ERASMUS UNIVERSITY ROTTERDAM

ERASMUS SCHOOL OF ECONOMICS

MSc Economics & Business

Specialization Financial Economics

Belligerent Countries and Historical Bond Market Perspectives

Analyzing French and German Government Bonds on the Amsterdam Stock Exchange Before and During World War I (1900 – 1919)

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08 August 2024

PREFACE AND ACKNOWLEDGEMENTS

Before you lies the master's thesis "Belligerent Countries and Historical Bond Market Perspectives. Analyzing French and German Government Bonds on the Amsterdam Stock Exchange Before and During World War I (1900 – 1919)." This thesis was written to fulfill the graduation requirements for the MSc Financial Economics at Erasmus University Rotterdam, the Netherlands. The research and writing were conducted from February to August 2024. The research presented here explores the relationship between historical events and financial markets, thereby combining two of my main academic interests: economics and history. My background with an MA in the History of International Relations has helped me feel confident about diving into economic history.

My interest in the interaction between financial markets and geopolitical events – how investors' accumulated perspectives anticipate, react to, and reflect on contemporary developments – prompted me to pursue this study. With its sensitivity to political changes, the bond market serves as a valuable lens through which one can understand the broader implications of a war from a financial market perspective. By analyzing historical bond prices, I hoped to understand better how investors of the past perceived the unfolding of events and their potential impacts on the financial stability of belligerent nations. Investor sentiment towards wars is not only relevant from a historical perspective but could also help better understand the implications of war and conflict in modern times.

I would like to express my deepest gratitude to my supervisor, Dr. L.A.P. Swinkels, for his guidance and expertise throughout this process, motivating me to combine multiple perspectives. His insightful feedback and support in considering different approaches were very valuable. Furthermore, this research would not have been possible without the rich historical data available through the digital archives of the Amsterdam Stock Exchange and various historical newspapers. I am also grateful to the librarians from the University of Amsterdam for their assistance in navigating these archives. I am deeply thankful to my family, especially my dad, who was always willing to discuss and question my findings, and my friends for their unwavering support and encouragement, especially when I struggled with motivation.

I hope this thesis contributes to the field of economic history by providing a deeper understanding of the interplay between economic tensions and financial markets before and during times of war and conflict. I also hope it sparks further interest and research in this area and motivates others to investigate the wealth of data the archives of the Amsterdam Stock Exchange provide.

Niek F. Franzen
Erasmus University Rotterdam (August 7, 2024)

The views stated in this thesis are those of the author and not necessarily those of the supervisor, second assessor, Erasmus School of Economics or Erasmus University Rotterdam.

ABSTRACT

This thesis investigates the relationship between historical events and financial markets by analyzing the price trends of French and German government bonds on the Amsterdam Stock Exchange from 1900 to 1919. The study uses a newly created dataset to examine how events before and during World War I influenced bond prices. Employing econometric methods to identify structural breaks in the price trend development of government bonds, the research highlights that while some significant wartime events are reflected in bond prices, others are not mirrored. This approach allows the historical data to speak for itself without *ex-post* interpretation. The findings offer insights into contemporary investors' perceptions and reactions, providing a perspective on the financial market implications of geopolitical tensions. This analysis contributes to new economic history by demonstrating the utility of financial market data in evaluating historical events within the broader narrative.

Keywords: Structural Breaks; Historical Financial Markets; Stock Market History; War History; New Economic History.

JEL Classification: N20, N23, N24, N40, N43 and N44.

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1. INTRODUCTION

From the end of the 1990s onwards, a growing body of literature analyzed political and institutional changes using historical financial market data. Although the study of economic developments through historical data – known as *new economic history* – has been around since the 1960s, the increased interest since the turn of the century is well justified. The advancements in digitizing historical data and making it more accessible have significantly contributed to this renewed interest. These advancements have allowed researchers to examine established economic relationships in a historical context.

For example, the relationship between political events and financial markets: as political events are reflected in asset prices, public opinion concerning these events is likewise mirrored within financial markets. Research on the causality or correlation between political events and asset prices is well-documented in academic literature. This also applies to events that occurred in further back in the past: in those cases, the impact of historical events can be observed in the asset prices from that time. Analyzing historical financial markets offers a valuable method for assessing the significance that contemporaries attributed to past events. Thereby, researchers gain insights into the perceived importance and impact of these events on the financial landscape of that time.

However, there may be a discrepancy between a historical event identified by historians and the actual point in time reflecting the historical event in its contemporary capital markets – if there was any echo in capital markets at all. For example, while the outbreak of World War II in September 1939 with the invasion of Poland was reflected in a significant downturn in Germany's bond values, which fell even further when the United States entered the war in December 1941, Germany’s capitulation in May 1945, although historically perceived as a significant turning point, was not reflected as such in the capital markets (Frey & Kucher, 2001). How can this be? Because the capital market reflects its traders’ prospects on the expected course of events: they had already expected Germany's capitulation. This elucidates how turning points from a *historical perspective* and a *financial perspective* might not occur simultaneously throughout time, as markets can anticipate events to happen.

Similarly, a study on French government bonds during World War II showed a spread between pre-war and collaborationist government-issued bonds. This indicates that investors anticipated the Allies' victory would lead the new French government to default on the latter bonds (Oosterlinck, 2003). Furthermore, research on the Swiss capital market during World War II revealed how some wartime events – such as the Battle of Stalingrad – caused synchronous but opposite responses for German and Belgian bond values, underscoring the market's adeptness at anticipating political changes if Germany would lose the war (Frey & Waldenström, 2004; Frey & Kucher, 2000). In other words, while most historical events are simultaneously mirrored as changes in asset prices, some events to which historians attach great importance are incorporated much earlier or are not at all reflected in capital markets. To summarize, analyzing government bond prices at capital markets in periods of war allows researchers to evaluate how traders perceived the performance and prospects of belligerent states, offering a complementary method for assessing the importance of historical events from a financial perspective.

Generally, information on past political and economic events is prone to biases as historians collect and select facts before *ex-post* interpreting their meaning within the historical context. Historical financial market data offers an alternative method as it shows information *a priori* historical events: the data indicates an event and not vice versa. In this regard, Willard et al.'s (1996) analysis of the connection between financial markets and events in the U.S. Civil War is considered path-breaking. Their method for identifying structural breaks in a series of exchange rates served as an example to later researchers, such as Frey and Kucher (2001), who investigated the systematic effects of major war events on German and Austrian bond values and showed how markets incorporated information in an early stage. For example, their study shows a significant structural break in November 1942, when German bonds dropped by approximately 6.5 percent after the Soviet Union launched a counteroffensive at Stalingrad. However, the eventual capitulation of the German army at Stalingrad in February 1943 did not cause a structural break in the financial market. Thus, traders anticipated the capitulation after information on it became available, not when it occurred.

Willard et al. (1996) and Frey and Kucher (2001) used similar econometric methods. A sequential test procedure – as demonstrated by Banerjee et al. (1992) but extended with a dummy variable as introduced by Perron (1989) – searches for structural breaks in the series of financial asset data, such as currencies or bond prices. The procedure estimates conditional random walks in pre-specified time windows, analyzing them for possible structural breaks, which are reflected by changes in the corresponding statistics (steps 1–3). Lastly, the time windows meeting a set threshold are examined for structural breaks and tested for statistical significance (step 4). The dates of structural breakpoints with enough statistical value reflect a notable market change and can, therefore, be linked to a historical event. This combination of a structural break and a historical event is also known as a *turning point*. This approach differs from an event study, as the starting point is not a list of dates indicating relevant events, as that would not solve the historians' problem of *ex-post* collecting, selecting, and interpreting the historical information. Instead, the method works the other way around: it allows the data to speak for itself without an *a priori* specification of the relevant events.

Therefore, this type of research holds significant academic value because it encourages researchers to re-examine the past through an alternative lens. By using a series of structural breaks based on historical financial data, rather than adhering to a traditional event study, the retrospective interpretation of reactions to historical events supposes only a marginal role: the data itself mirrors the reaction with lesser need for interpretation. So, a series of structural breakpoints offers insights into the expected progression of events – in the case of the abovementioned studies, wars. Thus, these structural breakpoints can be used as a financial historical lens, providing an alternative perspective on historical events.

A notable amount of literature has dedicated itself to World War II by analyzing changes in financial values as reflections of war-time-related events (Frey & Kucher, 2000; Frey & Waldenström, 2004; Frey & Kucher, 2001; Oosterlinck, 2003; Frey & Kucher, 2000). While most studies focus on World War II, some researchers have likewise analyzed World War I. For example, Jopp (2014) evaluates Germany’s prospects for winning World War I

through the lens of the Amsterdam capital market and finds multiple turning points implying a significant adjustment of traders' confidence in Germany's chances of winning the war. Similarly, by using data from the Swiss currency market, Hall (2004) examines the exchange rate movements between the Allied Powers (Great Britain, France, and Italy) and two Central Powers (Germany and Austro-Hungary) to identify a common factor – changes in war causalities and prisoners – reflecting market expectations about the war's progression. Furthermore, Ferguson's (2006) analysis of European bond yields from 1848 to 1914 suggests that the London capital market did not expect the outbreak of World War I despite earlier yield fluctuations due to pre-war crises. While all these articles are of notable scientific importance, one study within the field of new economic history on World War I stands out: *War, Bond Prices, And Public Opinion* by Jopp (2021) is an extensive research on how contemporaries perceived the war's course by investigating the perception of financial market players on the war as reflected in sovereign bond prices traded in Amsterdam during between 1914 and 1919.

However, research on the development of government bond prices of belligerent countries as reflections of events *before* and *during* World War I within one study has not been conducted to this date. This thesis aims to address this gap within the field of new economic history by comprehensively examining the position of French and German government bonds on the Amsterdam Stock Exchange over an extended period. To achieve these objectives, this research draws inspiration primarily from three studies: the study by Frey & Kucher (2001), which not only uses financial data to identify turning points during World War II but also applies this methodology to the years preceding the outbreak of the war, and the two studies by Jopp (2014 & 2021) on the development of government bond prices at the Amsterdam Stock Exchange during World War I. This research has not randomly selected the Amsterdam market. Recognized as an internationally influential and well-established capital market and located in a neutral country during the war, the Amsterdam market is suited for studying the price developments of German and French bonds during World War I.

This thesis is relevant both practically and academically. Practically, it enhances financial analyses by emphasizing the importance of the historical context. The financial market aggregates individuals' opinions, expectations, and beliefs, and linking this aggregated opinion to the historical context gives insight into how contemporary markets responded to political tensions and conflicts. This thesis's academic relevance lies in its dual historical and economic perspectives. This study hopes to approach the historically significant period of World War I from a pluriform perspective, combining historical and economic viewpoints to enrich the historical narrative.

Furthermore, by analyzing government bonds traded in Amsterdam between 1900 and 1919, this study extends the existing literature by expanding the research period by incorporating the pre-war period (1900 – 1914), and it expands the existing literature by examining the position of two belligerent countries from a single perspective. Jopp (2014 & 2021) similarly adopted a capital market perspective but focused more on individual country positions rather than directly exploring the belligerent tensions between France and Germany together. This study, in contrast, seeks to enhance economic and historical understanding of the financial interactions between antagonistic countries during the periods before and during wartime. Lastly, this study aims to compare its

findings with the existing literature on the World Wars to identify potential regularities and similarities. Given these objectives and aspirations, this thesis attempts to answer the following research question:

How were belligerent tensions and wartime events between France and Germany reflected in their respective government bond prices on the Amsterdam capital market from 1900 to 1919?

Bond values are hypothesized to reflect historical wartime events. Hence, this research expects to find two outcomes. The first expectation is that the financial market reacted to certain pre-war developments to reflect the tensions between Germany and France in the period 1900 to 1914, such as the Moroccan crises (1905 & 1911) and the formation of the Triple Entente (1907), similar to the pre-war turning points leading up to World War II as identified by Frey and Kucher (2001). The second expectation is that during the war period (1915 – 1919), turning points are synchronous but opposite, echoing the idea that war developments favoring one belligerent party have a reversed effect on the other party, as a change in bond value should reflect a country's probability of winning the war, *ceteris paribus*. In both cases, the historical financial data serves as the starting point, preceding the connection to historical events and interpreting turning points within their historical context.

Following most previous studies, which used monthly data, this research will analyze the end-month prices for French and German bonds traded in Amsterdam between January 1900 and December 1919. This would equal 240 data points per country over twenty years. Data will be hand-collected from the digitalized database of the Amsterdam Stock Exchange, an initiative of the Capital Amsterdam Foundation that contains digital copies of the exchange's original pricelists since 1796 (Exchange History NL, 2024). In line with many other studies, this research follows a sequential test procedure based on Banerjee et al. (1992) by replicating the econometric model of Frey and Kucher (2001). Their model incorporates a market index of all government bonds to control for market movements. Unfortunately, no market index for government bonds traded in Amsterdam between 1900 and 1919 is available. Instead, Jopp (2014) used an alternative approach, incorporating the most important Dutch obligation as a proxy for the market index. Therefore, this thesis continues with the econometric model of Frey and Kucher (2001) while controlling for market movements by including a Dutch government obligation as a market proxy, similar to Jopp (2014).

This research is structured as follows. Chapter two establishes the theoretical and historical framework for studying historical bond prices by exploring the relationship between financial markets and historical events. This framework provides context for interpreting observable changes in bond prices within the historical periods in which they were traded. Chapter three details the data collection from the Amsterdam Stock Exchange and provides background information on the bonds under investigation. Chapter four outlines the econometric methods employed in the analysis. Chapter five presents the results of the econometric model, identifying breakpoints and corresponding changes in government bond prices for France and Germany. Chapter six discusses the overall findings and their implications. Finally, chapter seven concludes the study.

2. THEORETICAL AND HISTORICAL FRAMEWORK

This chapter starts by introducing a straightforward pricing model for government bonds to provide insight into the economic and historical factors affecting bond prices (§2.1.). The section thereafter will discuss the theory behind research on structural breaks in historical data in more detail as part of the study of new economic history, also known as *cliometrics* (§2.2.). The last section will discuss the outbreak of World War I and its direct effect on some capital markets (§2.3.).

2.1. BOND PRICING IN FINANCIAL MARKETS: A SIMPLIFIED APPROACH

Following a simple textbook definition, a bond is a fixed-income security issued to raise capital, entitling the holder to fixed interest payments over a specified period. Even zero-coupon bonds, which do not offer periodic interest payments, involve interest since they are issued at a discount, with the difference between the issuance price and the par value realized at maturity as a one-time payment (Jopp, 2014). Bond prices tell something about the underlying asset – in the case of this research, the probability that a country can meet its long-run financing capacity. Therefore, the following definition reflects the price of a country's bond P_t at issuance by representing the net present value of all cash flows it will generate over its duration under the assumption of a pre-specified maturity date (Jopp, 2014). The price of this bond can be written as:

$$[1] \qquad P_0 = \sum_{t=0}^{t=T} \frac{(c*N)*(1-\beta^c)}{(1+r)^t} + \frac{N*(1-\beta^N)}{(1+r)^T} \quad , t = 0, \dots, T,$$

where c denotes the coupon rate, N is the nominal value redeemed at maturity, $(c * N)$ represents the periodic coupon payments on regular intervals, and r is the discount rate. The parameters β^c and β^N will be discussed in more detail in the following paragraphs, particularly their role concerning different types of uncertainty and risk. The equation above assumes yearly coupon payments, but the equation can, of course, be adjusted for semi-annual payments, monthly payments, et cetera.

In an ideal world, the bond issuer always meets its debt obligations. However, there is almost always uncertainty about a country's ability or willingness to meet these debt obligations, for example, during wartime. This uncertainty, influenced by government finances and political factors, negatively impacts bond prices (Jopp, 2014). Rephrased differently, the likelihood of bondholders receiving their interest payments and principal value is related to – maybe even dependent on – the war's outcome: a victorious country might alleviate financial pressure through reparations, whereas a defeated one might struggle to fulfill its obligations.

Frey and Kucher (2001) and Frey and Waldenstörm (2004) highlight that financial markets reflect assets' actual and expected future performance, particularly concerning the likelihood of repayment and continued tradability. While financial markets are not inherently tied to the fate of a nation or its population, a strong correlation often exists. Under normal circumstances, the fate of a nation and its population is closely linked to the trading value of its liabilities – its outstanding bonds and securities. If a nation is destroyed, its public debt typically goes unpaid, causing asset values to plummet to zero if there is no hope of repayment. Therefore, adverse events affecting a

country's population, such as natural disasters or war, can impede the government's ability to service debt, mirrored by declining asset values in financial markets.

To account for these forms of uncertainty, equation [1] incorporates a default probability for the coupon payments β^c and the principal β^N (Jopp, 2014). These probabilities and the underlying discount rate (r) vary over time, reflecting bondholders' confidence in the underlying asset. In other words, a price decline between P_t and P_{t+1} can indicate rising default probabilities, *ceteris paribus*, affecting future payment expectations. Thus – in the context of war – the lower the investor confidence in a country's position to win the war, the higher the probability of default, as the country might be unable to meet its long-term financing requirements and the lower the price level of its government bonds.

Of course, other factors besides fluctuations in the default probabilities might cause a change in a bond's price. For example, a bondholder's subjective discount rate may shift, affecting the average discount rate (r) used on the bond price since economic agents do not necessarily equally discount payments occurring in different periods. Or, as discussed in the next paragraph, bondholders might adjust their inflation expectations, anticipating that while a country may service its debts, the real value of the interest payments and principal value could decline due to expected inflation – something that regularly happens during wartime when a country finances its internal debt by printing money (Jopp, 2014).

When bonds are paid out in their domestic currency, they are directly related to the nation's monetary policy and specifically to the government's ability to service debt. Concerning World War I, there is no evidence that interest payments were guaranteed in a special way, such as servicing debts in gold. So, governments could print new currencies to meet their debt obligations (Jopp, 2021). Without being linked to gold, governments may keep printing new money to pay for their outstanding bonds. This disturbs the purchasing power through inflation, affecting the underlying currency's exchange rate. This implies an investor may still get all his cash flows paid out in a foreign currency, but it might have lost value upon converting to domestic currency. This is considered an exchange rate risk. This is also a form of uncertainty, although not legally defaulting on the bond, as the debt obligations are met, but the bond did lose value from the investor's perspective.

To summarize, bond prices principally reveal information on the past development of underlying economic fundamentals. A country's financing capacity depends on aspects such as accumulated debt, willingness to honor its debts, domestic inflation, and exchange rates with foreign currencies, depending on, among other things, inflation and currency restrictions. In shaping their expectations, investors respond to various news events that could ultimately impact the likelihood of sovereign debt repayment.

2.2. NEW ECONOMIC HISTORY AND THE IDENTIFICATION OF STRUCTURAL BREAKS IN HISTORICAL ASSET PRICES

Analyzing structural breaks in a series of historical data does not independently identify historical facts. Still, it serves as a method for acquiring and assessing information relevant to bondholders that can be studied within their historical context. As discussed, wartime events are evaluated based on their impact on the likelihood that government bonds will be serviced and repaid correctly. Bond traders, driven by monetary incentives, are primarily concerned with predicting how these events affect the bonds they own or plan to acquire; they are less concerned about the historical significance of the events. Therefore, while some events are important to investors and significantly influence the prices at which assets are traded, other events may not affect the probability of default or the discount rate and thus leave the asset's value unchanged. Traders' reactions to wartime events thereby reflect the contemporary financial perspective. This perspective does not necessarily have to align with the historical importance of an event, although the two perspectives are often related.

Identifying structural breaks in historical financial data, such as exchange rates or bond prices, aims to combine the financial perspective with its historical context. For example, analyzing structural breaks and linking them to historical events – a method usually addressed in the relevant literature as identifying *turning points* – can help to understand how holders of sovereign debt perceived the performance and prospects of countries in the historical context (Jopp, 2014). For this research, identifying structural breaks in bond prices helps to reveal events that required bondholders to adjust their expectations regarding the likelihood of the outbreak of war, the duration of the war, the economic impact on France or Germany, and the potential costs if one of the governments had to take the option of defaulting on its debts.

Studying historical market developments with modern-day statistical, mathematical, and econometric approaches or methods has become more popular in the last three decades, with a growing body of literature analyzing political and institutional change using historical financial data. This area of research regained interest around the turn of the century after the highly valued analysis of Willard et al. (1996) on the effect of U.S. Civil War events on the domestic currency market. This systematic application of econometric methods to studying history is known as *new economic history* or *cliometrics* and began in the 1960s (Fogel, 1966). From then on, it occupied a central role in American economic history, predating much of the more recognized research from the 1990s. Since the late nineties, there has been a revival in new economic history, as exemplified by the work of Willard et al. (1996). This renewed interest is primarily due to the increased availability of high-quality historical data, the reduced costs of digitizing data and the adoption of computationally intensive methods to transform extensive qualitative information into quantitative data that significantly reshaped new economic history (Abramitzky, 2015).

The availability of historical data is of foremost importance within new economic history, yet many research opportunities remain underutilized. Jopp's (2014 & 2021) studies are particularly notable in using new data sources. His latest work can be considered pioneering, as it established the first wartime sovereign bond price database at a daily frequency for any bond market. This hand-collected database of Amsterdam's entire sovereign

bond market, including all available domestic and foreign bond prices, covers six years and encompasses 288 bond series from 38 countries, totaling 161,000 price observations, demonstrating the vast potential and scope of historical data in economic history. To put this in perspective, the Amsterdam Stock Exchange has over two hundred years of digitized information on its market left to convert into usable data.

While the past continues to offer new sources of historical data that can fuel a continuous stream of cliometric research focused on historical developments, there are also more theoretically compelling arguments supporting cliometric approaches. An overview of the advantages of analyzing historical asset markets as a complementary method for evaluating historical events is given by Frey and Kucher (2000 & 2001) and Frey and Waldenström (2004). These authors highlight the value of using historical data by noting two key advantages.

Firstly, financial markets mirror the actual behavior and evaluations of thousands of traders rather than the intentions or comments found in historical documents that often merely represent individuals or a group of individuals. Furthermore, historical financial data solely reflects a given point in time, and future developments and insights cannot enter the data later, making it a pure form of historical facts. In contrast, historians are prone to using newer information in hindsight. Furthermore, markets provide a contemporary assessment of events, as traders' behavior to make well-informed decisions is influenced by the judgments of others. Even though traders may not represent the entire population, their choices do, therefore, reflect general behavioral insight.

Secondly, participants in financial markets face monetary risks, which compels them to evaluate current conditions and potential future developments carefully. This necessity for consideration distinguishes capital market data from other data types, such as surveys or questionnaires, where errors do not have direct financial consequences. As a result, financial markets offer a more accurate reflection of the immediate impact of events on asset prices as a summation of subjective expectations of the future based on contemporary information incorporated in the data.

The study of cliometrics diverges from traditional historical analysis in its approach and methodology. As historians collect and interpret facts based on their knowledge and the specific context of events, this interpretation is inherently *ex-post*, occurring after outcomes are known, which can lead to biases and subjectivity (Frey & Waldenström, 2004). Therefore, historians should try to avoid attributing knowledge to historical events which was only available in hindsight. For instance, analyzing wartime decisions is challenging once the outcome is known, as it can lead to oversimplified explanations without understanding the contemporary context and information (Frey & Kucher, 2001). In contrast, cliometric approaches analyze historical financial data by capturing the subjective expectations of past financial actors. If accurately recorded, financial market data reflects the contemporary mood among traders without the bias introduced by later observers. This method helps to understand how traders perceived the impact of political, economic, and institutional changes on asset prices, providing a complementary perspective to traditional historical analysis (Frey & Waldenström, 2004).

While the analysis of financial markets cannot replace traditional historical inquiries, it is a valuable complementary method. Historians can evaluate historical sentiments and understand how anticipated events in the past have influenced market behavior (Frey & Waldenström, 2004). However, care must be taken to account for time delays and market overreactions as events anticipated by market participants can lead to visible price changes before the actual occurrence – as discussed earlier – and financial markets can overreact to news, causing financial markets to be potentially inflated relative to the actual historical impact of an event (De Bondt & Thaler, 1985). Despite these challenges, using historical financial data enriches both economic research and new economic history research by providing additional insights into financial actors' contemporaneous reactions and expectations.

2.3. THE HISTORICAL CONTEXT OF WORLD WAR ONE: A BRIEF RECAP

A structural break analysis serves as a complementary method for evaluating historical events and, in the case of this thesis, for identifying turning points before and during World War I. However, analyzing structural breaks requires historical context to give the to-be-identified turning points any meaning beyond their financial implications. To fully understand their meaning, the structural breaks must be contextualized within the broader historical narrative and linked to a historical event that might have caused the breakpoint. From then on, it's considered a turning point. Additionally, examining the years leading up to the outbreak of war gives a more comprehensive and complete understanding of World War I from a historical perspective.

While there is no unanimous consensus among historians on the exact start date of World War I, the assassination of Archduke Franz Ferdinand of Austria on 28 June 1914 is widely recognized as the catalyst and the most direct *casus belli*. This event triggered the July Crisis, a month of intense diplomatic maneuvers among Austria-Hungary, Germany, Russia, France, and Britain, trying to avoid further escalation (MacMillan, 2014). The situation escalated with Austria-Hungary's declaration of war on Serbia on 28 July 1914, followed by a series of war declarations among the major powers: Germany declared war on Russia on August 1, Germany declared war on France on August 3, and Britain declared war on Germany on August 4 (Clark, 2013; MacMillan, 2014). Scholars examining the long-term causes of the war refer to the rivalries between the German Empire, the Austro-Hungarian Empire, and the Ottoman Empire on one side and the Russian Empire, the French Republic, and the British Empire on the other. Other long-term factors include political, territorial, and economic competition, militarism, alliances, imperialism, and nationalism (Brose, 2014). Some examples of geopolitical tensions and conflicts predating World War I are the Triple Alliance (1882), the Berlin Conference and the 'Scramble for Africa' (1884), the Triple Entente (1907), the Moroccan crises (1905 & 1911), the Balkan Wars (1912 – 1913). These long-term factors were present since the end of the Franco-Prussian War of 1870 – 1871, also known as the Franco-German War, followed by Germany's unification and the German Empire's foundation. However, tensions between European powers really started to rise from around the turn of the century.

Furthermore, the arms race – particularly the rapid advancements in military technology during the Second Industrial Revolution (approximately 1870 – 1914) – heightened tensions between European nations. The race was characterized by significant developments in weaponry, changing military tactics and strategies, and intense competition among the great powers. These developments included the adoption of new artillery, such as machine guns, and a naval race focused on submarines and large naval battleships, so-called dreadnoughts (Brose, 2014). The Anglo-German Naval Race started around 1900 when Britain began developing new naval vessels, such as battlecruisers and larger battleships. The rapid construction of German battleships in response to these developments worried the British, especially after failed attempts to initiate a maritime agreement or alliance between the two empires (MacMillan, 2014). From then on, they tried to develop, strengthen, and enlarge their navy as quickly and numerous as possible. Similar tensions and developments were present between France and Germany concerning their army, which grew significantly in size and strength.

In light of growing tensions between European powers, as exemplified by geopolitical disputes such as the 'Scramble for Africa' (1884) and the Moroccan Crises (1905 & 1911), the formation of alliances such as the Triple Alliance in 1882 (Germany, Austria-Hungary, and Italy) or the Triple Entente in 1907 (United Kingdom, France, and Russia) and the military importance of the arms races, this research uses 1900 as the start of the analyses of the historical financial data. To analyze whether it makes sense to view this period as a precursor to the official war dates, monthly data from January 1900 is included in the analysis, meaning that this study will cover twenty years (1900 – 1919). This approach hopefully allows capturing the broader context and the underlying tensions that eventually led to the outbreak of World War I.

3. DATA

This research analyzes the development of government bond prices of France and Germany, two belligerent countries, traded at the Amsterdam market before and during World War I (1900 – 1919). The focus will be on the German 3 percent imperial loan (henceforth, the German Imperial) and the French 3 percent rentes (henceforth, the French Rentes), with the Dutch 3 percent bond serving as a market proxy to control for events that have affected the European market in general. The subsequent section provides context on the Amsterdam capital market around this time (§3.1.), followed by the approach used for collecting data (§3.2.). Next, an additional dataset is introduced (§3.3.), and the modification of the raw data to a usable dataset for the analysis is discussed (§3.4.) Lastly, some historical and financial background on the selected bonds is provided (§3.5.).

3.1. THE AMSTERDAM STOCK EXCHANGE DURING WORLD WAR ONE

The outbreak of World War I is an example of how *ex-post* understandings influence the interpretation of historical events. While in hindsight, the assassination of Archduke Franz Ferdinand of Austria on 28 June 1914 is considered to be the most direct cause of the war's outbreak, the European capital markets didn't react to this assassination. In other words, market investors didn't expect an outbreak of total war to be its consequence.

Niall Ferguson (2008) argues that on the eve of World War I, European capital markets were well integrated, with major and minor powers financially and economically interwoven as much as they were linked through international alliances. Due to the significant economic risks, this integration made a large-scale conflict seem highly unlikely. When analyzing the long-term development of sovereign bond yields in London, Ferguson notes that from 1880 onwards, the yields on bonds from powers such as Austria, France, Germany, and Russia steadily declined, indicating falling political risk premiums. Lastly, he also highlights that the first signs of concern in the London market regarding the potential economic impact of the political crisis sparked by Archduke Ferdinand's assassination appeared on 22 July 1914 – almost a month after the assassination.

Jopp's (2021) analysis supports Ferguson's *surprise hypothesis* by extending the analysis to three other European trading places: Amsterdam, Berlin, and Paris. If markets had anticipated the outbreak of World War I, a gradual and steady decline in bond prices would have been observed in the months leading up to the war's outbreak. However, bond prices did not exhibit a consistent gradual decline, suggesting that the war's onset surprised investors. Instead, significant price drops occurred suddenly when the war began, indicating that the markets had not factored in the increasing risk of war beforehand.

After this sudden drop in government bond prices, many governments intervened directly or indirectly in capital markets during World War I. For instance, trading in French and British government bonds was halted in foreign markets. Despite these restrictions, the Amsterdam Stock Exchange remained a crucial venue where government bonds from these countries were freely traded on either the official or the grey market (Jopp, 2021). Due to its neutral stance, the Dutch government neither controlled price movements nor restricted trading activity, allowing foreign investors to participate with minimal restrictions. Trading was temporarily suspended from the 28th of

July 1914, following the outbreak of the war, and officially resumed on the 3rd of January 1916 (Exchange History NL, 2024). However, trading on the grey market in Amsterdam resumed earlier, as several newspapers reported trading prices from July 1915 onwards (Jopp, 2021).

Unfortunately, no exact information on who traded at the Amsterdam Stock Exchange around 1900 is available. Even if such data existed, it would still be unclear whose money was invested and who the traders were, as they operated both for themselves and on behalf of investors. Traders at the Amsterdam capital market included private capital owners and institutional investors. Given Amsterdam's reputation as a well-established market, it is reasonable to assume that investors from across Europe traded here (Jopp, 2021). Therefore, the Amsterdam market mirrors broader investor sentiment and perception, not only those of Dutch traders.

3.2. COLLECTION OF THE DATA – AMSTERDAM STOCK EXCHANGE

The data for this research has been collected by hand from the official price list of the Amsterdam Stock Exchange, as published in the *Officieele Prijscourant der Vereeniging voor den Effectenhandel te Amsterdam* (the Official Price List of the Association for the Stock Exchange in Amsterdam), a daily newspaper publishing all prices determined on a trading day on the Amsterdam market. From 1796, the Amsterdam exchange published its prices in the Officieele Prijscourant until 2005, when it disappeared on paper and became digitalized. All the original price lists between 1796 and 2005 are now digitally accessible (Exchange History NL, 2024). Despite being digitally accessible, the quality of the scans necessitates manual selection of each price list, searching for the corresponding bond prices, and inputting these prices to construct a database suitable for further analysis. Additional data was collected from one of the prominent Dutch newspapers at the time, the *Algemeen Handelsblad*. Consulting this newspaper was essential due to some gaps in the available issues of the primary source, the Officieele Prijscourant. Expanding the range of sources helped to obtain a higher number of quotations.

Jopp (2021, p. 49) makes three notes on the price quotes in Dutch newspapers that are also important for this thesis. Firstly, this research deals with the secondary market for government bonds, which involves trading already issued securities, to be clearly distinguished from the primary market for securities. Secondly, the sovereign bond prices reported in the Officieele Prijscourant are spot market prices, ideally requiring immediate transaction fulfillment between buyer and seller, although effectively, spot market transactions were not strictly enforced. The importance lies in the fact that this research does not deal with forward transactions. Thirdly, prices are recorded in percent of the par value, which is 100 percent.

I thoroughly screened 331 publications (223 of the Officieele Prijscourant and 108 of the Algemeen Handelsblad) to compile monthly quotations covering January 1900 to December 1919. The total number of identified end-month prices equals 726 – the sum of the 437 data points for Germany (two bond series), 66 data points for France, and 223 data points for the Netherlands. Before using it for the analysis, the available data and the modifications will be discussed in more detail in a later section (§3.4.).

Dutch newspapers reported four different prices per security: *vorige koers*, *laagste koers*, *hoogste koers* and *gebleven koers*. According to Jopp (2014), who has analyzed the Amsterdam Stock Exchange for the time in question, these refer to the lowest quotation (laagste koers) and highest quotation (hoogste koers) of the actual day, the previous quotation (vorige koers) and the closing price of the current day (*gebleven koers*). The data is published in newspapers with a delay of one day. Thus, for example, the official price list for Thursday, February 1, 1900, reported the previous quotation of Wednesday, January 31, 1900 – the first month of the period on which this research focuses. The reason for using the quotation from the previous day instead of the closing price of the current day is straightforward: on quite some days, the closing price is not listed. Therefore, to improve data availability, this research uses the previous quotation to analyze the monthly developments in price levels.

The existing literature is confused about what the previous quotation resembles. Jopp (2014) states that the previous quotation depicts the average of the lowest and highest quotes of the previous day and refers to Brenninkmeyer (1920), who provides an institutional overview of the Amsterdam Stock Exchange for the time in question. A quick but thorough examination of the newspaper price quotations shows that the previous quotation is also recorded when no lowest or highest quotation is recorded on the previous day. This means that the interpretation used by Jopp and Brenninkmeyer is incorrect. For example, the official price list for Wednesday 07-03-1900 reported a previous quotation of 87 percent of par value for the German Imperial. However, on Tuesday 06-03-1900, neither the lowest nor the highest quotation was noted, meaning that no trade took place that day – again, only the 87, the previous quotation, is shown. Further investigation reveals that this 87 percent refers to a single quotation (laagste koers) on Friday 02-03-1900.

This means two things. First, the previous notation refers to the last trade, which does not necessarily have to be on the previous day but can also be longer ago. Second, it reflects either the average of the lowest and highest quotes or just the lowest quote in case the highest quote is missing. Additional checks confirm this interpretation of the previous quotation. It's important to clarify that these are the lowest and highest quotes, distinct from the modern concepts of 'bid price' and 'ask price.' As such, the exact transaction price isn't specified. However, it's reasonable to assume the transaction occurred at a price midway between the lowest and highest quotes of the day or at the lowest quote if it was the only quote.

Furthermore, as specified in the Algemeen Handelsblad, the previous quotation will not be noted if the moment of trading occurred more than four weeks ago. This means there is a maximum period for the prior price, as the previous quotation will no longer be published after four weeks. To ensure accuracy, this research consistently uses the previous price quotation noted on the first day of the following month, which reflects the latest trade in the previous month. If no trades occurred in the last four weeks, resulting in the absence of a published quotation on the first day of the following month, this study records the value for that month as empty.

3.3. ADDITIONAL DATASET FOR FRANCE: FRENCH WAR BONDS (NATIONAL DEFENSE LOANS)

An alternative bond has been incorporated into the dataset to address a shortfall in the availability of French government bond data, which is elaborated on in the following paragraph. During data collection, it became clear that there were significantly fewer price notations available for the government bonds issued by France: 66 compared to 222 for Germany (after merging the two series) and 223 for the Netherlands. Unfortunately, trading of French Rentes was remarkably lower than other bonds during the pre-war period and ceased completely after the closure of the Amsterdam market in July 1914, when the French government prohibited trading their bonds on foreign markets in response to the outbreak of World War I (Jopp, 2021). An additional dataset for France was necessary to mitigate the lack of information on French bond prices from August 1914 onwards.

For his research on the Dutch stock market during World War I, Jopp (2021) collected trading information from the Officieele Prijscourant and eight additional newspapers to construct an extensive dataset of all government bonds and securities traded in Amsterdam between 1 January 1914 and 31 December 1919. While trading of French government bonds was banned at the official markets, trading in Amsterdam continued in the so-called grey market on which the Dutch newspapers reported price quotations. In the absence of the French Rentes, the Amsterdam grey market started actively trading another French bond during World War I: the 5 percent French War Bonds (Jopp, 2021).

This study uses Jopp's dataset to extend the number of French bonds by 48 to a total of 114 data points by including the trade of French War Bonds (more on this type of bonds in §3.5.). Descriptive statistics on the bond prices and yields of France, Germany, and the Netherlands are given in Table 1, with the period up to July 1914 as the pre-war period, the period from January 1916 to November 1918 as the war period, and December 1918 to December 1919 as the post-war period. Note that in the case of France, the pre-war period refers to the French Rentes, and the war and post-war period refers to the French War Bonds.

The French War Bonds were a suitable alternative for the French Rentes from 1915 onwards for two reasons. Firstly, despite the 2 percent point difference in coupon rate, which affects the interest payments and thus the cash flows, the French War Bond is still suitable for this research because the econometric model focuses on price level changes in relatively short periods to identify structural breaks. The bond's real value and yield depend on multiple factors, including the transaction value and term structure. As bond prices are given in percentage of par value, the bond's real value – which could change because of a different coupon rate – doesn't affect the analysis. Secondly, the French War Bonds were the best and only option to reflect investor sentiment and expectations on France's position during World War I, as no French bonds issued before the outbreak of war were traded in Amsterdam during the war (Jopp, 2021). Therefore, the war bonds are the best available alternative to investigate the possible differences in investor sentiment regarding the position of these two belligerent countries.

Table 1

Descriptive Statistics on the Bond Prices and Yields of France, Germany and the Netherlands

France					
Period	Mean	Minimum	Maximum	Standard Deviation	N
Price					
▪ Pre-war	92.12	80.50	97.25	4.14	66
▪ War	68.47	57.38	74.90	5.44	35
▪ Post-war	66.82	45.00	80.00	9.72	13
Yield					
▪ Pre-war	3.26	3.08	3.73	0.16	66
▪ War	7.35	6.68	8.71	0.63	35
▪ Post-war	7.65	6.25	11.11	1.30	13
Germany					
Period	Mean	Minimum	Maximum	Standard Deviation	N
Price					
▪ Pre-war	84.56	73.03	92.47	4.80	175
▪ War	47.02	32.38	55.00	5.56	34
▪ Post-war	24.28	12.75	31.25	7.26	13
Yield					
▪ Pre-war	3.56	3.24	4.11	0.21	175
▪ War	6.48	5.45	9.27	0.90	34
▪ Post-war	13.73	9.60	23.53	5.08	13
The Netherlands					
Period	Mean	Minimum	Maximum	Standard Deviation	N
Price					
▪ Pre-war	89.63	77.13	97.25	5.98	175
▪ War	71.19	63.38	76.94	3.26	35
▪ Post-war	60.63	52.00	64.50	3.27	13
Yield					
▪ Pre-war	3.36	3.08	3.89	0.24	175
▪ War	4.22	3.90	4.73	0.20	35
▪ Post-war	4.96	4.65	5.77	0.29	13

Notes: The price is given as a percentage of par value. The yield is computed by [((100 * coupon rate) / price) * 100]. Raw data with gaps, so without any modifications, is used. Values are rounded to the two-decimal place.
Source: The author's dataset was collected from the Officieele Prijscourant and the Algemeen Handelsblad, extended with Jopp's (2021) dataset on French War Bonds.

Based on the descriptive statistics, several interesting preliminary observations can be made. Bond prices tend to decrease from the pre-war period to the war period and further into the post-war period across all three countries. Conversely, bond yields show a marked increase from the pre-war period to the war period, stabilizing or increasing in the post-war period. Pre-war yields for all three countries are quite similar. Overall, Germany faced the most severe impact, as evidenced by the dramatic decrease in bond prices and the substantial increase in yields. The next two paragraphs briefly discuss the findings of Table 1.

The outbreak of the war caused a notable drop in French bond prices, with an increased standard deviation (from 4.14 to 5.44 percent) suggesting more volatility. The higher risk caused by the war is also reflected in a doubling yield. While French bond prices and yields stabilized in the post-war period, price volatility increased to 9.72 percent. For Germany, the war led to a larger average price drop than in French bonds: whereas French bonds

decreased by 25.67 percent on average (23.65 percent point difference), the German bonds lost 44.39% of their value (37.54 percent point difference). France's price level stabilized in the post-war period, while the value of German bonds decreased significantly by losing 48.35 percent value (22.74 percent point difference).

Germany's volatility trend is similar to that in France, although Germany's price volatility was lower in the post-war period. This is interesting, as one might expect higher volatility (risk) for the country that lost the war, as it's likely to face more financial pressure from the payment of reparations. The yield trajectory differs: France's yield doubled in the post-war period to 1.30 percent, but Germany's yield quintupled to 5.08 percent. This indicates higher risk, consistent with the literature suggesting a country that has lost a war is perceived riskier due to the potential default on debt obligations.

Surprisingly, the war stabilized Dutch government bonds: although bond prices decreased, volatility also decreased during the war. This might be because traders perceived the Dutch bonds as relatively stable during the war's tumultuous period, leading to less volatile prices. Furthermore, the increase in yield for the Netherlands is much lower than for France and Germany, indicating a persistent but relatively low risk. The relatively low price and yield volatilities indicate that war-time events didn't influence the Netherlands that much. This reinforces the rationale for choosing the Dutch bond as a market proxy.

3.4. MODIFICATIONS ON THE ORIGINAL DATASET

Ideally, the dataset would consist of 240 data points per government bond, covering the entire period from January 1900 to December 1919. However, the closure of the Amsterdam Stock Exchange from August 1914 until December 1915 officially reduces this number by 17 months. A dataset with 223 data points per country would indicate no omitted official trading data and a complete dataset. However, there are options to bring this number closer to 240. Therefore, the data has been modified in two ways to increase the number of data points for the final analysis.

First, grey market trading in Amsterdam in 1915 has been included. Although official trading was suspended until the market officially reopened in January 1916, price quotations were noted in the Algemeen Handelsblad from June 1915 onwards. By including grey market trading, two additional data points for France and five for Germany and the Netherlands have been specified. Second, linear interpolation has been used to fill in the missing values, excluding the closing period of the Amsterdam market. This method filled one missing value for both Germany and the Netherlands, completing the dataset of both countries to 228 data points.

The situation with data for France remains complicated. In the pre-war period (1900-1914), only 66 data points were found over 175 months, and by including Jopp's (2021) database on the war and post-war period, this number was increased to 116 over 240 months. Although linear interpolation during the pre-war period increases this number to 225 and gives an idea of the price-trend developments of French government bonds (see §3.5), this approach is unsuitable for the econometric model as it will wrongly indicate structural breaks.

The limited availability of pre-war data on French government bonds necessitated the decision to limit the analysis of French government bonds to the war and post-war period (1915-1919) and exclude the pre-war period from this research. Only 48 data points between November 1915 and December 1919 were used for the structural break analysis on French government bonds.

3.5. THREE GOVERNMENT BONDS: FRANCE, GERMANY AND THE NETHERLANDS

The French Rentes were non-redeemable bonds issued by the French government. These bonds paid 3 percent annual interest indefinitely, known as *rente*, and were mainly traded from 1825 to 1949, mirroring the British consols in their design and fiscal reliability (Edlinger, Merli, & Parent, 2013). As pointed out, the additional dataset on the 5 percent French War Bonds was highly welcomed. According to the dataset provided by Jopp (2021), the first trade of the French War Bonds in Amsterdam took place on 27 November 1915. This bond refers to the national defense loans ("obligations de la défense nationale") issued with a fixed duration of ten years for the first time in early 1915. Jopp excluded the possibility of other French bond issues during the war, such as "national defense bills" and "victory loans," because they had a concise duration of just a few months. Therefore, he concludes that the 5 percent bond traded at the grey market in Amsterdam refers to the national defense loans. Together, the French Rentes and the French War Bonds indicate investor sentiment in the pre-war (January 1900 – July 1914), war (November 1915 – November 1918), and post-war periods (December 1918 – December 1919).

Jopp (2014) provides additional information on the German Imperial. Since 1890, the German Imperial was issued in two series traded separately because of different coupon payment dates (semi-annually): in April and October for the first series and in January and July for the second series. Although a small percentage of the total outstanding nominal principal was supposed to be redeemed annually, there was no final redemption date, and redemption was sporadic. As a result, the 3 percent German Imperial can be classified as a perpetual bond – similar to British consols and French Rentes – with the German Empire holding a call option. Notably, interest payments continued without suspension during World War I. For this research, the two German 3 percent bonds have been consolidated into a single series by computing the average values of the two bonds or by using the available value of one bond if the other was missing in any given month.

In addition to the German Imperial, other German bonds were traded in Amsterdam, such as bonds from the German state Prussia and the city of Bremen. However, these have been excluded from this research for three reasons. Firstly, as pointed out by Jopp (2021), the German Imperial bonds were the most representative German bonds traded at the Amsterdam market between 1914 and 1919, as they had the highest liquidity and the highest correlation with the country index for all German bonds in that period. Secondly, from a methodological standpoint, incorporating these bonds into the German series would be problematic because not all German states' and cities' bonds are traded throughout the entire research period, leading to poor data availability. Thirdly, from a historical standpoint, since the German unification in 1871, it makes more sense to focus on the bonds reflecting the strength of the German Empire as it was a unified Germany that declared war on France in 1914; not certain states, as was the case in the French-Prussian War of 1870 – 1871.

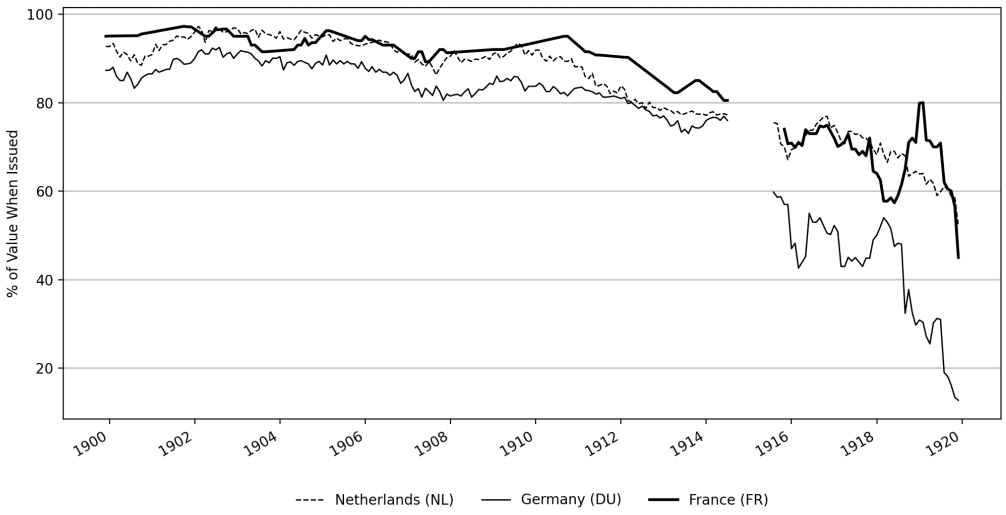
The Dutch government bond is of secondary importance for this research, as it serves as a market proxy to control for market developments that similarly affected the bonds of France and Germany, for example, reflecting changes in the general market participants' discount rate. It is possible that certain wartime events influenced the bond markets of the Netherlands, France, and Germany simultaneously, creating the appearance of a market-driven development when, in reality, these were historical events reflected uniformly across the capital markets. It is important to note that the Netherlands remained neutral during World War I. Therefore, war events impacting the Netherlands, France, and Germany likely influenced a broad spectrum of countries and can, with some caution, be interpreted as events affecting the market in general without reflecting changes in the default probability on the government bonds caused by war events. The same holds for events in the years before the outbreak of the war, during times of continuous tension between France and Germany as antagonists in Europe (more on the historical background of World War I in §2.3.)

The assumption of interpreting events that affected the Netherlands as events affecting the overall market is crucial for this research, as using the Dutch bond is the best available proxy without access to or the availability of a comprehensive market index. The Dutch 3 percent government bond was not chosen arbitrarily. According to Jopp (2021), it was the most traded Dutch government bond in Amsterdam and represented the largest share of all outstanding Dutch government debt. This means that this bond is a good reflection of the Dutch market and is, therefore, suitable to serve as a market proxy under the abovementioned assumption.

Figure 1 visualizes the price-level developments of the three government bonds. It plots the price levels of the combined German Imperial, the French Rentes (1900 – 1914) plus French war bonds (1915 – 1919), and the Dutch bond between 1900 and 1919 in percent of par value. Note that the complete modified dataset, including France's pre-war period, was used to generate this figure.

Figure 1

Price Trend of French, German and Dutch Government Bonds as Traded in Amsterdam (1900 – 1919)

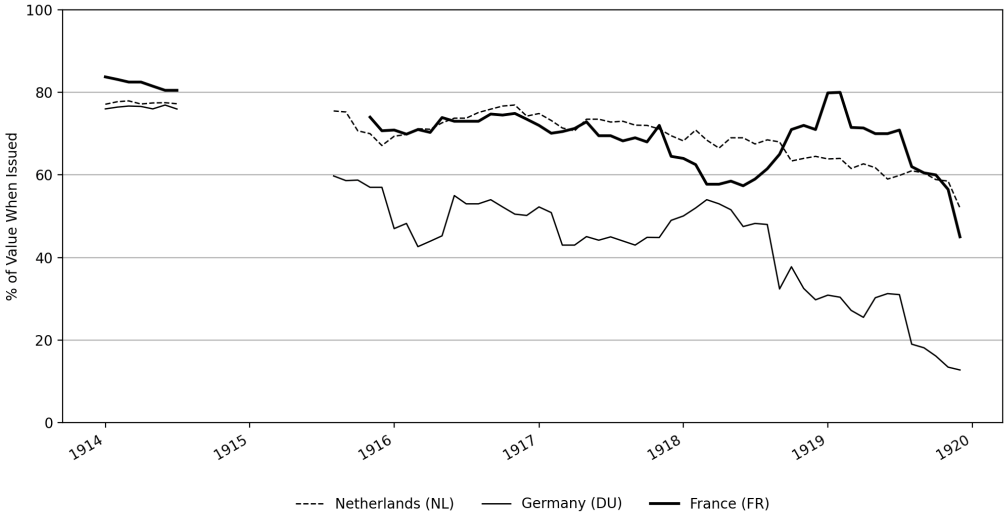


Notes: nominal price in percent of par value monthly.
Source: modified dataset (author's database + Jopp, 2021).

With some caution, the price trend of French and German government bonds during World War I was indeed synchronous but opposite in some periods. This trend is particularly evident from the war's final year onwards (1918). Figure 2 highlights the years around the war (1914 – 1918) to illustrate these contrasting developments.

Figure 2

Price Trend of French, German and Dutch Government Bonds as Traded in Amsterdam (1914 – 1919)

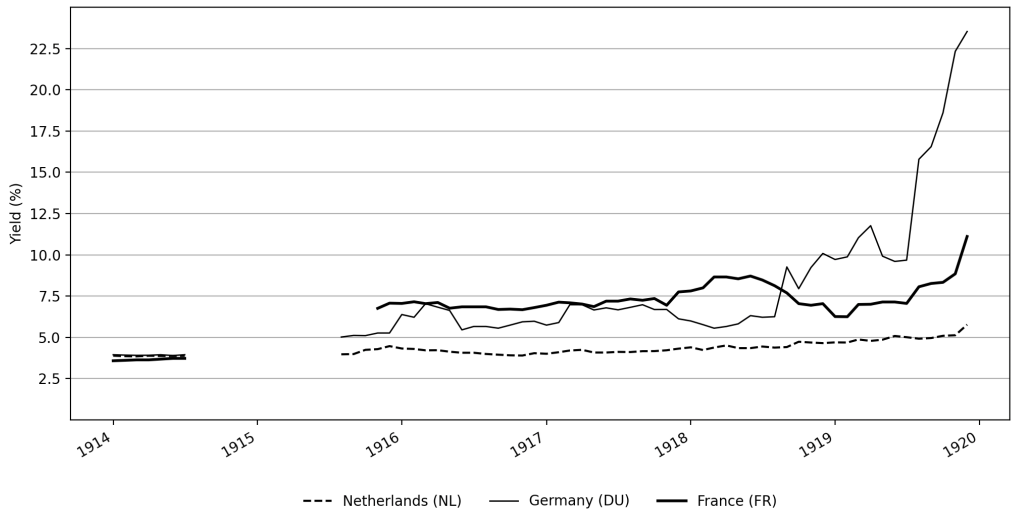


Notes: nominal price in percent of par value monthly.
Source: modified dataset (author's database + Jopp, 2021).

Figure 2 highlights a significant moment in which bond prices show an opposing yet synchronous trend. Shortly after mid-1918, there was a notable decline in German bond prices, while French bond prices increased. This can be linked to the successful offensives launched by the Allied forces against the German Empire towards the war's end, known as the 'Hundred Day Offensive.' When is converted to display yields – as shown in Figure 3 – it can be observed that from around September 1918, the yield on German government bonds surpasses that of France.

Figure 3

Yield of French, German and Dutch Government Bonds as Traded in Amsterdam (1914 – 1919)



Notes: current yield on a monthly basis.
Source: modified dataset (author's database + Jopp, 2021).

4. METHODOLOGY

The econometric method used for this research aims to identify structural breaks in the series of German and French government bond prices. In contrast to an event study, this approach allows the data to speak for themselves without *a priori* specification of dates referring to historical events. The subsequent test procedure is mainly based on the steps followed by Frey and Kucher (2001), who based their approach on methods developed by Banerjee et al. (1992) and Perron (1989). The procedure used by Jopp (2014), whose approach is of secondary importance, also follows this method. The basic idea is to estimate conditional random walks within small time windows and test for differences in the means of bond prices between these windows.

In their study on World War II, Frey and Kucher (2001) used 36-month time windows. However, this length is unsuitable for this thesis because the dataset is broken into two research periods: January 1900 to July 1914 and August 1915 (Germany and the Netherlands) or November 1915 (France) to December 1919. Given the relatively short duration of the second period, a 36-month time window would limit the analysis to only fifteen windows, with the latest midpoint for analysis in June 1918 (18 months before December 1919), before the war's end in November 1918. Therefore, this thesis uses a 12-month window, giving the option to analyze 42 windows in the war period, with the latest midpoint in June 1919 – following the formal end of World War I with the signing of the Treaty of Versailles on June 28, 1919. Note that compared to previous notations, e.g., in the descriptive statistics of the raw data (Table 1), the former post-war period (December 1918 to December 1919) is now considered part of the war period because of the methodological requirement of 12-month time windows.

4.1. THE FOUR-STEP STRUCTURAL BREAK ANALYSIS

A four-step methodology is applied to detect structural breaks in French and German bond prices, aiming to identify as many turning points as possible. Steps 1 through 3 isolate 12-month windows where a structural break is most likely. The last step tests for structural breaks within these windows. In this manner, the period is broken down into smaller time windows before identifying specific dates that indicate a turning point.

Applying only the final step could lead to misleading results, as it would assume a single breakpoint per time window, which could yield inappropriate results. If there were a second shift that reversed the first or a second shift that strengthened the earlier one, a conventional regression with a dummy variable for a possible breakpoint might miss some shifts. To address this problem, the method looks for mean shifts in relatively short time windows and uses steps 1 to 3 to determine which periods to look at.

Step 1 – Using data from a 12-month window starting on January 1900, the first step is estimating the regression:

$$[2] \qquad \ln p_t^X = \beta_0 + \beta_1 * \ln p_{t-1}^X + \beta_2 * \ln p_{t-1}^M + \epsilon_t$$

where p_t^X is the value of the government bond of either Germany or France, traded in Amsterdam on date t; p_t^M is the value of the Dutch government bond traded in Amsterdam on the same day, used as a proxy for overall

market performance; β are the parameters to be estimated, and ϵ_t is a white noise error term. Transforming bond prices to their natural logarithms is required to compute the percentual change around the turning point in step 4, as the coefficients β_1 and β_2 represent the elasticities of p_t^X with respect to p_{t-1}^X and p_{t-1}^M respectively. For example, a one percent change in p_{t-1}^X is associated with a β_1 percent change in p_t^X.

By including a proxy for market performance as one of the explanatory variables in the equation, the regression corrected for factors influencing the value of all bonds traded, such as changing interest rates. The idea behind step 1 is to understand the explanatory power of time-lagged prices and market performance on bond prices.

Equation [2] slightly differs from the one used by Frey and Kucher (2001), who had access to country-specific and overall market indices for government bonds traded in Switzerland. Therefore, this research had to adopt an alternative approach. Hence, the model also shares similarities with Jopp (2014), who used Dutch government bonds as a market proxy in his alternative approach, which included explanatory variables other than simply the daily lags of the dependent variable. Although this alternative model did not significantly alter his earlier findings, it identified two additional turning points. Furthermore, based on the difference in data frequency between Jopp's daily series and this study's monthly data, similar to the monthly frequency of Frey and Kucher (2021), a model based solely on lags of the dependent variable is expected to function less well. The simplified model, without the second explanatory variable, is tested in the discussion as the first robustness check (§6.1.).

The other explanatory variable Jopp (2014) used in his alternative model incorporated the exchange rate between the Dutch guilder and the German mark. Similarly, the discussion will also examine exchange rate data to test the equation's robustness. As discussed earlier, changes in the exchange rate – for example, caused by inflationary pressures on the foreign currency – affect the bondholder's position, so including it as an explanatory variable might alter the results. Frey and Kucher (2001) didn't have to include a similar variable, as the values of their government bonds at the Swiss capital market were denoted in domestic instead of foreign currency and, therefore, were not prone to currency or exchange rate risk. The extended model, including the exchange rate as a third explanatory variable, is tested in the discussion as the second robustness check (§6.1.).

Step 2 – In the second step, the regression is estimated again, using a 12-month window starting one month later, namely on February 1900. Step 2 is then repeated over and over, each time moving the window by one month until the entire period has been covered. In the case of Germany, a total of 206 windows of twelve months were used to cover the period from January 1900 to December 1919. France has just 39 windows due to a lack of available data during the pre-war period, limiting the research on the French structural breaks to the war period.

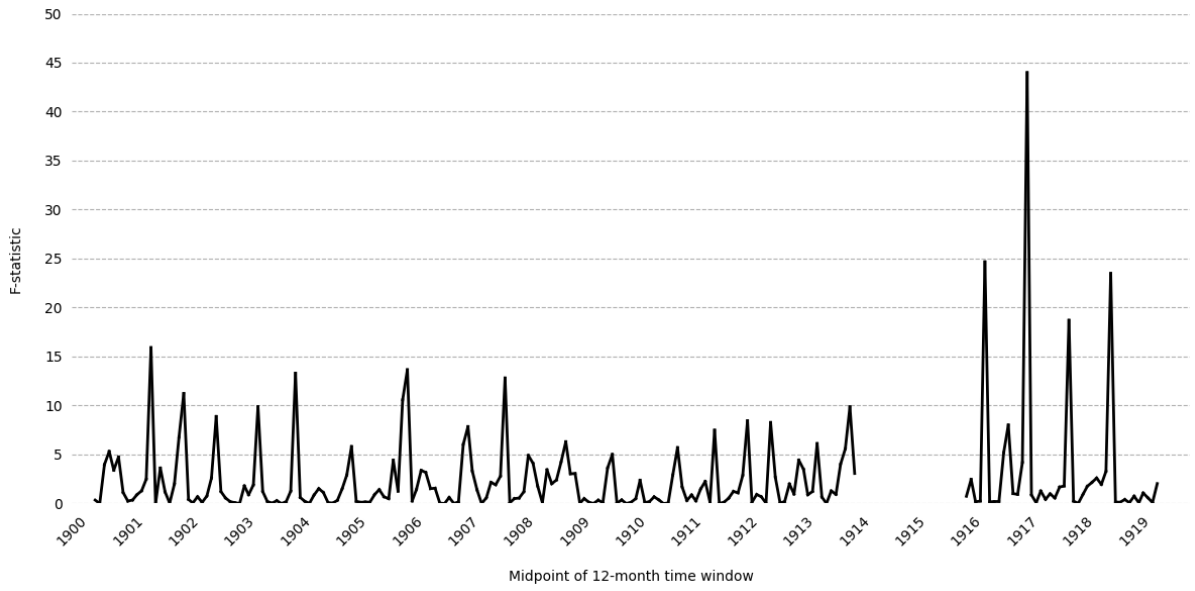
In general, three approaches have been applied in the existing literature to measure the performance of explanatory equation: (i) retaining R-squared values from the regressions, (ii) performing an F-test of the null hypothesis that there is an omitted variable, or (iii) performing an F-test of the null hypothesis that there is a structural break at the center of the window (Jopp, 2014). Frey and Kucher (2001) used the third option, and by

searching for peaks in the series of F-statistics, they identified the time windows in which the null hypothesis of no structural breaks was most strongly questioned. This research will also adopt the third option, utilizing a Wald test to test the null hypothesis that there was a shift in the mean at the window's midpoint.

Step 3 – The third stage involves identifying windows where the null hypothesis of no structural breaks is strongly questioned by searching for peaks in the series of F-statistics as computed in steps 1 and 2. The corresponding F-statistics from the Wald test on the regressions for Germany have been visualized in Figure 4. Windows with an F-statistic value above ten are considered periods where turning points are most likely – a threshold determined after screening the plot for peaks. Comparing structural breaks should utilize the same threshold to maintain consistency in interpretation. Therefore, the minimum F-statistic of ten also applies to France. This way, ten 12-month, partly overlapping windows were identified for Germany and four for France that met the threshold. The corresponding visualization was excluded since the data for France only covers the war period.

Figure 4

F-tests for Structural Breaks in the Price Trend of the German Imperial (1900 – 1919)



Notes: the graph shows the test outcome for a structural break at the midpoint of the 12-month window of the German bond.
Source: author's own calculations.

Step 4 – The last stage tests for statistically significant structural breaks within each window isolated in step 3. This is done by estimating a series of the following equation, which, in comparison with equation [2], has been extended by a dummy variable as suggested by Perron (1989):

$$[3] \qquad \ln p_t^X = \beta_0 + \beta_1 * \ln p_{t-1}^X + \beta_2 * \ln p_{t-1}^M + \gamma_s * D_{st} + \epsilon_t$$

where $D_{st} = 1$ if date t is on or after date s and zero otherwise. The parameter γ_s measures a change in the conditional mean, indicating a shift in the mean bond price, *ceteris paribus*, occurring at date s. Since all prices are in logs, γ_s can be interpreted as the percentage change in the conditional mean of the bond price. This

equation is estimated repeatedly, moving s by one month each time. Since sequential break tests cannot identify breaks around the beginning or end of a sample, the window is extended to identify turning points at the ends. Therefore, six observations are added at the beginning and end of the windows examined in step 4. So, for the first equation estimated, s is set at date six of the new window, equating to date one in the original window.

The final step is to identify whether there are statistically significant coefficients in a particular time window. If so, the month of the statistically significant dummy variable with the highest F-statistic within the 12-month window is selected as the moment when the most important mean shift occurred, marking the respective structural break.

4.2. NON-STATIONARITY AND FINANCIAL TIME SERIES ANALYSIS

Before discussing the econometric model's results, one further point warrants comment. A Dickey-Fuller Generalized Least Squares test (DFGLS test) on the modified dataset showed that bond prices of France and Germany are non-stationary and possess a unit root – as expected with financial time series data. The results of this test are presented in Table 2.

Table 2

Dickey-Fuller Generalized Least Squares test (DFGLS test) on German and French Bond Prices

	Germany	*France*
	Stationary around trend	Stationary around trend
Pre-war period (1900-1914)	– 3.78 ***	– 1.22
War period (1915-1919)	– 1.73	– 3.24 **
Total period (1900-1919)	2.35	– 0.52

Notes: *, * *, and * * * indicate the statistical significance of the confidence levels of 90%, 95%, and 99%, respectively. Values are rounded to the two-decimal place.
Source: author's own calculations.

The DFGLS test shows that only the pre-war period for Germany and the war period for France are stationary around their trend. The rest of the periods show non-stationarity. Therefore, the bond price series contains a unit root, and test statistics based on regression residuals will have a non-standard distribution. To control for the presence of a unit root, Frey and Kucher (2001) generated Monte Carlo critical values to select F-statistic values corresponding to statistical significance levels in step 4. Critical values were approximated with 5000 Monte Carlo simulations of $\ln p_t = c + \ln p_{t-1} + \epsilon_t$, with $c = 2.25$ and $\epsilon_t = 0.02$ for Germany and $c = 1.96$ and $\epsilon_t = 0.03$ for France. The rationale behind the parametric choices is that these are the average parameters from equation [2] used in steps 1 and 2 for Germany or France. This implies that the critical values depend on the model structure and the data. The resulting 90%, 95%, and 99% critical values are 3.36, 5.13, and 10.02 for Germany and 3.51, 5.38, and 10.50 for France. These computed Monte Carlo critical values are used to determine statistical significance in step 4 based on the corresponding F-statistic instead of the simpler t-statistic used by Jopp (2014). He, however, controlled for the presence of a unit root by including a deterministic time trend as an explanatory variable in his regressions since his daily series were stationary around the time trend.

5. RESULTS

The following section will discuss the empirical evidence derived from the price series of France and Germany by applying the econometric model explained in the methodology. The significance levels are based on the critical values of the F-statistic derived from the Monte Carlo simulations (see the previous page). Given these ten percent or better significance levels, a total of nice structural breaks have been identified for Germany between 1900 and 1919 and four for France between 1915 and 1919. Table 3 summarizes the results of these structural breaks; note that these are not yet the turning points.

To clarify the difference between a structural break and a turning point, a brief recap of the definitions used in this research: a structural break is a statistically significant change in the price series of a government bond, representing a deviation from the price that cannot be explained by the bond's time-lagged value or market developments, *ceteris paribus*. In contrast, a turning point is a structural break in the examined price series linked to a historical event likely to have caused this structural break.

Table 3

Structural Breakpoints and Corresponding Price Changes for Germany and France (1900 – 1919)

	Germany		*France*	
Date	% change in bond price [a]	Significance	% change in bond price [a]	Significance
1902, January	+ 1.33 %	*		
1903, August	– 1.76 %	*		
1906, January	– 2.11 %	* * *		
1906, February	– 2.64 %	* * *		
1907, May	– 2.59 %	*		
1916, January	– 10.48 %	*		
1916, May			+ 3.77 %	* * *
1916, December			– 2.18 %	*
1917, March	– 10.20 %	* * *		
1917, June			– 5.23 %	* *
1917, December	+ 11.31 %	* *	– 11.38 %	* * *
1918, September	– 34.53 %	* * *		

Notes: a) estimated percentual change in the conditional mean, i.e. the parameter γ_s [3]; *, * *, and * * * indicate the statistical significance of the confidence levels of 90%, 95%, and 99%, respectively. Values are rounded to the two-decimal place.
Source: author's own calculations.

Identifying turning points is the main focus of this research because these turning points reflect bondholders' perceptions of the positions of the belligerent parties (France and Germany) by linking historical events to unexpected adjustments in investor behavior. It is essential to clarify the underlying assumption of investor behavior. This research assumes that the identified turning points are caused by a change in bondholders' perceptions of their assets' default probabilities or average discount rates. The value of these bonds is substantiated by either France's or Germany's ability to fulfill its debt obligations now and in the future. The prospect of losing a major war severely pressures this ability. Therefore, it is assumed that the unexpected drop in a bond price's level is caused by a decline in bondholders' confidence in one of the belligerent powers to win the war. The same accounts for developments in the years before the war, as France and Germany had been antagonists for decades.

Hence, turning points can be linked to historical events affecting the belligerent position of France or Germany *before* and *during* the war. Furthermore, it is reasonable to imagine a turning point implying that the related event surprised bondholders, in contrast to an event that had already been factored into prices beforehand.

Two additional points need to be made. Firstly, there is always some uncertainty in linking a historical event to a structural break, as it is impossible to be a hundred percent certain whether this event directly caused the break. By analyzing the news from newspapers of that time, it is possible to get a comprehensive picture of public sentiment regarding developments in the war. This public sentiment can, in turn, be linked to the behavior and confidence of investors. Secondly, the pre-war period shows small, though significant, structural breaks for Germany. However, given the limited size of these breakpoints and the absence of concrete historical events that could explain them, not all structural breaks could be linked to historical events. These structural breaks are, therefore, not considered turning points in this research. To jump ahead, four turning points have been found for France and seven for Germany, meaning that only two structural breaks for Germany have not been linked to a historical event.

The identified turning points are presented in Table 4. The table shows the *estimated* percentage change indicated by the econometric model (given by the parameter γ_s) and the corresponding percentage change in the price level between the last available price quotation and the price quotation at the date of the structural break, i.e., the *observed* change in the bond price.

Table 4

Turning Points Regarding Germany's and France's Bond Price Performance (1900 – 1919)

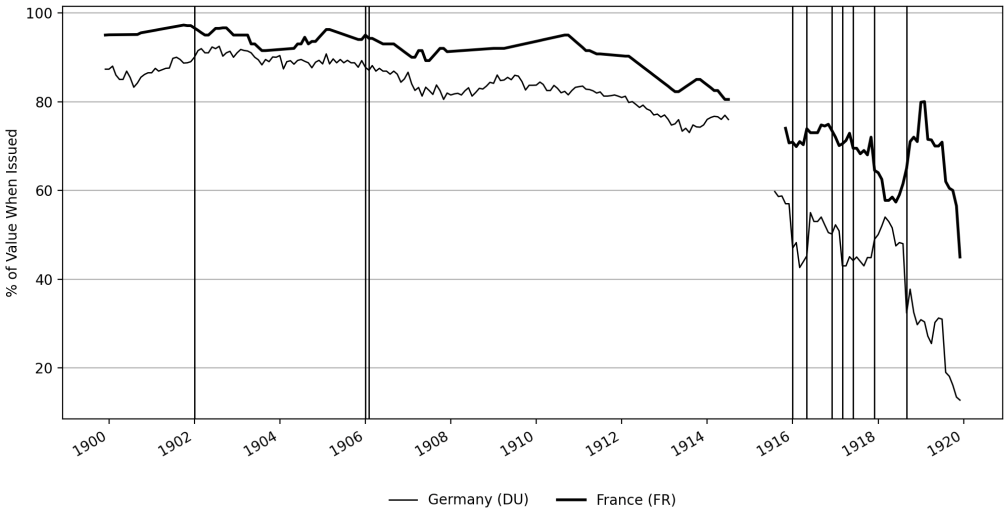
Germany			
Turning Point (t)	estimated % change for p_t [a]	observed % change from p_{t-1} to p_t	Historical Event
1902, January	+ 1.33 %	+ 1.16 %	Venezuelan Debt Crisis
1906, January	– 2.11 %	– 1.68 %	Algeciras Conference
1906, February	– 2.64 %	– 0.78 %	Algeciras Conference
1916, January	– 10.48 %	– 17.54 %	Conscription controversy in Britain
1917, March	– 10.20 %	– 15.48 %	British offensives at the Western Front
1917, December	+ 11.31 %	+ 9.27 %	Russian armistice
1918, September	– 34.53 %	– 38.71 %	Hundred Day Offensive
France			
Turning Point (t)	estimated % change for p_t [a]	observed % change from p_{t-1} to p_t	Historical Event
1916, May	+ 3.77 %	+ 5.12 %	Battle of Verdun
1916, December	– 2.18 %	– 1.87 %	The Financial Impact of War (general)
1917, June	– 5.23 %	– 4.63 %	Mutinies in the French Army
1917, December	– 11.38 %	– 10.42 %	Russian armistice

Notes: a) the percentual change in the conditional mean, i.e. the parameter γ_s from equation [3]. Values are rounded to the two-decimal place.
Source: author's own calculations

The analysis identifies three turning points in pre-war (1900 – 1914) and eight during wartime (1915 – 1918), including one synchronous but opposite turning point: December 1917, reflecting the traders' reaction to the defeat of Russia. One turning point stands out from a bondholder's perspective, namely September 1918, which was a reaction of the financial market to the Allied attacks as part of the Hundred Day Offensive. This event corresponds with the noted shift in the yield of France and Germany around this period, as visualized in Figure 3. Furthermore, January 1916 and March 1917 also show a notable decrease in Germany's bond values by approximately ten percent. These four dates show the largest price impacts throughout the observation period – all these breakpoints are identified in the war period. Figure 5 combines the price development of French and German government bonds (similar to Figure 2) with the identified turning points. When analyzing Germany's turning points, it stands out that the pre-war period had a lower frequency than the war period (0.2 versus 0.8 per year), and the turning points were smaller (2.02 percent versus 16.63 percent). The impact of the turning points during the war was at least four times bigger than during the pre-war period. The following paragraphs briefly go through the turning points chronologically, explaining how these events were reported in Dutch newspapers.

Figure 5

Price Trend of French and German Government Bonds + Turning Points (1900 – 1919)



Notes: nominal price in percent of par value monthly + turning points as identified in Table 4.
Source: modified dataset (author's database + Jopp, 2021) and author's own calculations.

The first turning point of January 1902 reflects the Venezuelan Debt Crisis. During this crisis, which began in 1901, the country defaulted on substantial debts owed to European nations. On January 3, 1902, *De Courant* highlighted Germany's plans to protect the interests of its citizens and businesses and mentioned that and President Theodore Roosevelt's support for Germany's non-military debt collection efforts (De Courant, 1902). A few days later, Algemeen Handelsblad reported the expired deadline for debt repayment, encouraging the German government to prepare for action (Algemeen Handelsblad, 1902). By January 22, 1902, Venezuelan President Castro indicated his willingness to negotiate compensation for German damages (Algemeen Handelsblad, 1902). These proactive yet diplomatic approaches by Germany probably have caused the estimated 1.33 percent spike

in German government bond prices, reflecting market optimism concerning the repayment of debts by Venezuela. The bond price surge reflects the repayment of debts without costly military intervention.

The second and third turning points refer to a prolonged conflict, the First Moroccan Crisis, and the Algeciras Conference of 1906, which aimed to resolve this issue. Sparked by German Emperor Wilhelm II's declaration of Moroccan independence in March 1905, the crisis challenged French and British interests in North Africa and aimed to enhance German trade prospects (Cambridge University Press, 1907). However, Germany's position led to diplomatic isolation. Dutch newspapers in January and February 1906 noted Germany's uncompromising stance, contributing to significant declines in German government bond prices: −2.11% in January and −2.64% in February. On January 17, 1906, Algemeen Handelsblad highlighted the ambiguity of Germany's interests, emphasizing that Germany could neither afford nor win a war with France over Morocco (Algemeen Handelsblad, 1906). By February 11, reports indicated Germany's growing isolation at the conference, with delegates viewing its position as exaggerated and indefensible (Algemeen Handelsblad, 1906). Germany's rigid stance was criticized, and the potential failure of the conference was attributed to Germany. Further isolation was noted on February 22, with Germany opposing the unified front of France, Britain, Italy, and Spain (Algemeen Handelsblad, 1906). Reports on February 23 suggested that Germany naively believed Britain would abandon France, while the conference turned out to strengthen the Franco-British alliance against Germany (Algemeen Handelsblad, 1906). The conference ultimately underscored Germany's diplomatic failures, naive foreign policy, and the strengthening of the Franco-British alliance, all contributing to bond price declines, reflecting market fears of escalating tensions and a more isolated Germany within Europe.

The fourth turning point in German bond prices was likely influenced by developments in Britain. The conscription controversy of January 1916, about one and a half years after the war began, led to an estimated decline of 10.48 percent in German government bond prices, reflecting market reactions to Britain's shift towards compulsory military service. The market viewed this as Britain's commitment to total war, significantly impacting bond prices. On January 2, Algemeen Handelsblad reported that most labor union representatives would approve compulsory service for all unmarried men on January 6 (Algemeen Handelsblad, 1916). By January 7, it was noted that over 650,000 men had yet to volunteer and could be conscripted (Algemeen Handelsblad, 1916). On January 12, successful recruitment campaigns were expected to yield 1.5 million additional troops (Algemeen Handelsblad, 1916). Finally, on January 25, the newspaper confirmed the conscription law had passed with 383 votes to 36 in the House of Commons (Algemeen Handelsblad, 1916). The British Military Service Act marked a departure from voluntary enlistment, signaling a prolonged and intensified war effort. Investors likely feared that Britain's increased military resources and commitment would prolong the war, strain German finances, and lower Germany's chances of victory. A sentiment reflected in a significant bond price drop.

During the fifth turning point in May 1916 – the Battle of Verdun – French government bonds saw a positive effect of approximately 3.77 percent, likely due to encouraging news about the French resistance. On May 11, Algemeen Handelsblad reported a positive mood among the French public concerning their prospects of winning the war

(Algemeen Handelsblad, 1916). Shortly after, letters from German officers were published, highlighting the impressive and resilient French defense (Algemeen Handelsblad, 1916). Continued failed German attacks boosted French morale, as noted in the press on May 23, when Russian parliament members praised French military strength, seeing it as a guarantee of victory (Algemeen Handelsblad, 1916). Another factor could be the announcement on May 10 of a $100 million loan secured for France on the New York capital market (Algemeen Handelsblad, 1916). While this financial support might have been seen as a positive boost for the French war effort and indicative of U.S. backing, the limited coverage in the news suggests it was less influential than the battlefield developments. The steady stream of positive reports about the Battle of Verdun likely fostered a favorable environment, reflecting investor confidence in France's resilience and prospects for victory at the Western Front.

The sixth turning point of December 1916 is not linked to a concrete event, but is likely to refer to more general investor sentiment in Amsterdam. During the last month of 1916, French government bonds saw a 2.18 percent decline despite relative victories in the Battles of the Somme (July 1916 – November 1916) and Verdun (February 1916 – December 1916). The news coverage was generally neutral, not explaining the decline directly. However, on December 24, the newspaper published an article highlighting the war's staggering costs and losses, which may have influenced investor sentiment (Algemeen Handelsblad, 1916). The report compared the World War I expenses to those of the Napoleonic Wars, noting that the ongoing conflict was a huge financial burden for France, with predictions of tripling national debt and significant future interest payments estimated at 20 percent of all government income. This awareness of the financial burden likely contributed to the negative sentiment and subsequent bond price drop.

During the seventh turning point of March 1917, German government bonds experienced a significant decline, likely due to the successful Allied offensives. By March 18, Allied forces forced a substantial withdrawal of German troops, resulting in the abandonment of heavily fortified German positions (Algemeen Handelsblad, 1917). This news dominated the press throughout March, with demoralizing effects on German soldiers, as confirmed by prisoners (Algemeen Handelsblad, 1917). Furthermore, German reporters criticized the abandonment of costly fortifications (Algemeen Handelsblad, 1917). Although the strategic purpose of the withdrawal of German troops became known by the end of the month, overall market sentiment was negative, reflected by an estimated 10.20 percent bond price decline. This decline indicates the market's reaction to Germany's setbacks on the Western Front, overshadowing other contemporary events such as the Russian Revolution. While Jopp (2014) attributes the decline to uncertainty surrounding Russia's future war efforts, the news coverage and market reactions suggest the immediate military developments had a more direct impact on investor confidence. The extensive media coverage of the German retreats and the negative portrayal of the strategic withdrawals by German forces likely fueled market pessimism.

In June 1917, French government bonds experienced a decline of 5.23 percent, as shown by the eight turning point, largely due to widespread mutinies within the French army. By late May and throughout June, these

mutinies affected nearly half of the French army divisions (French, 1991). Although Algemeen Handelsblad provided limited coverage, other Dutch newspapers highlighted the impact of the mutinies. On June 11, the *Delftsche Courant* reported prisoners revealing officers' reluctance to fight (Delftsche Courant, 1917), while the *Rotterdamsch Nieuwsblad* on June 18 described mutinies among Russian troops in France (Rotterdamsche Courant, 1917). News of various divisions refusing orders continued to emerge. This demoralization directly affected investor confidence, contributing to the decline in bond prices. The French government suppressed news of the mutinies to avoid alarming the Germans or demoralizing the home front. The full extent of the mutinies and their suppression became widely known only decades later, explaining the limited newspaper coverage at the time (Smith, 1995). Despite this, given the absence of other news explaining the downward trend in French bond prices that month, it is reasonable to assume that investors were aware of the mutinies through some newspapers and found the reports concerning. This awareness likely contributed to the decline in bond prices.

In December 1917, a turning point occurred with contrasting effects on French and German government bonds. French bonds fell by 11.38 percent, while German bonds rose by 11.31 percent. This shift was largely influenced by Russia's move towards an armistice and potential peace with Germany and its allies. On December 10, Algemeen Handelsblad reported Russia's pursuit of a ceasefire (Algemeen Handelsblad, 1917), leading to the December 17 announcement of an armistice on the Eastern Front (Algemeen Handelsblad, 1917). This development suggested a significant advantage for Germany, allowing them to redirect resources to the Western Front and potentially launch a strong offensive against France and Britain. The December 23 market overview in Algemeen Handelsblad highlighted this as an economic and military victory for Germany over an exhausted Russia (Algemeen Handelsblad, 1917). The prospect of peace with Russia reopened a significant market for Germany, providing an economic boost. These reasons explains the divergent bond market reactions, with optimism for Germany and concerns for France. This was the only turning point with a synchronous but opposite effect on French and German bonds, underscoring the importance of the Eastern Front's resolution for the overall development of World War I.

The last identified turning point occurred in September 1918, when German government bonds experienced a significant decline of 34.53 percent. The Hundred Days Offensive, begun on August 8, marked the Allies' decisive push, eventually breaking through the Hindenburg Line – the most important German defensive line at the Western Front. Furthermore, internal German political issues related to the development of the war also weakened Germany’s position. The people demanded more democratic influence over the course of the war and politics in general. Algemeen Handelsblad extensively detailed the events throughout September 1918. On September 7, the newspaper reported a strong Allied advance across the Western Front, forcing German retreats (Algemeen Handelsblad, 1918). By September 11, persistent rumors of a government crisis in Germany were noted, alongside continuous Allied progress (Algemeen Handelsblad, 1918). On September 18, the Algemeen Handelsblad referred to the *Berliner Tageblatt* – a highly valued German newspaper – that criticized the German leadership and highlighted internal political turmoil; the *Reichstag*, the German parliament, was sidelined and the German press condemned the undemocratic handling of the war (Algemeen Handelsblad, 1918). Finally, on

September 28, it was reported that Allied forces penetrated the German front lines, capturing thousands of prisoners of war daily (Algemeen Handelsblad, 1918). These developments underscored Germany's imminent defeat, culminating in the forced abduction of Wilhelm II and the proclamation of the Weimar Republic on November 9 and the November 11 armistice. The combination of military setbacks and internal crises led to a loss of confidence among investors about Germany's prospects of winning the war.

6. DISCUSSION

The following section discusses the results from both methodological and historical perspectives. First, alternative approaches will be applied to test the robustness of the results (§6.1.), followed by addressing the limitations of the research (§6.2.). This embodies the more technical approach of the discussion. Lastly, the results will be discussed in the historical context of World War I and are compared to other research (§6.3.).

6.1. ROBUSTNESS: TWO ALTERNATIVE ECONOMETRIC MODELS

As mentioned earlier, this study combines the approaches of Frey and Kucher (2021) and Jopp (2014). Frey and Kucher incorporate a variable in their model to control market developments. Alternatively, Jopp uses a market proxy merely as a robustness check due to the explanatory power of his daily data relying solely on lagged prices. Given that this study uses monthly data, similar to Frey and Kucher (2021), the econometric model applied includes two explanatory variables: the lagged bond price and the market proxy. The same approach is used to test for robustness but now without the market proxy variable. The simplified model is specified as follows:

[4] $$\ln p_t^X = \beta_0 + \beta_1 * \ln p_{t-1}^X + \epsilon_t$$

where p_t^X is the value of the government bond of either Germany or France, traded in Amsterdam on date t; β are the parameters to be estimated and ϵ_t is a white noise error term. The approach is the same as described in the general model's four-step methodology.

The results of the simplified model compared to the general model are given in Table 5. The simplified model confirms the appearance of the same turning points identified by the general model but adds four additional structural breaks of minor magnitude during the pre-war period for Germany (February 1907, September 1909, October 1909, and March 1912) and one additional structural break of more significant magnitude to France during the war period (July 1918). Furthermore, in the case of France, one structural break identified with the general model is no longer identified with the alternative model, namely December 1916 (the yearly reflection on the capital market). The effect on the estimated change in the conditional mean (γ_s) is marginal.

When comparing the average R^2 value of the 206 regressions on the 12-month time windows of Germany (39 regressions for France), the removal of the market proxy as an explanatory variable lowers R^2 from 0.55 (0.68) with the general model to 0.49 (0.65) with the simplified model. The inclusion of the market proxy variable in the general model enhances the explanatory power of the model, as evidenced by the higher R^2 values. A higher R^2 indicates that a greater proportion of the variance in the dependent variable is explained, suggesting that the market proxy provides valuable information that helps to explain the movements in bond prices more accurately (Brooks, 2008).

Overall, the general model appears robust, as the simplified model confirms its major findings and the inclusion of the Dutch obligation increases the explanatory value of the model. The additional breaks identified by the simplified model suggest it is more sensitive to smaller changes, possibly because these relatively small changes in the price of German bonds are no longer explained by developments in the (Dutch) market. Only the additional structural break for France in July 1918 is interesting because of its magnitude and direct relationship to a historical event: a successful French counterattack on the last major German offensive during the Second Battle of the Marne.

Table 5

General and Simplified Model: Comparison of Estimated Percentage Change (γ_s)

	Germany		*France*	
Structural Breakpoint	General Model	Simplified Model	General Model	Simplified Model
1902, January	+ 1.33 %	+ 1.33 %		
1903, August	– 1.76 %	– 1.70 %		
1906, January	– 2.11 %	– 2.11 %		
1906, February	– 2.64 %	– 2.64 %		
1907, February		– 2.74 %		
1907, May	– 2.59 %	– 2.59 %		
1909, September		– 1.49 %		
1909, October		– 2.26 %		
1912, March		– 1.43 %		
1916, January	– 10.48 %	– 10.48 %		
1916, May			+ 3.77 %	+ 4.34 %
1916, December			– 2.18 %	
1917, March	– 10.20 %	– 10.20 %		
1917, June			– 5.23 %	– 5.28 %
1917, December	+ 11.31 %	+ 11.31 %	– 11.38 %	– 9.03 %
1918, July				+ 5.20 %
1918, September	– 34.53 %	– 34.53 %		

Notes: values are rounded to the two-decimal place.
Source: author's own calculations.

The second robustness check for the general model investigates the impact of incorporating the exchange rate as an explanatory variable. As previously explained, Jopp (2014) did not find statistically different results when using an alternative model that included the Dutch obligation as a market proxy and the exchange rate between the Netherlands and Germany. This lack of difference in the results is likely due to his use of daily data. The exchange rate is included as an additional explanatory variable to determine if this finding also applies to the general model used in this research, which is based on monthly data. The extended model is specified as follows:

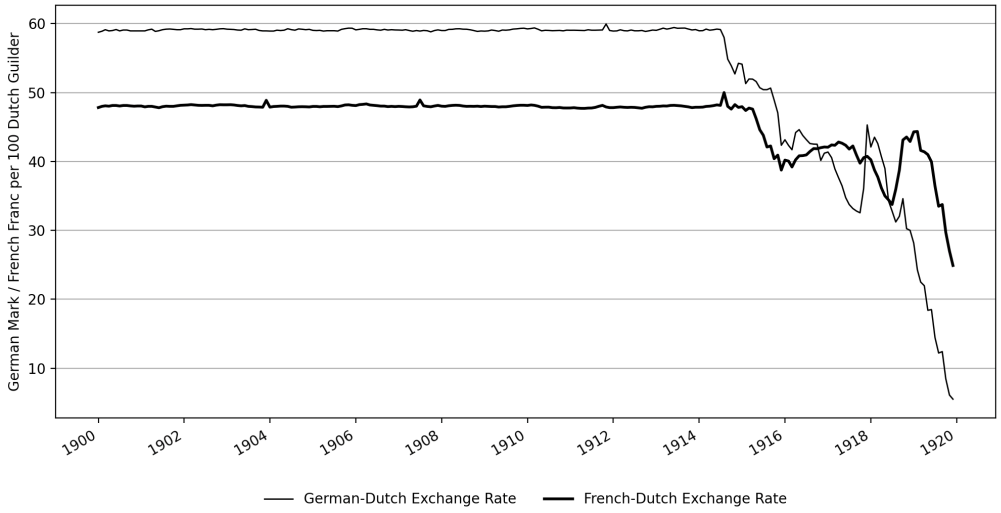
$$[5] \qquad \ln p_t^X = \beta_0 + \beta_1 * \ln p_{t-1}^X + \beta_2 * \ln p_{t-1}^M + \beta_3 * \ln ER_{t-1}^{X,Y} + \epsilon_t$$

where p_t^X is the value of the government bond of either Germany or France, traded in Amsterdam on date t; p_t^M is the value of the Dutch government bond traded in Amsterdam on the same day, used as a proxy for overall market performance; $ER_t^{X,NL}$is the exchange rate between country X (either France or Germany) and the Netherlands on the same day; β are the parameters to be estimated, and ϵ_t is a white noise error term.

Data on the exchange rates between the Netherlands (guilder) and France (franc) or Germany (mark) is obtained from two sources. For the period 1900 – 1914, the comprehensive study *Nederlandsche Prijsgeschiedenis Deel 1: Goederenprijzen op de beurs van Amsterdam 1585-1914 & Wisselkoersen te Amsterdam 1609-1914* (Dutch Price History Part 1: Commodity Prices on the Amsterdam Stock Exchange 1585-1914 & Exchange Rates in Amsterdam 1609-1914) by N.W. Posthumus (1943) provided information on the exchange rates. This information was converted into a dataset. For the period 1915 to 1919, data is obtained from the database provided by Jopp (2021). The development of the German–Dutch and French–Dutch exchange rates are visualized in Figure 6.

Figure 6

Mark–Guilder and Franc–Guilder Exchange Rates at the Amsterdam Stock Exchange (1900 – 1919)



Notes: the German–Dutch exchange rate represents the strength of the *Goldmark* to the Guilder and the French–Dutch exchange rate represents the strength of the Franc to the Guilder.
Source: author's own dataset based on Posthumus (1943) and Jopp (2021).

The results of the extended model are given in Table 6. The extended model yields the same results as the general model in the case of France; it slightly changes the conditional mean (γ_s) but does not generate new or falsify former turning points. Germany is a different case. The extended model adds four additional structural breaks of minor magnitude during the pre-war period (February 1902, April 1906, November 1907, and January 1914). More importantly, the extended model no longer identifies two pre-war and three war turning points. The effect on R^2 for the extended model differs from the simplified model. In the case of Germany (France), the exchange rate as explanatory variable increases R^2 from 0.55 (0.68) to 0.63 (0.74) with the extended model. The increase in R^2 indicates that the exchange rate does indeed have an explanatory power in the determination of bond prices.

At first glance, this model's results question the general model's robustness. However, this explanatory value should be understood with caution: a decrease in the exchange rate also weakens the bond's value. This implies that the interaction works both ways, potentially causing endogeneity in simultaneity or two-way causality (Gippel, Smith, & Zhu, 2015).

Table 6

General and Extended Model: Comparison of Estimated Percentage Change (γ_s)

	Germany		*France*	
Structural Breakpoint	General Model	Extended Model	General Model	Extended Model
1902, January	+ 1.33 %	+ 1.33 %		
1902, February		+ 2.19 %		
1903, August	– 1.76 %	– 2.00 %		
1906, January	– 2.11 %			
1906, February	– 2.64 %	– 2.63 %		
1906, April		– 2.27 %		
1907, May	– 2.59 %			
1907, November		– 1.89 %		
1914, January		+ 2.49 %		
1916, January	– 10.48 %			
1916, May			+ 3.77 %	+ 3.73 %
1916, December			– 2.18 %	– 3.58 %
1917, March	– 10.20 %			
1917, June			– 5.23 %	– 7.18 %
1917, December	+ 11.31 %		– 11.38 %	– 11.04 %
1918, July				
1918, September	– 34.53 %	– 29.92 %		

Notes: values are rounded to the two-decimal place.
Source: author's own calculations.

A brief explanation clarifies this issue. A decrease in the exchange rate of the currency in which the bond is denominated (German Mark or French Franc) can reduce the bond's value in terms of the investor's domestic currency (Dutch Guilder). This reduction occurs because the coupon payments and principal value have become less valuable when converted to domestic currency. The lower exchange rate decreases the bond's value and thus incentivizes investors to sell their assets denominated in that currency, which decreases the bond price.

Conversely, the bond's value influences the exchange rate as well. The sale of bonds by foreign investors, driven by concerns over the issuing country's ability to meet its debt obligations – possibly related to pre-war and war events – can increase the supply of foreign currency in the market. This occurs when domestic investors convert the foreign currency received through selling the bonds into their domestic currency. This conversion process increases the supply of foreign currency in the exchange market, leading to its depreciation relative to the domestic currency. Thus, falling bond prices and declining exchange rates can reinforce and explain each other.

This example illustrates how the exchange rate and bond value can mutually influence each other, potentially causing endogeneity in the econometric model. However, it is beyond the scope of this thesis to explore the possibilities to solve this endogeneity issue. Given the potential endogeneity problem, the results of the extended model cannot be interpreted with full certainty. Therefore, the outcome of this robustness test is not included in the assessment of the general model. However, the result could suggest future research to integrate the exchange rate into the model appropriately.

6.2. LIMITATIONS OF THE RESEARCH: DATA AVAILABILITY AND FREQUENCY

The research limitations can be divided into two main categories: data availability and data frequency. Regarding data availability, the pre-war data on French government bonds is minimal. Therefore, this period was excluded from the main analysis detecting turning points. This exclusion is unfortunate as it limits the identification of synchronous but opposite turning points to the war period. During the war, only one turning point with simultaneous but opposite effects was identified: the Russian armistice in December 1917, which resulted in an estimated price decline of 11.38 percent for France and an estimated price increase of 11.31 percent for Germany. It is premature to conclude that more simultaneous but opposite turning points for the belligerent countries cannot be identified, as data frequency issues need further exploration.

Although this study could not demonstrate synchronous but opposite price developments between French and German government bonds before and during World War I through structural breaks analysis, it is possible to investigate changes in the correlation between *returns* (i.e., price changes). This alternative approach provides insights into the overall development of German and French bonds by examining returns, which capture volatility and risk. Analyzing returns helps assess the bond markets' response to World War I without focusing on individual events. The outbreak of war in July 1914 is considered a potential breakpoint in the correlation between the returns of French and German bonds.

To test this, the dataset was divided into two 49-month periods: July 1910 to July 1914 (the closure of the Amsterdam Stock Exchange) and November 1915 to November 1918 (Armistice of 11 November 1918). These periods are based on data availability, with the first time window representing the pre-war period while the second time window representing the war period. Bond prices were converted to returns using logarithmic returns, a standard approach in financial econometrics (Brooks, 2008). Then, the means and volatilities for the returns of French and German bonds are calculated, as well as the correlations. Fisher's Z-transformation was applied to the correlation coefficients to test for a significant change in the relationship between these bonds, followed by a Z-test to determine if the difference between the pre-war and war periods was statistically significant (Wicklin, 2017). The results are summarized in Table 7.

Table 7

France and Germany: Changes in Monthly Return, Volatility and Correlation

	Pre-war	War	Δ (change)
France			
▪ Mean monthly return	– 0.34	– 0.72	0.38 *
▪ Volatility (σ_F)	0.50	4.55	4.05 ***
Germany			
▪ Mean monthly return	– 0.18	– 3.54	3.36 *
▪ Volatility (σ_G)	1.01	12.12	11.10 ***
Correlation ($\rho_{F,G}$)	– 0.16	0.29	0.45 **

Notes: returns and volatilities are given in percentages; Z-test statistic on the change in correlation is 2.189 with a p-value of 0.029, indicating that this change is statistically significant at the 5% level; *, * *, and * * * indicate the statistical significance of the confidence levels of 90%, 95%, and 99%, respectively. Values are rounded to the two-decimal place.
Source: author's own calculations

As expected and in line with the previous findings, volatility increased during the war compared to the pre-war period for France and Germany at the highest statistical significance level significance. The analysis also found a statistically significant change (5% level) in the correlation between French and German government bonds during the war compared to pre-war. Specifically, the correlation shifted from a weak negative to a moderate positive, indicating a change in the relationship between the bond returns. Before the war, the correlation was weakly negative (0.16), suggesting that bond prices moved independently or in opposite directions. This weak negative correlation might reflect France and Germany's relatively independent economic conditions and policies during the pre-war period. During the war, however, the correlation became moderately positive (0.29). This shift indicates that the bond returns started to move more in tandem.

The outcome of the analysis indicates that the covariance ($cov_{F,G} = \sigma_F * \sigma_G * \rho_{F,G}$) has changed from a negligible negative value (−0.000008) to a very small positive value (0.001649), indicating a stronger positive relationship between the bond returns during the war. The increased covariance and shift to a positive correlation suggest that the bond returns of France and Germany became more interconnected and behaved more similarly during World War I. Given these findings, it can be cautiously stated that contrary to expectations, there were no more opposing developments in French and German bond returns during the war than before, as the belligerent countries' correlation turned negative to positive.

When examining the returns of government bonds, it is important to note that a structural break analysis similar to that conducted on bond prices is not feasible. Structural break analysis aims to identify lasting price changes over a longer period. This research used a time window of 12 months, and focusing on changes in the midpoint means focusing on changes having an average effect lasting at least six months. This method helps determine which events have impacted the positions of France or Germany based on price developments, focusing on changes in non-stationary time series data. In contrast, returns are typically analyzed to identify changes in volatility (variance) using stationary data. Individual returns provide less insight into long-term trends and changes in investor perspectives on the belligerent positions of France and Germany. This is partly because short-term investor behavior, such as market overreaction, plays a more significant role. For example, despite a long-term downward trend in bond prices, positive short-term returns can still occur if there are price increases within that downward trend. Therefore, the econometric model for structural breaks in bond prices cannot be directly applied to returns.

Finally, two comments can be made regarding the data frequency used in this thesis, which is based on monthly data. Increasing the data frequency, as done in Jopp's (2014 & 2021) study, can offer several advantages. First, working with daily data could identify more potential breakpoints due to differences in the length of the time windows used for financial time series analysis. This research uses 12-month time windows over a twenty-year period, providing only 12 data points per initial regression to test for structural breaks. In contrast, Jopp used daily data with 101-day time windows over a three-and-a-half-year period (2014) or a five-and-a-half-year period (2021), resulting in 101 data points per initial regression and more precise outcomes. This may explain why this

research identified four breakpoints for Germany for the war period (1915 – 1919) while Jopp (2021) identified eight. For France, this research found three breakpoints compared to the seven identified by Jopp (2021).

Second, the current research's monthly analysis makes it more challenging to link specific historical developments to identified structural breaks. This is especially true for smaller structural breaks in the pre-war (1900-1914) period, where historical events are less well-known and harder to correlate with structural breaks. Increasing data frequency could alleviate this issue, as daily data allows for more precise identification of historical events corresponding to structural breaks. Instead of examining an entire month of events, one can focus on the days surrounding the break. In addition, with monthly data, it is possible that multiple events occurred in a month, which could explain a structural break. In this case, it is still necessary for the researcher to interpret which event is the most likely explanation for the change in the bond price. Although the data is still leading in this case, the researcher's *ex-post* interpretation plays a more important role. Daily data can further reduce the influence of *ex-post* interpretations - which is one of the aims of an analysis based on structural breaks.

6.3. CONCLUDING THOUGHTS AND COMMENTS ON THE RESULTS

When the results of this research are placed in their historical context and compared to other research, several noteworthy aspects arise. Firstly, many historically significant pre-war events, such as the Second Moroccan Crisis (1911), the Balkan Wars (1912–1913), and the war declarations in July and August 1914, were not reflected as turning points in bond prices (MacMillan, 2013). This is interesting, as one might expect these geopolitical tensions to be reflected in bond prices. This is unrelated to whether investors did not anticipate the outbreak of war: any geopolitical events can affect a country's international position and, thus, its bond prices. For instance, the Algeciras Conference weakened Germany’s international position, leading to a decline in its bond prices, even though it was not directly related to the possibility of war, as noted in the Dutch newspapers.

Other research on pre-war periods, such as that by Frey and Kucher (2021), also found few turning points. This suggests that while one might expect more turning points due to geopolitical tensions in the pre-war period, structural break analysis may not be the best method for detecting them. This could be because structural break analysis focuses on relative deviations. When studying pre-war and war periods together, deviations in the pre-war period may be overshadowed by the war period, resulting in fewer identified structural breaks.

Regarding the war period, several comparisons with other studies are worth noting. For example, the entry of the United States into the war in April 1917 did not lead to a turning point despite its historical significance. Frey and Kucher (2021) identified this moment as a turning point during World War II. It is also surprising that only one synchronous but opposite turning point was found: the Russian Armistice of December 1917. Studies on World War II found more synchronous but opposite turning points (Frey & Waldenström, 2004; Frey & Kucher, 2000). Nonetheless, some similarities were confirmed, such as investors anticipating the armistice and Germany's defeat, with the turning point occurring in September 1918, well before the official capitulation in November 1918.

This shows that historical investor expectations and behavior might differ from contemporary interpretations of the importance of pre-war and war events. The lack of turning points in the immediate years before the war supports the 'surprise hypothesis' of Ferguson (2006) and Jopp (2021), which suggests that financial markets did not signal an expected outbreak of large-scale war between France and Germany. The findings of this study, in terms of bond price and yield developments, confirm this hypothesis. The fact that the results of this study have many similarities with the findings of other studies on the World Wars lends greater certainty to their interpretation.

The direction and frequency of turning points also warrant discussion. Overall, negative effects on bond prices were more common and pronounced than positive ones, with five negative and two positive turning points for Germany and three negative and one positive for France. This suggests that historical markets reacted more strongly to negative news. The predominance of negative turning points and their larger magnitude may imply that synchronous and opposite developments exist, but the positive development may not be measurable within the current model.

Historically, events positively perceived by Germany's opponents resulted in negative price developments for Germany and vice versa. For example, the three negative turning points for Germany during the war (Conscription Controversy in Britain, British Offensives at the Western Front, and The Hundred Day Offensive) are all 'positive events' seen from the perspective of Germany's opponents, and these 'positive events' result in 'negative price developments' for Germany. In the case of France, this applies to the Russian Armistice: a positive event for Germany results in a negative price development for France. Only in the case of two war-period turning points is the event, or in fact, the news about this event, and the price change attributable to the same country: the resistance of France at the Battle of Verdun resulted in a bond price increase and the Munitions in the French army resulted in a bond price decrease. This might feel like stating the obvious, but the combination of positive news and negative developments in the historical bond market is worth mentioning.

This interpretation of negative turning points within the historical context provides valuable insights. It raises questions about why negative turning points are more frequent and impactful. What does the fact that more negative turning points are observed mean? Why is their value greater than that of positive turning points? In light of the above approach to the results, this may possibly be the result of the fact that negative news leads to an overreaction in the market. The fact that 'bad news seems to surprise, while good news is not' seems to be present here (DeFond & Zhang, 2011). An interesting point for further research.

7. CONCLUSION

This study analyzed the development of the bond prices of two belligerent countries, France and Germany, before and during World War I from a historical bond market perspective. The methodology combined a structural break analysis with a historical approach to identify turning points without relying on predefined dates. This allowed for a more objective identification of important events from a financial perspective before linking these events to their historical context. The research used monthly bond price data from the Amsterdam Stock Exchange to study the development of bond prices between 1900 and 1919. The Netherlands has been used as a market proxy in the absence of a market index. The section below discusses the main findings and concludes the research.

The research question of this thesis was to understand how belligerent tensions and wartime events between Germany and France were reflected in their respective government bond prices on the Amsterdam capital market between 1900 and 1919. The answer to this question is both ambiguous and nuanced. The study confirms that bond prices mirror pre-war tensions and significant wartime events, providing a financial perspective on historical events. However, no clear conclusion can be drawn regarding the direction (positive or negative) and frequency of these bond price developments. Therefore, the expectations regarding this research are partly confirmed and partly refuted.

The study hypothesized that the financial market would react to specific pre-war developments reflecting belligerent tensions between Germany and France. Due to data restrictions, the research could only confirm this hypothesis for Germany. Although only three pre-war turning points were identified for Germany, the historical context supports the hypothesis. The Algeciras Conference, which led to two significant declines in German bond prices, is historically regarded as a success for France and a geopolitical defeat for Germany. Thus, pre-war tensions between these countries were reflected in the bond market.

Furthermore, this research anticipated that during the war, turning points would exhibit synchronous but opposite effects for the belligerent countries. This hypothesis was supported by one turning point: the Russian Armistice of December 1917, which had opposite effects on French and German bond prices. The historical context further strengthens this argument: while most wartime turning points do not reflect synchronous but opposite effects, it is evident that events favoring one side result in a negative structural break for the other.

Therefore, in light of the abovementioned findings surrounding the hypotheses and research outcomes, it can be cautiously stated that wartime events between belligerent countries tend to lead to a negative structural break for the disadvantaged country, while the positive effect on the advantaged country is not as clearly measurable. This also explains why turning points are more often negative than positive and why the impact of negative turning points is stronger than that of positive ones. So, with some thoughtfulness, the answer to the research question is that geopolitical tensions and significant wartime events are indeed reflected in the bond prices of the belligerent countries. However, the 'synchronous but opposite' thesis cannot be fully proven yet, as it has mostly been supported from a historical perspective and not from a financial one.

In addition to the abovementioned findings, this research has shown two other results worth mentioning. Firstly, it has demonstrated that the reflections in the bond market, as indicated by turning points, do not necessarily align with events generally considered important by historians. Thus, the *financial* perspective from the past and the *historical* perspective on the past can differ, highlighting the value of studying historical financial data as an alternative perspective on historical narratives. This aligns with previous research within the field of new economic history, confirming that analyzing historical financial data is a valuable method for studying history and enriching the historical narrative. Secondly, an interesting finding emerged during the discussion: the correlation of returns on French and German bonds shifted from slightly negative to moderately positive from the pre-war to the war period, with July 1914 as the breakpoint. This indicates that bond returns began to move more in tandem during the war period. The finding that the bond returns of the belligerent countries became more interconnected and behaved more similarly during the war is intriguing from both financial and historical perspectives, as it contradicts expectations.

The study's limitations included data availability, particularly the minimal pre-war data on French government bonds, and the use of monthly data, which may have limited the precision of identifying turning points compared to studies using daily data. Furthermore, the econometric model requires improvements to account for exchange rate risk without causing endogeneity problems. Besides, a higher data frequency could reveal more turning points. So, Future research could benefit from using higher frequency data and further exploring the relationship between exchange rates and bond values. Additionally, it is recommended that future researchers study the pre-war and war periods separately. The econometric model in this study focuses on relative outliers over the entire study period – specifically, peaks in the F-statistic – meaning that those during the war may overshadow events in the pre-war period. By studying the pre-war period separately, researchers can facilitate a more equal comparison.

All in all, this thesis aimed to enhance financial analyses by emphasizing the importance of historical context in understanding market behavior, which can help analyze how contemporary markets might respond to political tensions and conflicts. By combining financial and historical perspectives, this study hoped to contribute to the field of new economic history, providing a richer understanding of the financial interactions between belligerent countries. The research demonstrated that geopolitical tensions are reflected in historical bond markets: both wartime events and pre-war tensions were mirrored in bond prices, illustrating how financial markets responded to historical events. The findings suggest that historical bond markets indicate investor sentiment and expectations during political instability and conflict. Furthermore, the study found negative structural breaks were more frequent and pronounced than positive ones. This financial perspective aligns with historical narratives and provides unique insights into how markets anticipate and react to geopolitical changes. These findings are valuable not only for economists and historians but for anyone interested in the broader context of war and conflict.

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