The war puzzle: contradictory effects of international conflicts on stock markets

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Abstract

We study stock market reactions on large international military conflicts since World War II. Using a news analysis proxy for the estimated likelihood that a conflict will result in a war, we find that an increase in the war likelihood tends to decrease stock prices, but the ultimate outbreak of a war increases them. In cases when a war starts surprisingly, however, the outbreak of a war decreases stock prices. We show that this puzzle cannot be explained by risk or ambiguity aversion or by expectations about a quick end of the war.

JEL classification: G11,G14,G19.
Keywords: International conflicts, war, stock market reaction, news analysis, behavioral finance.

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1 Introduction

"Buy on the sound of the cannon, sell on the sound of the trumpet." is an old proverb from the Napoleonic wars, attributed to London financier Nathan Rothschild. It suggests that the start of a war is a good time to buy stocks and that stocks should be sold once the war is over. The rationale behind this advice is that investors tend to overreact to the bad news of a coming war, leading to underpricing, and that they similarly overreact to the good news of the end of a war, leading to overpricing.

Economists have been concerned with the causes and consequences of international military crises for more than one hundred years, one of the first contributions being the work of Keynes ([1919] 1971). Further work focused on the interplay between economy and war (Holsti & North 1966, Russett & Hanson 1975, Collier & Hoeffler 1998) and the impact of war on financial markets throughout the history (Frey & Kucher 2000).

Recently, this financial market reaction induced by international conflicts has caught substantial interest in finance. News analysis has been used to reflect the perceived risk and consequences of the wars. In an early pioneering study, using content analysis of news, Holsti & North (1966) demonstrate that security prices are related to rising international tensions during the outbreak of World War I. In a more general framework, Niederhoffer (1971) codes the headlines on world events on a seven-point good-bad scale to examine the impacts of news and Cutler, et al. (1989) analyze the stock market reaction to world news (including wars) from 1926 to 1985. To quantify effects of international conflicts on stock prices, Goldstein (1992) has constructed a scale to code conflictive versus cooperative events that can be used to assess the impacts of war risk, as has been pointed out by Schneider & Troeger (2006). There are further studies on the relation between world news and financial markets, in particular during times of crisis: Elmendorf, et al. (1996) study the British bond market reactions to news by comparing the weeks with important news and the weeks without such news. Similarly, Rigobon & Sack (2005) distinguish the days with war-related news and the days without those news to measure the impacts of war risk on financial markets.

Whereas all of these studies either consider particular conflicts or impacts of war risk on financial markets during (at first glance) peaceful times, we want to focus in this paper on a slightly different aspect, namely wars with a "prologue", i.e., wars which follow a period of tension. In this type of wars we distinguish two phases: in the first phase, where the cannons are still silent, there is an increasing danger of a war, possibly interrupted by times of hope for a peaceful resolution. Afterwards, in the second phase, the "sound of the cannon" starts and war breaks out.

The surprising finding of our analysis is that often the reaction of the stock market to the likelihood of a war is different between these two phases: whereas in the pre-war phase an increased likelihood of war *decreases* market prices, the outbreak of the war itself, so to say the increase of the likelihood from 99% to 100%, *increases* market prices! On the day of the outbreak of some specific war, news coverage clearly is focused on this particular event. The development of the stock market index then reflects the market's reaction to and evaluation of the event, which is thus far from random.
We observe this striking puzzle for a number of larger wars, including the Iraq War and World War II. In all cases we study the impact on the US stock market as measured by S&P500 or Dow Jones Industrial Average. To complement our results, we also analyze all other international crises with large impact since World War II, in particular wars that started unexpectedly, such as the Korean War.
This paper is organized as follows. Section 2 discusses different proxies to estimate the likelihood of a war. Section 3 analyzes the Iraq War in 2003 using different likelihood measurements and shows that a puzzle in the development of stock prices along the evolvement of this international crisis can be observed. Using further examples of international wars in section 4, we show that this phenomenon does not seem to be restricted to the Iraq War. Section 5 discusses possible explanations for the puzzle and rejects some – at first glance natural – explanations. Section 6 concludes.

2 Estimating the likelihood of war

To analyze market reactions on changes in the likelihood of a war, we first need to find appropriate proxies for this likelihood. We analyze the Iraq War since for this war several independent estimates for the probability of a war are available. Using the Iraq War as a benchmark we establish a simple yet robust proxy using news that we can then readily apply to older wars where other data would not be available.
The Iraq crisis started to become serious on January 28, 2003 when President George W. Bush announced a possible attack of Iraq regardless of respective resolutions by the UN. After the ultimatum proposed to Saddam Hussein on March 17 to leave Iraq within 48 hours had expired, the first military intervention by the US started immediately in the early morning of March 20. Later that morning, President George Bush formally announced the Operation Iraqi Freedom after the military invasion had already begun.
Following Wolfers & Zitzewitz (2009), we use two independent estimates for the probability that a war would take place in Iraq: First, the "Saddameter",

	Saddam Security June	Iraq war news
Saddameter	$\rho = 0.86$	$\rho = 0.66$
	$N = 56$	$N = 81$
Saddam Security June		$\rho = 0.64$
		$N = 78$

Table 1: Correlations between different proxies for the probability of a war. All correlations are significant on the 1% level and use the largest available number of days from the time series discussed in the main text.

being an expert estimate for the likelihood of an invasion into Iraq which was published on a daily basis by William Saletan on www.slate.com. This estimate provides us with data from November 2002 to March 18, 2003. Second, on the online exchange platform www.tradesports.com there existed a security, called the "Saddam Security", which was designed to pay a certain amount if and only if Saddam Hussein, president of Iraq, would still be in power at a certain date. A war was expected to end his rule on Iraq, so the Saddam Security prices gave a good probability estimate for the likelihood of a war before the designated date (also see Amihud & Wohl (2004)). This security was available with different maturity dates, where only the March 2003 and June 2003 securities had long enough price series. We use the June security, since the pattern of the March security is somehow obfuscated by the fact that even though the probability for a coming war increased, it was at times not at all clear whether the eventual war would be over before the end of March.

As another proxy we studied news data from the New York Times. We counted how many articles with the key words "war" *and* "Iraq" appeared in each day's issue. To show that this variable is closely related to the above mentioned probability measurements and that it provides the same qualitative indications about the war likelihood, we regress each of the two measurements (i.e., the Saddameter and the Saddam Security) on our news proxy. The results are reported in Table 1. We see that the news variable is positively correlated with the Saddameter, that is, the expert measurement on the war likelihood and the number of (mostly negative) news items run in the same direction. The comovement between the Saddameter and the news variable between November 2002 to March 2003 is depicted in Figure 1 and is negatively related to the development of the S&P 500. Similarly, the news proxy is positively related to the Saddam Security.

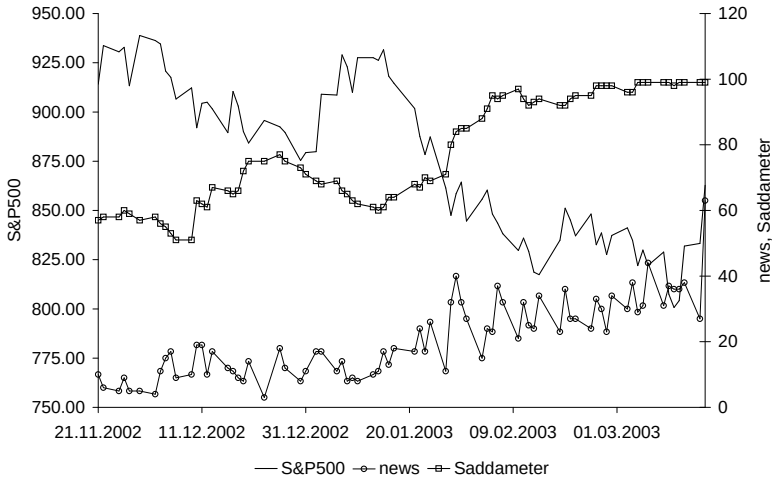


Figure 1: Iraq War: S&P 500 and probability of a war (November 2002 to March 2003).

3 The Iraq war puzzle

As mentioned earlier, a puzzle can be observed when analyzing data from stock market values prior to and at the onset of a war. The relation between stock market values and the probability of an international conflict emerging into a war is negative as long as the conflict is still evolving. However, it becomes positive at the actual onset of the war, thus a positive shock in the stock market can be observed when the war likelihood increases to 100%. In other words, an increasing war likelihood seems to decrease stock prices, while the outbreak of the war itself seems to increase stock prices. This is what we call the "war puzzle".

To provide empirical evidence for this puzzle, we begin with an analysis of the Iraq War in 2003. The main reason for this approach is the fact that for this war we are able to use two alternative measurements of the probability of a war, namely the Saddameter and the news variable described in section 2. As previously explained, this has the advantage that we are able to conduct econometric analyses for both types of probability measures in the same war. Hence, showing that the news variable is a valid proxy for the war likelihood, we can then use this variable to analyze periods of war where no alternative probability measures are available.

Analyzing the characteristics of the S&P 500, news, and the Saddameter, we find that these time-series are non-stationary in levels, but stationary in first differences (see Table 2 for augmented Dickey-Fuller test statistics for unit roots). Moreover, we find evidence for a cointegrating relationship between the S&P 500 and each probability measure of order one (see Table 3). This leads us to the choice of an error correction model to appropriately model the relation between the US stock market and the war likelihood. The econometric models employed to study the stock market in the pre-war phase are

$$\begin{aligned} \Delta SP500_{t-1} &= \beta_1 \Delta SP500_{t-2} + \beta_2 \Delta news_t + \gamma[SP500_{t-2} - \alpha_0 - \alpha_1 news_{t-1}] + \epsilon_t \\ \Delta SP500_{t-1} &= \beta_1 \Delta SP500_{t-2} + \beta_2 \Delta Sadd_{t-1} + \gamma[SP500_{t-2} - \alpha_0 - \alpha_1 Sadd_{t-1}] + \epsilon_t \end{aligned}$$

where $\Delta SP500$ measures absolute daily changes in the S&P 500 and the error correction parameter γ captures the degree to which deviations from an equilibrium in the previous period (captured by the error term) affect current values. Hence, γ is expected to be negative if a long run equilibrium relationship prevails. Note that the functional form of most of the regressions used in this and the following sections is such that the explanatory variable is lagged forward relative to the dependent variable. While this may seem

		Intercept	Intercept and trend
levels	$S\&P500$	-1.516701	-2.566209
	$news$	0.177096	-7.012188***
	$Saddameter$	-0.512926	-1.890143
first differences	$S\&P500$	-9.688364***	-9.622123***
	$news$	-7.768300***	-7.820706***
	$Saddameter$	-7.838634***	-7.784029***

Table 2: Iraq War: ADF test statistics for unit roots.

		Intercept	Intercept and trend
levels	$\epsilon_t = S\&P500_t - \beta_0 - \beta_1 news_t$	-3.097145**	-5.436361***
	$\epsilon_t = S\&P500_t - \beta_0 - \beta_1 Saddameter_t$	-3.838913***	-3.798512**
first differences	$\epsilon_t = S\&P500_t - \beta_0 - \beta_1 news_t$	-13.20518***	-13.14161***
	$\epsilon_t = S\&P500_t - \beta_0 - \beta_1 Saddameter_t$	-9.259228***	-9.200276***

Table 3: Iraq War cointegration tests: ADF test statistics for unit roots in residuals ϵ_t.

slightly counterintuitive at first sight, the reason is that there exists a certain delay between the stock market pricing an event and its actual publication in the newspaper.[1]

The estimated coefficients are presented in Table 4. Both news and the Saddameter are highly significant at the 1%- and 5%-level, respectively, and indeed indicate a negative relationship between stock prices and the war likelihood. An increase in the probability of a war is thus associated with decreasing stock market values.[2] In particular, an increase in the difference of the number of news, $\Delta news_t$, by one unit leads to a decrease in the difference in the S&P 500, $\Delta SP500_{t-1}$, by 0.507 points. Similarly, an increase in the difference of Saddameter value, $\Delta Sadd_{t-1}$, by one percentage point leads to a decrease in the difference in the S&P 500, $\Delta SP500_{t-1}$, by 1.112 points.

[1] Standard predictive models are often constructed such that changes in variables at time $t+1$ are explained by changes in variables at time t. In our case this approach would require to use a variable for the war likelihood which realizes prior to actual changes in the stock market. However, since our argument is to use the news proxy as a flexible probability measurement which is available for different wars over time, the functional forms used here slightly differ from standard models due to the delay of news publication. This however does not alter the models' predictive power.

[2] Also, the error correction parameter γ is significantly negative as expected for both types of probability measurements.

	Iraq War 2003 ECM stocks on news	Iraq War 2003 ECM stocks on Saddameter
$\Delta SP500_{t-2}$	-0.053043	0.051166
	0.110395	0.111035
γ	-0.227357***	-0.394025***
	0.068093	0.101989
$news_{t-1}$	-3.661144***	
	0.564399	
$\Delta news_t$	-0.507151***	
	0.183471	
$Sadd_{t-1}$		-2.305066***
		0.189155
$\Delta Sadd_{t-1}$		-1.114737**
		0.492670
R^2	0.168027	0.276713
N	78	78
from	Nov 21, 2002	Nov 21, 2002
to	March 18, 2003	March 18, 2003

Table 4: Iraq War: error correction model for the effect of the war likelihood on stock markets.

The one day lag in the news variable can be attributed to the time required for physical publication of the newspaper. Since both probability measures yield the same implications, they may both be regarded as valid proxies which ensures that we can employ the news variable as a valid proxy also in periods where alternative probability measures are not available.
To study the behavior of the stock market at the onset of the war, we conduct an analysis for structural breaks in the development of the stock market index. To this end, cumulative returns of the S&P 500 are regressed on a binary dummy D_t defined as

$$D_t = \begin{cases} 0 & \text{if } t < \tilde{t} \\ 1 & \text{if } t \geq \tilde{t} \end{cases}$$

where $\tilde{t}$ indicates a potential structural break, and a time window of size 51[3] around $\tilde{t}$ is used to obtain a set of regressions of the type

$$SP500_t = \beta_0 + \beta_1 D_t + \epsilon_t.$$

[3]That is, the data set ranges from $\tilde{t} - 25$ to $\tilde{t} + 25$ days around $\tilde{t}$.

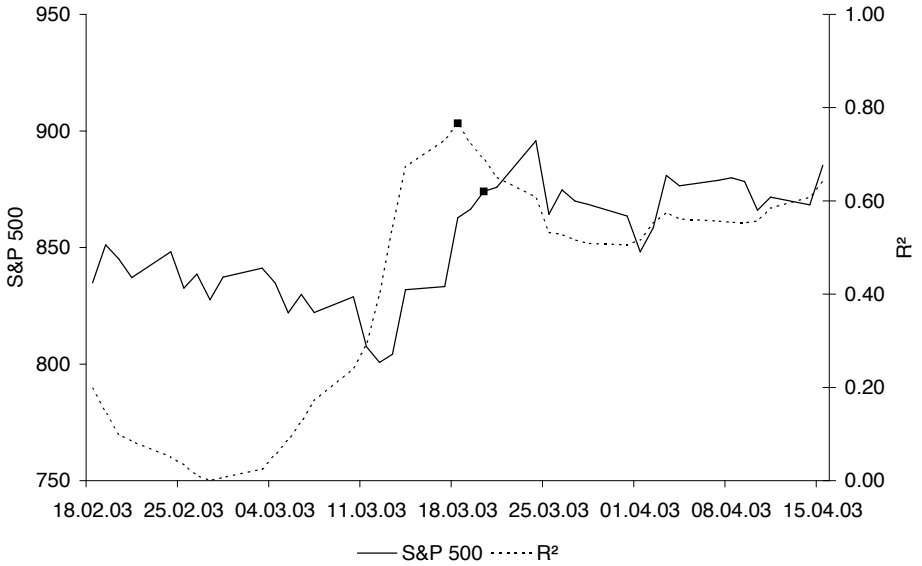


Figure 2: Iraq War: development of S&P 500 and explanatory power of structural breaks analysis.

Note: The largest local R^2 was reached for $\tilde{t}$ = March 18, 2003 while the invasion of Iraq occured two days later on March 20, 2003.

That is, $\tilde{t}$ is varied over time until the largest associated R^2 is found, where we suppose that the actual onset of a war, and hence the observed structural break denoted by t_0, lies in close proximity.[4] Note that while we are aware of potential problems of non-stationarity in the cumulative returns, our analysis of structural breaks would not be feasible using first differences here. Our interest lies in potential increases in stock market values at the beginning of a war, which has to be separated from the question of average increases or changing trends. The problem thus is to weight an interesting question with the obvious problems of not using differences in the regression in order to answer the issue.

The results are illustrated in Figure 2. The largest R^2 obtained amounts to 0.7665 and is associated with March 18, 2003 while on March 20, 2003 the invasion of Iraq occurred ($R^2 = 0.6898$). Hence, the true structural break

[4]We use this type of structural break analysis since we are interested in whether there exists an instantaneous jump in the stock market index at the onset of a war. An alternative question would be whether there are possible changes in the trend of the stock market. For that purpose a regression testing for changes in expected growth rates of stock returns may be appropriate (compare Amihud & Wohl (2004)).

can be relatively well predicted.[5] The S&P 500 increases by 46.4 points at the time of the predicted structural break and by 47.8 points at the time of the invasion two days later. Although it may prove difficult to interpret this absolute change in the stock market index at the onset of the war and compare it across conflicts, we refrain from calculating relative changes, for instance. As the volume of news items clearly differs between wars separated by several decades, a comparison of these relative values between the wars would be meaningless and thus reveal no further insights for the analysis.

4 The war puzzle – a general phenomenon

The results of the previous section could either be a general phenomenon or just an idiosyncrasy of the Iraq War. In this section we therefore extend the analysis to other wars with large international impact since World War II. We face two problems here: first, we need to decide which wars to include, and second, the number of large scale wars during this time was – fortunately – not big enough to use one econometric approach for all wars. Instead of trying a unified analysis, we are therefore forced to study the conflicts separately. As any event study involving data on stock market indices during international military conflicts, our subsequent analysis is necessarily based on a small number of observations.
We solve the above-mentioned selection problem by using the list of the most costly wars to the US (and thus arguably to the US economy) as composed by Stephen Daggett[6] (see Table 5). In the following we will study each of the wars from this list, where we make a distinction between wars with a surprising start and wars with a longer prelude. Since the wars took place at very different times, with news traveling at different speeds, the econometric models we apply necessarily differ in details.

4.1 World War II (1939–45)

To analyze World War II, two starting days can be studied: first, the German invasion in Poland on September 1st, 1939, and second the Japanese attack on Pearl Harbor on December 7, 1941, dragging the US into the war.
We study first the former event since it had a large prelude while we will study the latter rather surprising one in section 4.6. To analyze it in an

[5]Note that the estimated structural break on March 18 coincides with the beginning of the US ultimatum to Saddam Hussein. Investors might have anticipated that this ultimatum would not be agreed upon which caused an early rise in stock market values.

[6]CRS Report for Congress, costs of major US wars, July 2008.

	Costs in billion 2008 US$	% of GDP
World War II	4114	35.8
Korean War	320	4.2
Vietnam War	686	2.3
Gulf War	96	0.3
Iraq War	648	1.0
Afghanistan War	171	0.3

Table 5: List of the most costly wars to the US (Source: Stephen Daggett, CRS Report for Congress, costs of major U.S. wars, July 2008).

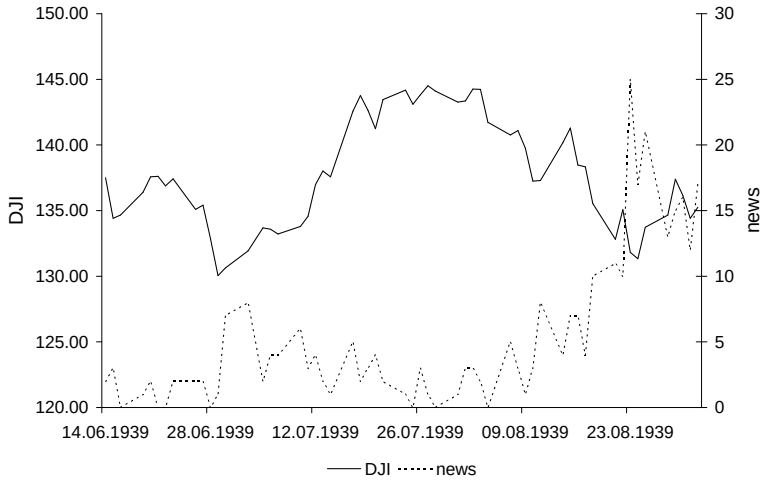


Figure 3: World War II: Dow Jones Index and probability of a war (June to September 1939).

	World War II: first differences stocks on news
constant	0.182669
	0.185875
ΔDJI_{t-2}	-0.000372
	0.118141
$\Delta news_t$	-0.284428***
	0.086258
$\Delta news_{t-1}$	-0.194573**
	0.074057
$\Delta news_{t+1}$	-0.265086***
	0.069688
R^2	0.227573
N	69
from	May 25, 1939
to	Aug 31, 1939

Table 6: World War II: first difference estimations of the effect of the war likelihood on stock prices.

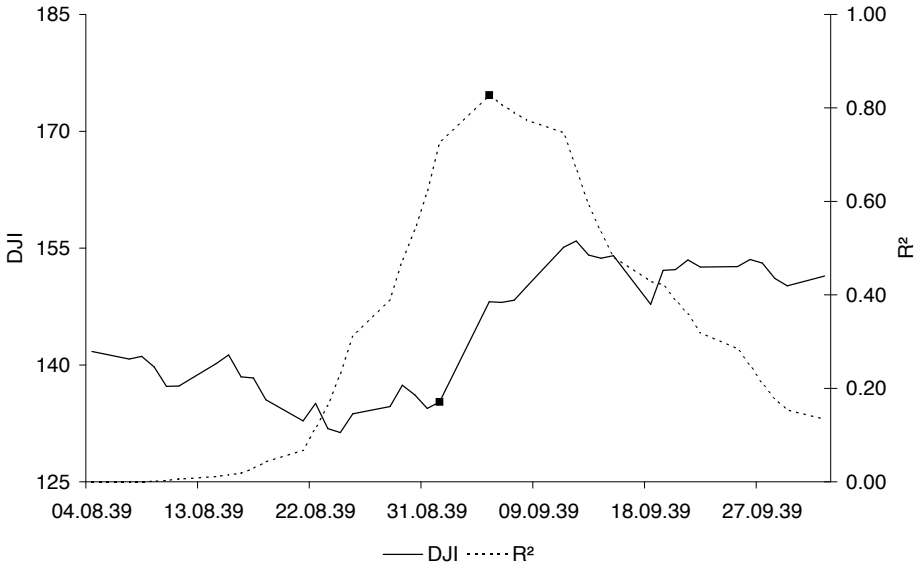


Figure 4: World War II: development of the Dow Jones Index and explanatory power of structural breaks analysis.

Note: The largest local R^2 was reached for $\tilde{t}$ = September 5, 1939 while the German attack of Poland occured on September 1, 1939.

econometric setting, a first differences approach of the form

$$\Delta DJI_{t-1} = \beta_0 + \beta_1 \Delta DJI_{t-2} + \beta_2 \Delta news_{t+1} + \beta_3 \Delta news_t + \beta_4 \Delta news_{t-1} + \epsilon_t$$

is most appropriate. The stock market is described by absolute daily changes in the Dow Jones Index, ΔDJI, and the war likelihood is from now on captured by the news proxy established in Section 2, i.e. in this case the number of articles in the New York Times featuring the key words "war" *and* "Poland". Figure 3 depicts the relation between the Dow Jones Index and the probability of a war between June and September 1939. Table 6 shows the regressions results obtained from estimating this equation. The marginal effect of the news variable is significantly negative for all different lags $\Delta news_{t-1}$, $\Delta news_t$, and $\Delta news_{t+1}$ and ranges from -0.195 ($\Delta news_{t-1}$) to -0.284 ($\Delta news_t$) points. Figure 4 illustrates the results obtained from the structural break analysis of type

$$DJI_t = \beta_0 + \beta_1 D_t + \epsilon_t.$$

September 5, 1939 is identified as the most likely structural break in the data set ($R^2 = 0.8274$). In fact, this lies close to the German attack of Poland being the critical event on September 1, 1939 ($R^2 = 0.7244$). The time lag might be explained by the slower speed of news publication at that time.

4.2 Vietnam War (1955–75)

Next, we examined whether there is empirical evidence for the war puzzle in case of the Vietnam War. This war distinguishes itself from others by the fact that its time line is less clear, but the onset of the large-scale US involvement is set in 1965. The development of the Dow Jones Index and the news variable between February 1964 and March 1965 is depicted in Figure 5. The most suitable regression for this war is a time-series approach of type

$$\Delta DJI_{t-1} = \beta_0 + \beta_1 \Delta DJI_{t-2} + \beta_2 \Delta news_t + \beta_3 \Delta news_{t-1} + \epsilon_t,$$

where the according results are presented in Table 7. Again, we see a significant negative relation between the war likelihood and the development of stock prices. Figure 6 then illustrates the results for the analysis of structural breaks in the Vietnam War. We see that the ad hoc regression identifies April 15, 1965 as the event associated with the largest coefficient of determination, $R^2 = 0.7860$. In fact, one critical event coincides with this date: it marks the first US and South Vietnamese bombing of Viet Cong positions. The jump

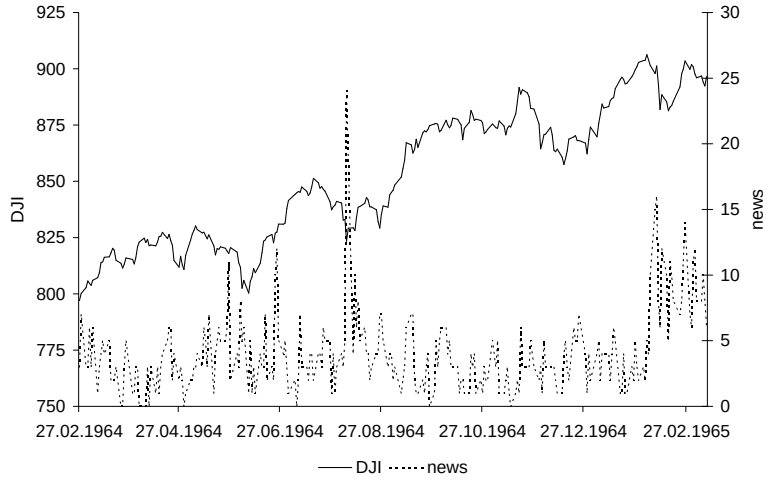


Figure 5: Vietnam War: Dow Jones Index and probability of a war (February 1964 to March 1965).

in cumulative returns is significantly positive at the 1%-level and amounts to an increase of the Dow Jones Index by 28.01 points.
Note that for the war in Vietnam, the analysis does not exactly describe the pre-war period and the distinct outbreak of the war itself, but nevertheless proves to be a useful method to analyze the reaction of cumulative stock returns to war news within a prolonged period of tensions.

4.3 Gulf War (1990-91)

We now analyze the Gulf War[7] which started with the invasion of Iraq into Kuwait on August 2, 1990 and ended with the defeat of the Iraq by the US and their allies on February 28, 1991. However, the relevant date for our analysis is January 17, 1991 when the Operation Desert Storm (with the goal to liberate Kuwait) was started by massive aerial bombing and the war started into its second and much larger phase. As such, our news series goes until this date, interpreting the preceding time span as a pre-war phase from the perspective of the US and their allies.

[7]The Gulf War is often also referred to as Second Gulf War or Persian Gulf War.

	Vietnam: first differences stocks on news
constant	0.203179
	0.160907
ΔDJI_{t-2}	0.151938***
	0.055254
$\Delta news_t$	-0.045566
	0.038402
$\Delta news_{t-1}$	-0.116012***
	0.038418
R^2	0.050994
N	311
from	May 6, 1964
to	March 12, 1965

Table 7: Vietnam war: first difference estimations of the effect of the war likelihood on stock prices.

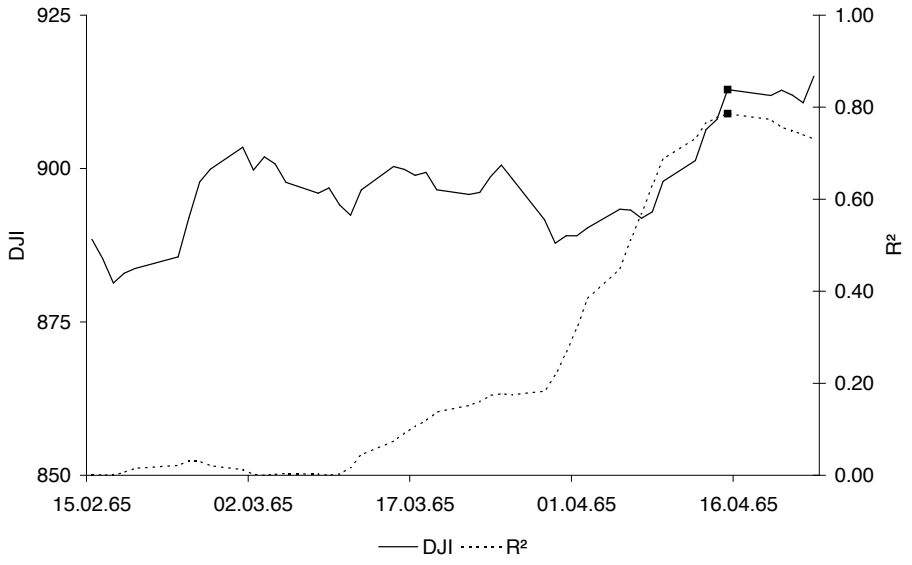


Figure 6: Vietnam War: development of the Dow Jones Index and explanatory power of structural breaks analysis.

Note: The largest local R^2 was reached for $\tilde{t}$ = April 15, 1965 which coincides with the first US and South Vietnamese bombing of Viet Cong positions on that day.

	Gulf War: first differences stocks on news
constant	0.178762
	0.373536
$\Delta SP500_{t-2}$	0.158764
	0.117019
$\Delta news_t$	-0.288532**
	0.128104
$\Delta news_{t-1}$	-0.220716
	0.132420
R^2	0.109827
N	72
from	Oct 10, 1990
to	Jan 1, 1991

Table 8: Gulf War: first difference estimations of stock returns and news.

Analyzing this relation again by a time-series approach, Table 8 shows the results. We see once more that there is empirical evidence for a significant negative relation between news and stock market values. The analysis for structural breaks in the development of cumulative returns (see Figure 7) identifies February 4, 1991 as the break point ($R^2 = 0.8457$) which, however, lies some days after the initial aerial bombing. In fact, the closest real event to this indication is Battle of Khafji being the first major ground battle in the Gulf War on January 29, 1991.

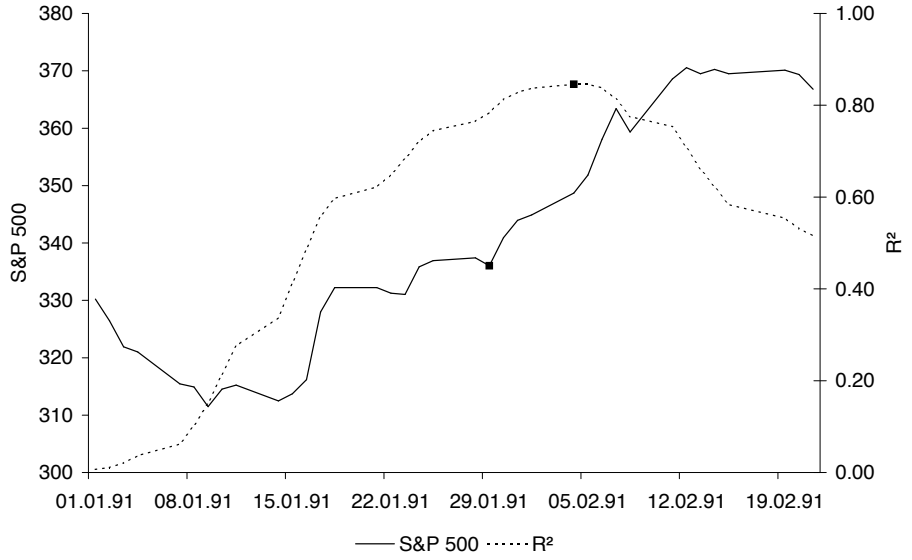


Figure 7: Gulf War: development of the S&P 500 and explanatory power of structural breaks analysis.

Note: The largest local R^2 was reached for $\tilde{t}$ = February 4, 1991 while the Battle of Khafji took place on January 29, 1991.

4.4 Afghanistan (2001)

In contrast to the conflicts analyzed in the previous sections, the Afghanistan war, starting in October 2001, had a too short prelude (beginning only after Afghanistan's involvement into the attack on September 11, 2001 became clear) to be analyzed in a sufficient way. However, we can still perform an analysis for structural breaks and show that there exists an increase in stock market values at the onset of the war. Figure 8 depicts the development of the S&P 500 and news between September and October 2001. Figure 9 shows the empirical results from the analysis for structural breaks. Again an increase in the S&P 500 around the time of the start of the war can be detected.

4.5 Behavior of other large stock market indices

Do stock markets in other countries behave similarly as the US market? For the two recent wars with sufficiently long prelude, i.e. the Gulf War and the Iraq War, Figure 10 shows that Japanese, German, and European stock indices mirror the development of the S&P 500 quite well. The analysis for

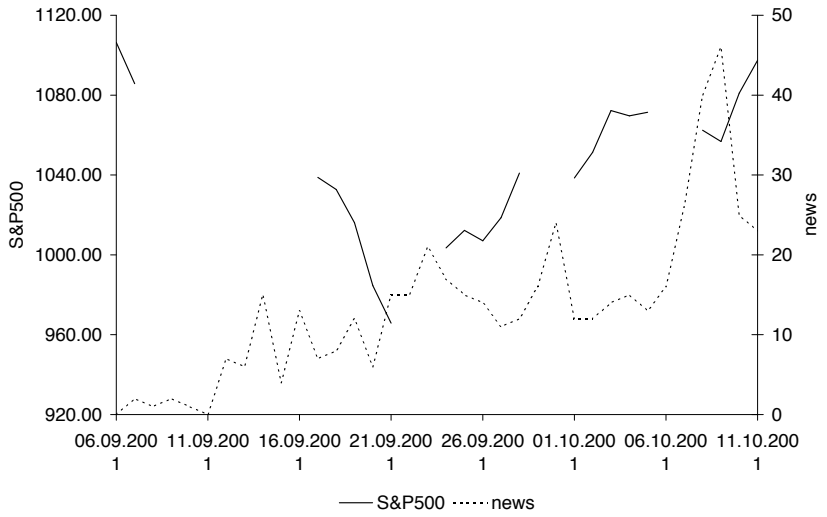


Figure 8: Afghanistan War: S&P 500 and probability of a war (September to October 2001).

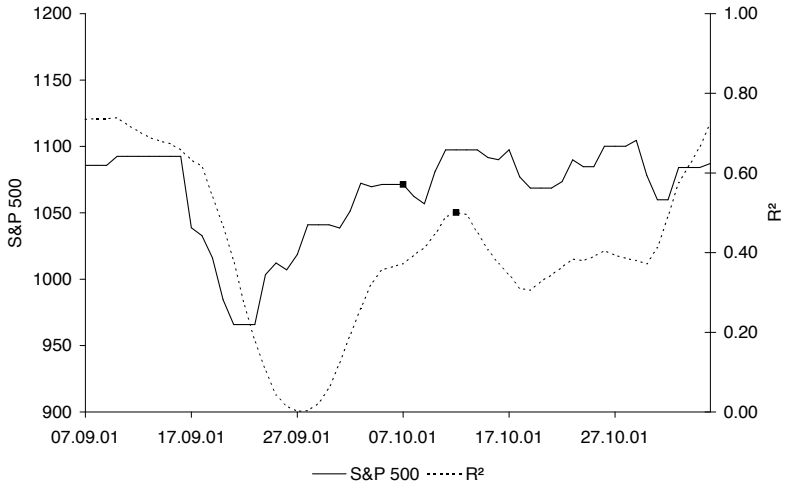


Figure 9: Afghanistan War: development of the S&P 500 and explanatory power of structural breaks analysis.

Note: The largest local R^2 was reached for $\tilde{t}$ = October 12, 2001 while the air attack took place on October 7, 2001.

	Critical event	Estimated breaks			
		S&P 500, DJI	Nikkei	DAX	Eurostoxx
Iraq War	Mar 20, 2003	Mar 18, 2003	Mar 7, 2003	Apr 7, 2003	Feb 25, 2003
Gulf War	Jan 29, 1991	Feb 4, 1991	Feb 5, 1991	Jan 30, 1991	N/A

Table 9: Analyses for structural breaks in other large stock market indices.

structural breaks (see Table 9) shows particularly for the Gulf War simultaneous up-moves at the onsets of war.[8] The fact that the US, Europe and Japan are strongly interconnected in economic terms may further account for the clear comovement of Nikkei, DAX, and Eurostoxx which can be observed during these two wars in the Middle East. A similar, though less pronounced comovement also exists for the Afghanistan War.[9]

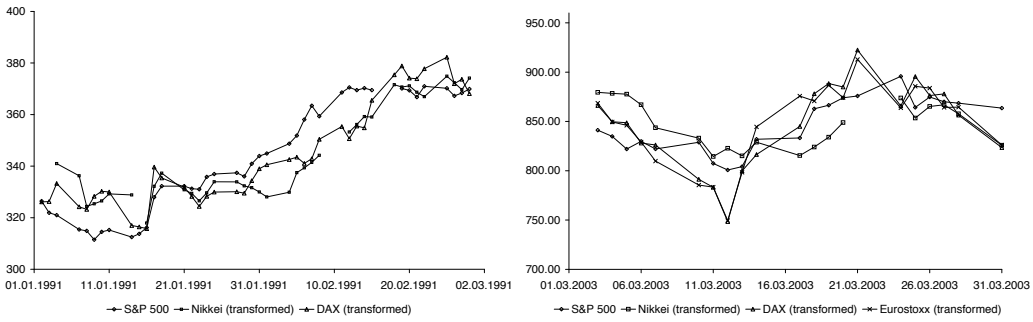


Figure 10: Comovement of other stock market indices for the Gulf War (left) and the Iraq War (right).
Note: For the sake of comparability, the data series of Nikkei, DAX, and Eurostoxx are linearly transformed such that all series have a mean equal to the mean of the S&P 500.

[8] Although it would be interesting to see how stock markets evolved in the countries were war actually took place, this analysis is often not feasible. Either stock exchanges were not yet institutionalized, or controlled by the government so that data would not be reliable, or data is not available.

[9] Due to issues of data availability, we could not perform a similar analysis for global wars having occurred earlier in history.

4.6 Wars "out of the blue"

So far we have analyzed wars that had a more or less pronounced prelude. However, there are also some wars with a very fast and unexpected onset.[10] Most notably, these are:

- the start of the involvement of the United States into World War II (Pearl Harbor) on December 7, 1941,
- the Korean War, that started with the rather unexpected invasion of North Korea into South Korea on May 25, 1950,
- and finally the Gulf War, or more precisely, the invasion of Iraq into Kuwait on August 2, 1990.

In all of these cases we cannot expect to find the pattern that we have observed before the outbreak of the wars analyzed in the previous section. There is simply no pre-war phase that could be analyzed and where an increase in the probability of war could decrease stock market prices.[11]
What we *can* observe, however, is whether the onset of a war led to a sudden increase or decrease of the stock market prices. A structural break analysis, very similar to the analysis conducted above, shows that this is indeed the case for all three wars. – However, the pattern is inverted: In all three cases the stock market prices went significantly down at the outbreak of the war. In the case of Pearl Harbor the Dow Jones index went down nearly 3% on one day, in the case of the Korean War nearly 5% and in the case of the Gulf War it went down around 5,7% within a week.

4.7 What's puzzling about the war puzzle

Our analysis so far has revealed quite a peculiar pattern: on the one hand, stock prices tend to fall when the probability of a war increases and tend to rise when there are signs for a peaceful resolution. However, the eventual onset of the war will increase stock market prices.
While this by itself is already puzzling it becomes even more puzzling considering the evidence that we have found about surprising wars (wars without a lengthy prelude): here we observe that stock market prices tend to decrease once the war breaks out. In other words, whether stock prices decrease or increase when a war breaks out does not seem to depend much on the particular war but more on the previous history or, more precisely, whether the

[10] Li & Sacko (2002) find that an unexpected onset of a military dispute reduces bilateral trades more severely.

[11] Unless we studied intra-day data which in most of these cases is not available.

		Stock market reaction to:		
		increasing prob.	expected start	surprising start
	Probability range (schematic)	0%-99%	99%-100%	0%-100%
Wars	WW II (start in Europe)	↘	↗	
	WW II (Pearl Harbor)			↘
	Korean War			↘
	Vietnam War	↘	↗	
	Gulf War (Kuwait invasion)			↘
	Gulf War ("desert storm")	↘	↗	
	Afghanistan War	$\star$	↗	
	Iraq War (2003)	↘	↗	

Table 10: Summary of stock markets' reactions to news.
Note: $\star$ indicates a lack of data in order to investigate this point.

war was surprising or not. But even this observation cannot explain the discrepancy that one and the same war first suggests a pattern that an increase in the likelihood of a war decreases stock market prices but then ultimately the onset of the war itself increases them. This cannot easily be accommodated with the idea that stock market prices reflect expectations of the future economic development of a country.

Table 10 summarizes the stock markets' different reactions towards news for all conflicts studied.

5 Attempts to explain the puzzle

5.1 War as a stimulus package for the US economy

The first idea about this puzzle might be that it is none: a war can be considered as a stimulus package for the US economy and thus lead to an increase in stock market prices.

However, this line of argument does not work for two reasons: First, we have seen in section 4.5 that the puzzle also seems to be present for countries which were not involved in the respective war, as, for instance, Germany in the Iraq War. Second, the explanation fails to explain why *before* the war, prices fall whenever the war becomes more likely.

Falling prices when war is looming and rising prices when war is starting: only the combination of these two observations makes the war puzzle a puzzle.

5.2 Expectations about a quick end of the war

A natural idea is to consider the time dimension (Schneider & Troeger 2006): once the war breaks out, it is clear that the trouble will be over soon, thus investors buy stocks again. For example, the Saddam Security can be interpreted as the likelihood of a coming war, but also as expected length of the war after the war took place (Amihud & Wohl 2004, Wolfers & Zitzewitz 2009). Chappell & Eldridge (2000) have also suggested psychological explanations such as "despair" and "renewed hope", regarding the UK stock index reactions to the two sub-periods during World War II. There are, however, at least three arguments that lead us to discard this natural looking idea to explain our findings as well:

- Since the Saddam Security works well as a proxy for the estimated probability for a war, it is clear that investors did not expect the war to take place in a far future: recall, that the particular security that we studied would only pay out if Saddam Hussein was out of power by June – not long after the war indeed took place!

- While the positive expectation about a quick war that ends the costly and lengthy tensions before, might be true, e.g., for the war on Iraq (although in hindsight it turned out to be overly optimistic), this cannot explain the pattern observed at the onset of World War II, given that it was generally not expected that this war would end quickly, given the experience of the four year long World War I.

- The expectation about a quick end of the war cannot explain why investors do not seem to appreciate the increase of the likelihood for a coming war earlier, as this brings the war (and hence its end) closer.

5.3 Ambiguity averse investors

An alternative explanation that seems to be natural is to assume that investors show ambiguity aversion. At first the ambiguity about the probability, that a war starts, makes people to shy away from the stock market and hence leads to lower stock prices. This effect stops as soon as it becomes clear that a war is indeed starting for sure and uncertainty is reduced (Schneider & Troeger 2006). Guidolin & Ferrara (2005) suggest that the initiation of conflict can been seen as a sign of resolve and investors tend to show positive reactions by buying stocks
However, this seemingly natural behavioral explanation cannot accommodate our empirical data, as ambiguity cannot make an ambiguous situation seem

worse than its worst possible outcome! In this situation that would mean that even though the probability for the start of a war is uncertain and hence ambiguous, an ambiguity-averse investor would still prefer this situation over a situation where the war has started for sure.

5.4 Uncertainty about investment decisions

Another idea to resolve the puzzle is to consider the uncertainty about a war as an uncertainty about the decision between different portfolio allocations: in case of a peaceful resolution an investor should have invested into different assets than in the case of a war. While it is uncertain which of the two outcomes will occur, it might be optimal for an investor to stay out of the stock market entirely, or at least to reduce its holdings substantially.
To study this idea more in details, we describe a small model:
When facing a possibility for the outbreak of a war, an investor has to decide between investing into two different portfolios, a "war portfolio" that will be successful if a war breaks out, and a "peace portfolio" that will be successful if the conflict ends in a peaceful resolution. We summarize the four potential outcomes in the following table[12]:

	War breaks out (probability p)	Peaceful resolution (probability $1-p$)
war portfolio	a	-b
peace portfolio	-c	1

Assuming that it is in any case bad for the investor to speculate on the wrong outcome, we have $a, b, c \geq 0$.
The expected payoff of the investor now depends on his portfolio decision. If he decides for the war portfolio, it is $ap - b(1-p)$. If he decides instead for the peace portfolio, it is $(1-p) - cp$ (compare Fig. 11). Obviously, the war portfolio is better for large values of p and worse for small values. The cut-off point is at

$$p^* = \frac{1+b}{1+a+b+c},$$

as a small computation shows.
This model indeed predicts the observed pattern: an increase in p makes at first the peace portfolio less and less attractive. Consequently, investors will sell the corresponding stocks. At the same time, however, the war portfolio is still even less attractive, thus the falling prices of the peace portfolio stocks

[12]For simplicity we normalized the investor's return in the case of a peaceful resolution for a "peace portfolio" to one.

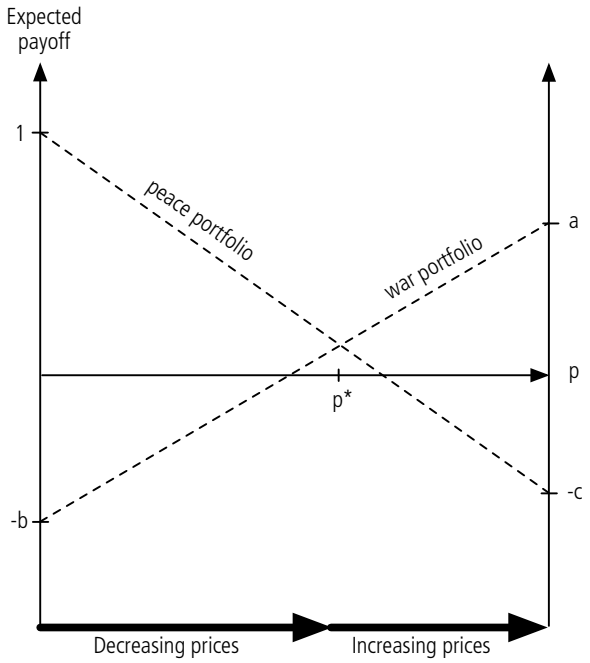


Figure 11: Investors switching from a "peace portfolio" to a "war portfolio" when the probability of a war increases beyond a threshold p^* could explain the war puzzle.

can not be matched by rising prices of stocks in the war portfolio. Once the probability of a war reaches p^*, the pattern changes: now, war stocks become more and more attractive, thus investors buy them and the overall market starts to rise.

In order to find a probability p^* that is close to one and thus in line with our empirical evidence, b needs to be sufficiently large, thus the potential loss when choosing a war portfolio, but encountering a peaceful resolution should be fairly big.

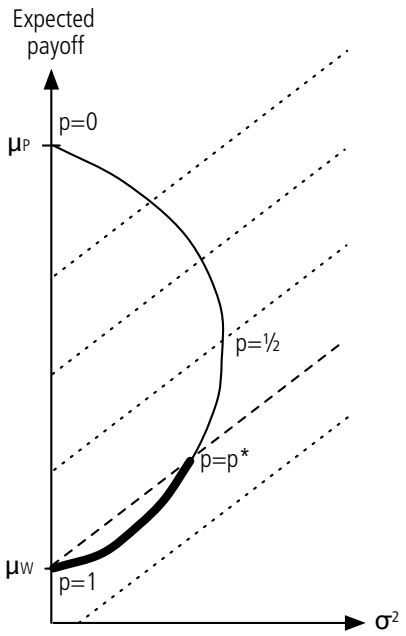
Theoretically, we can explain the puzzle in this way, but how is it in reality? How can we test empirically whether this model indeed explains the war puzzle? The general idea is that different stocks should show a different pattern during the different phases before an outbreak of the war: stocks that are in the "peace portfolio", i.e. stocks that would profit from a peaceful resolution of the conflict, should initially be sold whenever the likelihood of a war increases. Thus we would expect that they follow the general observed pattern of the stock market, but only before the outbreak of the war: at that point these stocks should not increase significantly, as there is no reasons for

investors to purchase them once it is clear that the "war portfolio" is the right investment.
Stocks from the "war portfolio" instead should follow the increase of the stock market at the start of the war, but not its previous decrease whenever the war became more likely.
A simple empirical test is now possible by looking at differences between sectors that should clearly be in the war portfolio (weapon-related industry) and sectors that should clearly be in the peace portfolio (e.g., travel related industry). It turns out, however, that as convincing as the theoretical idea is, as thoroughly it fails this simple, but clear-cut test: in fact, whereas sectors that one would undoubtedly assign to the peace portfolio (e.g., travel stocks, like airlines) increased *most* at the outbreak of the war, while stocks in the war portfolio (weapon manufacturers) did not.
To sum up, this explanation looks good in theory, but does unfortunately not help to resolve the puzzle in reality.

5.5 Mean-variance preferences

Finally there is a rather unexpected possible explanation for the phenomenon: classical mean-variance-preferences. Indeed, this concept could surprisingly well explain the observed data. One could argue that people do not buy when it is unsure what is going to happen due to their variance aversion, even though the expected return might still be a little bit better than when the war finally started. In this sense the observed phenomenon could be related to the mean-variance-paradox.
To formalize this idea, we assign average expected returns μ_W and μ_P to the two potential outcomes (war and peace). We denote the probability of a war by p, then we can compute the variance of the two-outcome lottery (μ_W with probability p and μ_P with probability $1-p$) as $\text{var}(p) = (1-p)^2(\mu_P - \mu_W)^2$. If $p = 0$ (i.e. peace is sure) or $p = 1$ (i.e. war is sure) the variance accordingly becomes zero and it is maximal for $p = 1/2$ (see Fig. 12).
Typical indifference curves for a mean-variance investor with utility $\mu - \alpha\sigma^2$ are also shown in Fig. 12. Looking at the indifference curve through the point $(0, \mu_W)$ (i.e. a certain war) we see that this investor would prefer a certain war ($p = 1$) over a situation where p is large, but still smaller than one.
When the probability p increases slowly from zero to one, at first the situation worsens for the investor (who consequently would value stocks less), but after a certain point (in our model at $p^* = (\alpha - 1)/\alpha$, as a short computation shows) there is indeed a perceived improvement for the investor, explaining the increase in stock prices at the outbreak of a war.

Figure 12: Mean-variance preferences can explain the war puzzle. Here μ_P and μ_W are the returns in case of peace and war, respectively. σ is the variance of the situation, depending on the probability for a war. It is maximal when the probability is one half (maximal degree of uncertainty). The dashed lines are indifference curves, i.e. they mark combinations of mean and variance on which an investor would be indifferent. A certain war is preferred over an uncertain situation with a high probability of a war (points on the thick line).



6 Conclusions

We have observed that stock market prices react very sensitively to the probability for the outbreak of a major war. The pattern that has been confirmed with several wars during the last century shows that an increase in the likelihood of a war decreases stock prices and vice versa. Puzzling, however, is that once a war breaks out, stock market prices do not decrease further, but on the very opposite, increase significantly. This was true for all wars with a more or less lengthy prologue. Wars that occur "out of the blue" show a different pattern in that their sudden outbreak tends to decrease stock market prices. These results are certainly a challenge for classical asset pricing models.

Mean-variance preferences of investors might be able to explain the observed pattern. There could be, however, different explanations for this puzzle based on other behavioral factors. Future research, e.g. with the help of laboratory experiments, might be able to shed more light on this puzzle.

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