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Aims & Scope

In the 21st century, great changes are occurring in the management, economics and business in the world. During and after the covid-19 pandemic, new economic models, supply chains and monetary systems have been discussed. Traditionally, it is seen that change and transformation in the field of management, economics and business takes a little more time compared to fields such as health, technology and engineering. However, this situation seems to have started to change with the Covid-19 epidemic disease. It is expected that changes will occur in management, economics and business during and after the Covid 19 epidemic disease. For this reason, this conference focused on the changes and innovations in the field of management, economy and business that started with Covid 19. However, the organizing committee also recognizes the value of traditional knowledge in the management, economy and business. For this reason, the conference is also open to traditional studies in the field of management, economics and business.

The aim of the conference is to bring together researchers, business executives and administrators from different countries, and to discuss theoretical and practical issues in management, economics and business. At the same time, it is aimed to enable the conference participants to share the changes and developments in the field of management, economics and business with their colleagues.

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IConMEB 2022: International Conference on Management Economics and Business

Moderating Effect of Investment Opportunity in the Association of Market Response and Capital Expenditure

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Abstract: This study aims to reveal empirical evidence related to the market response to investment spending associated with investment opportunities, considering that investment opportunities is a crucial factor in capital expenditure decisions. This study used data from the Indonesia Stock Exchange in 2016-2021. The sample is only devoted to large-cap companies because this kind of company concerns investors more. The sample does not exclude the business sector, as in previous studies. Following previous research, investment opportunities are measured by Tobin's Q (TQ); a TQ of more than 1 indicates a higher investment opportunity and vice versa. The results show that the market responds negatively to investment spending, and investment opportunities moderate the market's response to investment spending. In addition, it was revealed that the industrial sector strengthened the influence of investment spending on market response. Therefore, management needs to consider investment opportunities before making investment expenditures to avoid getting caught up in over-investing or under-investing, both of which are detrimental to the company. This study also adds empirical evidence in developing countries where the information gap between management and external parties (markets) is still vast.

Keywords: Investment spending, Investment opportunities, Market response, Large capitalization

Introduction

Empirical evidence on the market response to the announcement of additional capital expenditures has grown significantly in recent years. For example, Woolridge (1988) reported positive and significant market reactions to more than 600 long-term-oriented investment projects announced from 1972 to 1984 in America. The study also noted a significant average return in the announcement period, which was 0.78% per sector. In comparison, Burton et al. (1999) found an increase in stock returns in 499 CAPEX announcements from 1989-1991. These two studies support previous findings by McConnell and Muscarella (1985) on the effect of changes in capital expenditure levels, including highlighting the market response to news of investments made as part of a joint venture. In contrast, Burton et al. (1999) found the mean abnormal return for investments declared as part of a joint venture to be higher than the sample as a whole, particularly in the case of Burton et al. (1999), where the investment made by each company proved to have a negligible impact on equity.

Some researchers added more detailed information related to CAPEX. Burton (2006) examines the effect of capital expenditures on market reactions simultaneously with the announcement of corporate alliances. The

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results show that the market response is highest when the new investment is not part of the alliance's activities. The findings are consistent with the scenario that the market is concerned about the dangers of over-commitment from partnerships. Khanal and Mishra (2017) found a significant increase in stock prices when dividends were announced. The increase in stock prices around the announcement date was due to increasing market expectations of future cash flow increases, consistent with the market signaling hypothesis.

Although much research on market response to CAPEX investment news has been conducted, more is needed to know about the role of investment opportunities in the relationship between CAPEX and market response. Investment opportunities are an essential characteristic of companies and significantly influence how companies are viewed by managers, owners, investors, and creditors (Kallapur, 2001). Furthermore, investment opportunities have been shown to theoretically be an important determinant of firm risk characteristics (Miles, 1986; Skinner, 1993), results confirmed empirically by Riahi-Belkaoui (1999). Consistent with what was predicted, Chung et al. (1998) found that capital expenditures were positively and negatively related to stock prices, excluding investment opportunities. Furthermore, Chung et al. (1998) found that the quality of investment opportunities determines the market reaction to investment decisions compared to industry affiliation.

Market responses need to be contextualized within the path of growth opportunities (Brailsford & Yeoh, 2004). Therefore, it is essential to integrate new capital expenditure decisions with growth opportunities when analyzing market reactions. This study will integrate capital expenditure decisions with growth opportunities. Failure to control the aspect of growth opportunities will appear as if the market is not responding or responding negatively to the company's capital expenditure decisions (Brailsford & Yeoh, 2004). Companies with higher investment opportunities will receive a higher value for investors because such companies have a higher probability of success related to their capital expenditure decisions. In addition to accommodating investment opportunities, this research is applied to large-cap companies, considering that large-cap companies are more at the center of investors' attention than small-cap companies. Small-cap companies also experience limited access to internal funding, which is not a problem for large-cap companies (Guariglia & Carpenter, 2008). If these groups of companies are combined, the results will be biased because investors may not care about the capital expenditure decisions of small-cap companies, so they do not respond not because of these decisions but because low-cap companies that make these decisions

Capital Expenditure Decisions and Market Response

The capital market hypothesis argues that when managers use the capital market to obtain external funding, it puts the company in market monitoring. This is because the market will monitor the company's ability to generate profits in the future. On the other hand, management tries to influence market valuations through some corporate actions to impress the company's commitment to continue to grow and generate positive returns (Bae et al., 2018).

Capital expenditure decisions are operational and strategic because of their long-term implications (Kothari et al., 2002; Canace et al., 2018). As a strategic decision, the company will carefully choose which investment provides a commensurate return (Kim et al., 2020). Capital expenditure information provides an essential signal to the market about potential future cash inflows. The act of companies investing their resources in certain capital expenditures is captured as an opportunity to increase value in the future (Kaur & Kaur, 2019). Sophisticated managers will send messages to the market through corporate actions to influence the market's assessment of the company, which less sophisticated managers cannot imitate.

This corporate action signals the company's future growth, in line with the efficient securities market hypothesis, so this information immediately moves to the securities market price. Therefore, an efficient securities market mechanism will test the market reaction to information on capital expenditures made by the company. Previous results support that the market responds to capital expenditure announcements characterized by increasing stock returns around the announcement date (Kerstein & Kim, 1995; Burton et al., 1999; Vafeas & Shenoy,2005; Akbar, 2008; Bhanna, 2008; Luo, 2016). However, some others find that the market responds negatively to the actions of companies doing capital expenditures (Qhandari, 2016; Chen & Chang, 2020).

H1. The market responds positively to capital expenditure

The role of investment opportunities in the relationship between market response and capital expenditure

The company's market value can be identified through the following two things: the present value of assets in place and the value of investment opportunities (Myers, 1977). The value of investment opportunities depends on future investment policies, while the value of assets in place does not. Many previous studies have tried to construct investment opportunities by using the correlation measurement of cash flow and investment (Bond et al., 2004; Cummins et al., 2006). Another alternative is to use Tobin's Q; this alternative is based on the argument that the measurement of Q is more forward-looking and can be captured by market participants who are also naturally forward-looking (Guariglia & Carpenter, 2008).

Several subsequent studies expanded the research on market responses to capital expenditures by considering the role of investment opportunities (Szewczyk et al.,1996; Chen & Ho, 1997; Chung et al.,1998). Using the well-known Q ratio as a proxy for investment opportunities, these studies prove an increase in abnormal returns around the announcement date of capital expenditures in companies with high investment opportunities. However, the market response to capital expenditures on capital expenditures in companies with a negative Q is still not diverse (Chen & Ho, 1997; Chung et al.,1998).

By using a sample of companies classified as big companies whose corporate actions get more attention from market analysts than non-big companies (Botosan, 1997; Sengupta, 1998). This study will examine the moderating impact of opportunity. Investment in the relationship between market response and capital expenditure. Therefore, the hypotheses proposed in this research are:

H2. Investment opportunities moderate the effect of market response on capital expenditures.

Method

Sample

This study aims to identify how the market responds to investment spending with investment opportunities as moderating variable. Capital expenditure is measured by the growth of fixed assets for the current period, with companies whose fixed assets are growing, indicating that capital expenditures are being made. The market response is measured by the market-to-book ratio to evaluate a company's current market value relative to its book value. Investment opportunities are measured by Tobin's Q (TQ). The industrial sector, companies' industrial sales, debt, returns, and competitiveness are important to control variables used in this study. The sample was selected using purposive sampling on large-cap companies listed on the Indonesia Stock Exchange in 2016-2021. The total samples used in this study are 232 company data from six years. The selection of big-cap companies is a sample because big-cap companies are generally more active in making capital expenditures, and this kind of company is more of a concern to investors.

Model Analysis

The proposed model in this study uses market-to-book (MTB) to measure market response to capital expenditure. MTB reflects the market's value to a company's equity relative to the book value and could be used as a predictor of market returns (Pontiff, 1998). The independent variable capital expenditure growth (GCAPEX) is the accumulation of capital spending in the current and previous periods divided by the prior period. Our model then assesses the moderating effect of investment opportunity (TQCAPEX) on the relationship between market response and capital expenditure. The investment opportunity is measured using Tobin's Q, which is percept as a more forward-looking measurement fit with the search for opportunity in future investment (Guariglia & Carpenter, 2008). Tobin's q is arguably the most common regressor in corporate finance and has a usual role as a proxy for investment opportunities (Erickson & Whited, 2012).

The control variables are classified into two groups, these are firm characteristics and operational characteristics. The firm characteristics group consists of control variables related to the firm's identity, which includes variables related to its position in the industry, including capital expenditure, compared to the industry (CAPEXSC), and the firm's sales compared to the industry (SALESSIC). In addition, ownership structure has been known to influence market performance (al Farooque et al., 2020; Madyan et al., 2020; Din et al., 2021;) and also included in the model; namely, the percentage of public-owned shares (PUBLIC) and management owned shares (MANOWNER) (Brailsford & Yeoh, 2004). The rest of the firm characteristics groups also includes sector, firm size (Corvino et al., 2019; Chen & Chang, 2020; Kim et al., 2021), competition intensity (Javeed et al., 2020; Juniarti, 2020) and reputation of audit firm (REPUTATION) (Al-ahdal & Hashim, 2022).

The second group is operational characteristics which consist of control variables related to the company's operational conditions that reflect the firm's financial condition. These include total investment in the current year (INVESTED), return on asset, return on equity, earning after tax, and debt-to-equity ratio, which are important metrics that influence a company's profitability (Chen & Ho, 1997; Chen & Chang, 2020; Kim et al., 2021).

The research model of this study is as follows:

$$MTB_{i,t} = \beta_0 + \beta_1 GCAPEX_{i,t-1} + \beta_2 TQCAPEX_{i,t-1} + \beta_3 CAPEXSC_{i,t-1} + \beta_4 INVESTED_{i,t-1} + \beta_5 ROA_{i,t-1} + \beta_6 ROE_{i,t-1} + \beta_7 DER_{i,t-1} + \beta_8 FISIZE_{i,t-1} \beta_9 REPUTATION_{i,t-1} + \beta_{10} PUBLIC_{i,t-1} + \beta_{11} MANOWNER_{i,t-1} + \beta_{12} SALESSIC_{i,t-1} + \beta_{13} SECTOR_{i,t-1} + \beta_{14} COMP_{i,t-1} + \varepsilon \qquad (1)$$

Dependent Variable:

Market response in this study is proxied by MTB. Market to Book (MTB) compares a company's market value to its book value and reflects the value that the market percept to a company's equity relative to the book value. A stock's market value is a forward-looking metric that reflects a company's future cash flows. The book value of equity is an accounting measure based on the historical cost principle and reflects past equity issuances. Therefore, the ratio of market-to-book values could be used as a predictor of market returns (Pontiff, 1998).

Independent Variable:

Capital Expenditure Growth (GCAPEX) is the accumulation of capital spending in the current and previous periods and then divided by the prior period.

Moderating Variable:

Tobin's Q. measures Investment Opportunity. This measurement is based on the argument that the measurement of investment opportunity using Q is more forward-looking and can be captured by market participants who are also naturally forward-looking (Guariglia & Carpenter, 2008)

Control Variables:

Berikut sejumlah variabel kontrol yang mewakili karakterisktik perusahaan dan karakteristik operasional:

1. Capital expenditure in the industry (CAPEXSC) is the company's capital expenditure on industrial capital.
2. The amount of investment (INVESTED): is the amount of investment for the current year.
3. The return on assets (ROA) with earnings after tax as the denominator is measured by total assets divided by earnings after tax.
4. The return on equity (ROE), with earnings after tax as the denominator, is measured by total equity divided by earnings after tax.
5. Debt to equity ratio (DER) measures a company's risk, obtained from total liabilities divided by total equity.
6. Firm size (FISIZE) shows the company's size and is measured by the log market value of equity.
7. The type of audit firm (REPUTATION) refers to the quality of auditor used by the company, whether big four or non-big four.
8. Public ownership (PUBLIC) is the percentage of publicly owned shares measured by publicly owned shares divided by total shares.
9. Managerial ownership (MANOWNER) is the percentage of management-owned shares
10. Sales industry (SALESSIC) refers to a firm's sales compared to its industry.
11. The industrial sector (SECTOR) is the industrial sector of the firm sample.
12. The market competitiveness (COMP) shows the competitive level in the industry, the measurement was adopted from the Herfindahl index (HHI) using the following formula (Li et al., 2008).

$$HHI_{it} = S1^2 + S2^2 + S3^2 + \ldots + Sn^2$$

where:

S1; S2 . . . Sn = market share of a firm in a similar industry.

Results and Discussion

The profiles of the research variables are presented in Table 1 below. The average CAPEX is positive, this indicates that the sample companies have continuously made capital expenditures in the last five years. The average sample has a reasonably high growth opportunity; this is indicated by the mean TQ value, which is close to 1. The company makes a reasonably high investment expenditure in the current year, as indicated by the high mean LOGINVEST value. In general, the sample companies can generate a high return on equity, which is 0.142 and 0.07 for the return on total assets. The composition of debt to equity needs attention because the mean DER value is close to 0.50, which means that, on average, the company's leverage is protected by equity. The average sample company provides broad opportunities for managers and the public to own a company. The level of competition in all industrial sectors is very tight with an average HH Index of 0.05.

Table 1. Descriptive analysis

	N	Minimum	Maximum	Mean	Std. Deviation
GCAPEX	232	-0,299	1,676	0,106	0,204
TQ	232	0,604	1,236	0,919	0,109
LOGINVEST	230	9,000	12,000	10,426	0,538
ROA	232	-0,141	0,498	0,066	0,090
ROE	232	-0,285	1,451	0,142	0,219
DER	232	0,000	5,155	0,459	0,622
FSIZE	232	9,461	12,237	10,725	0,575
MANOWNER	232	0,470	0,980	0,690	0,145
PUBOWNER	232	0,020	0,530	0,311	0,145
SALESSIC	232	0,000	1,000	0,172	0,209
COMP	232	0,034	0,254	0,057	0,046

The results of hypothesis testing are presented in Table 2 below. Hypothesis 1 states that the market responds positively to capital expenditures; the test results show the opposite, where the market responds negatively to capital expenditures. The t value is significantly negative at the level <0.01. Apart from the results of a number of previous studies which found that the market responded positively to capital expenditure activities, the results of this study contradicted a number of previous studies. The findings of this study add to the diversity of previous research results, some of which found positive results (Kerstein & Kim, 1995; Burton et al., 1999; Vafeas & Shenoy,2005; Akbar, 2008; Bhanna, 2008; Luo, 2016) and others found negative results (Qhandari, 2016; Chen & Chang, 2020).

Testing hypothesis 2, that investment opportunities moderate the market response to capital expenditure measures is proven. CAPEX conducted by companies that have high investment opportunities responded positively to the market and vice versa. The test results show the TQCAPEX moderating coefficient with a positive coefficient value (0.070) and significant at the <0.1 level, meaning that investment opportunities moderate the effect of capital expenditure on market response. This finding contributes to the diversity of the results of previous studies, where capital expenditures are responded positively or negatively by the market. The results of this study confirm that the market is considering investment opportunities. Companies that have high investment opportunities indicate a high success rate of investment decisions compared to companies with low investment opportunities.

The managerial implication of this finding is that the market responds to capital expenditure actions by paying attention to future growth opportunities. Capital expenditures cannot cover market concerns about the company's future performance for companies in a declining industry. Capital expenditures under conditions of low investment opportunities are counterproductive. Investment expenditure must be proportional to the company's ability to generate revenue in the future.

Table 2. Hypothesis results

	Coefficient	t-stat	p	
Constant	3.471	0,626	0,532	
GCAPEX	-0,113	-3,033	0,003	***
CAPEXSC	0,070	1,869	0,063	*
TQCAPEX	0,034	1,684	0,094	*
INVESTED	0,051	0,924	0,356	
ROA	0,132	2,702	0,007	***
ROE	-0,092	-2,247	0,026	**
DER	0,975	43,753	0,000	***
FISIZE	0,038	0,928	0,355	
REPUTATION	-0,033	-1,639	0,103	
PUBLIC	-0,697	-0,497	0,620	
MANOWNER	-0,730	-0,520	0,604	
SALESSIC	-0,308	-5,762	0,000	***
SECTOR	-0,068	-2,793	0,006	***
COMP	0,270	4,858	0,000	***
Adj R2		0,923		
F		179,673	0,000	***
Dependent variable: MTB				

This study has several limitations; it does not distinguish whether the sample is in a growth or decline phase. The phase of the life cycle can affect the company's investment opportunities. Macroeconomic indicators also can influence the market response to capital expenditures, so macro aspects need to be considered in addition to company characteristics. Issues that have not been covered in this study leave an opportunity for future research.

Conclusion

This study examines investment opportunities as a moderator in the effect of market response on capital expenditures. The research sample is specifically for large-cap companies on the Indonesia Stock Exchange. The test results prove that the market responds negatively to capital expenditures, which is consistent with a number of previous studies. Furthermore, this study proved that investment opportunities moderate the effect of market response on capital expenditures.

This finding provides critical implications for managers to consider the company's investment opportunities when making capital expenditures. First, the market appreciates capital expenditures from companies with good investment opportunities. Conversely, investment spending in conditions of low investment opportunities will be counterproductive.

This research model has included many control variables related to company-specific and operational characteristics. However, this study has yet to include macroeconomic indicators that have the potential to influence market response, such as industry prospects and inflation index. Future research can address these issues, thus providing more complete results.

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in EPESS journal belongs to the authors.

Acknowledgements or Notes

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The Industrial Revolution and the Ottoman State: Its' Reflection on the Economic Policies of the Tanzimat Period

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Abstract: With the industrial revolution of the 18th century, a new world order was formed such as mechanization, large-volume production, raw material and market needs, division of labor and specialization. The Ottoman state has been in an economic structure based on agriculture, trade and small-scale workshops since the classical period. At this point, industrial production is carried out through state-controlled guilds. The Ottoman state has developed new regulatory policies since the Tanzimat period in order to adapt to this structure with the industrial revolution. It has introduced innovations and reforms in its efforts to support competition and domestic industry, such as the establishment of factory and industrial facilities, incorporation studies, the establishment of industrial schools, and the construction of railway networks. As a matter of fact, administrative weaknesses, deterioration of the timar system, inadequacy of the treasury, traditional economic mentality, capitulations granted to foreign countries, land losses and wars increased foreign dependency and caused damage to the domestic industry. In addition, the fact that the industry did not operate in an industrial order benefiting from capitalist accumulation and did not allow capital accumulation, and the accompanying competent personnel and scientific deficiencies caused the industrial revolution to have negative consequences in the Ottoman state.In this study, it is aimed to examine the effect of the industrial revolution of the Ottoman state on the economic policies of the Tanzimat period, the results it revealed and the applications made.

Keywords: Industrial revolution, Ottoman empire, Tanzimat period, Industrial policy

Introduction

In today's economic policies industrialization is seen an important problem. Beginning from industrial revolution, which emerged in 1750s and forms the foundation of economic development in modern meaning, for most economies, industrialization has been primary priority. Industrialization is a measure of the developedness and less developedness levels of country economies. The main difference between the countries whose life standards are high and the ones whose life standards are low, arises from industrializing or not industrializing.
In 18th and 19th centuries, two elements, which especially change European societies, are mentioned. The first of them is a political and administrative structure in France and England, and the second is the development of capitalism in England. Industrial revolution, which began in England and, later, enlarged its effective area in West European Countries, changing the existing socioeconomic structure of Europe, initiated a full-scale transformation. Firstly, depending on noticing surplus value in agricultural sector of England, city centers showed an intensive development and formed a market quality for surplus value in rural areas. In view of the reasons such as the increasing demand, sufficient capital accumulation and adaptation of social structure to change, industrialization rapidly affected Europe. Transformation experienced in weaving sector became the first step of industrialization, later, with invention of machines working with steam power, the first phase of industrial revolution was completed.

In Ottoman State, industry, which has been tried to be developed beginning from 18th century, although it is not in parallel with the West, remained under state monopoly at the beginning. The power of central authority, inadequate private enterprise and mercantilist mentality in the West are among the main causes of this development. In addition, centralist control of government in the military, agricultural and mining areas led industrialization to take place in the form of certain factories and in certain cities. This case lowered technological productivity in industry and led industry to remain in narrow area and in the form of craft-typed organization. Another factor here is that private sector slowly leaves its power to central authorization runs into industrialization approach, especially tried to be newly developed in 18th century, together with Tanzimat beginning from 19th century. In the times, when an industrial movement similar to that in the West was tried to be started, that central authorization gains power led a large part of industrialization- especially large scale- to remain under state monopoly.

At the present time, the subject how industrial revolution reflects to the economy policies of Ottoman State in Tanzimat Period is an important study subject. Why did not Ottoman State succeed as much as pioneer countries that initiated industrial revolution process? In this study, how Ottoman State developed its economy policies after economic policies and why it was not included in Industrial Revolution were studied in the framework of internal and external factors in the context of Tanzimat Period. In the direction of this aim, first of all, in pre-industrial revolution, a brief analysis of industrial activities and economic structure in Ottoman State was made. Following this analysis, setting out from either these structures or developments experienced in Europe before Industrial Revolution, how Industrial Revolution shaped the economy policies of Tanzimat Period was studied. Lately, the causes of why Ottoman State included in industrial revolution were identified.

Industrial Revolution: Overview

The first and the most important stages of industrial revolution emerged in England. According to Wallerstein, the causes of that mechanization began in England are the increasing demand, sufficient capital, agricultural revolution and development of land-rent patterns enabling demographic growth (Wallerstein, 2011). In England, which is the leading geography, where government intervention is limited, circulation of private capital is supported, mew inventions and technologies in industry were begun to be seen in the early 18th centuries with also contribution of social triggering. However, it is necessary to state that industrialization did not consist of only England. Beginning from the early 18th century, in the development of English cotton weaving industry, the effect of foreign markets was not also denied. Moreover, in 18th contrary, England domestic market did not fully enlarged, instead of this, it was seen that an growth actualized toward the markets in North America, Continental Europe and Third World Contrives (2). However, England overtook Netherland, which is in front of it in weaving industry, in time. The main reason for this is the intertwining of the English weaving industry with agriculture and the transfer of Netherlands capital surplus to English entrepreneurs. (3). Industrial revolution especially showed itself in cotton weaving industry. However, [the first] modern factory was founded in the third quarter of 18th century (Wallerstein, 2011). In this sense, the number of cotton weaving factor was 900 in 1797, this number amounted to 1407 in 1850s (Chapman, 1972). When regarded to the cause of that industrial revolution first emerged in weaving industry, it can be attributed to the closeness of raw material to the regional geography. Depending on specialization and technical development, industrialization also increased rapidly.

Industrial revolution dating from the late 18th century to the early 19th century is a great modernization age characterized with invention of machinery used for making automatized production processes in manufacturing, mining and agriculture. Together with modernization, factories were built and, by means of these factories, mass production was made it possible. Together with mass production, production costs, thus, prices decreased and so it enabled ordinary people to be able to reach the products they cannot buy earlier. Depending on the developments in production, the developments in transportation enabled the merchants to transport and market their goods and services to more remote distances (Curley, 2009).

With beginning of industrialization (1750), manufacturing industry productions of European Countries began to rise. In 1750, while total share of all Europe in world production was 23%, this number rose to 28% in the early 19th; 53.2%, in the second half of 19th century and 61.3% in the third quarter of 19th century (Freeman-Louçâ, 2001: 183). In this context, manufacturing industry under control of Third World Countries passed to monopoly of European Countries.

In pre-industry period, in Europe, especially in England as well in China and Ottoman Empire, tax rates generally ranged at the low levels. In these society, mostly based on agriculture, as the cause of that tax rates are low, it was shown that the prevailing classes in the countries above mentioned have high income resources even if there is no tax income. The element providing this wealth to the prevailing sector of interest is the lands (Clark, 2013). As a natural result of this case, trade was encouraged and industrialization began to gain importance.

The technological and economic developments in the time passing from invention of script to industrial revolution remained limited with a constraint effective area. Therefore, over hundreds of years, a large development and variation was not seen in average real wages and life standards of about one billion of people (Skousen, 2003). Together with industrial revolution, radical changes were experienced in economic mindset and economic structure. A period, in which modern science and empirical information were applied in production process, began. Instead of producing for livelihood and limited economies like family economies, production approach for national and international markets has emerged. Small production units making production with traditional methods developed and their effective areas enlarged. In other words, instead of family enterprises, companies and public institutions have begun to take place in production, Labor factor has directed to goods and service production from the activities related to the production of primary products. Instead of human labor, as a complementary of it, intensively and widely use of capital resources emerged. The new social and professional classes that work with production tools other than land (Deane, 1979).

Industrialization Activities Before Tanzimat Period

In Ottoman State, an Europe-similar industrialization was not fully actualized. While Industrial Revolution introduced a transition from agricultural production to machinery technology, this process began to show itself more differently in Ottoman State. Ottoman State having a very large geographical area, for being able to control this geography, had to have a strong military and financial structure. In view of this, in order to be able to keep its power, Ottoman State gave importance to building factories and manufacturers in military areas. Thus, as heavy industry in Ottomans, shipyard, ammunition and gunpowder factory are seen, and these are mostly established in Istanbul and some cities. To give an example, in İstanbul, Sinop, Izmit, Gelibolu and Suez, shipyards were built and, in addition to these, gunpowder factories were established in the places such as İstanbul, Selanik, Gelibolu, Bor and İzmir (Berkes, 1975). When regarded to pre-Tanzimat Ottoman Industry, It is seen that there is private sector as mostly small crafts shops in industry institutions and that large majority of industrial institutions under state sector are mostly military-aimed industrial institutes. In Ottoman State these first industrial institutions and attempts, whether belong to public sector or private sector, remain very weak compared to European Industry. But these industrial sectors established in the eras of Mahmut II and Selim III formed a foundation for the next sectors.

There are idiosyncratic features of Ottoman Industry of Ottoman Industry that began to develop beginning from 18th century, On the one hand, it began to develop under the effect of the industrialization in the West, on the other hand, it contained local features changing time and space. However, at the local level, it is difficult to say that the desired results are reached in industrialization in broad meaning. In Ottoman State, another cause of that industry that began to newly develop in 18th century is not more spread to private sector is the power of craft organizations. Strong craft organizations remained closed to industrialization and facilitated industrialization to be mostly collected in hands of government.

Government, in order to increase control power in economy, leaving minor solder salaries to treasury, ignored them to undertake new duties such as housekeeper, secretary, observer in the various areas. This case led industry to be kept under control of government in certain centers and to be kept closed to the changes from the aspect of cooperation, productivity and technological developments. That craft-type organization prevails in production kept industry away the industry from differentiations to start a transformation in capitalist sort (Genç, 1991). As a result of the support government for craft organizations i.e. guilds, an important case appeared for industrialization in the next period. With this method, first of all, production forms that emerge or can emerge out of guilds were impeded.

Beginning from the era of Fatih Sultan Mehmet, it is possible to see public enterprise especially in military industry area, armory and shipyard built in the era of Fatih are seen as a large industrial institutions serving army. After 18th century, large scale public enterprise industrial institutions have increasingly continued. Especially in Istanbul, after 1718, largely public enterprise industrial institutions were established. Silk manufacturers (in Üsküdar), paper factory (in Yaloba 1744-1745), cannon foundries (in Hasköy), gunpowder factory (between Bakırköy and Yeşilköy), rifle factory (in Levent Çiftligi and Dolmabahçe), glass and porcelain manufacturing (in İncirköy) and kâgıthane paper factory are some of these (Wiener, 1992).

Ottoman State did not wait for Tanzimat reforms for receiving European industrial techniques. In 1790s, action of Selim III to form Nizam-ı-Cedit is the first action, in which European industrial techniques were begun to be used in military industry. After 1793, in such a way that it will cover a larger area, manufacturing of cannon,

cannon ball, gunpowder and mine containing European methods and equipment was introduced to Ottoman State.

After Selim III, the efforts to take Western industrial techniques interrupted in the first 20 years of the era of Mahmut II. Following slowdown of 20 years, the efforts to transfer European industrial superiority to Ottomans continued again. On the other hand, in the same period, it is seen that Ottoman State was not in very back of the West in military, mining, clock and the other industrial areas but it is seen that it has some difficulties in supplying raw material. In the essence of industrial enterprise covering the eras of Selim III and Mahmut II, there are a sort of import substitution industrialization regarding arm manufacturing cannon and rifle as well as fez and clothing the solders will use, triggered by renewing action (nizam-ı-cedit), especially initiated in military area, in state and society life. These polices and plants could not be sustained, because they were not built in and effective resource supply and supply chain like in the West. Some of these attempts are given as follow together with foundation years (Bozdemir, 2011).

Table 1. The factories founded in pre-tanzimat period

Years	Factory
1804	Beykoz Paper Factory
1812	Beykoz Leather and Shoes Factory
1822	Paşabahçe Monopoly Spirit Factory
1827	Eyüp Thread Factory
1830	İslimye Broadcloth Factory

Resource : Bozdemir, 2011

In Ottoman State, after the first enterprise in 1984, for a long time, any factory was not opened in the different places of the country. However, Mahmut II (1808-1839), after a long time his acceding, in 1827, opened a thread factory in Eyüp (7). In Istanbul, in 1810, Beykoz Leather Factory, founded by an entrepreneur called Haydar Bey, being bought by Sultan Mahmud II, was given to the service of army. In the era of Mahmud II, for meeting fez need of army, Fez Factory (Fezhane) called Defterdar Factory, was founded in 1835 (Arslan, 1964). While good developments stated above were experienced in the era of Mahmud II, in addition, domestic revolts much more increased. Among these, events such as that Greece declares independence and that Mehmet Ali Pasha, Egypt Governor, revolted against central administration can be accounted. These cases experienced pulled the course of the country to a different dimension and state began to weaken every passing day. While Ottoman State, on the one hand, lost its political power, on the other hand, slowly coming in the effective area of capitalism, it also began to lose its economic power. Based on this, most economic historians said that Ottoman State did not have sound and preserving economic policy by 1830 (Sayar, 1986).

Also in the first half of 19th contrary, civil war, political problems, improvement movements and economic troubles continued. Especially removal of Guild of Janissaries, separatist movements in Greece and Egypt highly disturbed the domestic and foreign policy and economic balances. Ottoman State applied to some economic precautions to be able to reorganize economic balance disturbed. The most traditional one among these is adulteration of the money. Especially between the years of 1809-1831, very frequent applied adulterations demonetized money. Thus, silver content of Ottoman kurus that is 5.9 g in 1808 regressed to 0.5 g in 1831 (Erdem, 2006). As a result of adulterations, purchasing power of the money decreased; budgetary deficits increased, because tax income decreased; costs of domestic borrowing increased and repayment became very difficult.

As known, Ottoman State signed Baltalimanı Trade Treaty with England on the date of August 16, 1838. With this treaty made, Ottoman State was obliged to make heavy concessions to English Government to be able to suppress the revolt of Mehmet Ali Pasha, Egypt Governor in exchange of not disintegrating its lands. Because, together with this treaty, English merchant gained the quality that has to be given the most privilege and, thus, had equal rights with the domestic merchant. In a few years following this, similar treaties were made with some other European countries. However, it can be said that the treaty of interest brought a partial initiative through foreign trade to Ottoman State. Because it is known that this treaty made some contribution to Ottoman Budgetary due to comparative advantage Ottoman State has about agricultural food prices in the period of Free Trade (1840-1870) Policy applied with European countries. However, in the years following this decision Ottoman administers made with good intension for the sake of not losing Egypt, Ottoman State could not keep in step with industrial revolution adequately. Domestic Ottoman Industry highly sweating in keeping comparative advantage in international markets was heavily damaged; foreign capital was gradually strengthened; foreign trade balances were much more disturbed and the country was obliged to borrow from abroad (Erdem, 2016).

Industrialization Movements in Ottoman State After Tanzimat Period

The effort of Ottoman State to industrialize gained a different quality beginning from 19th century. The first of the main elements leading this difference is European industrialization, which appeared beginning from 1750s and also affected Ottoman State like all states of the world. The second factor is economic privileges, which are called capitulation and which began France and became common in most European countries. It is also possible to include trade agreements in the second group. Thus, in parallel with these two main factors, under the pressure of orthodox craft organizations, Ottoman industry remaining on the back of Europe was tried to be stimulated again especially after Tanzimat.

Together with mercantilism, that national capital accumulations strengthened in the West facilitated industrialization. However, in the same period, in Ottoman State, applications against mercantilism pushed industrialization to slow development. Again in this period, That Ottoman central government weakens negatively affected industrialization. As mentioned earlier, in Ottoman Empire, an Europe-similar industrial structure did not form. While Industrial revolution essentially expresses the transition from agricultural production to machinery technology, this process emerged in Ottoman State in the different areas. In Ottoman Empire, which has a large area in terms of geographical borders, being able to control geography in the hegemonic area was possible to keep military and fiscal power in a functional and sound structure. From this aspect, the state-owned factories and manufactories were mostly built to use in making military tools (Murphey, 1992).

Industrialization activity in Ottoman State began in 19th century in the form of transition from livelihood small scale industry, based on small hand crafts, to mass production with factory. Tanzimat had been a period, when the most remarkable steps were taken in industrial area. When the Rescript of Gülhane was announced, much as provisions related to industry did not take place, in this period, that statesmen realized how important economy was for a country and that radical steps were taken in industrial area is an important case.

Ottoman Industry that began to develop in parallel with post- Tanzimat renewing movements sustained this development as two dimensionally. In Ottoman State, public enterprises formed the first leg of industrialization movement gaining acceleration beginning from 19th century. Public enterprise actualized as industrial institutions requiring enormous labor. The second leg of the industrialization efforts in Ottoman State formed private enterprise organization. This sort of organizations is generally seen as enterprises working less capital and less labor in very local meaning (Pamuk, 2005).

The statesmen of Tanzimat Period, especially Mustafa Reşit Pasha, made several works we can say “operation for strengthening industry” to develop industry. It is possible to divide the works in this area into two sections. The period of about 20 years, in which statist polices prevail covers the first period and the second period between the years of 1860-1876, in which private sector supports industrialization. The industry between the years of 1840-1860, qualified as “First Period” mostly continued as an industry adopted and developed with government support and leadership. The fact that private entrepreneurs are not seen in this period and that such a discussion is not experienced in İstanbul or all of Ottoman State arise from that public sector does not continue a long time. Whenever the government supports private sector, it is seen that investments are stimulated. When reached 1960s, Ottoman top bureaucracy realized that it was remained in the back of Europe and understood that it was time to make something about it (Seyitdanlıoğlu, 2009).

After Ottoman State saw these developments, it began to support industrialization efforts via private sector. For these efforts to be able to realize, it made efforts to take the following precautions: At the beginning, considering to reduce import customs, it gave importance to increase competitive power of domestic industry (Önsoy, 1984).

Together with Tanzimat, until the beginning of Crimea War a number of state-owned industrial institutions was built. In this transformation process, which can be qualified as an exceptional period in Ottoman history, as mentioned earlier, industrial institutions directed to manufacturing and domestic raw material were put into operation. Most of these industrial institutes were built in İstanbul and around Istanbul (Clark, 2013). Together with Tanzimat, efforts to strengthen central government brought together intervention of government to economic life with it. Naturally this intervention also reflected to industrialization area. Ottoman Industry remaining behind Europe with Industrial Revolution and trade agreement made was tried to be developed by the support of government with priority. The main aim here is seen as meeting the main needs of especially army, and government and increasing tax incomes.

Table 2. Large scale factory founded after tanzimat period

Activity Area	Name of Factory
Nail and ceramic	Beykoz Çini Factory (1845)
	Yıldız Çini Fabrika-i Hümayunu (1890-92)
Elecricity Production	Dolmabahçe Gasworks (1853)
	Beylerbeyi Sarayı Gasworks (1862)
	Yedikule Gasworks (1880)
	Kadıköy Hasanpaşa Gasworks (1891)
	Silahtarağa power plant (1910-13)
	Üsküdar Elektrik Factory (1911)
Leather and Shoes	Osmanlı İttihat Saraçlık Incorporated Company (1913)
	Beykoz Shoes Factory (1884)
Textile and ready wear	Feshane-i Amire (1839).
	İslimye Şayak Factory (1840).
	Hereke Fabrika-i Hümayunu (1843-45).
	İzmit Çuha Factory (1844).
	Hereke Çuha Factory (1845).
	Bursa İpek Factory (1846).
	İzmir Muslin Boyama and Basma Factory (1847).
	Bakırköy Bez Factory (1850).
	Izmir Fabric Factory (1861)
	Kırkağaç Çırçır Factory (1876).
	Izmit Silk Factory (1880).
	Adana Milli Mensucat Factory (1907).
Chemistry	Izmir Oil Factory (1850).
	Beykoz İspermecet Factory (1863).
	Second Izmir Oil Factory (1870).
	Tanen (Asit) Fabrikası (1891).
	Küçükçekmece-Osmanlı Kibritleri Factory (1898).
	Galata Yüksek Kaldırım Battery Factory (1917)
Machinery and Metal	Zeytinburnu Iron Factory (1843).
	Yedikule Şimendifer Factory (1843).
	Eskişehir Railroad Factory (1894).
	Şakir Zümre Stove Factory (1918-23).
	Zeytinburnu Mavzer Factory (1902).
	Zeytinburnu Acid and Ether Factory (1902).
	Zeytinburnu Chemistry Laboratory Factory (1902)
Defense Industry	Istinye Shipyard (1856).
	Cebehane-i Amire (Savaş Mühimmatı İmalatı (1868).
	Kayseri Güherçile Factory (1891-92).
	Konya Güherçile Factory (1896).

Resource: Erdem, 2016:24-25

If regarded to the activities areas of industrial enterprises mentioned above, as in industrial revolution that began in England, also in Ottoman Industrialization, textile and ready wear sector stand out. Furthermore, also before Tanzimat, it is seen that weaving factories were active. So, it is seen that total of 14 factories were founded in this century. Hence, it is understood that effect of industrial revolution showed itself in sectorial basis. However, in addition to leather and shoes sectors (3 factories) and tile and ceramic sectors 2 factories), whose competitive power are traditionally high, in the areas of machinery and metal (7 factories), chemistry (6 factories), defense (4 factories) and electricity production (6 factories), it is understood that a number of factories were active (Erdem, 2016).

Evaluation of the Effects of Industrial Revolution on Ottoman State

There are very different views about why Ottoman State could not keep in step with industrial revolution. According to Rhoads Murphey, Ottoman State continuously supported the developments in three areas, among these developments, renewals in military area, mining and clock making and application of mechanical movements in the other works. The main factor in acquiring target supporting the development in these three areas continuously has been the supply of material and manpower (Murphey, 1992).

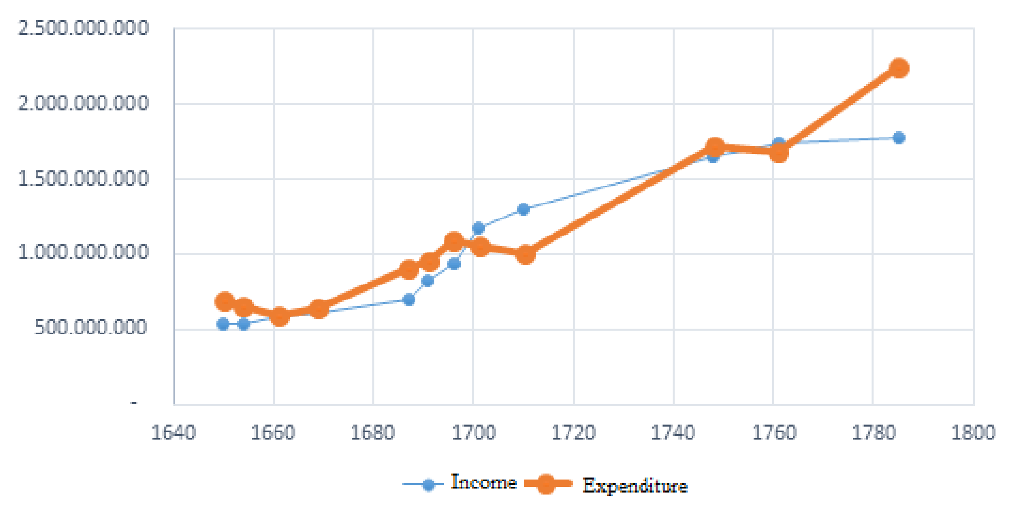
Ottoman Stated waited for having the new industrial techniques of Europe until 1840s. Selim III brought contemporary European techniques, used in cannon, cannon ball, mine and gunpowder, to the country in the years of 1793-1794. Ottoman society, as of its structure, is, in fact, a society, which is open to new ideas and willing to use foreign technologies. However, the ways of economic and technological exchange and contact with Europe began to slowly disappear toward the late 17th century. The reason for not closing this gap is that the natural resources of mineral, timber and other materials gradually decrease. But the effects of this decrease in the resource much more increased due to the fact that the state is consciously excluded by North Atlantic economies. In the light of all of these data, it will be certainly true to say that Ottoman State has an industrialization policy. The scientific developments followed and technological investments and inventions made certainly form the most important beginning factor in industrialization of a country. Unfortunately, Ottoman State could not completely follow these developments, did not take the necessary step in especially education area in time for industrializing and, the efforts made in forming this structure remained weak. This case can be seen as one of the cause that Ottoman State is not industrialized (Ünal, 2010:101). Industrial Revolution extremely negative affected Ottoman State especially from economic point of view.

Table 3. England 1381–1700. Annual production in agriculture, increase rates of labor force and labor force productivity

Years	Production Increase	Labor Force Increase	Productivity of Labor
1381-1522	0.01	-0.01	0.02
1522-1700	0.38	0.25	0.13
1700-1759	0.79	0.22	0.57
1759-1801	0.85	0.44	0.41

Resource : Şahin, 2019:6

As in pre-industrial revolution society, also in Ottoman State, economy was largely based on agriculture. A large part of state revenues consisted of agriculture and agriculture-based activities and war incomes. In statesmen and bureaucrats, the thought that “the power and continuity of a state is possible with keeping the existing order” was dominant. Over four centuries dating from the late 14th century to the early 18th century, in Ottoman agricultural sector, the fluctuations in production, labor force and productivity of labor occurred, and a stable increase could not be provided, because Ottoman agriculture consisted of producers making production in small lands for only livelihood (Şahin, 2019). Agricultural techniques did not change for thousands of years and remained in a primitive structure. As a result of this mindset, Ottoman State was late in the process going to industrial revolution and, although it was one of the most powerful countries of the period from military, economic and political point of view, it cannot be included in industrial revolution.



Graph 1. Budgetary incomes and expenditure (akçe)s in the period of 1600-1785 in ottoman state
Resource: Kaya, 2021:441

After 1500, when Spain silver began to flow in Ottoman economy, fiscal balance of Ottoman State disturbed and, with the effect of the wars lost, government budget began to have a deficit beginning from this date. Since a large part of tax incomes is expensed with military aim, finance of Ottoman State came into a heavy pressure in war period.

By 18th century, high birth and death rates kept in balance classical demographic structure in Europe. However, in 18th century, together with the increase of agricultural productivity and diversity, this case began to change. Together with the developments such as effectiveness in diet, improvement in health conditions, high life standards, etc., the deaths experienced due to starvation, war and pandemic have begun to decrease and average life duration to increase. As a result of these developments experienced, Europe population that is about 100 to 200 million reached 450 million at the early 20th century. In the essence of these developments experienced in demographical structure, the increase experienced in agricultural production and productivity play role. Agricultural revolution and demographical revolution is the most important elements for industrialization. In the pre-industrial revolution period, Ottoman State could not realize either agricultural revolution or demographical revolution (Kunt et al., 1997). As a result of all of these developments, we can summarize the effects of industrial revolution on Ottoman State as follows:

- In Ottoman State, small workshops and handlooms were closed. So, unemployment increased.
- Agricultural production reached the level of market economy from livelihood level.
- While export was decreasing, import increased.
- The value of Ottoman currency decreased.
- From economic point of view, dependency on Europe increased.
- Ottoman State became open market of Europe.
- Ottoman State, due to its need for raw material and market, was begun to be occupied by European states.
- Regression in economy accelerated political collapse.

Ottoman Empire remained “strange” to new world system, which began before industrial revolution and reached summit. It could not adapt to, especially the production, foreign trade and financial system of the period, systems giving direction to world economy and could not bring a national identity to bourgeoisie, whose majority consist of foreigners. These cases of interest paved the way for economic collapse of the country and, as a result of this economic collapse, it was unavoidable that political existence of Ottoman Empire ended.

Conclusion

In 18th century, while the first phase of industrial revolution in the West was experienced, Ottoman State remained incapable in predicting the results of this great transformation, thus, in keeping in step with this transformation. The reason for this incapability was based on long before the revolution, a long process dating to geographical discoveries, because lost silk and spice routes lost its importance due to new trade rates discovered after geographical discoveries. These routes, which were the most important trade routes of that period, were under control of Ottoman State. The economy of Ottoman State was in a good condition thanks to customs and trade taxes it acquired through these routes in addition to tax incomes obtained from the lands. However, as a result of that these routes lost its importance, Ottoman State lacked these incomes. Gold and silver mines, which flowed to Europe from the lands newly discovered, led to inflation in Ottoman State. As a result of these developments, Income-expense balance of Ottoman State disturbed and government budget shook. After these negativities experienced, the political, economic and social problems began to emerge in the state. As a result, increase of the share of capital-intensive productions became possible with the presence of technology, information accumulation and capitalist thought. However, industrialization movements in Ottoman Empire did not form in a structure similar to Europe. While Industrial revolution is expressing the transition from agricultural production to machinery technology, this process appeared in the different area in Ottoman State.

Ottoman State attempted to much more scale industrial investments in 19th century compared to the previous centuries. Industrialization requires a total change not only alone but also in the other areas such as agriculture, trade, capital and population. However, in Ottoman State, that agricultural transformation that is necessary to industrialize, due to the problems inadequacy of labor force i.e. population to be employed in industry out of agriculture, lack of qualified staff, transportation and insufficiency of capital, it was completely dependent on foreign aids in industrialization attempts and these investments made did not become lifelong and permanent.

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in EPESS journal belongs to the authors.

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A Bibliometric Analysis of Artificial Intelligence-Based Stock Market Prediction

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Abstract: The primary purpose of this study is to conduct a scientometrics analysis of stock market forecasts based on artificial intelligence. This research examined 1,301 publications that were published between January 2002 and June 2022. We investigated 183 journal articles among 1,329 papers. In addition to entering the keywords into Scopus, a comprehensive dataset of relevant research papers was compiled. These papers discussed the optimization of investment portfolios, artificial intelligence-based stock market forecasts, investor emotions, and market monitoring. We found the most prolific documents by affiliation, the most prolific author, the most cited papers, nations, institutions, co-authorship maps, inter-country co-authorship maps, and keywords occurrences in this study. Co-authorship analysis network maps and keyword occurrence linkages are generated using the VOS-viewer software. According to our findings, it is evident from the review that the body of literature is becoming more specific and extensive. Primarily, neural networks, support vector machines, and neuro-fuzzy systems are employed to predict the future price of a stock market index based on the composite index's historical prices. Artificial intelligence techniques are able to consider challenges facing financial systems when forecasting time series. Our findings provide actionable guidance on how artificial intelligence can be used to predict stock market movements for market participants, including traders, investors, and financial institutions.

Keywords: Neural network, Stock market prediction, Algorithm, Machine learning, Artificial intelligence, Sentiment analysis.

Introduction

The prediction of the stock market has become a contentious issue for academics in recent years. The rise in stock market investments helped to establish artificial intelligence as a critical and promising area of research. Incorporating machine learning into the prediction of the future value of stocks, bonds, and other financial assets on an exchange can be highly beneficial (Li et al., 2014). Forecasting the future performance of the stock market is difficult due to the additional economic and psychological components, rational and irrational behaviour, etc. that are incorporated into the projection. The combination of these factors produces dynamic and fluctuating stock prices. This makes it incredibly difficult to predict stock values effectively in a turbulent market.

Two traditional theories must be considered when predicting the stock price: the efficient market hypothesis (EMH) and the random walk theory (RW). EMH asserts that a stock's price incorporates all market knowledge at any given time. As a result of market players' optimal utilisation of all available information, price movements are unpredictable due to the random appearance of new information (Fama, 1970). In contrast, according to the random walk theory, stock prices conduct a "random walk," which indicates that future prices do not follow any trends or patterns and are a spontaneous deviation from prior values, making it impossible for an investor to predict the market (Ferson & Harvey, 1991; Jarrett, 2008). There has been controversy over the

- Selection and peer-review under responsibility of the Organizing Committee of the Conference

validity of the EMH and RW theories. With the advent of computational and smart finance, as well as behavioural finance, economists have attempted to establish the inefficient market hypothesis (IMH), which suggests that financial markets aren't necessarily efficient (Malkiel, 2003). The majority of studies (Goodell et al., 2021; Khadjeh Nassirtoussi et al., 2014; Pan et al., 2016; Zhang et al., 2018; Khaing et al., 2020;) have employed AI approaches to demonstrate these claims, and the fact that selected players may continuously outperform the market indicates that the EMH may not be applicable in practice.

Consequently, stock market analysis can be a difficult and multidimensional operation. AI and ML help simplify this effort. AI and ML can facilitate unbiased data collecting, data classification, stock analysis, and pattern recognition. Ding et al. (2015) has developed a model that improves S&P 500 index and individual stock forecasts by over 6% relative to current best practices. This research demonstrated that the model is able to consistently gain sustainable competitive advantage. According to Khaing et al. (2020) experiments, trend extraction with additional criteria on stock news extracts more trends. In addition to additional parameters, the stock trend extraction findings are more consistent with the actual stock price movement. Chen (2021) created the new neural network model to develop the prediction model's concepts. (Belciug et al., 2021) evaluated the efficacy of a statistical learning framework using an algorithm based on a competitive/collaborative method for generating a reliable real-time forecast of the next stock market transaction price for a share. Biswas et al.(2021) investigated numerous models and approaches used in stock market prediction and focused on their advantages and disadvantages. This study also examined over ten approaches used in the recent decade to estimate stock market values. Serrano (2022) demonstrated that the proposed methodology using RNN models accurately predicts the performance of various investment portfolios.

Using machine learning, Stock Price Prediction may determine the future price of a company's stock and other financial assets traded on an exchange (Nayak et al., 2016). The entire purpose of predicting stock prices is to generate substantial profits. Forecasting the future performance of the stock market is difficult. In addition to physical and psychological elements, reasonable and irrational conduct, etc., there are additional components involved in the forecast. All of these elements combine to create dynamic and volatile stock prices (Mamun et al., 2015). This makes it extremely difficult to accurately estimate stock prices. Researchers are constantly seeking ways to predict the future. Given the rapid rise of the economic-focused society, it is always necessary to research and discover relevant information to select a better stock in the stock market. Stock Market Predictions' bibliometric analysis was inspired by an increase in the number of articles that applied and measured this concept over the past two decades, demonstrating the richness of this concept in the research ground.

AI and Stock Market Prediction: Background Information

Research on artificial intelligence in the stock market has been well documented in previous studies. An accurate prediction of stock prices is impossible due to the complexity and uncertainty of the stock market. For the successful study of the future stock price of any company, a reliable forecasting system is required (Ishwarappa & Anuradha, 2021).

Previous research (Khadjeh Nassirtoussi et al., 2014) reviewed related articles on market prediction based on online text mining and drew a picture of its generic components. Reaz et al. (2002) showed the implementation of backpropagation on the Altera FLEX10K FPGA device for stock market prediction by exploiting the parallelism in the neural network design; this method increases the convergence speed of the network and the accuracy of the stock market forecast. Chen (2011) argued that artificial intelligence (AI) may be a more appropriate tool than classical statistics for predicting the possible short-term financial problems of a corporation. (Rodr\'\iguez-González et al., 2011) indicated that the CAST is capable of predicting both the market as a whole and particular IBEX 35 stocks. For example O et al. (2004) found in the Korean stock market, the trading system with the suggested asset allocator outperforms other systems with fixed asset allocation methods. Reinforcement learning can have synergistic impacts on the decision-making problem by utilising supervised-learned predictors. Yang and Chen (2014) implies that the neural network has the analytical capacity to deal with the current disordered and mixed information processing. In addition, it is already the most effective tool for intelligent processing. In numerous fields, including recognition processing, signal analysis, and control, the BP algorithm has been widely adopted and has represented a significant breakthrough. Ng et al. (2014) proposed the algorithm LG-Trader, which simultaneously identifies classifier architecture selection and feature selection using a genetic algorithm to minimize a new Weighted Localized Generalization Error (wL-GEM). In both stock and index trading, the LG-Trader generates higher profits and return rates, as demonstrated by experimental results. A two-stage fusion method utilizing Support Vector Regression (SVR) as the first stage was used by (Patel et al., 2015) to establish predictions for 1–10, 15–30, and days in advance. The SVR-ANN, SVR-RF, and SVR-SVR fusion prediction models are produced in the second stage of the fusion approach using Artificial Neural Networks (ANN), Random Forests (RF), and Support Vector Regressions (SVR). Ding et al. (2015) introduced a deep learning strategy for event-driven stock market prediction, and discovered that the model can produce about 6% increases in S&P 500 index prediction and individual stock prediction, respectively, compared to baseline methods at the forefront of the field. Wang et al. (2015) investigated extensive information diffusion-related knowledge and modelled it scale-independently. Extensive testing on a Sina Weibo reposting dataset revealed the suggested method's higher performance in forecasting the burst time of posts. Shynkevich et al. (2016) predicted stock price movement using the multiple kernel learning technique, which integrates information from multiple news categories while separate kernels investigate each category. They also observed that increasing the number of related news categories used as data sources for market prediction positively affects the predictive framework relative to techniques based on fewer categories. Pan et al. (2016) evaluated the impact of data normalization on SVM and technical indicator stock index price prediction.

Experimental results suggested that a prediction system based on SVM and technical indicators should carefully choose a data normalization strategy to decrease forecast accuracy and training time. Due to the prevalence of the Internet, Google, Wikipedia, and other sources. Weng et al. (2018) predicted the price of the stock market. This data provides insight into the financial performance of companies and captures traders' interest through search trends, website visits, and financial news sentiments. The study uses a meticulous approach to gathering its data. The AI platform subsequently trains the following four ensemble machine learning techniques: (a) a neural network regression ensemble; (b) a support vector regression ensemble; (c) a boosted regression tree; and (d) a random forest regression. The AI platform selects the "best" ensemble for a certain stock during the cross-validation phase. Zhou et al. (2020) predicted the directions of stock price movements using a variety of heterogeneous data sources, including historical transaction data, technical indicators, stock posts, news, and the Baidu index. Researchers looked at the support vector machine's (SVM) ability to anticipate price movements for a single firm under various activity levels, and their results show that this method is more effective at doing so during periods of moderately and highly active trading.

Ghanavati et al. (2016) proposed a hierarchical beta process (HBP) approach for predicting stock market trends. Preliminary results indicate that the technique is promising and outperforms other prevalent techniques. Ghanavati, et al. (2016) discovered that metric learning-based methodologies can substantially increase performance. In addition, based on the results, it was determined that adding news to historical stock prices to feed the algorithms will not improve the outcomes for all stocks. A detailed examination of each stock revealed that considering an additional source such as news is more advantageous for larger and more popular stocks. Several attempts have been made using the Recurrent Neural Network (RNN) as a benchmark. Singh and Srivastava (2017) observed that the accuracy for Hit Rate has been enhanced by 15.6% when using a model of deep learning. DNN outperforms RBFNN and RNN by a factor of 43.4% in terms of the correlation coefficient between actual and expected returns. Nelson et al. (2017) employed LSTM networks to predict price movements based on market history and technical analysis. A prediction model was built and a series of experiments were done to assess if this algorithm improves on existing Machine Learning techniques and investing strategies. The results were good, with 55.9% accuracy when predicting a stock's price rise.

A number of researchers have been (Waqar et al., 2017) applied principal component analysis (PCA) and linear regression to predict stock market patterns. PCA improves machine learning predictions and reduces data redundancy. Experiments were performed on a high-dimensional spectrum of the NYSE, LSE, and KSE. According to Maini and Govinda (2017), the Random Forest model is an ensemble learning technique that has proven to be a highly effective classification and regression model. Support vector machine is a classification-based machine learning model. Sato et al. (2018) suggested a method for short-term foreign currency forecasting and demonstrated its utility. EA (Expert Advisor) was implemented on Meta Trader (MT4)6. EA runs MT4. Once accomplished, the purchase can be repeated automatically per regulation. In this investigation, the author used the free edition of EA, ran two functions concurrently at the modified function frequency and the usual time, and proved the usefulness of the proposed method by comparing real volume differences for price movement and time series prediction. Ebadati and Mortazavi (2018) developed a hybrid approach combining Genetic Algorithm (GA) and Artificial Neural Network (ANN) technologies. It is feasible to correct faults in the GA method by feeding its output values into an ANN-built algorithm. The results of the tests revealed that the GA and ANN can be deployed to enhance accuracy with fewer trials.

Recently investigators have (Shastri et al., 2019) determined that a mix of sentiment analysis and neural networks is utilized to generate a statistically significant association between the historical numerical data records of a specific stock and other sentimental variables that can affect the stock values. Rajab and Sharma

(2019) developed an effective and interpretable neuro-fuzzy system for predicting stock prices employing various technical indicators, with an emphasis on the interpretability–accuracy trade-off. Cheng et al. (2020) confirmed the ARIMA model for model testing, selected the model with the lowest AIC, BIC, and hqlc values, and visualised 10 percent of the total data. The prediction effect is poor, there are relatively large errors, and the closing price trend is inconsistent, according to the visual results. Almehmadi (2021) applied artificial intelligence to obtain a stock market forecast accuracy of 99.71 percent, which is far higher than the 89.93 percent accuracy recorded in the relevant literature; the addition of COVID-19 data increased accuracy by 9.78 percent. The application of the ARIMA model to the stock market is inadequate and must be improved. Nayak et al. (2016) constructed a model using algorithms for supervised machine learning. In the daily prediction model, previous prices and sentiments are linked. Using supervised machine learning techniques on the daily prediction model yields up to 70% accuracy. Qiu et al. (2016) predicted the return of the Japanese Nikkei 225 index using an artificial neural network (ANN) that can map any nonlinear function without a previous assumption and provided a new set of input variables for ANN models to improve the efficacy of prediction algorithms. Zhang et al. (2018) determined that four well-known machine learning models could accurately predict the growth and fall of a stock in the Shanghai Stock Exchange (SSE) 50 index after 30 trading days. Results show that ANN (Artificial Neural Network) is superior than the other three models in terms of accuracy. Finding valuable patterns in the stock market may be possible with the help of neural networks, according to our research. The AUC of the model is consistent between 0.72 and 2.74, and the value of F1 is constant between 0.66 and 0.70, as demonstrated by Wu et al. (2020), proving that discretized technical indicators can accurately forecast short-term changes in share price. Yang et al. (2021) designs experiments to validate the function of the model from the perspectives of stock data collecting and processing, and stock price prediction accuracy, and draws statistical graphs in accordance with the statistical research results. TupeWaghmare (2021) revealed various techniques for forecasting and analysing the movement of stock values. They can indeed be broadly categorized as statistical or artificial intelligence-based. Artificial intelligence is used to predict future stock prices, employing a variety of algorithms such as SVMs, CNNs, LSTMs, RNNs, etc. Hogenboom et al. (2021) investigated the reliability of generated buy and sell signals based on anticipated stock price movements, as well as the excess profits offered by a trading strategy that incorporates these signals, and found that Event-based stock price forecasts appear to be the most accurate two days in advance. Hájek (2018) applied a combination of financial indicators, readability, sentiment categories, and bag-of-words (BoW) to improve prediction accuracy, demonstrating that the prediction quality risen exponentially when applying the correlation-based feature selection of BoW. This prediction performance is independent of industry classification and event timeframe.

The sentiment analysis and market movements have been studied by many researchers using AI based neural network. Coyne et al. (2017) examined the conceptual model and reported that there was no association between general stock Twits postings and stock price. While the second and third models adopted an innovative approach and effectively filtered through the twits to discover relevant tweets, the first model struggled to do so. Based on sentiment analysis and intelligent user identification, these influential Twitter users could anticipate stock price changes with a greater degree of accuracy (about 65% on average). Li et al. (2018) applied to predict tweet sentiment and acquire insight into the relationship between twitter sentiment and stock prices. Tweet sentiment is determined via SVM-based sentiment analysis according to Batra and Daudpota (2018). Therefore, each tweet is either bullish or bearish. The sentiment score and market data are used to build an SVM model that predicts stock movement the next day. People's opinions and market data are correlated, and the proposed study predicts stock prices with 76.65% accuracy. This association is found by using Twitter's search API and analysing the results. The Twitter sentiment is determined employing Nave Bayes classification and Support vector machines. The support vector machine is the most accurate model to predict the sentiments based on cross-validation. Camara et al. (2018) proposed a computationally estimating technique for forecasting the impact of hurricanes on the stock market using fuzzy logic-based data analytics. PCA-WSVM is effective and can be used to forecast the stock trading signals in a real-world application, as shown by the experiment results Chen and Hao (2018). Kumar et al. (2018) tested stock market prediction models' efficiency. These models are based on SVM, Random Forest, KNN, Naïve Bayes, and SoftMax. The Random Forest approach performs better with big databases than the Naïve Bayesian Classifier. The HyS3 hybrid supervised semi-supervised model for movement prediction was put forth by Kia et al. (2018). The graph-based semi-supervised component of HyS3 simulates global market interactions using a ConKruG-generated network. The supervised half of the model injects historical market data into the network when the hybrid model allows it. Malagrino et al. (2018) identified the model that accounts for a single index per continent. This design had a mean accuracy of approximately 71%. (With almost 78 percent top accuracy). In addition to producing results equivalent to those of the relevant literature, this model is also simpler and more user-friendly. Nam and Seong (2019) indicated that establishing causal relationships is significant in prediction problems, and they recommend that it is also important to construct machine learning algorithms and find linkages with well-established theories such as the complex system theory. Artificial intelligence and signal processing-based techniques are more efficient than traditional financial forecasting methodologies, according to Nair and Mohandas (2015) survey. According to a literature review, neural networks (NNs), support vector machines, and neuro-fuzzy systems are used to estimate a stock's future price.

The literature discussed above can be divided into five categories: return prediction, stock trend forecasting using artificial intelligence, market sentiment analysis, use of AI in the financial market, and combinations incorporating two or more approaches. The researcher outlines the study that led up to the current applications in each area. Existing reviews of AI in stock market prediction are narrowly focused and discuss different topics separately. None of these assessments classifies AI's financial applications to predict the movement of stock market comprehensively. This review adopts a holistic and inclusive approach to describe AI's adoption and deployment in the financial market.

Research Methodology and Data Collection

In academia, bibliometric analysis has been used frequently to examine the growth rate and the prominence of numerous academic topics. A Bibliometric analysis is a publication-based statistical technique that provides measurable insight into academic literature. To ensure the relevance and validity of research, it is essential to identify and choose high-quality international scientific articles that provide original and reliable information and knowledge sources. Regarding artificial intelligence in the stock market, the Scopus database is systematically searched (Ahmed et al., 2022).

We used the following protocol [TITLE-ABS-KEY (artificial AND intelligence+stock+market)]. This study analysed 1,301 papers published between January 2002 and June 2022. Among these 1,329 documents, 183 journal articles were determined as pertinent to the investigation's purpose. After putting "Artificial Intelligence application in the stock market" into the Scopus database, a significant set of research publications was reviewed (Ruiz-Real et al., 2021). With a focus on the most important scientific methodologies and tools employed, as well as the most significant results and conclusions made by the authors (Berradi et al., 2020).

Finally, it's essential to reveal which topics remain open in this domain and focus future research on these gaps. Data gathering and research technique selection are crucial to the process for analysing scientific articles and contributions. In this section, we have introduced the effective bibliometric tool VOS Viewer version 1.6.18 and database selection and data collecting, including establishing various parameters to assure research reliability. We follow (Goodell et al., 2021) four steps procedure for bibliometric reviews:(1) establishing the review's aims and scope; (2) selecting the analysis tools; (3) collecting the data for analysis; and (4) analysing and reporting the findings.

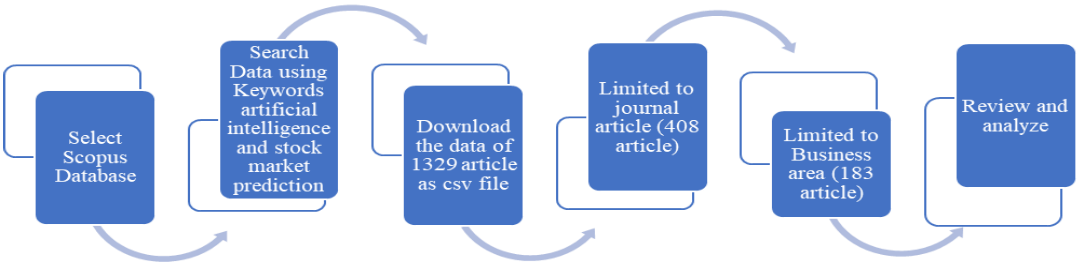

Figure 1. A flowchart depicting the process for literature review.

In order to analyse co-authorship, inter-country, and keyword co-occurrence, the software VOS viewer 1.6.18 is used; it is a tool for making network maps that are based on the network analysis database. Additionally, these maps can be visualized as well.

a. Top prolific Institutions which have published the highest number of papers.
b. Which year publishes maximum number of the papers.
c. Analysis of Publication based on source
d. Analysis of Publication based on the type
e. The highest number of cited documents in the study.
f. Top prolific authors.
g. Top prolific countries.
h. Analysis of co-authorship connection with the other authors.
i. Most occurring keywords.

Analysis and Discussion of Results

Analysis based on Affiliation

Figure 2 shows that various universities have published research papers on stock market prediction using artificial intelligence. Universities in China and India have made significant contributions. Research on Stock Market Prediction using artificial intelligence has been increasing day by day. Further, looking at the key institution that published the most papers on stock market prediction using AI, as shown in Figure 2.

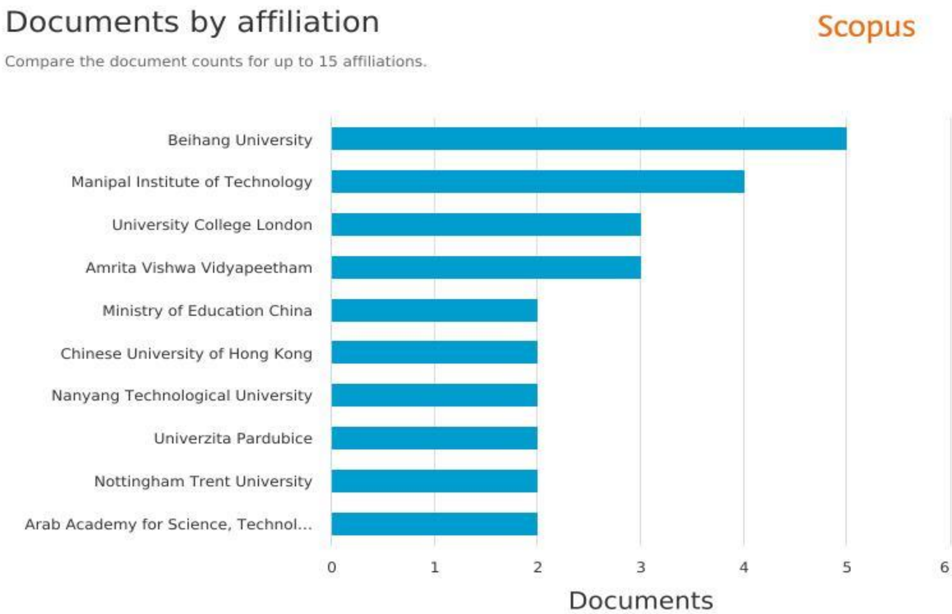

Figure 2. An analysis of publications based on affiliations

Analysis of Publication based on Year

Stock Market Prediction using Artificial Intelligence is investigated based on the keywords extracted from 183 different types of publications during 2002-2022. As shown in figure 3, the number of publications per year is analysed. A majority of the work was published in 2016 and 2018, with no paper being published in 2003.

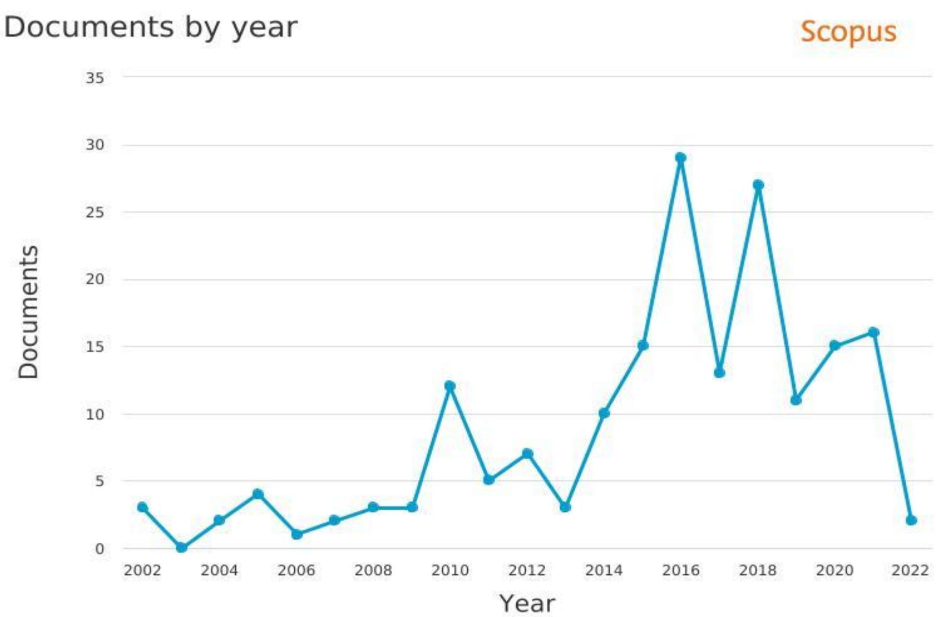

Figure 3. Analysis of publication based on year (source Scopus)

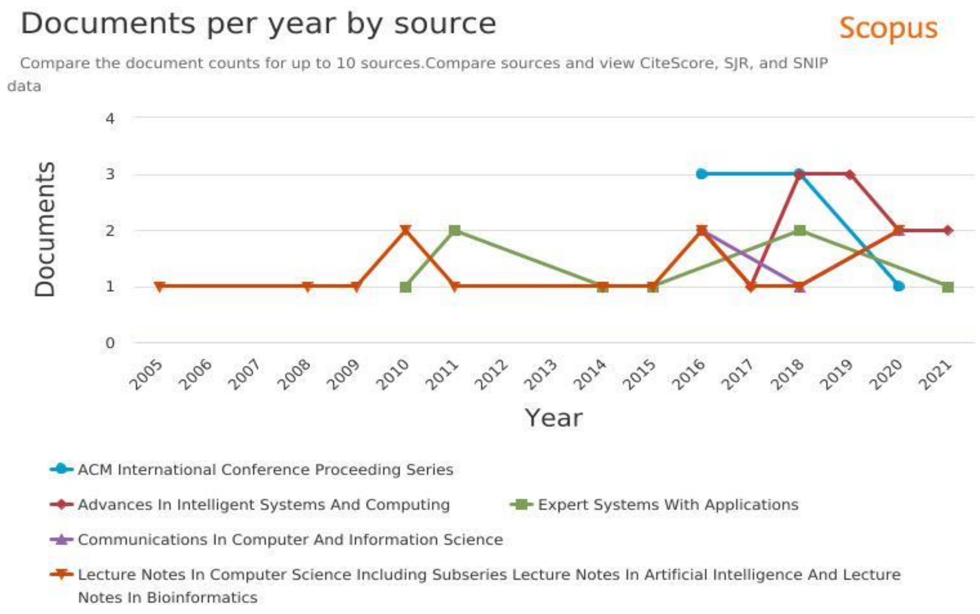

Figure 4. Analysis of publication based on source

Analysis of Publication based on Source and Publications

Figure 4 depicts a stratification of document sources. The significant substantial research was published in Lecture Notes in Advances in Intelligent Systems and Computing, Lecture Notes in Computer Science, including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics, and expert system with applications. Communication in Computer and Information Science has minor papers in Stock Market Prediction and ACM International conference proceedings series.

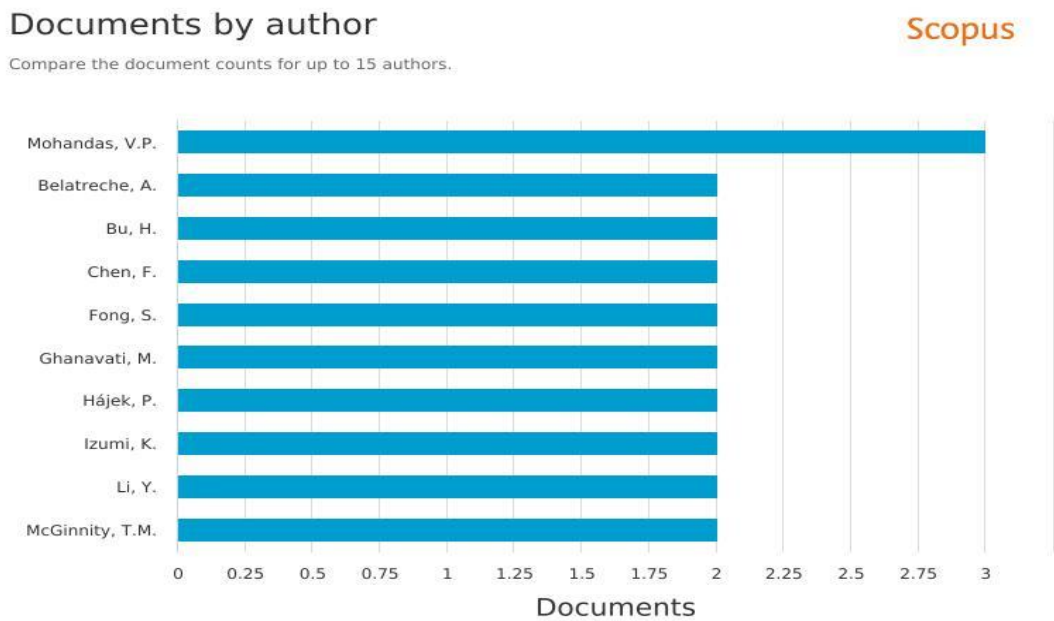

Figure 5. Analysis of publication based on author

Figure 5 depicts the biggest contributors to Stock Market Prediction by applying artificial intelligence. The first ten researchers were considered based on the Scopus website's available statistics.This survey has been the subject of a study published in journal articles, book chapters, conference proceedings, etc. The majority of the Researchers in the field of Stock Market Prediction applying artificial intelligence have published recent research at conferences. There were 73.8% of conference papers, 22.4% of journal articles, 2.2% of review articles, and 1.6% of book chapters as shown in figure 6.

Table 1. Top prolific authors based on citations

Sr. No.	Author Name	Citations	Sr. No.	Author Name	Citations
1	Zhang Y.	420	29	Pan R.	61
2	Ding X.	418	30	Zhang X.-D.	61
3	Duan J.	418	31	Colomo-Palacios R.	59
4	Liu T.	418	32	García-Crespo A.	59
5	Aghabozorgi S.	323	33	Guldrís Iglesias F.	59
6	Khadjeh Nassirtoussi A.	323	34	Gómez-Berbís J.M.	59
7	Ngo D.C.L.	323	35	Rodríguez-González A.	59
8	Ying Wah T.	323	36	Belatreche A.	57
9	De Oliveira R.A.	322	37	Mcginnity T.M.	57
10	Nelson D.M.Q.	322	38	Shynkevich Y.	57
11	Pereira A.C.M.	322	39	Malagrino L.S.	54
12	Ghanbari A.	267	40	Monteiro A.M.	54
13	Hadavandi E.	267	41	Roman N.T.	54
14	Shavandi H.	267	42	Li J.	52
15	Kotecha K.	258	43	Nam K.	49
16	Patel J.	258	44	Seong N.	49
17	Shah S.	258	45	Nayak A.	48
18	Thakkar P.	258	46	Pai R.M.	48
19	Srivastava S.	128	47	Chung H.	43
20	Singh R.	121	48	Li Z.	43
21	Chen M.-Y.	117	49	Shin K.-S.	43
22	Akagi F.	116	50	Coleman S.A.	42
23	Qiu M.	116	51	Romanowski A.	42
24	Song Y.	116	52	Skuza M.	42
25	De Lima B.S.L.P.	87	53	Adekoya A.F.	41
26	Evsukoff A.G.	87	54	Nti I.K.	41
27	Vargas M.R.	87	55	Weyori B.A.	41
28	Li A.	61	56	Pai M.M.M.	40

Table 2. Top prolific countries

Sr. No.	Id	Country	Documents	Citations
1	15	India	40	715
2	6	China	34	715
3	41	United Kingdom	15	175
4	42	United States	11	124
5	1	Australia	10	88
6	37	Taiwan	8	146
7	19	Japan	7	126
8	14	Hong Kong	6	57
9	16	Iran	6	324
10	33	South Korea	6	102

Analysis of Top Prolific Authors based on Citations

Table 2 lists the ten countries with the highest number of English-language publications on stock market forecasting using artificial intelligence. India ranks first with a total of 40 papers. China, the United Kingdom, the United States, Australia, Taiwan, Japan, Hong Kong, Iran, and South Korea are the following highest-documented countries. Out of a total of 183 papers, more than half, or 100 documents, are provided by authors from the top four nations.

Table 3. Top prolific titles based on citations

Sr. No.	Authors	Title	Citation
1	Ding X., Zhang Y., Liu T., Duan J.	Deep learning for event-driven stock prediction	418
2	Khadjeh Nassirtoussi A., Aghabozorgi S., Ying Wah T., Ngo D.C.L.	Text mining for market prediction: A systematic review	323
3	Nelson D.M.Q., Pereira A.C.M., De Oliveira R.A.	Stock market's price movement prediction with LSTM neural networks	322
4	Hadavandi E., Shavandi H., Ghanbari A.	Integration of genetic fuzzy systems and artificial neural networks for stock price forecasting	267
5	Patel J., Shah S., Thakkar P., Kotecha K.	Predicting stock market index using fusion of machine learning techniques	258
6	Singh R., Srivastava S.	Stock prediction using deep learning	121
7	Chen M.-Y.	Predicting corporate financial distress based on integration of decision tree classification and logistic regression	117
8	Qiu M., Song Y., Akagi F.	Application of artificial neural network for the prediction of stock market returns: The case of the Japanese stock market	116
9	Vargas M.R., De Lima B.S.L.P., Evsukoff A.G.	Deep learning for stock market prediction from financial news articles	87
10	Zhang X.-D., Li A., Pan R.	Stock trend prediction based on a new status box method and AdaBoost probabilistic support vector machine	61
11	Rodríguez-González A., García-Crespo A., Colomo-Palacios R., Guldrís Iglesias F., Gómez-Berbís J.M.	CAST: Using neural networks to improve trading systems based on technical analysis by means of the RSI financial indicator	59
12	Malagrino L.S., Roman N.T., Monteiro A.M.	Forecasting stock market index daily direction: A Bayesian Network approach	54
13	Nam K., Seong N.	Financial news-based stock movement prediction using causality analysis of influence in the Korean stock market	49
14	Chung H., Shin K.-S.	Genetic algorithm-optimized multi-channel convolutional neural network for stock market prediction	43
15	Shynkevich Y., McGinnity T.M., Coleman S.A., Belatreche A.	Forecasting movements of health-care stock prices based on different categories of news articles using multiple kernel learning	42
16	Skuza M., Romanowski A.	Sentiment analysis of Twitter data within big data distributed environment for stock prediction	42
17	Nti I.K., Adekoya A.F., Weyori B.A.	A systematic review of fundamental and technical analysis of stock market predictions	41
18	Nayak A., Pai M.M.M., Pai R.M.	Prediction Models for Indian Stock Market	40
19	Batra R., Daudpota S.M.	Integrating Stock Twits with sentiment analysis for better prediction of stock price movement	39
20	Wang S., Yan Z., Hu X., Yu P.S., Li Z.	Burst time prediction in cascades	39

Table 3 contains the titles of the most cited papers and the number of citations they've got as of the date the data for this study have been extracted.

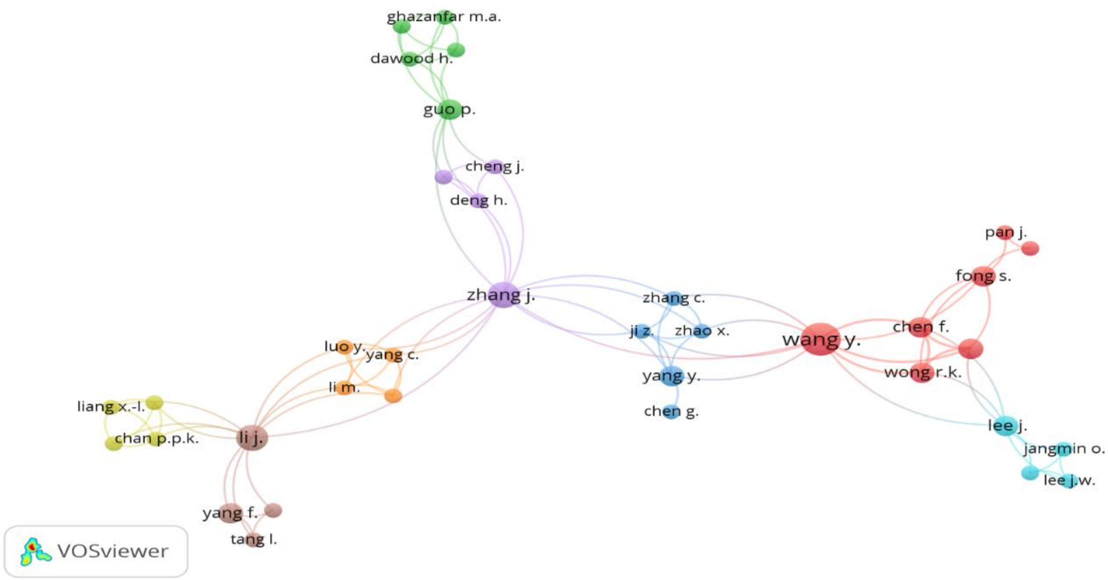

Figure 7. Analysis of co-authorship connection with the other authors

Analysis of Co-authorship Connection

The cluster to which an item belongs determines what colour it is. Lines between things signify links. In Figure 7, there are eight different groups of various colours. These colours show how the authors are connected. In this study, we searched at how eight groups of authors worked together. In the network visualization, each item is shown by its name and, by default, by a circle. A large circle shows how well an author has contributed to a related field.

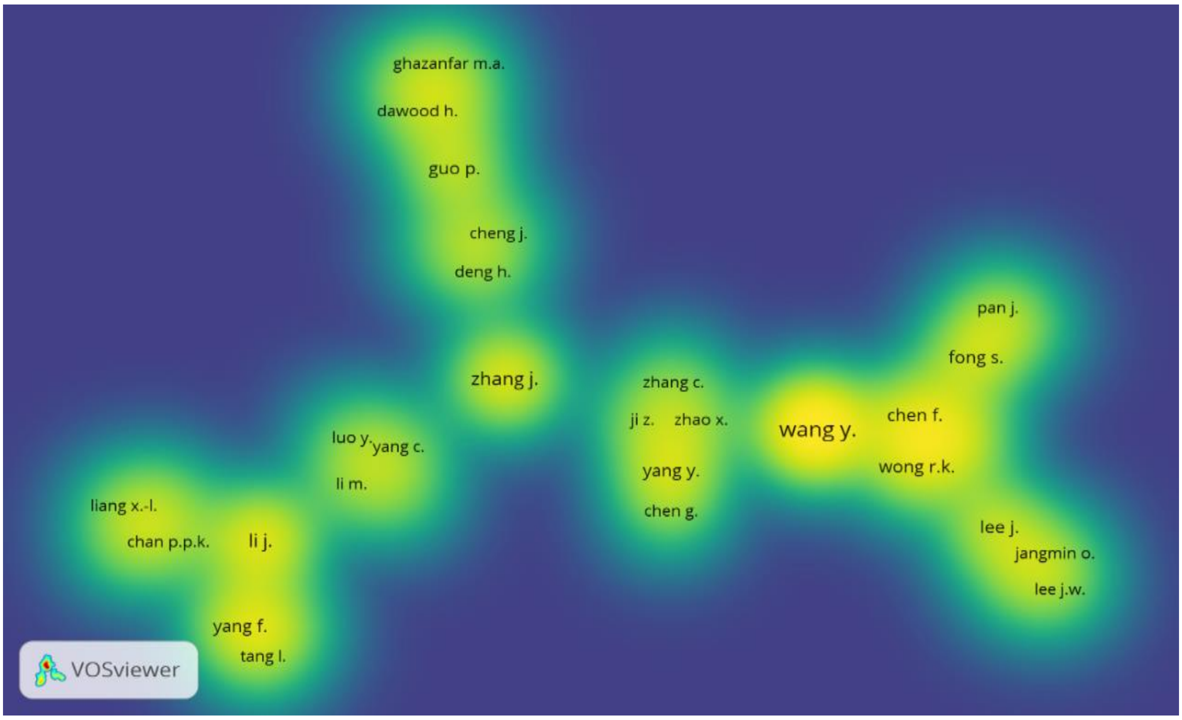

Figure 8. Authorship density visualization

Similar to the network visualisation and the overlay visualisation, authors are represented by their label in the author density view. Each point in the author density image is coloured according to the item density at that location. The default colour palette consists of blue, green, and yellow. The greater the number of things in a point's neighbourhood and the greater their weights, respectively

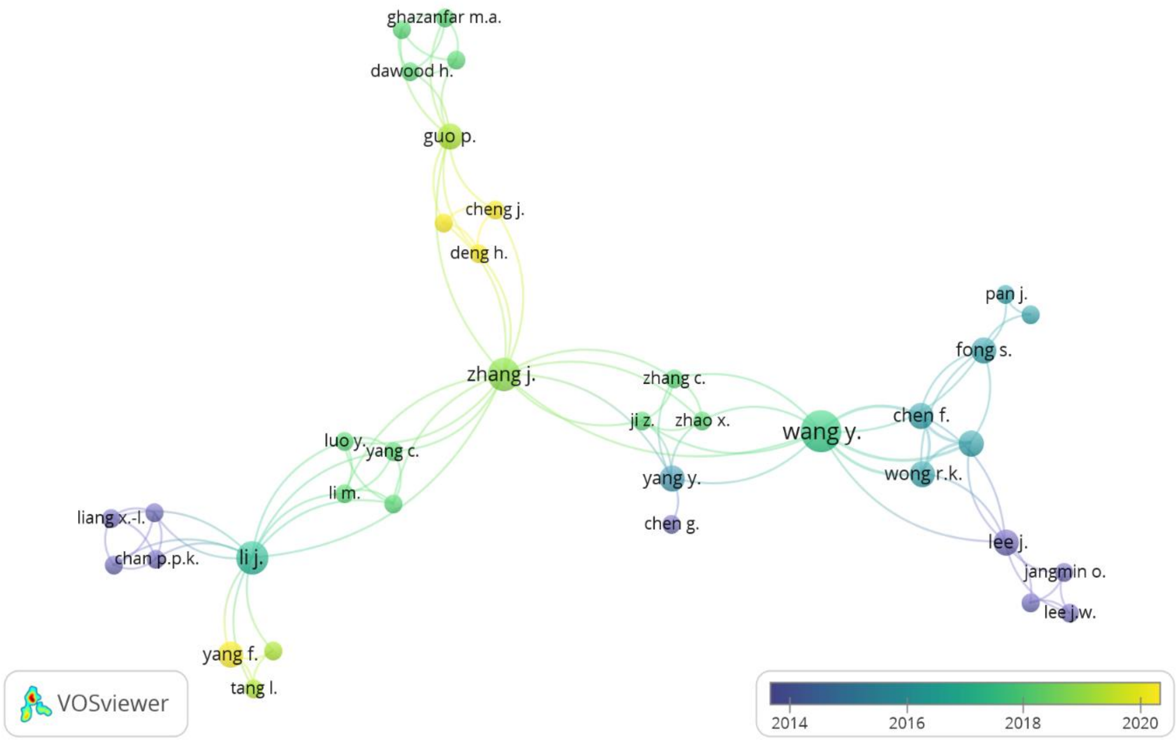

Figure 9. Authorship network overlay visualization

The Prediction of the Stock Market Using Artificial Intelligence is examined using authorship overlay visualization extracted from 183 distinct categories of articles published between 2002 and 2022. The number of publications based on the most prolific author per year is analysed, as shown in figure 9. The majority of articles have been published between 2016 and 2018.

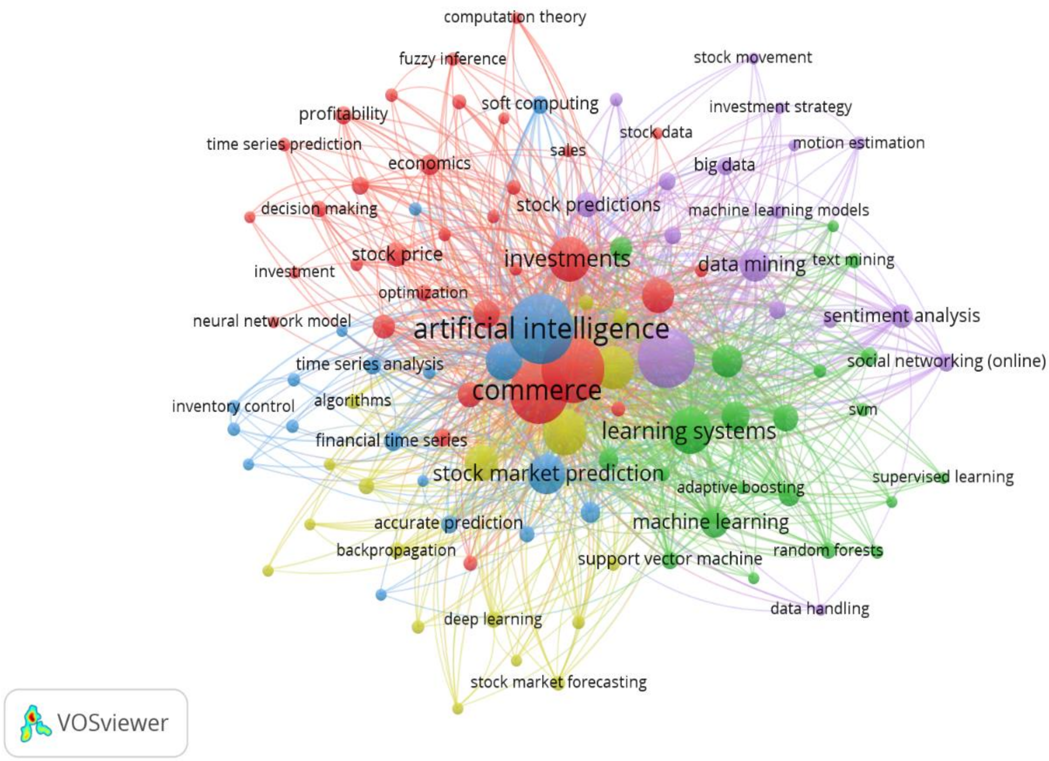

Figure 10. Keywords occurs the maximum number of times

Analysis of Co-occurrence of Keywords

Figure 10 illustrates the co-occurrence analysis of keywords. There are a total of 1,123 terms in the study's database. These 108 keywords that have appeared in the database more than five times are used to generate a keyword map.

Table 4. Keywords occurrences

Id	Keyword	Occurrences	Total Link	Id	Keyword	Occurrences	Total Link
13	Accurate Prediction	12	121	895	Mean Square Error	8	98
21	Adaptive Boosting	5	71	925	Motion Estimation	7	72
43	Algorithms	8	98	945	Multilayer Neural Networks	5	47
72	Artificial Intelligence	167	1708	972	Natural Language Processing Systems	6	84
76	Artificial Intelligence Techniques	7	53	976	Nearest Neighbour Search	5	75
80	Artificial Neural Network	11	128	998	Neural Network	9	131
114	Backpropagation	10	132	1004	Neural Network Model	5	42
115	Backpropagation Algorithms	5	64	1007	Neural Networks	44	519
138	Big Data	11	129	1072	Optimization	10	120
185	Classification (Of Information)	11	138	1121	Prediction	21	241
203	Clustering Algorithms	6	70	1122	Prediction Accuracy	16	176
210	Commerce	130	1423	1127	Prediction Model	8	98
217	Complex Networks	6	83	1132	Prediction Performance	8	96
220	Computation Theory	5	63	1137	Prediction Systems	6	70
224	Computational Intelligence	5	61	1159	Principal Component Analysis	6	72
249	Convolutional Neural Network	5	56	1174	Profitability	11	100
256	Costs	40	488	1189	Random Forest	6	88
277	Data Handling	5	54	1195	Random Forests	9	122
279	Data Mining	37	461	1216	Recurrent Neural Networks	5	55
297	Decision Making	9	98	1224	Regression Analysis	10	91
300	Decision Support System	5	53	1274	Sales	5	66
301	Decision Support Systems	11	118	1305	Sentiment Analysis	19	229
309	Decision Trees	24	303	1330	Signal Processing	7	79
311	Deep Learning	10	111	1351	Social Networking (Online)	12	140

374	Economics	15	166	1355	Soft Computing	12	141
386	Electronic Trading	71	840	1389	Stock Data	5	49
462	Feedforward Neural Networks	5	42	1391	Stock Exchange	6	54
465	Finance	65	788	1395	Stock Forecasting	6	65
472	Financial Data Processing	23	248	1398	Stock Market	50	496
480	Financial Forecasting	5	55	1399	Stock Market Analysis	5	53
489	Financial Markets	124	1397	1401	Stock Market Forecasting	8	95
503	Financial Time Series	13	151	1407	Stock Market Prediction	56	587
508	Fintech	8	73	1410	Stock Market Prices	12	152
515	Forecasting	151	1626	1412	Stock Markets	7	46
552	Fuzzy Inference	6	68	1413	Stock Movement	5	53
555	Fuzzy Logic	8	88	1416	Stock Prediction	12	122
556	Fuzzy Neural Networks	6	53	1418	Stock Predictions	23	233
561	Fuzzy Systems	6	65	1419	Stock Price	19	182
581	Genetic Algorithm	5	63	1421	Stock Price Forecasting	8	86
582	Genetic Algorithms	9	109	1423	Stock Price Movements	11	131
693	Information Science	5	45	1424	Stock Price Prediction	29	327
736	Inventory Control	7	50	1439	Stock Trend Prediction	7	80
737	Investment	5	50	1451	Supervised Learning	5	74
744	Investment Strategy	5	64	1452	Supervised Machine Learning	5	75
745	Investments	68	754	1454	Support Vector Machine	11	140
793	Learning Algorithms	36	480	1457	Support Vector Machines	32	414
799	Learning Systems	74	898	1465	SVM	6	93
843	Machine Learning	31	343	1477	Technical Analysis	7	82
845	Machine Learning Methods	5	52	1481	Technical Indicator	16	189
846	Machine Learning Models	8	100	1493	Text Mining	8	104
849	Machine Learning Techniques	18	251	1513	Time Series	20	212
877	Market Trends	6	53	1514	Time Series Analysis	12	136
879	Marketing	7	50	1519	Time Series Prediction	7	60
887	Mathematical Models	7	61	1553	Trend Prediction	5	55

The keyword map displays relevant keywords that are interconnected through several lines. These lines denote the co-occurrence network map for the Keywords that have co-occurred and are connected. As indicated in Table 4, the most frequently occurring keywords recommend the study fields relating to the keywords that need to be undertaken more in the future.

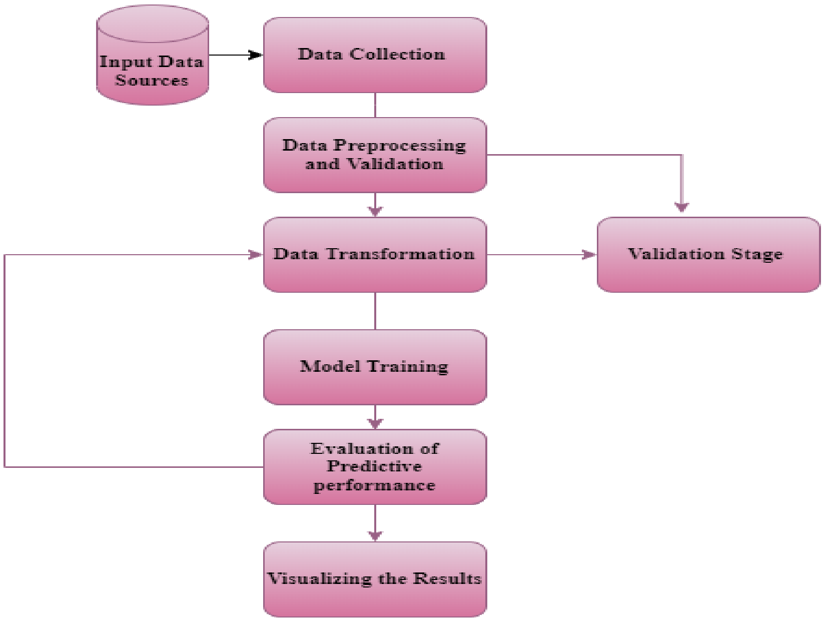

Figure 11. Flowchart for stock market forecasting with artificial intelligence

The scholarly literature on stock prediction has highlighted the rise of various opposing ideas. In contrast to the efficient market theory, numerous researchers (Hargreaves & Hao, 2012; Nti et al., 2020) believe that market prices follow a trend. Following this approach, there are two schools of market analysis: technical analysis defends tendencies in stock price movements and seeks to anticipate them using prior asset prices; and fundamental analysis argues that a firm's socioeconomic background impacts its future stock price and, thus, gives knowledge that may be used to forecast future asset prices. Figure 11 illustrates the overall structure for an Artificial Intelligence prediction model applied to financial forecasting. The initial stage is to collect all of the data needed to train and test the prediction model. These data can be processed, modified, or decreased in order to eliminate noise and emphasise crucial information. The predictor then utilises the treated data to train its model, after which it may tune its hyperparameters in a validation step. Finally, the trained model's performance with tuned hyperparameters must be assessed in a test phase.

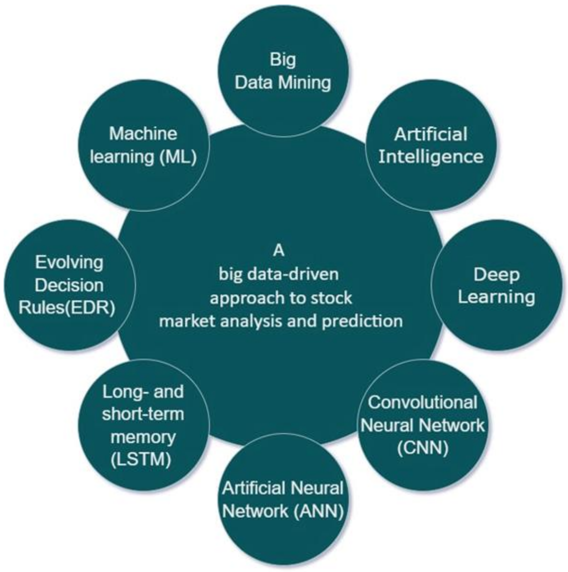

Figure 12. Shows the different techniques to predict the stock market movements

In this portion of the study, we intend to examine the research around the tools and platforms utilized in artificial intelligence for stock price movement prediction. However, for this part, we go beyond the papers originally selected because they frequently do not describe the research methods employed. The stock market is evaluated using the approaches shown in Figure 12: Deep learning; machine learning; neural networks; LSTM, ANN, CNN; and data mining, among others.

Conclusion

In the past two years, a vast number of experimental research has been conducted on stock market prediction using artificial intelligence, as demonstrated by this study. If we discuss the research questions in this study, we must begin with the journal Lecture Notes in Advances in Intelligent Systems and Computing, Lecture Notes in Computer Science, including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics which has the most records. According to the analysis, "Deep learning for event-driven stock prediction" is the title with the highest number of citations and the author with the highest number of citations. Zhang et al., 2018) developed a model of multiple sine functions extraction (MSFE), for example, to anticipate the future stock market, and predicted the Chinese stock market's peak. Artificial Intelligence, Commerce, and forecasting are the keywords that appeared most frequently in the study. Table 2 includes the 10 countries with the most English-language AI stock market forecasting publications. India has 40 papers, the most. China, the UK, the US, Australia, Taiwan, Japan, Hong Kong, Iran, and South Korea are well-documented. The literature of the study classified the five categories for further research: return prediction, stock trend forecasting using artificial intelligence, market sentiment analysis, use of AI in the financial market, and combinations incorporating two or more approaches. Furthermore, an exhaustive comparison analysis was conducted, and it was determined that SVM, DNN and LSTM are the most often utilised approach for stock market prediction(Nelson et al., 2017; Weng et al., 2018; Zhou et al., 2020). Techniques like as ANN and CNN, on the other hand, are widely employed because they generate more accurate and quicker predictions (Wu et al., 2020). In addition, using both market data and textual data from web sources enhances forecast accuracy.

It is evident from the review that much attention is being given to this field of research, and the literature is becoming more specialized and comprehensive. Our findings provide practical advice to market players, particularly traders, investors, and financial institutions, on how artificial intelligence could be utilized to predict stock market movements. The study uses only Scopus database publications, resulting in a blending of research keywords. It does not analyse many databases that contain research publications, such as PubMed, Web of Science, and Google Scholar. These databases have the potential to be considered for future research.

Challenges and Scope for Further Study

The most difficult aspect of reading articles is creating Scopus searches that eliminate irrelevant documents while including as many relevant documents as feasible. The second significant challenge is analysing the staggering number of published articles sorted by clustering. As a result, this work solely looks at the most important articles. Stock prices have recently been forecasted with machine learning techniques based on historical data. There has been a significant development in Deep Learning approaches, which have generated a promising result. Meanwhile, the elements used in various research, including technical and fundamentalist indications, differ significantly. Despite this, little research has been conducted to assess the contribution of each of these features to the performance of the approaches.

Declaration of conflict of interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication.

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Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in EPESS journal belongs to the authors.

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Modeling of Contingent Capital Under a Double Exponential Jump-Diffusion Model with Switching Regime

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Abstract: This paper discusses a theoretical explanation that relies on investment within the framework of a regime-switching structural model whose investment cost is financed by equity and CoCos. The unexpected return of the project is governed by a continuous and temporal Markov chain. Explicit solutions have been proposed under a regime-switching structural model when the value of the cash flows generated by the firm follows a double-exponential step-distribution diffusion process. The equilibrium price theory under the jump diffusion model was developed using the structural model introduced by Leland (1994) and later extended by Kou (2002) and Chen and Kou (2009). The study focused on the influence of contingent convertibles on investment and financing policies and the inefficiencies related to debt overhang and asset substitution in the presence of an investment option.

Keywords: Contingent capital, Jump-diffusion model, Credit risk, Real option.

Introduction

Credit risk is still a major concern in both asset pricing and corporate finance. There are two basic approaches to modeling credit risk: the reduced form model and the structural model. The first model directly allocates credit with an intensity process. The default time in this model is obtained at the first jump times. This model specifies the firm value process and models the balance sheet components as contingent claims on the firm value process. However, the first jump time in structural models is specified by which, the enterprise value falls below a barrier level. Unlike intensity models, structural models are more popular for examining capital structures because they provide information about the components of the balance sheet. One of the earliest structural models dates back to Merton (1974). Later, Black and Cox (1976) extend this model by allowing default to occur before debt maturity. In this context, Longstaf and Schwartz (1995) extend the Black and Cox model by introducing interest rate risk.

In the field of corporate finance, it is well known that the capital structure depends optimally on the financial conditions of the company such as the level of cash flow generated by the company or the value of the unlevered company. Generally, financial conditions change randomly all the time, and more often than not the optimal capital structure that has been established will quickly become obsolete. In order to keep the optimal capital structure stable, one must update the capital structure dynamically and continuously. For example, if a firm is in financial distress, it must retire or issue debt to dynamically adjust the firm's leverage, see Titman and Tsyplakov (2007). Typically, such an adjustment would entail considerable adjustment costs in many situations. For example, if the firm is a small and medium-sized enterprise, the adjustment is very difficult and the adjustment costs are very high (Yang & Zhang, 2013). On the other hand, if a firm has introduced CoCo into its capital structure, to some extent, the adjustment is done automatically and usually does not involve any additional costs (Song & Yan, 2016). Goncharenko et al.Rauf (2021) provided evidence that banks are less likely to issue CoCo

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bonds when their asset values are volatile. In this context, Avdjiev (2020) showed that larger and better capitalized banks are more likely to issue CoCo bonds.

This paper mainly focuses on the business cycle whose value of the firm's cash flows follows an exponential double jump diffusion process. In this sense, Chen (2010) and Bhamra et al. (2010) incorporated the economic cycle into a consumption-based asset pricing model. Guo et al. (2005) addressed an irreversible investment problem related to regime change for a firm that is fully funded by equity. Barucci and Del Viva (2012a) explored the prices of CoCos, direct equity and debt, and the capital structure of the firm with a two-period model.

Yang and Zhao (2015) developed a new form of CoCo called contingent convertible securities when the value of the issuing firm follows a diffusion process with double exponential distribution jumps. However, their research does not account for the change in economic cycle. Pengfei et al. (2017) evaluated a standard model of real options when the cash flow follows an exponential diffusion process with expected return determined by a continuous-time two-state Markov chain. They examined explicit solutions and evaluated the investment option with complete information using the "estimate and verify" method. Also, they provided a free boundary partial differential equation to evaluate the option with partial information. To this end, they solved an optimal stopping problem with a bi-variate Markov process by applying the filtering techniques of Liptser and Shiryayev (1977) and finite difference methods.

Incorporating jumps into the firm value dynamics can solve several problems, to have the uncertainty of triggering a conversion or default event because it creates non-zero credit spreads for short maturities, as Pleger (2012) points out. On the other hand, following Duffie and Lando (2001), incorporating jumps in the firm value process could cause sudden information release. Therefore, it can reduce the conflict-of-interest problem (information asymmetry) between shareholders and bondholders. These jumps can be reflected on significant events, such as the introduction of new products, technical innovations, changes in laws or government policies, and tax or interest rate adjustments. To insert the timing and size of these jumps into the valuation model, it is assumed that the value of the asset follows a diffusion process with jumps of double exponential distribution. This allows us to evaluate an explicit equation for the value of the firm's securities. Based on Merton (1976), the jumps are described by a fish-counting process.

The dynamics of asset value are divided into two processes: a continuous process capturing new information that has a marginal effect on the firm and a diffusion process with jumps capturing instantaneous new information that has a significant impact on the firm. In fact, these jumps are described by two distributions, the first fish distribution is characterized by the intensity of the process and the second exponential distribution is specified by the importance of the jumps. Thus, the value of the company will depend on the importance of each of the jumps as well as the number of jumps during a given period. We note that the different sources of hazards, size of jumps and number of jumps are independent of each other. Jumps in the general model Kou (2002) and Kou and Wang (2003) can be positive or negative. The jump size follows a specific exponential distribution according to the sign of the jump, consequently the name of double exponential function. Recently, Siamak et al. (2022) modeled contingent capital based on a market trigger in double jump diffusion processes for asset values and stock prices. They showed that designing a contingent capital contract with a predetermined and pre-specified conversion ratio is not feasible to maintain a single equilibrium state. The conversion ratio depends on the jump in equity and the conditional expectation of contingent capital at the time of conversion; therefore, it is a random variable at the time of conversion and cannot be assigned a predefined value.

In addition, there is sometimes a sudden change in the project's performance with its continuous variation and therefore a diffusion process with jumps will be more appropriate for the cash flows. The double exponential distribution provides analytical solutions for debt and equity values. Note that the analysis of these solutions is difficult in the standard jump diffusion process. The diffusion process with double exponential distribution jumps is first introduced by Kou (2002). It is a special case of Levy processes. Moreover, the double exponential distribution has a memoryless function that facilitates the computation of expected means and variance terms. The main objective of this paper is to examine the value of the firm in a regime-switching model when the firm's cash flow follows a diffusion process with jumps of double exponential distribution. We attempt to explore the value of the investment option and the timing of the option exercise in a structural model that combines jump risk and regime switching. Indeed, we develop the theory of equilibrium prices under a diffusion process with jumps using a structural model introduced by Leland (1994) and later extended by Kou (2002) and Chen and Kou (2009). We also try in this paper to model the investment decision (behavior) of a firm as a real option and study the optimal policy of the firm in maximizing its equity value.

Regime-Switching Model of a Company with an Investment Option

Consider a probability space (Ω, F, P) on which B is a standard Brownian motion, L represents the two-state continuous-time Markov chain. It is right-continuous with values $\{0,1\}$ without loss of generality and defines bad and good economic regime states, respectively. Let a standard poisson process N of intensity λ. We assume that the process L starts from $i \in \{0,1\}$, for an exponential time distribution with its parameter λ_i until reaching a jump to state $j \in \{0,1\}$, $(j \neq i)$, i.e., λ_i representing the jump intensity from state i to state j. The inter-regime times that are exponentially distributed are independent. Similarly, they are independent of the Brownian motion B and the poisson process N. We consider a firm with no assets in place but initially has a perpetual option to invest at any time in a project by incurring a fixed sunk cost $I > 0$. We also assume that the state variable of our model (cash flow) follows a diffusion process with double exponential distribution jumps, which leads to a more sophisticated and realistic model. For any time t, we obtain a continuous stochastic cash flow denoted x. Time is continuous and infinite, and defined by t where $t \in (0, \infty)$. We note that τ is the constant tax rate that the firm should pay on their revenues, $\tau \in \{0,1\}$. We assume that the firm finances its investment cost with the contingent convertible debt and that the value of the project is equal to the value of the unlevered firm.

After exercising the investment option, the firm's capital structure has three hybrids, equity, risky debt and CoCos. To determine them, we only need to specify their cash flows. Indeed, we assume that the issued debts are perpetual and we specify the coupon rate of the risky debt by c_s (constant) and the coupon rate of the contingent convertible debt by c_c (constant). We denote by x_0^c and x_1^c the two CoCo conversion thresholds and by x_0^b and x_1^b the two risky debt default thresholds that relate to the two regime states of the firm. We assume that 0 and 1 represent the recession and boom regimes of the economy respectively. The indices 0 and 1 express the states of the economic regime $l = 0$ and $l = 1$ respectively. Due to the homogeneity of time in the model, we assume that the CoCo default thresholds and conversion thresholds are time independent. We note that the conversion thresholds are determined exogenously by a financial regulator while the default thresholds are specified endogenously by the firm's shareholders to maximize the value of equity. If a conversion trigger event occurs, shareholders distribute to CoCo holders a fraction noted, β_l, of the equity; where $0 \leq \beta_l \leq 1$ represents the conversion ratio under the regime-switching model. If the firm defaults, a fraction noted, α, of the value of future cash flows will be lost due to bankruptcy costs; where $0 \leq \alpha \leq 1$ is a constant representing the loss rate or bankruptcy rate.

Model Setup

In this paper, we try to determine the prices of the company's securities and the optimal investment problem if the company's cash flow follows a diffusion process with double exponential distribution jumps. To do this, we apply the risk-neutral price theory, the equilibrium price theory under the jump diffusion model and the reverse induction method. Certainly, the objective of the investor is to choose the optimal investment time to maximize the return of the return of the project. For this purpose, we assume that the dynamics of the firm's cash flow follow a diffusion process with double exponential distribution jumps which is determined by:

$$\frac{dX_t}{X_{t^-}} = \mu(L_t)dt + \sigma(L_t)dB_t + d\left(\sum_{i=1}^{N_t} Z_i - 1\right) - \lambda\varepsilon\, dt, \quad (1)$$

with $\mu(L_t)$ and $\sigma(L_t)$ representing the risk-adjusted average and volatility parameters respectively determined by the state L of the economic environment (recession or boom), ε denotes the average percentage of the size jump that is equal to $\mathbb{E}(Z_i - 1)$ where Z_i represents identically independent distributed random jumps with the same non-negative laws defined on (Ω, F, P) and the density of its logarithm follows a double exponential distribution which is expressed as follows:

$$f(y) = p\eta_1 e^{-\eta_1 y} 1_{\{y \geq 0\}} + q\eta_2 e^{\eta_2 y} 1_{\{y < 0\}} \qquad \eta_1 > 1, \qquad \eta_2 > 0 \quad (2)$$

with $p\,, q\ \geq 0$ and $p + q = 1$ representing the jump probabilities up and down respectively, $1/\eta_1$ and $1/\eta_2$ determine the means of the two distributions, respectively. Therefore, the average percentage jump size ε is expressed by the following formula:

$$\varepsilon = \mathbb{E}(Z_i - 1) = \frac{p\eta_1}{\eta_1 - 1} + \frac{q\eta_2}{\eta_2 + 1} - 1 \quad (3)$$

We assume that all processes B, N, L and $\{Z_i\}$ are mutually independent and $Y_i = \ln(Z_i)$. The unique solution of equation (1) is expressed by:

$$X_t = xe^{A_t} \quad (4)$$

Where $A_t = \int_0^t \mu(L_s)\, ds - \int_0^t \left(\frac{\sigma(L_s)^2}{2} + \lambda\varepsilon\right) ds + \int_0^t \sigma(L_s)\, dB_s + \sum_{i=1}^{N_t} Y_i$

Note that $\mu_0 \equiv \mu(0)$, $\mu_1 \equiv \mu(1)$, $\sigma_0 \equiv \sigma(0)$ and $\sigma_1 \equiv \sigma(1)$. Obviously, we assume that $\mu(0) < \mu(1)$, i.e. the expected return to cash flow in a bad economic regime (recession) is low and the expected return to cash flow in a good economic regime (boom) is high. Process A is a Levy process, i.e. a process with stationary and independent increments. According to Pengfei et al. (2017), the Laplace transform of A is the function $g_l(\cdot)$ such that:

$$g_l(\beta) = r + \lambda_l - \frac{1}{2}\sigma_l^2\beta^2 - \left(\mu_l - \frac{1}{2}\sigma_l^2 - \lambda\varepsilon\right)\beta - \lambda\left(\frac{p\eta_1}{\eta_1 - \beta} + \frac{q\eta_2}{\eta_2 + \beta} - 1\right), l \in \{0,1\} \quad (5)$$

To examine the optimal investment behavior, we follow the same approach as Pengfei et al. (2017) except that our study considers the value of the non-leveraged firm as the value of the project. Certainly, any investor aims to maximize the return on the future cash flow of the company by choosing an optimal investment time. Thus, the objective function (the value of the investment option) can be expressed as follows:

$$f(X_t, L_t) = \max_{T_D \in \mathcal{T}} \mathbb{E}\left[\int_{T_D}^{\infty} e^{-r(s-t)} X_s ds - e^{-r(T_D - t)} I |\ \mathcal{F}_t\right], \quad (6)$$

where $r > 0$ denotes the risk-free interest rate, $\mathcal{T}$ denotes a set of all stopping times, $\mathcal{F}_t \equiv \mathcal{F}_t^{L,B,N,X} = \sigma\{L_s, B_s, N_s, X_s | s \leq t\}$ represents the σ-algebra over Ω generated by observations of L, B, N, X up to time t. Note that the value of the option in equation (5) is defined before the triggering of the fault time T_D.

Let $V(X_t;\ L_t)$ be the present value of the future cash flow at time t, i.e. the present value of the project. Therefore, we have:

$$V(X_t;\ L_t) = \mathbb{E}\left[\int_{T_D}^{\infty} e^{-r(s-t)} X_s ds \mid \mathcal{F}_t\right] \quad (7)$$

Using the project present value expression above and the conditional expectation property, the value of the investment option is calculated as follows:

$$f(X_t, L_t) = \max_{T_D \in \mathcal{T}} \mathbb{E}\left[\int_{T_D}^{\infty} e^{-r(T_D - t)} \left(V\left(X_{T_D}, L_{T_D}\right) - I\right) |\mathcal{F}_t\right] \quad (8)$$

Firm Value under a Double Exponential Jump-Diffusion Model with the Regime Switching

Project Value

A European call option is considered as an investment option with a maturity t, payoff f and whose underlying is given by equation (8) (the discounted risk-neutral expectation of its future flow). For a current cash flow level x and a current economic regime state $l \in \{0,1\}$, we note that $V_l(x)$ is the equilibrium price of the project value, which is a function of $(x\ , l)$, i.e. $V_l(x) = V(x, l)$. Since our model is homogeneous, then $V_l(x)$ is independent of time. Thus, applying standard risk-neutral pricing theory, the project value under the regime-switching model must satisfy the following system:

$$\begin{cases} rV_0(x) = (\mu_0 - \lambda\varepsilon)xV_0(x)' + \dfrac{\sigma^2}{2}\, x^2V_0(x)'' + \lambda_0\big(V_1(x) - V_0(x)\big) \\ \qquad + \lambda\mathbb{E}\big(V_0(xe^{Y_i}) - V_0(x)\big) + \xi(x) \\ rV_1(x) = (\mu_0 - \lambda\varepsilon)xV_1(x)' + \dfrac{\sigma^2}{2}\, x^2V_1(x)'' + \lambda_1\big(V_0(x) - V_1(x)\big) \\ \qquad + \lambda\mathbb{E}\big(V_1(xe^{Y_i}) - V_1(x)\big) + \xi(x) \end{cases} \qquad (9)$$

Where $\xi(x_t) = ax_t + b, t \in [0,T_D)$ is an always linear function of the cash rate x up to a stopping time $T_D = inf\{\, t \geq 0 : x_t \notin D\}$, corresponding at the time of the first passage of x from the domain D. At this instant, the company's assets generate a lump sum dividend of the value of the unlevered firm, which can be expressed by the function $(.)$. With a and b are constants to be determined. Hence, the values of $V_0(x)$ and $V_1(x)$ must satisfy the following ordinary differential equations:

$$\begin{cases} rV_0(x) = (\mu_0 - \lambda\varepsilon)xV_0(x)' + \dfrac{\sigma^2}{2}\, x^2V_0(x)'' + \lambda_0\big(V_1(x) - V_0(x)\big) + \lambda\mathbb{E}\big(V_0(xe^{Y_i}) - V_0(x)\big) \\ \qquad + (1-\tau)x \\ rV_1(x) = (\mu_1 - \lambda\varepsilon)xV_1(x)' + \dfrac{\sigma^2}{2}\, x^2V_1(x)'' + \lambda_1\big(V_0(x) - V_1(x)\big) + \lambda\mathbb{E}\big(V_1(xe^{Y_i}) - V_1(x)\big) \\ \qquad + (1-\tau)x \end{cases} \qquad (10)$$

The first term in equation (10) denotes the marginal increase in the value of the unleveraged firm if the cash flow increases by one unit. The second determines the effects of cash flow volatility. The third represents the effects of the stochastic transition of the growth rate on the expected change in the value of the unleveraged firm. The last term indicates the effects of the stochastic transition of the jumps on the expected variation of $V_l(x)$.
Certainly, the return of cash flows (after the option is exercised) is constant. Hence, for a given cash flow level x, and a regime state $l \in \{0,1\}$, the value of the project is expressed as:

$$V_l(x) = q_l x \;, \quad l \in \{0,1\} \quad (11)$$

Where q_l is a constant to be determined. If we substitute equation (11) into (10), we obtain the constant q_l as follows:

$$q_l = \frac{(1-\tau)(r + \lambda_0 + \lambda_1 - \mu_0 - \mu_1 + \mu_l)}{(r + \lambda_1 - \mu_1)(r + \lambda_0 - \mu_0) - \lambda_0\lambda_1}\;, \quad l \in \{0,1\} \quad (12)$$

From the results obtained, we deduce that the value of the investment project is independent of the project risk and it does not depend on jumps. These findings can be attributed to the risk adjustment of the parameter in our model. Furthermore, jumps do not change the project return on average because we have $\sum_{i=1}^{N_t}(Z_i - 1) - \lambda\varepsilon_t$ is a martingale with zero mean.

The Equity Value after Conversion

According to the risk-neutral pricing method, the value of equity after CoCo conversion, $E_l^c(x)$, for $x \in (x_0^b, +\infty)$ is expressed as:

$$\begin{cases} rE_0^c(x) = (\mu_0 - \lambda\varepsilon)xE_0^c(x)' + \dfrac{\sigma^2}{2}\, x^2E_0^c(x)'' + \lambda_0\big(E_1^c(x) - E_0^c(x)\big) + \lambda\mathbb{E}\big(E_0^c(xe^{Y_i}) - E_0^c(x)\big) \\ \qquad + (1-\tau)(x - c_s) \\ rE_1^c(x) = (\mu_1 - \lambda\varepsilon)xE_1^c(x)' + \dfrac{\sigma^2}{2}\, x^2E_1^c(x)'' + \lambda_1\big(E_0^c(x) - E_1^c(x)\big) + \lambda\mathbb{E}\big(E_1^c(xe^{Y_i}) - E_1^c(x)\big) \\ \qquad + (1-\tau)(x - c_s) \end{cases} \qquad (13)$$

For $x \in (x_1^b, x_0^b]$,

$$\begin{cases} E_0^c(x) = 0 \\ rE_1^c(x) = (\mu_0 - \lambda\varepsilon)xE_1^c(x)' + \frac{\sigma^2}{2}x^2E_1^c(x)'' + \lambda_0\big(0 - E_1^c(x)\big) + \lambda\mathbb{E}\big(E_1^c(xe^{Y_i}) - E_1^c(x)\big) \\ +(1-\tau)(x - c_s) \end{cases} \quad (14)$$

And for $x \in (0, x_1^b\,]$,

$$E_0^c(x) = E_1^c(x) = 0 \quad (15)$$

According to Gua et al. (2005), we define the set $[x_l^b, \infty)$ by the continuity region, $(0, x_l^b)$ by the stopping region and $[x_1^b, x_0^b]$ by the transition region. Subsequently, we impose the following smooth-pasting conditions: $E_0^c(x_0^b)' = 0$, $E_1^c(x_1^b)' = 0$ which ensure the continuity of the slopes at the endogenous fault thresholds. We also have, $\lim_{x\to x_0^{b+}} E_1^c(x) = \lim_{x\to x_0^{b-}} E_1^c(x)$.

The solution of equation (13) and (14) is based on equation (5) of Yang and Zhao (2015) and the guess-and-verify method. Thus, the general solutions are expressed as:

$$\begin{cases} E_0^c(x) = \sum_{i=1}^{4} A_i x^{\beta_i} + q_0 x - \frac{(1-\tau)c_s}{r} & if\ x > x_0^b \\ E_1^c(x) = \sum_{i=1}^{4} B_i x^{\beta_i} + q_1 x - \frac{(1-\tau)c_s}{r} & if\ x > x_0^b \\ E_1^c(x) = \sum_{i=1}^{4} C_i x^{\gamma_i} + \frac{(1-\tau)x}{(r+\lambda_1-\mu_1)} - \frac{(1-\tau)c_s}{r+\lambda_1} & if\ x_1^b \le x \le x_0^b \end{cases} \quad (16)$$

- For $x \in (x_0^b, +\infty)$

To determine the value of $E_0^c(x)$ for $x \in (x_0^b, +\infty)$, we impose the following boundary conditions: $E_0^c(x) = q_0 x - \frac{(1-\tau)c_s}{r}$ if $x > x_0^b$ and $E_0^c(x) = 0$ if $x \le x_0^b$. Subsequently, substituting equation the boundary conditions into equation (14), we obtain the solution of the equity value as follows:

$$\frac{\sum_{i=1}^{4} A_i (x_0^b)^{\beta_i}}{\eta_2 + \beta_i} + \frac{q_0 x_0^b}{1+\eta_2} - \frac{(1-\tau)c_s}{r\eta_2} = 0 \quad (17)$$

- For $x \in (x_1^b, x_0^b\,]$

The boundary conditions suitable for the transition region $(x_1^b, x_0^b\,]$ are as follows: $E_1^c(x) = q_1 x - \frac{(1-\tau)c_s}{r}$ if $x > x_0^b$, $E_1^c(x) = \frac{(1-\tau)x}{(r+\lambda_1-\mu_1)} - \frac{(1-\tau)c_s}{r+\lambda_1}$ if $x_1^b \le x \le x_0^b$ and $E_1^c(x) = 0$ if $x < x_1^b$. Substituting the boundary conditions into (14) and (15), we obtain the solutions of the equity value for this region:

$$\frac{\sum_{i=1}^{4} C_i (x_1^b)^{\gamma_i}}{\eta_2 + \gamma_i} + \frac{(1-\tau)}{(r+\lambda_1-\mu_1)}\frac{x_1^b}{1+\eta_2} - \frac{c_s(1-\tau)}{(r+\lambda_1)\eta_2} = 0 \quad (18)$$

$$\frac{\sum_{i=1}^{4} C_i (x_0^b)^{\gamma_i}}{\gamma_i - \eta_1} + \frac{(1-\tau)}{(r+\lambda_1-\mu_1)}\frac{x_0^b}{(1-\eta_1)} - \frac{c_s(1-\tau)}{(r+\lambda_1)(-\eta_1)} - \left(\frac{\sum_{i=1}^{4} B_i (x_0^b)^{\beta_i}}{\beta_i - \eta_1} - \frac{q_1 x_0^b}{1-\eta_1} + \frac{(1-\tau)c_s}{r(-\eta_1)}\right) = 0 \quad (19)$$

To conclude, the value of equity after conversion for different situations and for different states is determined by the following system:

$$E_0^c(x) = \begin{cases} \frac{\sum_{i=1}^{4} A_i x^{\beta_i}}{\eta_2 + \beta_i} + \frac{q_0 x}{1+\eta_2} - \frac{(1-\tau)c_s}{r\eta_2}, & if\ x > x_0^b \\ 0 \quad , & if\ x \le x_0^b \end{cases} \quad (20)$$

$$E_1^c(x) = \begin{cases} \frac{\sum_{i=1}^4 B_i x^{\beta_i}}{\beta_i - \eta_1} + \frac{q_1 x}{1-\eta_1} - \frac{(1-\tau)c_s}{r(-\eta_1)} , & if\ \ x > x_0^b \\ \frac{\sum_{i=1}^4 C_i x^{\gamma_i}}{\eta_2 + \gamma_i} + \frac{(1-\tau)}{(r+\lambda_1-\mu_1)} \frac{x}{1+\eta_2} - \frac{c_s(1-\tau)}{(r+\lambda_1)\eta_2}, & if\ \ x_1^b \le x \le x_0^b \\ 0 \qquad , & if\ \ x < x_1^b \end{cases} \quad (21)$$

The equity value $E_l^c(x)$ in the continuity regime $\left[x_l^b, \infty\right)$ is specified by the following two terms: $q_l x - \frac{(1-\tau)c_s}{r}$ which denotes the value of equity in the absence of default and $\sum_{i=1}^4 A_i x^{\beta_i}$ which offers the change in the value of $E_l^c(x)$ when there is a regime change or when the cash flow level x crosses the default threshold x_l^b. Similarly, in the transient regime $[x_1^b, x_0^b]$, the value of equity is also represented by two terms: the first $\frac{(1-\tau)\lambda_1 x}{(r+\lambda_1-\mu_1)} - \frac{(1-\tau)c_s}{r}$ which determines equity if there is no default, while the second captures the change in $E_l^c(x)$ at the time of default or at the time of the regime change.

We note that;

$$A_i = \frac{\lambda_0}{g_0(\beta_i)} B_i \text{ and } B_i = \frac{\lambda_1}{g_1(\beta_i)} A_i \quad (22)$$

With $i = 1,2,3,4$ and the functions $g_0()$ and $g_1()$ are determined from the equation $g_l(\beta)$. Using equation (22), we obtain the following expression:

$$g_0(\beta) g_1(\beta) = \lambda_0 \lambda_1 \quad (23)$$

The above equation has 8 distinct roots of which four are positive. Based on the study of Pengfei et al. (2017), we deduce that the function $J(\beta) = 0$ has eight real roots and only four of them are positive, where $J(\beta) = (g_0(\beta)g_1(\beta) - \lambda_0\lambda_1)(\eta_1 - \beta)^2(\eta_2 + \beta)^2$. Similarly, we note that $\{\gamma_i\}$ are four roots of the equation $g_0(\gamma_i) = 0$ with $i = 1,2,3,4$ i.e., the parameters to be determined are only the roots of the equation $g_0(\gamma) = 0$.

From the smooth-pasting conditions at the optimal fault thresholds x_0^b and x_1^b, we deduce that the optimal fault thresholds x_0^b and x_1^b must satisfy the system of the following equation:

$$\begin{cases} \sum_{i=1}^{4} A_i (x_0^b)^{\beta_i} \beta_i + q_0 x_0^b = 0 \\ \sum_{i=1}^{4} C_i (x_1^b)^{\gamma_i}\ \gamma_i + \frac{(1-\tau)}{r+\lambda_1-\mu_1} x_1^b = 0 \end{cases} \quad (24)$$

Risky Debt Value under Different Regions

To determine the value of risky debt after the exercise of the investment option under the regime-switching model with jumps, we first consider that there are three different regions. Indeed, for $x \in (x_0^b, +\infty)$, the value $D_l^s(x)$ is expressed as:

$$\begin{cases} rD_0^s(x) = (\mu_0 - \lambda\varepsilon) x D_0^s(x)' + \frac{\sigma^2}{2} x^2 D_0^s(x)'' + \lambda_0\left(D_1^s(x) - D_0^s(x)\right) \\ \qquad + \lambda \mathbb{E}\left(D_0^s(xe^{Y_i}) - D_0^s(x)\right) + c_s \\ rD_1^s(x) = (\mu_1 - \lambda\varepsilon) x D_1^s(x)' + \frac{\sigma^2}{2} x^2 D_1^s(x)'' + \lambda_1\left(D_0^s(x) - D_1^s(x)\right) \\ \qquad + \lambda \mathbb{E}\left(D_1^s(xe^{Y_i}) - D_1^s(x)\right) + c_s \end{cases} \quad (25)$$

For $x \in (x_1^b, x_0^b)$,

$$\begin{cases} D_0^s(x) = (1-\alpha)q_0 x & (26) \\ rD_1^s(x) = (\mu_1 - \lambda\varepsilon)xD_1^s(x)' + \frac{\sigma^2}{2}x^2 D_1^s(x)'' + \lambda_1\big((1-\alpha)q_0 x - D_1^s(x)\big) \\ \qquad +\lambda\mathbb{E}\big(D_1^s(xe^{Y_i}) - D_1^s(x)\big) + c_s \end{cases}$$

And For $x \in (0, x_1^b)$,

$$\begin{cases} D_0^s(x) = (1-\alpha)q_0 x \\ D_1^s(x) = (1-\alpha)q_1 x \end{cases} \quad (27)$$

According to Yang and Zhao (2015) and the guess-and-verify method, the general solutions of the stochastic differential equations of (25) and (26) are expressed as:

$$\begin{cases} D_0^s(x) = \sum_{i=1}^{4} A_{4+i}\, x^{\beta_i} + \frac{c_s}{r} & if\ \ x > x_0^b \\ D_1^s(x) = \sum_{i=1}^{4} B_{4+i} x^{\beta_i} + \frac{c_s}{r} & if\ \ x < x_1^b \\ D_1^s(x) = \sum_{i=1}^{4} C_{4+i}\, x^{\gamma_i} + \frac{(1-\alpha)\lambda_1 q_0 x}{(r+\lambda_1-\mu_1)} + \frac{c_s}{r+\lambda_1} & if\ \ x_1^b < x < x_0^b \end{cases} \quad (28)$$

- For $x \in (x_0^b, +\infty)$

To examine the value of the risky debt if $x \in (x_0^b, +\infty)$, we impose the following boundary conditions: $D_0^s(x) = \frac{c_s}{r}$ if $x > x_0^b$ and $D_0^s(x) = (1-\alpha)q_0 x$ if $x \le x_0^b$. Substituting equation the boundary conditions into equation (25), we obtain the value of risky debt after the investment, which is represented by the following expression:

$$\frac{(1-\alpha)q_0 x_0^b}{1+\eta_2} - \frac{\sum_{i=1}^{4} A_{4+i}\, {x_0^b}^{\beta_i}}{\eta_2+\beta_i} - \frac{c_s}{r\eta_2} = 0 \quad (29)$$

- For $x \in (x_1^b, x_0^b)$

Referring to Luo and Yang (2017), we impose the following boundary conditions on risky debt: $D_1^s(x) = \frac{c_s}{r}$ if $x > x_0^b$, $D_1^s(x) = \frac{(1-\alpha)\lambda_1 q_0 x}{(r+\lambda_1-\mu_1)} + \frac{c_s}{r+\lambda_1}$ if $x_1^b \le x \le x_0^b$ and $D_1^s(x) = (1-\alpha)q_1 x$ if $x < x_1^b$. If we substitute the boundary conditions in the ODE (25) and (26), then the value of the risky debt is defined by the following solutions:

$$\frac{(1-\alpha)q_1 x_1^b}{1+\eta_2} - \left(\frac{\sum_{i=1}^{4} C_{i+4}(x_1^b)^{\gamma_i}}{\eta_2+\gamma_i} + \frac{(1-\alpha)\lambda_1 q_0}{(r+\lambda_1-\mu_1)}\frac{x_1^b}{1+\eta_2} + \frac{c_s}{(r+\lambda_1)\eta_2}\right) = 0 \quad (30)$$

$$\frac{\sum_{i=1}^{4} C_{i+4}(x_0^b)^{\gamma_i}}{\gamma_i-\eta_1} + \frac{(1-\alpha)\lambda_1 q_0}{(r+\lambda_1-\mu_1)}\frac{x_0^b}{1-\eta_1} + \frac{c_s}{(r+\lambda_1)(-\eta_1)} - \frac{\sum_{i=1}^{4} B_{i+4}(x_0^b)^{\gamma_i}}{\beta_i-\eta_1} - \frac{c_s}{r(-\eta_1)} = 0 \ (31)$$

The results obtained for the two regimes $l = \{0,1\}$ are summarized by the following system of equation:

$$D_0^s(x) = \begin{cases} \frac{\sum_{i=1}^{4} A_{i+4} x^{\beta_i}}{\eta_2+\beta_i} + \frac{c_s}{r\eta_2}, & if\ x > x_0^b \\ \frac{(1-\alpha)q_0 x}{1+\eta_2}, & if\ x \le x_0^b \end{cases} \quad (32)$$

$$D_1^s(x) = \begin{cases} \frac{\sum_{i=1}^4 B_{i+4} x^{\beta_i}}{\beta_i - \eta_1} + \frac{c_s}{r(-\eta_1)} & , \quad if\ x > x_0^b \\ \frac{\sum_{i=1}^4 C_{i+4} x^{\gamma_i}}{\eta_2 + \gamma_i} + \frac{(1-\alpha)\lambda_1 q_0}{(r+\lambda_1-\mu_1)} \frac{x}{1+\eta_2} + \frac{c_s}{(r+\lambda_1)\eta_2} & , \quad if\ x_1^b \le x \le x_0^b \\ \frac{(1-\alpha) q_1 x}{1+\eta_2} & \quad x < x_1^b \end{cases} \quad (33)$$

The value of the risky debt is equal to the value of the perpetual coupons c_s plus the change in the value of the risky debt at a regime change or default time of the firm T_D (the state variable x reaches the default threshold x_l^b).

The Equity Value before Conversion

In order to obtain the value of equity after the exercise of the investment option prior to the conversion of the contingent convertible debt, $E_l(x)$, we must first identify the conversion time and subsequently determine the value of the conversion threshold. Indeed, following Glasserman and Nouri (2012), we assume that the conversion event is triggered at the moment when the value of the unlevered firm is less than or equal to the value of the levered firm. Therefore, we can define the conversion time by the following expression:

$$T_l^c = inf\left\{t \ge 0 : \psi V_l(x_l^c) \le \frac{c_s + c_c}{r}\right\} \quad l \in \{0,1\} \ (34)$$

And therefore, the conversion threshold in a regime-switching model is expressed as:

$$x_l^c = \frac{1}{\psi q_l} \frac{c_s + c_c}{r} \qquad \psi \in (0,1) \quad (35)$$

As $E_l^c(x)$ determines the value of equity after conversion, x_l^c represents the conversion barrier and c_c denotes the coupon rate of the CoCo debt paid continuously, hence referring to Barucci and Del Viva (2013), the conversion rate in a regime-switching model is defined by, $\beta_l = min\left(\frac{\frac{c_c}{r}}{E_l^c(x_l^c)}, 1\right)$, where $l \in \{0,1\}$.

We now represent the value of equity before CoCo conversion for the three regions we specified earlier. In fact, for $x \in (x_0^c, \infty)$, the equity value must satisfy the following equation:

$$\begin{cases} rE_0(x) = (\mu_0 - \lambda\varepsilon) x E_0(x)' + \frac{\sigma^2}{2} x^2 E_0(x)'' + \lambda_0\big(E_1(x) - E_0(x)\big) + \lambda \mathbb{E}\big(E_0(xe^{Y_i}) - E_0(x)\big) \\ \qquad + (1-\tau)(x - c_s - c_c) \\ rE_1(x) = (\mu_1 - \lambda\varepsilon) x D_1^s(x)' + \frac{\sigma^2}{2} x^2 E_1(x)'' + \lambda_1\big(E_0(x) - E_1(x)\big) + \lambda \mathbb{E}\big(E_1(xe^{Y_i}) - E_1(x)\big) \\ \qquad + (1-\tau)(x - c_s - c_c) \end{cases} \quad (36)$$

For $x \in (x_1^c, x_0^c)$,

$$\begin{cases} E_0(x) = (1-\beta)\left(\sum_{i=1}^4 A_i x^{\beta_i} + q_0 x - \frac{(1-\tau)c_s}{r}\right) \quad (37) \\ rE_1(x) = (\mu_1 - \lambda\varepsilon) x E_1(x)' + \frac{\sigma^2}{2} x^2 E_1(x)'' + \lambda_1\left((1-\beta)\left(\sum_{i=1}^4 A_i x^{\beta_i} + q_0 x - \frac{(1-\tau)c_s}{r}\right) - E_1(x)\right) \\ \qquad + \lambda \mathbb{E}\big(E_1(xe^{Y_i}) - E_1(x)\big) + (1-\tau)(x - c_s - c_c) \end{cases}$$

And for $x \in (0, x_1^c)$,

$$\begin{cases} E_0(x) = (1-\beta)\left(\sum_{i=1}^{4} A_i x^{\beta_i} + q_0 x - \frac{(1-\tau)c_s}{r}\right) \\ E_1(x) = (1-\beta)\left(\sum_{i=1}^{4} B_i x^{\beta_i} + q_1 x - \frac{(1-\tau)c_s}{r}\right) \end{cases} \quad (38)$$

Similarly, referring to Yang and Zhao (2015) and the guess-and-verify method to solve the ODE of (37) and (38). Thus, these solutions must satisfy the following equations:

$$\begin{cases} E_0(x) = \sum_{i=1}^{4} A_{i+8} x^{\beta_i} + q_0 x - \frac{(1-\tau)(c_s+c_c)}{r} & if\ x > x_0^c \\ E_1(x) = \sum_{i=1}^{4} B_{i+8} x^{\beta_i} + q_1 x - \frac{(1-\tau)(c_s+c_c)}{r} & if\ x > x_0^c \\ E_1(x) = \sum_{i=1}^{4} C_{i+8} x^{\gamma_i} + \frac{(1-\tau)\lambda_1 x}{(r+\lambda_1-\mu_1)} - \frac{(1-\tau)(c_s+c_c)}{r+\lambda_1} & if\ x_1^c \le x \le x_0^c \end{cases} \quad (39)$$

➢ For $x \in (x_0^c, \infty)$:

The equity value for this region is determined in two steps, first we impose the boundary conditions for $l = 0$: $E_0(x) = q_0 x - \frac{(1-\tau)(c_s+c_c)}{r}$ if $x > x_0^c$ and $E_0(x) = (1-\beta)\left(\sum_{i=1}^{4} A_i x^{\beta_i} + q_0 x - \frac{(1-\tau)c_s}{r}\right)$ if $x \le x_0^c$. Second, we substitute equation the boundary conditions into (36). Thus, the solutions of the equity value $E_0(x)$ is determined by:

$$(1-\beta)\left(\frac{\sum_{i=1}^{4} A_{i+8}(x_0^c)^{\beta_i}}{\eta_2+\beta_i} + \frac{q_0 x_0^c}{1+\eta_2} - \frac{(1-\tau)c_s}{r\eta_2}\right) - \left(\frac{\sum_{i=1}^{4} A_{i+8}(x_0^c)^{\beta_i}}{\eta_2+\beta_i} + \frac{q_0 x_0^c}{1+\eta_2} - \frac{(1-\tau)(c_s+c_c)}{r\eta_2}\right) = 0 \quad (40)$$

➢ For $x \in (x_1^c, x_0^c)$

Then, we impose the following boundary conditions in the transitional regime $[x_1^c, x_0^c]$: $E_1(x) = q_1 x - \frac{(1-\tau)(c_s+c_c)}{r}$ if $x > x_0^c$, $E_1(x) = \frac{(1-\tau)\lambda_1 x}{(r+\lambda_1-\mu_1)} - \frac{(1-\tau)(c_s+c_c)}{r+\lambda_1} + (1-\beta)\left(\sum_{i=1}^{4} B_i x^{\beta_i} + \frac{q_0 x \lambda_1}{(r+\lambda_1-\mu_1)} - \frac{\lambda_1(1-\tau)c_s}{(r+\lambda_1)r}\right)$ if $x_1^c \le x \le x_0^c$ and $E_1(x) = (1-\beta)\left(\sum_{i=1}^{4} B_i x^{\beta_i} + q_1 x - \frac{(1-\tau)c_s}{r}\right)$ if $x < x_1^c$. We integrate the boundary conditions into equation (37), we find that the value of the equity $E_1(x)$ in the region where $x \in (x_1^c, x_0^c)$ is represented by the following solutions:

$$\begin{aligned} &(1-\beta)\left(\frac{\sum_{i=1}^{4} B_i(x_1^c)^{\beta_i}}{\eta_2+\beta_i} + \frac{q_1 x_1^c}{1+\eta_2} - \frac{(1-\tau)c_s}{r\eta_2}\right) \\ &\quad - \left[\frac{\sum_{i=1}^{4} C_{i+8}(x_1^c)^{\gamma_i}}{\eta_2+\gamma_i} + \frac{(1-\tau)}{(r+\lambda_1-\mu_1)}\frac{x_1^c}{1+\eta_2} - \frac{(1-\tau)(c_s+c_c)}{(r+\lambda_1)\eta_2} \right. \\ &\quad \left. + (1-\beta)\left(\frac{\sum_{i=1}^{4} B_i(x_1^c)^{\beta_i}}{\eta_2+\beta_i} + \frac{q_0\lambda_1}{(r+\lambda_1-\mu_1)}\frac{x_1^c}{1+\eta_2} - \frac{\lambda_1(1-\tau)c_s}{(r+\lambda_1)r\eta_2}\right)\right] = 0 \quad (41) \end{aligned}$$

$$\begin{aligned} &\frac{\sum_{i=1}^{4} C_{i+8}(x_0^c)^{\gamma_i}}{\gamma_i-\eta_1} + \frac{(1-\tau)}{(r+\lambda_1-\mu_1)}\frac{x_0^c}{1-\eta_1} - \frac{(1-\tau)(c_s+c_c)}{r+\lambda_1} \\ &\quad + (1-\beta)\left(\frac{\sum_{i=1}^{4} B_i(x_0^c)^{\beta_i}}{\beta_i-\eta_1} + \frac{q_0\lambda_1}{(r+\lambda_1-\mu_1)}\frac{x_0^c}{1-\eta_1} - \frac{\lambda_1(1-\tau)c_s}{(r+\lambda_1)r(-\eta_1)}\right) \\ &\quad - \left[\frac{\sum_{i=1}^{4} B_{i+8}(x_0^c)^{\gamma_i}}{\beta_i-\eta_1} + \frac{q_1 x_0^c}{1-\eta_1} - \frac{(1-\tau)(c_s+c_c)}{r(-\eta_1)}\right] = 0 \quad (42) \end{aligned}$$

The value of equity before conversion in different situations is summarized by the following equation:

$$E_0(x) = \begin{cases} \dfrac{\sum_{i=1}^{4} A_{i+8} x^{\beta_i}}{\eta_2 + \beta_i} + \dfrac{q_0 x}{1+\eta_2} - \dfrac{(1-\tau)(c_s + c_c)}{r\eta_2}, & if\ x > x_0^c \\ (1-\beta)\left(\dfrac{\sum_{i=1}^{4} A_i x^{\beta_i}}{\eta_2 + \beta_i} + \dfrac{q_0 x}{1+\eta_2} - \dfrac{(1-\tau)c_s}{r\eta_2}\right), & if\ x \le x_0^c \end{cases} \quad (43)$$

$$E_1(x) = \begin{cases} \dfrac{\sum_{i=1}^{4} B_{i+8} x^{\beta_i}}{\beta_i - \eta_1} + \dfrac{q_1 x}{1-\eta_1} - \dfrac{(1-\tau)(c_s + c_c)}{r(-\eta_1)}, & if\ x > x_0^c \\ \dfrac{\sum_{i=1}^{4} C_{i+8} x^{\gamma_i}}{\gamma_i - \eta_1} + \dfrac{(1-\tau)}{(r+\lambda_1-\mu_1)}\dfrac{x}{1-\eta_1} - \dfrac{(1-\tau)(c_s+c_c)}{r+\lambda_1} + & \\ (1-\beta)\left(\dfrac{\sum_{i=1}^{4} B_i x^{\beta_i}}{\beta_i - \eta_1} + \dfrac{q_0\lambda_1}{(r+\lambda_1-\mu_1)}\dfrac{x}{1-\eta_1} - \dfrac{\lambda_1(1-\tau)c_s}{(r+\lambda_1)r(-\eta_1)}\right), & if\ x_0^c \le x \le x_1^c \\ (1-\beta)\left(\dfrac{\sum_{i=1}^{4} B_i x^{\beta_i}}{\eta_2 + \beta_i} + \dfrac{q_1 x}{1+\eta_2} - \dfrac{(1-\tau)c_s}{r\eta_2}\right), & if\ x < x_1^c \end{cases} \quad (44)$$

The equity value $E_l(x)$ in the continuity regime $[x_l^b, \infty)$ is composed by the following two components: the first $q_l x - \frac{(1-\tau)(c_s+c_c)}{r}$ determines the equity value if there is no conversion event and the second captures the change in the $E_l(x)$ value at the time of the regime change or if a conversion trigger event occurs. Equivalently, the equity value in the transitional regime $[x_1^b, x_0^b]$ is composed by two the following two terms: the first $\frac{(1-\tau)\lambda_1 x}{(r+\lambda_1-\mu_1)} - \frac{(1-\tau)(c_s+c_c)}{r+\lambda_1}$ specifies the value $E_l(x)$ if there is no conversion and the second defines the change in the equity value $E_l(x)$ at the time of conversion or at the time of regime change.

The Value of the Contingent Convertible Debt CoCo

The value of equity after the conversion of CoCo $D_l^c(x)$ for $x \in (x_0^c, +\infty)$ is expressed as:

$$\begin{cases} rD_0^c(x) = (\mu_0 - \lambda\varepsilon)xD_0^c(x)' + \dfrac{\sigma^2}{2}x^2 D_0^c(x)'' + \lambda_0\left(D_1^c(x) - D_0^c(x)\right) \\ \qquad + \lambda\mathbb{E}\left(D_0^c(xe^{Y_i}) - D_0^c(x)\right) + c_c \\ rD_1^c(x) = (\mu_0 - \lambda\varepsilon)xD_1^c(x)' + \dfrac{\sigma^2}{2}x^2 D_1^c(x)'' + \lambda_1\left(D_0^c(x) - D_1^c(x)\right) \\ \qquad + \lambda\mathbb{E}\left(D_1^c(xe^{Y_i}) - D_1^c(x)\right) + c_c \end{cases} \quad (45)$$

For $x \in (x_1^c, x_0^c]$,

$$\begin{cases} D_0^c(x) = \beta\left(\sum_{i=1}^{4} A_i x^{\beta_i} + q_0 x - \dfrac{(1-\tau)c_s}{r}\right) & (46) \\ rD_1^c(x) = (\mu_0 - \lambda\varepsilon)xD_1^c(x)' + \dfrac{\sigma^2}{2}x^2 D_1^c(x)'' + \lambda_0\left(\beta\left(\sum_{i=1}^{4} A_i x^{\beta_i} + q_0 x - \dfrac{(1-\tau)c_s}{r}\right) - D_1^c(x)\right) \\ \qquad + \lambda\mathbb{E}\left(D_1^c(xe^{Y_i}) - D_1^c(x)\right) + c_c \end{cases}$$

And for $x \in (0, x_1^c]$,

$$\begin{cases} D_0^c(x) = \beta\left(\sum_{i=1}^{4} A_i x^{\beta_i} + q_0 x - \dfrac{(1-\tau)c_s}{r}\right) \\ D_1^c(x) = \beta\left(\sum_{i=1}^{4} B_i x^{\beta_i} + q_1 x - \dfrac{(1-\tau)c_s}{r}\right) \end{cases} \quad (47)$$

The ODE solution of (45) and (46) is based on the solution of equation (5) in Yang and Zhao (2015). Thus, the solutions of these differential equations are represented by:

$$\begin{cases} D_0^c(x) = \sum_{i=1}^{4} A_{i+12} x^{\beta_i} + \frac{c_c}{r} & if\ x > x_0^c \\ D_1^c(x) = \sum_{i=1}^{4} B_{i+12} x^{\beta_i} + \frac{c_c}{r} & if\ x > x_0^c \\ D_1^c(x) = \sum_{i=1}^{4} C_{i+12} x^{\gamma_i} + \frac{c_c}{r+\lambda_1} + \\ \beta\left(\sum_{i=1}^{4} B_i x^{\beta_i} + \frac{q_0 x \lambda_1}{(r+\lambda_1-\mu_1)} - \frac{\lambda_1(1-\tau)c_s}{(r+\lambda_1)r}\right) & if\ x_1^c \le x \le x_0^c \end{cases} \quad (48)$$

- For $x \in (x_0^c, +\infty)$

In order to obtain the CoCo value $D_0^c(x)$ for $x \in (x_0^c, +\infty)$, we impose the following boundary conditions: $D_0^c(x) = \frac{c_c}{r}$ if $x > x_0^c$ and $D_0^c(x) = \beta\left(\sum_{i=1}^{4} A_i x^{\beta_i} + q_0 x - \frac{(1-\tau)c_s}{r}\right)$ if $x \le x_0^c$. We integrate the boundary conditions into equations (45), we obtain the CoCo value is expressed as follows:

$$\beta\left(\frac{\sum_{i=1}^{4} A_i (x_0^c)^{\beta_i}}{\eta_2+\beta_i} + \frac{q_0 x_0^c}{1+\eta_2} - \frac{(1-\tau)c_s}{r\eta_2}\right) - \left(\frac{\sum_{i=1}^{4} A_{i+12}(x_0^c)^{\beta_i}}{\eta_2+\beta_i} + \frac{c_c}{r\eta_2}\right) = 0 \quad (49)$$

- For $x \in (x_1^c, x_0^c)$

Similarly, to obtain the value of the CoCo debt in the region (x_1^c, x_0^c), we impose the boundary conditions as follows: $D_1^c(x) = \frac{c_c}{r}$ if $x > x_0^c$, $D_1^c(x) = \beta\left(\sum_{i=1}^{4} B_i x^{\beta_i} + \frac{q_0 x \lambda_1}{(r+\lambda_1-\mu_1)} - \frac{\lambda_1(1-\tau)c_s}{(r+\lambda_1)r}\right) + \frac{c_c}{r+\lambda_1}$ if $x_1^c \le x \le x_0^c$ and $D_1^c(x) = \beta\left(\sum_{i=1}^{4} B_i x^{\beta_i} + q_1 x - \frac{(1-\tau)c_s}{r}\right)$ if $x < x_1^c$. We now substitute the boundary conditions into equation (46), from which the value of the CoCo debt is determined by the following solutions:

$$\beta\left(\frac{\sum_{i=1}^{4} B_i (x_1^c)^{\beta_i}\eta_2}{\eta_2+\beta_i} + \frac{q_1 x_1^c}{1+\eta_2} - \frac{(1-\tau)c_s}{r\eta_2}\right) - \left(\frac{\sum_{i=1}^{4} C_{i+12}(x_1^c)^{\gamma_i}}{\eta_2+\gamma_i} + \frac{c_c}{(r+\lambda_1)\eta_2} + \beta\left(\frac{\sum_{i=1}^{4} B_i (x_1^c)^{\beta_i}\eta_2}{\eta_2+\beta_i} + \frac{q_0\lambda_1}{(r+\lambda_1-\mu_1)}\frac{x_1^c}{1+\eta_2} - \frac{\lambda_1(1-\tau)c_s}{(r+\lambda_1)r\eta_2}\right)\right) = 0 \quad (50)$$

$$\frac{\sum_{i=1}^{4} C_{i+12}(x_0^c)^{\gamma_i}}{\gamma_i-\eta_1} + \frac{c_c}{(r+\lambda_1)(-\eta_1)} + \beta\left(\frac{\sum_{i=1}^{4} B_i (x_0^c)^{\beta_i}}{\beta_i-\eta_1} + \frac{q_0\lambda_1}{(r+\lambda_1-\mu_1)}\frac{x_0^c}{1-\eta_1} - \frac{\lambda_1(1-\tau)c_s}{(r+\lambda_1)r(-\eta_1)}\right) - \left(\frac{\sum_{i=1}^{4} B_{i+12}(x_0^c)^{\beta_i}}{\beta_i-\eta_1} + \frac{c_c}{r(-\eta_1)}\right) = 0 \quad (51)$$

The value of CoCo can be summarized by the following system:

$$D_0^c(x) = \begin{cases} \sum_{i=1}^{4} A_{i+12}\frac{(x_0^c)^{\beta_i}}{\eta_2+\beta_i} + \frac{c_c}{r\eta_2}, & if\ x > x_0^c \\ \beta\left(\frac{\sum_{i=1}^{4} A_i (x_0^c)^{\beta_i}}{\eta_2+\beta_i} + \frac{q_0 x_0^c}{1+\eta_2} - \frac{(1-\tau)c_s}{r\eta_2}\right) & if\ x \le x_0^c \end{cases} \quad (52)$$

$$D_1^c(x) = \begin{cases} \frac{\sum_{i=1}^{4} B_{i+12}(x_0^c)^{\beta_i}}{\beta_i - \eta_1} + \frac{c_c}{r(-\eta_1)} & , \quad if\ x > x_0^c \\ \frac{\sum_{i=1}^{4} C_{i+12}(x_0^c)^{\gamma_i}}{\gamma_i - \eta_1} + \frac{c_c}{(r+\lambda_1)(-\eta_1)} + \beta \left(\frac{\sum_{i=1}^{4} B_i (x_0^c)^{\beta_i}}{\beta_i - \eta_1} + \frac{q_0 \lambda_1}{(r+\lambda_1-\mu_1)} \frac{x_0^c}{(1-\eta_1)} - \frac{\lambda_1 (1-\tau) c_s}{(r+\lambda_1) r(-\eta_1)} \right) & if\ x_1^c \le x \le x_0^c \\ \beta \left(\frac{\sum_{i=1}^{4} B_i (x_1^c)^{\beta_i} \eta_2}{\eta_2 + \beta_i} + \frac{q_1 x_1^c}{1+\eta_2} - \frac{(1-\tau)c_s}{r\eta_2} \right) & if\ x < x_1^c \end{cases} \quad (53)$$

The value of the contingent convertible debt is determined by the value of the perpetual coupon payments c_c plus the change in the value of the convertible debt CoCo at the time of the regime change or at conversion, i.e. when the state variable x crosses the conversion threshold x_l^c.

The total value of the firm before conversion $V_l^T(x)$, is determined by the sum of the value of risky debt before conversion, the value of equity and the value of CoCo. It is expressed as:

$$V_0^T(x) = D_0^c(x) + D_0^s(x) + E_0(x)$$

$$V_0^T(x) = \frac{\sum_{i=1}^{4} A_{i+12} x^{\beta_i}}{\eta_2 + \beta_i} + \frac{\sum_{i=1}^{4} A_{i+4} x^{\beta_i}}{\eta_2 + \beta_i} + \frac{\sum_{i=1}^{4} A_{i+8} x^{\beta_i}}{\eta_2 + \beta_i} + \frac{q_0 x}{1+\eta_2} + \frac{\tau(c_s + c_c)}{r\eta_2} \quad (54)$$

$$V_1^T(x) = D_1^c(x) + D_1^s(x) + E_1(x)$$

$$V_1^T(x) = \frac{\sum_{i=1}^{4} B_{i+12} x^{\beta_i}}{\eta_2 + \beta_i} + \frac{\sum_{i=1}^{4} B_{i+4} x^{\beta_i}}{\eta_2 + \beta_i} + \frac{\sum_{i=1}^{4} B_{i+8} x^{\beta_i}}{\eta_2 + \beta_i} + \frac{q_1 x}{1+\eta_2} + \frac{\tau(c_s + c_c)}{r\eta_2} \quad (55)$$

The Optimal Capital Structure and the Agency Cost of Debt

Timing and Pricing of the Investment Option

We examine the price and time of the investment option with reference to Yang and Zhao (2015) and Pengfei et al. (2017). Since the model is time-homogeneous, the optimal investment decision making can be evaluated as a threshold policy. Let $x^i(l),\ l \in \{0,1\}$ be the optimal investment threshold with T_l^i corresponding to the optimal investment time which is determined by $T_l^i = inf\{t \ge 0 : X_t \ge x^i(l)\}$. Thus, the exercise of the investment option occurs at the time when the cash flow level x crosses the threshold $x^i(l)$, with the current economic regime state being $l \in \{0,1\}$. Let $x_0^i \equiv x^i(0)$ and $x_1^i \equiv x^i(1)$ exist. Obviously, we have $x_0^i > x_1^i$.

For any t, $l_t = 0$ $(l_t = 1)$ and $X_t \ge x_0^i$ $(X_t \ge x_1^i)$, the irreversible investment option must be exercised immediately by the investor to obtain a perpetual stochastic cash flow x. Let $f_0(x) = f(x,0)$ and $f_1(x) = f(x,1)$ correspond to the investment option functions for a bad economic regime and a good economic regime, respectively. Indeed, according to the optimality principle, the option value for $x \in (0, x_1^i]$ must satisfy the following equation:

$$\begin{cases} rf_0(x) = (\mu_0 - \lambda\varepsilon) x f_0(x)' + \frac{\sigma^2}{2} x^2 f_0(x)'' + \lambda_0 \big(f_1(x) - f_0(x)\big) + \lambda \mathbb{E}\big(f_0(xe^{Y_i}) - f_0(x)\big) \\ rf_1(x) = (\mu_1 - \lambda\varepsilon) x f_1(x)' + \frac{\sigma^2}{2} x^2 f_1(x)'' + \lambda_1 \big(f_0(x) - f_1(x)\big) + \lambda \mathbb{E}\big(f_1(xe^{Y_i}) - f_1(x)\big) \end{cases} \quad (56)$$

For $x \in (x_1^i, x_0^i]$

$$\begin{cases} rf_0(x) = (\mu_0 - \lambda\varepsilon) x f_0(x)' + \frac{\sigma^2}{2} x^2 f_0(x)'' + \lambda_0 \big((V_1^T(x) - I) - f_0(x)\big) + \lambda \mathbb{E}\big(f_0(xe^{Y_i}) - f_0(x)\big) \\ f_1(x) = V_1^T(x) - I \end{cases} \quad (57)$$

And for, $x \in (x_0^i, \infty)$

$$\begin{cases} f_0(x) = V_0^T(x) - I \\ f_1(x) = V_1^T(x) - I \end{cases}, (58)$$

Where $q_0 \equiv q(0)$ and $q_1 \equiv q(1)$ are determined in the equation (11).

For $x \in (0, x_1^i]$

Motivated by the relevant results obtained by Yang and Zhao (2015) and Pengfei et al. (2017), the general solution of $f_l(x)$ for $x \in (0, x_1^i]$ is determined by:

$$f_0(x) = \sum_{i=1}^{8} A_{i+16} x^{\beta_i} \quad and \quad f_1(x) = \sum_{i=1}^{8} B_{i+16} x^{\beta_i} \quad (59)$$

Since 0 is an absorbing barrier of the cash flow process, the first condition on the option boundary is equal to $f_0(0) = f_1(0) = 0$ and the parameters β_i must be positive. Hence,

$$f_0(x) = \sum_{i=1}^{4} A_{i+16} x^{\beta_i} \quad et \quad f_1(x) = \sum_{i=1}^{4} B_{i+16} x^{\beta_i} \quad (60)$$

Similarly, based on equation (5) of Yang and Zhao (2015) and the guess-and-verify method, the resolution of equation (56) and (57) is expressed as follows:

$$\begin{cases} f_0(x) = \sum_{i=1}^{4} A_{i+16} x^{\beta_i} & if\ x < x_1^i \\ f_0(x) = \sum_{i=1}^{4} C_{i+16} x^{\gamma_i} + \frac{\lambda_0 q_1 x}{(r + \lambda_0 - \mu_0)(1 + \eta_2)} + \frac{\tau \lambda_0 (c_s + c_c)}{r(r + \lambda_0)\eta_2} - \frac{\lambda_0 I}{r + \lambda_0} \frac{\sum_{i=1}^{4} B_{i+12} x^{\beta_i}}{\eta_2 + \beta_i} + \\ \quad \frac{\sum_{i=1}^{4} B_{i+4} x^{\beta_i}}{\eta_2 + \beta_i} + \frac{\sum_{i=1}^{4} B_{i+8} x^{\beta_i}}{\eta_2 + \beta_i} & if\ x_1^i \le x \le x_0^i \\ f_1(x) = \sum_{i=1}^{4} B_{i+16} x^{\beta_i} & if\ x < x_1^i \end{cases} \quad (61)$$

If we substitute equation the boundary conditions into (56), then the option value for the region $(l = 1)$ is expressed by the following solution:

$$\frac{\sum_{i=1}^{4} B_{i+16} (x_1^i)^{\beta_i}}{\beta_i - \eta_1} + \frac{\sum_{i=1}^{4} B_{i+12} (x_1^i)^{\beta_i}}{(\beta_i - \eta_1)(\eta_2 + \beta_i)} + \frac{\sum_{i=1}^{4} B_{i+4} (x_1^i)^{\beta_i}}{(\beta_i - \eta_1)(\eta_2 + \beta_i)} + \frac{\sum_{i=1}^{4} B_{i+8} (x_1^i)^{\beta_i}}{(\beta_i - \eta_1)(\eta_2 + \beta_i)} + \frac{q_1 x_1^i}{(1 - \eta_1)(1 + \eta_2)} + \frac{I}{\eta_1} + \frac{\tau (c_s + c_c)}{r \eta_2 (-\eta_1)} = 0 \quad (62)$$

- For $x \in (x_1^i, x_0^i]$

Substituting the above equation into equation (57), the option value if $x \in (x_1^i, x_0^i]$ is determined by the following expressions:

$$\frac{\sum_{i=1}^{4} A_{i+16} (x_1^i)^{\beta_i}}{\eta_2 + \beta_i} + \frac{\sum_{i=1}^{4} C_{i+16} (x_1^i)^{\gamma_i}}{\eta_2 + \gamma_i} + \frac{q_1 \lambda_0 x_1^i}{(r + \lambda_0 - \mu_0)(1 + \eta_2)^2} - \frac{I \lambda_0}{(r + \lambda_0)\eta_2} + \frac{\lambda_0 \tau (c_s + c_c)}{(\eta_2)^2 r (r + \lambda_0)} + \frac{\sum_{i=1}^{4} B_{i+12} (x_1^i)^{\beta_i}}{(\eta_2 + \beta_i)^2} + \frac{\sum_{i=1}^{4} B_{i+4} (x_1^i)^{\beta_i}}{(\eta_2 + \beta_i)^2} + \frac{\sum_{i=1}^{4} B_{i+8} (x_1^i)^{\beta_i}}{(\eta_2 + \beta_i)^2} = 0 \quad (63)$$

$$\frac{\sum_{i=1}^{4} A_{i+12}\left(x_0^i\right)^{\beta_i}}{(\beta_i-\eta_1)(\eta_2+\beta_i)}+\frac{\sum_{i=1}^{4} A_{i+4}\left(x_0^i\right)^{\beta_i}}{(\beta_i-\eta_1)(\eta_2+\beta_i)}+\frac{\sum_{i=1}^{4} A_{i+8}\left(x_0^i\right)^{\beta_i}}{(\beta_i-\eta_1)(\eta_2+\beta_i)}+\frac{q_0 x_0^i}{(1-\eta_1)(1+\eta_2)}+\frac{I}{\eta_1}+\frac{\tau(c_s+c_c)}{r\eta_2(-\eta_1)}$$
$$-\frac{\sum_{i=1}^{4} C_{i+16}\left(x_0^i\right)^{\gamma_i}}{(\gamma_i-\eta_1)}+\frac{\lambda_0 q_1 x_0^i}{(r+\lambda_0-\mu_0)(1-\eta_1)}+\frac{\tau\lambda_0(c_s+c_c)}{r(r+\lambda_0)(-\eta_1)}-\frac{\lambda_0 I}{(r+\lambda_0)(-\eta_1)}=0 \quad (64)$$

Where $g_0(\gamma_i)=0$, with $i=1,2,3,4$. In other words, the parameters γ_i are determined by solving $g_0(\gamma)=0$. The value of the investment option can be summarized by the following equation:

$$f_0=\begin{cases}\dfrac{\sum_{i=1}^{4} A_{i+16}x^{\beta_i}\eta_2}{\eta_2+\beta_i}, & if\ x\le x_1^i\\[2ex] \dfrac{\sum_{i=1}^{4} B_{i+12}x^{\beta_i}}{\eta_2+\beta_i}+\dfrac{\sum_{i=1}^{4} B_{i+4}x^{\beta_i}}{\eta_2+\beta_i}+\dfrac{\sum_{i=1}^{4} B_{i+8}x^{\beta_i}}{\eta_2+\beta_i}+\dfrac{\sum_{i=1}^{4} C_{i+16}\left(x_1^i\right)^{\gamma_i}}{\eta_2+\gamma_i} & \\ +\dfrac{q_1\lambda_0 x_1^i}{(r+\lambda_0-\mu_0)(1+\eta_2)}-\dfrac{I\lambda_0}{(r+\lambda_0)\eta_2}+\dfrac{\lambda_0\tau(c_s+c_c)}{\eta_2 r(r+\lambda_0)} & if\quad x_1^i\le x\le x_0^i\\ V_0^T(x)-I & if\ x>x_0^i\end{cases} \quad (65)$$

$$f_1=\begin{cases}\dfrac{\sum_{i=1}^{4} B_{i+16}x^{\beta_i}}{\beta_i-\eta_1} & if\ x<x_1^i\\ V_1^T(x)-I & if\ x\ge x_1^i\end{cases} \quad (66)$$

After assessing the value of the firm and the value of the investment option, we can specify the solutions of the optimal investment thresholds and the agency cost of debt in order to study the impact of contingent convertible bonds on the debt overhang problem, asset substitution and firm value in a regime-switching model and a diffusion process with exponential distribution jump.

Optimal Investment Thresholds and the Agency Cost of Debt

Our objective in this section is to examine the optimal firm investment policy that maximizes the equity value $E_l(x)$ and the total firm value $V_l(x)$. Referring to Mauer and Sarkar (2005) and Song and Yang (2015), we take the investment threshold x_l^i as a decision variable for given coupon rates. Since shareholders optimally choose the investment threshold x_l^i, we consider two different investment policies that maximize the equity value $E_l(x)$ and the firm value $V_l(x)$. Indeed, we assume that there are two types of investment thresholds "the first-best thresholds" denoted, x_l^{iF}, which maximizes firm value and "the second-best thresholds" denoted, x_l^{iS}, which maximizes firm value. Therefore, the last smoth-pasting condition at the investment thresholds x_l^{iF} and x_l^{iS} must satisfy the following formulas respectively:

$$f_l'\left(x_l^{iF}\right)=V_l'\left(x_l^{iF}\right) \quad (67)$$

$$f_l'\left(x_l^{iS}\right)=E_l'\left(x_l^{iS}\right) \quad (68)$$

Since equations (67) and (68) determine the option's investment time and equation (58) presents the option's exercise region and its continuation, then the optimal investment threshold, x_l^{iF} where $l\in\{0,1\}$, satisfies the following system of equations:

$$\begin{cases}\dfrac{\sum_{i=1}^{4} B_{i+16}\beta_i\left(x_1^{iF}\right)^{\beta_i}}{\beta_i-\eta_1}=\dfrac{\sum_{i=1}^{4} B_{i+12}\beta_i\left(x_1^{iF}\right)^{\beta_i}}{\eta_2+\beta_i}+\dfrac{\sum_{i=1}^{4} B_{i+4}\beta_i\left(x_1^{iF}\right)^{\beta_i}}{\eta_2+\beta_i}+\dfrac{\sum_{i=1}^{4} B_{i+8}\beta_i\left(x_1^{iF}\right)^{\beta_i}}{\eta_2+\beta_i}+\dfrac{q_1 x_1^{iF}}{1+\eta_2}\\ \dfrac{\sum_{i=1}^{4} C_{i+16}\gamma_i\left(x_0^{iF}\right)^{\gamma_i}}{\eta_2+\gamma_i}+\dfrac{q_1\lambda_0 x_0^{iF}}{(r+\lambda_0-\mu_0)(1+\eta_2)}=\dfrac{q_0 x_0^{iF}}{1+\eta_2}\end{cases} \quad (69)$$

And the optimal investment threshold x_l^{iS}, $l\in\{0,1\}$ satisfies:

$$\begin{cases} \dfrac{\sum_{i=1}^{4} B_{i+16}\beta_i\left(x_1^{iS}\right)^{\beta_i}}{\beta_i-\eta_1} = \dfrac{\sum_{i=1}^{4} B_{i+8}\beta_i\left(x_1^{iS}\right)^{\beta_i}}{\beta_i-\eta_1} + \dfrac{q_1 x_1^{iS}}{1-\eta_1} \\ \dfrac{\sum_{i=1}^{4} C_{i+16}\gamma_i\left(x_0^{iS}\right)^{\gamma_i}}{\eta_2+\gamma_i} + \dfrac{q_1\lambda_0 x_0^{iS}}{(r+\lambda_0-\mu_0)(1+\eta_2)} = \dfrac{\sum_{i=1}^{4} A_{i+8}\,\beta_i\left(x_0^{iS}\right)^{\beta_i}}{\eta_2+\beta_i} + \dfrac{q_0 x_0^{iS}}{1+\eta_2} \end{cases} \quad (70)$$

After the determination of the optimal investment thresholds, we can calculate the agency cost of debt by subtracting the value of the firm under the investment threshold x_l^{iF} from the value of the firm under the investment threshold x_l^{iS}, see Mauer and sarkar (2005). Thus, following Luo and Yang (2017), the agency cost of debt is expressed as:

$$AC = \frac{f_l^F - f_l^S}{f_l^S}, \qquad l \in \{0,1\} \ (71)$$

Where f_l^F and f_l^S denote the value of the firm below the investment threshold x_l^{iF} and x_l^{iS} respectively.

The Optimal Capital Structure of the Company

Based on the previous conclusions, we discuss in this part the evolution of the value of the company with the coupon rate of the risky debt and the coupon rate of the CoCo debt. In addition, we discuss the optimal capital structure. For this, we assume that the level of cash flow x at the time of investment and debts are valued at a reasonable price due to the standard assumption that bondholders are rational. Therefore, we choose the optimal coupon rates c_s of SBs and c_c of CoCos to maximize the firm value $V_0^T(x)$ determined by (54) if the current economy is in recession and maximize the value of company $V_1^T(x)$ specified by (55) if the current economy is expanding.

From the above, we note that the two coupon rates correspond to the following nonlinear programming problems:

$$V_l^{T^*}(x) = \sup_{c_s \geq 0, c_c \geq 0} V_l^T(x; c_s, c_c), \qquad l \in \{0,1\} \quad (72)$$

We denote $V_0^T(x)$ by $V_0^T(x; c_s, c_c)$ to emphasize that the value of the firm depends on the coupon rates. If we solve equation (72) for $l = 0$, we obtain the optimal coupon rate c_s^* of the risky debt and the optimal coupon rate c_c^* of the CoCos.

Numerical Analysis and Discussion

To clarify the impact of contingent convertible bonds on firm valuation under the regime-switching model if the state variable follows a diffusion process with doubly exponential distribution jumps, we first select the values of basic parameters that are related to the business as follows: current cash flow level $x_0 = 1$, annualized risk-free interest rate $r = 0.06$, rate of return for $(l = 0)$ $\mu_0 = 0.01$, the rate of return $(l = 1)$ $\mu_1 = 0.04$, the volatility $\sigma_0 = \sigma_1 = 0.25$, the effective tax rate $\tau = 0.35$, the cost of bankruptcy $\alpha = 0.25$ and the investment cost $I = 200$. The conversion ratio $\beta = 0.4$ according to Koziol and Lawrenz (2012) and the capital adequacy ratio $\phi = 0.05$ according to Glasserman and Nouri (2012). The coupon rate of the risky debt $c_s = 1.1$ and the coupon rate of CoCos $c_c = 0.5$ are determined by maximizing the value of the total enterprise. Second, we choose the variables which are related to jumps referring to Kou and Yang (2003), $q = 0.7$ defines the probability of jumping +up, $p = 0.3$ denotes the probability of jumping down $\frac{1}{\eta_1} = 0.02$ and $\frac{1}{\eta_2} = 0.03$ represent the means of two distributions respectively. According to Pengfei et al. (2017), we take the intensity of the jump $\lambda_0 = 0.3$ and $\lambda_1 = 0.1$.

Debt Overhang Effect

To solve the problem of debt overhang, as Pennacchi et al. (2014), we calculate the net increase in the value of equity when the value of firms without debt (or value of assets) adds one unit, i.e. $\partial E/\partial A - 1$, of which one negative value means that the amount that the shareholders collect is ultimately less than what they originally invested and therefore indicates a distortion of debt overhang.

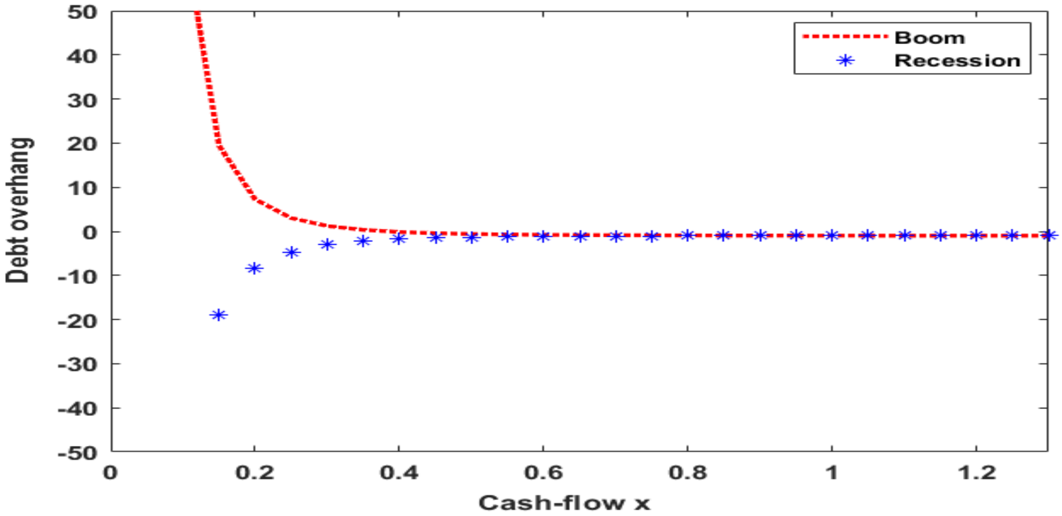

Figure 1. Debt overhang effects vs cash-flowx

Figure 1 graphically represents the effect of cash level and economic regime on over-indebtedness. In general, the inefficiency linked to debt-overhang decreases with the level of cash and even gradually disappears if the level is high enough, as expected. Inefficiency is less evident in times of expansion than in times of recession. These conclusions are easy to understand. Also, we find that there is almost no debt overhang during booms and busts if CoCos debt is issued in the capital structure of the firm, for a high level of cash-flow. Moreover, Figure 1 reveals that the closer the level of cash-flow is to the conversion threshold, the closer the debt overhang problem is to 0. In fact, the more the level of cash-flow tend towards the conversion threshold, the more the he incentive for shareholders to inject equity is important to avoid any conversion, because conversion is very costly for them.

Asset Substitution Effect

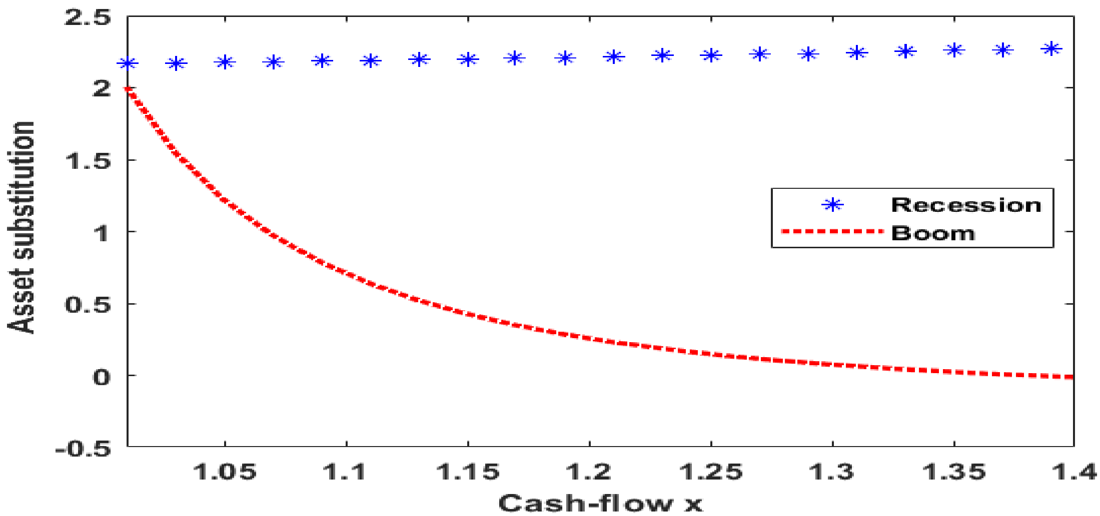

Figure 2. Asset substitution effect vs cash

To measure the incentive to transfer risk, following Pennacchi et al. (2014), we take the value of equity as a function of the volatility rate and calculate its derivative, namely $\partial E/\partial\sigma$. If positive, an increase in business risk leads to an increase in equity value and therefore shareholders have an incentive to transfer the risk to debt holders. Naturally, the higher the value, the stronger the incentive. As expected, Figure 2 indicates that there is a stronger incentive for risk transfer during recessions than during booms. Figure 2 shows that if the current cash level is close to the conversion threshold during boom times, the incentive to transfer risk decreases and even it may be disappears altogether and becomes close to 0. In general, the lower the level cash-flow, the weaker the incentive to transfer risk.

Intuitively, the inefficiencies resulting from asset substitution and o debt overhang should decrease with the conversion rate of the CoCos. Indeed, a higher conversion rate means a more severe penalty in case of conversion and, therefore, shareholders have less incentive to invest in a high-risk period and to inject funds into the company more actively. Indeed, Figures 1 and 2 further show that inefficiencies are much larger in recession than in boom times and during boom times, if the conversion rate is high enough, around $\beta = 0:4$, the two inefficiencies disappear.

Conclusion

In this paper, we consider a company without assets in place with a perpetual option in an investment project whose cost of exercising this option is sunk. The unexpected return of the project is governed by a continuous and temporal Markov chain. We present explicit expressions for the pricing of the company's securities and we evaluate the value of the investment option as well as the optimal investment time.

Closed-form solutions have been examined in a regime-switching structural model when the value of cash flows generated by the firm follows a diffusion process with double exponential distribution jumps. This makes the model proposed in this paper more complicated and realistic. The equilibrium price theory under the jump diffusion model was developed based on a structural model introduced by Leland (1994) and later extended by Kou (2002) and Chen and Kou (2009).

This paper presents a theoretical explanation that is based in particular on investing in a regime-switching model for a firm's capital structure composed of CoCos, equity and risky debt. The modeling of a firm's investment decision is determined as a real option and the optimal policy of the firm is obtained by maximizing the equity value and the value of the firm. Additionally, we examine the impact of CoCo contingent capital as a financing instrument on the inefficiencies resulting from over-indebtedness and asset substitution under a double exponential Jump-diffusion model with switching regime.

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in EPESS journal belongs to the authors.

Acknowledgements or Notes

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Role of Learning and Knowledge Transfer for Sustainable Development of the Company

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Abstract: Sustainable development and the building of competitive advantages occupy a central place in the company's strategy. The new challenges require finding a balance between the economic, social and environmental aspects of business, through a fundamental rethinking and change in strategic policies, decisions and actions, which in practice means forming a new way of thinking and a model of behavior. The main factor and driver for achieving the sustainable goals is the process of learning and the transfer of knowledge in the company. The aim of the study is to develop a model in which learning and knowledge transfer are a link between dynamic capabilities and the firm's sustainable strategy and the building of competitive advantages. The conducted empirical research confirms the inferred relationships and dependencies in the model. The results prove the extremely important role and importance of information, learning, knowledge transfer and the creation of new knowledge in the company as factors for building the system of dynamic capabilities and developing a sustainable strategy, which allow adaptation to new development trends and realization of strategic goals.

Keywords: Sustainable development, Dynamic capabilities, Knowledge, Company strategy

Introduction

Sustainable development and building competitive advantages (in three aspects – economic, social and environmental) occupy a central place in the strategic behavior of the company. Although there is still relatively little evidence, practice proves the existence of a strong relationship between sustainable development and the long-term success of the firm (building competitive advantages), which is mediated by the firm's strategy. The development of a sustainable strategy depends on both external factors (monitoring the external environment, assessment, learning and reconfiguration) and internal factors (culture, history, reputation, resource base, distinctive competencies, organization, management).

The complex issue facing each management team is to develop relevant strategic policies and solutions aimed at creating, offering and realizing additional economic, social and environmental value and satisfying the interests of a company (realization of company goals), consumers and society as whole. Success can only result from building dynamic company capabilities oriented towards sustainable development, which are directly related to the strategic objective and support strategic change, through learning, integration of knowledge, coordination and reconfiguration of resources and competences. Their building and development is a function of managerial skills, knowledge, values and leadership, which allows adaptation to the dynamic environment to begin with change within the firm itself, making it different and creating conditions for advantages.

Dynamic capabilities (ability to monitor, evaluate, absorb information and learn, knowledge transfer) are intellectual inputs built on the basis of company resources and operational competencies. They influence, change strategic behavior, improve company competencies and operational activity (but without directly participating in production), which in turn has a positive impact on their development. Resources, operational competencies, dynamic capabilities, and strategy build a system of interrelated and dependent elements that collectively determine a firm's competitiveness.

Competitive advantages grow when these firm-level elements are strong and aligned with each other and with the external environment (Teece, 2018). In the conditions of a dynamic environment, the relationship between dynamic capabilities and the company's strategy is not direct, but indirect, through the process of learning and knowledge transfer (a relationship that is rarely the subject of in-depth research) (Fig. 1.).

This also determines the purpose of the research - 1) development of a conceptual model in which learning and knowledge transfer are a link between dynamic capabilities and the company's sustainable strategy and the building of competitive advantages, and 2) empirical study of the model to prove the interrelationships and dependencies and the influence on the process of building competitive advantages.

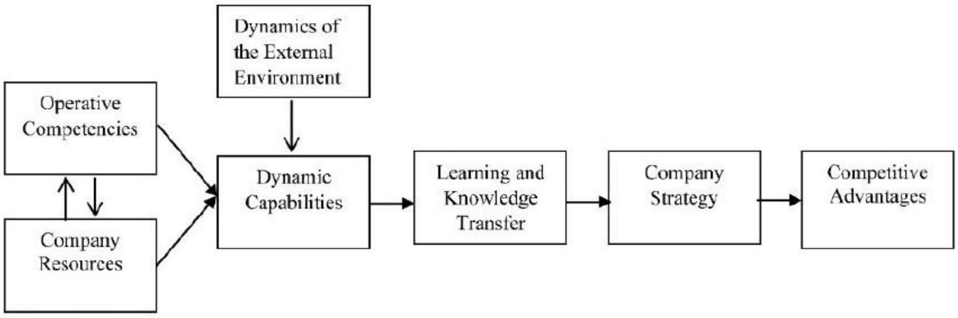

Figure 1. Learning and knowledge transfer – a link between dynamic capabilities and the company strategy and the building of competitive advantages

Therefore, this paper aims to investigate how and with what characteristics learning and knowledge transfer influence sustainable development and building competitive advantages at an empirical level. To meet this goal, the empirical analysis focuses on Bulgarian companies that develop a sustainable strategy, applying known good practices, taking into account their company and market specificities. The conclusions contribute to the understanding of the key success factors (dynamic capabilities, training, knowledge transfer, creation of an extended firm), enrich the theory and practice in this direction, providing information and stimulating the sustainable development of other firms. The article is structured as follows: Literature Review, Definition of Hypotheses and Conceptual Model (Section 1), Method (Object of the Research, Procedure and Research Tools - Section 2) and Results and Discussion Questions (Section 3).

Literature Review, Definition of Hypotheses and Conceptual Model

The research of the problems related to the sustainable development of the company is based on several theories. First of all, the firm's decision to accept the social, environmental and economic challenges is influenced by various directly and indirectly stakeholders (government regulators, non-governmental organizations, local communities, shareholders, customers - Stakeholder theory) (Elijido-Ten, 2007). On the other hand, company activity is strongly influenced by accepted standards, norms and requirements and the need to make them part of its activity, regardless of economic results (Institutional theory - Delmas, Hoffmann, &Kuss, 2011).

Next, the resource-based theory (RBV) has emerged as the most widely used approach to explain the relationship between a firm's resources and the developed strategy as a factor in realizing competitive advantages and the firm's goals (Barney, 1991, Barney, & Clark, 2007, Peteraf, 1993, Barney, & Hesterly, 2005, Newbert, 2008). In a dynamic environment, resource-based theory has limited potential to explain the sources and factors that influence the building of competitive advantages.

Under such conditions, the firm can develop and adapt, by building new capabilities and competencies and their constant configuration and reconfiguration in response to changes in the external and internal environment. Successful company development requires analysis and evaluation not only of internal resources but also of external factors/resources, which necessitates the need for a new approach that takes into account the influence of both types of resources or application of the theory of dynamic capabilities (Teece, Pisano, & Shuen, 1997, Helfat, et al., 2007, Eisenhardt, & Martin, 2000, Zollo, & Winter, 2002). A central place in the theory is the connection of external and internal resources with the organization and company management, which in their unity can ensure the building of competitive advantages. From such a point of view, it is first necessary to clarify the relationship between resources, dynamic capabilities and strategy, and the place and role of learning and knowledge transfer in the activity of a company oriented towards sustainable development.

Resources are defined as all the assets that the firm owns, controls or has access to, and competencies (market, technological, innovative, managerial, organizational) are its ability to perform a coordinated set of tasks in order to achieve a certain end result (Helfat, & Peteraf, 2003). Company resources include tangible (property, plant, equipment, financial assets, IT systems and personnel) and intangible (information, knowledge, history, reputation, experience, leadership skills, brand, customer relationships) resources (Gruber et al., 2010). Intangible resources can also be defined as an opportunity, flexibility of the company to adopt and further develop all new technological and competitive discoveries, to create and offer higher added value for its customers, through creative development, combining, transferring, accumulating knowledge, experience, which determine increasing opportunities to build competitive advantages (Petricket et al., 1999).

A central place is occupied by knowledge, which includes information and know-how, technological, managerial and marketing competences in various spheres of the company's activity. It can be explicit (written, defined - facts, theories, principles, etc.) and therefore easy to assimilate and disseminate, and tacit knowledge (acquired, developed personal skills and experience), which is more difficult to assimilate and distribution (Easterby-Smith, & Prieto, 2008).

The source of knowledge can be external - obtaining, collecting, analyzing, absorbing new information and innovations, or internal - various mechanisms for its intra-organizational sharing, development and enrichment (Zahra, & George, 2002). Knowledge as a basic resource alone cannot create the desired additional value and provide competitive advantages. It must be combined effectively with the company's other intangible and tangible resources/assets, which can be defined as complementary and they generally create new opportunities for growth and development, through effective control and management. The development of knowledge in the company can improve and develop complementary intangible and material resources, and they, in turn, have an impact on its development at a new level, or there is a dynamic permanent relationship and influence between them.

Corporate knowledge is a system of internally accumulated/generated knowledge and assimilated, acquired external knowledge. Due to the growing dynamics of the external environment and the increasingly difficult predictability of processes, the importance of external knowledge is increasing. Under these conditions, the main task and goal of the company is learning. It is a constant dynamic process of strategic renewal, a function of the transfer and diffusion of new knowledge and its use (replacement of existing knowledge), which turns it into a key, fundamental, specific resource and therefore a source of competitive advantage (Grant, 1996).

To realize this task, it is necessary to create a system for managing the learning and knowledge transfer process, which includes: 1) technological side - the created information processing system, information-technological infrastructure, data collection system, virtual expert centers, as well as others technical and managerial procedures, and 2) a social side that concentrates on the firm's accumulated knowledge resulting from history, experience, cultural factors and social relations. The two sides of the learning and knowledge transfer management process - technological and social are independent but interacting (Easterby-Smith, & Prieto, 2008).

Each company has a unique, specific ability to identify, absorb and use information and knowledge from the external environment. The relationship between external and internal resources/knowledge in order to build competitive advantages is realized by three main factors, defined as adaptive, absorptive and innovative ability of the managers, which provide a constant opportunity to integrate, reconfigure, renew, develop and change resources in accordance with changes in the external environment (Wang, & Ahmed, 2007, 44). They are interrelated but conceptually distinct: Adaptability is related to a firm's ability to adapt to changes in the environment, through resource flexibility and alignment of internal and external factors and capabilities. Absorptive capacity develops the skills of assimilating new knowledge, combining external and internal knowledge and using it effectively. Innovative capability refers to a firm's ability to develop new products, services, markets, and the relationship between them (Wang, & Ahmed, 2007).

Furthermore, there is a difference between potential capability and realized capability, which is the basis of the creation of a strategic resource and the construction of competitive advantages (Zahra, & George, 2002). The dynamism of the external environment creates the potential for assimilation and transformation of information, both from different types of markets (moderately or rapidly dynamic) and from companies with high learning potential, through a diffusion process. Potential absorptive capacity is related to the ability to acquire knowledge, resources, but these have value only when properly combined with the resources available to the given firm.

The transformation of the absorption potential and the achievement of a real absorption capacity is the result of the existing mechanism of integrating the individual contribution within the business unit, entering people and activities into the common organization and structure (through a shared understanding, creating a common basis and developing of a new model for perception). In this mechanism, various administrative and technical processes can influence the behavior of the company's employees and reduce or increase efficiency. Therefore, the potential capacity for absorption is the basis for acquiring and assimilating knowledge, but it does not have the ability to disseminate and use this knowledge. For this purpose, the ability to collect and interpret information and discover guidelines for its use in order to adapt to the external environment is necessary. The potential adaptive capacity provides the necessary strategic flexibility of the firm (development and implementation of a new product/process, new development strategies or a combination thereof), or its innovative capacity (Wang, & Ahmed, 2007).

The learning mechanism implicitly includes and emphasizes the importance of the accumulated experience and skills, and the transfer of knowledge points to the need to absorb information and integrate it as new knowledge in the company. The new collective knowledge created is a major factor in change, reconfiguration of resources and competences, which is crucial for a firm operating in a complex environment with a high degree of uncertainty and turbulence. Therefore, the management of learning in the company is aimed at creating new knowledge, through the identification, transfer, integration of internal and external knowledge and its use, with the aim of strategic renewal and increasing its competitiveness. They are key to its sustainable development and connection between dynamic capabilities and the realization of strategic goals, which will be analyzed in more detail.

Dynamic capabilities are defined as "a system of the firm's ability to integrate, build, develop and adapt its external and internal resources and competencies to changes in the business environment that ensure its development, growth and building competitive advantages" (Teece et al., 1997, 516) and also as "a system for learning and creating stable internal and external connections through which it generates higher operational efficiency, allowing it to realize its long-term goals" (Zollo & Winter, 2002, 344). They are "a specific company process through which resources are integrated, reconfigured, acquired and released, as well as organizational, strategic procedures through which the company creates new resources and configurations in order to realize competitive advantages and higher profit in the conditions of constant market dynamics" (Eisenhardt & Martin, 2000, 1105). Other authors define dynamic capabilities as the ability of any firm to identify the need for changes, evaluate alternatives and make appropriate decisions to adapt to external changes, which include strategic and organizational internal changes (create, develop, expand and modify its resources) (Helfat, et al., 2007).

The new challenges related to the sustainable development of the company - the simultaneous solution of economic, environmental and social challenges and the building of competitive advantages require their redefinition and expansion of the scope. The author defines the dynamic capabilities oriented towards sustainable company development as a complex, multidimensional system of interconnected and complementary specific activities that include: 1) the ability of the senior management team to identify and analyze the need for economic, environmental and social changes by monitoring the dynamics of the external environment, analyzing information, evaluating alternatives and learning (higher-level dynamic capabilities), 2) targeted solutions related to the internal operational organization and company management and aimed at knowledge transfer and their integration, coordination and reconfiguration of resources and company competencies (market, technological/innovative, organizational and managerial), which ensure the operational efficiency of the company (dynamic capabilities from a lower level). The ultimate goal is to create a strategic resource in response to changes in the external environment and the expectations of stakeholders, which allows offering higher economic, social and environmental value to the market when performing one or more core activities, or building of competitive advantages.

Building dynamic capabilities is not a one-time action to provide changes in resources and capabilities as a response to the dynamics in the environment, but an ongoing process of monitoring, evaluating, analyzing alternatives. This is the basis for developing the company strategy, defining the strategic goals, tasks and the necessary strategic changes of resources and competencies, response to the growing economic, environmental and social demands of stakeholders and society as a whole.

Strategic management recognizes both the evolutionary nature of the company (adaptation and development based on accumulated experience and knowledge), and the role of managers to transform and create new knowledge in a way that ensures the realization of competitive advantages in the conditions of market dynamics.

Strategic leadership involves making clear decisions about vision (positions today, desired position tomorrow), time (present and future), assessment of opportunities, resources and knowledge (learning and action) and integrating the idea of sustainable development into the corporate thinking of all companies levels. The dynamic environment requires the senior management team to be more knowledgeable, innovative and adaptable. The most important thing is to accept the need for change, reconfiguration of resources and competences, as a continuous process, in order for the company to maintain and expand its market positions.

The development of a strategy oriented towards sustainable development combines corporate thinking, visioning, leadership, innovation aimed at change and adaptation to new conditions. As stated, this is a function of analyzing the impact of the external environment (stakeholders) and built dynamic capabilities, as well as analyzing and evaluating internal resources and operational competencies. The goal is change in order to create a strategic resource, a factor for building competitive advantages and realizing the company's goals (in all three aspects). This requires a comprehensive view of the business environment, taking into account social, economic and environmental aspects of the activity, but also traditional company goals - satisfying the wishes of customers and expanding market positions. In this process, the principles of sustainable company development must be implicitly embedded.

The environmental and social aspects of the given company activity must be effectively integrated into strategy, policies, economic priorities and managed as a single system. The goal is to create the perfect firm with a clearly defined mission, vision, effective management and organization, in a way that allows maintaining a viable fit between strategic goals, resources and competencies, through change and adaptation (Cyfert, et al., 2021).

The company's sustainable development-oriented strategy is based on several key premises:

The first of them is that the realization of the set goals - building competitive advantages is a function of the ability to create, offer and realize higher additional economic, ecological and social value. Secondly, the inclusion of sustainability in the company's strategy should be the result of a systemic, holistic approach, covering all structures and business units. This in turn is achieved through strategic leadership across the organization, proactive business strategy development, strategic innovation, implementation and execution. Next, the ability of the management team to move beyond the traditional viewpoints of the supply and demand approach and the narrow focus on competitors, markets and customers is of particular importance. He must engage, interact and understand market dynamics and the entire social, natural and business environment.

It is necessary to collect and process a large amount of information about development prospects, opportunities for sustainable results and long-term financial success, and on this basis make decisions aimed at change, which are significantly different from traditional ones.
Important drivers of sustainable development are cultural factors, such as motivation, information absorption skills, commitment and a long-term management horizon.

One of the main challenges in developing the company strategy is the ability to integrate principles, norms of sustainable development into the overall philosophy and policy (such as mission, vision, goals) of the company, and not as a separate aspect in separate directions of development. The idea of sustainable development must be dominant, determining in decision-making, both at the strategic (relationships, relations with stakeholders) and at the operational level (concrete actions, daily company work).

Synchronizing interests and building trust between the company, customers and stakeholders is essential for developing a successful strategy oriented towards sustainable development. A key success factor is the building of dynamic capabilities, the assessment of resources (tangible and intangible) and operational capabilities/competencies and their change through learning and knowledge transfer.

The first task in developing a strategy is to identify and analyze the challenges and develop an approach to overcome them (Rumelt, 2011). A source of information to prompt and facilitate managers in making these important decisions to reconfigure operational competencies is the dynamics in the external environment. The main problem facing every company is creating an effective monitoring system, assessment of development opportunities and threats, forecast of expected changes in the external environment and active communication with stakeholders.

Monitoring is related to the collection of information, data on changes in tastes, preferences, consumer demand, competitive actions and reactions, the emergence and development of new technologies. The information thus collected identifies the possibilities for the development of innovations (product and/or process) and the prospects of the company. Stakeholder pressure (customer demands, vertical chain participants, government regulations) is a particularly important factor affecting a company's reputation and image. This necessitates the creation of a robust and permanent mechanism for communication and information exchange with them in order to promptly recognize new sustainable challenges and analyze their impact on operational activity. These capabilities in today's environment are a function of a company's ability to analyze, assimilate information, and transfer it into knowledge.

The ability to monitor and analyze the external environment focuses on gathering and evaluating new market information and development alternatives, and learning is the ability to develop and enrich the firm's internal knowledge by acquiring, assimilating, sharing, integrating, transforming and creating new knowledge on the collected information. The two capabilities are different, but there is a reciprocal two-way relationship between them – the monitoring process stimulates the learning process, and the learning improves monitoring and analysis skills. Learning and knowledge transfer are the factors that drive activity, enable innovative problem solving and the development of new change initiatives, reconfiguring resources, operational capabilities and creating new distinctive competencies.

On the other hand, the new knowledge created in the learning process is owned by individuals and must be integrated at the collective level (Teece, 1982), by developing new patterns of interaction in the different units of the firm. This process involves spreading individual contributions within the business unit, fitting people and activities into the overall organization and structure and interaction between them, which allows the realization of change through collective activity (Helfat, Peteraf, 2003). Along with this, it is necessary to build a system for distribution, storage of knowledge, management of intellectual property, promotion of innovation and experimentation. The integration of external and internal knowledge is the basis of the system of dynamic capabilities and an important factor in developing a new strategy that meets the challenges.

The activities related to the process of learning and knowledge transfer require a new distribution of tasks, resources and people, as well as coordination and synchronization of their activities. Coordination is carried out through the exchange of information between individual employees, teams, different departments, which allows the company to evaluate a given resource and find a way to use it in a new, more efficient way. The new challenges require the creation of a mechanism that integrates the stakeholder in the company's activity, in the integrated vertical supply chain, strategic alliances, which is also a factor in building their loyalty. The active inclusion and engagement of employees in decision-making, integration and coordination of business processes that support the realization of the desired change is particularly important.

The reconfiguration of resources and competences as the ultimate goal must be carried out in such a way that stakeholders not only accept the need for change, but also are confident in the environmental and social effectiveness of the decisions taken by managers - implementation of new technologies, creation, acquisition, or integration of new resources and capabilities, or disposal (release) of unnecessary and redundant resources and capabilities. Therefore, the ultimate reconfiguration and creation of new resources and operational competencies in response to the dynamics in the environment is a function of the development of a learning system, the creation of the capacity to acquire, transfer and integrate knowledge (Zahra, George, 2002) at all levels in the firm and its partners, participants in the vertical chain, and coordination focuses on the organization and implementation of the activities themselves.

Even more important is the firm's ability to integrate existing, accumulated internal knowledge with external knowledge, which very often forms the basis of creating completely new knowledge and competitive advantages. The source of external knowledge is usually the interested parties, and the various alliances, networks to which the company belongs. These are usually formal or informal arrangements between actors that enable them to pool and exchange resources or commit to common goals (Gulati, 1998). In these alliances, strategic relationships and various mechanisms are created for exchange, dissemination of information, experience, ideas for innovation, and ultimately transfer of knowledge, which brings mutual benefit.

Each firm can acquire new technological, marketing, management, production and other necessary knowledge from its partners. On this basis, it can develop and generate new internal technological, marketing, management, production knowledge. Participation in alliances, vertical chains, facilitates the mechanism of integration of external and internal knowledge, by increasing the flow of knowledge obtained from different segments, teams, individuals, different technological, market areas, joint research associations. This stimulates organizational and managerial changes and reconfiguration of resources and capabilities, which is the end point (and goal) in the whole process of building dynamic capabilities – monitoring the dynamics of the environment, analysis, evaluation of alternatives, learning and knowledge transfer (Zheng et al., 2011).

Sustainable development requires the creation of new, specific internal processes and procedures supported by information technology that facilitate the transfer of information between all stakeholders. To develop these strategic business relationships, it is vital to create an internal company infrastructure that supports long-term relationships with key partners and enables the codification, sharing and exploitation of knowledge about markets, supply chains and customers.

Today, the strategy must include not only the company itself, but also extended firm (Rainey, 2009). It is a complex of connections, relations between internal strategic business units and their value delivery systems (supply chains, related industries, partners, customers, stakeholders and other participants in them), which are created by management teams at different levels. The goal is information exchange, coordination and knowledge transfer, which ensures maximum benefit for all participants. A valuable source of knowledge is the participating companies, which share their understanding of sustainable development, application of circular economy principles, opportunities to create new capabilities, competencies, which is a factor in building collective competitive advantages (not company ones), a function of strategic cooperation. The larger number of participants in the extended firm, with different functions and expertise, increases the knowledge capacity, facilitates the integration of external and internal knowledge and the creation of new ones. Active formal and informal connections facilitate its transfer and use, which ultimately makes innovation and company development successful. In this case, the less overlapping the field of knowledge of the related firms, the more successful this process can be.

The exchange of ideas from different fields and free communication encourages everyone to participate in the search for new, better solutions. Shared knowledge makes it possible to timely define new opportunities or threats in the market and to take appropriate actions. The combination of the company's internal learning mechanism and access to external sources of knowledge is a factor in achieving goals. Intercompany knowledge transfer covers both economic and environmental (reducing environmental pollution through the development and implementation of new technologies, use of recycled materials, etc.) and social aspects. This facilitates a firm's ability to sense and manage both internal and external social and environmental issues, which are by definition long-term and distinct from immediate, short-term financial benefits.

The creation of the extended firm increases the firm's competences because it provides access to the specific knowledge and resources that other actors possess and this is an important factor for stimulating innovation, especially "open, complementary" innovation. The interdependence of the specific assets that are complementary implies a policy of integration and cooperation between the companies, exchange of information, knowledge from suppliers, customers, competitors. The end result is the creation of new knowledge that enables the creation of a package of complementary products (goods and/or services) that increase the satisfaction of the end customer and stakeholders.

The specificity of the assets and the product created with them means that not only is it difficult for competitors to imitate the product, but it is also difficult for them to purchase this asset from the market, use it in the same efficient way and realize competitive advantages. The creation of the extended company allows interaction between partners through joint training programs and knowledge transfer, effective management, which is a strong factor in building not firm but interfirm competitive advantages (in the three aspects - economic, social and environmental). On this basis, the author derives the dependencies in the conceptual model: "Learning and knowledge transfer - a connection between dynamic capabilities and the firm's sustainable strategy and the construction of competitive advantages" and defines the following hypotheses that must be tested empirically (Fig.2):

Hypothesis 1. Learning and knowledge transfer have a positive impact on the sustainable development of the company and the construction of competitive advantages, through the system of dynamic capabilities.

Hypothesis 2. Learning and knowledge transfer have a positive impact on firm development and building competitive advantages through sustainable strategy development and implementation.

Hypothesis 3. Learning and knowledge transfer have a positive impact on sustainable company development and building competitive advantages, through the creation of an expanded company.

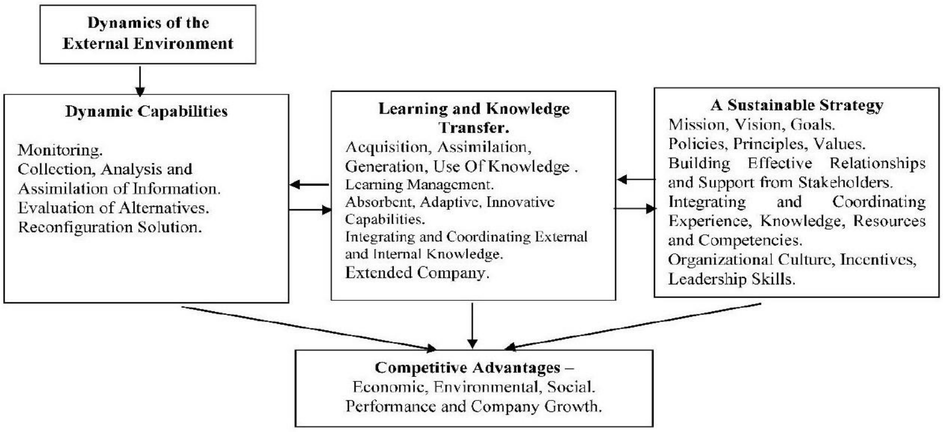

Figure 2. Conceptual model: Learning and knowledge transfer – a link between dynamic capabilities and the firm's sustainable strategy and building competitive advantages

Method

Object of the Research. Procedure and Research Tools

The empirical research was conducted using a developed and applied methodology for evaluating the defined hypotheses and uses a method based on data collection in an open and standardized way and correlation analysis. The necessary information for the study was collected through an online survey among senior managers of the selected companies. The specificity of the researched problem necessitates the inclusion of one respondent from each company, who, however, is assumed to have complete information and knowledge about the organization he leads. Due to the expressed desire of most of them for confidentiality and anonymity (referring to company secrecy), respondents are given the opportunity to submit the survey without indicating their name or the name of their company.

Of the questionnaires sent to 90 firms, 84 were returned, of which 22 were rejected due to lack of complete responses and 7 who had been in business for less than 5 years, ultimately resulting in a sample of 55 firms and 55 managers. The research includes an equal number of small, medium and large companies operating in different markets in Bulgaria (pharmaceuticals, civil engineering, building construction, manufacturing industry, mobile services, trade, services, tourism), which have different specializations, history, territorial location, resources and competences, dynamic capabilities and a developed strategy for sustainable development, which allows generalizations and conclusions to be made with the necessary objectivity.

Since the aim is to determine the correlation and evaluate the impact of learning and knowledge transfer, through the system of dynamic capabilities, the developed strategy and the created extended firm on the sustainable company development and the building of competitive advantages in the three dimensions (economic, social and ecological) and performance, the main directions of the research and the profile of the investigated companies are summarized in Table 1 (details of the study from point 6 to point 14 are given in Appendix 1). The summarized results outline above all market and company specifics that determine different degrees of commitment to the problems of sustainable development.

The survey card included a total of 18 questions constructed as statements to which respondents referred by marking their answers from 1 to 5 on a Likert scale (where 1 means "strongly disagree" and 5 means "strongly agree"). The questions are divided into three parts that follow the formulated hypotheses (Appendix 1). In this way, the influence of the independent variables (training and knowledge transfer) on the dependent (sustainable development and building competitive advantages) can be determined.

The questions are formulated comprehensibly, the necessary explanations for certain terms have been added, but they do not exclude the influence of the subjective factor when evaluating the results achieved as a function of the specifics of the company and the market in which it operates. Cronbach's alpha coefficient was also used, whose high value (significantly higher than the accepted base of 0.7) proves internal interrelationship, consistency of the questionnaire and representativeness of the final results.

Table 1. Main directions of the study

Main directions of the study	Summary of survey results
1.Type of organization	Single entrepreneurs – 35 Stock companies - 20
2. Size of the organization (small, medium, large)	Small companies – 22 Medium companies – 19 Large companies - 14
3. Age of the company	5-10 years – 30 Over 10 years - 25
4. Sector	Pharmaceuticals (production and distribution) – 6 Mobile services – 3 Civil engineering – 5 Manufacturing industry – 11 Tourism – 6 Trade, services – 15 Building construction - 9
5. Market dynamics	The markets (pharmaceuticals, tourism, civil engineering, mobile services) are moderately dynamic, oligopolistic, with higher concentration, where a small number of large companies with significant influence in society operate. The markets (building construction, trade, services) are highly dynamic, with effective monopolistic competition, with a lower degree of concentration, where a large number of relatively small companies operate.
6. Assessment of resources (tangible, intangible)	
7. Distinctive competencies	
8. Dynamic capabilities	
9. Learning	
10. Transfer of knowledge	
11. Adaptive, absorptive and innovative capacity	
12. Sustainable strategy	
13. Extended Company	
14. Evaluation of competitive advantages. Performance	

The questions included in the survey (Appendix 1) allow to determine the impact of the defined key factors on sustainable development and the realization of competitive advantages (economic, environmental and social) and efficiency, taking into account the following aspects of the company's activity:

The assessment of the impact of training and knowledge transfer on sustainable development and the building of competitive advantages, through the system of dynamic company capabilities (Hypothesis 1) includes – established system for monitoring the dynamics of the external environment, analysis of collected information and evaluation of alternatives for company development, developed effective procedures for identification, evaluation and transfer of new information and knowledge that have the potential to stimulate innovation and reconfigure resources and distinctive competences in response of new development trends and expressed preferences of interested parties.

The role of the company's sustainable strategy, a function of the influence of learning and knowledge transfer (Hypothesis 2), includes an assessment of opportunities to develop a new vision and strategies, which takes into account the interests of the three parties - customers, company and society, solves environmental and social problems and tasks, which is a strong factor for building competitive advantages and realizing company goals, measured by non-financial and financial results.

The impact of learning and knowledge transfer on sustainable company development and building competitive advantages, through the creation of an extended company (Hypothesis 3), has been evaluated based on the established mechanism for the exchange of information and knowledge, the interaction between all participating companies, creates new perspectives for sustainable development and new ways for mutually beneficial cooperation with stakeholders.

Finally, the respondents of the surveyed companies are asked to evaluate the sustainable development and the built competitive advantages as a function of the learning and the knowledge transfer process according to the following several groups of indicators (Do, Nguyen, 2020) - assessment of market positions (a function of the dynamic capabilities built and the strategy implemented), objective assessment (degree of reduction of harmful emissions, amount of resources used, reuse, recycling, all aimed at minimizing company costs) and evaluation of the company's activity by customers and stakeholders, which are basically subjective (reputation of a sustainable company, innovativeness, environmental characteristics of the product, creation of facilities for customers).

Results and Discussion

When analyzing the results obtained from the survey, the average values of the answers from the conducted online survey were first calculated. On this basis, the Pearson coefficient (R) was calculated for the entire sample, which measures and shows the impact of training and knowledge transfer on the sustainable development of the company and the construction of competitive advantages. To add more explanatory power to the empirical results, the analysis also used the coefficient of determination (in %) - R^2 , which gives a more accurate estimate and shows what percentage of changes in the independent variable will lead to changes in the dependent (the remaining percentages up to 100 define the uncertainty coefficient) (Table 2).

Table 2. Correlation between learning and knowledge transfer (through the system of dynamic company capabilities, developing a sustainable strategy and creating an extended company) and sustainable development and building competitive advantages

Impact of Learning and Knowledge Transfer, through:		Sustainable Development of the Company and Building Competitive Advantages.
Building Dynamic Capabilities	Pearson Correlation – R	0.683
	Coefficient of Determination (%) -R^2	46.64
	N=55	
Developing a Sustainable Strategy	Pearson Correlation – R	0.725
	Coefficient of Determination (%) - R^2	52.56
	N=55	
Creating an Extended Company	Pearson Correlation – R	0.614
	Coefficient of Determination (%) - R^2	37.69
	N=55	

Correlation is significant at the 0.01 level (1-tailed).

The correlation between the sustainable development of the company and the building of competitive advantages (economic, environmental and social) as a function of learning and knowledge transfer is also determined (Table 3).

Table 3. Correlation between the sustainable development of the company and the building of competitive advantages (economic, environmental and social) as a function of learning and knowledge transfer

		Learning and Knowledge Transfer
Sustainable Development of the Company and the Building of Competitive Advantages (Economic, Environmental, Social)	Pearson Correlation – R	0.695
	Coefficient of Determination (%) - R^2	48.30
	N=55	

Correlation is significant at the 0.01 level (1-tailed).

The calculated Pearson correlation coefficient in Table 2 and Table 3 is statistically significant, indicating that there is a relationship between the studied variables. Since the correlation coefficient is significantly greater than zero, this by definition allows the rejection of the null hypothesis of independence between the variables under study.

The obtained results make it possible to determine the impact of each individual key factor included in the study (in %, using the coefficient of determination), on sustainable development, the realization of competitive advantages (economic, environmental and social) and performance (Diagram 1).

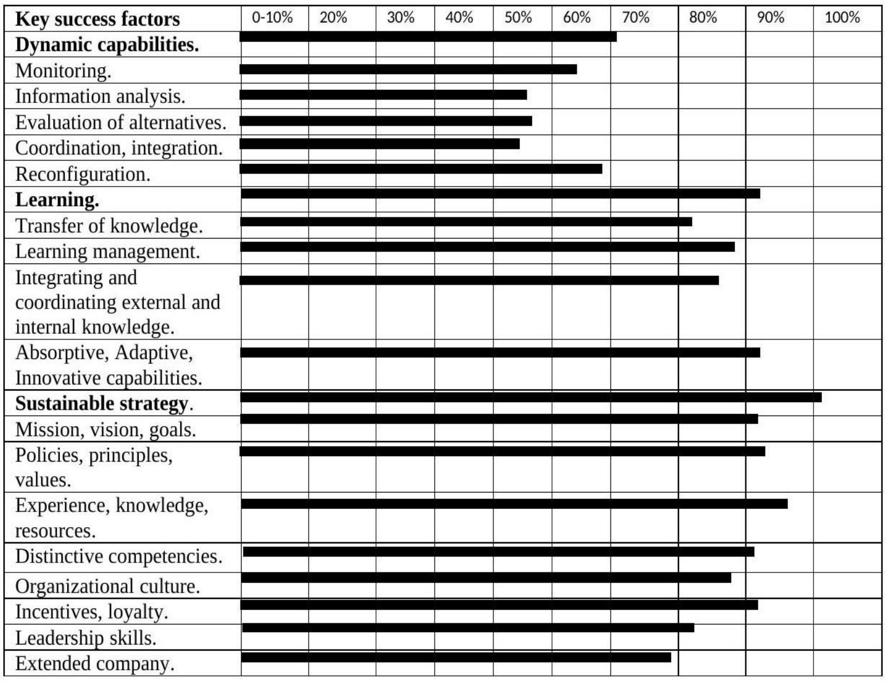

Diagram 1. Evaluation of the key factors fort he success of the sustainbale development of the company and building competitive advantages

Discussion

The conducted empirical study of 55 companies confirms the relationships and dependencies inferred in the model: "Learning and knowledge transfer - a link between dynamic capabilities and the sustainable strategy of the company and the building of competitive advantages" and allow the following conclusions to be drawn:

The surveyed managers understand sustainable development as a long-term goal that requires a process of constant monitoring, assessment of opportunities and threats to the company's development, analysis, assimilation of information from the external dynamic environment, learning and decision-making to change resources and to adapt to the new conditions, i.e. building dynamic capabilities (H1=0.683). Their building and development over time stimulates the ability not only to discover, but also to assimilate the new (adaptive capability), secondly it is a factor for creating a long-term vision of development (against the short-term one) and thirdly for the exchange of knowledge, information from partners, training (absorptive capability), which are the basis for developing own research (innovative capability) and for applying new technologies and creating a unique product (versus the imitation strategy). Therefore, dynamic capabilities based on information, learning, knowledge, impose and facilitate a change in strategic skills, thinking and decisions related to reconfiguring resources and their more efficient use, or creating a new combination.

According to the respondents, a radical change is needed in the strategic behavior, organization and management of the company's activities (integration of individual knowledge into a collective system, coordination, development of a new vision and development strategy that takes into account the interests of all three parties - customers, company and society), which enable the realization of company goals (H2=0.725). The management team must engage people with the idea, principles and goals of sustainable development and support the building of knowledge, capabilities and actions necessary to realize the transformation, by discovering new directions for growth, development and improvement of the activity, as well as reducing negative defects and impacts. Managers are responsible for setting the strategic direction for development, developing policies, principles and values, as well as ensuring governance, control, reporting, ethical behavior and have overall responsibility for ensuring that company policy meets the set economic, social and environmental aims.

Managing a company is becoming increasingly complex and requires new thinking, expanding the scope of analysis, evaluating vast amounts of information and making decisions that take into account many additional considerations. The challenges today require the management team to include in its analysis all the forces that affect the company - supply networks, partners, stakeholders and customers, to take into account all the effects, reactions and impacts of its activity, operations, used resources and competencies. This is essentially a process of creating an expanded firm, forming a new corporate mindset and implementing a strategy that enables the achievement of short-term and long-term goals based on the exchange of information, knowledge and strategic cooperation (H3=0.614).

In addition, the research shows that the firm's sustainable development and the building of competitive advantages based on learning and knowledge transfer (through dynamic capabilities, strategy development and the creation of an extended company) are influenced by market and firm characteristics. In other words, different markets (sectors) have different opportunities and threats, different dynamics, which determines different specifics in strategic behavior, changing decisions or developing new ones. At the same time, precisely these specifics determine a different degree of commitment to the problems of sustainable development (Diagram 2).

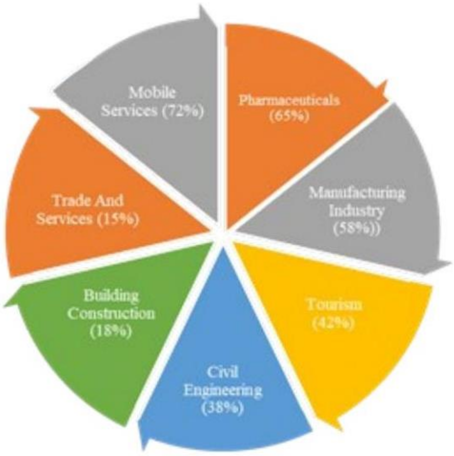

Diagram 2. Engagement of companies with building dynamic capabilities, strategy development and creation of the extended company based on learning and knowledge transfer by sector (influence of market and company characteristics)

Engagement is higher in markets with greater concentration (oligopoly), where a small number of large firms with significant influence in society operate (pharmaceuticals, mobile services, civil engineering, tourism) which are highly concerned about their reputation, image, media attention and building strong relationships with stakeholders. In large companies, sustainability orientation is a leading cultural characteristic and is not dictated by business strategy. Companies develop general principles of sustainable behavior and procedures on the basis of which they develop their relationships with stakeholders. Their strategic behavior does not exclude, but on the contrary, accepts joint work on current issues of sustainable development as mandatory, including with state institutions and their cooperation and assistance in solving problems. Typically, these firms apply a systematic, holistic approach, consistent actions based on accumulated experience and history. All this generally strengthens the trust in them and increases the public's appreciation of the way the market functions.

These markets (defined as moderately dynamic, oligopolistic) are characterized by a stable industry structure, relatively stable horizontal and vertical boundaries, a stable number of competitors, consumers, suppliers, clear and predictable behavior of the participants. Therefore, each company develops its sustainable strategy based on detailed, analytical procedures and routine actions, the result of accumulated experience, integration of knowledge and sufficient information. The decisions taken are implemented over a long period of time after a thorough evaluation, analysis of the existing alternatives and generally the results are predictable. The procedures for assessment and analysis of the current situation and development of new strategic solutions are applied frequently, with different variations that take into account the specifics of the occurring changes in the external environment.

The managers' assessment of the external and internal environment is in accordance with the accumulated experience, knowledge, competences. This allows them to plan and organize their activity as a well-structured and organized analytical process, which includes several sequential steps, starting with data collection, development of different alternatives, evaluation and selection. In certain situations, in some companies these activities are carried out by individuals who have the relevant knowledge and specialization. These practices enable the integration of external and internal knowledge and the creation of a new one, which increases the accumulations in the company's memory, expands routine actions and facilitates subsequent procedures and their predictability.

In markets with a lower degree of concentration (monopolistic), there are usually a large number of relatively small companies that do not have a clearly developed strategy and vision for development (building construction, trade, services). They often imitate, follow the approach of large companies to the problems of sustainable development and look for ways of formal and informal cooperation with them and with other competitors.

The goal is access to information, news, learning and protection of one's own interests. There is a lack of a common, long-term approach by all actors to stakeholders and pooling of resources and competences to solve sustainable problems. It is difficult to create independent associations with common interests, and each survives alone, coping better or worse with the tasks set by customers and society as a whole.

These markets are usually fast-changing, unstable, which means lack of a clearly defined market structure and delineated boundaries, participants (competitors, consumers, suppliers, etc.) are constantly changing, with an unclear profile, unknown actions and reactions. There is no known, established and well-functioning business model, which puts every manager to a serious test. Under these conditions, it is difficult for the management team to analyze and assess the situation and make well-thought-out decisions oriented towards sustainability. Uncertainty does not allow the creation and implementation over a longer period of time of an effectively working model, albeit with relevant variations. Analysis and decisions are not the result of the use of knowledge, experience, but above all of intuition, business acumen, chance, luck and propensity to risk. The results are unpredictable, the actions are based on the principle of "trial and error" and in the end there are no conditions for stability.

A characteristic feature of highly dynamic markets with high-speed changes is the lack not so much of necessary, but of timely information, time and knowledge about the new situation. This does not allow the application of familiar, routine actions, rules, procedures and compliance with deadlines, but it is the favorable time for creating new specific knowledge, skills corresponding to the new situation.

Company behavior is usually a function of simple decisions, intuition, used to quickly assess the current, specific situation at the moment, limited only by the rules in force in the company. The speed of decisions guarantees frequent and rapid success and growth of the company, which, however, are quickly forgotten due to the next new, completely different situation, requiring qualitatively new solutions. However, as a result of these quick decisions and actions, knowledge and corporate memory are accumulated through which the company learns. The model of behavior under these conditions is "learning by doing," not "learning before doing" and creating new opportunities in the company (with small losses and fast feedback), which allows to compensate for the lack of appropriate knowledge for the given specific situation. This is an unstable state that makes it difficult for the company to sustainably develop.

In other words, in moderately dynamic markets, the threat is first and foremost external, but in rapidly changing markets, it is both external and internal, due to limited managerial capabilities and time for analysis and change. Analysis and assimilation of the necessary information, the learning, the integration of external knowledge, the application of known "good practices", taking into account the specifics of the company and external factors, can only provide the desired result.

Nevertheless, the decisions and implemented strategies, although expressed through simple, single and unambiguous actions, are the basis for the development and creation of new specific knowledge and skills, which is a factor in the following period for the company to develop and implement a sustainable strategy and build competitive advantages. On the other hand, however, there is also the undeniable fact that small companies and their managers are less burdened with responsibilities, resources, assets that are difficult to part with. Therefore, these small firms are often more flexible, innovative, adaptable and a source of new original knowledge and competences. They are brave and determined, because they have nothing to lose, and can only gain from the new decision. The absence of a complex administrative structure, bureaucracy, accumulated inertia and routine are also factors that increase their effectiveness.

Therefore, the company and market characteristics influence the sustainable development of the company and the realization of the goals. Strategic firm behavior thrives on real-time information, integration of knowledge and learning, relationships and intensive communication with all stakeholders, and especially participants in the extended firm. Information in real time, its absorption creates new knowledge, develops intuition to dynamic changes in the environment, so that managers can more quickly understand these changes and adapt to them.

The final conclusion is necessary - in oligopolistic markets with moderate dynamics, moderate stability, strategic behavior oriented towards sustainability is a complex of complex analyses, assessments and combinations. The results of the decisions made are predictable, a function of external and internal knowledge, learning, accumulated experience, competences, history, evolution, which ensures long-term stable development of the company.

In dynamic markets, with effective monopolistic competition, decision-making is not the result of deep, sequential analysis, but the result of simultaneous consideration, evaluation and analysis of different situations. These partial or complete decisions are within the framework of accepted rules and delegated rights to managers, which creates a sense of trust and stimulates their activity. The main problem for them remains uncertainty and the degree of personal assessment, own knowledge, competences and propensity to risk.

Conclusion

In the presented research, the author considers the process of learning and knowledge transfer as a link between dynamic capabilities and the realization of strategic goals aimed at sustainable development of the company and building competitive advantages, which allows the following generalizations to be made:

Building dynamic capabilities is based on learning, which in turn is based on the firm's ability to assimilate (acquire), transfer, integrate and generate knowledge, a function of its ability to observe the dynamics of the environment in which it operates, analyze, compare and evaluate different alternatives. Personal skills and knowledge, technological, structural and management systems, as well as cultural values and norms are essential components for building dynamic capabilities and developing company strategy. The same components (cultural, structural, human, technological) participate in the knowledge management system and stimulate the process of generation, assimilation, transfer and use of knowledge.

The development of a firm's sustainable strategy (definition of mission, vision, strategic goals) is a function of the dynamic capabilities built and includes the analysis of external factors (monitoring and evaluation of dynamic conditions, collaboration with stakeholders, training and reconfiguration) and internal factors (culture, history, reputation, resource base, distinctive competencies, organization, management). In their totality, they determine the success of the company's efforts for sustainable development, creating and offering higher economic, social and environmental added value to the market when performing one or more main activities, or building competitive advantages.

Particularly important is the conclusion that the development and implementation of a sustainable company strategy is influenced by the characteristics of the market in which the company operates and by its own characteristics (size, history, experience) and may have different characteristics determined by desires, competencies and company capabilities, which is a direction for future research.

Combining the dynamics (uncertainty) of the market with the complexity of the connections in the industry, creates various opportunities for the development of the company. A low degree of uncertainty combined with a low degree of relationship complexity suggests stability. A characteristic feature of all markets today is the increasing degree of market uncertainty and complexity. This requires managerial decisions and actions to be aimed at the development and accelerated implementation of new technologies, development of innovations, new, efficient business models, building an expanded company based on long-term relationships, exchange of information with the active participation of the end customer and stakeholders and ultimately, orienting towards a clear proactive sustainable strategy that will provide competitive advantages.

Digitalization (the subject of future in-depth research) has a strong influence on this process, which stimulates and facilitates the construction of dynamic capabilities, creates conditions for developing new business strategies based on the collected and analyzed information, transforms the structure of social relationships between users, between companies and between consumers and companies, through social media and social networks.

A key factor for the success of the learning and knowledge transfer process in the company is the ability to absorb innovations, assimilate, generate, transfer, integrate the external with the internal and create new knowledge, which determines the current activity and future development of the company. The effectiveness of learning and knowledge transfer in the company can be greater as a result of the following actions, which essentially mean building dynamic capabilities:

• Development of effective procedures for identification, evaluation and transfer of new information, its assimilation, assimilation and transformation into knowledge.

• Applying adequate, routine practices for assimilating new information and integrating knowledge.

• Development and use of new knowledge that has the potential to stimulate innovation aimed at creating new products and processes.

Particularly important are the following actions, aimed at creating a mechanism for integrating individual knowledge into a collective system and coordinating people and operations, which enable managers to evaluate the resource in a new way and find a way to use it in a new, more efficient way:

• A periodic valuation of each individual's contribution to the overall activity.

• Clearly defining the tasks and responsibilities of each team and unit.

•Integration of specialized skills and knowledge in the general company activity.

• Changing and reconfiguring knowledge, decisions, actions in order to adapt to the dynamics in the external environment.

• Synchronization of company activities with the activities of stakeholders.

• Effective distribution of resources (information, time, tasks, reports) in the company as a whole and in individual units, the result of the individual assessment of knowledge, skills, competencies of everyone, which increases efficiency.

The research proves that the learning mechanism implicitly includes and emphasizes the importance of the accumulated experience and skills, and the transfer of knowledge the need to absorb information and integrate it as new knowledge in the company. The new collective knowledge created is a major factor in change, reconfiguration of resources and competences, which is crucial for a firm operating in a complex environment with a high degree of uncertainty and turbulence. The process of reconfiguration involves routine procedures of applying existing skills and acquired new knowledge in order to improve, expand and transform the resource base. The knowledge that can be used is influenced by important factors, such as historical experience and identity of the firm, values and perceptions of stakeholders. Creating the necessary organization for its use is a key success factor. The exchange of information, experience, knowledge and training are the basis for improving the organization of the various internal units and the business relations between them, formed by two-way communication, the inclusion of local, national, regional stakeholders, as well as expanding the activity through mergers, acquisitions, creating strategic alliances and other forms of association.

In short, information, new knowledge and learning in the firm are development factors and a function of the system of dynamic capabilities and the development of a sustainable strategy. The success (or failure) of resource reconfiguration can be quickly assessed by market reaction. Achieving the desired results - building economic, social and environmental competitive advantages requires a skillful combination, coordination, compliance and synchrony between the construction of dynamic capabilities and the development of a sustainable strategy of the company, based on learning and knowledge transfer, which is in accordance with the dynamics of the external environment. The basis for this result is the skills and competencies of the senior management team to outline a sufficiently broad vision for long-term development, to take the risk and the commitment to actively involve all stakeholders, to direct, lead and make decisions aimed at innovation, learning and motivation of employees, with the clear awareness that there is a significant lag between the time of launching sustainable practices and achieving the set, expected results.

Scientific Ethics Declaration

The author declares that the scientific ethical and legal responsibility of this article published in EPESS journal belongs to the author.

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Appendix 1.
Components of dynamic capabilities, learning and knowledge transfer, sustainable strategy and the extended firm, evaluated by the surveyed managers "Please rate the impact of the indicated key factors on sustainable development, the realization of competitive advantages (economic, environmental and social) and performance in your company (mark your answers from 1 to 5, where 1 means "strongly disagree" and 5 means 'strongly agree', on a Likert scale):
I. Assessment of the impact of learning and knowledge transfer on sustainable development and building competitive advantages, through the system of dynamic company capabilities:
The company has a well-established system for monitoring the dynamics of the external environment in order to identify new opportunities.
The company has the necessary competencies to analyze the collected information and evaluate alternatives for company development.
The company has developed effective procedures for identifying, evaluating and transferring new information and knowledge.
Efficiency is achieved in the process of learning and assimilating existing information into new knowledge and competencies that have the potential to stimulate innovation.
The processes of monitoring, evaluation of alternatives, learning, knowledge transfer, integration and coordination, or the building of dynamic capabilities in the firm allow for the successful reconfiguration of resources and distinctive competences in response to new development trends and expressed preferences of stakeholders.
Managers have created their own rhythm, a habit of building and developing dynamic capabilities that ensure effective reconfiguration of resources and competencies regardless of the dynamics of the environment.
II. Assessment of the impact of learning and knowledge transfer on the development of the company and the building of competitive advantages through the development and implementation of a sustainable strategy:
The learning, transfer and integration of external and internal knowledge allows the development of a new vision and development strategy that takes into account the interests of the three parties - customers, company and society.
The company's sustainable strategy supports and facilitates the solution of environmental and social problems and tasks, and at the same time is a strong factor in building competitive advantages and realizing the company's goals, measured by non-financial and financial results.
Sustainable strategy is a framework for strategic management that combines knowledge, corporate thinking, visioning, leadership, innovation aimed at changing the firm and adapting to new conditions.
A firm's sustainable strategy is a function of the owner/manager's competencies, knowledge, culture, personal value system, and desire for a high reputation in society.
The firm's sustainable strategy creates a mechanism of coordination and building loyalty among all stakeholders, which allows the firm to reassess the resource and find a way to use it in a new, more efficient way through information exchange and absorption of new knowledge.
The company's sustainable strategy is successfully implemented based on the use of digital resources, which facilitates the process of creating, offering and realizing additional value for customers, the company and society.
III. Assessment of the Impact of learning and knowledge transfer on the sustainable development of the company and the building of competitive advantages through the creation of an extended company:
In the extended firm, based on the exchange of information and knowledge, linkages (upward and downward) are built, which facilitates the creation of additional value for the end user and stakeholders and the realization of higher efficiency.
The extended firm stimulates interaction between all participating firms, creates new perspectives for sustainable development and new ways of cooperating with stakeholders, which brings mutual benefit.
The partners involved in the extended firm are a valuable source of knowledge on sustainable development, the principles of the circular economy, which is a factor in building collective competitive advantages (rather than firm ones), a function of strategic cooperation.
Knowledge transfer in the extended firm encompasses a wide range of formal and informal economic, environmental and social relationships and activities.

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First Passage Time Model Based on Lévy Process for Contingent Convertible Bond Pricing

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Abstract: This paper develops a general Lévy framework to reduce the pricing problem of contingent convertible (CoCos) bonds to the problem of the first pass time of the triggering process. We consider two Lévy models driven by the derived Brownian motion and the spectrally negative Lévy process. These two Lévy models keep the form of the Lévy process unchanged under the measure transform, which avoids the difficulty that only rare forms of Lévy processes solved the first passage time problem. We use single and double Laplace transform in combination with numerical Fourier inversion to find closed form expressions for the price of CoCos bonds. The results show that the model driven by the spectrally negative Lévy process would provide a more accurate CoCos bonds price when taking into account the phenomenon of jumps in the financial market. Indeed, negative jumps play a much critical role in the pricing of CoCos bonds. This paper underlines the importance of the evaluation of the CoCos bonds by the Lévy process.

Keywords: CoCos bonds, Lévy process, Financial market, Laplace transform, Fourier inversion.

Introduction

In this paper, we review all the work carried out so far by the authors, and we introduce new questions concerning jumps. Most models are Brownian driven, we will focus on jump driven models like Madan and Schoutens (2007). In addition, we illustrate the structural hop diffusion model with a study of the capital structure of a bank that issues CoCos bonds. CoCos bonds can be converted into equity when the issuing bank encounters financial difficulties. This loss absorbing debt is invented to protect the taxpayer from bank bailouts in the event of a financial crisis. Basel III encourages banks to issue this financial instrument, and many Asian and European banks have issued it for regulatory purposes. This complex product has a variety of designs, focusing on trigger events and conversion mechanisms. The price of CoCos bonds follows the Brownian motion process and the Lévy process. We consider the jump risks in order to compare these two models, including the Black-Scholes model (derived Brownian motion) and the exponential jump diffusion model (spectrally negative Lévy process).

In this sense, a Lévy model was examined to intuitively show the hybrid nature of CoCos bonds and to reduce their pricing problem to the problem of the first time of the triggering process. We return to Merton (1974), Black and Scholes (1973) and Black and Cox (1976).The main pricing models offered by CoCos bonds include the intensity model and the first pass model. The intensity model is also called a credit derivatives model in some papers and the first transit time model can be considered to be a structural model and an equity derivatives model because they all use a barrier approach based on the first passing time distribution. The intensity model has been studied by De Spiegeleer and Schoutens (2012) and Cheridito and Xu (2015). However, most studies focus on the first pass time model with a triggering process, which can be either an accounting ratio or a market price.

Several papers use structural models to derive the price of CoCos bonds, but their focus is more on the role and behaviors of CoCos bonds. Pennacchi (2010) investigates the influence of contractual terms and different sources of risk of the issuing firm on the value of CoCos bonds by simulation in a structural jump diffusion model. Koziol and Lawrenz (2012) show that CoCos bonds reduce incentives for risk taking and possibly create negative externalities under certain conditions. Berg and Kaserer (2015) show that CoCos bonds would agitate shareholders' risk-taking incentives and the problem of over-indebtedness. Hilscher and Raviv (2014) point out that banks issuing CoCos bonds would have a lower probability of default and that proper design of CoCos bonds could completely eliminate shareholder risk-taking incentives. Himmelberg et al. (2014) show that CoCos bonds can, if well designed, induce banks to seek conservative capital structures to avoid the risk of dilution resulting from forced conversion and reduce the problem of over-indebtedness. Albul et al. (2010) use a structural model to determine the role of CoCos bonds in the optimal capital structure of the issuing company in a context of infinite maturity and analyze the behaviors of CoCos bonds in different scenes. Metzler and Reesor (2015) indicate that the terms of the conversion fundamentally change the nature of CoCos bonds thanks to the Merton-type structural model.

Some more theoretical work studies equity derivatives models and Wilkens and Bethke (2014) shows that this model is the most practical for pricing and risk management of CoCos bonds by comparing the credit derivatives model, the structural model and the equity derivatives model through empirical studies based on a broadly adapted market price.De Spiegeleer and Schoutens (2012) approximate the event of non-compliance with the accounting trigger level by an event where the price of observable securities is below an implicit obstacle and model the stock market process of the issuing company as a geometric Brownian movement and derive a closed-form expression for the price of CoCos bonds. Cheridito and Xu (2015) develop a general continuous model and obtain the price of CoCos bonds by solving a parabolic partial differential equation with Dirichlet boundary conditions. These equity derivative models assume that the triggering process evolves continuously, thereby neglecting sudden movements in which most of the risk is concentrated.

Discontinuous models describing the risk of jumping due to exogenous shock are worth studying, and De Spiegeleer and Schoutens (2012) also suggest that their Black-Scholes model be extended to the Lévy model to incorporate jumps and heavy tails for CoCos bond prices. Corcuera et al. (2013) propose the family-driven model of the Lévy process and exploit the Weiner-Hopf Monte Carlo method to price CoCos bonds. Corcuera and Valdivia (2016) propose a one-sided treatment of CGMY Lévy-like stock price dynamics and give the CoCos bond price by combining the closed-form expression of the CoCos bond price at the Laplace transform with a numerical inversion of Fourier.

This paper references this work and proposes two first passage time models guided by the derivative Brownian motion and the spectrally negative Lévy process for the pricing of CoCos bonds. Here, the equity derivative models are called the first-passage-time models because their results are easily extended to structural models to study the role and behaviors of CoCos bonds.Since the pricing of CoCos bonds is our primary concern and the equity derivatives model has proven to be more practical, only equity derivative models focusing on Brownian motion, the spectrally negative Lévy process will be discussed. The derived Brownian motion provides closed form expressions while the spectrally negative scattering process possesses them up to the Laplace transform whose results are given by combining with numerical Fourier inversion. Although the model based on the derived Brownian motion was given by De Spiegeleer and Schoutens (2012), the result given in the general framework of Lévy can provide different indications, and it would be more practical to compare the model of Black and Scholes with the spectrally negative Lévy process in the general Lévy framework. We assume in our paper that the defect occurs when this process reaches a given level. The calculation of the probability of default in finite time is thus done from the first passage time, in an equivalent way, from the minimum of the Lévy process.

To achieve this, this paper presents an extended version of the framework proposed by Rogers (2000), which allowed the calculation of the probability of the first passage time of the spectrally negative Lévy process. Indeed, we develop the formulas of the calculation of the probability of default in order to show in particular how these formulas are obtained via the simple or double Laplace transform and the numerical inversion of Fourier to determine the pricing of CoCos bonds.

This paper is organized as follows. The characteristics of the contract are specified in section 2. In addition, a general Lévy framework of the first transit time model for CoCo bond pricing is presented to establish the general pricing problem. Section 3 presents two advanced models. On the one hand, a Brownian motion is built into the stock price dynamics, and the corresponding prices are subsequently obtained by a barrier option approach. On the other hand, a spectrally negative Lévy model, and the obtaining of the corresponding prices are processed by a Fourier method exploiting the Wiener-Hopf factorization for the Lévy processes. Finally, section 4 will discuss the numerical results.

General Lévy Framework for CoCos Bonds Pricing

A CoCo bond is a bond issued by a financial institution where an automatic conversion into a predetermined number of shares takes place upon the occurrence of a trigger event, linked to a distress of the institution. By considering only the structure of CoCos bonds, a general expression of the price of CoCos bonds can be derived in this chapter. Instead of thinking of CoCos bonds as fixed income securities, we can think of them from the equity side.

This chapter will describe and analyze the approach to equity derivatives, introduced by De Spiegeleer and Schoutens (2012). We will follow closely the notations of De Spiegeleer and Schoutens (2012) to present closed-form solutions to equity derivatives for the pricing of CoCos bonds. The intuition behind the equity derivatives approach is that current and existing equity derivatives are added together to replicate the payout structure of a CoCo bond. To value the CoCo bond using equity derivatives, the CoCo bond is divided into different parts, which will add up to the total value of the CoCo bond.

Defining a CoCo bond requires specifying its face value (C) and maturity (T), as well as the random time (τ) at which the conversion will take place. Assuming that (m) coupons are attached to the CoCo bond. The coupon structure of the CoCo bond$(c_i,\ t_i)_{i=1}^{m}$ is defined so that the amount c_i is paid at time $t_i$provided that $\tau > t_i$. In our case, we will assume that the issuer of the CoCo bond pays dividends according to a deterministic function (κ) and that, on the side of the investors, no dividend is paid after the conversion time τ. We therefore assume below that there is no dividend after the conversion time τ and receiving βS_τ at τ is equivalent to receiving βS_T at T. Let r be the risk-free interest rate. Recall that in the approach to equity derivatives, the price of CoCos bonds is broken down into three parts, which all boil down to the total value of the instrument. As a result, the price of CoCos bonds under arbitrage can be broken down into three parts:

The value of the principal payment at maturity

$$V_p = \mathbb{E}^Q\left[Ce^{-rT}\mathbb{1}_{\{\tau>T\}}\right] \quad (1)$$

The value of coupon payments

$$V_c = \sum_{i=1}^{m}\mathbb{E}^Q[c_i e^{-rt_i}\mathbb{1}_{\{\tau>t_i\}}] \quad (2)$$

The value of converting

$$V_e = \mathbb{E}^Q\left[\beta e^{-rT}S_T\mathbb{1}_{\{\tau\leq T\}}\right] \quad (3)$$

Hence the value of a CoCo bond is expressed as follows:

$$\begin{aligned} V = V_p + V_c + V_e &= \mathbb{E}^Q\left[Ce^{-rT}\mathbb{1}_{\{\tau>T\}}\right] + \sum_{i=1}^{m}\mathbb{E}^Q[c_i e^{-rt_i}\mathbb{1}_{\{\tau>t_i\}}] + \mathbb{E}^Q\left[\beta e^{-rT}S_T\mathbb{1}_{\{\tau\leq T\}}\right] \\ &= Ce^{-rT}Q(\tau>T) + \sum_{i=1}^{m} c_i e^{-rt_i}\,Q(\tau>t_i) + \beta e^{-rT}\mathbb{E}^Q\left[S_T\mathbb{1}_{\{\tau\leq T\}}\right] \quad (4) \end{aligned}$$

Let $\Psi(x,t,\mu,\sigma,\upsilon) = Q(min_{0\leq s\leq t}X(s)\leq x)$, then the value of a CoCo bond can be written in the following form

$$\begin{aligned} V = Ce^{-rT}&\left(1-\Psi\left(log\,{}^{k}/_{S_0}, T,\mu,\sigma,\upsilon\right)\right) + \sum_{i=1}^{m} c_i e^{-rt_i}\left(1-\Psi\left(log\,{}^{k}/_{S_0}, t_i,\mu,\sigma,\upsilon\right)\right) \\ &+ \beta e^{-rT}\mathbb{E}^Q\left[S_T\mathbb{1}_{\{\tau\leq T\}}\right] \quad (5) \end{aligned}$$

It suffices to calculate the probability of conversion for the valuation of the CoCo bond. In fact, the key step in calculating the conversion value V_e is the determination of the joint modeling of the conversion time τ and the stock price S_τ. In the CoCos bond pricing framework, we show how to derive the probability of conversion. In effect, we are applying the measurement change that simplifies the pricing formula for conversion value by eliminating the stock price dependence. First, we fix a probability space $(\Omega, (F_t)_{t\geq 0}, Q)$ in which Q is a neutral risk measure. All underlying processes of our model are assumed to be observable and suitable for $(F_t)_{t\geq 0}$ filtration. We consider a financial institution issuing a contingent convertible bond to avoid financial deterioration or bankruptcy when a trigger event occurs. In this section, we will consider an exponential Lévy model for stock price. We assume that this triggering process is a stock price process that follows an exponential Lévy process under the risk-neutral probability measure Q;

$$S_t = S_0 e^{X_t}, \qquad t \geq 0 \qquad (6)$$

where S_0 is the initial value of the stock price and X_t is a general Lévy process that starts at zero and has independent and stationary increments. For more information on Lévy processes, see the book by Bertoin (1996). By defining a price action barrier, k, such that $k < S_0$. When the trigger processS_t crosses the barrier k, the fault occurs, and the conversion will take place. Therefore, the trigger event occurs at the first passage time if$X_t$exceeds the boundary condition $log\left({}^{k}/_{S_0}\right)$ and is given by

$$\tau = inf\{t \geq 0, S_t \leq k\} = inf\left\{t \geq 0, X_t \leq log\left({}^{k}/_{S_0}\right)\right\} \qquad (7)$$

From the Lévy-Khintchine formula, we see that in general a Lévy process consists of three independent parts: a linear deterministic part, a Brownian part and a pure jump part. According to the Lévy-Itô decomposition, X_t can be written in the following form:

$$X_t = \mu t + \sigma W_t + \int_0^t \int_{|x|\geq 1} x J_x(ds, dx) + \int_0^t \int_{|x|<1} x(J_x(ds, dx) - \upsilon(dx)ds) \qquad (8)$$

with

$$\mu = r - \frac{1}{2}\sigma^2 - \int_{\mathbb{R}} (e^x - 1 - x I_{\{|x|\leq 1\}})\upsilon(dx)$$

The first part designates the diffusive part with W_t being a standard Brownian motion ($W_0 = 0$) and the constants μ and $\sigma > 0$ constitute the drift and the volatility of the diffusive part of the price dynamics. The second part identifies the small jumps which describe the daily jitters caused by minor stock price fluctuations, while the third represents the large jumps which describe the large stock price fluctuations caused by major market disturbances. $J_x(ds, dx)$ is a random Poisson measure on $[0, \infty[$ and $(J_x(ds, dx) - \upsilon(dx)ds)$ represents its compensated Poisson measure. The measure υ, called Lévy measure, is a positive measure on $\mathbb{R}\backslash\{0\}$ which determines the progress of the jumps and verifies the following condition

$$\int_{-\infty}^{+\infty} inf\{1, x^2\}\upsilon(dx) = \int_{-\infty}^{+\infty} (1 \wedge x^2)\upsilon(dx) < \infty$$

Processes W_t and $J_x$are assumed to be independent.
The Lévy process satisfies $\int_{|x|<1} |x|\upsilon(dx) < \infty$ and $\int_0^t \int_{|x|<1} x J_x(ds, dx) < \infty$.

If we set $d = \mu - \int_{|x|<1} x\upsilon(dx)$

Then the Lévy process can be written as follows:

$$X_t = dt + \sigma W_t + \int_0^t \int_{\mathbb{R}} x J_x(ds, dx) \qquad (9)$$

We define a stock price adjustment process $\widetilde{S_T} = S_T e^{-rT}$. Girsanov's theorem allows us to show that there is a probability Q^* equivalent to Q under which the discounted price $\widetilde{S_T}$ is a martingale. Indeed, if the market is free of arbitrage, there is a probability measure Q^* equivalent to Q under which the updated asset $\widetilde{S_T}$ is a martingale. AOA (Absence of Arbitrage Opportunity) implies that the present value of any asset is a martingale under the measure, which is called a martingale measure. Thus, any AOA pricing rule is given by an equivalent martingale measure. Therefore, since $S_T e^{-rT}$ is a martingale under the neutral risk probability measure Q, we can take $S_T e^{-rT}$ to construct a change of measure. We assume a new probability measure Q^* such that:

$$Z_t = \frac{dQ^*}{dQ}\bigg|_{F_t} = \frac{\widetilde{S_T}}{\widetilde{S_0}} = \frac{S_T e^{-rT}}{S_0} = \frac{S_0 e^{X_t} e^{-rT}}{S_0} = e^{X_t - rT} \quad (10)$$

Under the stock price measure Q^* and assuming that the dynamics of the process of X_t is specified by (2), X_t is a new Lévy process under the probability measure Q^*. Indeed, we refer to proposition 9.8 in Tankov (2003), the elements of the new Lévy triplet are given by:

$$\mu^* = \mu + \sigma^2 + \int_{-1}^{1} x(e^x - 1)\upsilon(dx)$$

$$\sigma^* = \sigma$$

$$\upsilon^*(dx) = e^x \upsilon(dx)$$

If $\int_{|x|<1} |x| \upsilon^*(dx) < \infty$, we note that $d^* = \mu^* - \int_{|x|<1} x\upsilon^*(dx)$ and the relation between μ^* and μ can be simplified by

$$d^* = d + \sigma^2 = \mu + \sigma^2 + \int_{-1}^{1} x(e^x - 1)\upsilon(dx) - \int_{-1}^{1} xe^x\, \upsilon(dx)$$

So, $X_t$under Q^*can be expressed in the following form:

$$X_t = \mu^* t + \sigma^* W_t^{\,*} + \int_0^t \int_{|x|\geq 1} xJ_x^{\,*}(ds, dx) + \int_0^t \int_{|x|<1} x(J_x^{\,*}(ds, dx) - \upsilon^*(dx)ds) \quad (11)$$

Therefore, the value of the conversion is given by:

$$\beta e^{-rT}\mathbb{E}^{Q}\left[S_T \mathbb{1}_{\{\tau\leq T\}}\right] = \beta e^{-rT}\mathbb{E}^{Q^*}\left[S_T \mathbb{1}_{\{\tau\leq T\}}/Z_t\right] = \beta e^{-rT}\mathbb{E}^{Q^*}\left[S_0 e^{rT} \mathbb{1}_{\{\tau\leq T\}}\right] = \beta S_0 Q^*(\tau \leq T)$$

Finally, we get the following formula for the value of a CoCo bond

$$V = Ce^{-rT}\left(1 - \Psi\left(log\, {}^{k}/_{S_0}, T, \mu, \sigma, \upsilon\right)\right) + \sum_{i=1}^{m} c_i e^{-rt_i}\left(1 - \Psi\left(log\, {}^{k}/_{S_0}, t_i, \mu, \sigma, \upsilon\right)\right) + \beta S_0 \Psi\left(log\, {}^{k}/_{S_0}, T, \mu^*, \sigma^*, \upsilon^*\right) \quad (12)$$

This equation shows that the CoCos bond pricing problem is a problem of the first time of the passage of two Lévy processes. It reflects the hybrid nature of the CoCo bond. Indeed, the closed-form expression of the price of CoCos bonds consists that the Lévy processes (8) and (11) have closed-form expressions for their distributions of the first time of the passage.

Valuation of a Contingent Convertible Bond according to the First Passage Time and the Probability of Default

Brownian Motion

In our context, we are interested in the value of the probability of default where default occurs at maturity for the first time. Merton's original model (1974) does not allow for premature default, in the sense that default can only occur at the maturity of the claim. We will therefore examine the version of the first passage time models following Black and Cox (1976). They represent an important extension of Merton (1974) in many respects.

First, they form security covenants that allow creditors to take over the borrowing company when its value is below a certain threshold. The stock is no longer a European call option on the borrower's assets. Rather, the stock is a "down-and-out" call option on the company's assets, implying that the presence of security covenants transfers the value of the stock to creditors and allows the issuance of debt with higher circulation. Also, they consider senior and subordinate debts. Then, they develop an approach to value risky bonds paying with the limit of default, with and without asset sale restrictions, and demonstrate that security covenants and asset sale restrictions can improve creditor rights and increase debt values. Indeed, instead of only admitting the possibility of default at maturity (T), Black and Cox (1976) postulated that default occurs at the first time the asset value of the business drops below a certain barrier. In most of these models, the time to default is given as the first time the process passes from the value of assets S_t to a deterministic or random barrier. Default can therefore occur at any time before or on the maturity date of the CoCo bond (T). However, the fault occurs the first time $(S_t)_{t\geq 0}$ touches barrier k such that $\tau = inf\{t \geq 0, S_t \leq k\}$. Following Black and Cox (1976), let $m_t = min_{0<t\leq T} S_t$ be the first time the asset value process crosses the bankruptcy barrier and let $\upsilon = 0$ lead at $\upsilon^* = 0$ then $X_t = \mu t + \sigma W_t$is a Brownian motion. Let $f(y)$ be the probability density of S_t such that:

$$f(y) = \frac{1}{\sigma\sqrt{2\pi t}} e^{-(y-\mu t)^2/2\sigma^2 t} \qquad (13)$$

and $g(y, x)$ is the joint probability density with $x = log\left({}^{k}/_{S_0}\right)$ such that:

$$g(y, x) = \frac{1}{\sigma\sqrt{2\pi t}} e^{2\mu x/\sigma^2} e^{-(y-2x-\mu t)^2/2\sigma^2 t} \qquad (14)$$

The probability of default is given by:

$$\mathbb{P}(\tau_x \leq t) = \mathbb{P}\left(\min_{0<t\leq T} S_t \leq x\right) = \mathbb{P}(S_t \leq x) + \mathbb{P}\left(\min_{0<t\leq T} S_t \leq x, S_t > x\right) = \int_{-\infty}^{x} f(y)dy + \int_{x}^{+\infty} g(y,x)dy$$

$$= N\left(\frac{log\left({}^{k}/_{S_0}\right) - \mu t}{\sigma\sqrt{t}}\right) + \left(\frac{k}{S_0}\right)^{2\mu/\sigma^2} N\left(\frac{log\left({}^{k}/_{S_0}\right) + \mu t}{\sigma\sqrt{t}}\right) (15)$$

Where $N()$ is the cumulative function of the normal distribution. Then, the first passage time model driven by the derived Brownian motion yields the following CoCos bond price:

$$V = Ce^{-rT}\left(1 - N\left(\frac{log\left({}^{k}/_{S_0}\right) - \mu T}{\sigma\sqrt{T}}\right) + \left(\frac{k}{S_0}\right)^{2\mu/\sigma^2} N\left(\frac{log\left({}^{k}/_{S_0}\right) + \mu T}{\sigma\sqrt{T}}\right)\right)$$

$$+ \sum_{i=1}^{m} c_i e^{-rt_i}\left(1 - N\left(\frac{log\left({}^{k}/_{S_0}\right) - \mu t_i}{\sigma\sqrt{t_i}}\right) + \left(\frac{k}{S_0}\right)^{2\mu/\sigma^2} N\left(\frac{log\left({}^{k}/_{S_0}\right) + \mu t_i}{\sigma\sqrt{t_i}}\right)\right)$$

$$+ \beta S_0\left(N\left(\frac{log\left({}^{k}/_{S_0}\right) - \mu^* T}{\sigma^*\sqrt{T}}\right) + \left(\frac{k}{S_0}\right)^{2\mu^*/\sigma^{*2}} N\left(\frac{log\left({}^{k}/_{S_0}\right) + \mu^* T}{\sigma^*\sqrt{T}}\right)\right) (16)$$

This equation represents the closed-form expression of the first passage time of the price of CoCos bonds with the model of Black and Scholes (1973).

Spectrally Negative Lévy Process

General Framework

The mathematical notion on which the modeling of asset prices is based is the notion of stochastic process, modeling price trajectories amounts to specifying a family of stochastic processes. The common point shared by a large part of the stochastic processes used in finance is to belong to the sub-family of diffusion processes, which is based on Brownian motion. The best known of these models is the Black and Scholes (1973) model, which models price trajectories as an exponential of Brownian motion. However, the observation of prices reveals the presence of visible jumps, which the Black and Scholes model (1973) does not allow to reproduce. These phenomena can be of great importance for risk management because they correspond to periods of crisis.

The inadequacy of the Black and Scholes (1973) model to the reality of the markets can also be seen graphically when, instead of considering price trajectories, we compare "returns", i.e. differentials to time course of the logarithm of prices. The returns of most financial assets take on much more dispersed values than those of the Black and Scholes (1973) model, with frequent peaks corresponding to "jumps" in prices. We are interested here in the models of the first transit time based on the Lévy process. Indeed, several models incorporating jumps in the dynamics of firm value are described in the literature. Hilberink and Rogers (2002) opt for an extension of

Leland (1994), using Lévy processes which only allow downward jumps in the value of the firm. Kou and Wang (2003) showed how to use fluctuation identities from Lévy process theory to path-dependent options on assets driven by jump diffusions with exponentially distributed Poisson jumps. Madan and Schoutens (2007) work with downward jumping strategies, and thus allow situations where the default barrier is not only hit, but crossed by a jump. They detail the theory of spectrally negative Lévy processes in general and detail some popular examples. We return to the dynamics of the stock price process $(S_t)_{t\geq 0}$which is described by the exponential of a (non-Brownian) Lévy process. Indeed, we will consider a numerical approach to the pricing of CoCos bonds based on the explanation of the de Wiener-Hopf factorization of the Lévy process $(X_t)_{t\geq 0}$. This approach has been applied recently to set the contract price as in Corcuera et al (2013) and Madan and Schoutens (2007).

Let $\sigma, \upsilon \neq 0$ and $\upsilon([0,\infty[) = 0$ then $(X_t)_{t\geq 0}$ becomes a spectrally negative Lévy process. Since these conditions lead to $\sigma^*, \upsilon^* \neq 0$ and $\upsilon^*([0,\infty[) = 0$, (11) is always a spectrally negative Lévy process.

The closed-form expression of the Laplace transform of the distribution of the first passage time of the negative Lévy process on the spectral plane was given by Rogers (2000) thanks to the Wiener-Hopf factorization. Rogers (2000) determines the time distribution of the first pass by approximating the standard inverse Fourier transform, which exploits the change in the appropriate integration limit to avoid the difficulty of directly solving the Laplace exponent equation.

Let $= \inf\{t \geq 0, X_t \leq x\}$, with $x = log\left({}^{k}/_{S_0}\right)$.

Since the default is triggered by the crossing of a low barrier, or by the point where the minimum current will cross this level. The distribution of the current maximum and minimum of the Lévy process $(X_t)_{t\geq 0}$ will be as follows:

$$\overline{X_t} = sup_{s\leq t}\, X_s$$
$$\underline{X_t} = inf_{s\leq t}\, X_s$$

We assume that e_λ is an exponential distribution with parameter λ, independent of $(X_t)_{t\geq 0}$. Then the default probability of a Lévy process $(X_t)_{t\geq 0}$ is factored into a Laplace transform of the current minimum and maximum taken at exponential time.

However, we can write $\mathbb{E}(e^{zX_t}) = e^{t\varphi_x(z)}$.
Where $\varphi_x(z)$ is the Laplace exponent of the spectrally negative Lévy process (Bertoin, 1996) and is represented by:

$$\varphi_x(z) = \mu z + \frac{1}{2}\sigma^2 z^2 + \int_{-\infty}^{0} [e^{zx} - 1 - zx\mathbb{1}_{\{|x|\leq 1\}}]\upsilon(dx) \qquad (17)$$

Therefore, the Laplace transform of the process $(X_t)_{t\geq 0}$ taken at exponential time is given by:

$$\mathbb{E}\left(e^{zX_{e_\lambda}}\right) = \frac{\lambda}{\lambda - \varphi_x(z)} \qquad (18)$$

According to this equation and that the Wiener-Hopf factorization (Rogozin, 1966) is valid for general Lévy processes, we then have:

$$\frac{\lambda}{\lambda - \varphi_x(z)} = \mathbb{E}\left(e^{z\overline{X_{e_\lambda}}}\right)\mathbb{E}\left(e^{z\underline{X_{e_\lambda}}}\right) = \varphi_\lambda^+(z)\varphi_\lambda^-(z) \qquad (19)$$

Based on the knowledge of one of the two factors of this equation, we can obviously establish the other. Moreover, the classical theory of the Lévy process (Bertoin 1996, Sato 1999 or Kyprianou 2006) shows that, for a spectrally negative process, the right-hand Wiener-Hopf factor is expressed by:

$$\varphi_\lambda^+(z) = \frac{\chi^*}{\chi^* - z} \qquad (20)$$

with χ^* is a constant independent of λ and χ^* is the solution of $\varphi_x(\chi) = \lambda$.

So, once the current maximum taken at exponential time is exponentially distributed with the parameter $\chi^* = \varphi_x^{-1}(\lambda)$, we have calculated χ^* explicitly and we get the following expression for the left Wiener-Hopf factor:

$$\varphi_{\lambda}^{-}(z) = \mathbb{E}\left(e^{z\underline{X_{e_\lambda}}}\right) = \frac{\lambda}{\lambda - \varphi_x(z)} \frac{\chi^* - z}{\chi^*} (21)$$

This equation can be related to the distribution function of $(\underline{X_t})$ (current minimum) following a partial integration. Indeed, we have:

$$\varphi_{\lambda}^{-}(z) = \int_0^{+\infty} \lambda e^{-\lambda t} dt \int_{-\infty}^{0} e^{zx} f_{\underline{X_t}}(x) dx = \int_0^{\infty} \lambda e^{-\lambda t} dt \int_{-\infty}^{0} z e^{zx} \mathbb{P}(\underline{X_t} > x) dx$$
$$= \lambda z \int_{t=0}^{t=+\infty} \int_{x=0}^{x=+\infty} e^{-\lambda t - zx} f(t,x) dt dx = \lambda z \tilde{f}(\lambda, z) \quad (22)$$

However, we have defined the default time by $\tau_x = inf\{t \geq 0, X_t \leq x\}$ and according to Rogers (2000),

$$f(t,x) = \mathbb{P}(\tau_{-x} > t) = \mathbb{P}(\underline{X_t} > -x)$$

This equation represents the probability that the current minimum remains above $(-x)$ in t time units. Note that $\tilde{f}(\lambda, z)$ is the Laplace transform of $f(t,x)$. Indeed, the double Laplace transform of $f(t,x)$ is determined as follows:

$$\tilde{f}(\lambda, z) = \int_{t=0}^{t=+\infty} \int_{x=0}^{x=+\infty} e^{-\lambda t - zx} f(t,x) dt dx = \int_{t=0}^{t=+\infty} \int_{x=-\infty}^{x=0} e^{-\lambda t + zx} \mathbb{P}\left(\underline{X_t} > x\right) dt dx$$
$$= \frac{\chi^*(\lambda) - z}{(\lambda - \varphi_x(z))\chi^*(\lambda) z} \quad (23)$$

As Madan and Schoutens (2007) show, it is possible from this equation to show that $f(t,x)$, the probability that the minimum stays above $(-x)$ in t time units, can be obtained by the double inverse Fourier transform. The Fourier transform pricing method is a widely used method for valuing options in financial models when the risk-neutral density of the underlying asset is not given in an analytically tractable form, however the characteristic function, which describes the probabilistic behavior of the underlying, can be easily assessed. So far, there is a wide variety of Fourier-based pricing algorithms, but we limit the discussion to one of the most common versions.

A method based on Monte Carlo simulation is inefficient, due to slow convergence due to the large amplitude of the jumps, and the inherent difficulties in identifying the optimal exercise policy. Knowing the characteristic function of the Lévy process paves the way for a Fourier approach to evaluating options on the spot. The algorithm for evaluating the first passage time distribution of the spectrally negative Lévy process can be summarized as follows. We set $\lambda_1, \lambda_2, z_1$and z_2 which are real numbers with $\lambda_1, z_1 > 0$such that $\lambda = \lambda_1 - i\lambda_2$and $z = z_1 - iz_2$.

Then, we can write $\tilde{f}(\lambda, z)$ in the following form:

$$\tilde{f}(\lambda_1 - i\lambda_2, z_1 - iz_2) = \int_{t=0}^{x=+\infty} \int_{x=0}^{x=+\infty} e^{-(\lambda_1 - i\lambda_2)t - (z_1 - iz_2)x} f(t,x) dt dx$$
$$= \int_{t=0}^{t=+\infty} \int_{x=0}^{x=+\infty} e^{i\lambda_2 t + iz_2 x} e^{-\lambda_1 t - z_1 x} f(t,x) dt dx (24)$$

This new function represents the double Fourier transform of $e^{-\lambda_1 t - z_1 x} f(t,x)$. As a result, following the inverse Fourier transform, we then have:

$$e^{-\lambda_1 t - z_1 x} f(t,x) = \frac{1}{(2\pi)^2} \int_{\lambda_2=-\infty}^{\lambda_2=+\infty} \int_{z_2=-\infty}^{z_2=+\infty} e^{-(i\lambda_2 t + iz_2 x)} \tilde{f}(\lambda_1 - i\lambda_2, z_1 - iz_2)\, dz_2 d\lambda_2 (25)$$

or,

$$f(t,x) = \frac{1}{(2\pi)^2} \int_{\lambda_2=-\infty}^{\lambda_2=+\infty} \int_{z_2=-\infty}^{z_2=+\infty} e^{(\lambda_1 - i\lambda_2)t + (z_1 - iz_2)x} \tilde{f}(\lambda_1 - i\lambda_2, z_1 - iz_2)\, dz_2 d\lambda_2$$

Therefore,

$$f(t,x) = -\frac{1}{(2\pi)^2}\int_{\Gamma_1}\int_{\Gamma_2} e^{\lambda t+\tau x}\frac{\chi^*(\lambda)-z}{(\lambda-\varphi_x(z))\chi^*(\lambda)z}d\lambda dz (26)$$

Where the limits Γ_1 and Γ_2 are defined as follows:

$$\Gamma_1 = \{\lambda_1 + i\lambda_2 \backslash \lambda_2 = -\infty \dots \infty\}$$
$$\Gamma_2 = \{z_1 + iz_2 \backslash z_2 = -\infty \dots \infty\}$$

This problem is solved by performing a boundary change following Rogers (2000) and using the Abate and Whit (1992) approximation.

Lemma 1.
For fixed t and x;

$$S_N(t,x) = \frac{h_1h_2}{(2\pi)^2}\sum_{n=-N}^{N}\sum_{m=-N}^{N} h'(a_1+inh_1)\tilde{f}(h(a_1+inh_1), a_2+imh_2)e^{h(a_1+inh_1)t+(a_2+imh_2)x}$$

with i being the imaginary unit, $h = \varphi \circ \varphi_0^{-1}$, h' is its derivative and

$$\tilde{f}(h(\varsigma),z) = \frac{\varphi_0^{-1}(\varsigma)-z}{(h(\varsigma)-\varphi_x(z))\varphi_0^{-1}(\varsigma)z},$$

Where $\varphi_0(z) = \mu z + (1/2)\sigma^2 z^2$ and $\varphi_0^{-1}(z) = (\sqrt{\mu^2+2\sigma^2 z}-\mu)/\sigma^2$.

Given the set of parameters (A_1, A_2, l_1, l_2, N) and following Madan and Schoutens (2007), it is suggested to take

$a_1 = {A_1}/{2tl_1},\ a_2 = {A_2}/{2xl_2}$
$h_1 = {\pi}/{tl_1},\ h_2 = {\pi}/{xl_2}$
$A_1 = A_2 = 22$
$l_1 = l_2 = 1$

and Rogers (2000) suggests that choosing $N = 6$ gives satisfactory results. The double sum in the previous equation is used as an initial approximation of $f(t,x)$ and the parameters (A_1, A_2, l_1, l_2) are positive real numbers chosen large enough to control the error of spectrum aliasing. Finally, it is incited to take an Euler sum

$$f(t,x) \doteq \sum_{k=0}^{M} 2^{-M}\binom{M}{k} S_{N+k}(t,x)$$

with $M = 9$ and the symbol $\doteq$ indicates an Euler sum. This final Euler sum is used to improve the accuracy of the raw approximation $S_N(t,x)$. Given the expression for the first passage time distribution of the spectrally negative Lévy process, the expression for the CoCos bond pricing valuation can be expressed as:

$$V = Ce^{-rT}\left(1-\Psi\left(\log {k}/{S_0}, T, \mu, \sigma, \upsilon\right)\right) + \sum_{i=1}^{m} c_i e^{-rt_i}\left(1-\Psi\left(\log {k}/{S_0}, t_i, \mu, \sigma, \upsilon\right)\right) + \beta S_0 \Psi\left(\log {k}/{S_0}, T, \mu^*, \sigma^*, \upsilon^*\right) \quad (27)$$

with $\Psi(x,t,\mu,\sigma,\upsilon) = \mathbb{P}(\tau_x \le t) = 1 - f(t,-x)$.

The spectrally negative Lévy process is a large family of Lévy processes including various forms of jumping. To price of CoCos bonds in this case, the jump form of the spectrally negative Lévy process need not remain unchanged under the measure transform. The one-sided CGMY Lévy model proposed by Corcuera and Valdivia (2016) is a practical and specific case of this work. Since downside risk should always be considered in the financial market, the spectrally negative Lévy process has been widely applied in finance. From there, the expression for the CoCos bond pricing valuation enriches the financial applications of the spectrally negative Lévy process. A simple example is given below.

Exponential Jump Diffusion Process

In this example, the jumps of the spectrally negative Lévy process have an exponential distribution with the parameter η, arriving at the rate λ. The jump shape does not change under the measuretransform. The density function of the exponential distribution is given by:

$$f_X(x) = \eta e^{\eta x} I_{\{x<0\}} (28)$$

The Lévy measure of an exponential jump diffusion process can be expressed as

$$\upsilon(dx) = \lambda f_X(x)dx (29)$$

Returning to the general equation for the Laplace exponent above and following integration by parts, the Laplace exponent can be expressed as

$$\varphi_x(\tau) = \left(\mu + \lambda\left(\frac{1 - e^{-\eta}}{\eta} - e^{-\eta}\right)\right)z + \frac{1}{2}\sigma^2 z^2 - \frac{\lambda z}{\eta + z} \quad (30)$$

By noting $\omega = \mathbb{E}^Q(e^X) = \eta/(\eta + 1)$

After the measure transform, the jumps have an exponential distribution with a new rate $\lambda^* = \lambda \mathbb{E}^Q(e^X) = \lambda\eta/(\eta + 1)$ and the new density function under the probability measure Q^* is in the following form:

$$f_{X^*}(x) = (\eta+1)e^{(\eta+1)x} I_{\{x<0\}} \quad (31)$$

The jump distribution under the probability measure Q^* is always an exponential distribution with parameters $\eta^* = \eta + 1$, which proves that the exponential jump diffusion process under the measure transform is always an exponential jump. Then the Laplace exponent can be expressed as

$$\varphi_x(\tau) = \left(\mu + \sigma^2 + \lambda\left(\frac{1 - e^{-\eta}}{\eta} - e^{-\eta}\right)\right)z + \frac{1}{2}\sigma^2 z^2 - \frac{\lambda\eta z}{(\eta + 1)(\eta + z + 1)} \quad (32)$$

Then the price of CoCos bonds can be evaluated through the previous expression.

Numerical Example

In this section, we try to compare the two Lévy models. Indeed, we study the difference in the price of CoCos bonds between the two Lévy models and how the price of CoCos bonds changes with the parameters of the models. For a simple statement, the models driven by the derived Brownian motion and the spectrally negative Lévy process are abbreviated as BS and SN, respectively. To make the comparison results more explainable, the jumps of the spectrally negative Lévy process are chosen to arrive at a limited speed and have an exponential distribution. The parameters mainly refer to Rogers (2000) and Kou and Wang (2003). Since these Lévy models all satisfy $\int_{|x|<1} |x| \upsilon(dx) < \infty$ under the assumptions, X_t can be expressed as (9) in the Lévy models. μ is chosen to satisfy the martingale condition as

$$\mu = r - \tfrac{1}{2}\sigma^2 - \int_{\mathbb{R}} (e^x - 1 - xI_{\{|x|\le 1\}})\upsilon(dx).$$

Like Rogers (2000) and Kou and Wang (2003), σ is equal to 0.2 for both models. The risk-free rate is assumed to be 0.05. The numerical inverse Fourier parameters for SN are chosen as follows:

$$l1 = l2 = 1, A1 = A2 = 22, N = 6 \text{ and } M = 9.$$

CoCos bonds are supported with a 10-year maturity and a fixed coupon of 0.16 paid annually. Let the principal C of the CoCos bonds be 100, the initial price $S_0 = 10$ and the implied market price barrier $k = 8.5$. Once the trigger event occurs, the CoCos bonds per share are converted into 20 shares. In this section, we analyze the effect of λ on the price of CoCos, the effect of volatility on the price of CoCos and the effect of the conversion ratio on the price of CoCos.

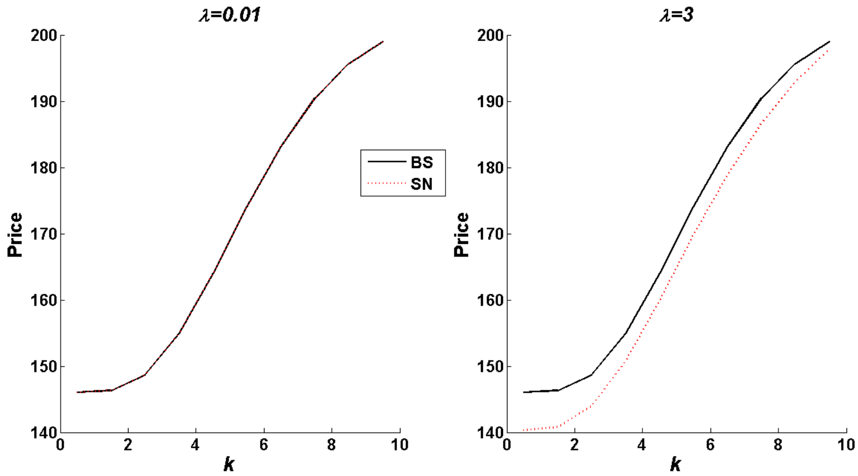

Figure 1. The price sensitivity of CoCos when (a) $\lambda = 0.01$ and (b) $\lambda = 3$.

Figure 1. Examines the price of CoCos bonds at different k values when $\lambda = 0.01$ and $\lambda = 3$. If λ is small enough, the jumps in SN are so few that the price evaluated from this term is almost identical to that of BS. The charts are not monotonous, reflecting the hybrid nature of CoCos bonds. If $\lambda = 3$, the SN curve almost overlaps. This result shows that jumps have a limited influence on the pricing of CoCos bonds and the difference in CoCos bond prices between BS and the other spectrally negative Lévy model. SN is a natural improvement over BS as they embed a jump structure in BS for the characterization of the jump phenomenon in the financial market. The difference between these two models shows the value and importance of introducing the SN model which has a lower price of CoCos bonds than BS, which shows that BS would overestimate the price of CoCos bonds to compress the information on the jumps in volatility. The result of BS overestimation goes against the intuitive understanding that BS would underestimate the price of CoCos bonds without considering jump risk. Using the Lévy SN model, we clearly observe a significant improvement over the BS model. We can conclude that the more flexible Lévy processes are more suitable than the normal distribution.

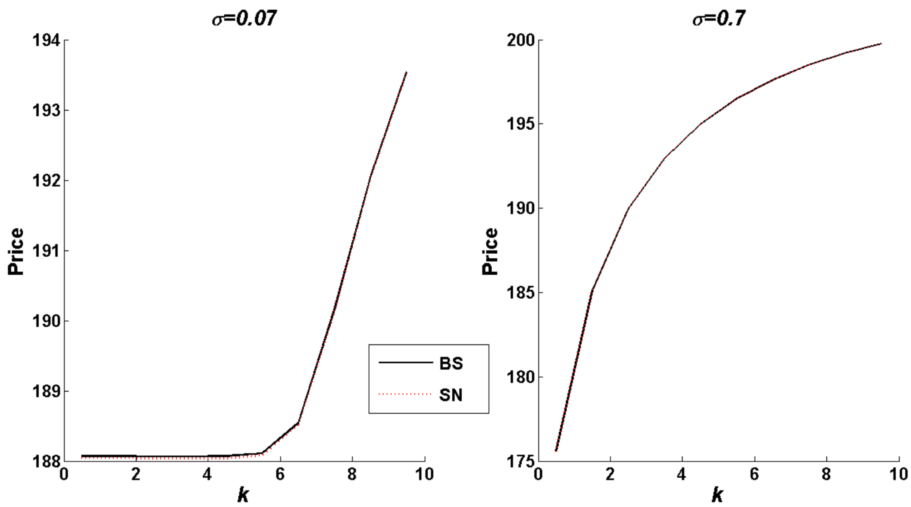

Figure 2. The price sensitivity of CoCos when (a) $\sigma = 0.07$ and (b) $\sigma = 0.7$.

Figure 2 shows that when σ is larger, we note an increase in the price of CoCos bonds in both models. Indeed, it indicates that an increase in volatility will increase the price of CoCos bonds. In addition, the increasing speed decreases for the upper bound of the trigger probability. The increase in σ plays an increasingly critical role in the pricing of CoCos, smooths the influence of jumps, and narrows the spread between CoCos bond prices among these patterns.

Figure 3 proves that the conversion ratio has a significant effect on the price of CoCos bonds for each of the two models, BS and SN. We note that if the conversion ratio is higher, the price of the CoCos bonds rises, while if the conversion ratio is lower, no progress is noted for the price of the CoCos bonds. Therefore, the conversion ratio plays an important role in the pricing of CoCos regardless of the process used.

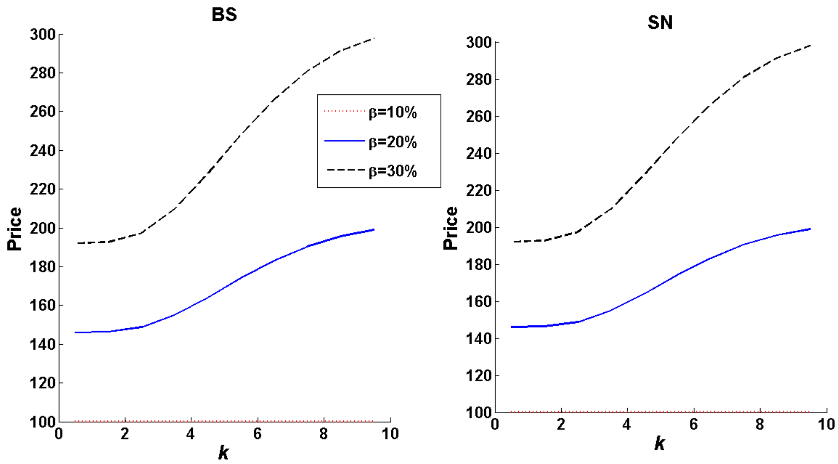

Figure 3. CoCos bond prices of the black-scholes model and the spectrally negative lévy process, respectively, for a range of the conversion ratio β.

Conclusion

Despite its success, the formula of Black and Scholes (1973) is often criticized for its inadequacy to the realities of financial markets. Several families of models have thus been proposed to remedy its deficiencies, leading in particular to relaxing the assumption of continuity of price trajectories. This chapter develops a general Lévy framework for pricing CoCos bonds. Lévy's framework intuitively shows the hybrid nature of CoCos bonds and reduces the problem of pricing CoCos bonds to the problem of the first passage time of the triggering process. According to the characteristics of the new Lévy measure after the measure transform, two Lévy models driven by the derived Brownian motion and the spectrally negative Lévy process are proposed. These two Lévy models keep the form of the Lévy process unchanged under the measure transform, which avoids the difficulty that only rare forms of Lévy processes solved the first passage time problem. These Lévy models provide closed form expressions for the price of CoCos while one owns it up to the double Laplace transform, the pricing results of which are given by combining with the numerical Fourier inversion.

The numerical results show that negative jumps play a much critical role in the pricing of CoCos bonds. The Black-Scholes model compresses all the information about jumps in volatility, which makes a big difference in the price of CoCos bonds between the Black-Scholes model and the SN model. The model driven by the spectrally negative Lévy process only compresses the information of positive jumps in volatility. Without the characterization of jumps in the triggering process, the Black-Scholes model would overestimate the price of CoCos bonds. The model driven by the spectrally negative Lévy process would provide a more accurate CoCos bond price taking into account the phenomenon of jumps in the financial market. The proposed Lévy models can capture the short-term behavior of the triggering process. However, the long-term phenomenon such as volatility clustering is not characterized. In addition, stochastic volatility Lévy models and regime-switching Lévy models, which can capture long-term behavior, deserve further study. Some special regime-switching Lévy models solved the first passage time problem, and the next step can extend Lévy models to regime-switching Lévy models. Since different designs of CoCos bonds lean towards different pricing models, Levy models for more complex designs of CoCos with features such as multi-variate trigger are also for further study.

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in EPESS journal belongs to the authors.

Acknowledgements or Notes

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Comparison of the Multiannual Financial Frameworks in the European Union and its Hungarian Aspects

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Abstract: The long-term viability of the European Union depends not only on well-defined goals, but also on the financial means behind them. Integration can achieve greater success in areas that nation states would otherwise not be able to do effectively enough on their own. Examples include sustainability and strengthening international competitiveness. There are therefore some tasks that can be more successfully achieved at Community level, but they would require adequate financial support. The EU itself has an annual budget, but even more interesting is the so-called Multiannual Financial Framework, which sets out not only the financial possibilities but also the prevailing economic strategic orientations. Some areas are given priority, while others have to be diverted. Budgeting in this way is a continuous series of choices and dilemmas, which are not easy decisions for the decision-maker. The present study aims to compare the structure of the two most recent Multiannual Financial Frameworks and focuses on Hungary's share of each heading. The study will hopefully make it clear that EU funding is a complex issue and that planning an appropriate budget is not as simple as one might first think.

Keywords: EU, Budgeting, Crisis management

Introduction

War. The Treaty of Rome in 1957 set in motion a process that has now resulted in a multi-country economic integration. Although this is not a long history, the events and changes that have taken place during this period have nevertheless presented the Member States with significant challenges. It can be argued that, although the common journey so far has been short in time, the challenges have become greater in recent years. This is particularly true today, as the 2000s have brought very serious challenges. The crisis of 2008 was a stark testimony to this, and we recovered a little from it to witness a new set of adverse events. The COVID-19 pandemic situation should be mentioned here, and then the Russian-Ukrainian conflict, which culminated in a major energy crisis, which together created a very difficult situation in the countries of the European Union. Since the first wave of the pandemic, a permanent emergency situation has been present in the European Union, which has required member states to adapt to a permanent emergency mode (Tesche, 2021).

The stability and prosperity of the European Union (EU) depends on its ability to take timely and effective measures to repair the damage caused by COVID-19 and prepare for a better future for the next generations (Crescenzi et al, 2021). The decision-makers had little choice. It is necessary to adapt to the situation, to mitigate the adverse effects and to take measures to make this period as painless as possible for economic operators and society. This is obviously not an easy task, but flexibility, adaptation and change are needed at EU level. This comparative study seeks to explore the tangible manifestations of this. The EU has also tried to adapt quickly to changed circumstances (Fernandez, 2021). The real evidence of this is the EU budgeting, where we can always observe some kind of strategic priority (Murzyn, 2018; Reininger, 2021). It should also be seen that in such a period of crisis, it is not possible to focus on all areas at once. Challenges make policy changes in, for example, R&D policy quite likely, but this is also true for other areas (Kaiser & Prange-Gstöhl, 2010). EU budget planning refers to the process of budget planning for a given year, while we can also talk about a so-called Multiannual Financial Framework (MFF), which plans the direction of the EU budget for longer cycles. EU budget planning has also had to respond to current challenges, since the resources provided by the EU must also serve to finance specific objectives. Obviously, different objectives were set for the 2014-2020 planning period (for example, support for agriculture was of paramount importance) (Greer, 2013) compared to the current 2021-2027 period. The priorities have changed (Rabesandratana, 2018).

Today, the aim is to mitigate as much as possible the effects of the recent crises and to help EU actors through the crisis. New goals have emerged today. Creating a more resilient, flexible and dynamic integration has become a key priority. Building resilience, promoting sustainability or supporting digitalisation are important priorities. All this requires a completely different budget, as these EU-level objectives need to be financed through programmes, projects and appropriations. New funds need to be created to ensure that they are adequately funded. So the question is: has the EU budget planning really changed in the last period and can we detect a change in priorities? The best way to get a sense of this is to compare two multiannual budgetary periods, the Multiannual Financial Framework 2014-2020 and the Multiannual Financial Framework 2021-2027. From these, we should see what were the most important objectives to be achieved for the two periods. Is the current budget planning focus really different from previous years? Is successful crisis management and resilience building really the main priority of the current budget planning? These questions are also answered by comparing the EU's last and current Multiannual Financial Framework. Given that Hungary is also a full member of the European Union, we looked with interest at the Hungarian economy's relationship with the common budget.

In our study, we set out hypotheses.

> H1: the Multiannual Financial Framework 2021-2027 has a stronger focus on investment and employment in crisis management and resilience building, but not enough focus on adequate support for the competitiveness pillars, which would be key for the growth and competitiveness of the EU as a whole. The Multiannual Framework is thus primarily more of a bail-out and support to Member States rather than a longer-term boost to competitiveness, which would be essential to recover from crises.
>
> H2: In the 2021-2027 budgetary programming period, Hungary will not be able to draw on any more resources to further strengthen Hungarian competitiveness. Hungary will not be in a better position in the coming years than in the previous period.
>
> H3: In the new EU programming period (2021-2027), the Digital Europe goal (to promote digitalisation) and the European Green Deal (the European Green Deal, which sets a target of 0% emissions in the EU by 2050) mean that the Multiannual Framework will need to show an intensive increase in the sustainability or digitalisation chapters to help achieve these goals.

To test these hypotheses, a comparison of the Multiannual Financial Frameworks provides useful information.

Systematic Literature Review

The EU budget still functions essentially as an intergovernmental budget (Crowe, 2021). This means that although the budget is managed at EU level, the contributors are the member states that create the revenue side of the budget through GNI-based contributions. These contributions are the most important items on the revenue side, which are supplemented by other sources (also seeking to reduce the Member States' liabilities). EU expenditure is spread over a number of programmes and mechanisms (Cipriani, 2021). The nature of these programmes and mechanisms is essentially aligned with the EU's objectives and policy priorities for the period. The EU budget must therefore be understood in terms of a comparison between revenue and expenditure. The general budget of the EU is nothing but a public finance plan, comprising revenue and expenditure, which is economic in nature and an instrument of EU financial policy (Tyniewicki, 2008).

The EU budget is essentially linked to:

- achieving regional convergence
- increasing economic growth
- achieving EU goals and objectives (Ferrer & Katarivas, 2014).

The EU's common budget should always be aligned with the objectives set out in EU policies. However, other circumstances often influence the structure of the EU budget. In recent years, new spending needs have emerged (e.g. external border protection, climate protection), but there have also been significant changes in revenue, with the departure of a major contributor after the UK's exit from the EU (Elżbieta, 2020). There have also been repeated debates among member states and EU institutions on what constitutes an adequate budget, the size of the budget, the level of net contributions, the mix of revenue and expenditure (Begg, 2016).

The EU has essentially an annual budget and a long-term financial framework. The annual budget will of course be a set of appropriations and commitments that can be planned and used for a given year, for example the budget for 2021 or 2022. The EU budget is basically set up to ensure the financing of the common policies adopted by the Member States (Szemlér, 2019). However, the annual budget is different from the multiannual framework. The annual budget is embedded in the EU's multiannual financial framework, so the difference between the two is that the multiannual framework can be said to be a financial planning over a longer period of time, while the EU budget itself is a financial plan for a given year to promote EU goals. The multiannual financial framework has been a concept in the European Union since 1988. It has also brought great stability to the annual budget negotiations and put an end to a long-standing interinstitutional conflict. The formulation of EU policies and the limits of financial flexibility in budget planning depend to a large extent on the final agreement on the long-term framework. It can therefore be said that the adoption of the MFF will determine the planning and structure of each budget year.

The MFF sets the ceilings on the amount of money the EU can spend, establishes budget programmes that specify where money is to be spent and also sets out the rules that describe how spending is to be financed (Leen, 2016; Rodriguez, 2021). Since the adoption of the multiannual financial framework, it has almost always been possible to adopt annual budgets (Halmai, 2018). Another argument in favour of the multiannual framework is that investment and investment programmes are, by their very nature, more sensible to plan for the long term (OECD, 2017). Once the multiannual framework has been adopted, it also allows for budget planning for specific years. The most recent period of long-term planning was the 2014-2020 programming period and we are now in the 2021-2027 period. The following chapters of this study will attempt to compare these. Both the EU annual budget and the new multi-annual framework will have to address a number of challenges.

The main crises affecting the Union and budget planning have been:

2008: Financial crisis
2011-2014: euro area crisis
2015-2016: migration crisis
2016-2020: Brexit
2021- : COVID-19
2022- : Russian-Ukrainian conflict

These crises have posed significant challenges for EU budget planning, not only to finance core policy objectives and the functioning of the Union, but also to promote crisis adaptation and resilience, which require additional budget headings (Rietig, 2021; Gravey, 2014). The question is therefore whether their impact will be directly reflected in the new programming period (2021-2027) and whether a financing structure for integration that meets these objectives can be successfully put in place.

Results and Discussion

1. EU Multiannual Financial Framework 2014-2020

For the programming period 2014-2020, the Multiannual Financial Framework had six basic chapters. The chapters always refer to the key policy areas where EU integration aims to achieve significant results in the period.

Chapters:

1. Smart and Inclusive Growth (INK)
2. Sustainable growth: natural resources (FEN)
3. Security and citizenship (BIS)
4. Global Europe (GLO)
5. Administration (ADM)
6. Compensation (COM)

For the first time we need to look at the total appropriations for the Multiannual Framework 2014-2020. As the following graph shows, the 7-year envelope has increased the most in the last two years, resulting in a significantly higher budget compared to 2017. This of course required a strengthening of the revenue side of the budget. Unsurprisingly, own revenue in 2018 and 2019 was higher than in previous years, but this was of course complemented by additional resources.

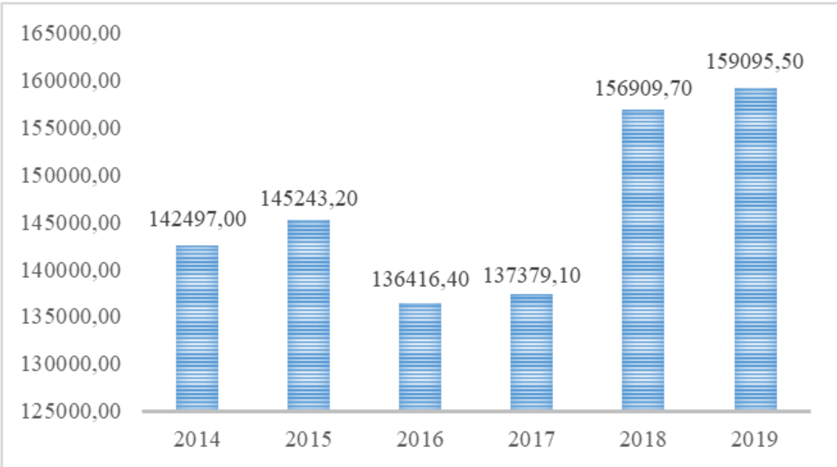

Figure 1. Total budget timeline for the seven-year framework (in MEUR) (2014-2020)
Source: Databases of the European Union

Own resources are always more interesting because they are paid directly by the Member States as a GNI-based contribution. Looking at the data series, we can see that the evolution of own resources was already much higher in 2019 compared to 2014. This is strongly linked to the fact that the EU has gradually faced new challenges. New problems and new tasks have increased the number of projects and investments to be financed, more and more earmarked funds have had to be set up and the number of operational cases has gradually increased. The latter also increased administrative and management costs at EU level.

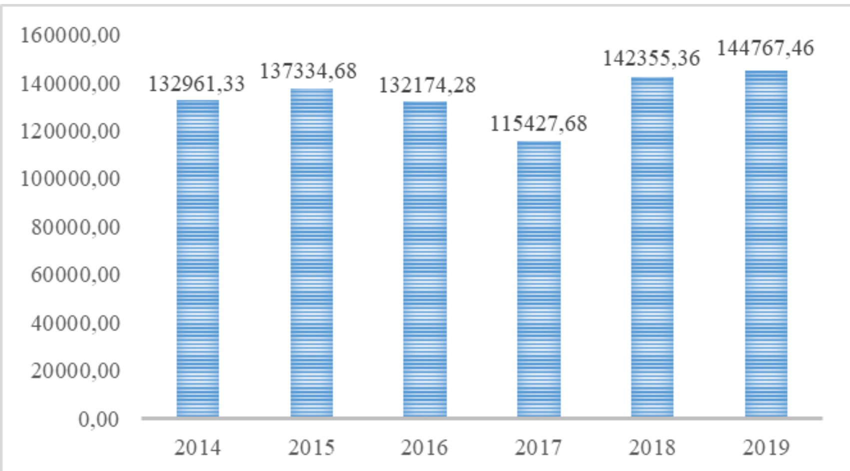

Figure 2. Evolution of own revenue for the seven-year framework (in M EUR)(2014-2020)
Source: Databases of the European Union

It may be particularly interesting to know what each chapter covers. In an earlier paragraph of the study, we argued that these chapters also express policy priorities, EU and national objectives and ambitions. The following sub-areas and objectives were identified in each chapter:

1. smart and inclusive growth (smart and inclusive growth): jobs, employment, research, innovation, education skills, trans-European networks, transport, social policy, enterprise development, regional cohesion, catching-up.
2. sustainable growth: natural resources (FEN): agricultural policy, fisheries policy, rural development, environmental protection measures
3 Security and Citizenship (SCC): justice and home affairs, border protection, immigration and asylum policy, public health, consumer protection, culture, youth, citizens' dialogue
4 Global Europe (GLO): EU external policy, assistance to third world countries
5. administration (ADM): EU institutions
6. compensation (COM): temporary payments

The study also looks at the share of the Hungarian economy under each chapter. The table below shows that Hungary's share of the MFF was highest under two headings. These two headings were Smart and Inclusive Growth (SGG) and Sustainable Growth (SGG). The other headings allocated little or no money to Hungary.

Table 1. Hungary's share of the multiannual framework chapters (in M EUR)(2014-2020)

Years							
2014	6620,21	4686,70	1894,60	18,62	5,22	15,07	0,00
2015	5629,08	3774,71	1791,35	42,19	6,37	14,45	0,00
2016	4546,11	2836,49	1667,17	27,17	0,05	15,23	0,00
2017	4049,14	2480,33	1516,87	35,96	0,00	15,98	0,00
2018	6298,11	4533,46	1715,81	31,81	0,41	16,62	0,00
2019	6202,47	4305,62	1827,30	52,80	0,00	16,75	0,00
	TOTAL	INK	FEN	BIZ	GLO	ADM	KOM

Source: Databases of the European Union

Looking again at all the chapters, it is perhaps not surprising that Hungary was the country most interested in the first two. Indeed, these two chapters are the ones most closely associated with economic growth or national competitiveness. These are precisely the areas where the country would have liked to catch up more intensively. At the same time, we have also mentioned that the budget is not only drawn down by the Member States, but also paid into. It is therefore worth looking at the ratio between payments and calls. We need to compare the country's payments (on a GNI basis) with the amounts called up. We can see that in 2016 and 2017, Hungarian contributions hardly changed, but significantly less money was available for drawdown. This started to recover in 2018, but from 2018 onwards Hungarian payments have also increased. The country was able to draw down the most money in 2014, when it had the highest drawdown/deposit ratio. We should also see that Hungary has been drawing down significantly more money each year than it has been paying into the budget. The drawdown/deposit ratio is calculated by dividing the drawdown by the deposit. This shows how many times more Hungary has called than it has paid into the common budget.

Table 2. Drawdowns and payments and their share for Hungary (2014-2020)

Years	Deposit	Drawdown	Drawdown/Deposit rate
2014	1020,72	6620,21	6,49
2015	1093,75	5629,08	5,15
2016	1066,63	4546,11	4,26
2017	969,78	4049,14	4,18
2018	1268,92	6298,11	4,96
2019	1289,73	6202,47	4,81

Source: Databases of the European Union

Table 3. Evolution of the INK heading in Hungary in relation to total available resources (2014-2020)

Years			*Distribution in %*
2014	6620,21	4686,70	70,79%
2015	5629,08	3774,71	67,06%
2016	4546,11	2836,49	62,39%
2017	4049,14	2480,33	61,26%
2018	6298,11	4533,46	71,98%
2019	6202,47	4305,62	69,42%
	TOTAL	INK	%

Source: Databases of the European Union

The vast majority of the funds that Hungary was able to draw down were related to two headings, namely Smart and Inclusive Growth (SGG) and Sustainable Development (SD). Hungary hardly drew down funds from the other headings. It is worth looking at what the country has used most of the resources under these two main headings. The Smart and Inclusive Growth (INK) chapter accounted for the largest percentage of the resources called up by Hungary. The following table illustrates this very well.

Smart and inclusive growth can be divided into two parts:

1.1 Competitiveness for growth and jobs sub-heading (COM)
1.2 Economic, Social and Territorial Cohesion (ESC)

The following table shows the share of sub-heading 1.1 under heading INK, which is indicated by COM, and the share of sub-heading 1.2, which is indicated by COH. As can be seen from the table below, of the Smart and Inclusive Growth heading, which accounted for 70% of our total resources available, almost 100% of this heading is also 1.2, i.e. Economic, Social and Territorial Cohesion. It can be seen from the table that the TOTAL column represents the total resources received, compared to which the cohesion sub-heading accounts for the largest share. However, the resources allocated to strengthening competitiveness are smaller. It is also worth looking at the factors within the two sub-headings which are highly valued. In the table, the % column indicates the percentage of the total INK heading allocated to competitiveness and the percentage allocated to cohesion. It is clear that this resource is used by Hungary for cohesion.

Table 4. Utilisation of the INK heading in Hungary in relation to the total available resources (2014-2020)

Years						
2014	6620,21	4686,7	232,16	4,95%	4454,54	95,05%
2015	5629,08	3774,71	81,52	2,16%	3693,20	97,84%
2016	4546,11	2836,49	98,03	3,46%	2738,46	96,54%
2017	4049,14	2480,33	339,78	13,70%	2140,54	86,30%
2018	6298,11	4533,46	98,08	2,16%	4435,38	97,84%
2019	6202,47	4305,62	134,61	3,13%	4171,01	96,87%
	TOTAL	INK	Com	%	Coh	%

Source: Databases of the European Union

In the following, those rows are highlighted which represent the most significant item in row 1.1 (COM) and row 1.2 (COH). First, the sub-heading Competitiveness for Growth and Jobs (COM) is reviewed. Hungary could also receive less funding from this sub-heading for 2019 than it did when the MFF started. In 2014, 232.16 MEUR were available for strengthening competitiveness, but this dropped quite a bit. In 2019, 134.61 MEUR was available, but this was still only 3.13% of the Smart and Inclusive Growth resource. Overall, it can indeed be concluded that only a small part of the resources was used to strengthen competitiveness. But this sub-heading covers quite a number of areas, such as innovation, education and entrepreneurship. What follows is a description of where most of the resources within this sub-heading have been spent:

1.1.3 Common Strategic Framework (CSF) Research and Innovation EN (EUR million)

Common Strategic Framework for Research and Innovation. Within sub-heading 1.1, most budget lines have 0 EUR or very low, almost negligible values. "More 'serious' amounts were only found for 1.1.3. The values are illustrated in the following table. It is clear that hardly any resources are allocated to innovation and R&D. In 2017, this was an outlier, but apart from that, the values of EUR 40-50 million are not really outstanding. This is around 16-20 billion forints. This is hardly enough to create an innovative economy. Within 1.1.3 we find the Horizon2020 strategy, which can be understood as a framework programme for innovation and R&D.

Table 5. The common strategic framework for R&D and innovation in Hungary (2014-2020)

Years	
2014	193,25
2015	44,43
2016	44,00
2017	284,57
2018	47,64
2019	54,73

Source: Databases of the European Union

The other major item within this is 1.1.5, The Union Programme for Education, Training and Sport (Erasmus+) EN (EUR million), the EU's joint programme for education, training and sport, Erasmus+. Again, only two years, 2018 and 2019, were available under this line, with EUR 40 MEUR in 2018 and EUR 70M in 2019.

The other lines either have virtually no amounts or barely a few million euros. For example, if we add up the 2018 figures, we see that the CSF (1.1.3) amounts to 47.64 MEUR and Erasmus+ to 40 MEUR, which is almost the same as the 2018 figure for sub-heading 1.2. In short, it can be seen that apart from the two points above, the competitiveness sub-heading does not really represent a large proportion. The other heading, cohesion (COH), contains much larger amounts. As shown above, the cohesion sub-heading accounts for about 95-97% of the inclusive growth heading, while the inclusive growth heading itself accounts for about 70% of the total resources, so it can be said that Hungary could indeed spend most on cohesion. The blue line indicates the total resources. The grey line shows smart and inclusive growth. You can see that this accounts for a significant part of the resources. Within inclusive growth, the thick orange line shows that this heading is almost entirely devoted to cohesion.

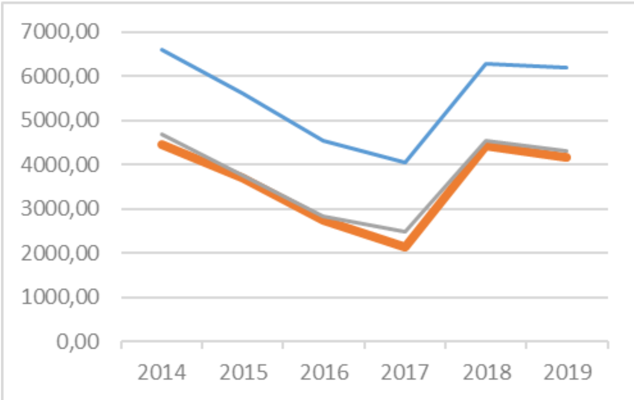

Figure 3. Changes in cohesion funding in Hungary (2014-2020)
Source: Databases of the European Union

It is worth looking at the nature of the budget lines within the COH heading where there are priority amounts. There is only one such line, which is 1.2.1.

- 1.2.1 Investment for growth and jobs EN (EUR million)

Investment for growth and jobs. This sub-heading is hereafter called INV. It is necessary to examine how much of sub-heading 1.2 is accounted for by this heading, as shown in the following table.

Table 6. Changes in the most important heading of the cohesion heading (INV) in Hungary (2014-2020)

Years				
2014	4686,70	4454,54	4287,06	0,962404
2015	3774,71	3693,20	3503,51	0,948638
2016	2836,49	2738,46	2575,26	0,940405
2017	2480,33	2140,54	2126,39	0,993388
2018	4533,46	4435,38	4281,09	0,965213
2019	4305,62	4171,01	3915,06	0,938636
	INK	Coh	INV	%

Source: Databases of the European Union

In practice, there is no point in analysing further lines, as it can be seen that the cohesion sub-heading goes almost entirely to line 1.2.1. We can clearly state that in the programming period 2014-2020, Hungary could spend most of its money in the cohesion area on growth and jobs. Looking at the above headings and budget lines, the following conclusions can be drawn for Hungary:

1. the Multiannual Framework has financed inclusive growth and sustainability,
2. it could hardly allocate resources to competitiveness within inclusive growth,
3. within inclusive growth, it could spend almost everything on cohesion,
4. within cohesion, it could spend all its resources on growth and jobs,
5. in sustainability, it could spend around 30% of its available resources.

2. EU Multiannual Financial Framework 2021-2027

The 2014-2020 Multiannual Framework had a budget of €1.082 billion. For the period 2021-2027, it will (has been) slightly higher: €1.134 billion. Although the amount of the Multiannual Framework shows a slight increase, the contribution as a percentage of GNI will decrease. While the EU27 contributed 1.16% of GNI for the previous envelope, the next envelope will only require a contribution of 1.11%. This is explained by the fact that other own resources will be valorised and is certainly commendable for the next cycle. The next multiannual framework will also be structured around headings, with some headings overlapping, while new headings have been added in the new framework.

Table 7. Chapters of the Multiannual Framework 2021-2027 and the previous period

Multiannual Framework 2014-2022 & 2021-2027	
1. Smart and Inclusive Growth (47.2%) 1.a Competitiveness (13%) 1.b Cohesion (34.2%) 2. Sustainable Growth: Natural Resources (38.6%) 3. Security and Citizenship (1.6%) 4. Global Europe (6.1%) 5. Administration (6.4%) 6. Compensation (1%)	1. Single Market, Innovation, Digitalisation (14.7%) 2. Cohesion and Values (34.5%) 3. Natural Resources and Values (29.7%) 4. Migration and Border Management (2.7%) 5. Security and Defence (2.1%) 6. Neighbourhood and The World (9.6%) 7. European Governance (6.7%)
2014-2020	2021-2027

Source: Databases of the European Union

Cohesion will not have a bigger share in the next multiannual framework, but it will still be the biggest heading. In the 2014-2020 framework, Hungary also received the largest share of cohesion and this will not change in the next cycle. In fact, Hungary is not the biggest beneficiary of the new framework, but countries such as Poland. The next big budget cycle will create the transition support that would be provided to those who need to become climate neutral in most areas. Basically, the next multi-annual framework will be divided into two parts. On the one hand, the EU's seven-year budget, and on the other, recovery. For recovery, €750 billion will be available for Member States. Of this, €390 billion is grant aid and €360 billion is loans. The latter will of course have to be repaid by the Member States. The loan is also appropriate because it will have to be repaid from 2028. Another special feature of the new budgetary period is that new resources are being sought. It is almost certain that several countries will take up the possibility to borrow. The EU's new financial framework will seek to continuously expand financial possibilities. This means, on the one hand, that mechanisms for raising funds have been developed, such as the Green Bond and other bond issuance standards. Bond issuance allows for additional market borrowing that can be used to finance long-term goals and to support recovery. The framework is indeed flexible. This flexibility is reflected in the fact that new resources would be created on the fly, for example in the form of new taxes and levies. A number of environmental taxes could be introduced, but perhaps the biggest draw would be a tax on digital businesses or a tax on large, international multi- and transnational corporations. These could only help to finance the framework after 2023. Hungary will also have access to the appropriations offered by the main chapters of the framework. The new framework's chapters are significantly different from the previous ones. But there are significant changes. 30% of total programme spending will be linked to climate, so there will be more opportunities for countries that implement projects in this context. The new framework puts the issue of digitalisation at the forefront. Helping the digital switchover is a priority for the next seven years. The Multiannual Framework also includes a reserve to help and support the Member States most affected by Brexit. As Hungary has a number of trade links and interests with the UK, it could also legitimately apply for this funding. The introduction of new funds also creates new opportunities. The framework would reduce the GNI-based contribution of Member States, but this is conditional on the generation of own resources in the long term. The own resources system would be developed in four stages. First, a contribution based on non-recycled plastic waste would be introduced. This is already in place from 1 January 2021. This would be followed by a mechanism to offset the carbon intensity of imported consumer goods and a digital levy, to be introduced from 1 January 2023. After that, no specific dates are given, but it is expected that the 3rd step would be the creation of a dedicated resource based on the EU ETS. In these years, further own resources will have to be decided and provided for. The latter are also very important because they would finance the EU's Next Generation programme, which is key to recovery. In this budget period more resources are available for Horizon Europe, which is also closely linked to innovation and research and development. This programme will also provide Hungary with a larger framework to support innovation and education more intensively. In particular, more resources should be used effectively for innovation and research and

development. Hungary will also have wider access to mobility programmes, especially student mobility. This has already been done in the 2014-2020 budget period, as we have seen, to the tune of between €40 and €70 million. This will increase in the future. The new multiannual framework will give all Member States, including Hungary, the opportunity to spend more on climate policy, on promoting migration and border protection, on digital transformation. The allocations for these have been increased. In conclusion, Hungary is not the biggest winner of the long-term budget envelope, but we will have the possibility to call on relatively more resources.
The following points show that Hungary has also won with the new long-term framework:

- we can draw down roughly the same amount from the cohesion heading
- Hungary will also have the possibility to attract additional resources, such as loans
- the reconstruction fund will provide the country with approximately €6 billion in aid (but this is subject to rule of law conditions)
- the Multi-annual Framework includes the Equitable Transition Fund, with a value of €7.5 billion. Poland is the biggest beneficiary, with Hungary receiving €82.2 million.

Conclusion

In writing this study, we have set out to achieve two main goals. One is to examine changes in the European Union's so-called Multiannual Financial Framework. This was achieved by comparing the 2014-2020 and the 2021-2027 long-term programming periods. We also wanted to focus on Hungary's share of these and on the way in which the country can draw down the amount available under each heading. In addition to the objectives, hypotheses were formulated. According to H1, the current MFF is structured with a strong focus on crisis management and resilience building, but not enough focus on competitiveness. Looking at the previous and current Multiannual Framework, it can be seen that there will not be significantly less money for competitiveness, but in fact no more. At the same time, it has to be said that preventing crises or increasing resilience could have required that the strengthening of competitiveness at EU level be stepped up even further. This hypothesis has been confirmed, as the current framework is indeed more conducive to recovery and consolidation of the economy than to strengthening long-term competitiveness. The new framework also strengthens financially chapters such as Neighbourhood, Border Management or Public Administration. None of these really promote competitiveness. Resisting crises requires strengthening competitiveness factors in economic actors. This means investing more resources, for example in innovation, education, R&D, knowledge, the human factor or health. We also need to better support entrepreneurship, SMEs and strengthen social care systems. In addition, there is a need to safeguard environmental values, sustainability and the protection of natural and social assets. What makes an economy more resilient? If we build in the skills to respond flexibly, quickly and dynamically to environmental changes. This starts with identifying and strengthening the pillars of competitiveness. But if we look at the chapters of the new Framework, we see that previously 47.2% was the chapter on inclusive and smart growth. This has been split in the new Framework, with cohesion essentially remaining unchanged in proportion, while digitalisation has also been added, for which additional resources will be needed. At the same time, other forms of innovation should be supported, so it might have been more justified to have a larger increase under these headings. A shift in the EU budget towards competitiveness-related headings would have been necessary to strengthen EU competitiveness by an order of magnitude. This has not been done. But the promotion of the green transition is clearly visible, as is the drive towards digitalisation.

In hypothesis H2, it was assumed that Hungary would not be in a more favourable position than in the previous period. This hypothesis has not been confirmed. Overall, Hungary is not the country that will receive the most funds available, so it will not be the biggest winner under the new Framework, but it will be able to draw on slightly more funds than in the previous period. According to hypothesis H3, the new Framework clearly reflects the EU's most important strategic objectives, such as promoting digitalisation and sustainability. The EU has announced a digital and green transition, for which it intends to create the right funding opportunities. We assumed that this would be reflected in the new Framework. The hypothesis has been confirmed. The Multiannual Framework 2021-2027 includes digitisation as a budget heading. However, we can see that the former sustainable growth heading, which accounted for 38.6% of the total envelope, is now renamed Natural resources and values and represents only 29.7%. This is a somewhat deceptive figure because the EU has stipulated for most of the headings for the period 2021-2027 that it will give priority to projects related to climate and climate change, green transition or sustainability. For this reason, part of the other headings will also be linked to greening, so that in fact much more money will be spent on these objectives than is specifically earmarked for them under this heading. For Hungary, cohesion funds will continue to be the biggest item. The amount available under the previous envelope was EUR 21.633 million, under the new envelope it will be EUR

22.526 million. More money can therefore be spent on growth and employment, which can be very important in a period of crisis. The priority for the EU and its Member States now is to stabilise the economy. However, being reactive cannot stop at stabilisation. Longer-term thinking is needed. While this can be seen, for example, in the climate targets for 2050 or in the planning of new own resources, it is less visible in what will be the basis for EU and national competitiveness in the future. What will really make Europe stronger and what does the EU Multiannual Financial Framework aim to support most in order to make integration more competitive and thus more crisis-resilient? This is difficult to take out of the current Multiannual Framework for the time being, but it can help to stabilise the EU with the Next Generation EU.

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in EPESS journal belongs to the authors.

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