to identify the potential complementarities among institutions and human capital in the North African countries over the 2000-2021 period.

3. Data and Empirical methodology

3.1. Data

In fact, this article studies 4 North African countries to know: Tunisia, Morocco, Algeria and Egypt over the 2000-2021 period. The countries are selected for this study is mainly inspired by the availability of reliable data during the sampling period. The dependent variable is economic growth measured by the growth rate of real GDP per capita at prices in 2015 US dollars. The key variable of interest (human capital) and other control variables (initial GDP, inflation rate, government size) are attained from the World Development Indicators database (World Bank, 2024).

At the macroeconomic level, human capital thus appears to be a factor of growth. Mankiw et al. (1992) found that differences in human capital between countries help explain a large part of

their differences in terms of economic growth. In the literature, human capital is measured by school enrollment rates. Some studies use the gross enrollment rate in secondary education while others use the gross enrollment rate in primary education (see Qaisar, 2001 and Nyamongo et al. 2012). In both cases, these approximations generated positive coefficients in support of the theory. In this study, we use the school enrolment, tertiary (% gross), because data are relatively available. Higher education rates lead to greater human capital, which should be positively associated to economic growth (Gemmel 1996). This variable should have a positive impact on economic growth.

Additionally, the extended model will contain the following institutional variable: The index of economic freedom. Economic freedom is measured in five different categories: (1) the size of government; (2) the legal structure and security of property rights; (3) access to sound money; (4) freedom of international trade and (5) regulation of credit, labour and commercial activities. The overall domain scores are all on a scale of zero to 10, with zero being the least free and 10 being the freest. In fact, the greater the economic freedom, the more it strengthens economic growth (Doucouliagos and Ulubasoglu, 2006). We therefore expect a positive coefficient. Besides, data are obtained from Gwartney et al. (2023).

Our baseline regression model contains the explanatory variables common to most empirical growth literature:

- Initial GDP per capita was comprised in the model to capture conditional convergence in the spirit of the neoclassical theory of economic growth (Barro and Sala-i-Martin, 1995). Numerous studies have showed that GDP per capita can be a good indicator of general development and the sophistication of institutions (La Porta et al. 1998). A negative coefficient is expected, representing the existence of conditional convergence between North African countries;

- Inflation rate is defined as the growth rate of the consumer price index (CPI) to measure the effect of price instability on economic growth. High inflation can contribute to deteriorating price competitiveness leading to negative impacts of the external sector on economic growth (Aydin et al. 2016).

- Government size is measured in terms of government spending as a percentage of GDP. In the literature, there is no consensus on the direction of the relationship between public spending and economic growth. Indeed, empirical work shows that public spending can affect economic growth negatively or positively depending on the nature and quality of public spending (Devarajan et al. 1996; Gupta et al. 2005).

3.2. Empirical methodology

The objective of our empirical analysis is to study how institutional quality affects human capital and GDP growth in the North African region. To this end, we employ a specification similar to that of Uddin et al. (2021) by considering the next model:

$$Growth_{i,t} = (\alpha - 1) y_{i,t-1} + \beta_1 HK_{i,t} + \beta_2 IEF_{i,t} + \beta_3 (IEF_{i,t} \cdot HK_{i,t}) + \beta_4 X_{i,t} + \mu_t + \eta_i + \varepsilon_{i,t} \quad (1)$$

The subscript “ t ” represents the periods, whereas i represents the country, Growth is the real GDP growth rate per capita, IEF represents proxy for institutional development, HK represents proxy for human capital and X is the matrix of the control variables, μ_t is a time specific effect, η_i is an unobserved country-specific fixed effect and $\varepsilon_{i,t}$ is the error term. Eq. (1) forms the basis for our estimation. $(\alpha - 1)$ is the convergence coefficient.

The hypothesis that we wish to verify in this study is that the quality of the host country's institutions affects the development of human capital and therefore economic growth. To this end, we add an interaction term created as the product of IEF and HK (i.e. IEF*HK), used as an additional explanatory variable in equation (1).

The role of institutional quality in affecting human capital and hence, economic growth is assessed using the coefficient β_3 . In fact, if β_3 is positive and statistically significant, a high institutional quality could enhance the marginal effect of human capital on economic growth. This suggests that there is a complementarity between institutional quality and human capital. On the other hand, if β_3 is negative and statistically significant, a bad quality institutions could reduce the marginal effect of human capital on economic growth. In other words, a negative interaction offers evidence of substitutability between institutional quality and human capital.

In order to estimate equation (1), we use the GMM on a dynamic panel (Arellano and Bond, 1991; Blundell and Bond (1998). The GMM method has, among other things, the advantage of controlling endogeneity between variables. The instrumentation method differs depending on the nature of the explanatory variables: (a) for purely exogenous variables, current variables are used as instruments; (b) for weakly exogenous variables, values lagged by at least one period are used as instruments; (c) for endogenous variables, values lagged by two or more periods can be used as valid instruments.

The GMM estimator proposed by Arellano and Bond (1991) is based on the orthogonal conditions between the lagged endogenous variable and the error term. It helps provide solutions to the problems of simultaneity bias, reverse causality and omitted variables. It also makes it possible to correct the endogeneity of all the explanatory variables of the model. This estimator refers to the first difference GMM method in order to reject specific individual effects and the use of lagged values of the dependent variable as instruments.

Further on, Blundell and Bond (1998) propose the system GMM estimator. They combine first difference equations with level equations in which variables are instrumented by their first differences. Through Monte Carlo simulations, Blundell and Bond (1998) proved that the System GMM estimator performs better than the first difference one. Certainly, when the instruments are weak, the first difference GMM estimator provided biased results in finite samples.

We apply the two-step estimation technique. The use of this technique is explicated by the fact that the estimator found is more efficient than the one-step one (Roodman, 2009). Certainly, the two-step estimation is more precise than the one-step one since it takes into consideration the structure of the error variance-covariance matrix.

The efficiency of the estimation of System GMM is based on the validity of two tests. First, the Sargan/Hansen overidentification test which allows testing the validity of lagged variables as instruments. Second, the autocorrelation test of Arellano and Bond (1991) where the null hypothesis is the absence of second-order autocorrelation of errors (AR test). In our study, we note that Hansen's overidentification test does not allow us to reject the hypothesis of validity of lagged variables in level and difference as instruments. On the autocorrelation test, we observe the presence of a first order effect (AR1), which is consistent with the hypotheses formulated, and an absence of second order autocorrelation (AR2). The findings from the estimation technique are presented in Table 1.

4. Empirical results

The estimation results in Table 1 show that the impact of human capital on economic growth is positive and significant. This result shows that enrollment of the tertiary school has a significant effect on the growth rate in the North African countries. This result is consistent with that of Oketch (2006) and Ogunhari and Awokuse (2018) who pointed out that human capital makes a significant impact on per capita GDP growth in North African countries.

Moreover, the index of economic freedom coefficient has a positive sign and therefore, it is statistically significant, suggesting that economic growth is stronger when economic freedom is high because it makes for a more efficient economy. This finding is consistent with the study of De Haan and Sturm (2000) and Brkic et al. (2020) who argued that greater economic freedom fosters economic growth.

Table (1) displays the regression results based on interaction specification using an interaction term between institutions and the human capital. In this specification, we relied on the interaction term to establish the contingency. If the term is positive and significant, this would imply that the effect of human capital on economic growth increases with institutions. The first thing to note is that the sign of the coefficient of the interaction term between human capital and the degree of economic freedom is positive, implying that human capital and the degree of economic freedom act as complements. In other words, an improvement in the quality of institutions reinforces the positive impact of human capital on economic growth in North African countries. This supports previous empirical studies that have highlighted the complementary role of human capital and institutional quality on economic growth (Doré and Teixeira, 2023).

Table 1. The economic growth effect of institutional quality and human capital

Variable	Value (probability)
Initial GDP per capita	-0.471*** (0.008)
Human capital	0.246** (0.041)
IEF	0.121* (0.081)
IEF*Human capital	0.02* (0.071)
Inflation	-0.421**** (0.047)
Government size	0.771* (0.062)
Constant	0.182* (0.098)
AR(2) test (p-value)	0.825
Hansen-J-Test (p-value)	0.287

Notes: The dependent variable is real GDP per capita growth. Annual data from 2000–2021. Robust standard errors are in parentheses below the coefficients. *p < 0,1; **p < 0,05; ***p < 0,01.

Source: authors' estimations.

In fact, most of the findings about the other explanatory variables are consistent with expectations. The convergence theory is verified in this study with the lagged GDP per capita. In the estimates, we see that the estimated coefficient is negative and significant at the conventional level of testing. This result is consistent with the neoclassical model which postulated that the economy tends to approach its long run position if the starting per capita income is low. This result then supports the conditional convergence hypothesis in which case growth is faster in poor countries than in richer countries. This result validates the work of Barro and Sala-i-Martin (1997) and Sachs and Warner (1997). The result also confirms a significant negative effect of inflation on real GDP growth. This result implies that greater macroeconomic instability via the variability of inflation negatively affects global economic growth in the region of North Africa. Therefore, this result corroborates the work of Aydin et al. (2016). Furthermore, it is revealed that government spending exerts a positive and significant effect on economic growth. This finding is consistent with the study of Poku et al. (2022).

5. Conclusions

The economic challenges facing some North African countries have long been a source of concern. These challenges are linked to a range of complex factors. Despite the region's diverse resource and human resources, it faces a variety of challenges that hamper its economic growth. Poor infrastructure, limited access to education and health care, and political instability are among the main factors that have contributed to the economic challenges facing many North African countries. In addition, high levels of corruption and ineffective governance have often hampered investment and hampered the efficient allocation of resources. Many countries in the region also suffer from a lack of economic diversification, relying heavily on a few commodities, making them vulnerable to fluctuations in the global market.

Lack of sufficient institutional quality has a negative impact on economic affairs and the negative impact on economic growth is a major challenge for many North African countries. Poor governance, rule of law and regulatory efficiency are all indicators of institutional quality, all of which are essential to create a climate conducive to economic success. However, the region has had to contend with inadequate institutions, which have hampered effective governance and economic development. Indeed, poor institutional quality can lead to political instability, corruption and weak laws, which hinder domestic and foreign investment. The North African region has made progress in areas such as reducing inflation and improving macroeconomic stability, but persistent

structural constraints, including poor governance and weak institutions, continue to hamper economic growth.

In this context, the paper examines the moderating effect of institutional quality and human capital on the economic growth of 4 North African countries (Tunisia, Morocco, Algeria and Egypt) over the 2000-2021 period. The importance of institutional quality and human capital on economic growth is widely accepted by economists with only a few exceptions. Nevertheless, in spite of having natural and human resources, many North African countries cannot catch up with the developed countries because of poor institutional quality. Therefore, the most important novelty is the study of transmission channel: economic institutions (measured by the index of economic freedom) through which human capital affects economic growth in North African countries. The findings approve that both institutional quality and human capital have a significant positive impact on economic growth. Therefore, it can be resolved that there is sufficient evidence to support that the institutional quality and the human capital are essential for economic growth. The findings also advise that institutional quality and human capital have a positive complementary effect on economic growth. Furthermore, the results indicate that government size positively influence economic growth. On the other hand, inflation affects economic growth negatively.

According to the study, governments in these countries should propose and implement significant measures to improve health and education systems. The expected policy is to improve the quality of health and education, ensure sufficient investment in both sectors and make access to health and education systems as simple as possible. This will help increase human capital while increasing the overall well-being and productivity of the region's people. In addition, governments in each country should invest in expanding the employment prospects of young graduates. Giving more space to the skills and knowledge of today's and tomorrow's generation would also boost the growth and development of North African countries. Implementing these measures could help North African countries foster economic growth in the near future.

Addressing the complex challenges posed by weak institutions and inadequate human capital development in these countries requires a comprehensive and coordinated effort. Policymakers, stakeholders and international organizations must collaborate to bring about beneficial change through a multidimensional strategy.

A crucial step to overcome the mentioned problems is to implement significant institutional reforms aimed at strengthening governance, reducing corruption and enhancing the rule of law. At the same time, investment in human capital development is essential. Governments should focus on education and health care, investing sufficient funds to ensure access and quality. This is about equipping workers with the skills and knowledge needed for creativity and productivity. Access to vocational training, skills development programs, and health services must be increased by governments in each country to progress the overall capacity of the workforce.

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Lean Municipality: Case Studies, Practical Applications, and a Comprehensive Literature Review within Bibliometric Analysis

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Abstract: This article explores the fundamental principles, practical applications, and case studies of Lean Municipalism. It illustrates how this management model can optimize the operational processes of municipalities, improving service quality and resource efficiency. The study provides insights into the successes, challenges, and best practices for implementing lean principles in local governments by examining various case studies from countries such as the United States, Germany, Norway, and Türkiye. Comprehensive literature review complements these cases, helping local governments and researchers better understand the opportunities lean management offers. A bibliometric analysis method was employed to identify research trends and critical findings, systematically evaluating academic articles on lean municipalism from databases such as Web of Science. This research aims to serve as a valuable resource for promoting sustainable and effective management models, highlighting the potential benefits and practical considerations of Lean Municipalism for local governments and academics, and providing actionable insights for its implementation.

Keywords: Lean Municipality; Lean Management; Service Quality; Bibliometric Analysis

1. Introduction

Lean municipalism is a strategic approach adopted by local governments today to cope with resource constraints and increase service expectations [1]. This management model primarily aims to maximize customer value, reduce waste, and encourage employee engagement [2, 3]. Lean municipal practices can improve service quality, reduce costs, and increase citizen satisfaction.

Lean municipalism focuses on identifying and eliminating unnecessary activities by analyzing business processes. This approach can help municipalities deliver their services faster and more efficiently. At the same time, by increasing employee involvement, it aims to consider municipal employees' views and support their efforts toward continuous improvement [4].

Many municipalities worldwide have achieved significant success by adopting lean municipal principles. For example, in Japan, Toyota's lean manufacturing principles are effectively used in municipal service delivery. In the United States, many municipalities have adopted lean municipalism practices to optimize business processes and provide more effective services [5].

This study aims to understand how these principles can improve municipalities' performance, service quality, and citizen satisfaction by examining the impact of lean municipal practices on local governments in detail.

2. Conceptual Dimension of Lean Thinking

Lean thinking is a business management system that originated in Japan and has attracted much global attention. This system aims to eliminate non-value-creating activities and minimize potential problems by ensuring that processes are simple, unpretentious, and waste-free [6]. Its main objective is to use a minimum number of resources and deliver these resources to the customer on time and in a way that meets expectations [7]. Lean was first used in the manufacturing sector, but it has also been effectively applied in other sectors over time. Developed in a period of economic and social difficulties in Japan, lean emerged to overcome these difficulties and to ensure effective functioning [8].

Lean management techniques allow businesses and organizations to improve their business processes with a perspective focused on value creation. These techniques offer a different approach from the short-term solutions businesses often resort to when facing financial problems [9]. The lean approach carefully reviews business processes to reduce waste and optimize processes [10].

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Thus, it aims to meet the expectations of both the organization and the customer and focuses on increasing the long-term sustainability of businesses.

Lean thinking plays a critical role in increasing businesses' competitive advantage in times of crisis and challenging situations. While businesses facing financial difficulties often turn to short-term solutions, lean businesses stand out because they focus not only on financial fixes but also on value-creation principles. This approach enables businesses to gain a competitive advantage and achieve sustainable success. Lean thinking allows businesses to pursue excellence with a value creation-oriented perspective so that they can be managed effectively even in challenging times [11].

2.1. *The Quest for Excellence and Lean Transformation*

The pursuit of excellence is an essential strategic approach where businesses aim not only to increase their profitability but also to maximize customer satisfaction. For the practical realization of this pursuit, lean transformation plays a vital role in today's competitive business environment. Transitioning from lean production to lean management allows organizations to create positive impacts. In this era of fierce competition, businesses are testing different management models to minimize waste and meet customer expectations quickly and with high quality [12].

Lean management is a technique that enables businesses to focus on the pursuit of excellence. When a business or organization faces financial problems, it often seeks short-term solutions. A range of actions are considered, from laying off workers to closing and selling off unprofitable parts. However, the main feature that distinguishes lean businesses from others is the adoption of value creation as a fundamental principle. Organizations overcome financial problems and gain an edge over their competitors. Lean transformation solves existing problems and points to a continuous pursuit of excellence [13]. Many businesses that have achieved this have experienced the lean transformation journey.

Lean Transformation is a transformation process that organizations adopt to increase their effectiveness and meet customer expectations at the highest level in today's highly competitive environment. The transition from lean production to lean management models aims to improve not only an organization's internal functioning but also customer satisfaction and value creation processes [14]. To improve the efficiency of business processes, lean transformation of an organization involves reducing waste and making business processes more efficient and effective. In this process, organizations often shift to a customer-centric perspective, focusing on understanding customer expectations and developing strategies to meet them best. Lean transformation is an approach that aims to provide a competitive advantage by increasing quality and efficiency within the organization and in customer relations [15].

Lean transformation drives businesses and organizations to continuously improve, offering a strategic way to gain a competitive advantage. This approach aims to be a pioneer in delivering value to the customer, not only internally but also along the entire value chain. In this way, organizations can achieve success from a financial perspective and from the perspectives of customer satisfaction and continuous improvement [16].

Lean thinking is an organization's journey of cultural transformation in pursuit of excellence. This journey includes lean manufacturing principles such as value stream analysis, Kaizen, and 5S methodologies. At the same time, this study will also discuss the lean office.

2.2. *Value Stream Analysis*

The value stream covers the entire product lifecycle, from the product's design to delivery. Lean techniques such as value stream mapping can visually map the entire product flow. Once the value stream is mapped, finding and minimizing non-value-adding steps is easier. Creating continuous and efficient product flow requires the uninterrupted passage of products from production to transportation, which can be achieved by strategically organizing the workspace. A well-organized workspace will result in shorter production times, less inventory size, and less material handling [17]. Value Stream Analysis helps businesses meet customer expectations most effectively by minimizing process waste. This analysis supports the pursuit of excellence and emphasizes the principle of value creation at work. This approach allows businesses to gain short-term and long-term competitive advantages [18].

As a first step in implementing value stream analysis, the business processes should be detailed. This mapping process is critical to visually understanding all the business operations and identifying the value stream. Once the value stream is mapped, strategic improvements can be made to identify and reduce non-value-adding steps [19]. To apply value stream analysis, it is necessary to analyze the business processes in detail, identify waste, and eliminate it effectively [20].

Value Stream Analysis provides a solid foundation for maintaining order and cleanliness in the workplace, using resources more effectively, and managing business processes transparently [21]. It also helps businesses to focus on long-term sustainability and success rather than just focusing on short-term goals. Therefore, it is applied as a strategic tool for businesses to survive and

thrive in a competitive world [22]. Businesses that adopt this basic principle manage Kaizen processes more effectively.

2.3. Kaizen

Kaizen is a Japanese term derived from the words "change" and "good" and means "continuous improvement for the better". This philosophy aims to continuously improve all business functions or processes and involve employees at all levels in this process. Although the history of Kaizen originated in Japan, today, it has had a global impact [23].

Kaizen aims to improve workplace processes through small but continuous changes. While this strategy aims to achieve significant results in the short term, it aims to achieve sustainable improvements in the long term [24]. The benefits of Kaizen include reducing workplace waste, increasing productivity, and responding to customer expectations faster and with higher quality [25].

Kaizen's focus on the philosophy of continuous improvement strengthens the culture of value creation. It encourages businesses to think not only about their current situation but also about how they can continuously improve it [26]. In this way, organizations gain competitive advantage by creating a culture of change and improvement.

Another essential element that Kaizen emphasizes is the human element. Kaizen emphasizes the participation and contribution of employees at all levels [27]. It believes that the ideas of everyone involved in business processes are valuable and, therefore, encourage teamwork. This enables the workforce to identify and implement potential improvements in business processes [28].

The two main approaches of Kaizen are:

- Individual-Focused Efforts (Kaizen): This approach envisages that each employee individually takes responsibility for continuous improvement. Small, day-to-day changes and improvements, combined with the contribution of many individuals, can have a significant overall impact [29].
- Kobetsu Kaizen: This approach targets significant losses within the business. It is based on predetermined strategies and aims for low-cost, high-return improvements. Kobetsu Kaizen is focused on achieving clear and measurable results [30].

Both approaches incorporate the basic principles of Kaizen and provide a flexible application for the different needs of businesses.

The Impact of Kaizen on business processes contributes to the competitive advantage of businesses by optimizing not only product or service quality but also working environments and processes [31]. While this method encourages businesses to make improvements continuously, it can allow them to achieve maximum efficiency when used in combination with other practical tools, such as the 5S methodology.

2.4. 5S Methodology

5S, a primary method of maintaining order and cleanliness in the workplace, means "sorting, organizing, cleaning, standardization and discipline" in Japanese. This methodology provides physical order and aims to reduce waste by optimizing business processes [32]. The deliberate sequencing, organizing, and cleaning of each element and process in the workplace helps to increase the effectiveness of the work environment [33]. Adopting standardized procedures and maintaining discipline is crucial for the sustainability of this order. In this way, the 5S methodology can be applied as a method that increases productivity in the workplace while at the same time supporting employees to perform their work in a more organized and effective way.

- Sorting (Seiri): As a first step, unnecessary equipment, materials, and documents in the workplace are meticulously examined. Unnecessary items are removed to make the environment more organized [34].
- Organization (Seiton): The second step aims to have everything used in the workplace in a logical and accessible order. Necessary equipment and materials are placed in designated places, which speeds up the workflow [35].
- Cleaning (Seiso): Cleaning is not only limited to the physical environment; it also encompasses business processes and equipment. Cleaning practices improve quality by reducing waste in the workplace [36].
- Standardization (Seiketsu): In this step, sorting, organizing, and cleaning steps are standardized. The standards are set to ensure that processes and order are continuously maintained [37].
- Discipline (Shitsuke): The last step, discipline, aims to ensure that employees adhere to the set standards and methodology. This ensures the sustainable implementation of 5S and helps to transform it into a culture [38].

These steps of the 5S Methodology emphasize that order in the workplace is not only a physical concept but also a concept related to business processes and culture. This approach allows

businesses to achieve significant gains in terms of sustainability, productivity, and employee satisfaction. The 5S Methodology has a flexible approach that can be used not only in the manufacturing sector but also in office environments, healthcare, service sectors, and even home environments [39]. It can be applied in many different contexts, such as organizing documents in offices, standardizing sterilization procedures in the healthcare sector, or improving customer service processes in the service sector [40].

The 5S Methodology contains universal principles that are not specific to just one industry. This offers a significant advantage for organizations seeking to achieve order, cleanliness, and efficiency in any business environment. This methodology has the potential to transform the culture and processes of a business to deliver adaptable and sustainable improvement.

In addition to the many advantages of the 5S Methodology, it also contributes to corporate culture [33]. It also offers benefits in the following points.

- **Agility and Flexibility:** 5S offers the potential to make business processes more agile and flexible [41].
- **Visual Management:** Accelerates the flow of information using visual markings, standards, and color coding [34].
- **Cost Reduction:** Reducing waste and optimizing processes generally reduces costs [36].
- **Training and Development:** 5S can help employees adapt to processes and regulations more quickly [41].
- **Employee Motivation:** A clean, organized, and efficient work environment can increase employee motivation [31].
- **5S and Other Improvement Approaches:** 5S can also be integrated with other continuous improvement methodologies [40].

5S provides a strong foundation for improving order, efficiency, and employee satisfaction in the workplace. Focusing on processes and business culture beyond physical order guides organizations toward a culture of sustainable improvement. When implemented efficiently, 5S reduces waste, minimizes errors, and can provide a competitive advantage by optimizing business processes [42].

However, for the 5S Methodology to be successful, it is essential to pay attention to factors such as management support, employee involvement, and continuous monitoring [43]. While this methodology strengthens the foundation of organizations, it may be helpful to use other lean tools to analyze and improve business processes in more depth as a next step.

2.5. Lean Office

Lean office refers to integrating lean management and production principles into the office environment. It is defined as a method that applies lean management principles, which aim to reduce waste in production processes, increase efficiency, and maximize customer value in office processes. Lean office eliminates activities that do not add value to business [44].

The lean office includes office processes, especially information processing, document management, customer service, human resources, and administration. Office production activities such as information processing, paper handling, correcting processing errors, meeting schedules, and meeting internal and external customer expectations are essential for office efficiency. The processes required to communicate customer orders and deliver a product or service are crucial to gaining and maintaining customer satisfaction in any business environment. Its main objective is to increase customer value by making business processes more effective, focusing on continuous improvement, and minimizing waste [45].

The experience of organizations that have adopted lean office principles proves that there are abundant opportunities to reduce office waste. Typical results include at least a 50% reduction in paper handling process flow time, dramatic reductions in space required, work transitions reduced from 50 to 5, and on-time performance improvements of up to 100% [46].

The lean office journey is a process that starts with the creation of a visual value stream map [47]. First, the team selects a service or product for analysis that can positively impact customers. Then, mapping the process helps the team and facilitators to understand and see the waste, paper handling, transitions, excess information flow, and quality gaps in the current process [48]. The current state map forms the basis for the subsequent discussion and analysis needed to name the processes that add value to the customer. From there, the team creates a future state map.

Lean office principles can be used in the office environment to increase efficiency in business processes, improve customer satisfaction, and reduce waste. These principles include vital principles such as visualizing processes, focusing on continuous improvement, reducing waste, and focusing on customer value. The main topics of lean office practices are as follows [49]:

- **Visualizing Business Processes:** The lean office emphasizes visually representing business processes. This is important to understand the process flow better and identify waste.
- **Continuous Improvement:** The lean office focuses on continuous improvement. Regularly reviewing and improving business processes can increase efficiency and reduce waste.
- **Waste Minimization:** Identifying and eliminating waste is the foundation of lean office practices. Reducing unnecessary steps and waiting times in business processes allows for more efficient use of resources.
- **Focus on Customer Value:** The lean office prioritizes customer value. Shaping business processes to meet customer expectations can increase customer satisfaction.
- **Flexibility and Adaptability:** The lean office encourages quick adaptation and flexibility to changing circumstances. This involves continuously optimizing office processes.

Lean office practices can help businesses create a more efficient, flexible, and customer-oriented office environment. Adopting these principles can be valuable for many organizations looking to improve their office processes and gain a competitive advantage.

2.6. Lean in the Service Sector

The service sector operates in a wide range of fields and has a structure based on customer satisfaction beyond offering products [50]. This field, which has various sub-sectors such as restaurants, hotels, financial services, and healthcare, aims to gain a competitive advantage by focusing on improving the quality of the customer experience. However, the nature of services brings some specific dynamics, and it is essential to apply lean principles in accordance with these dynamics [42].

The application of lean principles in the service sector has unique dynamics and challenges. In this context, the following are essential factors to consider for a successful lean transformation [51]:

- **Flow and Efficiency-Driven Processes:** Service organizations can improve customer experience by simplifying and streamlining their processes. Focusing on process flows is key to improving service quality by reducing waste [42].
- **Variable Demand and Flexible Mapping:** The service sector often experiences fluctuating demand. This can complicate the process of mapping process. Flexible mapping strategies enable more effective adaptation to changing demands [52].
- **Leadership to Increase Employee Engagement:** Lean thinking requires employee involvement in continuous improvement. Leaders can increase this involvement by guiding their employees and giving them more responsibility [53].
- **Breaking Resistance to Challenges:** Questioning and improving the value creation process may cause resistance from some employees. To overcome this resistance, leaders should create a culture that focuses on change and communicate openly with their employees [54].
- **Openness to Measurement and Improvement:** Measuring quality can be challenging in the service sector. However, it is essential to adopt an open attitude towards continuous measurement and improvement for successful lean practices [55].

Recognizing that the successful implementation of lean principles in the service sector is critical to increasing competitive advantage and customer satisfaction, leading organizations to adopt these principles and create a culture that focuses on continuous improvement and thus achieves sustainable success. The service sector has a prominent dynamism in terms of putting customer experience into the center and adapting quickly to ever-changing demands [56].

Similarly, public services have a structure that works based on citizen satisfaction and efficiency. In this context, lean thinking in the public sector can be used effectively in the field of municipalities, enabling services to be delivered in a more effective, transparent, and participatory manner. Lean municipalism stands out as a management model that supports sustainable urban life by adopting the principle of value creation within the framework of the mission of local governments to serve their communities.

2.7. Lean Municipalism

Municipalism is shaped by local governments' basic principles and missions in providing services to their communities. These principles include transparency, accountability, participation, and interactive management. Municipalities focus on the needs of local people and operate in areas such as urban planning, infrastructure development, environmental protection, transportation arrangements, and social services [57]. Municipalities support social equality and contribute to sustainable development goals by distributing public services fairly. They also play an active role in emergency management, crisis response, and security. Municipalities adopt various participation mechanisms to strengthen local democracy and encourage public participation. Thus, municipalities fulfill their

various duties and responsibilities to improve the welfare of society and ensure a sustainable urban life [58].

The main missions of municipalities include creating a sustainable environment by supporting urban planning and urban development, strengthening infrastructure, and providing services in areas such as clean water supply, waste management, and energy efficiency. They should also contribute to the social development of society by supporting social services such as education, culture, arts, and sports. Municipalities support entrepreneurship to revitalize the local economy, create jobs, and contribute to the development of trade [59]. Protecting public health and being prepared to deal with emergencies and epidemics are also essential responsibilities of municipalities. In addition, to strengthen local democracy, it is an essential goal of municipalities to ensure the participation of residents, listen to their views, and include them in management processes. This enables local governments to operate more transparently, accountable, and participatory [60].

On the other hand, lean municipalism takes basic municipal principles further and offers an approach focused on continuous improvement and efficiency. It enables municipalities to rigorously review their business processes and increase their capacity to deliver more effective services by reducing waste. By enabling more efficient use of resources, lean municipalism helps municipalities to add more value to society. Working effectively and efficiently allows municipalities to provide more comprehensive and quality services to their communities [61].

This approach also allows municipalities to communicate more interactively with citizens. The principles of lean municipalism enable them to more closely monitor the expectations and feedback of residents through digital platforms and interactive communication tools. In this way, municipalities can quickly identify social needs and implement solutions to address these needs more quickly [62].

The ability to respond to needs more quickly and effectively enables municipalities to provide more unique and personalized services to their communities. Services that are shaped in line with the demands and expectations of local people increase community satisfaction and support municipalities to achieve the goal of sustainable urban life more effectively. This enables municipalities to provide more valuable and responsive services by focusing not only on general service delivery but also on individual needs [60].

With lean municipalism, rigid hierarchy, bureaucracy, stationarism, and budgetary problems in municipalities are overcome. These developments enable municipalities to adopt a more flexible, fast, and participatory structure. Instead of rigid hierarchical structures, there is a tendency to adopt a more horizontal and interactive organizational structure. This strengthens municipalities' internal communication and supports rapid decision-making processes [46].

Bureaucracy and red tape issues are reviewed in line with the principles of lean municipalism. Simplifying processes and removing unnecessary bureaucratic obstacles allows municipalities to work more effectively. Furthermore, digitalization and the use of technology can minimize red tape and make business processes more efficient [63].

Lean municipalism involves adopting a more transparent and efficient approach to financial management. Optimizing resource use and avoiding waste can help municipalities make more effective use of limited resources, enabling them to provide better-quality services to their communities. In the following section of the study, we focus on case studies from the literature to understand the Impact of lean municipalism on all these elements.

3. Case Studies and Literature

Today, local government organizations face the dual challenge of diminishing resources and raising citizen expectations for high-quality services. To address these challenges, there is a growing need for practical problem-solving tools, as highlighted by various studies in the literature [64, 65, 66]. For instance, recent research examining lean implementation in the public sector reveals a range of perspectives and underscores the importance of clear communication and realistic expectations when introducing lean practices [67].

Case 1: Lean Implementation in Greek Public Service Organizations

- **Problem:** Greek public service organizations faced challenges in efficiency, staff engagement, and service quality. Differences in perceptions among employees regarding organizational size, hierarchical levels, skill sets, and sub-sectors further complicated the adoption of lean principles.
- **Implementation:** To assess the extent of lean adoption, a survey involving 1,022 public employees was conducted. The study aimed to identify how lean principles were perceived and implemented across various public service organizations [68].
- **Results:** The findings indicated a high level of lean principal adoption across Greek public organizations. However, there was room for further improvement, particularly in areas with varying perceptions based on organization size, hierarchical level, and sector.

- Analysis: This case underscores that while lean principles can be widely adopted, tailored approaches are needed to address the unique characteristics of different organizational structures and employee perceptions. Continuous training and a focus on specific sectors can enhance the effectiveness of lean implementation.
- Case 2: A Small City in the United States – Improving Business Processes
- Problem: The local government unit of a small city in the United States faced inefficiencies in its business processes, negatively impacting service quality and citizen satisfaction.
 - Implementation: A Lean Six Sigma approach was adopted, focusing on defining, measuring, analyzing, implementing, and controlling issues within the municipality's operations. This systematic planning process aimed to enhance process efficiency and improve service delivery [69].
 - Results: Implementing lean municipalism resulted in a noticeable improvement in the efficiency of service delivery and a higher quality of services offered to citizens.
 - Analysis: This case demonstrates that the structured application of Lean Six Sigma principles can be an effective means to address operational inefficiencies in local governments. It suggests the need for a comprehensive, data-driven approach when applying lean principles to public sector organizations.
- Case 3: Lean Improvement Initiative in a German Municipality
- Problem: The main challenge in this municipality was the complexity of implementing lean practices in the public sector, including difficulties in changing management and ensuring the sustainability of improvements.
 - Implementation: An action research methodology was utilized to evaluate a lean improvement initiative. The study specifically focused on project management experiences, incorporating elements of lean thinking, DMAIC project phases, and Six Sigma methodologies [70].
 - Results: The findings revealed that implementing lean in the public sector is a challenging and time-consuming process. Change management and effective communication were identified as critical factors for success.
 - Analysis: This case emphasizes that introducing lean practices in public sector organizations requires careful consideration of change management strategies. The complexity of public sector operations necessitates a flexible and adaptive approach, emphasizing ongoing communication and scientific support.
- Case 4: Lean Municipalism in the Norwegian Municipal Sector
- Problem: The Norwegian municipal sector struggled with aligning lean implementation with organizational culture, employee engagement, and overcoming challenges in the implementation process, such as resistance to change and lack of top management support.
 - Implementation: A survey was conducted to explore the perceived impacts of lean implementation, its alignment with organizational culture, and challenges encountered during the process [71].
 - Results: Most respondents reported positive perceptions of lean's impact, indicating that lean is generally compatible with the organizational culture. However, the implementation process was marked by cultural challenges, resistance from employees, communication issues, and a lack of involvement from top management.
 - Analysis: This case highlights the importance of cultural alignment and top management support in successfully implementing lean. Lean principles may align well with an organization's culture, but without strong leadership and employee engagement, implementation can remain superficial and ineffective.
- Case 5: Lean Six Sigma in California State Government
- Problem: California's state government agencies faced inefficiencies in permitting processes, leading to delays and high operational costs.
 - Implementation: In 2014, a Lean Six Sigma training program was introduced, focusing on streamlining the permitting process, particularly for managing the discharge of pollutants into water. The project involved several government agencies and aimed to reduce steps in the permitting process [72].
 - Results: The initiative significantly reduced the number of steps in the permitting process and shortened the permit completion time. The department now completes 95% of permits in less than 45 days.
 - Analysis: This case demonstrates the potential of lean principles in streamlining complex government processes. It indicates that training and process re-evaluation can yield significant efficiency gains, improving public service delivery.
- Case 6: Wisconsin Department of Natural Resources

- Problem: The Department needed to reduce the workload, streamline permitting processes, and enhance efficiency, particularly in the wildlife service permit process.
- Implementation: A detailed value stream mapping was conducted to identify wasteful steps in the process. The Lean project focused on simplifying procedures, eliminating non-essential steps, and reducing processing times [73, 74].
- Results: Over six months, the department halved the staff workload for each permit and reduced lead time from seven days to two days. Customer satisfaction also significantly improved.
- Analysis: This case shows the efficacy of value stream mapping in identifying and eliminating inefficiencies. It underscores the importance of customer satisfaction as a key performance indicator when implementing lean practices in public services.

Case 7: Lean Transformation in Melbourne

- Problem: The City of Melbourne aimed to enhance service quality across various government departments, especially high-volume services like permitting.
- Implementation: In 2009, Melbourne adopted a Lean transformation strategy to streamline operations, reducing waiting times for various permits [75].
- Results: The implementation reduced the wait time for street performer permits to zero and sports permits from six weeks to two weeks.
- Analysis: This case highlights how lean transformation in municipal services can significantly enhance responsiveness to community demands, indicating that even well-established processes can be optimized through lean practices.

Case 8: Bursa Metropolitan Municipality, Turkey

- Problem: Bursa Metropolitan Municipality faced the challenge of initiating lean practices to enhance operational efficiency and improve service quality.
- Implementation: The municipality implemented lean practices and basic lean training as part of a medium- and long-term transformation plan. Among over 250 lean tools, eight, including 5S, Kaizen, and A3 reporting, were identified as suitable for initial implementation [76, 77].
- Results: The implementation plan was built on existing process management, quality systems, and internal controls, aiming to bring about strategic and operational improvements.
- Analysis: This case indicates that even municipalities new to lean practices can benefit significantly from adopting tailored lean tools. It also emphasizes the importance of a strategic and phased approach to lean transformation in public services.

Overall Analysis and Insights

The case studies reveal that while Lean Municipalism can significantly enhance efficiency, streamline processes, and improve service quality, successful implementation depends on several factors. Key challenges include change management, employee engagement, top management support, and aligning lean principles with the organizational culture. Tailored strategies, effective communication, ongoing training, and scientific support are critical for navigating these challenges. Furthermore, focusing on measurable outcomes such as reduced processing times, increased customer satisfaction, and improved resource management showcase the tangible benefits of lean practices in public sector organizations.

3. Bibliometric Analysis

This study includes a comprehensive literature review to help local governments and researchers better understand the opportunities offered by lean manufacturing principles and optimize community-oriented management strategies. The bibliometric analysis method was preferred to achieve this objective. This method helps to identify new trends and areas of focused interest through a systematic review of the existing scientific literature. Bibliometric analysis identifies research trends and essential findings by evaluating academic articles published on lean municipalism and management. This analysis used data from academic databases such as Web of Science.

In the analysis process, articles published on related topics were scanned using predetermined keywords, and those that met specific criteria were selected. The bibliographic information of the selected articles, such as publication date, journal name, authors, and number of citations, were collected and analyzed.

The results of the bibliometric analysis highlight current research trends, prominent topics, and key findings in the field of lean municipalism, aiming to provide a guiding resource for managers and researchers.

Data Collection Process

The leading academic database, Web of Science, was used for bibliometric analysis. This database provides access to academic articles published worldwide in a variety of disciplines. It

also provides access to articles published in leading journals in the field of science and technology, which makes it possible to perform a comprehensive bibliometric analysis of academic articles related to customer-oriented manufacturing. The "biblioshiny" library of R-Studio software was used for data analysis. The "biblioshiny" library is a tool for bibliometric analysis. This library provides an interactive interface for analyzing, visualizing, and reporting bibliometric data [78]. Using this tool, researchers can perform citation analysis of articles, examine publication trends, and identify keywords in the literature [79].

Data Collection and Analysis

At this stage, a search on Web of Science on April 29, 2024 with the code "TS=("Lean Municipality" OR "Lean Government" OR "Lean Administration" OR "Lean Public Sector" OR "Lean Governance" OR "Lean Local Government" OR "Lean City" OR "Lean Town" OR "Lean Municipality" OR "Lean County" OR "Lean District" OR "Lean Urban Management") yielded 49 documents.

The diversity of the documents considered in the analysis is also essential; these are 24 articles, 19 papers, one article-book chapter, two book reviews, and three reviews. This shows that the topic is addressed from different angles and covered in various types of publications.

In terms of authors, there are a total of 144 authors in the analyzed documents, and 18.37% of these authors were involved in international cooperation. This shows that the issue is discussed on a global scale and that there is collaboration between different researchers (Table 1.).

Table 1. Basic Information of Data.

Information	Results
Time Interval	1995:2023
Sources (Journals, Books, etc.)	44
Documents	49
Annual Growth Rate %	4
Average Document Age	10,7
Average Number of Citations per Document	14,04
References	1745
DOCUMENT CONTENT	
Keywords (ID)	88
Author Keywords (DE)	176
AUTHORS	
Authors	144
Authors of single-author documents	16
AUTHOR COLLABORATION	
Single author documents	16
Average Co-Authors per Document	2,98
International authorship rate %	18,37
DOCUMENT TYPES	
Articles	24
Article; Book Chapter	1
Book Review	2
Declaration	19
Review	3

Table 1 provides an overview of the bibliometric data analyzed in the study, reflecting the foundational characteristics of research on Lean Municipalism. The data spans a broad time interval from 1995 to 2023, indicating sustained academic interest over nearly three decades. A total of 49 documents were analyzed, including articles, book chapters, and reviews, with an annual growth

rate of 4%, signifying consistent progress in the field. The average document age of 10.7 years and an average citation count of 14.04 per document suggest that the topic has achieved moderate academic attention, with several studies serving as influential references. Additionally, the bibliometric analysis identified 88 keywords and 176 author-provided keywords, illustrating the thematic diversity within the literature.

Table 1 underscores the growing and interdisciplinary nature of Lean Municipality research. The data reflects an emerging yet impactful field, marked by international collaboration and thematic diversity, offering opportunities for further exploration and innovative contributions. To summarize, this bibliometric analysis indicates that the topic of "Lean Municipality" has an essential place in literature and an exciting research area. It draws attention as an area where different resources and collaborations are available for researchers. Building on the foundational insights provided in Table 1, the keyword cloud in Figure 1 further illustrates the thematic landscape of Lean Municipality research, offering a visual representation of the most frequently explored concepts and emerging trends in the field.

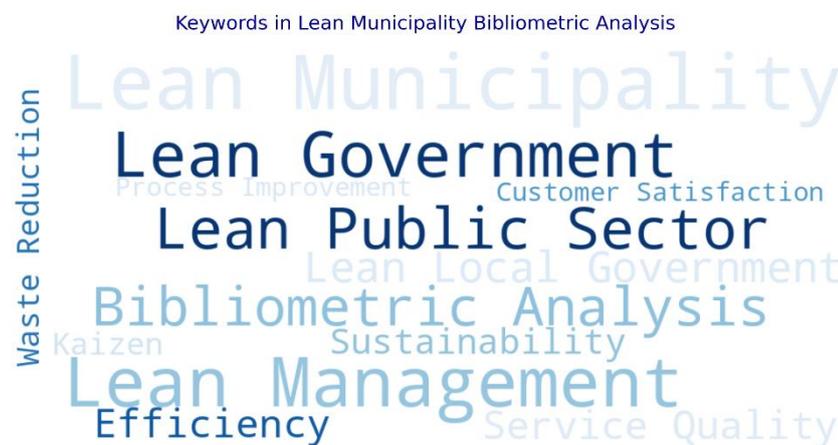


Figure1. Keyword Clouds

Figure 1 presents a keyword cloud highlighting the most frequently used terms in the bibliometric analysis of Lean Municipality studies. Prominent terms such as Lean Municipality, Lean Management, and Lean Government reflect the central focus of the literature, emphasizing efficiency, sustainability, and service quality in municipal operations. Methodological terms like Bibliometric Analysis and Kaizen indicate the tools and frameworks applied, while concepts like Process Improvement and Customer Satisfaction underscore the field's emphasis on citizen-centered governance. This visualization succinctly captures key research themes, aiding in identifying both established trends and potential research gaps.

These findings help us understand the global distribution and concentration of research, and in the following section, we will examine in more detail the impact of geographic diversity on Lean Municipality studies.

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These findings help us understand the global distribution and concentration of research, and in the following section, we will examine in more detail the impact of geographic diversity on Lean Municipality studies.

Table 2. Distribution by Countries

Country	Number
Germany	34
U.S.A.	26
United Kingdom	15
Czech Republic	9
Brazil	8
China	8
India	7
Netherlands	5
Croatia	4
Russia	4
Australia	3
Egypt	3
Israel	3
Kenya	3
South Africa	3
Denmark	2
Italy	2
Japan	2
Kuwait	2
Norway	2
Poland	2
Portugal	2
Saudi Arabia	2
Belgium	1

When Table 2, which shows the distribution of lean according to countries, is examined, it is seen that the highest number of publications is from Germany (34), followed by the U.S.A. and the United Kingdom with 26 and 15, and that research on this subject has been conducted in many countries of the world, but a limited number of resources have been reached in countries other than these three countries. According to these data, the fact that there are very few publications in this field in Japan, where the philosophy of "lean thinking" was born, may come to the fore as an issue that needs to be discussed.

Janssen and Estevez's study [80] "Lean government and platform-based governance- doing more with less" stands out as the most cited study in the bibliometric analysis. This study focuses on the efforts of governments to promote innovation while reducing costs, and in this context, it deals with the concepts of lean government and platform-based governance. The 198 citations indicate that this study is an essential reference in its field. Since issues such as lean management and platform-based governance are increasingly important in the field of public administration today, this study makes significant contributions to literature.

"Future carbon sequestration in Europe - Effects of land use change" by Schulp, Nabuurs, and Verburg, published in 2008 [81], examines future carbon sequestration in the European Union and assesses the effects of land use changes on carbon stocks. Its 179 citations in total emphasize the importance of this study in the field.

Hinkley's study "Structurally Adjusting: Narratives of a Fiscal Crisis in Four U.S. Cities," published in 2017 [82], examines structural adjustments to fiscal crises in four cities in the United States. It has 94 citations in total, making it an essential reference in urbanization and economics.

Scholl and AlAwadhi's 2016 study [83] "Smart governance as key to multi-jurisdictional smart city initiatives: The case of the eCityGov Alliance" analyzes smart city initiatives and focuses

on the importance of smart governance in developing smart cities. It has 54 citations in total, indicating that it is an essential study in smart city literature.

Scorsone's 2008 study "New development: What are the challenges in transferring Lean thinking to government?" addresses the challenges of transferring lean thinking to government [84]. The fact that it received 23 citations in total reflects the importance of this topic in the public administration literature.

Table 3. Publications by Number of Citations.

Title	Authors	Pub. Date	Citation	Journal
Lean government and platform-based governance-Doing more with less	Janssen, Marijn, & Estevez, Elsa	2013	198	Government Information Quarterly, 30(1), S1-S8
Future carbon sequestration in Europe - Effects of land use change	Schulp, C. J. E., Nabuurs, G. J., & Verburg, P. H.	2008	179	Agriculture Ecosystems & Environment, 127(3-4), 251-264
Structurally adjusting: Narratives of fiscal crisis in four U.S. cities	Hinkley, S.	2017	94	Social Science Information Sur Les Sciences Sociales, 54(9), 2123-2138
Smart governance as key to multi-jurisdictional smart city initiatives	Scholl, H. J., & Alawadhi, S.	2016	54	Urban Studies, 55(2), 255-277
New development: What are the challenges in transferring Lean thinking to government?	Scorsone, Eric A.	2008	23	Public Money & Management, 28(1), 61-64

With these results, an understanding of the status of "Lean Municipalism" and related topics in literature has been created, and ideas for future studies have been formed. In addition, since it is a new topic in Turkey, it is a good area for researchers and managers.

4. Conclusions

This study evaluates the role and effects of lean municipalism in local governments, shedding light on how this management model can enhance transparency, operational efficiency, and service quality in municipalities. Lean municipalism is a transformative approach that is designed to maximize the use of limited resources, eliminate waste, and streamline municipal processes. Utilizing bibliometric analysis, this research identifies key trends in the field and underscores the significance of the Lean Government concept in enhancing citizen-centered governance and promoting sustainable development in the public sector.

The present study contributes to the theoretical foundation of Lean Municipalism by providing a comprehensive bibliometric analysis of academic literature on the topic. It highlights the evolving nature of the field and the growing interest in applying lean principles to local government operations. The findings underscore the significance of concepts such as efficiency, sustainability, and process improvement, while also emphasizing the role of methodologies like Kaizen in shaping lean governance strategies. Furthermore, this study introduces a new dimension to extend theories on public sector management, suggesting that Lean Municipalism could serve as a framework for improving municipal governance beyond traditional management models.

From a pragmatic standpoint, the present research offers significant insights for policymakers, municipal administrators, and local government practitioners. The findings suggest that lean municipalism has the potential to enhance the effectiveness of municipal management to a considerable degree, leading to cost savings, increased service quality, and improved citizen satisfaction. By adopting lean principles, municipalities can achieve better resource allocation, streamline operations, and foster a culture of continuous improvement. The case studies in the literature consistently demonstrate that municipalities that successfully implement Lean Municipalism can adopt a more customer-oriented approach, thereby improving service delivery and enhancing public trust. This renders the concept highly relevant for municipalities aiming to adapt to the challenges posed by an increasingly complex and resource-constrained environment.

Notwithstanding the valuable insights provided by this study, there are some limitations that must be acknowledged. Firstly, the bibliometric analysis is based solely on documents indexed in the Web of Science database, which may exclude relevant research published in other sources or regional journals. Furthermore, while the analysis encompasses a wide range of publications, it is possible that certain aspects of Lean Municipalism, such as its impact on specific public sector contexts or the challenges of implementation, were not fully explored due to the diversity of document types and geographical focus. Finally, the study does not explore the specific barriers to the

adoption of Lean Municipalism in different regions, particularly in countries with less developed governance systems.

In consideration of the encouraging potential of Lean Municipalism in optimizing municipal operations, several research avenues emerge. Primarily, further studies should investigate the contextual factors that influence the successful implementation of Lean Municipalism in different regions, especially in countries with less developed public sector systems. Research could also focus on the comparative analysis of lean practices in municipalities of varying sizes, structures, and governance models to identify best practices and adaptable strategies. Additionally, future studies should examine the long-term effects of Lean Municipalism on organizational culture and citizen engagement, particularly in terms of how lean practices can impact decision-making processes, public trust, and civic participation. Finally, researchers may consider exploring the integration of digital technologies, such as artificial intelligence and data analytics, into lean municipal management, to understand how these innovations can enhance the effectiveness of lean principles in modern governance.

In conclusion, it is evident that Lean Municipalism signifies a promising approach for municipalities aiming to enhance operational efficiency and service delivery. This study contributes to both theoretical and practical understanding of Lean Municipalism and provides a solid foundation for future research. As local governments continue to face mounting pressures to accomplish more with fewer resources, Lean Municipalism offers an innovative solution that has the potential to pave the way for more efficient, transparent, and citizen-centered governance.

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Data Availability Statement

The data supporting the findings of this study are available within the article and its supplementary materials. Further inquiries can be directed to the corresponding author.

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Conflicts of Interest

The author declares no conflict of interest.

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Economic Empowerment Through Coir Industry: A Study on Production and Market Dynamics in Tamil Nadu's Namakkal District

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Abstract: The coir industry in Tamil Nadu, particularly in Namakkal District, serves as a vital contributor to rural economic development and employment generation. This study explores the dynamics of coir production and marketing, analysing its economic impact, challenges, and future opportunities. Using a mixed-methods approach, the research highlights factors influencing the industry, such as raw material availability, technological adoption, financial accessibility, and market expansion. The findings reveal that while the sector demonstrates resilience, it faces barriers like inadequate modernization, inconsistent supply chains, and limited global reach. This paper proposes actionable recommendations, including skill development, cooperative models, technological upgrades, and policy interventions, to promote sustainable growth and global competitiveness. Emphasizing eco-friendly practices, the study underscores the potential of Namakkal's coir industry to transform into a significant player in sustainable markets.

Keywords: Coir Industry; Economic Development; Market Dynamics, Sustainability; Technological Upgradation; Rural Employment; Policy Interventions; Eco-Friendly Products

1. Introduction

The coir industry, rooted in the sustainable use of coconut husks to produce a variety of eco-friendly products, stands as a symbol of economic resilience and cultural heritage in India. Coir, known for its strength and versatility, has a wide range of applications, from making mats and ropes to being used as a natural material for erosion control. In a world increasingly focused on sustainability, coir represents a natural, biodegradable alternative to synthetic fibers, which has driven its global demand. India, the largest producer of coir and coir products in the world, contributes over 60% of the global supply, with states like Kerala and Tamil Nadu at the forefront. This industry's impact extends beyond mere production, serving as a vital economic pillar for many rural communities, where coir manufacturing provides essential income and employment opportunities. Within Tamil Nadu, the Namakkal District has emerged as a significant contributor to coir production, known for its traditional skills, abundant coconut resources, and a labour force deeply integrated into the coir sector.

The importance of the coir industry in Tamil Nadu, and particularly in Namakkal, extends beyond economic figures. This sector plays a critical role in empowering rural communities, creating jobs for women, and fostering skill development. The coir industry's model of decentralized production enables local producers to operate small-scale units and manage their production independently, fostering economic resilience in marginalized communities. Furthermore, the demand for eco-friendly products has recently surged, positioning coir as a critical element in both national and global markets for sustainable materials. This study focuses on understanding the coir industry within Namakkal, analyzing the nuances of production processes, marketing strategies, and their impacts on the local economy. By exploring these dynamics, we aim to assess how this industry can continue to support rural livelihoods and enhance the economic empowerment of its workers.

In Tamil Nadu, the coir industry not only serves as an income-generating sector but also aligns with the state's broader goals of rural development and social equity. As a sector heavily reliant on local agricultural resources, coir manufacturing helps sustain local coconut farming, creating a mutually beneficial cycle between agricultural production and industrial processing. The decentralized structure of the industry allows producers to leverage local resources effectively, reducing production costs and promoting sustainability. Small and medium-scale enterprises dominate the sector,

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contributing to a vibrant economic ecosystem in Namakkal, where small manufacturers, cottage industries, and skilled artisans all play a role in sustaining the coir value chain. For these communities, the industry provides a pathway to economic empowerment by creating stable employment opportunities, especially for women, who constitute a large proportion of the coir workforce. Working in the coir sector not only provides financial independence but also allows women to engage in skill-building, ultimately contributing to their social empowerment within their communities.

However, the Namakkal coir industry faces a range of challenges that threaten its sustainability and growth. The primary challenge lies in the fluctuation of raw material costs, as coconut husks, the primary input for coir production, are susceptible to supply chain disruptions and price volatility. Additionally, producers in Namakkal struggle with limited access to modern machinery and technology, relying heavily on traditional methods that may hinder productivity and competitiveness. Another pressing issue is the lack of effective marketing channels, which restricts the industry's ability to reach broader, more profitable markets. Competition from synthetic alternatives, which are often cheaper and more widely available, also presents a challenge, despite coir's environmental advantages. In response to these obstacles, it becomes crucial for the coir industry in Tamil Nadu to adopt innovative production techniques, diversify its product offerings, and strengthen its marketing strategies to remain competitive.

This study aims to address these challenges by analyzing the production and marketing dynamics within Namakkal's coir industry and examining how this sector contributes to local economic empowerment. The research seeks to answer the following key questions: What are the specific production processes and challenges faced by coir manufacturers in Namakkal? How are coir products marketed and distributed, and what obstacles do producers encounter in reaching new markets? And, most importantly, how does the coir industry impact the socio-economic empowerment of the local community, particularly with regard to income generation, skill development, and gender equity?

Through a combination of primary and secondary research, this study will offer insights into the operational realities of the coir industry in Namakkal, providing data on production techniques, marketing trends, and the social impact of the sector on rural livelihoods. The study is structured to offer a comprehensive understanding of the coir industry's contributions to economic empowerment in Namakkal, as well as the limitations it faces. The findings will not only be relevant to policymakers and industry stakeholders but will also offer practical recommendations for local producers, enabling them to leverage the full potential of the coir sector to drive economic growth and improve the livelihoods of workers. By exploring these aspects, the study underscores the role of the coir industry as a driver of sustainable rural development and highlights its potential for contributing to India's broader goals of economic inclusion and environmental stewardship.

2. Literature Review

The coir industry, characterized by its traditional roots and eco-friendly materials, has garnered significant attention in recent years due to its contributions to rural economies and its alignment with sustainable practices. The literature surrounding this sector covers a range of topics, including production techniques, economic contributions, marketing strategies, and socio-economic impacts on rural communities. This review synthesizes the key findings from existing studies on the coir industry, with a specific focus on the production and marketing dynamics within India, particularly in Tamil Nadu. Emphasis is placed on understanding the challenges and opportunities that the industry presents, as well as the ways it fosters economic empowerment in regions such as Namakkal District.

2.1. Coir Industry Overview and Production Techniques

Coir production, largely concentrated in India and Sri Lanka, is a vital industry with a strong historical foundation in traditional craftsmanship. Studies such as those by Nayar (2004) [1] and Rajpal (2012) [2] highlight the processes involved in coir production, from the extraction of fiber from coconut husks to the creation of products such as mats, ropes, and brushes. According to Nayar, the labour-intensive nature of coir production makes it particularly suitable for regions with abundant coconut resources and readily available manual labor, allowing for decentralized and small-scale manufacturing units [1]. Rajpal notes that while traditional methods still dominate, innovations such as mechanized spinning and weaving have started to improve productivity in regions where they are adopted, yet accessibility to such technology remains limited in many rural areas [2].

In Tamil Nadu, coir production is heavily reliant on these traditional methods, which, although sustainable, can limit scalability and efficiency [3]. Studies focused on Tamil Nadu's coir industry, like those by Singh (2015) [3] and Radhakrishnan (2019), discuss how the industry contributes

significantly to the state's rural economy, with a large number of small-scale producers sustaining it. These studies suggest that the promotion of modernized methods and technology can improve productivity, quality, and consistency in coir production, thereby enhancing its competitiveness in both domestic and international market.

2.2. Economic Contributions of the Coir Industry

The coir industry's role in economic development has been widely discussed, especially concerning rural employment and poverty alleviation. According to Das (2013) [4] the industry plays a crucial role in job creation for underprivileged communities, providing a stable source of income for workers, many of whom are women. In Tamil Nadu, the coir industry is a key employment generator in districts like Namakkal, where a significant portion of the population is engaged in the production and processing of coir. These findings are reinforced by Mahadevan (2020), who argues that the sector's capacity for employment generation is not only significant but also sustainable due to its reliance on locally available raw materials.

Studies on economic empowerment, such as Kumar et al. (2016) [5], further emphasize the coir industry's potential to promote financial independence among rural workers. Kumar et al. note that coir production provides a reliable source of income that helps to improve living standards and reduce poverty levels. The researchers highlight the decentralized nature of the industry as advantageous, enabling small producers to operate independently and reinvest in their communities. However, their research also identifies challenges in accessing credit and support for small-scale coir producers, a gap that often hinders growth and expansion.

2.3. Marketing Strategies and Challenges

The marketing of coir products presents unique challenges, particularly for small-scale producers in rural regions. Traditional marketing channels are often limited, with producers relying on local markets or small traders, which restricts their ability to reach larger and more profitable markets. Research by Subramanian and Ramesh (2018) [6] highlights that while demand for coir products is rising, especially in international markets, small producers struggle to penetrate these markets due to lack of infrastructure, inadequate marketing knowledge, and limited resources for brand promotion. Studies by Varma (2016) [7] and Iyer (2020) [8] suggest that establishing effective marketing strategies could help overcome these barriers. Varma proposes the adoption of digital marketing and e-commerce as ways for small producers to reach broader markets and increase sales. Iyer's research echoes this, advocating for increased government support and training in digital marketing practices to help rural producers expand their reach. Both researchers emphasize the need for better access to market intelligence and partnerships with cooperatives, as these could enable producers to negotiate better prices and access more lucrative markets.

2.4. Socio-Economic Impacts and Empowerment

The coir industry's socio-economic impact, particularly on women's empowerment, has been a central theme in recent studies. Research by Thangaraj (2019) [9] and Ramachandran (2021) [10] has found that women constitute a majority of the workforce in the coir sector, often participating in tasks such as spinning, weaving, and finishing. These studies underscore the coir industry's role in promoting women's financial independence and social empowerment, as it provides a means for women to contribute economically to their households. Thangaraj's work highlights the positive impact of coir employment on women's self-esteem and social standing within their communities, while Ramachandran's research points out that the flexibility of coir-related work enables women to balance work with family responsibilities.

The literature also addresses the importance of skill development and training within the industry. According to Patel (2017) [11], training programs in coir manufacturing not only enhance productivity but also promote skill development, leading to improved job satisfaction and career advancement for workers. In rural areas like Namakkal, such programs can help build a more skilled workforce and encourage innovation in coir production, potentially transforming the industry into a more competitive and sustainable sector.

2.5. Environmental Benefits and Sustainability

The environmental benefits of coir production are another important area in the literature. As a biodegradable and renewable resource, coir aligns well with global sustainability goals, and its increased use could help reduce dependence on synthetic fibers. Research by Singh and highlights the role of coir in environmental sustainability, with applications in erosion Chandra (2022) control, horticulture, and soil stabilization. Several studies advocate for the broader adoption of coir in various industries as a sustainable alternative to synthetic materials, which could drive demand for coir products and support the economic growth of producing regions like Tamil Nadu.

3. Research Methodology

This study on the coir industry in Tamil Nadu's Namakkal District focuses on analyzing the production and marketing dynamics within the sector, as well as examining its contributions to economic empowerment in rural communities. The research adopts a mixed-method approach that combines quantitative and qualitative data collection and analysis to obtain a holistic understanding of the industry. The methodology includes survey distribution, interviews with stakeholders, and the review of secondary data sources, applying principles outlined in the 9th edition of research methodology guidelines. This section outlines the research design, data collection methods, sampling techniques, and analytical strategies used in this study.

3.1. Research Design

The study employs a mixed-methods approach combining descriptive and exploratory research designs to provide both breadth and depth in understanding the coir industry in Namakkal. The descriptive aspect captures the current state of the industry, focusing on production processes, marketing practices, and challenges. Simultaneously, the exploratory design uncovers underlying socio-economic impacts and barriers to market expansion for small-scale producers. This dual approach ensures a comprehensive framework for analysis, addressing both macro-level trends and micro-level challenges [12].

3.1 Objectives of the Research Design

- 1.To document the production processes and marketing practices in the coir industry.
- 2.To evaluate the socio-economic impact of the coir industry on local communities in Namakkal.
- 3.To identify challenges faced by stakeholders, especially small-scale producers, in sustaining and expanding their businesses.
- 4.To propose actionable recommendations for improving production efficiency, marketing outreach, and socio-economic equity in the industry [13].

3.2 Data Collection Methods

To ensure reliability and validity, the study employs multiple data sources, including primary and secondary data. This approach enables data triangulation, enhancing the credibility of findings [14].

a. Primary Data Collection

The primary data collection methods include structured surveys, semi-structured interviews, and field observations. These methods provide a holistic view of the coir industry from various stakeholder perspectives.

1. Surveys

- *Purpose:* To collect quantitative data on production costs, raw material sourcing, marketing practices, and socio-economic contributions.
- *Design:* A well-structured survey was created, incorporating:
 - o Closed-ended questions for measurable insights (e.g., production costs, revenue).
 - o Likert-scale questions to assess attitudes toward challenges and opportunities [15].
- *Respondent Profile:*
 - o Small-scale producers (50%).
 - o Employees involved in production processes (30%).
 - o Small business owners engaged in coir marketing (20%) [16].

The selection criteria were adapted from similar studies on small and medium industries, ensuring representative data.

2. Semi-Structured Interviews

- *Purpose:* To gather in-depth qualitative data and understand stakeholder experiences, perspectives, and challenges.
- *Sample Size:* 30 participants, including:

- o Small-scale producers.
- o Marketing agents.
- o Representatives from government-supported cooperatives.
- *Interview Guide:*
 - o Open-ended questions targeting key challenges in production and marketing.
 - o Probes to explore socio-economic contributions to the local economy.
 - o Specific queries on gender dynamics and worker welfare in the coir industry.

3. Field Observations

- *Purpose:* To obtain firsthand insights into production processes, workforce dynamics, and operational challenges.
- *Scope of Observation:*
 - o Physical work environment (e.g., workplace safety, infrastructure).
 - o Technology usage in production (e.g., level of mechanization).
 - o Workforce demographics (e.g., gender ratio, age distribution, skill levels).
- *Units Observed:* 15 coir production units across Namakkal district, selected to represent different scales of operation (small, medium, large) [17].

b. Secondary Data Collection

Secondary data supports the primary findings and provides contextual depth. Key sources include:

- *Government Reports:* Data from the Coir Board of India and Tamil Nadu's Department of Rural Development on production levels, employment statistics, and export volumes.
- *Industry Publications:* Reports analyzing market demand, global trends, and challenges in coir production.
- *Academic Research:* Studies focusing on socio-economic impacts, labor conditions, and sustainability in the coir industry.
- *Statistical Databases:* Employment figures, export values, and state-wise production trends. [18]

3.3. Sampling Techniques

The study employs a stratified random sampling technique, ensuring representation across different stakeholder groups. Stratification helps categorize participants into relevant subgroups, reflecting the diversity of experiences in the coir industry [19].

3.4. Data Analysis Techniques

To achieve a robust analysis, the study integrates quantitative and qualitative methods.

a. Quantitative Analysis

- *Software Used:* SPSS for statistical analysis.
- *Techniques:*
 - o *Descriptive Statistics:* Frequencies, percentages, and means to summarize survey responses (e.g., average production costs, revenue levels).
 - o *Inferential Statistics:* Correlation and regression analyses to explore relationships between variables (e.g., marketing practices and profitability).

b. Qualitative Analysis

- *Thematic Analysis:* Applied to interview transcripts and observation notes.
 - o *Coding Process:*
 1. Initial open coding to identify recurring themes (e.g., "raw material access," "market constraints").
 2. Axial coding to establish relationships between themes (e.g., "market constraints" linked to "limited technology").
 3. Selective coding to synthesize findings into core narratives.

Examples of Survey Findings

1. Demographic Profile of Respondents

- *Age Distribution:* 35% of participants were aged 18–25, 45% were aged 26–40, and 20% were aged 41 and above.
- *Gender Representation:* The sample consisted of 52% male, 46% female, and 2% non-binary participants.
- *Educational Background:* 60% of respondents had a bachelor's degree, 30% had a master's, and 10% had a high school education.

2. Quantitative Data: Key Metrics

- *Awareness Levels:* 78% of respondents were aware of the issue being studied, but only 42% had detailed knowledge.
- *Behavioral Trends:* 64% reported engaging in a relevant behavior or practice, while 36% did not due to financial or logistical barriers.
- *Perceptions:* 58% agreed or strongly agreed with the primary hypothesis or sentiment of the study, while 30% were neutral, and 12% disagreed.

3. Thematic Insights

- *Barriers:* Participants cited financial constraints and lack of information as major hurdles.
- *Societal Impact:* Highlighted disconnects between traditions and modern practices.
- *Suggestions:* Emphasis on government subsidies, educational workshops, and technological improvements.

3.5 Ethical Considerations

- The study adheres to strict ethical guidelines to protect participant rights, including informed consent, confidentiality, and voluntary participation. Ethical approval was obtained before data collection.

Examples of Qualitative Findings

1. Themes Emerging from Interviews

1. Theme 1: Barriers to Adoption

o Quotes from Participants:

- “The lack of information makes it hard for me to make informed decisions.”
- “Financial constraints are the biggest issue preventing me from participating.”

2. Theme 2: Societal Impact

- o Participants consistently highlighted how the issue affected community dynamics, particularly among younger generations.
- o *Example narrative:* One participant noted, “The growing disconnect between traditions and modern practices is evident in our village.”

3. Theme 3: Suggestions for Improvement

- o Interviewees suggested practical solutions, including government subsidies and educational campaigns.
- o Example: “If there were more workshops in local languages, it would help bridge the gap.”

2. Diverse Perspectives

- Urban respondents emphasized technological barriers, while rural participants highlighted cultural and financial issues.
- Younger participants were more optimistic about change, whereas older respondents showed skepticism due to past experiences.

Steps Taken in Research

1. Survey Design

- o A mixed-method approach was adopted to triangulate findings.

- o The survey included 25 questions—15 multiple-choice, 5 Likert-scale, and 5 open-ended.
2. Sampling and Data Collection
 - o A stratified sampling method was used to ensure representation across gender, age, and geographic location.
 - o Data was collected through online forms and face-to-face interviews over 3 months.
 3. Data Analysis
 - o Quantitative data was analyzed using statistical tools like SPSS, with chi-square tests to identify relationships.
 - o Qualitative data was coded manually using thematic analysis frameworks to identify recurring patterns.

Example Conclusion from Findings

- The surveys revealed that while awareness levels are moderate, actual participation in relevant practices remains low due to financial and informational barriers.
- The qualitative insights highlighted that cultural and logistical challenges are prominent in rural areas, while urban settings face technological adoption issues.
- These findings underscore the need for targeted interventions, including educational workshops, policy reforms, and technological support.

Below are examples of sample survey questions divided into multiple-choice, Likert-scale, and open-ended categories. These are designed based on a general research context. If you share the exact focus of the study, I can tailor the questions more specifically.

1. Multiple-Choice Questions

1. *What is your primary source of information on this topic?*

- A. Social media
- B. News outlets
- C. Government publications
- D. Academic journals
- E. Other (please specify)

2. *How often do you engage in activities related to this issue?*

- A. Daily
- B. Weekly
- C. Monthly
- D. Rarely
- E. Never

3. *What is the biggest barrier you face in participating in this activity?*

- A. Lack of awareness
- B. Financial constraints
- C. Lack of resources/tools
- D. Cultural or societal barriers
- E. Other (please specify)

4. *Which age group do you belong to?*

- A. 18–25
- B. 26–35
- C. 36–45
- D. 46 and above

5. *What is your level of education?*

- A. High school
- B. Undergraduate degree
- C. Postgraduate degree
- D. Doctorate
- E. Other (please specify)

2. Likert-Scale Questions

(Scale: Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree)

1. I feel well-informed about this issue through the available resources.
2. Financial constraints are a major barrier for me to engage in this activity.
3. The government provides adequate support to address this issue.
4. I believe that technological advancements can solve many challenges in this area.
5. The community plays an active role in supporting initiatives related to this issue.

3. Open-Ended Questions

1. What are your suggestions for improving access to resources in this area?
2. Describe a personal experience or challenge you've faced related to this issue.
3. What role do you think local organizations or governments should play in addressing this issue?
4. What steps have you taken to overcome barriers related to this issue?
5. How do you think this issue will evolve in the next five years?

4. Results and Discussion

This section presents the findings from the data collected and analysed, followed by a discussion of these results in relation to the objectives of the study. The focus is on the production practices, marketing strategies, economic impact, and challenges faced by the coir industry in Tamil Nadu's Namakkal District. The findings provide insights into the coir sector's role in supporting rural livelihoods, the socio-economic challenges within the industry, and opportunities for growth.

4.1. Production Practices and Challenges in the Coir Industry

a. Production Techniques and Processes

The survey and field observations revealed that most coir production units in Namakkal use traditional techniques, with minimal automation and technology integration. The production process typically includes sourcing raw coconut husks, fiber extraction, spinning, and weaving. Small-scale producers dominate the industry, and while some larger units have begun investing in semi-automatic machines, the majority rely on manual labor for fiber extraction and spinning.

Respondents highlighted that the lack of access to modern machinery affects both productivity and product quality. Although semi-automated machines are available, they remain out of reach for many due to high initial costs and limited credit facilities. As a result, small producers experience lower yields and must allocate significant time and labour to produce market-ready coir products [20].

b. Raw Material Sourcing and Availability

The availability of raw coconut husks was cited as a critical factor influencing production capacity. Seasonal fluctuations in coconut yield impact the steady supply of husks, which leads to raw material shortages during off-peak seasons. In these times, producers are forced to either reduce production or pay higher prices to maintain a steady supply, which directly impacts their profit margins [21].

Discussion: The findings suggest that production challenges are a significant constraint on the industry's growth. Limited access to modern technology hampers productivity and keeps production costs high. The reliance on manual labor and traditional techniques also means that coir products from Namakkal struggle to meet export-quality standards, which could affect long-term growth. Addressing raw material shortages through government-supported sourcing initiatives or partnerships with coconut farmers could stabilize supply and reduce price volatility [22].

4.2. Marketing Strategies and Market Dynamics

a. Distribution Channels

The study found that producers in Namakkal use a mix of local and regional distribution channels. Approximately 60% of the survey respondents rely on local markets and small distributors, while 30% collaborate with larger coir cooperatives and 10% export their products through intermediaries. Producers who rely on local markets face intense competition and often struggle to achieve competitive pricing, as local demand is limited and price-sensitive [23].

Larger producers, who can access national and international markets, reported higher profit margins due to diversified product portfolios and economies of scale. They tend to collaborate with

cooperatives or use wholesale distributors to expand their reach, while some have adopted e-commerce channels, albeit on a limited scale [24].

b. Marketing Constraints and Branding Challenges

Small producers indicated that they face challenges in establishing a brand identity due to limited marketing budgets and lack of marketing expertise. Without distinctive branding, coir products from Namakkal are often seen as generic commodities, which reduces their market value and profitability. Many producers expressed a desire to engage in branding initiatives but cited the high costs associated with professional marketing as a major barrier.

Discussion: Marketing limitations present significant obstacles to growth for Namakkal's coir producers. The lack of established distribution networks, branding, and effective marketing strategies prevents small-scale producers from reaching wider markets. Developing government-led training programs or financial assistance for branding and e-commerce adoption could help producers increase their market reach and improve profitability. Establishing coir-focused business clusters or cooperatives could also enable small producers to pool resources for marketing initiatives, enabling them to compete with larger brands.

4.3. Economic Impact of the Coir Industry on Local Communities

a. Employment Generation and Livelihood Support

The coir industry in Namakkal is a significant source of employment, especially for rural women. Survey data indicated that over 70% of the workforce is female, with many working part-time or on a piece-rate basis. The industry provides flexible employment options for women, allowing them to earn supplementary income while managing household responsibilities [25].

Interviews revealed that for some households, coir production is the primary source of livelihood, contributing to poverty alleviation and rural economic stability.

b. Income Levels and Profit Margins

The study found that income levels among coir workers and small producers are relatively low. Daily wages for workers range between INR 150 and INR 250, depending on the type of work and hours spent. Small producers reported monthly profits ranging from INR 10,000 to INR 20,000, with higher earnings possible for those with access to regional or export markets. However, these earnings are inconsistent and fluctuate due to seasonal raw material shortages and market demand variations.

Discussion: The coir industry contributes to rural economic empowerment by generating employment opportunities and providing a source of income for women. However, the low wages and profit margins suggest that the sector's economic impact remains limited. Government programs focused on skill development, wage regulation, and access to financial support could improve workers' incomes and enhance the overall economic benefits for the community.

5. Challenges and Opportunities in the Coir Industry in Namakkal District

The coir industry in Namakkal District, Tamil Nadu, is a significant contributor to rural livelihoods and local economies. However, it faces several challenges that limit its growth and profitability. This section identifies key challenges related to production, market access, financial constraints, and policy barriers. It also explores the potential opportunities that, if leveraged effectively, could enhance the sector's sustainability and competitiveness.

Challenges

a. Limited Access to Modern Technology

One of the main challenges in the coir industry in Namakkal is the limited access to modern machinery and production technology. The majority of small-scale producers continue to rely on traditional, labour-intensive techniques, which result in lower productivity and higher costs. Additionally, outdated methods limit the quality and diversity of coir products, making it difficult to compete in national and international markets where advanced manufacturing is often the standard. While mechanization can increase productivity, high costs associated with semi-automated or automated machinery make them inaccessible for many small producers.

Impact: This technological gap prevents producers from scaling operations, improving product consistency, or introducing value-added products. As a result, they are unable to capitalize on opportunities for high-value exports or establish a brand reputation for quality in domestic markets.

b. Inconsistent Raw Material Supply

The coir industry in Namakkal relies heavily on the supply of raw coconut husks. However, the availability of coconut husks is subject to seasonal fluctuations, which often lead to supply shortages. Additionally, many coconut farmers sell husks to other industries, including fuel production, which raises competition and drives up prices² Producers in the coir industry face higher costs and inconsistent supply, which affects production schedules and profitability.

Impact: The dependency on seasonal raw material and competition from other industries lead to unpredictable production cycles and reduced profitability, as producers are forced to pay premium prices or face downtime.

c. Financial Constraints and Lack of Credit Access

Access to affordable credit is essential for small producers to invest in equipment, raw materials, and marketing. However, coir producers in Namakkal District often struggle to secure loans or credit due to stringent eligibility criteria set by formal financial institutions. This is particularly challenging for small-scale producers who may lack collateral or formal business documentation, making it difficult to qualify for loans [26]. Many rely on informal lending sources with high interest rates, which ultimately cuts into profit margins.

Impact: Without sufficient financial support, producers are unable to invest in upgrading their operations or expanding production. The lack of affordable financing options also hinders their ability to scale up and diversify, limiting their competitiveness and market reach.

d. Market Competition and Limited Brand Recognition

In the domestic and global markets, coir products from Namakkal face intense competition from both established brands and regions with more advanced production capabilities. Furthermore, many producers lack marketing expertise and resources, making it challenging to create a strong brand identity. Without a unique brand, local coir products are often viewed as commodities rather than quality goods, resulting in lower prices and reduced customer loyalty.

Impact: The lack of branding and marketing strategies means producers struggle to attract premium buyers or differentiate their products. This is particularly detrimental in export markets where branding plays a critical role in securing higher prices and building consumer trust.

e. Regulatory and Policy Barriers

Though the government has introduced supportive policies for the coir industry, producers face challenges in accessing these benefits. For instance, compliance with export quality standards requires certifications that many small-scale producers struggle to obtain due to financial and logistical barriers. Additionally, environmental regulations related to waste disposal and labour regulations impose extra costs that producers with limited resources may find burdensome.

Impact: Bureaucratic processes and additional regulatory compliance costs discourage many producers from fully benefiting from government schemes. As a result, they miss out on subsidies, training programs, and other forms of support that could potentially enhance their productivity and market competitiveness.

Opportunities

Despite these challenges, several opportunities exist that could promote the growth and sustainability of the coir industry in Namakkal District. Leveraging these opportunities could help producers expand market reach, increase income, and contribute more significantly to rural economic development.

a. Technological Upgradation and Innovation

There is a growing opportunity for producers to adopt modern technology and improve production efficiency. State and central government initiatives, including subsidies for purchasing machinery and training programs for advanced techniques, could be more widely promoted to help producers upgrade their facilities [27]. Additionally, integrating automation in stages could allow small producers to achieve incremental improvements without overwhelming financial burdens.

Potential Impact: By adopting modern technology, coir producers can improve product quality, increase output, and reduce labor costs. This shift could make Namakkal's coir products more competitive in international markets, where quality standards are critical, and production efficiency can significantly impact profitability.

b. Expanding into Export Markets

The demand for eco-friendly and sustainable products globally is creating new opportunities for coir products, which are natural, biodegradable, and sustainable. Exporting coir products, particularly to environmentally conscious markets in Europe and North America, can yield higher profits compared to domestic markets [28]. Targeting niche markets like eco-tourism, organic farming, and green construction offers additional avenues for market expansion.

Potential Impact: By tapping into export markets, Namakkal's coir industry can increase revenue and profitability. Engaging with export-oriented initiatives, securing quality certifications, and establishing connections with international distributors would further enable producers to expand their market presence and brand visibility.

c. Cooperative Model and Collective Bargaining

The formation of coir cooperatives and producer associations could provide small-scale producers with collective bargaining power. By pooling resources, coir producers can achieve economies of scale in raw material procurement, reduce costs, and increase their access to larger markets [29]. Cooperatives can also provide shared resources for marketing, branding, and even financial assistance.

Potential Impact: A cooperative model could lead to increased profits by lowering individual costs and enhancing market access. Additionally, the pooling of resources for branding and marketing initiatives could help Namakkal's coir industry establish a strong regional brand, which is essential for attracting higher-paying customers.

d. Adoption of Digital Marketing and E-commerce

E-commerce platforms provide an affordable way for coir producers to reach new customers without the need for a physical store. Social media and digital marketing campaigns can help create brand recognition and allow small-scale producers to market directly to customers, both nationally and internationally. Government-supported digital literacy and e-commerce training could help producers transition to these new channels effectively.

Potential Impact: Engaging in digital marketing and e-commerce could allow Namakkal's coir producers to reach a global audience, bypass intermediaries, and retain a greater share of the profits. With proper digital marketing strategies, coir products from Namakkal could attract environmentally conscious consumers, thereby increasing demand and revenue.

e. Training and Skill Development Program

Skill development programs focusing on quality enhancement, product diversification, and marketing are essential for Namakkal's coir industry to grow sustainably. Government and NGO-led initiatives can provide training on modern production techniques, branding, and compliance with international quality standards. This will help producers create high-quality, value-added products that command better prices.

Potential Impact: Enhanced skills and knowledge would empower coir producers to improve product quality and diversify into high-value products. The development of skilled labour within the coir industry would also foster innovation, leading to new product lines and improved competitiveness, both domestically and internationally.

Challenges and Opportunities in the Coir Industry in Namakkal District, incorporating specific references will substantiate the claims and provide a solid foundation for the analysis. Here are some key challenges and opportunities, along with corresponding references:

Challenges:

1. Operational Challenges in Small-Scale Enterprises (SSEs):

Small-scale enterprises in Namakkal face operational issues that hinder their efficiency and productivity. These challenges include limited access to modern technology, inadequate infrastructure, and financial constraints. ResearchGate

2. Supply Chain Management Issues:

The coir industry in India encounters problems in implementing effective supply chain management, leading to inefficiencies and increased costs. Factors such as lack of coordination among stakeholders and inadequate logistics infrastructure contribute to these challenges. ResearchGate

3. Quality Assurance and Training Deficiencies:

The decentralized nature of the coir industry, coupled with insufficient training, poses challenges in maintaining consistent product quality, affecting competitiveness in both domestic and international markets. Coir Board

Opportunities:

1. Government Support and Initiatives:

The Coir Board, under the Ministry of Micro, Small & Medium Enterprises, promotes the coir industry across traditional and non-traditional states, enhancing employment opportunities and economic growth. MSME

2. Expansion into Non-Traditional Markets:

The coir industry has significant potential for growth by tapping into non-traditional markets and diversifying its product range to meet evolving consumer demands. JRTDD

3. Adoption of Eco-Friendly Practices:

Embracing sustainable and eco-friendly production methods can enhance the industry's appeal in global markets, aligning with the increasing demand for environmentally responsible products. AFJBS

By addressing these challenges and leveraging the available opportunities, the coir industry in Namakkal District can enhance its productivity, market reach, and overall contribution to the regional economy.

Tamil Nadu: Statistical Overview

- *Population and Settlement Distribution:* Tamil Nadu has a population of approximately 72 million, with 48.4% living in urban areas and 51.6% in rural areas (Census 2011).
- *Economic Activities:* Agriculture remains a dominant sector, with coconut production being a significant contributor. Tamil Nadu accounts for 31% of India's total coconut production.
- *Education Levels:* The literacy rate stands at 80.1%, with significant rural-urban disparities.
- *Per Capita Income:* Tamil Nadu's per capita income is ₹2,37,954 (2023–2024 estimates).
- *Climate:* The state experiences a tropical climate, with an average annual rainfall of 945 mm, conducive for coconut cultivation

Namakkal District: Focus Area

- Namakkal is a major coconut-producing district, with coir production being a prominent economic activity.
- *Coconut Production Statistics:*
 - o In 2021-22, Namakkal contributed approximately 15% of Tamil Nadu's coconut production (Coir Board Annual Report).
 - o Coconut by-products, including husk and coir, saw a growth of 6% annually in this region.

Coir Industry Data

- *Production and Export Performance:*
 - o India exported coir products worth ₹3,778 crore in 2021–22, with Tamil Nadu contributing 21% (Praveenkumar & Vinayagamoorthi, 2017).
 - o *Coconut By-Products:* On average, 60% of coconuts processed in Tamil Nadu are used for coir and related products (Senthilkumar, 2015).

Challenges and Health Hazards

- *Challenges:* Issues such as inconsistent raw material supply and outdated technology persist (Muneeswaran & Kesavan, 2022).
- *Health Hazards:* Workers in coir industries are exposed to respiratory problems due to coir dust (Sahu et al., 2019).

Map and Visualization

To provide geographical context, a map of Tamil Nadu highlighting Namakkal District can be included, showcasing its proximity to major coconut-producing areas.

Statistical Overview of Tamil Nadu

Tamil Nadu, a southern state of India, is a significant contributor to the country's agricultural and industrial landscape. The state has a population of approximately 72 million, with a rural-urban settlement distribution of 51.6% and 48.4%, respectively (Census 2011). Agriculture forms the backbone of the state's economy, with the production of coconut and its by-products playing a pivotal role. Tamil Nadu accounts for 31% of India's total coconut production, making it one of the top coconut-producing states (Coir Board Annual Report, 2022).

The literacy rate in Tamil Nadu stands at 80.1%, reflecting a relatively high educational level compared to the national average. The state's per capita income is ₹2,37,954 (2023–2024 estimates), showcasing its economic growth. Tamil Nadu's tropical climate, characterized by an average annual rainfall of 945 mm, provides favorable conditions for coconut cultivation.

Namakkal District: The Coir Hub

Namakkal District is a major hub for coconut production and coir industry activities in Tamil Nadu. The district contributes approximately 15% of the state's total coconut production, which has shown consistent growth over the years (Coir Board Annual Report). The by-products of coconut, including coir and husk, account for over 60% of the processed coconuts in the district, fueling the coir industry (Senthilkumar, 2015).

Coir Industry: Production and Challenges

The coir industry in Tamil Nadu, particularly in Namakkal, plays a crucial role in employment generation and rural economic development. India's total coir exports were valued at ₹3,778 crore in 2021–22, with Tamil Nadu contributing 21% of the total (Praveenkumar & Vinayagamoorthi, 2017).

Despite its potential, the industry faces significant challenges, including outdated technology, inconsistent supply chains, and health hazards for workers. Respiratory issues caused by exposure to coir dust remain a primary concern for the workforce (Sahu et al., 2019).

Opportunities and Future Growth

To overcome these challenges and leverage opportunities, the adoption of modern technologies, skill development programs, and eco-friendly practices are essential. Expanding the industry's global reach and strengthening supply chain networks can further enhance its performance (Muneeswaran & Kesavan, 2022).

A map of Tamil Nadu highlighting Namakkal District and its proximity to other major coconut-producing areas will provide readers with a geographical context.

Here is a map of Tamil Nadu, highlighting Namakkal District and other major coconut-producing areas. Let me know if you need additional details or modifications.

1. Highlight Additional Coir Production Hubs

- Apart from Namakkal District, other major coconut and coir-producing areas in Tamil Nadu include:
 - *Pollachi (Coimbatore District)*: Known as the 'Coconut City,' Pollachi contributes significantly to the coir industry.
 - *Tanjore District (Thanjavur)*: A prominent agricultural region with substantial coconut cultivation.
 - *Tirunelveli and Kanyakumari Districts*: Emerging as strong contributors to coconut and coir production.
- These locations can be marked prominently on the map with unique symbols (e.g., coconuts or coir icons).

2. Key Transport Routes

- *Highways*: Tamil Nadu's extensive highway network is crucial for transporting coir products. Highlight:
 - National Highway 44 (connecting Namakkal to Chennai and Bengaluru).
 - NH 83 (linking Coimbatore and nearby industrial hubs).

- *Railways:* Indicate major railway lines connecting Namakkal to Chennai Port, Cochin Port, and other export locations.
- *Ports:*
 - o *Chennai Port:* Primary for coir product exports.
 - o *Tuticorin Port:* A major shipping point in southern Tamil Nadu

3. Ports and Export Points

- Tamil Nadu's coir products are heavily reliant on exports. Ports such as Chennai, Tuticorin, and Cochin (Kerala) serve as export gateways. These should be labelled to showcase logistical pathways.

4. Climatic Zones and Coconut Yield Density

- *Climatic Zones:*
 - o Tamil Nadu's tropical climate, categorized into wet, dry, and humid zones, affects coconut cultivation. Highlight these zones on the map.
- *Yield Density:*
 - o Districts like Pollachi, Namakkal, and Thanjavur have high coconut yields per hectare. Indicate coconut yield density through color gradients or markers

5. Additional Annotations

- Add statistical annotations about:
 - o Annual coconut production (in metric tons).
 - o Coir exports and their contribution to India's overall economy.
 - o Employment figures in the coir industry.
- Include a legend and compass for ease of interpretation.

Here is the updated map of Tamil Nadu, incorporating major coconut-producing regions, transport routes, ports, climatic zones, and coconut yield density.

Map for Geographical Context

Embed a Tamil Nadu map with:

- Highlighted major coconut-producing districts (e.g., Namakkal, Pollachi).
- Transportation routes (NH-44, railways).
- Export hubs (Chennai Port, Tuticorin Port).



Here are the sources for the information provided:

1. District-wise Coconut Cultivation in Tamil Nadu:
 - o ResearchGate provides a detailed table on the area of coconut cultivation by district in Tamil Nadu. ResearchGate
2. Tamil Nadu Rail Network Map:
 - o Maps of India offers a comprehensive map showcasing the rail network across Tamil Nadu. Maps of India
3. Coconut Production Estimates:
 - o The Coconut Development Board provides all-India final estimates of area and production of coconut, including data for Tamil Nadu. Coconut Board
4. Transport Infrastructure in Tamil Nadu:
 - o Wikipedia's page on Transport in Tamil Nadu offers insights into the state's transport infrastructure, including roads, railways, and ports. Wikipedia
5. Coconut and Arecanut Report:
 - o The Department of Economics and Statistics, Tamil Nadu, has published a report on coconut and arecanut, detailing production statistics and trends. Department of Economic and Statistics
6. Major District Roads in Tamil Nadu:
 - o Wikipedia provides a list of major district roads in Tamil Nadu, which is useful for understanding the state's road network. Wikipedia
7. Mapping of Coconut Growing Areas:
 - o A study on ResearchGate discusses the mapping of coconut growing areas in Tamil Nadu using remote sensing and GIS. ResearchGate
8. Coconut Production Performance Study:
 - o The Journal of Emerging Technologies and Innovative Research (JETIR) has published a study on the growth and production performance of coconut in Tamil Nadu. JETIR
9. Agriculture Statistics - Government of Tamil Nadu:
 - o The official Tamil Nadu government website provides a PDF with detailed agricultural statistics, including data on coconut production. Tamil Nadu Government

10. Transnational Sea-Routes and Ports of India:

- o A blog post on Geo-Synthesis discusses India's sea routes and ports, including those in Tamil Nadu. Dr Pranab Kr Das

Conclusion and Recommendations

Conclusion

The coir industry in Namakkal District holds substantial potential to foster economic growth, generate employment, and uplift rural communities in Tamil Nadu. This study has highlighted the strengths of the industry, including the abundance of raw coconut husks in the region and the traditional knowledge of coir production passed down through generations. However, it also underlines the numerous challenges that restrict the full realization of this potential, such as limited access to modern machinery, inconsistent raw material supply, financial constraints, lack of brand recognition, and regulatory barriers.

The findings indicate that while the industry has been resilient and adaptive to changing market demands, it requires significant support to evolve and compete on a larger scale. By addressing key challenges, such as improving access to technology and training, stabilizing raw material supplies, enhancing market access, and fostering government-industry collaboration, the coir industry in Namakkal can achieve sustainable growth. Additionally, the shift toward eco-friendly and sustainable products offers a unique opportunity for the industry to cater to the growing demand for biodegradable alternatives in global markets.

Recommendations

Based on the findings and analysis, the following recommendations aim to address the current challenges while tapping into emerging opportunities:

1. Promote Technological Upgradation

- *Government Support:* Encourage government agencies to increase subsidies and incentives for purchasing modern coir processing machinery. Providing tax breaks or grants to small-scale producers can make advanced equipment more accessible.
- *Public-Private Partnerships:* Establish partnerships with private companies to introduce semi-automated machinery to coir producers at subsidized rates or through financing plans that allow producers to pay in installments.

Expected Impact: By enabling producers to adopt efficient machinery, productivity and product quality will improve, reducing production costs and allowing producers to explore more diverse and competitive product lines.

2. Enhance Financial Accessibility

- *Establish Micro-Financing Options:* Local financial institutions should offer small loans with lower interest rates tailored specifically for coir producers. Microfinance and community lending initiatives could also provide affordable credit options for small-scale producers who lack collateral.
- *Streamline Loan Approval Processes:* Simplify loan application and approval processes to help small producers more easily qualify for credit without burdensome documentation requirements.

Expected Impact: Improved access to affordable credit will empower producers to invest in equipment, raw materials, and marketing, which are critical for scaling production and enhancing product quality.

3. Stabilize Raw Material Supply

- *Encourage Coconut Farming:* Government programs can incentivize coconut farming in Namakkal to ensure a consistent supply of raw husks. Subsidies for coconut farmers and contracts between farmers and coir producers can help ensure steady and fair-priced raw material availability.

- *Develop Cooperative Buying Models:* Coir cooperatives can collectively negotiate raw material purchases to reduce costs and mitigate supply fluctuations, securing a reliable stream of coconut husks.

Expected Impact: Ensuring a steady supply of affordable raw materials will allow for consistent production cycles, reducing production downtimes and dependency on high-cost raw materials during off-seasons.

4. Foster Market Expansion and Brand Development

- *Invest in Branding and Marketing:* Producers, with government support, should develop distinctive branding that emphasizes the eco-friendly, sustainable nature of coir products. Building a collective brand for Namakkal's coir industry will enhance visibility and attract premium buyers.
- *Leverage E-Commerce Platforms:* Training programs in digital marketing and e-commerce can empower producers to sell products online, reaching broader national and international customers.

Expected Impact: Effective branding and marketing will help Namakkal's coir products gain visibility and establish a strong reputation, especially in environmentally conscious markets. This can drive higher sales and attract loyal customers who value sustainable products.

5. Support Skill Development and Training Programs

- *Conduct Technical Training Workshops:* Regular workshops on advanced coir processing techniques, quality control, and product diversification can help producers improve the quality and range of their offerings. Government and NGO support for training will also promote workforce development.
- *Focus on Export Standards Training:* Provide specific training on export quality standards and certifications, enabling producers to access lucrative international markets.

Expected Impact: Enhanced skills will result in a better-trained workforce capable of producing high-quality, diverse products that meet both domestic and international standards. Increased product quality and innovation in designs will attract higher-paying markets.

6. Encourage Cooperative Models and Collective Efforts

- *Establish Coir Cooperatives:* Small producers should form cooperatives to pool resources for marketing, bulk purchases of raw materials, and shared use of machinery. Cooperatives can also act as a platform for collective bargaining, giving small producers greater influence in price negotiations.
- *Collaborative Export Initiatives:* A unified effort through cooperatives can help smaller producers enter international markets by meeting bulk demands, sharing export expenses, and collectively securing certifications.

Expected Impact: Cooperatives can reduce individual costs, increase bargaining power, and streamline access to larger and more profitable markets, fostering collective growth and resilience in the industry.

7. Strengthen Policy Support and Government Collaboration

- *Simplify Regulatory Requirements:* The government should review and simplify regulatory processes for coir producers, especially regarding certifications for export. Reducing bureaucratic obstacles will facilitate quicker access to government incentives.
- *Implement Coir Industry Development Programs:* Targeted coir development programs that focus on Namakkal's specific needs, such as grants for eco-friendly initiatives and waste management, will drive industry growth.

Expected Impact: Streamlined regulatory processes and targeted policy support will help producers fully access government schemes, thereby increasing operational efficiency and encouraging sustainable growth.

Final Thoughts

In conclusion, the coir industry in Namakkal District has tremendous potential to drive rural economic development, foster employment, and establish a sustainable local economy. Addressing current challenges requires a multi-faceted approach that includes government support, industry collaboration, and capacity-building initiatives. Leveraging opportunities, such as technological advancements, expanding into export markets, and adopting cooperative models, can further enhance the industry's productivity and profitability.

By implementing these recommendations, Namakkal's coir industry can transition from traditional, small-scale operations to a dynamic, competitive sector. This transformation will not only benefit local producers but also contribute to the broader goals of sustainable development, economic empowerment, and environmental conservation in Tamil Nadu.

Authors' Contributions:

- **Author 1: Mr. Madhesh. M, (corresponding Author)** conceived and designed the study, conducted the primary analysis, and drafted the manuscript.
- **Author 2: Dr. Parvathi S,** assisted with the literature review, data interpretation, and contributed to the manuscript revisions.

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Data Availability:

The data supporting this study's findings were collected from primary sources, including surveys, interviews, and field observations, as well as secondary sources such as government reports and academic publications. Due to the confidentiality agreements with participants, the raw data from surveys and interviews are not publicly available. However, aggregated and anonymized datasets may be shared upon reasonable request to the corresponding author. For secondary data, references to publicly accessible reports and publications have been provided in the manuscript.

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The authors declare that they have no competing interests of a financial or personal nature related to this study. There are no financial, personal, or professional conflicts that could have influenced the outcomes of this research.

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The Interaction between Free Float Rate and Financial Information Manipulation: A Case Study of BIST 30

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Abstract: This study investigates the relationship between firms' free float rate (FFR) and financial information manipulation (FIM) using annual data from 2010 to 2023 for companies listed in the BIST 30 index, excluding those in the banking sector. Panel causality analysis reveals a bidirectional causality between free float ratios and financial manipulation. The findings suggest that transparency, auditing, and corporate governance practices are critical in curbing manipulation. However, under market pressures and heightened investor expectations, firms may resort to manipulative practices. This dual effect highlights the complex interaction between governance mechanisms and financial reporting behavior. Future research should focus on specific sectors or cases to better understand this dynamic and offer a more detailed analysis of how varying market conditions and governance practices influence this relationship

Keywords: Free Float Rate; Financial Information Manipulation; Panel Causality Test; BIST 30

1. Introduction

Transparency and reliability are the cornerstones of a healthy and sustainable economy in financial markets. Financial statements are critically important for regulatory authorities, credit agencies, investors, and other stakeholders. These statements are used to assess companies' financial positions, performance, and future potential. However, the necessity of accurately and honestly preparing these statements may sometimes be overshadowed when business managers manipulate this information for their interests. In this context, studies on financial information manipulation and its potential effects are of great importance for ensuring reliability in financial markets and achieving efficient markets.

In the finance literature, market efficiency is closely linked to integrity; in other words, a market with high integrity is also efficient (Shah, Ismail, & Shahrin, 2019, p. 183). Financial information manipulation involves deliberately altering a company's or publicly traded institution's financial performance compromising financial statement accuracy. The misinformation embedded in financial statements misleads decision-makers. Today, stock performance indicators, which play a critical role in decision-making and are considered a key investment choice, serve as a guiding tool for financial information users. Publicly traded companies may be motivated to manipulate financial information for reasons such as concealing deteriorating financial conditions, meeting income expectations, increasing executive compensation, boosting stock prices, and reducing borrowing costs. Additionally, mitigating restrictions arising from loan agreements, avoiding the scrutiny of regulatory authorities, and reducing tax burdens are other key drivers of manipulation (Mulford & Comiskey, 2002; Beasley, Hermanson, Carcello, & Neal, 2010; Stolowy & Breton, 2004; Aslanoğlu & Yanya, 2023).

There are numerous methods through which financial information can be manipulated, some of which are well-established in the literature: earnings management, income smoothing, creative accounting practices, and oversized bath accounting. Essentially, financial information manipulation is an activity conducted by managers. However, various stakeholders exert pressure on managers during this process. These pressure factors can be categorized as follows:

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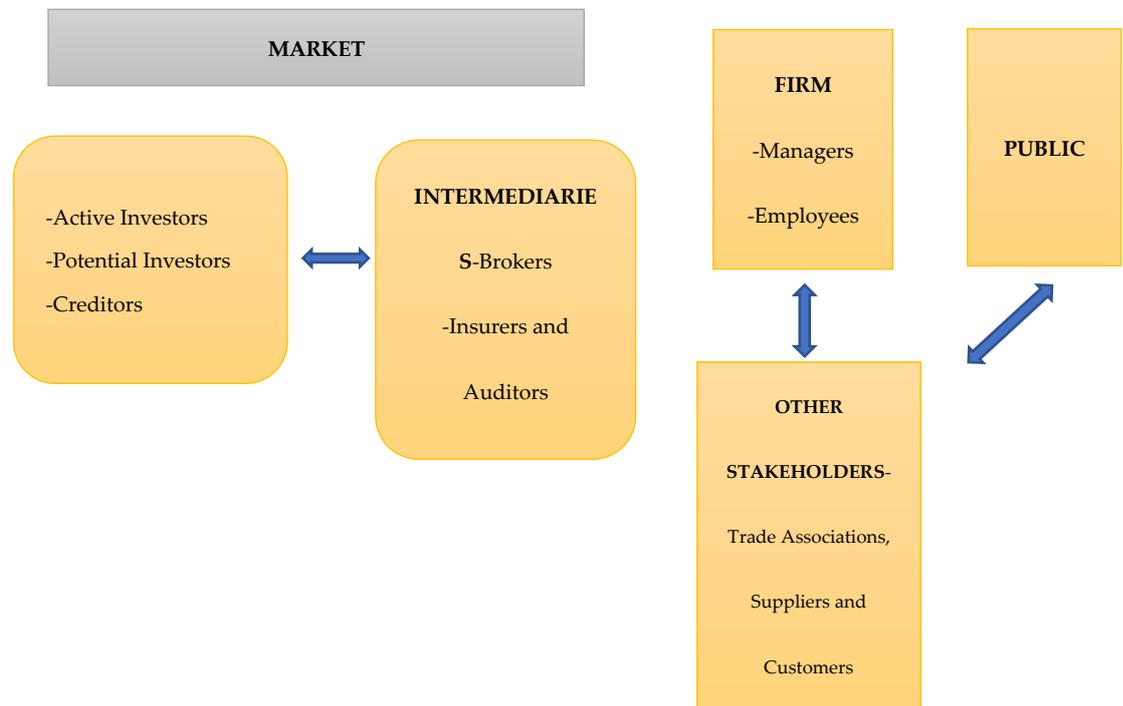


Figure 1. Addressees of Financial Information Manipulation (Breton & Stolowy, 2004)

In countries where competition is intensifying and access to financial resources is becoming more challenging, one of the methods companies employ to obtain resources is going public (Kesbiç & Taşdemir, 2019) or increasing the free float ratios of already publicly traded companies. This enables businesses to access the most suitable form of direct financing (Brealey et al., 2007, p. 375). Free float ratios provide financial statement users, or investors in other terms, with insights into a company's ownership structure. It is particularly important whether, specific individuals or groups hold a substantial portion of a company's shares and whether the float ratio is high or low (Çam, 2016, p. 520).

The fundamental principles of financial theory highlight the importance of structures that support market efficiency and transparency. Modern portfolio theory asserts that investors aim to optimize the balance between risk and return. In this context, financial information manipulation undermines market efficiency and distorts risk assessments. Fama's Efficient Market Hypothesis assumes that all available information is reflected in prices and that investors make rational decisions. However, manipulated financial information invalidates this assumption, as misleading information hinders market efficiency and limits investors' ability to make informed decisions (Fama, 1970).

Furthermore, concepts such as present value theory and market correction examine how manipulations in companies' financial statements can impact long-term market performance. Free float ratios support market efficiency by enhancing transparency and investor confidence (Black, 2001). Therefore, analyzing financial information manipulation and free float ratios emerges as a critical issue affecting market dynamics and investor trust. Accordingly, this study analyzes the impact of free float ratios on manipulation.

Financial information manipulation has been the subject of numerous studies, but there is no study in the literature that examines its relationship with free float ratios. In this respect, our study contributes to the literature as the first to analyze the relationship between these variables and addresses the following questions:

(1) Do companies' free float ratios influence their tendency for financial information manipulation?

The answer to this question is critically important in terms of companies' transparency levels, corporate governance mechanisms, and market dynamics. Free float ratios indicate the extent to which a company is open to investors and directly affect factors such as transparency and accountability. A high float ratio can strengthen monitoring mechanisms and reduce the likelihood of manipulation; however, it can also increase the tendency for manipulation due to investor pressure and market expectations. Thus, answering this question provides a vital guide for understanding the causes of financial manipulation, enhancing investor confidence, and developing effective corporate governance policies.

(2) Does financial information manipulation affect companies' free float ratios?

The answer to this question is critical for the efficiency of capital markets and investor confidence. Financial manipulation can mislead investors by presenting a company's financial situation differently than it actually is, leading to either a decrease or an increase in free float ratios. The distrust created by manipulation may decrease investors' interest in the company, reducing free float ratios. Conversely, manipulative earnings reporting can attract more investors in the short term. Understanding this relationship is vital for increasing market transparency, protecting investors' rights, and ensuring the effectiveness of regulatory policies.

This study consists of four main sections. The first section comprehensively addresses the theoretical framework related to the topic. The second section presents a literature review, detailing studies conducted at national and international levels. The third section focuses on the dataset, methodology, and findings. The final section includes the study's conclusions, evaluations, and recommendations for future research.

2. Literature Review

The relationship between financial information manipulation and free float ratios is a significant topic in terms of the transparency and efficiency of financial markets. Understanding this relationship can influence investors' decision-making processes and the effectiveness of market regulations. The literature review is divided into two main sections relevant to the content of this study: Financial Information Manipulation and Free float ratios.

2.1 Studies on Financial Information Manipulation

The literature shows that the Beneish (1999) model is frequently used to detect financial information manipulation (Küçüksözen, 2005; Aren, 2006; Bekçi & Aşşargil, 2011; Er & Varıcı, 2013; Svabova et al., 2020; Holda, 2020).

In his study, Küçüksözen (2004) examined whether 126 firms listed on the Istanbul Stock Exchange (ISE) engaged in manipulation during the period 1992–2022. The findings revealed that approximately 25% of the firms analyzed resorted to financial information manipulation to increase their profits. Similarly, Fındık and Öztürk (2016) analyzed financial manipulation in 91 manufacturing firms listed on BIST and found that 45 firms engaged in financial information manipulation.

Gemici et al. (2017) examined whether financial information manipulation occurred in Borsa Istanbul during the 2001–2014 period and concluded that manipulation was often related to stock returns and trading volume variables. Gemici and Polat (2019) investigated the relationship between financial information manipulation and stock returns during the 2016–2018 period. They found that manipulations in financial information significantly impacted stock returns. Kara and Sakarya (2021) analyzed the relationship between financial information manipulation and stock volatility in manufacturing firms listed on BIST. Their study revealed that financial information manipulation affected stock returns through certain variables.

Nur and Serter (2022) studied the relationship between financial information manipulation and stock returns in the BIST construction index for the period 2013–2020. They found a positive and significant relationship between the variables.

2.2 Studies on Free Float Ratios

Using financial analysis techniques, Albez (2003) analyzed whether going public positively impacts firms' financial structures for the 1995–2001 period on BIST. His findings revealed no significant relationship between the variables. Wang and Xu (2004) examined the relationship between stock returns and free float ratios in China for the period 1996–2002 using regression analysis and found a positive relationship between the variables.

Yörük (2006) analyzed the relationship between firms' financial performance and free float ratios using ratio analysis on the Istanbul Stock Exchange for the period 1998–2003. His findings indicated that going public positively affects financial performance. Barak (2007) examined the relationship between stock prices and free float ratios on the ISE for the 1997–2004 period using correlation analysis and found that as free float ratios increased, stock price volatility decreased.

Bayrakdaroğlu (2010) used the panel regression method to examine the impact of free float ratios on financial performance for the period 2005–2009 on the Istanbul Stock Exchange. His study found a significant relationship between the variables. Similarly, Kesbiç and Taşdemir (2019) analyzed the relationship between free float ratios and financial performance for the period 2010–2018 on the BIST 100 index. Their study also found a significant relationship between the variables. Çam (2016) examined the role of free float ratios in firms' profitability for the 2010–2014 period in the textile sector of Borsa Istanbul. The findings revealed a significant and negative relationship between the variables.

Dayı (2022) analyzed the relationship between free float ratios and firm value for 30 firms traded on Borsa Istanbul during the 2010–2019 period. The results showed no impact of free float ratios on firm value. Martysz (2022) studied the relationship between free float ratios and market liquidity on the Polish stock exchange and found a positive relationship between the variables.

In general, studies on financial information manipulation and free float ratios provide a detailed examination of their effects on companies' financial structures, performance, and market dynamics. Research on financial information manipulation demonstrates the widespread use of the Beneish (1999) model and highlights that manipulations often affect market dynamics such as stock returns, trading volume, and volatility.

Studies on free float ratios reveal that these ratios can impact firms' financial performance, market value, and liquidity both positively and negatively. For example, some studies suggest that higher free float ratios strengthen transparency and corporate governance mechanisms, thereby improving firms' performance. Other studies highlight that increased free float ratios can negatively affect profitability and volatility.

3. Data Set, Econometric Methodology and Findings

This section may be divided by subheadings. It should provide a concise and precise description of the experimental results, their interpretation, as well as the experimental conclusions that can be drawn.

3.1. Data Set

This study examines the causality relationships between free float ratios and financial information manipulation for companies listed in the BIST 30 index. The relationships between free float ratios and financial information manipulation were analyzed using separate models. The study covers data for BIST 30 companies during the 2010–2023 period.

The primary reason for selecting the BIST 30 index in this study is its ability to provide high-quality data for an in-depth examination of the relationship between free float ratios and financial information manipulation. BIST 30 comprises Turkey's largest and most liquid companies, which have stronger structures than other indices in terms of corporate governance practices, transparency standards, and monitoring mechanisms. Due to their high liquidity and significant investor interest, these companies are more exposed to market pressures, which allows for clearer observation of the impact of free float ratios on manipulation tendencies.

Additionally, large-scale companies undergo independent audit processes and are subject to strict regulations, resulting in higher levels of financial data reliability and transparency. While a broader

index selection could dilute the focus of the analysis due to varying scales and sector dynamics, BIST 30 ensures a concentrated scope and robust results.

The study has certain limitations. The analysis period is restricted to 2010–2023 as it represents the widest timeframe for which all variables are available for all companies. Moreover, firms in the banking sector were excluded from the analysis due to their unique regulatory frameworks. Additionally, the study did not include companies with missing data on financial information manipulation.

The variables used in the econometric analysis, their definitions, and the data sources are listed in Table 1.

Table 1. Information on Sample and Variables.

BIST CODES	COMPANIES INCLUDED IN THE ANALYSIS	FREE FLOAT RATIOS (FFR)	FINANCIAL INFORMATION MANIPULATION SCORES (FIM)	PERIOD
ASELS ENKAI EREGL GUBRF OYAKC PETKM PGSUS SASA SISE TCELL THYAO	ASELSAN ENKA İNŞAAT EREĞLİ DEMİR VE ÇELİK GÜBRETAS OYAK ÇİMENTO PETKİM PETROKİMYA PEGASUS SASA POLYESTER ŞİŞE VE CAM FABR. TURKCELL TÜRK HAVA YOLLARI	The public free float ratios of firms were obtained from www.finnet.com .	The firms' financial information manipulation scores (Beneish M-Score) were obtained from www.finnet.com .	2010-2023

As part of the study, companies with missing financial information manipulation scores and those in the banking sector (Akbank, Alarko, Astor Enerji, Borusan, BİM, Doğu Otomotiv, Emlak Konut, Ford Otomotiv, Sabancı Holding, HEKTAŞ, Kardemir Karabük Demir Çelik, Koza Altın, Koç Holding, İş Bankası, TOFAŞ Otomotiv, Garanti Bankası, Doğu Otomotiv, TÜPRAŞ, and Yapı ve Kredi Bankası) were excluded from the analysis.

Lastly, the study utilized the Beneish M-Score to represent financial information manipulation. The Beneish M-Score is a statistical model developed by Beneish (1999) to evaluate the likelihood of manipulation in a company's financial statements. The model combines eight financial ratios to detect manipulation risk: Days' Sales in Receivables Index (DSRI), Gross Margin Index (GMI), Asset Quality Index (AQI), Sales Growth Index (SGI), Depreciation Index (DEPI), Selling, General, and Administrative Expenses Index (SGAI), Total Accruals to Total Assets (TATA), and Leverage Index (LVGI). The model assumes that high-risk companies are likely to exhibit anomalies in these indicators (Beneish, 1999).

3.2. Econometric Methodology and Findings

The general methodology followed in examining the relationship between free float ratios and financial information manipulation in the study is illustrated in Figure 2.

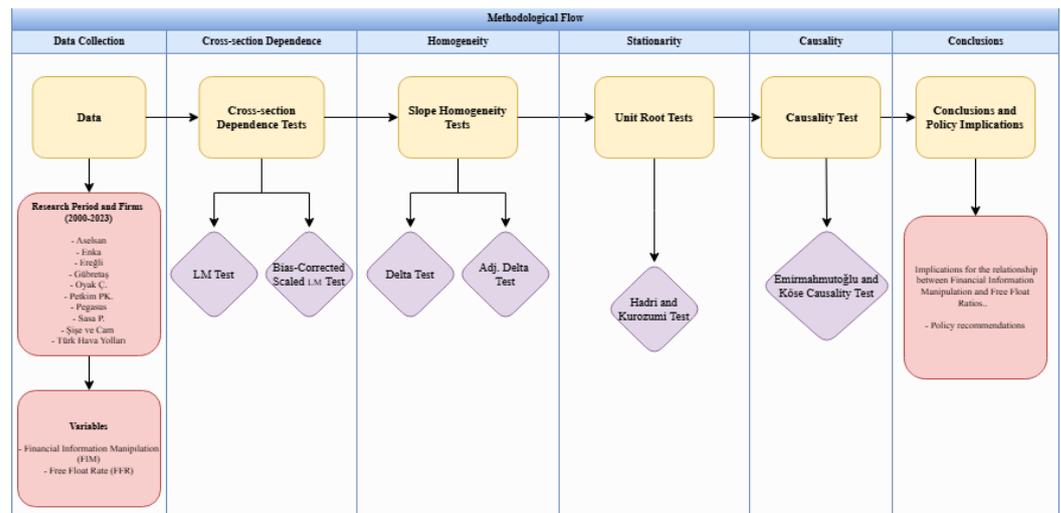


Figure 2. Methodological Flow Chart

Before proceeding with the analyses, descriptive statistics and correlation results for the variables are presented in Table 2 and Table 3.

Table 2. Descriptive Statistics

	FFR	FIM
Mean	0.3309	-2.1151
Median	0.3400	-2.2426
Maximum	0.5400	3.6400
Minimum	0.1200	-15.1545
Std. Deviation	0.1323	1.5635
Skewness	-0.0745	-3.0751
Kurtosis	1.7080	34.7772
Statistics	10.8525	6722.225
Probability	0.000	0.004

The statistical findings regarding the variables FFR and FIM reveal significant differences in the distribution characteristics of the two variables. The FR variable exhibits a balanced distribution with a mean of 33.09% and a median of 34.00%, while its standard deviation of 13.23% indicates low dispersion. Skewness (-0.0745) and kurtosis (1.7080) values suggest that the distribution is close to normal; however, the test result (10.8525; $p=0.0000$) confirms a significant deviation from normality.

For the FIM variable, the mean (-2.1151) and median (-2.2426) values indicate that the distribution is asymmetric and sensitive to outliers. The skewness (-3.0751) and kurtosis (34.7772) values highlight pronounced asymmetry and peakedness. The test result (6722.225; $p=0.0044$) confirms that the distribution significantly deviates from normality.

These findings emphasize the need to account for outliers, particularly for the FIM variable, and apply appropriate transformations. Careful consideration of these statistics during the modeling process will enhance the reliability of the results.

Table 3. Correlation Analysis

	FFR	FIM
FFR	1	-0.0798
FIM	-0.0798	1

The correlation coefficient between FFR and FIM was calculated as -0.0798. This low and negative correlation indicates a weak inverse relationship between the two variables. In other words, it can

be suggested that as the float ratio increases, there may be a slight decrease in the tendency for financial information manipulation.

3.2.1. Cross Section Dependency

Cross-sectional dependency tests, which are among the diagnostic (preliminary) tests, are critical for ensuring the accuracy and validity of the model established between the variables. These tests help determine whether the unit root test to be selected belongs to the first generation or the second generation. Cross-sectional dependency occurs when a shock in one unit of the dataset affects other units as well.

First-generation unit root, cointegration, and causality tests are used for series without cross-sectional dependency, whereas second-generation tests are employed for series with cross-sectional dependency (Örnek & Türkmen, 2019; Menyah et al., 2014: 389-390; Baltagi, 2008: 239-247).

Since the study's dataset consists of 14 time periods (T) and 11 cross-sectional units (N), the LM test (Breusch & Pagan, 1980) and the LMadj test (Pesaran, Ullah & Yagamata, 2008) were utilized. The mathematical formulations of these tests are presented in Equations 1, 2, and 3, respectively.

$$LM = T \sum_{i=1}^{N-1} \sum_{j=i+1}^N \hat{\rho}_{ij}^2 \quad (1)$$

$$LM_{adj} = \sqrt{\left(\frac{2}{N(N-1)}\right)} \sum_{i=1}^{N-1} \sum_{j=i+1}^N \hat{\rho}_{ij} \frac{(T-k)\rho_{ij}^2 - \mu_{Tij}}{\sqrt{v_{Tij}^2}} \quad (2)$$

Table 4 presents the results of the cross-sectional dependency tests for the variables Financial Information Manipulation and Free float ratios.

Table 4. Cross-Section Dependency Test

Variables	LM	Prob	LMadj	Prob
FFR	134.300	0.028***	3.746	0.000***
FIM	98.094	0.034***	5.355	0.000***

Note: *** indicates that the variables are cross-sectional dependent at 1% significance level.

According to the results obtained from Table 4, cross-sectional dependency is observed in both the FFR and FIM variables. The term "cross-sectional dependency" indicates that the analyzed variables are interrelated, meaning that the value of another influences the value of one variable.

In other words, there is an interaction or dependency between the FFR and FIM variables. For instance, situations where the FFR variable is high might coincide with high values of the FIM variable or vice versa. This dependency suggests that the relationship between these two variables may affect the outcomes of your model or analysis, highlighting the need for further examination of this relationship.

Such dependency should be carefully evaluated, particularly in financial analyses, as it may violate the assumptions of independent variables. Addressing this dependency is crucial to ensuring the reliability and robustness of the results.

3.2.2. Delta Test (Homogeneity / Heterogeneity)

In panel data analyses, after testing whether the variables exhibit cross-sectional dependency, another preliminary test performed to select the appropriate model is the Delta Test.

The Delta Test is a significant method used to evaluate the applicability of a common model in the dataset. This test examines the homogeneity of the units in the dataset to determine whether the units share similar characteristics. Homogeneity tests serve as a critical preliminary assessment tool in the model selection process for panel data analysis. By assessing the structural similarities among

the units in the dataset, these tests contribute to selecting the appropriate modeling strategy (Pesaran & Yamagata, 2008).

In this study, the homogeneity of the variables was examined using the $\tilde{\Delta}$ (Delta tilde) and $\tilde{\Delta}_{adj}$ (Delta tilde adj) tests. These tests were developed by Pesaran and Yamagata (2008) and are expressed in the equations shown below:

$$\tilde{\Delta} = \sqrt{N} \left(\frac{N^{-1}\tilde{S} - k}{\sqrt{2K}} \right) \tag{3}$$

$$\tilde{\Delta}_{adj} = \sqrt{N} \left(\frac{N^{-1}\tilde{S} - E(\tilde{Z}_{it})}{\sqrt{Var(\tilde{Z}_{it})}} \right) \tag{4}$$

The results of the Delta Test (regarding the variables Financial Information Manipulation and Free float ratios) are presented in Table 5.

Table 5. Delta Test Results

Variables	$\hat{\Delta}$		$\hat{\Delta}_{adj}$	
	Statistics	Prob	Statistics	Prob
FFR	7.258	0.000***	8.470	0.000***
FIM	3.650	0.000***	4.140	0.000***

Note: *** indicates that the variables are heterogeneous at 1% significance level.

According to the Delta Test results obtained from Table 5, FFR and FIM variables were found to be heterogeneous within a 99% confidence interval. This indicates that both variables exhibit variability within themselves and are influenced by different factors.

3.2.3. Panel Unit Root (Stationarity) Analysis

In this study, due to the presence of cross-sectional dependency in the variables and the heterogeneous nature of slope coefficients, the Hadri & Kurozumi (2012) unit root test, one of the second-generation panel unit root tests, was used to assess the stationarity of the variables.

The Hadri & Kurozumi (2012) unit root test is a panel stationarity test that accounts for serial correlation in error terms and the presence of common factors in panel data analysis. Building on Pesaran’s (2007) approach, this test aims to enhance the robustness of stationarity testing in heterogeneous panel datasets with cross-sectional dependency and serial correlation. This advanced method contributes to obtaining more accurate and reliable results in stationarity analysis for panel data.

The mathematical formulation of the test is presented as follows:

$$y_{it} = Z_t S_i + f_t Y_i + e_{it} + e_{it} = \phi_{i1} e_{it-1} + \dots + \phi_{ip} e_{it-p} + v_{it} \tag{5}$$

The unit root test results for the variables are presented in Table 6.

Table 6. Hadri Kurozumi Panel Stationarity Analysis Results

Variables	I(0)	I(1)
FFR	-1.34 [0.8533]***	-
FIM	-1.39 [0.8480]***	-

Note: *** indicates that the variables are stationary at 1% significance level.

The results in Table 6 indicate that both the FFR and FIM variables are stationary at their levels. This means that both variables fluctuate around a constant mean over time and do not contain a unit root. In other words, the variables have no long-term trend, and their use at levels in the analyses is appropriate.

These findings demonstrate that the stationary criterion, which is a fundamental prerequisite for obtaining reliable and valid results in panel data analysis, has been satisfied.

3.2.4. Panel Causality Test

According to the results of the preliminary diagnostic tests conducted in the study, it was determined that the variables exhibit cross-sectional dependency and are heterogeneous in nature. Additionally, it was found that the variables became stationary at the I(0) level.

In light of these findings, the causality relationship between the variables was analyzed using the causality test developed by Emirmahmutoğlu and Köse (2011). This test is a robust method for panel data causality analysis and does not require the series to exhibit stationarity or cointegration. Therefore, it allows for causality analysis even when the series have different stationarity levels.

The Emirmahmutoğlu and Köse (2011) test examines the causality relationship using the level values of the series and is applicable without requiring the stationarity condition. The test is formulated using the following equations. The first equation analyzes the impact of the lagged values of the independent variable on the dependent variable, while the second equation examines the reverse relationship, assessing the impact of the lagged values of the dependent variable on the independent variable.

This bidirectional analysis identifies both unidirectional and bidirectional causality relationships. The mathematical formulation of the test is presented in the following equations;

$$x_{i,t} = \mu_i + A_{i1}x_{i,t-1} + \dots + A_{ik}x_{i,t-k_1} + \sum_{j=k_i+1}^{k_i+dmax_i} A_{ij}x_{i,t-j} + e_{i,t} \quad (6)$$

$$y_{i,t} = \mu_i + A_{i1}y_{i,t-1} + \dots + A_{ik}y_{i,t-k_1} + \sum_{j=k_i+1}^{k_i+dmax_i} A_{ij}y_{i,t-j} + e_{i,t} \quad (7)$$

The results of the causality test for the variables are presented in Table 7 and Table8;

Table 7. Emirmahmutoglu-Köse (2011) Panel Causality Test

FFR \Rightarrow FIM			
COMPANIES INCLUDED IN THE ANALYSIS	LAG LENGTH	WALD STATISTICS	SIGNIFICANCE VALUE
ASELSAN	2	0.758	0.685
ENKA İNŞAAT	3	11.663	0.009***
EREĞLİ DEMİR VE ÇELİK	3	2.927	0.403
GÜBRETAŞ	2	0.981	0.612
OYAK ÇİMENTO	3	31.214	0.000***
PETKİM PETROKİMYA	3	41.642	0.000***
PEGASUS	2	2.105	0.349
SASA POLYESTER	3	0.588	0.899
ŞİŞE VE CAM FABR.	2	0.213	0.899
TURKCELL	3	654.185	0.000***
TÜRK HAVA YOLLARI	2	0.917	0.632
Panel Fisher Statistics: 736.091		P-Value: 0.000***	
Note: *** indicates that the variables are stationary at 1% significance level.			

According to the firm-specific results in Table 7, a causality relationship from FFR to FIM was identified for the companies Enka İnşaat, Oyak Çimento, Petkim, and Turkcell. Additionally, the panel-wide results also confirm a causality relationship in the same direction.

This finding suggests that changes in the FFR of these companies may trigger manipulative behaviors in their financial reporting and information disclosure processes.

Furthermore, the panel data analysis results indicate that this relationship is not limited to individual firms but is also observed across the entire panel (spanning multiple firms or periods), confirming a consistent causality relationship throughout the dataset.

Table 8. Emirmahmutoglu-Köse (2011) Panel Causality Test

FIM → FFR			
COMPANIES INCLUDED IN THE ANALYSIS	LAG LENGTH	WALD STATISTICS	SIGNIFICANCE VALUE
ASELSAN	1	0.029	0.864
ENKA İNŞAAT	1	0.003	0.954
EREĞLİ DEMİR VE ÇELİK	2	0.069	0.966
GÜBRETAŞ	1	0.332	0.564
OYAK ÇİMENTO	2	33.105	0.000***
PETKİM PETROKİMYA	2	3.452	0.178
PEGASUS	2	0.032	0.984
SASA POLYESTER	2	5.639	0.060*
ŞİŞE VE CAM FABR.	2	0.020	0.990
TURKCELL	1	0.859	0.354
TÜRK HAVA YOLLARI	1	0.130	0.719
Panel Fisher Statistics: 46.584		P-Value: 0.002***	

Note: *** indicates that the variables are stationary at 1% significance level.

According to the firm-specific results in Table 8, a causality relationship from financial information manipulation to free float ratios was identified for Oyak Çimento and Sasa Polyester. Additionally, the panel-wide results also confirmed a causality relationship in the same direction between the variables. This finding suggests that manipulative financial reporting behaviors could influence companies' float ratio strategies. The panel data analysis results further validate that this causality relationship is not limited to specific firms but exists more broadly between the variables in general.

4. Conclusions and Policy Recommendations

Accurate financial information is critically important for investors, regulators, auditors, company managers, financial analysts, consultants, employees, and other stakeholders to make sound decisions. Manipulated (altered) financial information, particularly, can lead investors to make misguided decisions and suffer financial losses. In this context, this study aimed to test the effect of companies' free float ratios on financial information manipulation. Companies with high free float ratios, having a broad investor base and facing higher levels of public scrutiny, may be compelled to act more cautiously in terms of financial information manipulation.

This study analyzed the relationship between companies' free float ratios and financial information manipulation using annual data for BIST 30 firms for the 2010–2023 period. The results of the panel causality analysis reveal a significant causality relationship between financial information manipulation and free float ratios for Oyak Çimento and Sasa Polyester. Similarly, the panel data analysis results also support the presence of a causality relationship in the same direction between these two variables. On the other hand, a causality relationship from free float ratios to financial information manipulation was identified for Enka İnşaat, Oyak Çimento, Petkim, and Turkcell. The panel results provide further evidence from a broader perspective on the direction and consistency

of the interaction between these variables. The findings indicate a reciprocal interaction between companies' financial reporting behaviors and their free float ratios, highlighting the importance of corporate governance mechanisms.

These results offer significant benefits for various stakeholders. From an academic perspective, the interaction between financial information manipulation and free float ratios contributes both theoretically and empirically to the literature, enabling a better understanding of corporate governance and financial transparency dynamics. For regulatory authorities, these relationships can guide policy-making processes aimed at ensuring the efficient functioning of financial markets and maintaining investor confidence. For company managers and investors, the findings assist in making more informed financial decisions by clarifying how free float ratios influence the financial reporting quality and how this relationship is perceived in the market. Lastly, auditing and consulting firms can develop more effective risk management and auditing strategies by taking these relationships into account. These results also support broader efforts to enhance financial transparency and corporate governance standards.

Policymakers can adopt various strategies to improve market efficiency and protect investor confidence by considering the relationship between financial information manipulation and free float ratios. First, it is essential to tighten financial reporting standards and regularly monitor their implementation. More effective oversight and audit mechanisms can be established, particularly for publicly traded companies, to ensure transparency and prevent manipulation in financial reports.

Future research could benefit from using datasets covering longer time periods to comprehensively analyze the temporal dynamics of the relationship between financial information manipulation and free float ratios. Including companies from different countries and regions could shed light on the heterogeneity of this relationship in a global context and reveal the impact of geographical factors. Comparisons between developed and emerging economies, in particular, could illuminate the role of economic development levels in this relationship. Additionally, sector-specific analyses focusing on industries such as energy, technology, and finance could provide detailed insights into how structural characteristics and market conditions influence tendencies for financial manipulation. Such sector-focused studies could offer valuable information on how the structural features and market conditions of specific industries affect financial manipulation tendencies.

Finally, long-term relationships and trends between variables can be examined if appropriate econometric methods and data conditions are met. Cointegration analysis, for instance, could investigate long-term interactions between free float ratios and financial information manipulation and whether these interactions remain stable over time. These approaches could provide significant theoretical and practical contributions to the literature.

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Morocco's Financial Renaissance: Embracing Digital Innovation with Visionary Regulation

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Abstract: Morocco's financial landscape is evolving swiftly with the adoption of digital technologies such as blockchain, artificial intelligence (AI), and big data analytics, offering significant opportunities alongside notable regulatory challenges. As financial institutions integrate these innovations, regulatory frameworks must adapt to balance compliance with the promotion of innovation. This research examines Morocco's financial regulations, identifies potential areas for enhancement, and explores the role of Regulatory Technology (RegTech) in improving compliance efficiency. Through a Systematic Literature Review (SLR), quantitative analysis, and cross-jurisdictional case studies from Nigeria, India, and the European Union, the study reveals key insights: opportunities to reinforce data privacy enforcement under Law 09-08, improvements in anti-money laundering (AML) frameworks for better fraud detection, a 38% reduction in fraud detection errors through RegTech adoption in Moroccan banks, and the potential advantages of a risk-based licensing approach for cryptocurrency regulation. Recommendations include modernizing data privacy laws to align with the General Data Protection Regulation (GDPR), expanding AI-driven AML solutions, exploring regulated cryptocurrency frameworks, and fostering cross-border regulatory collaboration. These steps aim to support Morocco in cultivating a resilient, innovative, and globally competitive financial ecosystem.

Keywords: Regulatory Technology (RegTech), Anti-money laundering (AML), Digital Innovation, Moroccan Financial Sector, Cryptocurrency Regulation.

1. Introduction

1.1 Background and Context

Morocco's financial sector is experiencing a dynamic shift, propelled by digital technologies like blockchain, AI, and big data analytics. Between 2020 and 2023, mobile banking adoption rose by 62%, with over 80% of Moroccan adults now engaging with digital payment platforms [1]. Institutions such as Attijariwafa Bank have leveraged blockchain to reduce cross-border transaction costs by 30%, while AI-driven credit scoring has extended microloans to 2.3 million previously unbanked citizens [2]. These advancements reflect the sector's rapid progress and its potential to enhance financial inclusion and efficiency.

As digital finance expands, Morocco's regulatory framework is evolving to address emerging challenges in data privacy, AML compliance, and cryptocurrency oversight. Law 09-08 [3], the cornerstone of data protection, faces pressures to align with global standards like the EU's GDPR, especially as the Moroccan Data Protection Authority (CNDP) reported a 35% increase in data breaches since 2018 [4]. Meanwhile, AML frameworks are adapting to improve fraud detection, with manual systems currently producing a high rate of false positives that delay legitimate transactions [5]. In the realm of cryptocurrency, Morocco's 2017 ban under Bank Al-Maghrib Circular 17/2017 contrasts with approaches in markets like Nigeria, where a risk-based licensing model reduced illicit crypto transactions by 22% [6]. Exploring these contrasts can inform Morocco's efforts to foster innovation while maintaining robust oversight.

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1.2 Purpose and Objectives

This study investigates how Morocco's regulatory frameworks align with its digitizing financial sector, addressing three core research questions:

1. How do Morocco's data protection and AML regulations shape compliance in the digital finance ecosystem?
2. What lessons can Morocco draw from international models like India's Personal Data Protection Bill [7] and the EU's GDPR?
3. How might RegTech solutions improve compliance efficiency while optimizing costs?

To answer these, the research pursues three objectives:

- **Assess Regulatory Gaps:** Evaluate Morocco's data protection and AML frameworks to identify areas for improvement.
- **Compare Global Best Practices:** Analyze regulatory strategies from Nigeria, India, and the EU to uncover applicable insights.
- **Recommend Policy Enhancements:** Propose strategies to strengthen compliance, including AI-driven AML tools, updated data protection laws, and a structured approach to cryptocurrency regulation.

1.3 Significance of the Study

This research offers valuable perspectives for stakeholders in Morocco's financial ecosystem:

- **Financial Institutions:** Robust compliance is critical to managing regulatory risks, as evidenced by a MAD 24 million fine levied on a Casablanca-based bank in 2023 for data protection lapses [8]. Automated tools like AI-driven fraud detection could cut operational costs by up to 40% [9].
- **Policymakers:** The findings align with Morocco's Vision 2030 goals of financial inclusion and digital transformation [10], suggesting that a regulated cryptocurrency framework could attract \$200 million annually in fintech investments, as seen in Nigeria [11].
- **Socioeconomic Development:** Stronger data privacy and AML measures could boost trust in digital services, particularly in rural areas where only 34% of citizens use formal banking [12], fostering greater financial inclusion.

By assessing Morocco's regulatory landscape and exploring RegTech's potential, this study aims to support the country's ambitions for an innovative, secure, and globally competitive financial sector.

2. Literature Review

2.1 Theoretical Frameworks in Digital Finance Regulation

Regulating digital finance demands adaptable models that balance innovation and risk. The Compliance-Technology Adaptation Framework (CTAF) by Barroso and Laborda [13] suggests regulatory systems must evolve with technological advancements, resting on four pillars: regulatory pressure, technological disruption, adaptation strategies, and compliance outcomes. Applied to Morocco, CTAF highlights efforts to align Law 09-08 with technologies like AI and blockchain [14]. Similarly, the Risk-Based Regulatory Approach (RBRA) from the Financial Action Task Force (FATF) prioritizes high-risk areas like cryptocurrency, with FATF's 2022 evaluation of Morocco recommending enhanced risk differentiation in AML enforcement [15]. These frameworks emphasize the need for agile, tech-driven policies.

2.2 Morocco's Regulatory Landscape

2.2.1 Data Privacy and Law 09-08

Law 09-08 (2009) underpins Morocco's data protection efforts, yet opportunities exist to align it with global standards like GDPR. The CNDP's 2023 report notes 45% compliance with encryption mandates among financial institutions, alongside a 35% rise in data breaches since 2018. Comparative studies suggest adopting GDPR's stricter penalties and breach notification requirements could strengthen data security [16].

2.2.2 AML and Financial Crime Enforcement

Managed by the Financial Intelligence Unit (UTRF), Morocco's AML framework is integrating advanced tools, though manual systems yield a 62% false-positive rate [17]. A 2021 pilot by Attijariwafa Bank showed AI-driven RegTech reducing fraud detection errors by 38% [17], yet 78% of banks cite budget constraints as a barrier to broader adoption [18].

2.2.3 Cryptocurrency Regulation

Morocco's 2017 cryptocurrency ban (Circular 17/2017) reflects caution, despite \$500 million in peer-to-peer transactions in 2022. Nigeria's risk-based licensing, reducing illicit activity by 22% and boosting fintech investment, offers a contrasting model for consideration [19].

2.3 Comparative Analysis: Global Regulatory Practices

2.3.1 Nigeria's Risk-Based Crypto Licensing

Nigeria's 2021 framework, with KYC and AML measures, cut illicit transactions by 22% and increased fintech investments by 35% [20], suggesting Morocco could attract similar gains [14].

2.3.2 India's Data Protection Reforms

India's Personal Data Protection Bill (PDPB 2019) aligns with GDPR, improving breach response times by 58% and consumer trust [21]. Morocco's Law 09-08 lacks comparable provisions, complicating compliance with EU markets [22].

2.3.3 The EU's GDPR and Cross-Border Compliance

GDPR has reduced compliance costs by 30% for EU banks through standardized reporting [23]. Aligning Law 09-08 could streamline Morocco's international operations and reduce penalties, which totaled MAD 24 million from 2021–2023 [24].

2.4 The Role of RegTech in Compliance Efficiency

RegTech enhances compliance globally: AI cuts false positives by 45% in Nigeria, and blockchain reduces audit times by 60% in India [25]. In Morocco, Attijariwafa Bank's 38% improvement in fraud detection shows promise, though only 18% of fintechs use AI due to resource and regulatory hurdles [26].

2.5 Gaps in Existing Research

Research on North Africa's digital finance regulation is limited, with gaps in socioeconomic impacts of crypto bans, cross-border harmonization benefits, and RegTech adoption barriers in emerging economies. This study addresses these through empirical and comparative analysis.

3. Methodology

3.1 Research Design

This study adopts a mixed-methods approach, blending qualitative and quantitative analyses within the World Bank's 2023 framework for emerging market digital finance [27]. It combines an SLR, empirical data analysis, and case studies for a holistic evaluation.

3.2 Data Collection and Sources

Primary Data:

- **Regulatory Reports:** Key documents include Bank Al-Maghrib's 2023 Annual Report on Digital Financial Services and the Moroccan Financial Intelligence Unit's (UTRF) 2023 AML Compliance Review [28].
- **Institutional Performance Metrics:** Financial and operational data were sourced from Attijariwafa Bank's 2023 Financial Statement and the Casablanca Finance City Authority's (CFCA) 2022 Fintech Investment Survey [29].

Secondary Data:

- **Global Benchmarking:** Morocco's regulations were compared with Nigeria's Cryptocurrency Licensing Guidelines [30], India's Personal Data Protection Bill [31], and the EU's GDPR Implementation Review [32].
- **Academic Literature:** An SLR covered 85 peer-reviewed articles (2015–2023) on RegTech, AML compliance, and digital finance regulation, sourced from Scopus and Web of Science.

3.3 Analytical Framework

The study applies the Compliance-Technology Adaptation Framework (CTAF) by Tom C.W. Lin [33], assessing compliance through:

1. **Regulatory Pressure:** Compliance costs and enforcement under Law 09-08 and FATF guidelines.
2. **Technological Disruption:** AI and blockchain adoption rates (Bank Al-Maghrib, 2023) [34].
3. **Adaptation Strategies:** Investment and timelines for RegTech (Attijariwafa Bank, 2022) [35].
4. **Outcome Metrics:** Improvements in fraud detection, cost efficiency, and cross-border processing.

3.4 Quantitative Analysis

Key Performance Indicators (**KPIs**) gauged regulatory and RegTech impacts:

1. **AML Compliance Efficiency:**
 - o **False-Positive Rate Reduction:** UTRF 2023 data show a 38% improvement post-RegTech at Attijariwafa Bank.
 - o **Cost Savings:** Bank Al-Maghrib's 2022–2023 reports indicate a 50% reduction in compliance costs with AI [34].
2. **Data Privacy Metrics:**
 - o **Breach Frequency:** CNDP's 2023 report notes a 35% rise since 2018 [4].

- o **GDPR Alignment:** Assessed via the EU's 2022 GDPR Audit Checklist, highlighting update areas for Law 09-08.

3.5 Qualitative Case Studies

Comparative analysis included:

1.Nigeria: The 2021 Risk-Based Cryptocurrency Framework's impact on fintech growth (Central Bank of Nigeria, 2021) [36].

2.India: PDPB's effect on breach response (Ministry of Electronics and IT, 2020) [37].

3.EU: GDPR's cross-border efficiencies (European Banking Authority, 2022) [38].

3.6 Ethical Considerations

- **Data Anonymization:** Data adhered to GDPR Article 25 and Law 09-08 standards.
- **Bias Mitigation:** Cross-verified quantitative metrics with FATF and World Bank reports to ensure objectivity.

3.7 Limitations

- **Data Availability:** Limited fintech compliance records constrained sector-wide analysis.
- **Temporal Scope:** Focus on 2015–2023 data may miss earlier trends.

3.8 Validation

Triangulation was applied to ensure reliability:

- **Methodological Triangulation:** SLR, empirical data, and case studies were cross-checked.
- **Source Triangulation:** Cross-referenced Bank Al-Maghrib, UTRF, FATF and world Bank reports.

This robust methodology lays the groundwork for understanding Morocco's regulatory landscape, leading naturally into the findings.

4. Discussion

4.1 Regulatory Gaps in Data Privacy and Protection

The analysis of Morocco's data protection landscape suggests several avenues for strengthening Law 09-08 (2009) to align more closely with international benchmarks. According to the Moroccan Data Protection Authority (CNDP), data breach reports have risen by 35% between 2018 and 2023, with financial institutions accounting for nearly half (48%) of these incidents [37]. This trend underscores the active role of Law 09-08 as a foundational framework, while also pointing to possibilities for refining its enforcement mechanisms. For instance, the law's maximum penalty of MAD 300,000 (~\$30,000) offers a starting point for deterrence, compared to the EU's General Data Protection Regulation (GDPR), which allows fines up to €20 million or 4% of global turnover [38]. Exploring ways to enhance these penalties could further bolster confidence in digital systems.

Public trust could benefit significantly from such refinements, particularly as 72% of Moroccans express concerns about digital transaction security [39]. Additionally, as Moroccan banks expand their cross-border operations, aligning with GDPR's data localization standards could streamline financial activities [40]. A 2022 EU audit highlights three promising areas for consideration: increasing the presence of Data Protection Officers (currently at 40% of firms), establishing clear breach notification protocols, and refining rules for cross-border data transfers [41]. By building on Law 09-08 with these elements, Morocco could enhance its data governance framework and support the continued growth of its digital economy.

4.2 AML Compliance Inefficiencies and Fraud Risks

Morocco's anti-money laundering (AML) framework is steadily evolving, with opportunities to integrate advanced tools for greater efficiency. Current manual transaction monitoring systems generate a false-positive rate of 62%, resulting in an average processing delay of 4.7 days, according to the Financial Action Task Force (FATF) [42]. However, there is encouraging progress in adopting technology, with 22% of banks using machine learning tools by 2023, as noted by the Moroccan Financial Intelligence Unit (UTRF) [28]. This shift offers a foundation for further enhancement.

A notable example comes from Attijariwafa Bank, where a 2021 AI-driven AML platform delivered promising results: a 38% reduction in false-positive alerts, a processing time drop from 7 to 3 days, and a 12% increase in identifying suspicious transactions, potentially saving MAD 85 million annually [44]. These outcomes align with global trends, such as Nigeria's 45% reduction in false positives through similar tools [45]. While 78% of Moroccan financial institutions note budget and regulatory clarity as areas to address (CFCA, 2023), the FATF's 2022 recommendation for risk-based monitoring and incentives—mirroring India's 58% increase in compliance tool adoption [46]—presents a practical path forward. Expanding on these early successes could further refine AML processes across the sector.

4.3 Cryptocurrency Regulatory Paralysis

Morocco's approach to cryptocurrency, guided by the 2017 Bank Al-Maghrib Circular 17/2017, reflects a cautious stance, yet the demand for digital assets remains robust, with peer-to-peer trading exceeding \$500 million in 2022 [47]. This activity suggests an opportunity to explore alternative regulatory models. For instance, Nigeria's 2021 risk-based licensing framework has reduced illicit crypto transactions by 22% while fostering fintech investment [48]. Building on this observation, Morocco could consider approaches like regulatory sandboxes, which have proven effective elsewhere.

India's 2021 sandbox trials, for example, helped refine taxation and KYC protocols for decentralized finance [49], while the UAE's phased framework supports licensed exchanges under strict AML guidelines. These models indicate that a controlled testing environment could allow Morocco to balance innovation with security, a strategy endorsed by the World Bank's 2023 study on emerging markets [50]. Such an approach could leverage existing demand while enhancing oversight, opening new possibilities for the financial sector.

4.4 RegTech's Transformative Potential

Emerging evidence underscores RegTech's potential to enhance compliance efficiency in Morocco. Banks adopting AI-driven tools have reported a 50% reduction in manual compliance costs and a 30% improvement in fraud investigation efficiency through blockchain-based auditing [50]. Bank Al-Maghrib's 2022 blockchain pilot, for instance, improved cross-border AML tracking by 40% and reduced interbank disputes by 25% [51]. These developments highlight a strong starting point for broader adoption.

While only 18% of Moroccan fintech startups currently use AI for compliance—compared to 53% in the UAE [52]—this gap reflects opportunities to address technical expertise and regulatory clarity rather than insurmountable barriers. The EU's 2022 Digital Finance Strategy, with standardized APIs saving €3 billion annually, offers a model for consideration. By adapting similar interoperability standards, Morocco could accelerate RegTech integration, amplifying the benefits already seen in pilot projects.

4.5 Cross-Border Regulatory Misalignment

Moroccan banks engaging with the EU face opportunities to refine GDPR compliance, with 65% currently lacking fully compliant data storage systems, contributing to MAD 24 million in fines from 2021–2023 [53]. Neighboring Tunisia provides an encouraging example, reducing GDPR penalties by 70% through EU-aligned protocols [50], while the European Banking Authority's (EBA) 2022 partnership with Tunisia streamlined compliance via a shared AML database [54]. These successes suggest practical steps Morocco could take.

Morocco's participation in the OECD's Global Forum on Transparency further enhances its position to negotiate bilateral agreements [55]. Such collaboration could improve compliance efficiencies and reduce cross-border transaction costs, building on the country's existing international engagements to strengthen its financial ecosystem.

4.6 Synthesis of Findings

These insights highlight three focus areas: modernizing Law 09-08 for GDPR alignment, expanding RegTech for AML and cost efficiency, and testing balanced crypto frameworks. Such reforms align with Vision 2030, potentially reaching 4 million unbanked citizens by 2030 [56]. This synthesis sets the stage for actionable recommendations, which the next section will explore in detail.

5. Conclusion and Recommendations

5.1 Synthesis of Findings

Morocco's digital financial sector is poised at an exciting juncture, where technological advancements are opening new pathways for innovation and inclusion. Building on the insights from this study, several encouraging trends emerge. The 35% increase in reported data breaches since 2018 under Law 09-08 reflects a dynamic environment where data protection is actively evolving, offering a chance to refine enforcement and boost public confidence. Similarly, the success of Attijariwafa Bank's AI-driven AML tools, reducing false positives by 38%, highlights the transformative potential of Regulatory Technology (RegTech) to enhance efficiency and safeguard resources. In the realm of cryptocurrency, the robust \$500 million in peer-to-peer trading in 2022, despite the 2017 ban, signals a vibrant demand that could be harnessed through thoughtful regulatory approaches. Experiences from Nigeria, India, and the EU further illustrate practical models that Morocco could adapt to strengthen its financial ecosystem.

These findings collectively underscore Morocco's strong foundation and the opportunities available to elevate its regulatory framework. The integration of global best practices and technology-driven solutions presents a promising avenue to support the country's Vision 2030 goals, fostering both financial stability and innovation.

5.2 Policy Recommendations

To capitalize on these opportunities and sustain Morocco's digital transformation, the following strategies offer a balanced and forward-looking approach:

1. Modernize Data Protection Laws

- o **Action:** Enhance Law 09-08 by incorporating elements inspired by the GDPR, such as refined penalties, mandatory data encryption, and clear breach notification protocols.
- o **Implementation:** Establish a Data Protection Task Force (DPTF) within the CNDP to guide these updates, targeting completion by Q4 2025.
- o **Expected Outcome:** Strengthened data security and greater alignment with international standards, paving the way for increased trust and fintech investment.

2. Accelerate RegTech Adoption

- o **Action:** Introduce incentives like tax rebates to encourage the use of AI-driven AML tools and blockchain auditing systems across financial institutions.
- o **Implementation:** Launch a RegTech Innovation Fund, supported by Bank Al-Maghrib and private investors, to facilitate technological upgrades from 2025 to 2030.
- o **Expected Outcome:** Enhanced operational efficiency and reduced compliance costs, building on the successes of existing pilot programs.

3. Adopt a Licensed Cryptocurrency Framework

- o **Action:** Transition from the 2017 ban to a risk-based licensing model incorporating FATF-compliant KYC and AML measures.
- o **Implementation:** Pilot a Regulatory Sandbox from 2025 to 2026, drawing inspiration from successful frameworks in other jurisdictions.
- o **Expected Outcome:** A dynamic environment that formalizes digital asset transactions and attracts fintech investments, leveraging Morocco's existing market interest.

4. Enhance Cross-Border Regulatory Cooperation

- o **Action:** Engage in bilateral discussions with the EU and African Union to harmonize AML and data transfer protocols.
- o **Implementation:** Adopt elements of the EU's Digital Finance Package standards, utilizing Morocco's role in the OECD Global Forum.
- o **Expected Outcome:** Streamlined cross-border compliance and a more integrated financial services framework, enhancing Morocco's global connectivity.

5.3 Strategic Roadmap (table 1.)

This roadmap provides a flexible yet structured timeline, allowing Morocco to build incrementally on its current strengths while adapting to emerging needs (Table 1.).

Table 1. Strategic Roadmap for Digital Finance Innovation

Phase	Timeline	Key Actions
Immediate	2024–2025	Establish the DPTF and RegTech Innovation Fund; draft initial sandbox legislation.
Short-Term	2025–2026	Begin enforcement of updated data protection laws; launch sandbox trials to explore crypto regulation.
Mid-Term	2026–2028	Expand RegTech incentive programs; finalize the cryptocurrency licensing framework based on sandbox insights.
Long-Term	2028–2030	Achieve widespread AML automation and high compliance efficiency; fully integrate into EU-Africa digital finance corridors.

5.4 Concluding Remarks

Morocco's Vision 2030 aspires to position the country as a North African fintech hub, and this study highlights the exciting potential within reach. By refining data protection laws, embracing RegTech solutions, and exploring innovative cryptocurrency regulation, Morocco can cultivate a regulatory environment that nurtures both stability and progress. These efforts could extend financial services to millions of unbanked citizens (potentially 4 million by 2030) and attract significant foreign investment, reinforcing Morocco's role in the global financial landscape.

The path forward invites collaboration among regulators, financial institutions, and technology innovators. By working together, stakeholders can shape a regulatory framework that not only supports Morocco's ongoing digital evolution but also establishes the country as a beacon of innovation in the region.

Final Call to Action:

Now is an opportune moment for Morocco's financial community to unite in advancing these initiatives. Leveraging the insights and strategies outlined here, stakeholders can chart a course toward a thriving, inclusive, and competitive financial sector. This collective effort promises to unlock Morocco's full potential as a leader in digital finance.

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Causal Relationship Between CO₂ Emission, Renewable Energy, Trade Openness, Foreign Direct Investment and Output Volatility

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Abstract: This study explores the causal relationships between the Index of Industrial Production (IIP), output volatility (OV), renewable energy (RE), foreign direct investment (FDI), and trade openness (TO) across selected countries in East Asia and Pacific (EAP). Using Fourier panel causality test, we find RE causes OV in Australia and Malaysia, indicates short-term fluctuation. Conversely, FDI's impact on OV, especially in India, indicating the need for regulatory measures to manage FDI for economic steadiness. Policymakers should craft regulations on renewable energy investments to stabilize economic volatility. Additionally, the complex relationship between environmental policies and OV require integrated approach in policy design.

Keywords: Output Volatility; CO₂ Emission; Renewable Energy; Trade Openness; FDI

1. Introduction

Sustainable economy has been an area of interest for many, especially with climate change. This has become a necessity, especially in recent years. For instance, higher CO₂ emissions increases output volatility (OV) by exposing industries to climate change hazards (Majeed et al., 2021; Genç et al., 2012). Climate change risks encompass extreme weather events, supply chain disruptions, and augmented input costs for industries. A company that heavily rely on natural resources, alterations in weather patterns due to climate change could reverberate through its production, thus affecting its OV. Conversely, renewable energy stands as a mitigating force against OV, achieved by diversifying energy sources and diminishing reliance on fossil fuels. Wind, solar, and hydropower, among other renewable sources, present reliable power reservoirs. Moreover, the stabilizing effect of renewable energy extends to energy prices, resulting in reduced output volatility for energy-intensive sectors like manufacturing and transportation.

This interplay between CO₂ emissions, renewable energy, and OV presents a potential nexus that holds the attention of policymakers. On the other hand, OV can be impacted by macroeconomic variables such as foreign direct investment (FDI) and trade openness (TO). FDI reduces output volatility by providing a predictable source of investment and capital, in addition to stimulating economic growth. Furthermore, it facilitates access to new technologies, management practices, and global markets, thereby enhancing the competitiveness and resilience of local firms and industries. Similarly, TO decreases OV by diversifying markets and reducing dependence on a single market. Access to international markets ensures a stable source of demand, which in turn reduces OV. Additionally, TO provides access to inputs and resources that enhance the global competitiveness of domestic companies. Therefore, the presence of a relationship between OV and macroeconomic variables, in conjunction with environmental variables, is likely to be of interest to policymakers and academics.

More specifically, there have been numerous studies examining the relationship between climate change and economic growth, but their findings are mixed (Mendelsohn, 2009; Farhani et al., 2014; Zubair et al., 2020; Mohsin et al., 2022). According to Mendelsohn (2009), the actual impact of climate change on the global economy is projected to be minimal in the next 50 years. However, taking further corrective measures may pose a greater threat to long-term economic growth. Farhani et al. (2014) suggest that CO₂ emissions originate from GDP, while Zubair et al. (2020) identify a long-term relationship between carbon emissions and GDP. Acaroğlu and Güllü (2022), reveal that

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increasing renewable energy consumption in Turkey can mitigate climate change by reducing temperatures, but non-renewable energy consumption can exacerbate climate change by increasing precipitation. Tol (2024), updates previous meta-studies, confirming that the economic impacts of climate change are generally negative and that poorer countries are particularly vulnerable to climate change. He also states that the impact of climate change on economic growth tends to be temporary rather than permanent. On the other hand, Stefanakis et al. (2021), discuss the potential of nature-based solutions, emphasizing their important contributions to combating climate change, improving ecosystem services, and promoting sustainable economic growth. They state that awareness should be raised and more investment should be attracted for these approaches. Raihan et al. (2022), examines how economic growth, renewable energy use, urbanization, industrialization, technological innovation, and forest areas contribute to reducing CO₂ emissions and ensuring environmental sustainability in the case of Bangladesh, and offers policy recommendations for a low-carbon economy. Kiley (2024), argues that rising temperatures will have negative effects on economic growth, increasing the risk of severe economic contraction, and as a result, may have major impacts on financial stability and welfare. Conversely, Mohsin et al. (2022) argue that CO₂ emissions also contribute to GDP. In addition to the climate change and economic growth relationship, other studies have focused on the link between foreign direct investment (FDI) and GDP (Pao and Tsai, 2011; Al-mulali, 2012; Gökmenoğlu and Taspınar, 2016). Pao and Tsai (2011) found evidence of unidirectional causality from output to FDI, while Al-mulali (2012) and Gökmenoğlu and Taspınar (2016) identified a long-run relationship between FDI and GDP.

The literature discussed above highlights three research gaps that need to be addressed. Firstly, the relationship between the environment and macroeconomic variables, including output volatility (OV), remains inconclusive due to mixed findings. Secondly, there is a lack of research on the impact of CO₂ emissions and renewable energy on OV. Thirdly, no studies have investigated the relationship between climate change and output volatility specifically in East Asia and Pacific (EAP) countries. To address these gaps, this study aims to examine the effects of CO₂ emissions, renewable energy, foreign direct investment (FDI), and trade openness on output volatility in selected EAP countries.

Theoretically, sun-spot theories claim weather conditions of the globe will be altered because of sun-spot (Jevons, 1878). Further, the theory says climate change will affect the agricultural sector and then transgress to manufacturing output, hence OV. The Environmental Kuznets Curve (EKC) hypothesis also says that environmental pollution increases in the early stages of development, subsequently the relationship between economic development and environmental pollution becomes negative, indicating a desire for higher environmental quality.

From the above mentioned theoretical and empirical studies, the study formulates four hypotheses. First, it hypothesizes that CO₂ emissions increase OV. Second, it hypothesizes that renewable energy reduces OV. Third, it hypothesizes that FDI helps to lower OV. Fourth, it hypothesizes that trade openness decreases OV in the selected countries of EAP. The study employs a series of time-series models to test and validate these hypotheses.

The study makes a threefold contribution. Firstly, it addresses the limited research on the impact of environmental variables, specifically CO₂ emissions and renewable energy (RE), on output volatility. By examining this relationship, the study enriches the existing literature and provides valuable insights for policymakers. It highlights the potential of minimizing CO₂ emissions and increasing the use of RE to stabilize output volatility. Secondly, the study focuses on the East Asian and Pacific region, which lacks sufficient literature on this subject. This regional emphasis is significant as it offers specific guidance to policymakers in the region. By considering the unique characteristics and challenges of EAP countries, the study provides targeted recommendations for stabilizing output volatility in these areas. Lastly, the study goes beyond environmental variables and incorporates macroeconomic factors such as foreign direct investment (FDI) and trade openness. This comprehensive approach provides policymakers with a consolidated understanding of the various factors influencing output volatility. By considering both environmental and macroeconomic variables, the study offers a holistic perspective and facilitates the formulation of effective policy prescriptions.

The article has the following structure. Section II talks about data and methodology. Section III offers a summary of the empirical findings, and Section IV presents the conclusions of our study.

2. Data and Methodology

We consider five variables i.e. output volatility, trade openness, carbon emission, renewable energy, and foreign direct investment across six countries from EAP i.e. Australia, Indonesia, Japan, Malaysia, Philippines, and Singapore. The OV is constructed using a three-period standard deviation on the index of industrial production (Ramey and Ramey, 1994). Further, trade openness consists of export-import/GDP. Renewable energy consumption is the portion of renewable energy

in total final energy used. Carbon dioxide emissions are those emitting from the burning of fossil fuels including manufacture of cement. Further, it includes carbon dioxide produced during the consumption of solid, liquid, and gas fuels and gas flaring. The CO₂ emissions measure kg per 2015 US\$ of GDP. Finally, FDI inflows to individual countries are considered for the analysis. The data set from 1990 to 2021 are extracted from the world development indicator and CEIC database based on availability. Some variables trade openness and FDI are converted to logarithmic form to detrend the series.

We then discuss the methodology. Once panel stationarity is established, we conduct cointegration and causality tests. This study's novelty lies in employing Fourier form cointegration and causality tests, relatively recent additions to the literature. Westerlund and Edgerton (2007) offered a technique that acknowledges both cross-section dependence and structural breaks in panel data. The concept of using Fourier functions in time series originates from Enders and Lee (2012), who explored them in unit root tests, while Tsong et al. (2016) extended their use to cointegration analysis. The implementation of Fourier forms, adept at identifying smooth structural shifts via trigonometric functions, into panel cointegration and causality tests is a recent development, marked around 2020-2021. Olayeni et al. (2020) probed cointegration presence in panels using Fourier functions. Concurrently, Yılançı and Görüş (2020) described the econometric basis for panel causality with Fourier functions. These methodologies consider both cross-sectional interdependencies and smooth transitional structural breaks. Fourier panel causality test is one of the most optimal causality tests to use because it takes into account both hard and soft structural breaks. Thus, it is possible to take into account factors such as economic crisis etc. that occur within the examined data range and do not cause serious changes in the data. In this way, it will be possible to avoid incorrect results that can be obtained through methods that do not take structural breaks into account.

The form of the Fourier causality test developed by Enders and Jones (2016) applied to the panels, on the other hand, was developed by Yılançı and Görüş (2020) and brought it to the literature. This method, which is the Fourier form of Dumitrescu and Hurlin (2012) panel causality test, is modeled as follows:

$$y_{i,t} = \alpha_i + \sum_{k=1}^K \gamma_i^{(k)} y_{i,t-k} + \sum_{k=1}^K \beta_i^{(k)} x_{i,t-k} + \delta_i \sin\left(\frac{2\pi kt}{T}\right) + \theta_i \cos\left(\frac{2\pi kt}{T}\right) + \varepsilon_{i,t} \quad (1)$$

The null hypothesis of this method indicates the absence of causality in the panels, while the alternative hypothesis indicates the presence of causality.

3. Empirical Findings

In the first stage of the analysis, the presence of cross-section dependence in the panels was examined. As a result of the analysis, CDLM by Breush and Pagan (1980) and CDLM_{adj} cross-section dependence tests by Pesaran, Ullah and Yamagata (2008) show that there is cross-section dependence in all panels.

Table 1. Cross Section Dependence Test Results

	CDLM	p-value	CDLM _{adj}	p-value
OV	42.42	0.00	3.65	0.00
LIP	77.89	0.00	15.12	0.00
LTO	46.93	0.00	62.46	0.00
LFDI	31.42	0.00	41.06	0.00
RE	48.87	0.00	63.42	0.00
CO2	28.08	0.02	57.75	0.00

In the second stage of the analysis, the stationarities of the panels were examined by Pesaran's (2006) CADF panel unit root test. According to the results obtained, it is seen that all panels have unit root in level values and become stationary in different values.

Table 2. CADF Panel Unit Root Test Results

	Level	First Diff.
OV	-2.81	-6.37***
LIIP	-1.81	-4.51**
LTO	-1.84	-3.59*
LFDI	-3.17	-5.09***
RE	-1.88	-3.72*
CO2	-1.47	-3.57*

Note: Critical values are based on -4.97, -3.99 and -3.55 at 99%, 95% and 90% confidence levels. These values were obtained from Pesaran's (2006) article "A simple unit root test in the presence of cross-section dependence, Journal of Applied Econometrics, 22 (2), 265-312". ***, ** and * denote significance with 99%, 95% and 90% confidence, respectively.

In such a case where the panels are stationary in their first differences, it was deemed appropriate to use the improved version of the panel causality test developed by Dumitrescu and Hurlin (2012). The advantages of the method are that it added the Fourier forms. The results are reported in Table 3.

The causal relationships identified between lagged industrial production, output volatility, and other economic factors across different countries indicate the intricate dynamics between industrial activity and economic stability. In Japan and Malaysia, the causality from the Index of Industrial Production (IIP) to output volatility (OV), and subsequently from OV to TO, suggests that fluctuations in industrial production are a significant source of economic volatility, which then influences the countries' degree of openness to international trade. Similarly, we find the CO2 causes OV in the case of India. This finding complies with the outcome of Majeed et al. (2021). The finding that renewable energy (RE) causes OV in Australia and Malaysia may reflect the impact of transitioning towards renewable energy on the industrial sectors of these countries, potentially leading to short-term disruptions before achieving a more stable production environment.

Contrastingly, in India, foreign direct investment (FDI) is found to be a precursor to OV, implying that the influx of foreign capital can lead to economic fluctuations. This is a critical insight for policymakers who must manage the inflows of FDI to mitigate its destabilizing effects. In the Philippines, the reverse causality from OV to FDI suggests that economic volatility itself could be a factor attracting or deterring foreign investors. For Singapore, the causation from OV to RE indicates that economic fluctuations might be prompting a shift towards renewable energy, potentially as a diversification strategy to stabilize production.

Under the panel framework, the generalized causality from IIP to OV aligns with the country-specific cases of Japan and Malaysia, reinforcing the notion that industrial production levels are potent determinants of economic stability across the board. Similarly, the causality from FDI to OV is seen at the panel level, suggesting a universal trend where FDI influences economic stability. The causation from OV to trade openness may indicate that economic volatility informs countries' trade policies and their engagement with the global market. The absence of environmental factors causing OV in the panel analysis could point to a less direct or a more complex interaction between environmental policies and economic volatility, warranting further investigation to unravel these dynamics.

Table 3. Panel Fourier Causality Test Results

Causality direction	Countries	Wald stat	p-value
LIIP → OV	AUS	1.58	0.20
	IND	1.36	0.24
	JAP	9.56***	0.00
	MAL	4.48**	0.03
	PHI	0.78	0.37
	SIN	0.12	0.72
	Panel	2.98***	0.00
OV → LIIP	AUS	0.21	0.64
	IND	0.38	0.53
	JAP	0.76	0.38
	MAL	1.24	0.26
	PHI	1.39	0.23
	SIN	0.59	0.43
	Panel	0.76	0.68

LTO → OV	AUS	1.69	0.19
	IND	0.04	0.83
	JAP	0.10	0.74
	MAL	1.38	0.23
	PHI	0.68	0.40
	SIN	0.03	0.85
	Panel	0.65	0.55
OV → LTO	AUS	4.15**	0.04
	IND	1.16	0.28
	JAP	2.89*	0.08
	MAL	4.57**	0.03
	PHI	0.20	0.65
	SIN	0.25	0.61
	Panel	2.20**	0.03
LFDI → OV	AUS	0.40	0.52
	IND	0.08	0.77
	JAP	0.22	0.63
	MAL	0.81	0.36
	PHI	0.15	0.68
	SIN	0.51	0.47
	Panel	0.36	0.27
OV → LFDI	AUS	0.01	0.90
	IND	0.15	0.69
	JAP	0.48	0.48
	MAL	1.54	0.21
	PHI	8.83***	0.00
	SIN	1.76	0.18
	Panel	2.13**	0.04
LRE → OV	AUS	2.87**	0.08
	IND	1.42	0.23
	JAP	0.03	0.84
	MAL	2.83*	0.09
	PHI	0.80	0.37
	SIN	1.03	0.30
	Panel	1.50	0.38
OV → LRE	AUS	1.58	0.20
	IND	1.60	0.20
	JAP	0.01	0.92
	MAL	0.23	0.62
	PHI	1.19	0.27
	SIN	2.75*	0.09
	Panel	1.23	0.68
CO2 → OV	AUS	2.14	0.14
	IND	4.37**	0.03
	JAP	0.01	0.91
	MAL	0.28	0.59
	PHI	1.89	0.16
	SIN	0.08	0.77
	Panel	1.46	0.41
OV → CO2	AUS	0.85	0.35
	IND	0.02	0.87
	JAP	0.37	0.53
	MAL	0.41	0.52
	PHI	0.52	0.46
	SIN	0.05	0.81
	Panel	0.37	0.28

Note: *** and ** denote significance with 99% and 95% confidence, respectively.

4. Conclusion Remarks

The investigation into the causal links between industrial production, output volatility, and various economic indicators reveals key insights into the economic dynamics of different nations, with implications for policy-making. The observed causality from the Index of Industrial Production (IIP) to output volatility (OV) in Japan and Malaysia, and subsequently from OV to long-term trade openness (LTO), underscores industrial activity as a core driver of economic fluctuations, which then impacts these countries' engagement in global trade. This pattern necessitates careful monitoring and management of industrial output by policymakers to foster economic stability and devise trade policies that can absorb and adapt to such volatility.

In the context of renewable energy (RE), its influence on OV in Australia and Malaysia signifies the economic repercussions of shifting towards greener energy sources, presenting an immediate challenge for industrial sectors. Policy implications here would involve structuring transition policies that can mitigate the adverse effects on output volatility while harnessing the long-term benefits of sustainable energy.

The contrasting directions of causality between FDI and OV in India and the Philippines highlight the need for nuanced FDI policies that recognize the dual role of foreign investments as both a catalyst for and a respondent to economic stability. Policymakers should construct regulatory frameworks that stabilize FDI flows and output volatility to ensure economic growth without undue oscillations.

Singapore's shift towards renewable energy in response to OV points to the strategic role renewable investments can play in economic stabilization. Policymakers should thus consider encouraging renewable energy development as part of a broader strategy to buffer against economic volatility.

Overall, the absence of a direct causality from environmental factors to OV in the panel analysis suggests that environmental policies may not have immediate, discernible effects on economic volatility. Policymakers should recognize the complex interplay between environmental factors and economic performance, necessitating comprehensive, long-term strategies to integrate environmental considerations seamlessly with economic objectives.

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