Time-Varying Risk Aversion during World War II: Evidence from Belgian Lottery Bond Prices

Matthieu Gilson, Kim Oosterlinck and Andrey Ukhov

Although of paramount importance in finance, empirical evidence on time-varying risk aversion remains mixed. This paper contributes to the existing literature by analyzing how investors’ risk preferences change under extreme circumstances. Using the market prices of a Belgian lottery bond, we build an index that tracks the attitude toward risk of financial markets’ participants during the Second World War. Results show that risk aversion dramatically changed during the Occupation period. Before 1943, investors showed strong signs of risk aversion; yet, in 1943 and 1944, they exhibited a risk-seeking attitude. After 1943, investors agreed to pay more and more for the lottery feature, and much more than the lottery’s expected payoff. In line with the behavioral finance literature, this puzzling result is attributed to psychological factors, most importantly the euphoria brought by the prospect of the war’s end.

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Abstract

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Risk Aversion during World War II: Evidence from Belgian Lottery Bond Prices

1. Introduction

Understanding how risk preferences of financial markets’ participants change over time is crucial to analyze the dynamics of financial markets. An investor’s risk attitude partially determines his asset allocation between risky and non-risky assets, the premium he will require for bearing risk, and hence, the price he is willing to pay for a specific asset. As a result, on an aggregate level, changes in investors’ attitude toward risk have a major impact on asset prices. Understanding the mechanism through which these risk preferences are formed, and how they change in extreme situations, such as during wars or financial crises is therefore key for analyzing behavior of financial markets.

Time-varying risk aversion has been a topic largely discussed in the finance literature. Campbell and Cochrane (1999), Constantinides (1990), Barberis et al. (2001), and Brandt and Wang (2003) have developed asset pricing models incorporating this feature. The literature has, however, so far failed to reach a consensus regarding the extent of changes in risk aversion, let alone the drivers of such changes. Using field experiments, Andersen et al. (2008) argue that risk preference are remarkably stable over time. Nevertheless, it seems that risk aversion may be affected by a dramatic change in the environment. M. Weber, E. Weber, and Nosic (2012) report a shift in risk taking behavior during the financial crisis of 2008. For the same period, Guiso, Sapienza, and Zingales (2013) also report a significant increase in risk aversion and hypothesize that the cause is psychological. This explanation is consistent with the behavioral finance literature, which emphasizes the impact of emotions on financial decisions (Daniel et al. 2002; Kuhnen and Knutson 2011; Loewenstein et al. 2001; Nofsinger 2005). Negative events need not lead to an increase in risk aversion. Indeed, Eckel, El-Gamal, and Wilson (2009) study the impact of the occurrence of a natural disaster on risk preferences and show that victims of Hurricane Katrina exhibit ex-post a risk loving bias. Using a series of field experiments in Burundi, Voors et al. (2012) find that individuals exposed to violence are more risk-seeking. Bchir and Willinger (2013) document an analogous finding for people exposed to natural disasters. These results, however, are hard to generalize. Indeed, Bucciol and Zarri (2013) find that negative life events,
such as being a victim of a natural catastrophe or losing a child, tend to increase risk aversion. Similarly, Cameron and Shah (2012) report that individuals that experienced a natural disaster exhibit a greater risk aversion. Callen et al. (2014) provide results from experiments in Afghanistan: individuals exposed to violence, when primed to recall fear, display a higher degree of risk aversion. Eventually, Cohn et al. (2015) find that fear reduce financial risk-taking, even if this fear is unrelated to economic events.

This paper contributes to the risk aversion literature by analyzing how investors’ risk preferences change during extreme circumstances. Whereas the literature has analyzed changes linked to natural disasters or financial crises, this paper focuses on the impact of war and occupation on investors’ risk taking behavior. To do so, this paper investigates the risk attitude of Belgian financial market participants during the Second World War. To elicit investors’ risk preferences, we opt for an original methodology using the market prices of a lottery bond issued by the Belgian government. Lottery bonds mix features of traditional bonds and lotteries. As a classical bond, the bearer receives a coupon every year until the bond is recalled. However, the date and the value at which the bond will be recalled are uncertain since they are determined via a monthly lottery. For each lottery, a pre-determined number of bonds are randomly drawn and each drawn bonds provides a monetary prize. The holder of the drawn bond receives the cash prize. In counterparty the bond is retired. This setting provides an ideal environment to study risk behavior. The specifications of the lotteries are determined and publicized upon the issue of the bond. For each lottery, any investor knows the a priori probability of being drawn and the value of the prize pool. Therefore, lottery bonds are close to a market traded lottery ticket. Since this security is quoted on a daily basis, investors’ willingness to pay can be assessed with the same frequency. Risk aversion is then measured by comparing the market price of the lottery bond to its theoretical price. Ceteris paribus, the higher the willingness to pay for the lottery feature, the lower the risk aversion.

Lottery bonds have been discussed in the literature (Schilbred 1973; Green and Rydqvist 1997; Florentsen and Rydqvist 2002; Lobe and Hölzl 2007), but seldom with the specific purpose of looking at changes in risk attitude over time. Ukhov (2010) uses the Russian lottery bonds to analyze investors’ risk preferences. He extracts absolute risk aversion parameters from the bond market prices and shows that risk aversion varies over time and is positively correlated with the price of the risk-free asset. Bühlcr and Herzog (2011) use a dynamic equilibrium model to estimate the size of the relative risk premium and the relative risk aversion coefficient from
German lottery bond prices. They also find a risk aversion coefficient that significantly varies over time, peaking during the 1980/1981 oil crisis, and is in line with the interest rates. Velde (2015) analyze the lottery loans issued by the British government during the 18th century. These securities were akin to a lottery ticket whose pay-off was a standard government bonds. After the issue, a draw, that lasted several weeks, determined the size of the government bond that the ticket holder would receive. He documents that the market price of the ticket was larger than its expected pay-off, and that this premium paid for lottery ticket systemically trended upward during the course of the draw.

This paper brings an original contribution to the existent literature on time-varying risk aversion. Recent literature suggests that risk preferences are not stable over time, especially when agents are placed under extreme circumstances. By choosing the WWII period, we deliberately choose an environment where physical, political and financial factors dramatically changed. To determine if the risk attitude of investors changed during the war, we build an index that tracks changes in risk preferences. The paper is organized as follows: Section 2 gives an overview of the economic context of the period. Section 3 describes the data. Section 4 provides the methodology used for pricing lottery bonds and extracting risk aversion parameters. Section 5 presents the results whereas section 6 concludes.

2. Belgian economy under the Nazi boot

Since the aim of the paper is to analyze the risk preferences of Belgian financial markets' participants, it is crucial to understand the context in which they operated. The data used in this paper range from 1938 to 1948, and cover three distinct periods.

The pre-war period, from October 1938 to May 10th 1940, date of the German invasion, was marked by the rising probability of the outbreak of the war. The German invasion of Poland, on September 1st 1939, shattered any hope for peace. Despite repeated statements of neutrality, Belgium had no illusions: its geographical position made the country a strategic place for battle. As a result, the country began to prepare for war, by mobilizing its troops and building defenses. This weighed heavily on the public finances. In addition, Belgium was facing at the time what Baudhuin (1945) describes as an economic stagnation, caused by the fact that people, in anticipation

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See Conway (2012) and Oosterlinck and White (2015) for two detailed accounts of the war economy and the aftermath of the war.
of the events, avoided all unnecessary expenses. Because the Belgian treasury needed to find 500 million BEF every month, the government resorted to new taxes and to massive issues of bonds and treasury notes. The public deficits of 1938 and 1939, in a framework of linguistic quarrels, caused a major political crisis in March 1939. Given the general atmosphere of fear and uncertainty, people began hoarding cash. Financial markets were paralyzed, bank deposits melted and capital flew outside the country (Baudhuin 1945).

On May 10th, 1940, Germany invaded Belgium. After, 18 days of resistance, king Leopold III capitulated against the will of part of the government, which fled to London. The German occupation force had one major priority: to exploit the economic resources of the country to fuel the German war effort. As noted by Warmbrunn (1993, p. 113), “most of the new organizations the Germans created were to perform economic rather than political functions”. A major instrument used to take advantage of Belgium was the clearing system, put in place originally to compensate the business transactions between Germany and Belgium. German purchases were unrestrained and largely overtook Belgian’s, leading to a rising imbalance of the clearing account. This situation led to an increase of 236% in the amount of currency in circulation (Belgium National Bank). To further exploit defeated Belgium, Germany imposed huge occupation costs, forcing the government to issue a massive amount of debt, mostly short-term securities (certificats de trésorerie)\(^2\). As a result, the public debt was multiplied by three between 1940 and 1944 (Vanheurck, 1954).

Belgian stock exchanges were closed on May 10th, 1940. Given the circumstances of life under the occupation, many people needed to realize their investments. Without a regulated official stock exchange, these people had to turn to unofficial circuits, where unscrupulous intermediaries were eager to take advantage of them. In this context, stolen securities were also likely to be sold. To avoid this situation, a reopening of the stock exchanges was needed. As Buelens and Willems (2006) report, this was one of the arguments the Brussels stock exchange commission put on the table. The German military command agreed, also because it knew that Belgian authorities were likely to have to rely on the financial markets to meet the occupation costs. At the end of August 1940, Belgian stock markets reopened, under strict conditions. Stocks immediately registered an impressive upward movement. Baudhuin (1945, p. 190) attributes it to a correction of the huge depreciation that happened before the war.

\(^2\) New debt issued in Belgium during the occupation amounted to 40,250 billion francs. 31,100 were raised through certificate de trésorerie. (BNB, 1945)
When the situation stabilized, people who had made liquidity provisions before the war began to look for secure investments. They feared the monetary consequences of the war and the impact of inflation. This concern was also shared by those who were seeking a discrete way to hide the illegal profits they had made during the occupation. Moreover, many firms had realized their stocks and needed to find a way to reemploy their liquidities. Banks faced the same investment problem. Bank deposits had surged because of capital repatriation in the country and the increasing money circulation. Yet, during this period, businesses had relatively low need for credit, which forced banks to find other investments. Despite significant inflation, financial markets’ participants turned to state securities, particularly short-term ones, because they were very liquid assets (Baudhuin, 1945, Oosterlinck, 1999). By 1944, Banks had 74% of their total assets invested in state securities (Cassiers et al., 1998). Overall, Belgian financial markets experienced a boom during the first phase of the occupation. Real assets and artworks in particular experienced an even greater boom (David and Oosterlinck, 2015). This financial boom can be explained by the lack of investment opportunities, especially after 1943 when people began to fear the withdrawal of high value banknotes, the uncertainty about the Belgian Franc, the financial repression and the constantly increasing monetary circulation. During this period, the same situation was observable in occupied France (Oosterlinck, 2003).

Most of the population was concerned with the cost of living which had surged during the occupation. Official prices had somehow been kept under control. After having been multiplied more or less by two in 1940-1941, they remained stable until the end of the war (Launay and Offergeld, 1982). However, given the scarcity of goods on the official market, many had to turn to the black market to live decently. Taking 1938 as standard, prices on the black market had increased by 1600% in January 1943 (Launay and Offergeld, 1982). For the same period, wages had on average only risen by 8%, with an average revenue increasing between 10 and 28% thanks to the extra-hours and indirect compensations (Jacquemyns, 1950). As a result, the majority of the population had not much money to save, and those who had financial investments were probably tempted to sell them in order to keep a decent living standard.

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3 Of course part of the population still remembered World War I and the monetary turmoil that resulted from the war.
4 As Baudhuin (1945), this fear was very lively in 1942-1943 among the population. Given the always increasing money circulation, they feared that the government might decide to retire a fraction of the country’s banknotes. In March 1943, when it happened in Holland, Belgian financial markets witnessed a very violent boom.
Brussels was liberated in September 1944. Even though Belgium managed in 1947 to be the first occupied country to restore its pre-war industrial level, the economic situation after the liberation was extremely preoccupying. Because of the enormous clearing imbalance and because the investment opportunities had been low during the war, the fiduciary circulation had tripled during the war. Inflation was a clear threat to the economic recovery (Eyskens, 1954). To address the problem, Camille Gutt, the minister of finance, designed a program of monetary purge. Known as the Plan Gutt, it had as objective the withdrawal of excess money from the economy. In practice bank deposits were blocked, in order to decrease the fiduciary circulation to a level corresponding to the real needs of the economy. 60% of these assets were definitively blocked and converted into a forced debt; the rest was temporarily blocked and released as the need of the economy grew (Banque Nationale de Belgique, 1945 and 1946). The Plan Gutt enabled to dramatically slow down the expansion of the money supply. As a consequence of the plan, the stock exchanges were closed in September 1944, and reopened only after a long break, the 4th June 1945, under special conditions.

3. Data

Lottery bonds (emprunts à lots) were a common feature of Belgian public finances at the eve of the Second World War. Already in the 19th century, cities and districts had used lottery bonds to finance their activities (e.g.: Anvers 1887, Gand, 1896, Schaerbeek 1897, Liege 1897). Even though lotteries were forbidden by the law of the 31st December 1851, lottery bonds, providing they met certain ethical criteria, were authorized upon approval by the government. The government turned to lottery bonds for massive public financing after World War I. The first nation-wide issue took place in 1921 and was at the heart of a parliamentary debate regarding the ethical nature of the bond. Eventually, the issue was authorized, and similar issues followed in 1922 and 1923.

Lottery bonds were again issued, with fewer debates however, in 1932, 1933, 1938 and 1941, to finance public deficit. At the end of the 1930s, a wide variety of lottery bonds coexisted on the Belgian stock exchanges. These bonds accounted for a small but significant part of Belgian public

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6 Lottery bonds issued by cities (e.g.: Brussels 1905), by public companies (Société nationale des Chemins de fers) or by banks (Crédit Communal) were also traded.
finance\(^7\). Knowing the exact repartition of the lottery bonds among the different categories of investors is extremely hard. According to Davin (1945), in 1942, the Belgian public debt repartition was as follow: 44.5% to public banking institutions, 26.6% to private financial investors and 28.9% to the general public. Cassiers et al. (1998) estimate the share of Belgian debt held by Belgian banks at 25%. Lottery bonds were specifically designed to appeal to the general public. Therefore the figures mentioned by Davin (1945) probably represent a lower bound for the share of lottery bonds held by the population. The prizes were significant and had the power to attract a large panel of investors. For a low-middle class family with an average income of 1,897 BEF in 1940, the prizes must have been perceived as a fortune (Jacquemyns, 1950, p. 16).

In order to concentrate on bonds most likely to be held by a large part of the population, this paper focuses on the 1938 bond, as on-the run bonds (recently issued ones) have been shown to be the most liquid (Goyenko et al., 2011). Being issued before the war, it was not facing the specific risk of repudiation of the bonds issued by the Secrétaires Génaux, which are known to have a specific price dynamic (Oosterlinck, 1999).

The 1938 Belgian lottery bond was issued on the 15\(^{th}\) October 1938 in order to cover the extraordinary expenses of the previous year, which were linked to the preparation of the country in prevision of a war with Germany. It consisted of 2 000 000 bonds of 500 BEF face value\(^8\). The issue price was set at 485 BEF. In order to simplify the drawings, the bonds were grouped in 200 000 series of 10 bonds. The lottery bond paid a variable interest rate: 3.5% from 1938 to 1948, then 4% from 1948 until maturity. The annual coupon was paid on the 15\(^{th}\) October. But the thrilling feature was that the series were to be redeemed within 70 years, randomly, via monthly lotteries. These monthly lotteries not only decided when the bonds were to be recalled, but also decided on their redemption value. These redemption values were equal to the prizes of the lottery. Thus, investors could neither know the maturity nor the recall payment of the bond. Both the maturity and the recall payment were random because of the lottery feature. The drawings were taking place publicly at the Belgian National Bank in Brussels, on the 5\(^{th}\) of each month, or the day before in case of a public holiday.

\(^7\) In 1938, lottery bonds represented more than 11% of Belgian long term sovereign debt (Baudhuin, 1945, p. 398)

\(^8\) It was possible to buy whole series. A part of the issue was meant to be sold as such. Therefore two 1938 lottery bonds coexisted on the market, a small one of 500 BEF, and a larger one of 5000 BEF. The trades in the latter being much less frequent, the analysis relies on the 500 BEF bond.
The prize values and the number of bonds to be recalled at each drawing had been scheduled at the issue. The drawing plan and the associated prizes were thus public information. For each outstanding series, a corresponding token was put into a ballot. Then, for each prize to be attributed at the lottery, a token was drawn, and the prize value was divided between the 10 bonds of the series. All prizes were to be paid on the 15th October following the drawing date, no matter the month of the drawing. If drawn, a bond was immediately retired, and ceased to participate in further lotteries; however, holders of these bonds kept the right to receive the coupon payment of the year. Eventually, coupons and prizes were both tax-free.

The value of the prizes varied depending on the month of the drawing, inducing a seasonal public attention. The total yearly value of the lottery also changed over the years. To attract the public, the biggest prizes were distributed during the first years, as seen in Table 1. However, a guiding principle remained for all drawings. For each monthly drawing, there was one big prize, ranging from 250,000 to 3,000,000 BEF which was attributed to one series, and a smaller prize of 25,000 BEF to be allocated to a number ranging from 11 to 30 series. There was of course no guarantee that investors would eventually win one of these prizes. Indeed, from 1949 onward, in addition to the lottery prizes, a fraction of the outstanding bonds was randomly amortized at face value each year. For an individual bond, this was equivalent to “winning” a 500 BEF prize and therefore, will be treated at such in the remainder of the paper. The number of bonds that experienced this fate far exceeded the number of bonds that won big prizes: for example, in 1949, 144 series received a true prize, and 682 were reimbursed at par. The number of par-redeemed bonds increased every year. Thus, the odds of winning the jackpot were rather poor, as it is common with many lotteries. Table 1 shows the prize distribution of the 1938 lottery bond⁹.

<table>
<thead>
<tr>
<th>Value (in BEF)</th>
<th>Total (number of bonds redeemed)</th>
<th>1938-1943</th>
<th>1943-1948</th>
<th>1948-2008</th>
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<tbody>
<tr>
<td>300 000</td>
<td>50</td>
<td>50</td>
<td>0</td>
<td>0</td>
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<tr>
<td>200 000</td>
<td>50</td>
<td>50</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>100 000</td>
<td>250</td>
<td>100</td>
<td>150</td>
<td>0</td>
</tr>
<tr>
<td>50 000</td>
<td>1 550</td>
<td>200</td>
<td>150</td>
<td>1 200</td>
</tr>
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</table>

⁹Skewness is often pointed out as one of the main drivers of a lottery success. A lottery should offer many small prizes, but also a small number of very large prizes (Golec and Tamarkin 1998; Lobe and Hölzl 2007). Lottery bonds issued in Russia in 1864 and 1866 had a similar prize structure.
The dataset is composed of the daily market price of the 1938 lottery bonds. The market prices were retrieved from two newspapers: *Le Soir* and *La Dernière Heure*. We also collected the daily price of the *Dette Unifiée*, a long-term bond with a 4% interest rate issued by the Belgian government. The *Dette Unifiée* is used as the proxy for the risk-free rate. The sample contains 1,815 daily observations, ranging from November 17th, 1938 to July 31st, 1947. The series suffers however from two large breaks due to the war. The Belgian stock exchanges were closed, first during the German invasion and the beginning of the occupation (from May 10th, 1940 to August 21st, 1940), secondly at the Liberation (from September 1st, 1944 to June 4th, 1945). Although transactions occurred unofficially, there are no market prices for this period (Baudhuin, 1945).

4. Methodology

This section shows first how to find the theoretical price of the 1938 lottery bonds. The methodology used is similar to the work of Ukhov (2010), to which adjustments are made to take into account the specificities of the Belgian lottery bonds. In order to conduct our analysis, we proceed in two steps. First, we derive the theoretical price of the bond. To do so, we decompose the lottery bond into two components. The first giving the right to claim an annual coupon until the bond was recalled, the other, determining the timing and the value of the recall payment, i.e. the lottery prize. Pricing the lottery bond can be achieved by pricing separately these two components. The theoretical price of the bond at time $t$ is equal to the sum of the present values of all the coupons to be received between $t$ and the uncertain recall date, plus, the present value of the expected lottery prize. Secondly, we use this theoretical price to build an index, which is simply the market price of the 1938 lottery bond, divided by its theoretical price. Changes in this index capture changes in risk preferences.

All values used in the pricing are discounted with the yield on the *Dette Unifiée*. The *Dette Unifiée* was a regular Belgian government bond with the same interest rate as the 1938 lottery bond, but without the lottery features. Both bonds were subject to exactly the same credit risk. Indeed there

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<tbody>
<tr>
<td>25 000</td>
<td>700</td>
<td>400</td>
<td>300</td>
<td>0</td>
</tr>
<tr>
<td>10 000</td>
<td>2 400</td>
<td>0</td>
<td>0</td>
<td>2 400</td>
</tr>
<tr>
<td>5 000</td>
<td>3 600</td>
<td>0</td>
<td>0</td>
<td>3 600</td>
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<tr>
<td>2 500</td>
<td>110 200</td>
<td>18 000</td>
<td>13 000</td>
<td>79 200</td>
</tr>
<tr>
<td>500</td>
<td>1 881 200</td>
<td>0</td>
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<td>1 881 200</td>
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is no reason to believe that the Belgian government would decide to default on one bond and not on the other. Since the issuer was the same both bonds should react in a similar way to macroeconomics and financial news. Even though the concept of risk free assets may be debatable in wartime, for investors, the *Dette Unifiée* probably represented a form of risk-free equivalent to the lottery bond\(^\text{10}\). The only difference between the *Dette Unifiée* and the lottery bond, was simply the existence of a lottery. Discounting with this yield enables us to control for changes in the environment. Indeed, it eliminates the impact of factors that affect systematically all securities issued by the Belgian government. As mentioned previously the core hypothesis being that events impact the two bonds in the same way.

Let’s consider an investor buying the 1938 bond when issued. Between the issue and the bond maturity 70 years later, 836 lotteries will take place\(^\text{11}\). Let \( k = \{1,2,3,\ldots,836\} \) corresponds to the \( k \)-th lottery. Each lottery has a specific pool of prizes. On the day of the first lottery, there are two alternatives for the investor. If the bond is drawn, he wins one of the \( p \)-prizes of the lottery; he keeps the right to receive the coupon of the year, but the bond is retired and ceases to participate in the future lotteries. If the bond is not drawn, the holder receives nothing. On the second drawing, conditional on not having been drawn at the first lottery, the same logic applies; and henceforth until the last 836-th lottery.

In General the theoretical price of the bond, at any time \( t \), is the sum, for each lottery \( k \) remaining, of all the cash-flows to be received if the bond is drawn at a the lottery \( k \), multiplied by the conditional probability of being drawn at the lottery \( k \). The cash-flows are the sum of a) the present value, at \( t \), of the expected value of the prize if drawn at the lottery \( k \), and b) the present value, at \( t \), of all the coupons to be received between \( t \) and \( k \). In other words:

\[
P_t = \sum_{k=1}^{836} \left[ \mathbb{P} \{ \text{Drawn at lottery } k \mid \text{Outstanding at time } t \} \cdot (L(t,k) + C(t,k)) \right] \quad (4.1)
\]

\(^{10}\) The yield on these bonds were also extremely low, an element consistent with this point. Even if, strictly speaking, this was not a risk-free asset, this is still an appropriate discount rate, because it reflects similar credit risk and similar systematic liquidity factors.

\(^{11}\) There were only 836 lotteries, not 840, because no lottery was scheduled in November 1938, January 1939, September 1939 and October 1939. In addition, it is reasonable to assume ex ante that during the life of the bond, all scheduled lotteries would take place, even during the war.
where \( L(t,k) \) is the present value in \( t \) of the expected value of the winnings of the lottery \( k \), \( C(t,k) \) is the present value in \( t \) of the sum of the annual coupons between \( t \) and \( k \), and \( \mathbb{P}\{ k \mid t \} \) is the probability, for a bond outstanding in \( t \), to be drawn at the lottery \( k \).

In the event that a bond is drawn at the lottery \( k \), \( L(t,k) \) represents the expected value of the recall payment that the holder is expecting to receive, discounted to time \( t \). Every bond outstanding has the same probability of receiving one of the \( p_k \) prizes of the lottery. If there are \( p_k \) prizes to be attributed at lottery \( k \), \( z_k(i) \) denotes the prize \( i \) of the lottery \( k \), and \( Z_k \) the total value of the prize pool of the lottery \( k \), the expected value of the drawing \( k \) is:

\[
L(t,k) = Df(t,k) \sum_{i}^{p_k} \frac{z_k(i)}{p_k} = Df(t,k) \frac{Z_k}{p_k}
\]

where \( Df(t,k) \) is the discount factor between \( t \) and the 15th October that follows the lottery \( k \).

\( C(t,k) \) is the sum of all the coupons that the holder in \( t \), of a bond drawn at the lottery \( k \), is expecting to receive. The coupon is paid annually on the 15th October and if a bond is drawn it still receives the coupon that is due for the year. The value of the coupon varies depending on the year. The interest rate was equal to 3.5% for the first 10 years, after which date it increased to 4%. The bond nominal amount was 500 BEF. If \( y \) denotes the year in which a coupon is paid, \( j \) the year in which the lottery \( k \) takes place, and \( y_t \) is the year of the first coupon to be paid after time \( t \):

\[
C(t,k) = \sum_{y=y_t}^{j} Df(t,y), \begin{cases} 17.5 & \text{if } 1938 \leq y \leq 1948 \\ 20 & \text{if } 1949 \leq y \leq 2008 \end{cases}
\]

with \( Df(t,y) \) the discount factor between \( t \) and the 15th October of the year \( y \).

Finally, the recall probability \( \mathbb{P}\{ k \mid t \} \) is the probability for a bond outstanding at \( t \) to be drawn at the lottery \( k \), conditional on not being drawn in the previous lotteries occurring between \( t \) and \( k \). For the first lottery that follows time \( t \), denoted \( k_1 \), the probability of being drawn is simply the number of bonds to be drawn, \( n_{k_1} \), which is equal to the number of prizes to be attributed, divided by the number of bonds outstanding before the lottery, \( O_{k_1} \). For the second drawing, the recall probability is similarly \( n_{k_2} / O_{k_2} \), yet because the probability of being drawn at this second lottery is conditional of not being drawn at the first lottery, it has to be multiplied by \( n_{k_1}/O_{k_1} \). And henceforth for all the following lotteries. Of course, for all the lotteries before \( t \), the recall probability is 0. Therefore:
\[\mathbb{P}\{k \mid t\} = \begin{cases} 0 & \text{for the lotteries occurring before } t \\
\frac{n_{k_1}}{O_{k_1}} & \text{for the lottery that follows } t : k = k_1 \\
\frac{n_k}{O_k} \cdot \prod_{i=k_1}^{k-1} \left(1 - \frac{n_i}{O_i}\right) & \text{for the rest of the drawings} \end{cases}\]

Since \(L(t, k), C(t, k), \) and \(\mathbb{P}\{k \mid t\},\) can be found using the bond specifications, which are public information, the theoretical price \(P_t\) can be calculated for any date \(t\) using the equation (3.1):

The findings of the previous section are used to build an index that will be used to analyze the daily changes in risk attitudes. The price index is simply the ratio of the market price of the lottery bond divided by the theoretical price calculated through (3.1):

\[PI = \frac{\text{market price in } t}{P_t}\]

When PI is above 1, investors pay more than the risk neutral value of the bond, and inversely. An increase in PI reflects a diminution (a decrease) of investors’ risk aversion. Another way of putting it is that when the PI is above 1, the yield on the lottery bond is lower than the yield on the \textit{Dette Unifiée}, the lottery-free equivalent. This means that lottery bond buyers pay a premium to hold this asset. The only difference between the lottery bond and the \textit{Dette Unifiée} being the lottery, we conclude that this is equivalent to paying a lottery premium, which is clearly a risk-loving attitude. In this case, investors are in effect favoring a bond with a random pay-off over a bond with a non-random pay-off.

A way to test the pricing methodology is to look at the PI at the date of issue. If the pricing and the methodology are correct, when issued the bonds should have had a PI close to 1. According to our metric, the 1938 bond was almost perfectly priced at issue, the issue price was 485 F and the bond had an actuarial value of 483.5 BEF. This is equivalent to a PI equal to 0.997.

5. Results
5.1. Analysis of the price index

The index provides valuable evidence on investors’ risk preferences. More than its absolute value, it is its variation over time that we are interested in. Figure 1 shows the evolution during the Second World War of the price index (PI), the ratio of the market price of the bond by its theoretical price. The index exhibits a significant evolution over time. It behaves differently during the pre-war, the war and the post-war period.

At the beginning of the observation period, in November 1938, the index is close to 1, meaning that investors are willing to pay the expected payoff of the lottery. In other words, when issued the market priced the bond at its theoretical value. The index dramatically plummets the following weeks. This is hardly surprising given the tense international context. In March 1939, as Germany annexed Czechoslovakia, war seemed increasingly likely. The political crisis Belgium went through during the months of March and April also increased concerns amongst investors (Oosterlinck, 1999). Proof of the fear that war would break out soon, advertisements for bomb shelters were published in *Le Soir*, one of the main Belgian newspapers, in February 1939. Once the war broke out, in September 1939, the index experienced a further severe decline in
September 1939 and this even though Belgium was at the time still neutral. During the first three weeks of September 1939 alone, the index lost 10% of its value. All Belgian securities were affected by this particular context, but by construction, our index captures the specific attitude of investors toward the risky lottery featured in the 1938 lottery bond. As the index shows, during the pre-war period, there was a clear reluctance to buy the lottery bond. In other words, investors exhibited a strong aversion to risk.

In May 1940, Belgium was invaded, and the Belgian stock exchanges were closed. As soon as the stock exchanges reopened, the index rocketed. Starting from a low level, it reached a value of 1 on January 15\textsuperscript{th} 1941, and then stabilized at slightly higher level. This behavior can be seen as a correction from the pre-war period. The extreme caution of the pre-war period gave way to a period alike the end of 1938, the beginning of our study. Baudhuin (1945) reports the same trend on the stock market. War was now a reality; the country was occupied, but not entirely destroyed. Slowly, life was going back to something as close as possible to normality (Dujardin et al., 2010). An additional element to take into account is that drawings had been suspended between May and August 1940. To catch up with the amortization plan, these missing drawings took place in October and November 1940, which excited investors.

From 1942 onwards, the evolution of the index is striking. From the end of 1941 to the middle of 1943, the index is almost constantly increasing. It then remains at a high level until the country liberation, in September 1944. The contrast between the values of the index during the months preceding the war and this period is remarkable. Our results show a distinctly observable risk-loving attitude. Investors were buying the lottery bond for much more than what a risk-neutral investor would have been willing to pay. In essence, they were paying a premium to hold a lottery bond. This happened even if they could obtain a higher yield by investing in the \textit{Dette Unifiée}, a lottery-free equivalent. Furthermore, what is noteworthy is that this risk-loving attitude is specific to the second part of the occupation period, 1942 to 1944. Although it stays moderately large, the index declines after the war.

By construction, the index captures the idiosyncratic behavior of the 1938 lottery bond. Factors that affect all Belgian government bonds should leave the index mostly unchanged. Therefore, we can rule out that what we observe during this period is simply a by-product of the financial environment of the period. To explain why the appetite for the lottery bond increased, we resort to an explanation of psychological nature. As the events of the war developed, so did
the sentiment of the Belgian population. We argue that the upward trend in the index is caused by rising optimism of the Belgian population with regards to the outcome of the war.

5.2. The evolution of sentiment in Belgium: from despair to euphoria

The dynamic of the index suggests two distinct phases: a risk averse/risk-neutral phase in 1940-1941, and a risk-seeking phase in 1942-1944. Documenting perceptions regarding the war outcome is not a trivial exercise for an occupied country. Newspapers were indeed heavily censored and it is hard to assess the reliability of the various clandestine newspapers. In view of these elements, the analysis relies on historical account of the war (Jacquemyns 1950, Sercu 1992, Dujardin et al. 2010), and on the personal diaries of two actors, Alfred Bastien and Paul Struye. Alfred Bastien, a Belgian painter, kept a daily journal in which he described, in addition to his personal life, social and political events in occupied Belgium. Paul Struye, an intellectual and politician, wrote a day-to-day chronicle of the war, as well as a specific semestrial report on the evolution of the public sentiment in Belgium. These diaries, which were written contemporaneously to the events and published after the war, are considered by historians as a reliable source. These diaries depict a similar evolution regarding the population sentiment, from the hopeless certainty of an Axis victory in 1940, to a euphoric confidence in an Allied victory from 1942 onwards.

The invasion of May 1940 had dealt a huge blow to the Belgian morale. For the second time in less than 30 years, the country was under the German boot. The destruction and the torment inflicted by the occupant during WWI were still present in the collective memory. In addition, whereas the country stood up and fought back during the previous war, Belgium capitulated on May 28th 1940. This capitulation was seen as shameful by a significant part of the nation, which added to the ambient negative sentiment (Dujardin et al. 2010). Except for a fringe part of the Belgian population that immediately collaborated with the German administration, the majority of Belgians initiated the Occupation period with an abysmal mood. This atmosphere was openly chronicled by Alfred Bastien. He describes in his journal a general feeling of anxiety in 1940. However, he adds that quickly people are trying to get back to a normal life (Bastien, 1940). With an ever escalating war, he notes that hope is fading, the only glimmer of hope could come from a US intervention, “it is from the US that we expect everything “(Bastien 1940, 17/6/1940, p.112).
Interestingly, the index will start its upward movement at the end of December 1941, just after Pearl Harbor and the involvement of the United States.

Undoubtedly, this sentiment of hopelessness gradually disappeared during 1942, 1943 and 1944. According to Paul Struye, a contemporary intellectual who held an account of the evolution of the population sentiment in his journal, the belief that Germany was never going to win the war was widespread among the society as early as January 1942 (Struye 1945, p. 51). Bastien (1942) report the same sentiment. Although military events were still favorable to the Axis, the idea of a positive outcome was gaining traction among the population. The strength of this conviction constantly grew during the following months and was amplified by the good military news: the British victory in Egypt, the Russian resistance in Stalingrad12, and most of all the allied landing in North Africa on the 8th November 1942. Struye (1945, p. 1071) notes that this event was “celebrated as a national day and considered as the first good day since the May 10th 1940”. Similarly, Bastien writes that “victory has changed side”, and “that he sees only happy faces on the street” (Bastien 1942, 14/11/1942, p.163). In 1943, for the majority of the population, the outcome of the war was certain. Struye (1945) reports an unbounded optimism among the population in May 1943. The allied landing in Sicily in July 1943 was acclaimed, “The axis is nothing but dust” (Bastien 1943, 9/9/1943, p.176). Liberation was expected for the end of the year or the end of 1944 at most. Sercu (1992) also attributes the optimism observable on the stock exchange in 1943 to expectations that the war would soon end. Any event that might precipitate the end of the war was positively received especially because life under the occupation was becoming increasingly difficult. Although Jacquemyns (1950) argues that the economic situation of households slightly improved in 1943, thanks to a better organization of the supply chain, the German demands became harsher. The military administration began to interfere in every aspect of the society and the compulsory work service was put in place, which had a great emotional impact on the population. In addition, allied bombings were progressively becoming more intensive. Struye (1945) describes “an atmosphere of terror and civil war”. Given this context, positive news were particularly celebrated.

5.3. Did investors become risk loving during the occupation?

Without a doubt, the mindset of the population changed during the war. Throughout the war, Belgians suffered from the socio-economic condition of the occupation, the oppression of the

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12 It is hard to assess the speed with which the news reached Belgium. Even though there was censorship for mainstream newspapers an important number of clandestine newspapers circulated at the time. Diaries from contemporaneous eyewitnesses show that war information reached the Belgian population.
German administration, and the looming physical risk. However, from despair and resignation after the invasion, hope and optimism progressively spread among the society as news from the front became more and more positive. In 1943 and 1944, Allied victories were celebrated. Contemporaneous actors report euphoria linked to the certainty that Belgium would be freed soon. Our line of argumentation is thus closely linked to recent research highlighting the influence of psychological factors on financial decisions (Slovic and Peters 2006). For Bossaerts (2009), “the evidence suggests that emotions play a crucial role in the mathematical computations needed for reasoned choice”. An implication for our paper could be that changing emotions altered the way investors perceived the lottery risk. During the end of the occupation, as they became more enthusiastic about the future, they may have overestimated the expected pay-off of the lottery. Indeed individuals in good mood tend to weight probabilities more optimistically (Fehr-Duda et al. 2011). The link between good mood and risk-taking has further been emphasized in the literature: elated (depressed) people exhibit less (more) risk aversion (Isen and Patrick 1983, Yuen and Lee 2002). Kuhnen and Knutson (2011) find that “positive emotional states such as excitement induce people to take risks and to be confident in their ability to evaluate investment options”. Eventually, positive mood generated by good weather promotes risk-taking behaviors (Bassi et al., 2013).

6. Conclusion

This paper analyzes changes in investors’ risk preferences during World War Two on basis of the daily market price of a lottery bond issued by the Belgian government in 1938. To assess changes in risk aversion the paper relies on a methodology which compares the market price of the bond to its risk-neutral price. The risk-neutral price is obtained by computing the expected pay-off of the bond, discounted by the yield of a lottery-free Belgian bond. This approach allows controlling for all the factors that affect Belgian bonds in general. The comparison between the risk neutral price and the market price of the bond gives a direct and daily measure of investors’ willingness to pay for the lottery.

The findings of the paper are threefold. First, investors’ risk preferences changed significantly over the period under consideration. This result contrasts with Andersen et al. (2008) who argue that risk preference tend to be stable. It is however in line with the literature on time-varying risk aversion (Campbell et al. (1999), Guiso et al. (2013)). Secondly, and in line with the findings of Velde (2015), investors are sometimes ready to buy the lottery bond for much more than its...
expected pay-off. At some point in 1943, investors were paying a hefty premium of 20% to acquire the security. Thirdly, and most importantly, investors’ risk preferences changed dramatically in the middle of the war. Whereas in 1940 and 1941 investors were risk averse or risk neutral their appetite for risk suddenly shifted upward in 1942. In 1943 and 1944, investors were paying a large premium to hold the lottery bond. In essence, lottery bond buyers were exhibiting a risk-seeking preference. This finding is coherent with the literature reporting that negative life events, such as natural catastrophe (Eckel et al. 2009, Behir and Willinger 2013) or physical violence (Voors et al. 2012), can increase risk-taking behaviors.

We attribute this puzzling result to psychological factors. As reported by the analysis of contemporaneous sources, the sentiment of the Belgian population changed dramatically during the course of the occupation. Morale bottomed out after the German invasion, but people became relatively more optimistic as the war progressed. From 1942 onwards, the population firmly believed that Germany was bound to lose the war. As news favorable to the Allied grew more frequent, enthusiasm spread out. We argue this changing sentiment affected the risk-taking behavior of investors. The risk-seeking attitude observed during the last part of the occupation was the result of the euphoria brought by the prospect of an Allied victory. This argument is in line with recent research reporting a link between positive feelings and risk-taking (Kuhnen and Knutson 2011, Bassi et al. 2013). This paper thus brings empirical evidence that psychological factors impact risk preferences.
References

- Banque Nationale de Belgique (BNB), "Annual reports of 1939, 1940-1944, 1945, 1946, 1947", Imprimerie de la Banque Nationale de Belgique, Bruxelles


