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Risk Aversion in Wartime

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Abstract

The literature links extreme events to changes in risk aversion but fails to find a consensus on the direction of this change. Due to data limitation the speed of the change in risk aversion is never analyzed. This paper overcomes this limitation on basis of an original methodology. To elicit changes in attitude toward risk, we rely on the daily market price of a lottery bond issued by Belgium. We provide evidence on the dynamic of risk preferences just before, during and just after the Second World War. Risk attitudes varied substantially between 1939 and 1947. Risk aversion increased at the outbreak of the war, then decreased dramatically during the occupation to increase again after the war. To our knowledge, this reversal in risk attitude is unique in the literature. We discuss several potential explanations to this pattern, namely changes in economic perspectives, mood, prospect theory, and background risk. While they might all have played a role, we argue that habituation to background risk most consistently explains the observed behavior over the whole period. Living continuously exposed to the war-related risks gradually changed the risk-taking behavior of investors.

Keywords: Lottery bonds, World War II, risk aversion, sovereign debt, background risk

JEL Classifications: N24, D81, G10

Risk Aversion in Wartime

1. Introduction

Understanding how risk preferences of financial markets' participants change over time is crucial to analyze the dynamics of financial markets. Investors' risk attitude determines their asset allocation between risky and non-risky assets, the premium they will require for bearing risk, and hence, the price they are 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. So far, the literature has however failed to reach a consensus regarding the extent of changes in risk aversion, let alone the drivers of such changes. Andersen et al. (2008), Brunnermeier and Nagel (2008), and Van de Venter et al. (2012) argue that risk preferences are remarkably stable over time. Nevertheless, it seems that risk aversion might be affected by dramatic changes in the environment. Weber et al. (2012) report a shift in risk taking behavior during the financial crisis of 2008. For the same period, Guiso et al. (2013) also report a significant increase in risk aversion and hypothesize that the cause is psychological. 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 (2015) and Cassar et al. (2011) argue that individuals who

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. These results are however hard to generalize. Negative events need not lead to an increase in risk aversion. Indeed, Eckel et al. (2009) show that victims of Hurricane Katrina exhibit ex-post a risk loving bias. Page et al. (2014) find that homeowners who were victims of floods and suffered large losses in property values opt comparatively for riskier gambles than homeowners who were unaffected. Using field experiments in Burundi, Voors et al. (2012) report that individuals exposed to violence are more risk-seeking. Bchir and Willinger (2013), Ingwersen (2014), Li et al. (2011) and Hanaoka et al. (2015) document analogous findings for people exposed to natural disasters.

This paper contributes to this literature by examining how the Second World War affected risk preferences. One of our original contributions resides in the methodology we use to elicit attitudes toward risk. Whereas the literature usually opts for lab and field experiments, or surveys, we call on the characteristics of Belgian financial markets and exploit a peculiar security traded on the Brussels stock exchange. We use the market price of a Belgian lottery bond, a security that mixes the features of a traditional sovereign bond and a lottery, to extract information regarding risk attitudes on Belgian financial markets. Because a lottery bond is a risky security with a distribution of payoff known ex-ante, it provides an ideal setting to analyze changes in risk preferences. It is indeed as close as imaginable to a market traded lottery ticket, meaning that its market price reflects the buyer's willingness to pay for joining the lottery. From the security's market price we build an index that tracks the daily evolution of risk preferences. The index is the ratio of the lottery bond market's price and its risk-neutral price, computed as the expected value of the lottery bond discounted by the yield of a lottery-free Belgian sovereign bond. This methodology controls for factors

affecting Belgian sovereign bonds in general, and therefore, variations of the index can only reflect changes in risk preferences.

In comparison to traditional methodologies involving experiments and surveys, this approach presents a series of advantages. First, since the market prices of the lottery bond are available daily, we are able to monitor daily attitude toward risk and study its dynamic continuously over a long period. Secondly, papers looking at the effect of adverse events on risk aversion using surveys and experiments frequently face problems of non-representative samples, selective exposure, or attrition. One key issue with these analyses lies in fact that the subsample of the population used in the study before and after the adverse event might have different characteristics. Here, we study the aggregate preferences of financial markets' participants. As we will show in the empirical section, the characteristics of this population remained homogenous over the whole period, which makes it easier to highlight the impact of WWII. Finally, we use a real-world and significant investment decision, not answers to hypothetical questions or behavior in low-stake gambles.

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 time¹. A few exceptions warrant however to be mentioned. 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. Bühler and Herzog (2011) use a dynamic equilibrium model to estimate the size of

¹ A recent strand of the literature has analyzed assets with a very similar structure such as Lottery-Linked Savings or Prize-Linked Savings in order to determine the relative importance of gambling versus saving. For Lottery-Linked Savings Tufano (2008) finds that investors buy them both for their gambling and investment features. Looking at Prize-Linked Savings Cookson (2016, p. 26) concludes that "linkages across lottery-style products are quite strong".

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 (2013) 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 the premium paid for lottery ticket systemically trended upward during the course of the draw.

We use World War II as a quasi-experiment to investigate the impact of a changing environment on risk attitudes. By selecting this period, we deliberately choose an environment where physical, political and economic factors were severely altered. Belgium was occupied between 1940 and 1944, and a fighting ground both at the beginning and end of this period. During the occupation, inhabitants had to face the repression of the German authority and a constant looming uncertainty about their and their country's fate. In essence, at the outbreak of the war, agents on Belgian financial markets met an additional quantity of risk. This risk was exogenous to them and unavoidable. In economic terms, we can assimilate this situation to an increase in background risk (i.e. a risk an agent cannot control or avoid). It is reasonable to expect that this change of background risk had an impact on risk preferences. Under expected utility, economic theory predicts that people are risk-vulnerable, meaning that risk averse agents will become even more risk averse when exposed to a background risk (Gollier and Pratt, 1996). In other words, theoretically the introduction of a background risk will lead agents to behave more cautiously with respect to their initial situation. Quiggin (2003) has shown however that the opposite might happen for a wide-range of generalized expected utility preferences. Empirically, Guiso and Paiella (2008) report that

individuals who are likely to face income uncertainty or liquidity constraints are more risk averse, which is consistent with the risk vulnerability conjecture. Laboratory experiments yield mixed evidence: Harrison et al. (2007) and Beaud and Willinger (2013) report evidence of risk vulnerability, whereas Lusk and Cobble (2008) find weaker results.

In this paper, we interpret our results in terms of change in background risk. Overall, we observe that risk attitudes dramatically changed during the period 1938-1947, which is coherent with the literature on extreme events and risk aversion. Furthermore, we highlight two major findings. First, matching the risk vulnerability hypothesis, investors became more risk averse around the outbreak of the war. Our second finding has a more general scope. We find a reversal in risk aversion. The outbreak of the war increased risk aversion but during the occupation period investors became more and more tolerant towards risk to a point where they were actually risk lovers. The end of the war led to yet another change in risk aversion leading to an increase in risk aversion. The risk-seeking attitude observed during the occupation is consistent with Voors et al. (2012), Bchir and Willinger (2013) and Ingwersen (2014), who document a link between a risk-loving attitude and living in areas with high background risks. This would essentially indicate that agents living in a risky environment develop a higher tolerance toward risk, or that they assess the riskiness of situations differently. This paper provides further evidence on this matter, and goes even farther by showing that this transformation might happen relatively quickly, that is in the space of just a few years. 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 Boot²

Since this paper analyzes 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. 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. Given the general atmosphere of fear and uncertainty, people began hoarding cash.

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 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

² See Conway (2012) and Oosterlinck and White (2016) for two detailed accounts of the war economy and the aftermath of the war, and Willems and Buelens (2006) for an account of the functioning of the Brussels exchange during WWII.

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*)³. 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, Belgian stock markets were reopened at the end of August 1940 (Buelens and Willems, 2006). 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. 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 inflation⁴. 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 monetary 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).

³ New debt issued in Belgium during the occupation amounted to 40,250 billion francs. 31,100 were raised through *certificats de trésorerie*, i.e. short term bills.(BNB, 1945).

⁴ World War I and the monetary turmoil that resulted from it were still remembered by a large part of the population.

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 banknotes⁵, the uncertainty about the Belgian Franc, the financial repression and the constantly increasing monetary circulation.

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% by 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 invested in securities were probably tempted to sell them in order to keep a decent living standard.

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. The fiduciary circulation had tripled during the war and 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

⁵ 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.

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, in June 1945.

3.Data

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 risk-neutral price. *Ceteris paribus*, the higher the willingness to pay for the lottery feature, the lower the risk aversion.

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.: Antwerp 1887,

Ghent, 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 ⁶. 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 1941⁷, 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 finance⁸. 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. 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 a monthly average income of 1,897 BEF in 1940, the prizes, which could be as large as 300 000 BEF, 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). Another

⁶ Cf. Law of the 30th December 1867, description in Levy-Ullman, H., *Lottery bonds in France and in the principal countries of Europe*, Harvard Law Review, Vol.9, No.6 (Jan. 25, 1896), pp. 386-405.

⁷ 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.

⁸ In 1938, lottery bonds represented more than 11% of Belgian long term sovereign debt (Baudhuin 1945, p .398).

argument for choosing this bond is that the 1938 issue had the largest prizes, and was therefore the trendiest lottery bond on the market. Furthermore, being issued before the war, it was not facing the specific risk of repudiation of the bonds issued by the *Secrétaires Généraux*⁹, which are known to have a specific price dynamics (Oosterlinck 1999).

The 1938 Belgian lottery bond was issued on the 15th 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 value¹⁰. 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 15th 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 5th of each month, or the day before in case of a public holiday. 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

⁹ The *Secrétaires Généraux* were members of the Belgian administration that were in charge of ruling the country under the supervision of the German occupation force. Their role has been associated as a form of collaboration and criticized, both by their contemporaries and recent historians.

¹⁰ 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.

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. 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 largest 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 large prizes. 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. Lottery bonds were a no-lose lottery, the worst case scenario was to get reimbursed at the face value. In this paper, we focus on the period 1938-1947, which is the period where the largest prizes were paying paid. The lowest prize during this period was 2500 BEF, which still represented a substantial amount, five times the bond face value. Table 1 shows the prize distribution of the 1938 lottery bond¹¹.

¹¹ Skewness 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.

Table 1: Prize distribution

Value (in BEF)	Total (number of bonds redeemed)	1938-		
		1943	1943-1948	1948-2008
300 000	50	50	0	0
200 000	50	50	0	0
100 000	250	100	150	0
50 000	1 550	200	150	1 200
25 000	700	400	300	0
10 000	2 400	0	0	2 400
5 000	3 600	0	0	3 600
2 500	110 200	18 000	13 000	79 200
500	1 881 200	0	0	1 881 200

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 hand-collected the daily price of the *Dette Unifiée*, a long-term Belgian sovereign bond with a 4% interest rate. The *Dette Unifiée*¹² 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 21th, 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).

¹² Issued in May 1935, the *Dette Unifiée* was a perpetuity paying a 4% annual coupon. The issue had for objective to convert older Belgian securities. Bonds bearing more than a 4% interest rate were transformed in *Dette Unifiée*.

4. Methodology

This section shows first how to find the risk-neutral 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 risk-neutral 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 risk-neutral 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 risk-neutral price to build an index, which is simply the market price of the 1938 lottery bond, divided by its risk-neutral price. Changes in this index capture changes in risk preferences.

All values used in the pricing are discounted with the yield on the *Dette Unifié*, our proxy for the risk-free rate, hence the use of the term risk-neutral price. The *Dette Unifiée* was a regular Belgian government bond. The *Dette Unifiée* and the 1938 lottery bond were subject to exactly the same credit risk. Indeed, there 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 bond¹³. The main difference between the *Dette Unifiée* and the lottery bond was simply the existence

¹³ 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.

of a lottery in the latter. Discounting with the yield on the *Dette Unifiée* enables us to control for changes in the environment. 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 place¹⁴. Let $k = \{1, 2, 3, \dots, 836\}$ 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 836th lottery.

In general the risk-neutral 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:

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

¹⁴ There were only 836 lotteries, not 840, because no lottery was scheduled in November 1938, January 1939, September 1939 and October 1939. It is however 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 $\mathbb{P}\{k | t\}$ 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:

$$L(t, k) = Df(t, k) \frac{\sum_i^{p_k} z_k(i)}{p_k} = Df(t, k) \frac{Z_k}{p_k}$$

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 value 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 :

$$C(t, k) = \sum_{y=y_t}^j Df(t, y) \cdot \begin{cases} 17,5 & \text{if } 1938 \leq y \leq 1948 \\ 20 & \text{if } 1949 \leq y \leq 2008 \end{cases}$$

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

Finally, the recall probability $\mathbb{P}\{k | t\}$ 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:

$$\mathbb{P}\{k | t\} = \begin{cases} 0 & \text{for the lotteries occurring before } t \\ \frac{n_{k_1}}{O_{k_1}} & \text{for the lottery that follows } t : k = k_1 \\ \frac{n_k}{O_k} \cdot \prod_{i=k_1}^{k-1} \left(1 - \frac{n_i}{O_i}\right) & \text{for the rest of the drawings} \end{cases}$$

Since $L(t, k)$, $C(t, k)$, and $\mathbb{P}\{k | t\}$, can be found using the bond specifications, which are public information, the risk-neutral 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 Lottery Ratio (LR) is simply the ratio of the market price of the lottery bond divided by the risk-neutral price calculated through (3.1):

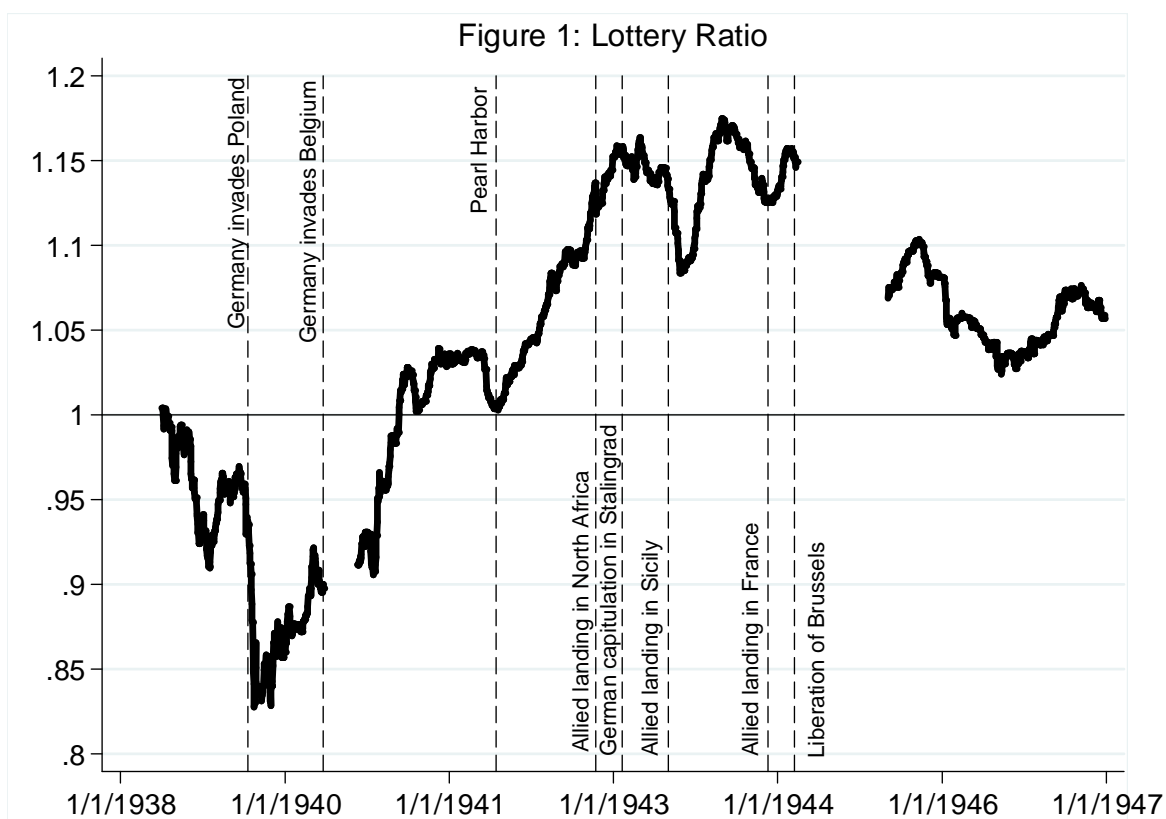
$$LR = \frac{\text{market price in } t}{P_t}$$

When LR is above 1, investors pay more than the risk neutral value of the bond, and inversely. An increase in LR reflects a diminution (a decrease) of investors' risk aversion. Another way of putting it is that when the LR is above 1, the yield on the lottery bond is lower than the yield on the *Dette Unifiée*, the lottery-free equivalent. This means that lottery bond buyers pay a premium to hold this asset. The main difference between the lottery bond and the *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.

5. Results

5.1 Analysis of the Lottery Ratio

The index depicted in Figure 1 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 Lottery Ratio (LR), the ratio of the market price of the bond by its risk-neutral price. The index exhibits a significant evolution over time. It behaves differently during the pre-war, the war and the post-war period. Changes are set into perspective by indicating some major war events on the graph.



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 risk-neutral 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. It is therefore impossible to assess the immediate impact of the country's invasion on investors' risk aversion. The stock exchange reopened however rapidly and as soon as the stock exchanges reopened, in August 1940, the index rocketed. Starting from a low level, it reached a value of 1 on January 15th 1941, and then stabilized at a 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 liberation of Brussels 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 *Dette Unifiée*, a lottery-free equivalent. Noteworthy this risk-loving attitude is specific to the second part of the occupation period, 1942 to 1944.

Eventually, even though it remains above one, the index declines after the war. During the period under study, there were thus sharp reversals in terms of risk aversion.

5.2. Discussion

By construction, the index captures changes in risk aversion as macroeconomic factors affecting Belgian government bonds leave the index unchanged. We can thus rule out that the observed changes are simply a by-product of the financial environment of the period. Could the variation be due to a change in investors with risk loving investors gradually replacing risk averse ones? This is highly unlikely for several reasons. Table 2 provides figures regarding the number of people who emigrated from Belgium. For the whole period the absolute number of people leaving the country remained fairly small with a maximum of people leaving the country in 1946. Emigration peaked before the war but remained constant in 1940 and 1941 to only decline slightly in 1942. It fell dramatically in 1943 and 1944 to increase again at the end of the war.

Table 2: Emigration from Belgium in 1,000

	Emigration
1938	16.1
1939	18
1940	13.7
1941	13.8
1942	10.7
1943	5.2
1944	2.9
1945	12.6
1946	20.3
1947	19.4

Source: Banque Nationale de Belgique, Statistiques économiques belges, 1929-1940 and 1939-1950)

To have a meaningful impact on the prices of the lottery bonds, the emigration should have been mostly concentrated on the wealthy active on the stock exchange. This was not the case. Jews who had the best reasons to leave the country did not necessarily belong to this group. In fact, Willems and Buelens (2006) argue, in view of the limited number of Jewish brokers and clients, that their prosecution had a negligible effect on the stock market activity in Belgium. By contrast there is firm evidence that the most important bankers remained in the country. On May 15th, 1940, before leaving the country, the ministers of finance, Camille Gutt, and of foreign affairs, Paul-Henri Spaak met with Alexandre Galopin, governor of the *Société Générale* and other influential Belgian businessmen¹⁵. They gave them guidelines on the economic and industrial policy of the country to be followed while the government would be in exile. The *Comité Galopin*, from the name of its most influential member received the global mission of taking in charge the economy and protecting the country during the Occupation. As Dujardin and van den Wijngaert (2010, p. 25) noted, they were the *de facto holder of the power in the occupied Belgium*. Thus if anything, the business world was probably the least affected by emigration. As a result, we argue that the dynamic of the LR is solely driven by variations in risk preferences¹⁶.

The recent empirical literature on risk aversion and extreme events fails to reach a consensus. Some articles suggest that adverse events increase risk aversion (Cameron and Shah, 2015; Cassar et al., 2011; Callen et al., 2014; Kim and Lee, 2014; Samphantharak and Chantarat, 2015) while others report the opposite (Bchir and Willinger, 2013; Page et al., 2014; Voors et al. 2012; Ingwersen, 2014; Hanaoka

¹⁵ Cf. the meeting of the 15th May between Alexandre Galopin, Max-Léo Gérard, Fernand Collin and the ministers Gutt and Spaak. Dujardin, V. and Van den Wijngaert, M., *Nouvelles histoire de Belgique 1940-1950: La Belgique sans roi*, Le Cri édition, 2010, Bruxelles, p. 17. This delegation of power has however been subject to many interpretations.

¹⁶ Part of the literature links changes in risk aversion to socio-demographic factors. For example, Clotfelter and Cook (1990) and Kearney (2005) find the demand for lottery tickets to depend on socio-demographic factors. Since the aggregate profile of lottery bond investors remained roughly the same during the whole period, this explanation may be ruled out.

et al., 2014; Li et al., 2011). These differences might be due to the horizon of the analysis or the frequency with which risk aversion is measured. Our empirical evidence shows that risk aversion may experience dramatic changes and that these changes may be fast and may experience reversals. Table 3 summarizes these changes in risk aversion. Before the war, investors were risk averse but during the occupation they became less and less so and at some point in 1941 became risk neutral before exhibiting a risk loving attitude. It was only after the Liberation that their attitude towards risk changed to gradually tend back to risk neutrality. The drop at the start of the war seems intuitive enough with regards to economic theory and will therefore not be discussed more in detail¹⁷. By contrast, the increase in appetite for lottery bonds we observe during the Occupation appears more challenging to explain. The decline in risk loving following the liberation is also puzzling at first sight. Therefore the analysis will focus on these two periods.

Table 3: Changes in the LR

	Pre-war	Occupation			Post-war
Year	1939-1940	1940-1941	1941-1943	1943-1944	1945-1947
Average of the LR	0.91	0.94	1.05	1.14	1.06
Annualized increase in the LR	-6.25%	8.79%	7.78%	1.73%	-0.47%

The bubble shaped pattern we observe for agents' risk aversion is to our knowledge unique. The literature on the demand for lottery, or risky assets in general, offers however understand grid to analyze this observation. Many theories

¹⁷ The decrease in LR could reflect an increase in background risk (Eeckhoudt et al., 1996; Gollier and Pratt, 1996; Eaton and Lucas, 2000) but may also be linked to depressed mood, to expected economic harshness, (the latter is consistent with Guiso and Paiella (2008), who report that agents anticipating future liquidity constraints or income uncertainty are more risk averse) or to the impact of extreme events (e.g. Cameron and Shah, 2015).

pertaining to changes in risk aversion have been proposed and tested in the literature. Our focus here will be on theories which fully or partially explain the changes in LR. More precisely we discuss the impact of changes in economic perspectives, changes in mood, prospect theory and habituation to background risk. Table 4 provides a synthetic summary of our findings. As shown in Table 4, habituation to background risk is the only theory which could account for the observed changes in the LR for the whole period. Hence, a particular emphasis will be put on the background risk theory. It is however important to stress that these theories need not be mutually exclusive. Sharp changes in the LR may thus reflect the combined effects of these different theories.

Table 4: Link between various theories and our empirical results

	Occupation			Post-war
Year	1940-1941	1941-1943	1943-1944	1945-1947
Economic perspectives	N	N	Y	Y
Mood	N	N	Y	N
Prospect theory	Y	Y	Y/N	Y
Habituation to background risk	Y	Y	Y	Y

Y denotes the fact that the theory could explain our empirical results, N denotes the opposite.

Changes in economic perspectives or changes in mood have also been suggested as factors affecting the attitude towards risk. Campbell and Cochrane (1999) and Brandt and Wang (2003) propose models where more optimistic economic perspectives lead agents to be less risk averse. Bassi et al. (2013) and Fehr-Duda et al. (2011) find that better mood is linked to increased risk-taking; emotions in general are shown to affect risk-taking decisions (Loewenstein et al., 2001; Bossaerts, 2009). Coman et al. (1997) make a link between stress and anxiety

and gambling addiction. Economic perspectives and mood are known to have changed during the war. But the timing of these changes is, for part of the sample, hard to reconcile with the observed change in risk aversion. Improved mood or better economic perspectives may have explained the rise in the LR at the end of the Occupation, when Belgians were anticipating the country's liberation. Indeed sources such as Struye (1945), Sercu (1992) or Bastien (2005), report evidence of optimism among the Belgian population in 1943 and 1944. The increase in the LR after 1943 could thus reflect euphoria linked to the war's end. But the LR takes off already at the end of 1941. At the time, given the circumstances of the war, it is far-fetched to assume that Belgian investors had formed better economic perspectives or were in a better mood. Better mood and economic perspectives could thus account for the increase in the LR for 1943-1944. Improved economic perspectives would also be relevant for the post-war period.

Prospect theory has also been invoked to explain risk loving attitude in an adverse environment. Blalock et al. (2007) argue that in bad times people might turn to lotteries as a last resort strategy. Using prospect theory, Page et al. (2014) argue that people who have just suffered an economic loss due to a natural hazard might opt for riskier gambles. These explanations are perfectly legitimate for the beginning of the occupation period as the occupation was of course a period of heightened risk. For the second part of the occupation the argument is slightly harder to make. If the invasion of the country is taken as the initial shock then for 1943-1944 it would be hard to argue that agents "just suffered" from the shock. On the other hand if the occupation is considered as a continuous shock then this explanation would remain perfectly valid. After 1945, the physical risk stemming from the war had disappeared. Furthermore as most goods imported in continental Europe by the victors transited through the port of Antwerp, the likelihood of famine was minimal. As a result the need to use last resort strategies became less acute, which would be consistent with a decrease in the LR. In general prospect

theory is thus a good candidate to explain the evolution of the LR. There are two periods for which it is less convincing, the end of the occupation as mentioned earlier, and the beginning of World War II which should in theory have prompted agents to exhibit a more risk loving attitude.

The literature on background risk and adaptation to background risk is the only one allowing explaining in a consistent way the change in the LR for the whole period. (The decrease in the LR, indicating a decrease in risk-seeking behavior, can be explained by an increase in background risk. But what about the occupation period? Adaptation to background risk is an appealing theory to explain our results. Several papers report that people exposed to frequent natural hazards or violent environments are more risk-loving (Bchir and Willinger, 2013; Voors et al., 2012). Exposure to violence has also been linked to greater risk-taking (Killgore et al. 2008). These papers suggest that living in an environment with a high background risk might shape risk preferences in a particular way. In accordance with these studies, we conjecture that living in the particularly risky environment of the occupation shifted the risk preferences of Belgian investors. In other words living continuously exposed to the war-related risks gradually changed the risk-taking behavior of investors. The perception of lottery bonds changed because investors adapted to their new environment. Lottery bonds, which were at first viewed as risky investments, became perceived as less risky as time went by. This shift happened very quickly in the span of just a few years. Most interestingly once the background risk diminished, after the Liberation of the country, attitudes towards risk changed again. Investors' change in risk attitude was in fact short-lived and once the environment came back to normal so did they risk taking behavior.

6. Conclusion

Despite their importance for financial modelling changes in risk aversion remain understudied. The impact of extreme events on changes in risk attitude has received some attention but when changes are assessed it is usually with a limited frequency. This limitation prevents understanding how fast changes in risk aversion may occur. This paper overcomes this limitation by relying on the daily market prices of lottery bonds traded before, during and just after World War II. To assess changes in risk aversion this 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 and hence of their attitude towards risk.

Our empirical analysis contributes to the literature in many ways. Most importantly, we show that changes in risk aversion may not only happen in a very short time span but may also be large in magnitude. 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. Investors' risk preferences changed thus 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). In line with the findings of Velde (2013), we also report that investors were 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.

How can these changes in risk attitude be reconciled with the existing theories on time-varying risk aversion? The increase in risk aversion before the war outbreak and when Belgium was invaded is hardly puzzling. Changes in mood, in economic perspectives or in background risk could all explain this sharp decline. The risk-loving attitude exhibited by market participants during the occupation is however harder to link to traditional theories. We attribute this observation to the combined effect of several elements. Habituation to background risk would have rendered investors more risk tolerant leading them to be willing to pay more than its risk neutral price for a lottery. We conjecture that the effect of habituation may have been compounded by three other elements. The increase in appetite for risk at the beginning of the occupation could be due to investors' willingness to take on higher risk because of the losses they just incurred. This would be in line with the findings of Page et al. (2014). By contrast at the end of the occupation, investors may have reassessed economic prospects in a more positive way and exhibited euphoria as victory was in sight. Following the literature, both elements could have increased risk appetite. But our results highlight mostly the importance of habituation to background risk. Living continuously exposed to the war-related risks gradually changed the risk-taking behavior of investors. Lottery bonds, which were at first viewed as risky investments, became perceived as less risky as time went by. This shift happened very quickly, in the span of just a few years. Most interestingly once the background risk diminished, after the Liberation of the country, attitudes towards risk changed again. Investors' change in risk attitude was in fact short-lived and once the environment came back to normal so did they risk taking behavior.

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