Scale matters: Risk perception, return expectations, and investment propensity under different scalings*

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April 19, 2018

Abstract

With a new experimental design we investigate whether risk perception, return expectations, and investment propensity are influenced by the scale of the vertical axis in charts. We explore this for two presentation formats, namely return charts and price charts, where we depict low- and high-volatility assets with distinct trends. We find that varying the scale strongly affects people's risk perception, namely, that a narrower scale of the vertical axis leads to significantly higher perceived riskiness of an asset across different return trends and across price and return charts, even if the underlying volatility is the same. Assets are usually perceived riskier when returns are shown than when prices are shown. Past returns predict future return expectations almost perfectly. We further find that risk perception is highly correlated with losses which in turn drive investment behavior. Subjects tend to invest in the asset they regard as more profitable, even if they think it bears higher risk.

JEL: D14, D18, G11, G41

Keywords: behavioral finance, judgment, risk perception, scaling, presentation format

*We thank Felix Holzmeister, Stefan Palan, Julia Rose, and Janette Walde, as well as conference participants at ESA 2017 in Vienna and seminar participants at the University of Linz for helpful comments and suggestions. Financial support from the Austrian Science Fund FWF (P29362-G27 and SFB-grant P4340-015-019, both J. Huber) and the University of Innsbruck (Doktoratsstipendium Netzwerk Banking, Accounting, Auditing, Finance & IT (BAFIT) C. Huber, Förderstipendium C. Huber) is gratefully acknowledged. A prior version of this paper was presented with the title "Scaling, Volatility, and Risk Perception."

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1 Introduction

When Gulliver traveled to Lilliput he was a giant. On his next journey to Brobdingnag he was a dwarf. While he had not changed, the scale of everything around him had. Obviously the scale that we see something in plays a major role in how we perceive it. In financial practice, the scaling of prices and returns, e.g. in documents given to customers, is an important issue – recognized by practitioners, but mostly ignored by regulators and research so far. We mention regulators as, for example, the European Union sets rules for the presentation of a security's past performance in a Key Investor Information Document (KIID; see Commission Regulation (EU) No 583/2010). According to that regulation, returns have to be shown in the form of bar graphs with a linear vertical axis. Additionally, the scale has to be adapted appropriately and *shall not compress the bars so as to make fluctuations in returns harder to distinguish* (p. 15). While the European Commission acknowledges the potential problems of highly compressed bars, it remains unclear what consequences arise regarding the risk and profit expectations to-be-identified by investors, and hence, regarding investment decisions. Maximizing the return bars on the available space makes yearly fluctuations more distinguishable, but also involves the danger of misinterpretation of the returns as highly volatile and therefore highly risky, even when they are not. Compressing the bars, however, could lead to risk being perceived as too low, possibly exposing consumers to unexpectedly high losses.

The perception of risk is one of the central topics of behavioral and experimental finance. While classical finance theory builds on the premise that risk is generally understood as a financial product's volatility – i.e., the standard deviation of its returns – and is perceived accurately (Markowitz, 1952), behavioral and experimental research shows that this prerequisite is often not fulfilled (e.g. Keller et al., 1986; Weber, 1990; Brachinger and Weber, 1997).

Current research on risk perception focuses particularly on which characteristic of a financial asset or return distribution people perceive as *risk*. Prominent alternatives to the standard deviation of returns are associated with losses, e.g. an investment's loss probability and its maximum expected loss (Unser, 2000; Duxbury and Summers, 2004; Veld and Veld-Merkoulova, 2008; Anzoni and Zeisberger, 2016; Huber et al., 2018). Duxbury and Summers (2017) report similar findings for price sequences.

Another line of research aims to analyze different graphical communication strategies regarding risk analysis purposes, as individuals are found to focus on graphical and salient pieces of information in their information processing strategies (Jarvenpaa, 1989). One of the earliest attempts to examine different graphical presentation formats for displaying quantitative information about uncertain values, such as risky returns, is by Ibrekk and Morgan (1987), who suggest displaying both a cumulative probability function and a probability density function. Weber et al. (2005) compare presenting returns as either bar charts or continuous density distributions but find no significant impact on risk perception. In a similar vein, Kaufmann et al. (2013) and Ehm et al. (2014) develop possibilities to better calibrate people's risk perception by experience sampling from return distributions. Nevertheless, these efforts require and imply a known stochastic process underlying the financial instrument of which risk is to be assessed. In real-world applications, however, we have to rely on historical data.

Research regarding different graphical presentation formats of past returns or prices in financial decision-making so far mainly focuses on the question of which presentation formats increase potential investors' forecasting abilities and accuracy. While Diacon and Hasseldine (2007) report higher perceived uncertainty and probability of losing all the money for return charts, Glaser et al. (2007) find that forecasts are higher (lower) for increasing (decreasing) trends and volatility is perceived as lower when subjects are asked for returns. Glaser et al. (2016) compare not only asking for, but also presenting either returns or prices. They find lower expectations when showing return charts. Stössel and Meier (2015) also discuss framing effects of different presentation formats on risk perception, but restrict themselves to different forms of graphical representations in the narrow domain of the KIID.[1]

In an early experiment in which subjects are confronted with groups of lines of varying length Lathrop (1967) finds that perceived variability is driven by order effects. To our knowledge, so far little attention has been paid to the scale of the vertical axis – in particular in presentations of past asset returns and prices, and with regard to risk perception and return expectations in an investment context. Lawrence and O'Connor (1992, 1993) identify a scale and a variability effect on forecasting ability: large scales or high variability in the presented time series lead to overly narrow confidence intervals and vice versa. Questions about the scale's effect on risk perceptions, return expectations, and consequently investment propensities, however, remain unanswered.

Our aim with this paper is to fill this gap and analyze the effect of the form of display – different presentation formats and different scales, in particular – of investment possibilities on subjects' expectations regarding the risk and return of an asset. The research questions we address are whether the presentation format – returns or prices – and the presentation scale – narrow or wide – affect people's risk perception, return expectations, and propensity to invest. We define a chart as having a *narrow* scale when the time series depicted extends close to the upper and lower borders of the chart, while a *wide* scale leaves ample space above and below.

In a laboratory experiment with a 2×2 design we vary the presentation scale (narrow or wide) and the presentation format: assets are presented either as return bar charts or as price line charts. In a within-subjects design, we ask participants to assess the riskiness, expected

[1]In developing the standardized KIID the European Commission employed a survey-based study by IFF Research and YouGov (2009). They mention different axis scales as a possible explanation for people's difficulties in assessing past performance but do not attempt to offer any evidence confirming this intuition.

return, and attractiveness as investment of the assets. In a second task subjects make pairwise comparisons between these assets along the same dimensions as mentioned above.

We find that varying the scale strongly affects people's risk perception, namely, that a narrower scale of the vertical axis leads to significantly higher perceived riskiness of an asset across price and return charts, even if the underlying volatility is the same. Assets are usually perceived riskier when returns are shown than when prices are shown. We demonstrate that adapting the scale to the span of the bars is reasonable with regard to recognizing yearly return variations *within* a single security, but at the same time makes it harder to identify differences *between* dissimilar securities. This result is also robust for different historical return trends. We further find that past returns predict future return expectations almost perfectly irrespective of the scale. In addition, risk perception is highly correlated with losses which in turn drive investment behavior. Concerning investment choices, subjects tend to invest in the asset they regard as more profitable, even if they think it bears higher risk.

2 The Experiment

2.1 Returns and Prices

To systematically vary expected return, time trend, and volatility of percentage return time series we create eight distinct return paths consisting of ten (hypothetical) annual returns each. Each asset's return path consists of a deterministic trend (POSITIVE STABLE, NEGATIVE STABLE, INCREASING, or DECREASING) and a normally distributed noise term $\varepsilon_t \sim N(\mu, \sigma^2)$ with $\mu = 0.0\%$, $\sigma^2 = 1.4\%$ and $t = 1, ...10$. Low-volatility assets consist of a linear return path plus the noise term for each year t. High-volatility assets have the same linear return paths but with the noise term multiplied by six before it is added.

Fig. 1 shows each distinct return trend as a function of time, depicted as RETURN charts (left) and PRICE charts (right). Assets with a POSITIVE STABLE trend are set up to yield positive returns fluctuating around a mean of 3% per year. The return path INCREASING starts at -3% in the first year and linearly increases to $+3\%$ in the tenth year plus a noise term. Assets with trend NEGATIVE STABLE contain the returns of the asset with trend POSITIVE STABLE multiplied by -1; the same relationship applies to assets with trends DECREASING and INCREASING. Price paths are generated by successively applying the corresponding returns to an initial price of 100.

2.2 Experimental Tasks

In the experiment subjects have to complete two main tasks, Task I and Task II. In both tasks participants were instructed to suppose that they want to invest 5,000 euros. Subjects

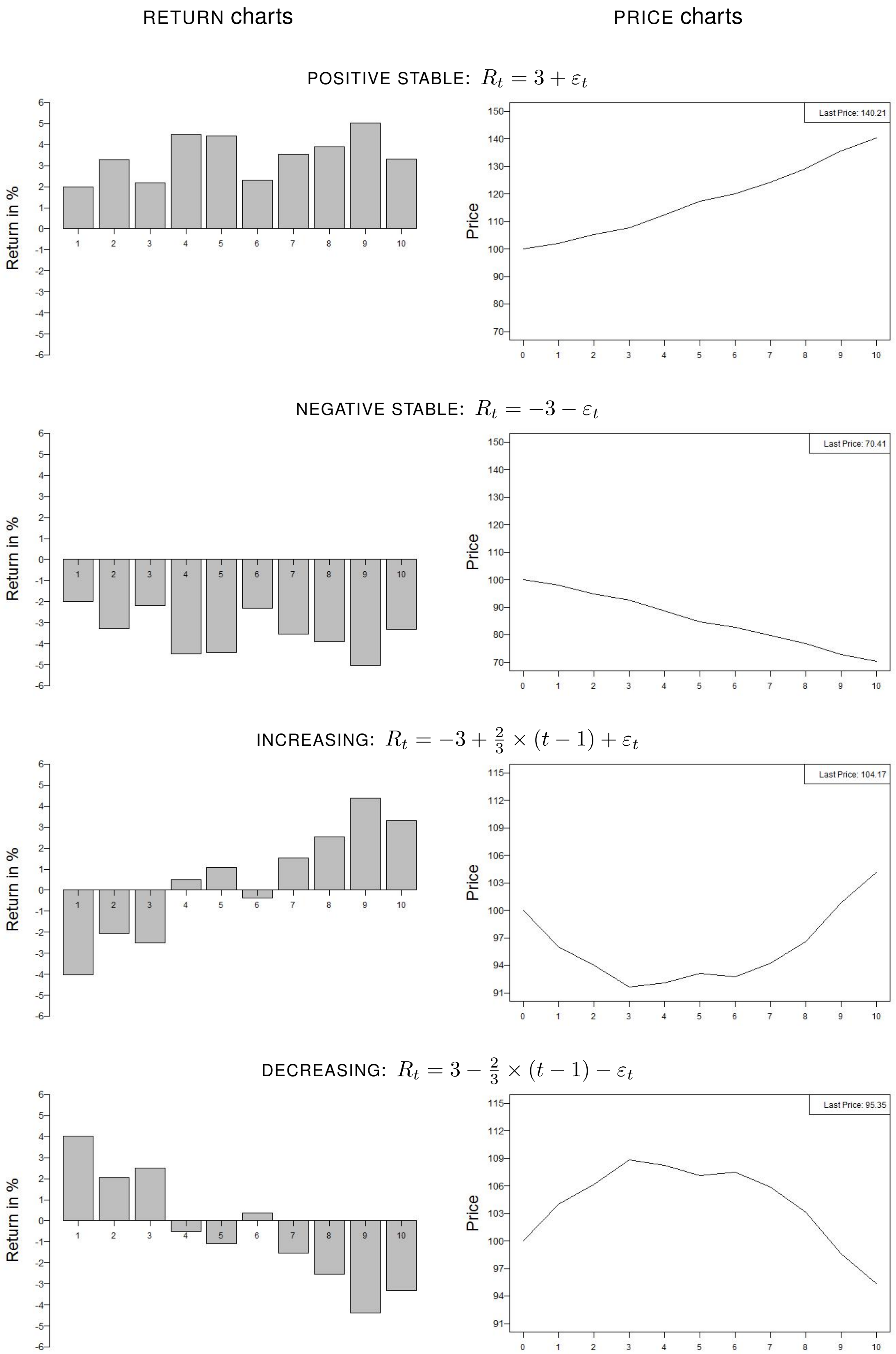

Figure 1: **Return and price paths.** This figure shows the four distinct return trends with the low volatility level as a function of time, depicted as return bar charts (left) and price line charts (right). For high-volatility assets, the added error term ε_t is multiplied by six.

are then presented with charts of hypothetical assets and are asked to assess the respective riskiness and profitability of one asset at a time in Task I, and to compare two assets at a time along these dimensions in Task II. There are two variants for each task: either a return bar representation (RETURN) or a line chart depicting the price development (PRICE).

Task I consists of a 2×2 treatment design in which we vary the presentation format (RETURN or PRICE) and the presentation scale of the vertical axis (NARROW or WIDE) to identify these variables' effect on risk perception as well as on return expectations and investment propensity. Subjects sequentially see eight different paths (RETURN or PRICE) and have to assess the assets' riskiness and estimate its returns over the following year and over the next five years. Whenever subjects are presented with return charts they are explicitly asked about future returns; when they see price charts they are asked to estimate future prices.[2] Each participant was presented with eight out of 16 possible return (price) charts (eight different assets in two different presentation formats, NARROW and WIDE) in which each chart has the same probability of appearing. The order in which participants saw the assets was randomized and participants were not aware of being presented only with a selection of the possible assets.

In Task II subjects make pairwise comparisons between assets regarding their riskiness and expected return. In a 2×2 design the combinations of volatility and scale of the vertical axis are varied in four distinct conditions: same scale/same volatility, same scale/different volatility, different scale/same volatility, and different scale/different volatility. Except for Condition SAME (same scale and same volatility), we name each condition after the variable in which the two charts of a pair *differ*. With this set-up we are able to generate a distinct number of 16 pairs for Condition SAME,[3] four pairs for Condition VOLATILITY, and eight pairs each for conditions SCALE and BOTH. Subjects are presented with a total of eight randomly chosen pairs – two for each condition. In this task, subjects have to compare two assets at a time; again, on the basis of the assets' riskiness, profitability, and investment attractiveness. They are asked to decide which of the two assets they perceive as riskier; which asset they think is more profitable; and which asset they would rather invest in. For each question there is also the possibility to choose the neutral option 'the same for both' (later also referred to as 'indifferent').

For both tasks there are again two variants: In Tasks Ia and IIa subjects are presented with return charts, in Tasks Ib and IIb they see price charts. The order is randomly determined

[2] Glaser et al. (2007) and Glaser et al. (2016) discuss the impact of presenting returns vs. presenting prices and asking for returns vs. asking for prices. We consciously refrain from presenting one format and asking for the other, as the tasks we have seem demanding enough for subjects and we want to rule out potential confusion.

[3] To avoid subjects being asked to compare two identical asset representations in setting SAME (same scale and same volatility), we permute the returns of an asset in a way that preserves the asset's characteristics but generates a marginally different path for comparison. One example can be seen in the first pair shown in Fig. D2 in Appendix D.

and subjects are randomly assigned to one of two groups to eliminate any order effects (see Fig. A1 in Appendix A).

In both presentation formats we vary the scale of the vertical axis to create a NARROW and a WIDE representation of each asset's past performance. In return charts, the maximum value on the vertical axis and the tick size of WIDE-scaled representations are three times the corresponding values of representations with scale NARROW. For price charts the scales are adapted analogously. Fig. 2 shows an example of RETURN charts (top) and PRICE charts (bottom), each with presentation scales NARROW (left) and WIDE (right). In each return (price) chart the value zero (100) as well as each tick (with precise values depending on asset and scale) is at exactly the same position in the graph to maintain consistency. Additionally, in order to reduce noise in estimating prices we provide the last price in the upper right corner of price charts (Glaser et al., 2016). In the experimental instructions, we explicitly point out that the scale of the vertical axis might change over the course of the experiment. This note also appears when subjects review the on-screen instructions at any point in time during an experimental task. This prominently-placed reminder should ensure that our results are not driven by subjects' inattention to the scale. To guarantee subjects' understanding of the term 'return' we also include a definition stating that the return is defined as the percentage change of the price over one year.

Table 1 summarizes the asset- and chart-specific variables and respective options: each chart is a distinct combination of volatility, trend, presentation format, and scale.

Table 1: **Summary of variables in each performance chart.** This table summarizes the relevant variables in specific to assets and charts: the volatility and trend of an asset, and the presentation format and scale of a chart.

	Variable	Possible Options
Asset specific	Volatility	LOW or HIGH
	Trend	POSITIVE STABLE, NEGATIVE STABLE, INCREASING, or DECREASING
Chart specific	Presentation format	RETURN or PRICE
	Scale (vertical axis)	WIDE or NARROW

2.3 Implementation of the Experiment

We conducted nine experimental sessions with a total of 193 students of business administration or economics in May and June 2017 at Innsbruck EconLab at the University of Innsbruck. The experiment was programmed and conducted using oTree by Chen et al. (2016). Subjects were recruited with hroot by Bock et al. (2014). 45% of the subjects were female; the mean

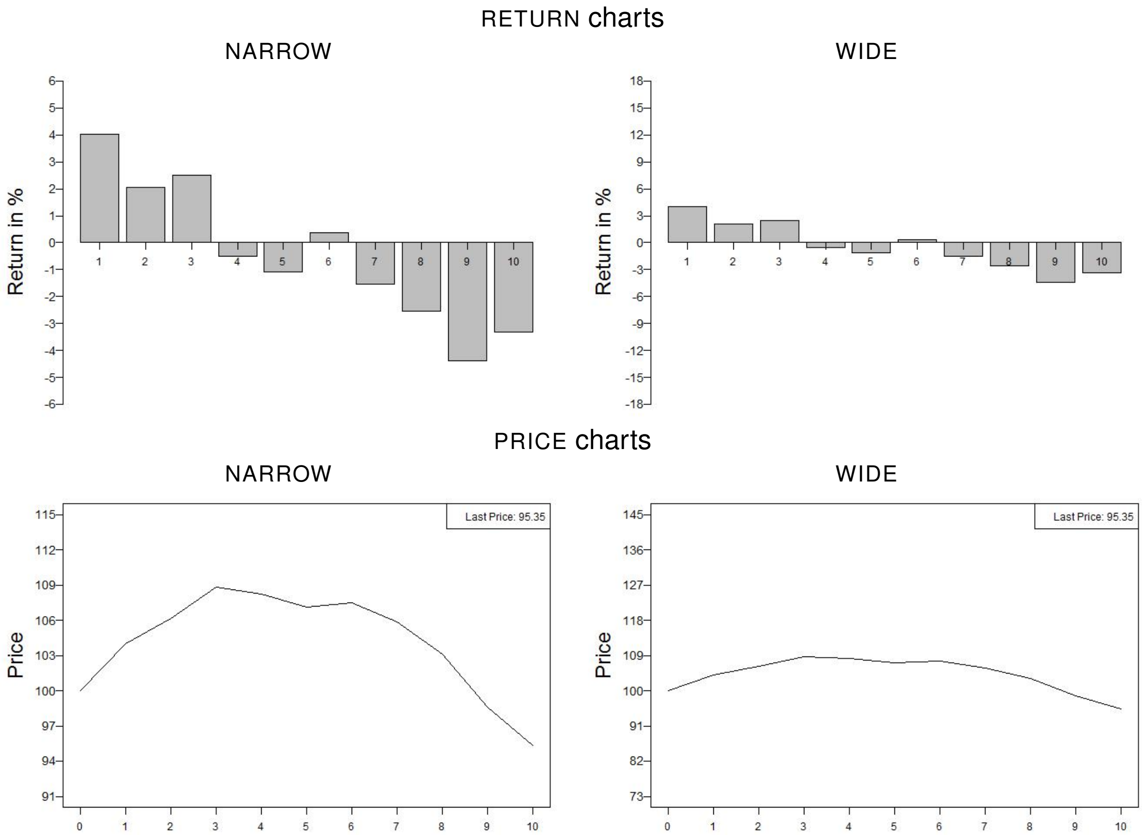

Figure 2: **Exemplary representations of the low-volatility asset with trend decreasing in a return chart (top) and a price chart (bottom) for presentation scales narrow (left) and wide (right).** This figure shows examples of our treatment variation in the charts' vertical axis scale – NARROW (left) or WIDE (right) – in RETURN charts (top) and PRICE charts (bottom). For return charts the value zero and for price charts the initial price of 100 as well as each tick are at the same positions for both scales. In return bar representations the tick size on a WIDE scale is three times the one on a NARROW scale; tick sizes in price representations are adjusted accordingly.

age was 23; and about 51% of subjects had completed an undergraduate course in financial management.

In total, each session lasted approximately 40 minutes. This included studying on-screen instructions for each part of the experiment as well as a multiple price list task measuring subjects' risk attitudes (Holt and Laury, 2002) and a certainty equivalence task to assess loss aversion (Gächter et al., 2007) using oTree applications by Holzmeister (2017). After the main experiment subjects completed a questionnaire assessing their risk attitudes and demographics. A graphical overview of the experimental procedure, as well as the experimental instructions, screenshots of the decision tasks, and exemplary charts for each condition are provided in Appendices B, C, and D.

Subjects are incentivized by being paid one randomly chosen return of the asset they chose to rather invest in in one randomly chosen pair they were presented with for both parts of Tasks II (prices and returns).[4] The chosen return times two is added to an initial amount of 5 euros for each task. For example, if the chosen asset of the randomly drawn pair pays 10% in the randomly drawn year, the participant receives 5 euros $\times(1+2\times 0.10) = 6$ euros for this task. Total payouts varied between 6.30 euros and 16.30 euros with a mean of 11.65 euros; these include payouts from the risk and loss aversion tasks.

3 Results

We organize the presentation of results as follows: first we analyze perceived risk, starting with individual risk perception (Task I), and continuing drivers of perceived risk. We then turn to the pairwise comparison of perceived risk (Task II). Subsequently, the same structure of analyzing first Task I (individual assessment) and then Task II (pairwise comparison) is repeated for expected returns and then for investment propensity.

3.1 Risk perception in individual assessments

We start our discussion by examining the influence of the scaling of the vertical axis on risk perception in Task I, where each asset is shown and assessed separately. We present analyses along the following dimensions: for both presentation formats (RETURN and PRICE charts) we compare the influence of scaling of the vertical axis (WIDE vs. NARROW). To get a comprehensive picture we do this separately for the four different return trends (POSITIVE STABLE, NEGATIVE STABLE, INCREASING, and DECREASING), where we have each return trend once with a low and once with high level of return volatility (LOW or HIGH).

[4] The return R of year $t \in [1, 10]$ of the chosen asset of pair $p \in [1, 8]$ in presentation format $F \in$ {RETURN, PRICE}; if subjects are indifferent between two assets, either A or B is chosen randomly. For each of the two tasks they receive 5 euros$\times(1 + 2 \times R^F_{t,p})$.

Fig. 3 shows the differences in average perceived risk (elicited on a scale from 1 to 7) for each asset from RETURN charts (left panel) and PRICE charts (right panel). The differences are from the same asset being displayed once with a WIDE and once with a NARROW scale.[5] The four bars in each group of bars represent the four different trends; LOW volatility is shown in the left group of each panel while HIGH volatility is shown in the right group of each panel. For all assets, except those with a POSITIVE STABLE trend, a NARROW scale leads to higher perceived risk compared to a WIDE scale. This holds for both presentation formats and both volatility levels. To test the statistical significance of the differences between charts with NARROW and WIDE axis scales, we run Fisher-Pitman permutation tests on the subject-demeaned data.[6] 10 out of 12 tests for assets other than with a POSITIVE STABLE trend deliver p-values of 0.02 or smaller (the remaining two having p-values of 0.09 and 0.11, respectively), corroborating that assets are perceived riskier when presented on a NARROW scale where fluctuations are thus easier visible. We conjecture that the non-difference in the POSITIVE STABLE trend results from the fact that these always-positive returns (monotonically increasing prices, respectively) are never perceived as risky, no matter how they are displayed or whether they fluctuate more. We will revisit this finding when we talk about drivers of risk perception in the next section.

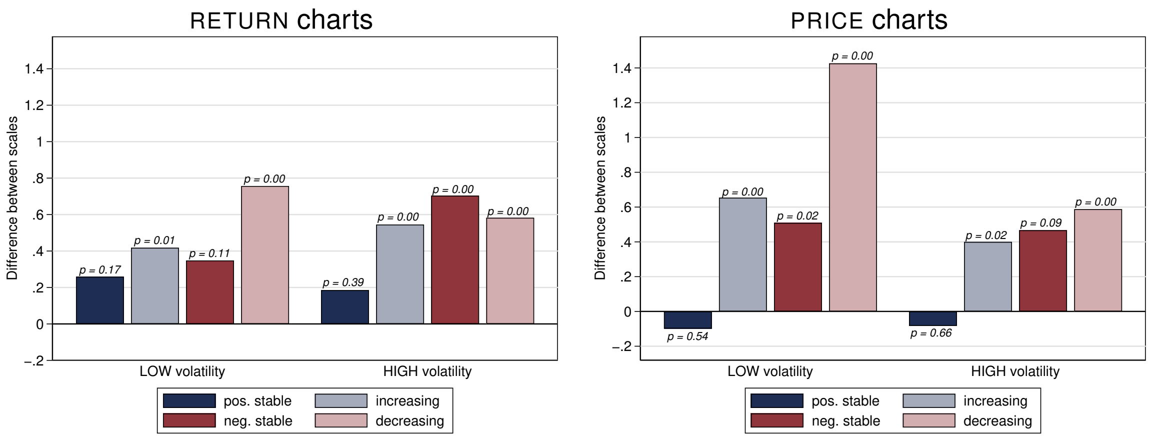

Figure 3: **Differences in average perceived risk (in NARROW minus WIDE) by trend and scale presented as return charts (left) and price charts (right).** This figure depicts differences in average perceived risk (on a scale from 1 = "not risky at all" to 7 = "very risky") for RETURN chart and PRICE chart representations of LOW (left bars in each panel) and HIGH (right bars in each panel) volatility assets. p-values above the bars are from Fisher-Pitman permutation tests on the subject-demeaned data.

[5]As the probability of appearance of one particular chart is determined randomly for each subject, the number of observed decisions for each distinct combination of presentation format, volatility, and trend varies between 179 and 206.

[6]Each subject sees a potentially different selection of charts. Hence, to establish independence between observations we subtract the mean across all of a subject's risk assessments from each data point. We then run non-parametric Fisher-Pitman permutation tests on these subject-demeaned data with 300,000 simulations as a more powerful alternative to Wilcoxon-Mann-Whitney tests (Kaiser, 2007). If not stated otherwise, we use the same procedure throughout the paper. Wilcoxon sign-rank tests on the matched pairs of the original observations yield similar results, see Table A2 in Appendix A.

As we specifically make subjects aware of varying axis scales in the instructions, and as we find no relationship between the differences in risk perception and the time it took subjects to complete all related tasks,[7] we attribute the reported differences in perceived risk to the differences in axis scales, as the differences seem not to stem from subjects being unaware of the varying axes or inattentively clicking through the tasks.

Regarding different return paths we observe that the POSITIVE STABLE trend is seen as the least risky one with average assessments between 2.08 and 3.51 on a 7-point scale, whereas NEGATIVE STABLE and DECREASING trends are viewed as carrying the highest risk (average riskiness assessments between 4.52 and 5.94) with trend INCREASING being in-between across all presentation formats (see Table 2).[8] This implies that an asset's volatility (standard deviation of returns) does not necessarily determine people's perceptions about its risk: e.g., for trend NEGATIVE STABLE we find no difference in perceived risk between the LOW and HIGH-volatility assets in return and price charts ($p = 0.17$ and $p = 0.40$) – even though their volatility differs by a factor of six. Furthermore, the standard deviation is the same for NEGATIVE STABLE and POSITIVE STABLE, but they are at opposite ends regarding perceived riskiness. Clearly, subjects perceive losses (negative returns) as *risk*, while profits are perceived as not risky, even if they vary by the same amount as losses do.

One remarkable finding with potentially important implications for practitioners and regulators is that people perceive risk as significantly higher when presented with RETURN charts as compared to PRICE charts (all differences have the same sign; five out of eight p-values are significant at $p < 0.01$, see Table 2). The observed effects of either a NARROW or a WIDE scale reported above are robust to the presentation format and take comparable magnitudes in both, RETURN and PRICE charts, but there is a level effect, with risk usually being perceived as significantly higher when the presentation format is RETURN charts. While most stock information systems usually present price charts, the EU demands that the KIID contains return charts of a fund's preceding ten years. If the regulator's intention is to ensure that investors act carefully, this approach seems sensible and likely to achieve the intended goal. However, while return charts tend to elevate perceived risk, we cannot tell whether people's risk assessments become more accurate as a result.

Our data also allows us to contribute to the ongoing discussion on which factors drive risk perception. Previous research has found that asset characteristics other than historical or theoretical standard deviation drive risk perception (e.g. Unser, 2000; Veld and Veld-Merkoulova, 2008; Anzoni and Zeisberger, 2016). We consider the relationship between possible alternative determinants of risk and subjects' perceived risk. Fig. 4 plots average perceived risk as a function of historical standard deviation, average historical return, maximum loss, last return, expected value of loss, and loss probability. One can easily see that standard deviation

[7] Pearson's correlation coefficients ρ are between –0.10 and 0.14 across presentation formats and volatilities.

[8] $p < 0.01$ for 22 out of 24 pairwise comparisons between trends; for details see Table A6 in Appendix A.

Table 2: **Risk perception in return and price charts.** This table shows the perceived risk for each of the eight assets in RETURN and PRICE charts, pooled across scales. The lines 'Diff.' show the average differences. *, **, and *** indicate the 10%, 5% and 1% significance levels of two-sided Fisher-Pitman permutation tests on the subject-demeaned data.

	LOW volatility			
	POS. STABLE	NEG. STABLE	INCREASING	DECREASING
RETURN	2.09	5.87	4.01	5.32
PRICE	2.08	5.17	3.76	4.52
Diff.	0.01	0.70***	0.25	0.80***

	HIGH volatility			
	POS. STABLE	NEG. STABLE	INCREASING	DECREASING
RETURN	3.51	5.94	4.37	5.69
PRICE	2.93	5.43	4.24	5.31
Diff.	0.58***	0.51***	0.13	0.38***

is indeed unable to sufficiently explain the risk subjects perceive. In contrast, we observe strong correlations between perceived risk and asset characteristics associated with returns, in particular with losses.[9] This is in line with recent literature (e.g. Anzoni and Zeisberger, 2016; Huber et al., 2018) who report that probability of loss is the main driver of perceived risk. With an R^2 of 0.84 the loss probability also has the highest explanatory power of the factors we consider in Fig. 4. Note that this finding is at odds with most of the neoclassical finance literature which uses standard deviation of returns as the main risk measure.

3.2 Risk perception in pairwise comparisons

In Task II subjects were asked to compare two assets displayed on the screen at the same time. We asked for perceived riskiness ("Which of the two assets do you consider to be more risky?"), perceived profitability ("Which of the two assets do you consider to be more profitable?"), and investment propensity ("In which of the two assets would you rather invest?"). In four different conditions the two displayed assets vary by neither scale nor volatility (Condition SAME), only in volatility (VOLATILITY), only in the scale of the vertical axis SCALE, or by both (BOTH), respectively, but the two assets shown always share the same presentation format and trend. Subjects compare assets eight times with RETURN charts and eight times with PRICE charts. We first present the results from RETURN charts and then the ones from PRICE charts. For an investment decision this pairwise comparison could be a more natural setting than Task I, as people (hopefully) consider more than one investment possibility before deciding to invest in one particular financial instrument.

[9] Note that – given our experimental set-up – these characteristics are highly correlated. Therefore, we are unable to identify which of these characteristics is the driving force behind perceived risk.

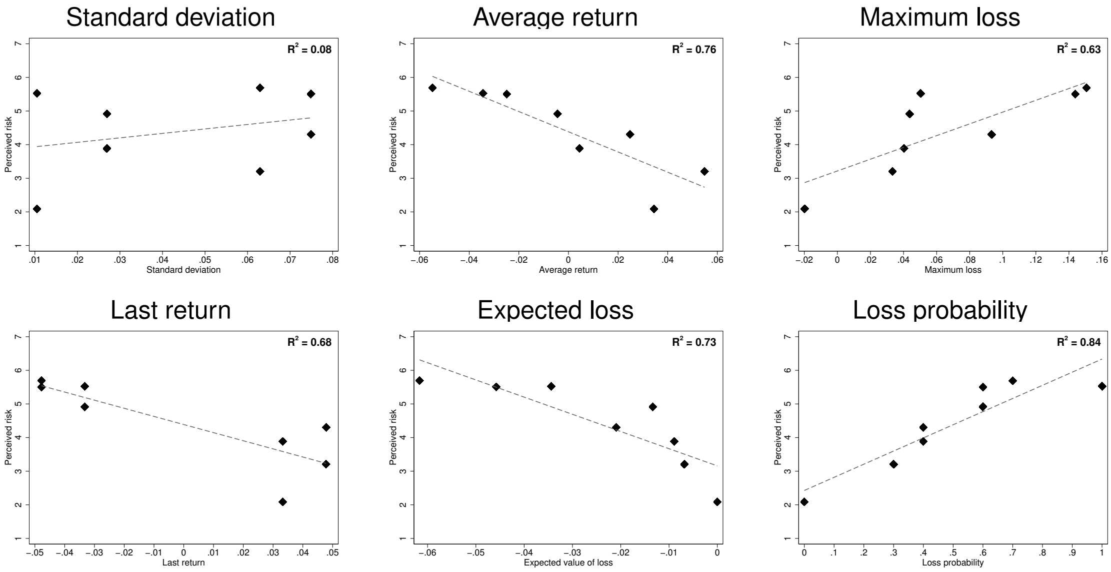

Figure 4: **Some potential determinants of perceived risk.** This figure shows scatter plots for the average perceived risk (depicted on the vertical axis) observed as a function of potential determinants associated with risk perception (depicted on the horizontal axis) and corresponding R^2 on the top right of each panel. Potential risk drivers analyzed are standard deviation, average return, maximum loss, last return, expected loss, and loss probability.

Fig. 5 summarizes the results of Task II for perceived riskiness for RETURN charts (left panels) and PRICE charts (right panels). Each panel shows the four distinct trends (POSITIVE STABLE, INCREASING, NEGATIVE STABLE, and DECREASING) and from top to bottom we show data for the four conditions SAME, SCALE, VOLATILITY, and BOTH. Each bar shows the percentage of decisions in which subjects perceive the risk as the same (light grey) or different (black in the top row of panels; dark and light red in the second row for NARROW vs. WIDE scaling, and dark vs. light blue in the bottom two rows for the high- vs. low-volatility asset being perceived as more risky.)

From the first row of panels we see that even when the two displayed assets have the same volatility and there is no difference in the scale, a surprisingly high share of between 23% and 60% of subjects (wrongly) perceive risk differently between the two assets. The share who perceives the risk differently is significantly higher for INCREASING and DECREASING trends than for POSITIVE STABLE and NEGATIVE STABLE trends ($p < 0.01$).[10] This holds for RETURN as well as PRICE charts.

The second line of panels of Fig. 5 shows the distribution of choices for Condition SCALE, i.e. when the asset volatility is the same but the scale is different (NARROW on one side, WIDE on the other). One could argue that this is the 'trap' case where two identical assets are shown

[10] For comparisons between different choices and conditions in the pairwise comparisons of Task II we conduct two-sided Wald tests on the respective proportions and report the corresponding p-values in parentheses.

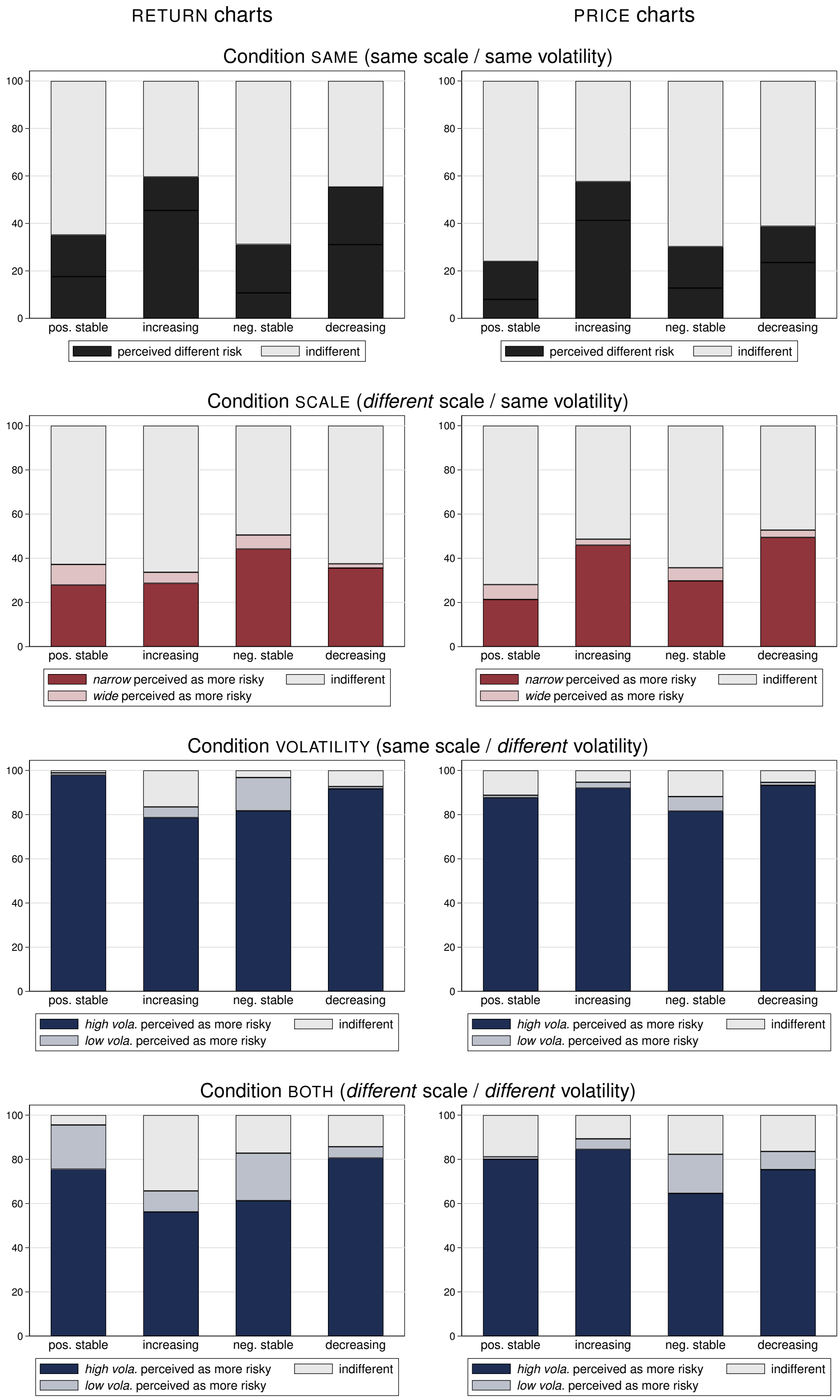

Figure 5: **Perceived riskiness in Task II.** This figure shows the percentage of decisions in which subjects perceive the riskiness the same or differently between different scalings and volatilities. The left panels show data for RETURN charts, while the right panels show the respective data for PRICE charts. From top to bottom we show the four different conditions, where the condition name corresponds to the variable in which the two assets of a pair *differ*: SAME (same scale / same volatility), SCALE (different scale / same volatility), VOLATILITY (same scale / different volatility), and BOTH (different scale / different volatility). In Condition SAME, the two charts differ by neither scale nor volatility. Each of the eight panels summarizes between 314 and 386 observations.

with different scaling to see whether subjects can be misled and thus perceive the asset shown with the narrower scale as more risky. This is indeed the case in 22% to 42% of all cases, while the asset with the wider scale is perceived as riskier in only 2% to 9% of all cases (in the remaining cases subjects are indifferent – most likely correctly seeing that only the scaling is different between both sides). Results are similar for RETURN and PRICE charts.

In the third row of panels of Fig. 5 we present the case where the volatility of the two assets varies by a factor of six while the scale is the same (Condition VOLATILITY). Here, both assets are displayed on exactly the same axes and it should thus be comparatively easy to identify the more volatile asset and, if volatility is perceived as 'risk', also to identify this asset as the riskier one. We find that with a POSITIVE STABLE trend in RETURN charts, almost 100% of subjects do exactly that. We also report very high shares of 90% and above identifying the more volatile asset as the riskier one for DECREASING trends, both in RETURN and PRICE charts, and for POSITIVE STABLE and INCREASING trends in PRICE charts. For INCREASING trends in RETURN charts we find 18% of subjects to be indifferent between the two assets – most likely as both trends start negative and then mostly increase, which is perceived as equally good, irrespective of volatility. An interesting case are the NEGATIVE STABLE trends, especially for RETURN (but also, to a lesser degree, for PRICE) charts: here around 20% do not see the less volatile asset as the less risky one – for RETURN charts, 16% even consider the more volatile asset as less risky. We conjecture that this is the case as all returns in the low-volatility case are clearly negative – hence, an investor always loses with this asset. With high volatility, the dispersion of returns is much wider and thus the chance of earning a positive return is also higher. The corresponding asset is therefore perceived as less risky in about every sixth decision.

Finally, the fourth row of panels in Fig. 5 displays the choices in Condition BOTH, where the shown assets again vary by their volatility and additionally by their scaling. Note that in the pairwise comparisons of Task II a varying scale means that the values on the axis are different – that is, as in Condition BOTH one side depicts a low-volatility asset and the other a high-volatility asset, hence different scales lead to both assets being displayed either on a WIDE or on a NARROW scale with the respective bars having comparable magnitudes. Comparing these values to the third row of panels we see that the choices are now more dispersed. While the high-volatility asset is still perceived as the more risky one in the majority of cases (between 56% and 83% of cases), 'indifferent' (up to 35%) and a preference for the low-volatility asset (up to 21% of cases) are chosen markedly more frequently than when the scaling is the same. In this condition, results between and within RETURN and PRICE charts vary more than in other settings. In trend POSITIVE STABLE the more volatile asset is seen as the riskier one in around 80% of decisions for both chart types. However, of the remaining 20% almost all see the low-volatility asset as the riskier one when returns are displayed while this is almost never chosen with prices – here, almost 20% choose 'indifferent.' We conjecture that with RETURN charts, the 20% who consider the low-volatility asset as more risky are misled by the different scalings. With PRICE charts, the 20% of subjects who are indifferent obviously perceived the high-volatility asset shown with WIDE scaling as equally risky as the low-volatility asset displayed with NARROW scaling – arguably a 'misperception.'[11]

Comparing two assets with INCREASING trends, a remarkably high share of 33% of subjects are indifferent between the high- and low-volatility assets with RETURN charts (for PRICE charts the respective number is only 11%). We argue that for these subjects the main decision criterion is the clear upward trend in returns, while the details of the vertical axis scale and the exact numbers playes a smaller role. With PRICE charts, however, the difference is easier to identify, as the final price (lower for the low-volatility asset) is also displayed on the screen.

With trend NEGATIVE STABLE (third bar) a significantly higher share of subjects picks the less volatile asset as the riskier one than in any other trend bar POSITIVE STABLE when RETURN charts are shown (all other $p < 0.05$). This holds for RETURN as well as PRICE charts. The particularly high shares of 21% and 19%, respectively, in RETURN and PRICE chart representations hint at losses being a driving force behind risk perception as all returns are negative in the low-volatility asset but not in the high-volatility one. Hence, in the NEGATIVE STABLE trend, having more volatile returns increases the chance that an investor could end up with a positive return. The substantial share of 'indifferent' answers we observe for trend NEGATIVE STABLE (around 20%), when both scaling and volatility are different, might result from the fact that the wider scaling counterbalances the higher volatility and probably leads some subjects to judge the two assets as fairly similar in risk when their volatility actually varies by a factor of six.

When we compare the perceived riskiness assessments vertically, i.e. comparing the same price trends across the four different conditions (SAME, SCALE, VOLATILITY, and BOTH), the upper two (with equal volatility) and the lower two (with volatility differing by a factor of six), respectively, form 'natural pairs.' We see many similarities, but also numerous systematic and significant differences. Specifically, in the lower pair comparing VOLATILITY and BOTH, we see that the share of subjects perceiving the low-volatility asset as the riskier one is always higher in BOTH than in VOLATILITY. Most likely this can be attributed to the task of assessing comparative risk being more demanding when the scaling is different on the vertical axis. In addition, also the share of subjects who were indifferent between the two assets is always higher in BOTH than in VOLATILITY – even though volatility is six times larger for one of the two assets displayed. As a consequence of more people being indifferent or considering the low-volatility asset as the riskier one, the share of subjects identifying the high-volatility asset as the riskier one is significantly lower ($p < 0.05$) in BOTH than in VOLATILITY in 6 out of 8 pairwise tests.

[11] We want to tread carefully here, though, as perceptions of people should not be judged as 'correct' or 'incorrect', but are by definition subjective.

When comparing the upper two panels, displaying conditions SAME and SCALE, we observe a high share of 40% to 70% of 'indifferent' choices between the two assets (who actually have the same volatility and trend and thus very similar or identical characteristics). However, that leaves up to 60% who see one of the two assets as less risky. Especially for the INCREASING trend subjects often express a preference for one asset – mostly for the one shown with the narrow scale in Condition SCALE.

3.3 Expected returns in individual assessments

Besides eliciting subjects' perceptions about risk we also asked participants to enter point estimates of future returns (when RETURN charts were shown) or future prices (when PRICE charts were shown) for a shorter (one year) and a longer (five year) horizon for each asset shown in Task I.[12]

We discuss short-term (1-year) forecasts first. The upper panels of Fig. 6 depicts the median one-year-ahead return expectations for each asset (vertical axis) in relation to the last return (horizontal axis) in both presentation formats for scales WIDE and NARROW. Short-term return forecasts are clearly not the same across assets, but strongly depend on the last return. Subjects thus seem to behave as short-term trend-followers. With an R^2 of 0.97 and a slope of 0.76 the past return almost perfectly explains return predictions when RETURNS are shown (upper-left panel of Fig. 6). When PRICES are shown (right panel) there is more dispersion, especially when the last return is negative. Still, with a slope of 0.98 and a R^2 of 0.85 the last return is a very good predictor of expected returns. In both presentation formats we do not find a systematic influence of the scale (NARROW or WIDE).

We also asked subjects for their 5-year return prediction (return per year); respectively price-prediction (price in 5 years). For RETURNS we find a very similar and consistent pattern to the 1-year-predictions where the last return is again a very good predictor with a slope of 0.82 and an R^2 of 0.90 (see lower panels of Fig. 6).

Returns calculated from PRICE predictions also show a strong positive relation between last return and expected return. However, with a slope of 0.42 and an R^2 of 0.50 the relation is markedly flatter and weaker than for the 1-year price data or the RETURN data. In contrast to Glaser et al. (2007) and Glaser et al. (2016) we find that even for five-year-ahead forecasts, on average participants do not expect trend reversals to the extent of a change in signs – we only find that the slope calculated from PRICES is only half as steep as for the 1-year forecasts.

[12] As mentioned above, we consciously refrain from presenting one format and asking for the other – i.e., we ask for returns when presenting returns and ask for prices when presenting prices. For the analysis we only consider returns, either directly from subjects' return estimates or calculated as the average annual difference between price estimates and the most current price.

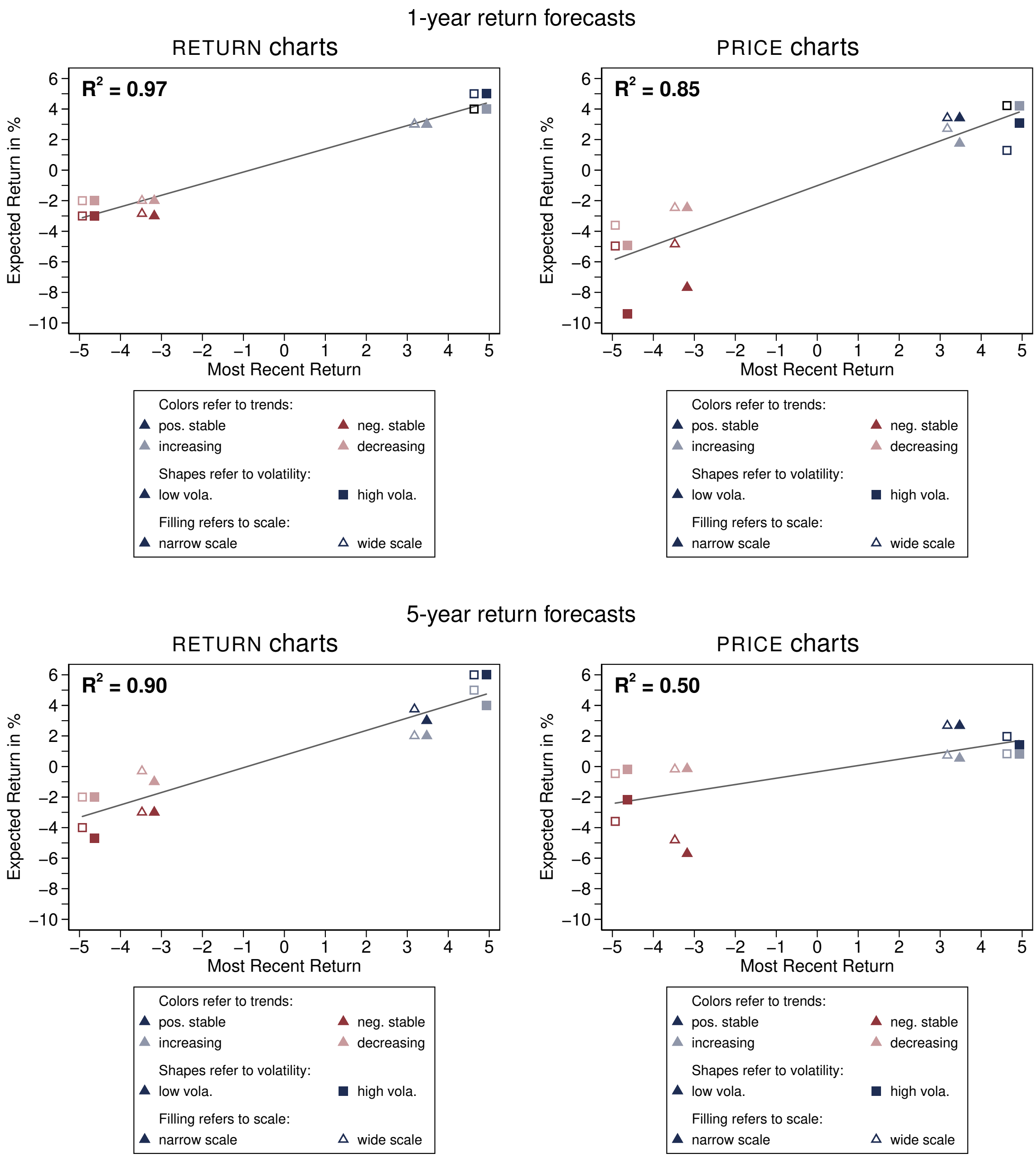

Figure 6: **Median one-year and five-year return forecasts.** This figure shows the median one-year (upper panel) and five-year (lower panel) return forecasts as a function of the most recent return, i.e. the return in Year 10. For better visibility, i.e. to avoid overlapping medians, we add 0.15% to the most recent return of scaling NARROW and deduct 0.15% for those of scaling WIDE on the horizontal axis.

3.4 Perceived profitability in pairwise comparison

We now turn to the comparison of perceived profitability when participants compare two assets at a time in Task II. With the same color codes and setup as in Fig. 5 above, Fig. 7 depicts the share of answers in which subjects perceive one asset as more profitable than the respective other asset (or are 'indifferent'). Again, each panel shows results from the four distinct trends (POSITIVE STABLE, INCREASING, NEGATIVE STABLE, and DECREASING) and from top to bottom we depict data for the four conditions: SAME, SCALE, VOLATILITY, and BOTH. Each bar shows the percentage of decisions in which subjects perceive the two assets as equally profitable (light grey) or not (black in the top row of panels; dark and light red in the second line for NARROW vs. WIDE scaling, and dark vs. light blue in the bottom two lines for the high- vs. low-volatility asset being perceived as more profitable).

In the top row of panels, showing results for Condition SAME, where the two displayed assets have the same volatility and there is no difference in scaling, between 35% and 72% still state a difference in perceived profitability, even though the two assets are essentially identical. The patterns observed, both with RETURN charts (left panels) and PRICE charts (right panels) are almost identical to the ones from perceived riskiness in Fig. 5.

When volatility and expected returns are the same but the charts are shown with different scaling (Condition SCALE; see second row of panels in Fig. 7), we find that between 49% and 73% of subjects (correctly) see no difference in profitability. However, up to 51% do see a difference. For the POSITIVE STABLE and INCREASING trends (first two bars of each panel) the results are again similar as for perceived riskiness – the asset shown with narrow scaling is perceived as the more profitable one as the (mostly positive) bars are displayed larger here. For the NEGATIVE STABLE and DECREASING trends, however, we find a marked difference: those 35% to 50% of subjects who do perceive a difference in profitability identify the asset displayed with wide scaling as more profitable – the mostly negative returns are shown with smaller bars and subjects are misled to think these are thus more profitable. Subjects fall into this 'trap' in between 20% and 38% of all decisions.

The third row of panels of Fig. 7 presents Condition VOLATILITY, in which the volatilities of the two assets vary by a factor of six while the scaling is the same. With PRICE charts this translates to more extreme prices in the last year for HIGH-volatility assets – that is, the HIGH-volatility asset yields higher prices with trends POSITIVE STABLE and INCREASING and lower prices with trends NEGATIVE STABLE and DECREASING (compared to the respective LOW-volatility assets). While almost 100% of subjects perceive the asset with the higher volatility as the riskier one with a POSITIVE STABLE trend in Fig. 5, we find 21% of subjects to assess the less risky asset as the more profitable one in this trend with RETURN charts. Obviously, for profitability assessments a lower volatility is also taken into account by subjects. Most notably, however, is that again we observe the same pattern as above: for POSITIVE STABLE

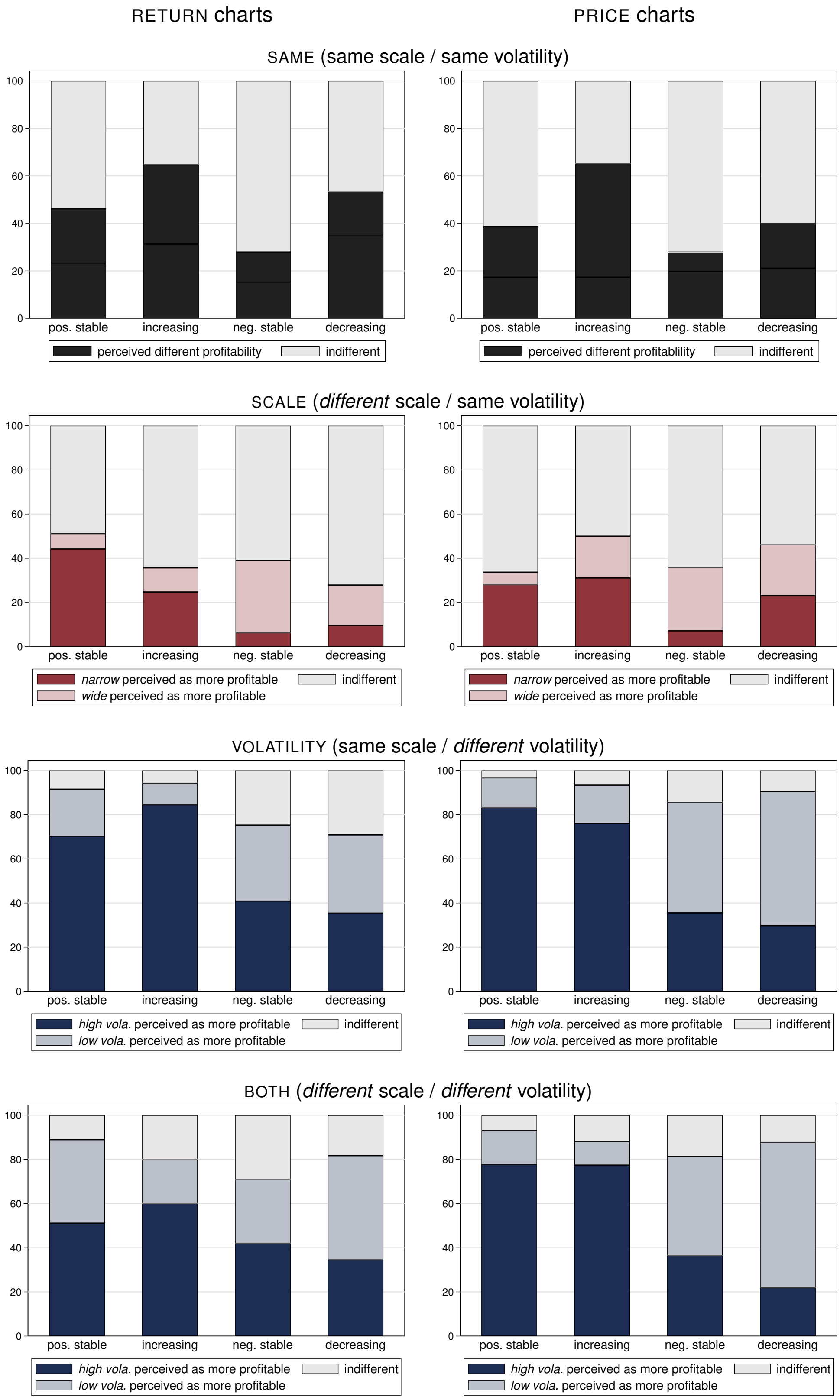

Figure 7: **Perceived profitability in Task II.** This figure shows the percentage of decisions in which subjects perceive the profitability the same or differently between different scalings and volatilities. The left panels show data for RETURN charts, while the right panels show the respective data for PRICE charts. From top to bottow we show the four different conditions, where the condition name corresponds to the variable in which the two assets of a pair *differ*: SAME (same scale / same volatility), SCALE (different scale / same volatility), VOLATILITY (same scale / different volatility), and BOTH (different scale / different volatility). In Condition SAME, the two charts differ by neither scale nor volatility. The number of observations varies between 314 and 386 observations.

and INCREASING trends (first two bars of each panel), most subjects perceive the more volatile asset as the more profitable one (as the returns bars are mostly positive, respectively the price mostly goes up), while for the NEGATIVE STABLE and DECREASING trends (last two bars of each panel), the opposite holds and the mostly negative returns/falling prices lead subjects to select the low-volatility asset as the more profitable one. For the latter two price trends the 'indifferent' choices are also markedly higher than for the positive price trends ($p < 0.01$ for RETURN charts, $p < 0.05$ for PRICE charts) – probably because subjects see both assets markedly going down and consider this a decision 'between a rock and a hard place', i.e. a choice between two equally bad alternatives.

Finally, in the fourth row of panels of Fig. 7 we display the choices from Condition BOTH, where the volatility and also the scaling vary between the two displayed assets. We find high shares of 28% to 66% of decisions in which subjects consider the asset with the lower volatility to be the more profitable one in the NEGATIVE STABLE and DECREASING trends. In addition, also in the two other trends (first two bars) the share of subjects considering the low-volatility asset as the more profitable one is substantial, especially when RETURN charts are displayed. These shares of up to 40% are markedly higher than the respective shares in Fig. 5 ($p < 0.01$).

When comparing the perceived profitability assessments vertically – i.e., we compare the same trends across the four different conditions (SAME, SCALE, VOLATILITY, and BOTH) – the upper two (with equal volatility) and the lower two (with volatility differing by a factor of six), respectively, again form 'natural pairs.' While we mostly see similarities, the differences are much less pronounced than in the risk assessment task: in the upper pair of panels we observe comparable shares of 'indifferent' choices with minor exceptions, e.g. for assets with INCREASING trend. For the lower pair, comparing VOLATILITY and BOTH, we see the choices to be quite similar as well: in the POSITIVE STABLE and INCREASING trends the majority of subjects consider the more volatile asset to be more profitable (both for RETURN as well as PRICE charts), while for the rightmost two bars, displaying NEGATIVE STABLE and DECREASING trends, large shares (mostly more than 50%) of subjects stating a preference considering the low-volatility asset as the more profitable one. We conjecture that both patterns are mostly due to the fact that during upward trends, high volatility (and thus larger bars) are welcome, while during downward trends, smaller bars (hence, smaller price drops) are preferred. Thus, the display mode in conjunction with the prevailing price trend defines which assets subjects consider as more profitable.

3.5 Investment preferences in individual assessments

We elicit subjects' propensities to invest (on a scale from 1 to 7) for each of the displayed return and price charts. Unsurprisingly, these are negatively related to perceived riskiness,[13]

[13] With a Spearman's rank correlation coefficient of –0.68 the relationships are far from perfect, though.

i.e. assets with a POSITIVE STABLE trend are the ones subjects would most like to invest in, while those with NEGATIVE STABLE trends are least preferred. What we are interested in, however, is, whether there are differences in investment preferences between scales (NARROW vs. WIDE), i.e. whether the differences in risk perception we report in Section 3.1 translate into differences in investment propensities. Fig. 8 summarizes subjects' answers by displaying the differences in average investment propensity (value in NARROW minus value in WIDE) by trend and scale presented as RETURN charts (left) and PRICE charts (right; the p-values above/below the bars are from Fisher-Pitman permutation tests on the subject-demeaned data). We see that only for DECREASING trends in PRICE charts we do find a significant difference, i.e. more investments when these are displayed with a WIDE scaling, while the other 14 tests do not yield significant differences. Hence, we do not find large, systematic differences between scales regarding their investment propensity.[14]

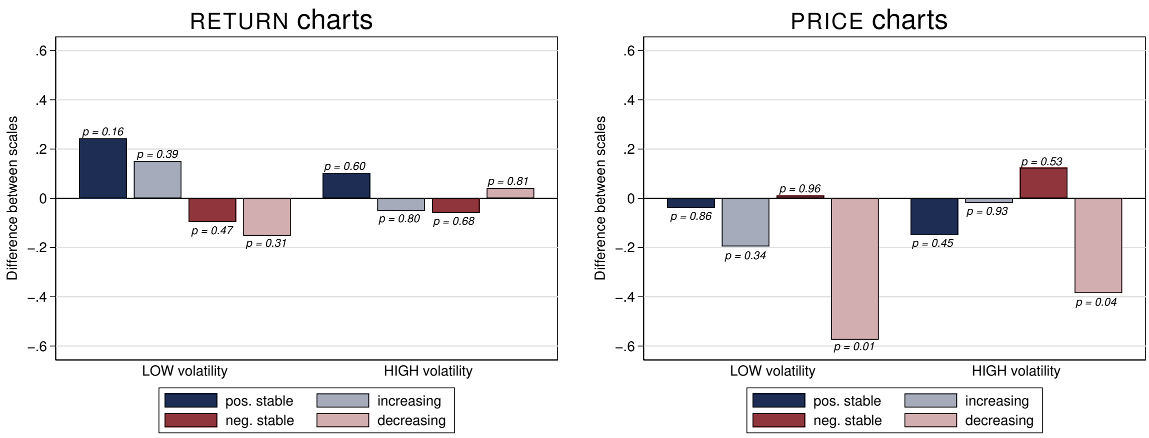

Figure 8: **Differences in average investment propensity (in NARROW minus WIDE) by trend and scale presented as RETURN charts (left) and PRICE charts (right).** This figure depicts differences in average investment propensity (on a scale from 1 = "very unlikely to invest" to 7 = "very likely to invest") for RETURN chart and PRICE chart representations of LOW (left bars in each panel) and HIGH (right bars in each panel) volatility assets. p-values above the bars are from Fisher-Pitman permutation tests on the subject-demeaned data.

In an attempt to explain investment behavior more generally, Nosić and Weber (2010) and Kaufmann et al. (2013) point out that in a behavioral risk-return framework risk taking – and therefore being willing to invest in risky assets – is driven not just by the historical return and volatility of an asset, but by the investor's risk attitude, her risk perception, and her subjective return expectation regarding the asset: thus, *Risk Taking* = f(*Perceived Return; Risk Attitude; Perceived Risk*) (also see Sarin and Weber, 1993; Jia et al., 1999). We therefore run ordinary least squares regressions similar to Nosić and Weber (2010) to examine subjects' investment behavior. Detailed results are provided in Table 3.

[14]The average investment propensity for each asset and corresponding significance tests for differences between scales are provided in Table A5 in Appendix A.

The first regression models subjects' investment propensity (measured on a scale from 1 to 7) as a function of subjects' risk attitude as well as the assets' (mean) historic return and volatility. We find that participants who declare to be more willing to take risk in financial decisions are also more likely to state a higher willingness to invest. Furthermore, higher historical return and lower historical volatility of the asset increase subjects' propensity to invest.

Model (2) regresses investment propensity on subjective measures of risk and return – that is, what subjects perceive. The estimates suggest that lower (subjective) perceived risk of an asset (given a specific presentation format) and higher subjective long-term expected returns increase the likelihood of investing. Combining (1) and (2) in Model (3) only marginally increases the model's explanatory power compared to the one with only subjective regressors, confirming the intuition put forward above: investment propensity predominantly relies on people's subjective perceptions.

In Section 3.1, we have demonstrated that the scale on which an asset's performance is presented drives people's perceptions about its risk. Therefore, we estimate an additional model, substituting risk perception by the interaction of the asset and the chart's scale; for the full data set in Model (4) as well as for return charts in Model (4a) and for price charts in Model (4b).[15] While the coefficients remain comparable in magnitude and significance, we can now run Wald tests for differences between scales for each of the eight assets. In the full-data Model (4), we find significantly lower investment propensity for the low-volatility asset with trend DECREASING when presented with a NARROW scale ($p < 0.01$). For five out of seven other assets, people's willingness to invest is also lower with a NARROW scale but the differences are insignificant. This tendency is more strongly pronounced for PRICE chart representations.

[15] For these models perceived risk is substituted by 16 dummy variables for each possible Asset×Scale interaction term (eight assets presented in two different scales, NARROW and WIDE). Corresponding Wald tests are provided in Table A8 in Appendix A.

Table 3: **Determinants of investment behavior**. The table presents the estimated coefficients of least squares regressions with *investment propensity* (1 = very likely to invest, 10 = not likely to invest) as the dependent variable. Subjects' self-reported risk attitude regarding financial decisions, the assets' average return and volatility, as well as subjects' perceived risk and return expectations act as independent variables. In Model (4), (4a), and (4b), perceived risk is substituted by 16 dummy variables for each possible Asset×Scale interaction term (eight assets presented in two different scales, NARROW and WIDE).

Dependent variable:		Pooled Data			RETURNS	PRICES
Investment propensity	(1)	(2)	(3)	(4)	(4a)	(4b)
Subj. Fin. Risk Attitude	0.059***		0.050***	0.060***	0.093***	0.031
	(0.020)		(0.017)	(0.019)	(0.025)	(0.029)
Hist. Return	0.431***		0.298***	0.370***	0.353***	0.374***
	(0.019)		(0.018)	(0.027)	(0.036)	(0.040)
Hist. Volatility	−0.152***		−0.033**	−0.145***	−0.214***	−0.069**
	(0.017)		(0.015)	(0.023)	(0.029)	(0.034)
Risk Perception		−0.385***	−0.384***			
		(0.015)	(0.015)			
Subj. Exp. Return (1y)		−0.001	−0.001	0.000	0.029***	−0.002
		(0.003)	(0.003)	(0.003)	(0.008)	(0.004)
Subj. Exp. Return (5y)		0.052***	0.052***	0.061***	0.053***	0.075***
		(0.005)	(0.005)	(0.005)	(0.008)	(0.007)
Constant	4.656***	6.780***	5.619***	4.650***	5.138***	4.129***
	(0.306)	(0.251)	(0.272)	(0.320)	(0.406)	(0.480)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Asset dummies	Yes	Yes	Yes	–	–	–
Asset×Scale interaction	No	No	No	Yes	Yes	Yes
Observations	3,088	3,080	3,080	3,080	1,544	1,536
Adj. R^2	0.567	0.665	0.666	0.590	0.675	0.529

3.6 Investment preferences in pairwise comparisons

In Task II we ask subjects to decide which of the two assets they are comparing at a time they would rather invest in. Again, a key question is how perceived riskiness and perceived profitability relate to investment decisions. For this purpose we estimate the probability with which a subject invests in either the NARROW-scaled or in the HIGH-volatility asset, respectively, depending on which asset she perceives as more risky and as more profitable, by running probit regressions.[16] The resulting probabilities are plotted in Fig. 9.

[16] In particular, we run probit regressions with the pooled decisions across all conditions in which the two assets differ by at least one variable of interest – i.e., conditions SCALE, VOLATILITY, and BOTH – and consider only those decisions in which a subject chose either one of the assets to invest in. Hence, the dependent variable is a binary variable taking the value 1 when a subject chose to invest in the high-volatility or narrow-scaled asset, respectively, and 0 otherwise. Her choices regarding riskiness and profitability act as explanatory variables. For estimating probabilities depending on the choice in riskiness, choices in profitability were assumed to be at their means and vice versa. We are aware that c.p. a higher volatility might have different effects as displaying

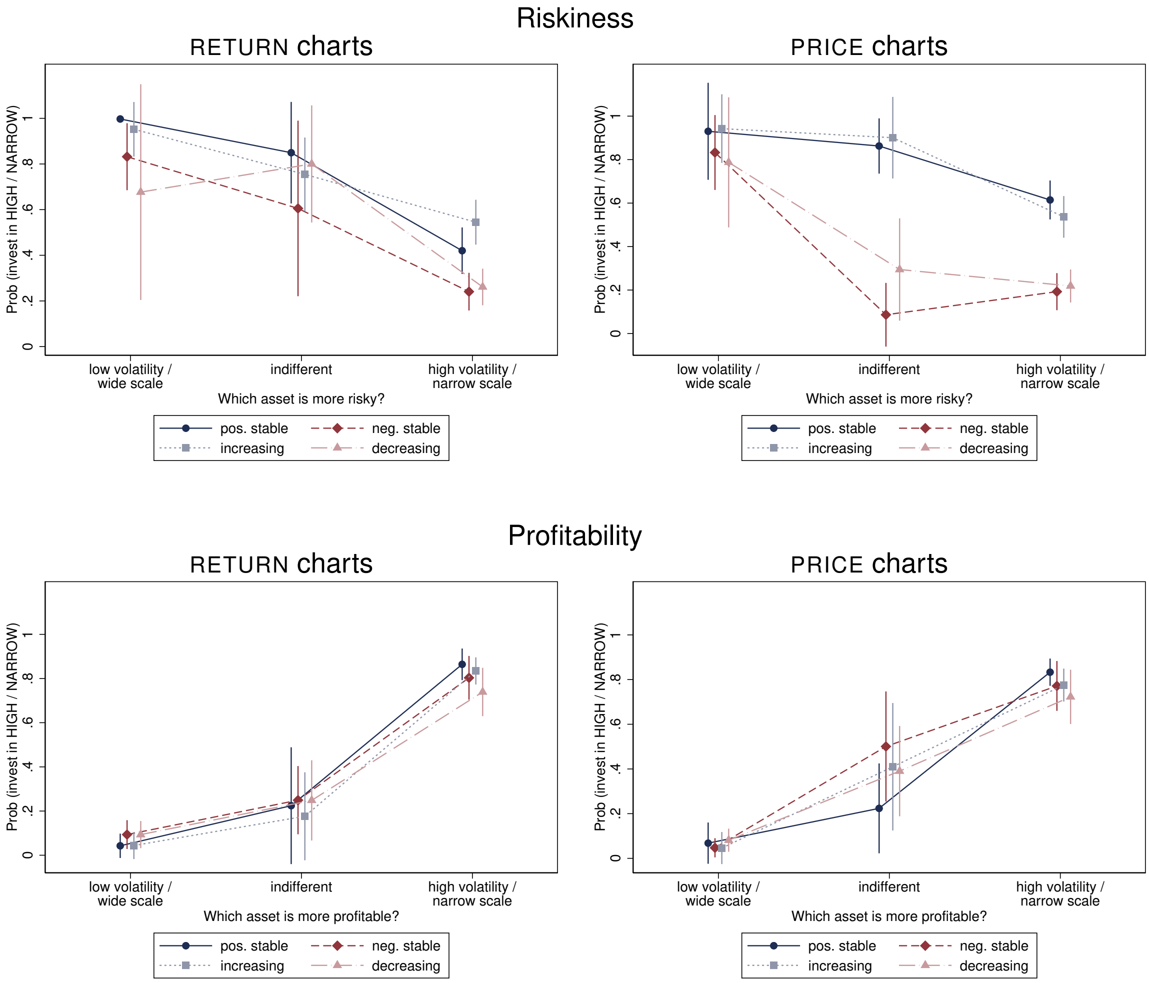

Figure 9: **Predicted probabilities of investing in the high-volatility or narrow-scaled asset.** This figure shows the predicted probabilities and 95%-confidence intervals of investing in the HIGH-volatility (NARROW-scaled) asset depending on which asset is perceived as *more risky* (top) or as *more profitable* (bottom). Probabilities are estimated from a probit model with a dummy variable indicating whether the subject would invest in the HIGH-volatility (NARROW-scaled) asset as the dependent variable and her choice regarding riskiness and profitability as independent variables. The numbers of observations lie between 171 and 222 for different presentation formats and trends.

Regarding the effect of perceived riskiness (top panel), we observe that in cases when a subject perceives the LOW volatility or the WIDE-scaled asset as more risky, the probability that she invests in the HIGH volatility or NARROW-scaled asset is between 68% and almost 100% across trends with return charts and even higher for price charts. Conversely, only around 25% tend to invest in this asset if it is perceived as riskier in trends NEGATIVE STABLE and DECREASING, with a significantly higher number for trends POSITIVE STABLE and INCREASING.

For price charts the probability of investing in the asset with higher perceived risk is 61 and 54%, respectively, with these trends – indicating that perceived risk is not necessarily the main determinant of investment behavior in the domain with mostly positive returns. Investing in the higher-volatility asset need not be a 'wrong' choice – especially in the case of a NEGATIVE STABLE trend having more volatile returns increases the chance that an investor could end up with a positive return. Such choices are thus in line with Prospect Theory (Kahneman and Tversky, 1979) which postulates risk-seeking behavior in the loss domain, where returns of assets with a NEGATIVE STABLE trend mostly are (assuming zero return as subjects' reference point). Hence, subjects who prefer the high-volatility asset over the low-volatility one in NEGATIVE STABLE (and with lower shares also in INCREASING and DECREASING trends) should not be judged 'irrational' or 'incorrect', but can merely be risk-seeking in the loss domain.

Analyzing probabilities to invest depending on perceived profitability (bottom panel), however, we observe very similar estimates across all trends. It comes as no surprise that if the HIGH volatility (NARROW-scaled) asset is perceived as more profitable, the probability of a subject investing in this asset is also very high (between 74 and 86%), and vice versa. As we observe comparable dynamics for all trends – also for POSITIVE STABLE and INCREASING, in particular – we conclude that perceived profitability is more important than perceived riskiness in these decisions. Subjects tend to invest in the asset which they regard as more profitable, even if they think it bears higher risk.

4 Discussion and Conclusion

In a novel experimental design we examined the impact of different vertical axis scales and presentation formats on risk perception, short- and long-term return expectations, and investment propensity. We explored return bar charts and price line charts for eight distinct assets, distinguished by either a low or a high volatility and one of four possible return paths.

We found that varying the scale strongly affected people's risk perception. Namely, a narrower scale of the vertical axis – that is, letting return bars and the line depicting the price, respectively, fill most of the available, vertical space in a chart – lead to significantly higher

the asset on a narrow scale; however, as we find very similar patterns within each condition, we presented results from the pooled data only. The estimates for each individual condition are available upon request.

perceived riskiness of an asset. This result is robust to varying the chart's presentation format (prices vs. returns) and the asset's volatility and trend. Only when returns were consistently positive, risk perception was the same across different scalings.

Assets were usually perceived as riskier when returns were shown than when prices were shown. Regulations like the European standard for investor documents (Commission Regulation (EU) No 583/2010, 2010, p. 15) demand return bar charts and a vertical axis that *shall not compress the bars so as to make fluctuations in returns harder to distinguish*. We demonstrate that adapting the scale accordingly is reasonable with regard to recognizing yearly return variations *within* a single security, but at the same time makes it harder to identify differences *between* dissimilar securities.

We further reported that past returns predicted future return expectations almost perfectly, irrespective of the presentation format. Most subjects in our setting thus act as short-term trend-followers when predicting future prices and returns.

In addition, risk perception is highly correlated with losses, which in turn drive investment behavior. This connects nicely to recent literature which also finds that risk perception is most strongly driven by 'probability of loss', and that this drives investment intentions (Anzoni and Zeisberger, 2016) and prices (Huber et al., 2018). Concerning investment choices, subjects tend to invest in the asset which they regard as more profitable even if they assess it to be riskier. Hence, in our setting perceived profitability was considered more important than perceived riskiness when making investment choices.

With regard to policy, our results have important implications: to our knowledge, financial market regulators in the US require consumer information documents to contain return bar charts representing past performance, but do not require a standardized appearance.[17] EU regulations also demand the presentation of return bar charts and, in addition, specific criteria regarding the presentation format. Yet, neither acknowledges the potentially distorting effects of the axis scale. In particular, the EU suggests *adapting the scale to the span of the bars* (Commission Regulation (EU) No 583/2010, 2010, p. 15). As we have shown, this makes it harder to distinguish assets with different levels of volatility.

To summarize, regulators should be aware of – and attentive to – the potentially distorting effects of different axis scales in performance charts. While return bar charts are appropriate, allowing issuers to adapt the axis scale arbitrarily leaves room for deliberate action aimed at distorting investors' perceptions about risk. Keeping the presentation scale constant across different securities enables better identification of risk and therefore better comparisons and decisions.

[17] See Zimmer (2009) for US regulations regarding past performance information in prospectuses and Mercer et al. (2010) for mutual fund advertisements.

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Appendix

A Additional Figures and Tables

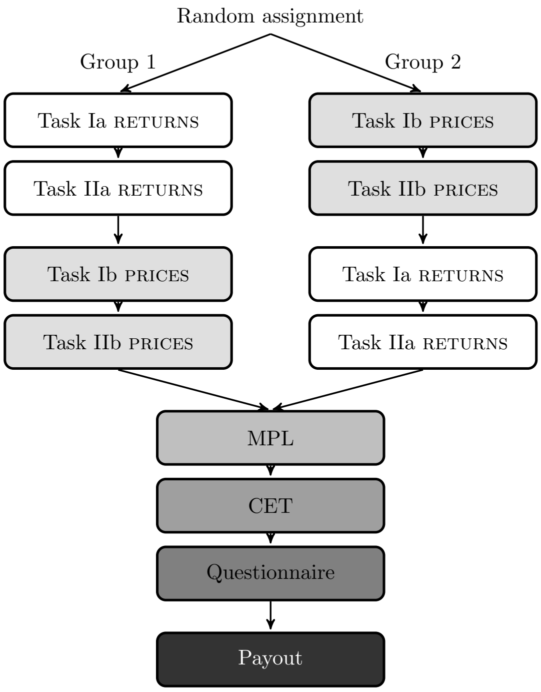


Figure A1: **Graphical overview of the experimental procedure.** This figure shows the experimental procedure: Subjects are randomly assigned into two groups with Group 1 being presented with RETURN charts first (Task Ia and Task IIa) and PRICE charts second (Task Ib and Task IIb) and Group 2 vice versa. Both groups complete a multiple price list task (MPL) and a certainty equivalence task (CET) to elicit risk and loss aversion parameters, as well as a questionnaire after the experiment.

Table A1: **Perceived risk of each hypothetical asset in return and price charts with wide and narrow scale.** This table shows the average perceived risk for each of the eight assets in *return* charts and PRICE charts and each with a WIDE and a NARROW scale. The lines 'Diff.' show the average difference in perceived risk between presentations with scale NARROW and scale WIDE. *, **, and *** indicate the 10%, 5% and 1% significance levels of two-sided Fisher-Pitman permutation tests on the subject-demeaned data. The sample size N for each test is between 179 and 206.

	LOW volatility			
RETURN charts	POS. STABLE	NEG. STABLE	INCREASING	DECREASING
WIDE scale	1.93	5.70	3.83	4.96
NARROW scale	2.24	6.03	4.21	5.64
Diff.	0.31	0.33	0.38^{**}	0.68^{***}
PRICE charts				
WIDE scale	2.09	4.91	3.47	3.70
NARROW scale	2.08	5.45	4.05	5.29
Diff.	−0.01	0.54^{**}	0.58^{***}	1.59^{***}

	HIGH volatility			
RETURN charts	POS. STABLE	NEG. STABLE	INCREASING	DECREASING
WIDE scale	3.43	5.54	4.05	5.39
NARROW scale	3.59	6.32	4.66	5.97
Diff.	0.16	0.78^{***}	0.61^{***}	0.58^{***}
PRICE charts				
WIDE scale	2.96	5.20	4.07	5.04
NARROW scale	2.90	5.64	4.41	5.59
Diff.	−0.06	0.44^{**}	0.34^{*}	0.55^{***}

Table A2: **Wilcoxon signed-rank tests for differences in perceived risk of each hypothetical asset in return and price charts between wide and narrow scales.** This table shows the average perceived risk for each of the eight assets in RETURN charts and PRICE charts and each with a WIDE and a NARROW scale for matched pairs. The lines 'Diff.' show the average difference in perceived risk between presentations with scale NARROW and scale WIDE. *, **, and *** indicate the 10%, 5% and 1% significance levels of two-sided matched-pairs Wilcoxon signed-rank tests. The sample size N for each test is between 36 and 50.

	LOW volatility			
RETURN charts	POS. STABLE	NEG. STABLE	INCREASING	DECREASING
WIDE scale	2.04	5.56	3.58	5.03
NARROW scale	2.43	5.92	4.23	5.67
Diff.	0.39*	0.35***	0.64***	0.64**
PRICE charts				
WIDE scale	2.12	4.83	3.22	3.52
NARROW scale	2.14	5.60	4.22	5.25
Diff.	0.02	0.77***	1.00***	1.73***

	HIGH volatility			
RETURN charts	POS. STABLE	NEG. STABLE	INCREASING	DECREASING
WIDE scale	3.15	5.52	4.18	5.40
NARROW scale	3.60	6.14	4.47	6.07
Diff.	0.45*	0.61**	0.29	0.67***
PRICE charts				
WIDE scale	2.79	4.96	3.70	4.95
NARROW scale	2.87	5.61	4.21	5.73
Diff.	0.09	0.65***	0.51*	0.78***

Table A3: **Average one-year return forecasts of each hypothetical asset in return and price charts with wide and narrow scale.** This table shows the average one-year return forecasts for each of the eight assets in RETURN charts and PRICE charts and each with a WIDE and a NARROW scale. The lines 'Diff.' show the average difference in one-year return forecasts between presentations with scale NARROW and scale WIDE. *, **, and *** indicate the 10%, 5% and 1% significance levels of two-sided Fisher-Pitman permutation tests on the subject-demeaned data. The sample size N for each test is between 179 and 206.

	LOW volatility			
RETURN charts	POS. STABLE	NEG. STABLE	INCREASING	DECREASING
WIDE scale	3.62	−2.60	2.89	−1.67
NARROW scale	4.02	−2.99	3.13	−1.90
Diff.	0.40	−0.39	0.24	−0.23
PRICE charts				
WIDE scale	3.32	−4.34	3.27	−2.86
NARROW scale	2.33	−6.90	2.27	−2.31
Diff.	−0.98	−2.56**	−1.00*	0.55

	HIGH volatility			
RETURN charts	POS. STABLE	NEG. STABLE	INCREASING	DECREASING
WIDE scale	5.04	−2.78	3.88	−1.08
NARROW scale	4.57	−2.27	3.74	−0.74
Diff.	−0.47	0.51	−0.14	0.35
PRICE charts				
WIDE scale	−0.50	−2.67	2.22	−0.77
NARROW scale	2.87	−5.97	1.54	−3.05
Diff.	3.37**	−3.30	−0.68	−2.27

Table A4: **Average five-year return forecasts of each hypothetical asset in return and price charts with wide and narrow scale.** This table shows the average five-year return forecasts for each of the eight assets in RETURN charts and PRICE charts and each with a WIDE and a NARROW scale. The lines 'Diff.' show the average difference in five-year return forecasts between presentations with scale NARROW and scale WIDE. *, **, and *** indicate the 10%, 5% and 1% significance levels of two-sided Fisher-Pitman permutation tests on the subject-demeaned data. The sample size N for each test is between 179 and 206.

	LOW volatility			
	Asset 1	Asset 2	Asset 3	Asset 4
RETURN charts	POS. STABLE	NEG. STABLE	INCREASING	DECREASING
WIDE scale	3.95	−2.87	2.57	−0.40
NARROW scale	4.79	−3.17	2.10	−0.94
Diff.	0.85*	−0.30	−0.46	−0.54
PRICE charts				
WIDE scale	2.51	−4.92	1.18	−0.17
NARROW scale	2.28	−6.21	0.15	−1.00
Diff.	−0.23	−1.29	−1.03**	−0.83

	HIGH volatility			
	Asset 5	Asset 6	Asset 7	Asset 8
RETURN charts	POS. STABLE	NEG. STABLE	INCREASING	DECREASING
WIDE scale	6.47	−4.71	4.89	−2.25
NARROW scale	6.27	−4.66	4.41	−1.69
Diff.	−0.20	0.05	−0.48	0.56
PRICE charts				
WIDE scale	1.09	−3.65	0.07	−0.34
NARROW scale	1.58	−3.39	0.49	−1.61
Diff.	0.49	0.27	0.42	−1.28

Table A5: **Average propensities to invest for each hypothetical asset in return and price charts with wide and narrow scale.** This table shows the average likelihood to invest for each of the eight assets in RETURN charts and PRICE charts and each with a WIDE and a NARROW scale. The lines 'Diff.' show the average difference in likelihood to invest between presentations with scale NARROW and scale WIDE. *, **, and *** indicate the 10%, 5% and 1% significance levels of two-sided Fisher-Pitman permutation tests on the subject-demeaned data. The sample size N for each test is between 179 and 206.

	LOW volatility			
RETURN charts	POS. STABLE	NEG. STABLE	INCREASING	DECREASING
WIDE scale	5.96	1.41	4.16	2.28
NARROW scale	6.09	1.38	4.32	1.99
Diff.	0.13	−0.02	0.16	−0.29
PRICE charts				
WIDE scale	5.85	1.81	4.41	3.23
NARROW scale	5.66	1.87	4.33	2.69
Diff.	−0.19	0.06	−0.08	−0.55***

	HIGH volatility			
RETURN charts	POS. STABLE	NEG. STABLE	INCREASING	DECREASING
WIDE scale	5.17	1.83	4.38	2.11
NARROW scale	5.22	1.72	4.30	2.15
Diff.	0.05	−0.11	−0.08	0.04
PRICE charts				
WIDE scale	5.43	2.24	4.68	2.81
NARROW scale	5.33	2.41	4.69	2.43
Diff.	−0.10	0.17	0.01	−0.39**

Table A6: **Differences in perceived risk between trends.** This table shows the differences in perceived risk between trends for LOW- and HIGH-volatility assets in RETURN and PRICE charts, pooled across scales. *, **, and *** indicate the 10%, 5% and 1% significance levels of two-sided Fisher-Pitman permutation tests on the subject-demeaned data.

	RETURN charts					
	LOW volatility			HIGH volatility		
	POS. STABLE	NEG. STABLE	INCR.	POS. STABLE	NEG. STABLE	INCR.
NEG. STABLE	−3.78***			−2.43***		
INCREASING	−1.92***	1.86***		−0.85***	1.58***	
DECREASING	−3.23***	0.55***	−1.31***	−2.18***	0.25*	−1.33***
	PRICE charts					
	LOW volatility			HIGH volatility		
	POS. STABLE	NEG. STABLE	INCR.	POS. STABLE	NEG. STABLE	INCR.
NEG. STABLE	−3.09***			−2.50***		
INCREASING	−1.68***	1.41***		−1.30***	1.20***	
DECREASING	−2.44***	0.65***	−0.76***	−2.38***	0.12	−1.07***

Table A7: **Differences in investment propensity between trends.** This table shows the differences in investment propensity between trends for LOW- and HIGH-volatility assets in RETURN and PRICE charts, pooled across scales. *, **, and *** indicate the 10%, 5% and 1% significance levels of two-sided Fisher-Pitman permutation tests on the subject-demeaned data.

	RETURN charts					
	LOW volatility			HIGH volatility		
	POS. STABLE	NEG. STABLE	INCR.	POS. STABLE	NEG. STABLE	INCR.
NEG. STABLE	4.63***			3.42***		
INCREASING	1.80***	−2.83***		0.86***	−2.56***	
DECREASING	3.91***	−0.73***	2.11***	3.07***	−0.36**	2.21***
	PRICE charts					
	LOW volatility			HIGH volatility		
	POS. STABLE	NEG. STABLE	INCR.	POS. STABLE	NEG. STABLE	INCR.
NEG. STABLE	3.92***			3.05***		
INCREASING	1.38***	−2.54***		0.69***	−2.36***	
DECREASING	2.80***	−1.12***	1.42***	2.76***	−0.29*	2.07***

Table A8: **Differences in investment propensity between scales.** This table shows Wald tests for differences in regression coefficients between NARROW and WIDE scales for the models with RETURN (4a) and PRICE (4b) charts from Table 3. *, **, and *** indicate the 10%, 5% and 1% significance levels.

	RETURN charts			
LOW volatility	POS. STABLE	NEG. STABLE	INCREASING	DECREASING
F-statistic	0.18	0.00	0.79	1.56
HIGH volatility	POS. STABLE	NEG. STABLE	INCREASING	DECREASING
F-statistic	0.35	0.34	0.07	0.00
	PRICE charts			
LOW volatility	POS. STABLE	NEG. STABLE	INCREASING	DECREASING
F-statistic	0.92	0.44	0.06	7.79***
HIGH volatility	POS. STABLE	NEG. STABLE	INCREASING	DECREASING
F-statistic	0.24	1.21	0.00	3.52*

Table A9: **Determinants of investment behavior (fixed-effects)**. The table presents the estimated coefficients of fixed-effects regressions with *investment propensity* (1 = very likely to invest, 10 = not likely to invest) as the dependent variable. Subjects' self-reported risk attitude regarding financial decisions, the assets' average return and volatility, as well as subjects' perceived risk and return expectations act as independent variables. In Model (4), (4a), and (4b), perceived risk is substituted by 16 dummy variables for each possible Asset×Scale interaction term (eight assets presented in two different scales, NARROW and WIDE).

	Dependent variable: *Investment propensity*					
	Pooled Data				RETURNS	PRICES
	(1)	(2)	(3)	(4)	(4a)	(4b)
Hist. Return	0.438***		0.312***	0.395***	0.368***	0.376***
	(0.019)		(0.017)	(0.027)	(0.036)	(0.040)
Hist. Volatility	−0.156***		−0.026*	−0.159***	−0.235***	−0.106***
	(0.016)		(0.015)	(0.023)	(0.028)	(0.035)
Risk Perception		−0.413***	−0.413***			
		(0.015)	(0.015)			
Subj. Exp. Return (1y)		0.000	0.000	0.001	0.024***	0.001
		(0.001)	(0.001)	(0.001)	(0.009)	(0.001)
Subj. Exp. Return (5y)		0.030***	0.030***	0.036***	0.050***	0.043***
		(0.003)	(0.003)	(0.004)	(0.008)	(0.005)
Constant	0.561	3.934*	2.886	0.321	1.320	−0.627
	(2.560)	(2.238)	(2.240)	(2.518)	(3.164)	(3.739)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Asset dummies	Yes	Yes	Yes	–	–	–
Asset×Scale interaction	No	No	No	Yes	Yes	Yes
Observations	3,088	3,080	3,080	3,080	1,544	1,536
Adj. R^2	0.597	0.692	0.692	0.611	0.702	0.556

B Experimental Instructions[18]

General Instructions

Dear Participants!

Welcome to the experiment. From now on, please refrain from talking to other participants.

If you have any questions about the procedure or the instructions, please raise your hand. Your question will be answered in private. The whole experiment and analysis will be conducted anonymously.

This experiment consists of 6 parts in which you can earn money and a questionnaire.

Instructions Single Chart

Suppose you want to invest 5000 euros.

In the following, you will be presented with eight bar charts *(price charts)*, each showing the returns *(price development)* of a hypothetical asset in the past 10 years *as well as the current price*. (The return is defined as the percentage change of the price in one year.)

For each of these assets, we ask you to assess the following values:

- the asset's risk,
- the probability with which you would invest in this asset,
- the return *(price)* of the asset in the following year *(in a year)*,
- the (average) return *(price)* of the asset in the following five years *(in five years)*.

(!) Note that the scale of the charts may vary.

Instructions Compare Charts

Suppose you want to invest 5000 euros.

On the following eight pages, you will be presented with two bar charts *(price charts)* per page, which each show the returns *(price development)* in the past 10 years *(as well as the current price)*. (The return is defined as the percentage change of the price in one year.)

For each of these combinations you will be asked to compare the two shown assets on the basis of the following characteristics:

- the assets' risks,

[18] The experiment was conducted in German. The following instructions have been translated to English. The German instructions are available upon request. Text parts in *italics* are only shown when subjects are presented with price charts; text parts in standard font but in parentheses only refer to the parts in which subjects are presented with return charts.

- the assets' return opportunities,
- in which asset you would rather invest.

(!) Note that the scale of the charts may vary.

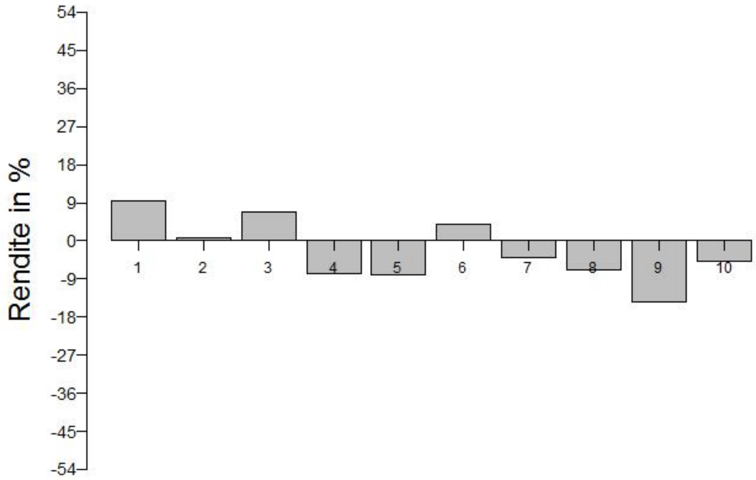
Payment: At the end of the experiment one of the eight rounds will be drawn randomly. The asset, which you chose in this round (that is, the one you would rather invest in), is relevant for your payment. If you did not decide to invest in one of the two assets in this round, one of the two will be chosen randomly. One of the ten past returns of this asset *(calculated as the percentage change of the price in one year)* will be chosen randomly.
You receive 5 € $\times$ $(1 + 2\times$ **this return.)**

Example: Suppose the chosen return of the asset you would rather invest in is 10%. Then your payment is 5 € $\times(1 + 2 \times 0.10) = 6$ €.

C Examples of the decision screens

Task Ia

Teil 1: Runde 1 von 8



		1	2	3	4	5	6	7	
Für wie riskant halten Sie dieses Wertpapier?	gar nicht riskant	○	○	○	○	○	○	○	sehr riskant
Wie wahrscheinlich ist es, dass Sie in dieses Wertpapier investieren?	gar nicht wahrscheinlich	○	○	○	○	○	○	○	sehr wahrscheinlich

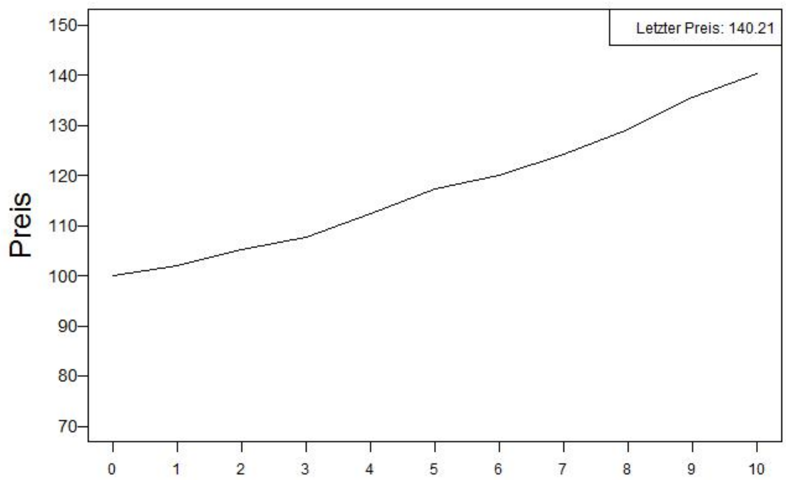
Wie hoch schätzen Sie die Rendite des Wertpapiers im folgenden Jahr? [ ] %

Wie hoch schätzen Sie die durchschnittliche Rendite des Wertpapiers in den folgenden fünf Jahren? [ ] %

Weiter

Task Ib

Teil 3: Runde 1 von 8



		1	2	3	4	5	6	7	
Für wie riskant halten Sie dieses Wertpapier?	gar nicht riskant	○	○	○	○	○	○	○	sehr riskant
Wie wahrscheinlich ist es, dass Sie in dieses Wertpapier investieren?	gar nicht wahrscheinlich	○	○	○	○	○	○	○	sehr wahrscheinlich

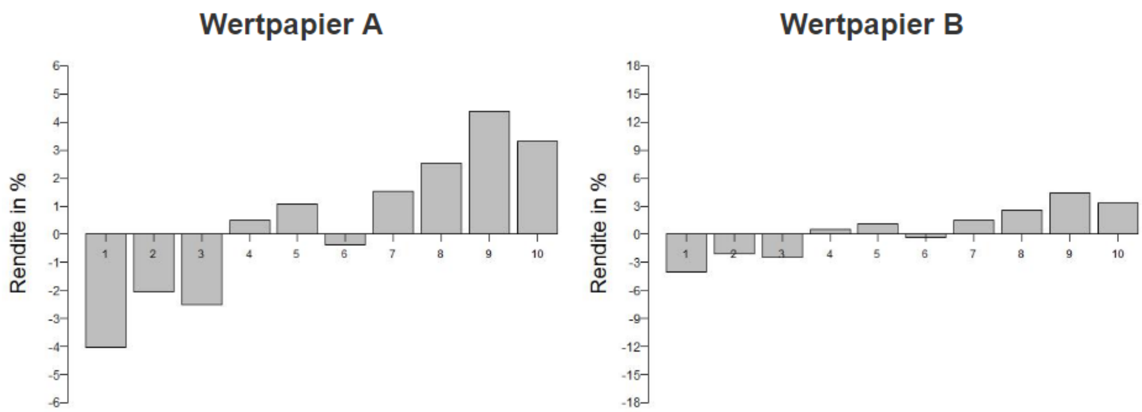
Wie hoch schätzen Sie den Preis des Wertpapiers in einem Jahr? Euro

Wie hoch schätzen Sie den Preis des Wertpapiers in fünf Jahren? Euro

Weiter

Task IIa

Teil 2: Runde 3 von 8



Welches Wertpapier halten Sie für riskanter?

Wertpapier A | beide gleich | Wertpapier B

Welches Wertpapier halten Sie für ertragsreicher?

Wertpapier A | beide gleich | Wertpapier B

In welches Wertpapier würden Sie eher investieren?

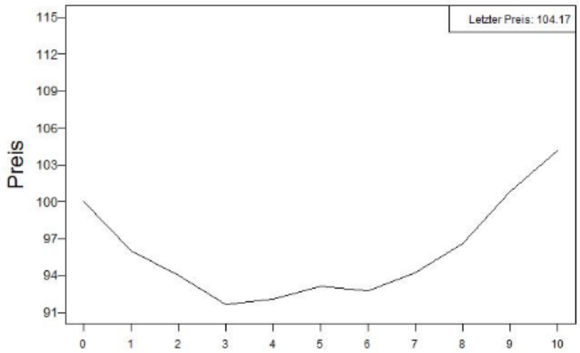
Wertpapier A | beide gleich | Wertpapier B

Weiter

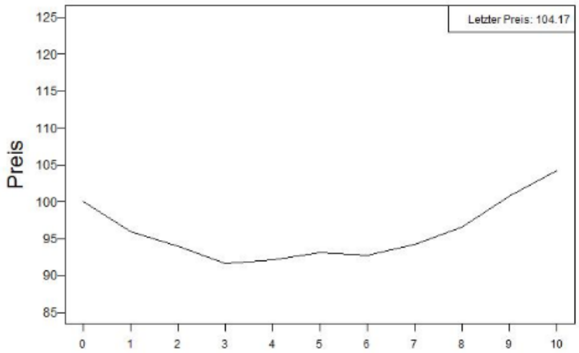
Task IIb

Teil 4: Runde 2 von 8

Wertpapier A



Wertpapier B



Welches Wertpapier halten Sie für ertragsreicher?

Wertpapier A | beide gleich | Wertpapier B

Welches Wertpapier halten Sie für riskanter?

Wertpapier A | beide gleich | Wertpapier B

In welches Wertpapier würden Sie eher investieren?

Wertpapier A | beide gleich | Wertpapier B

Weiter

D Examples of return and price chart comparisons in Task II

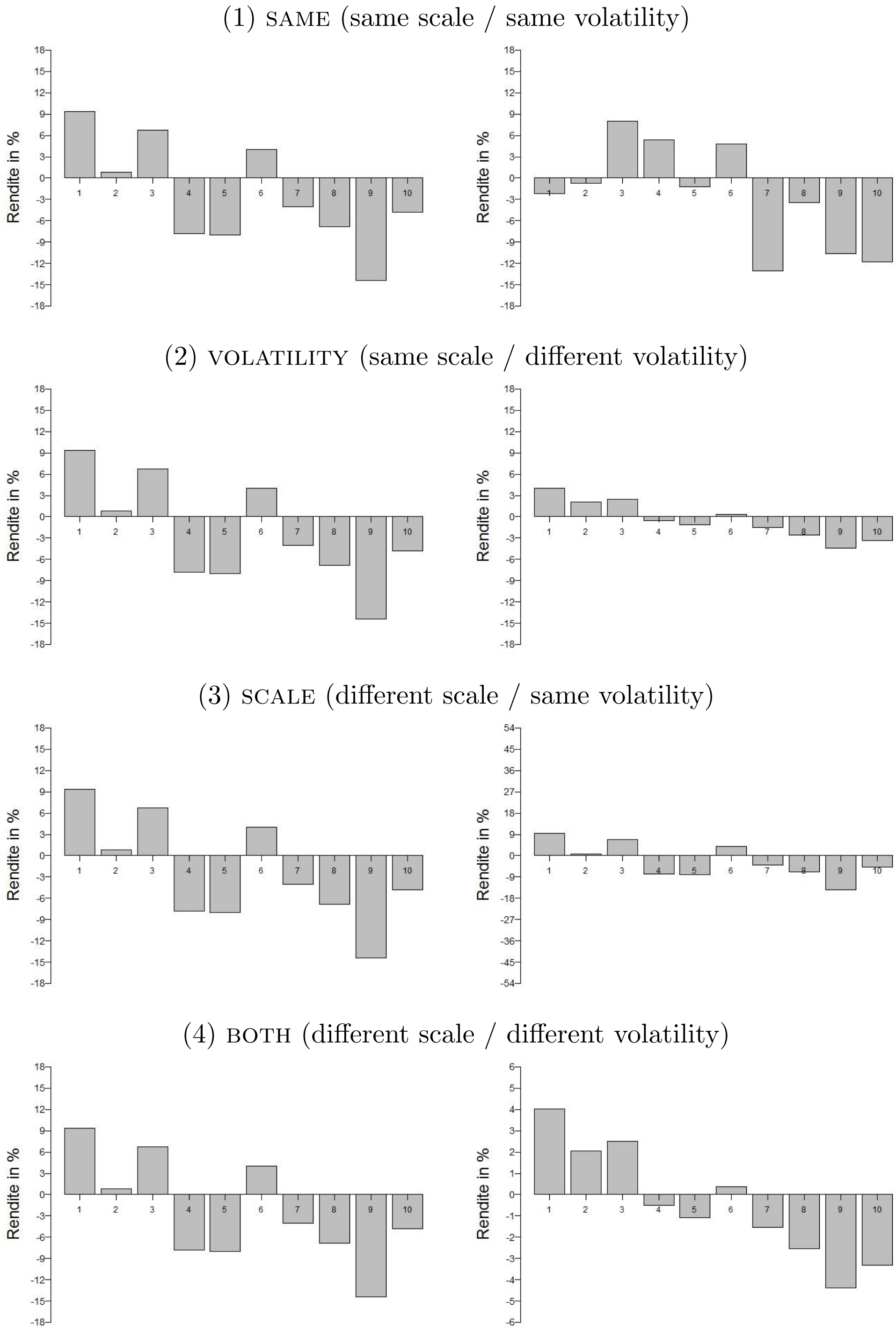
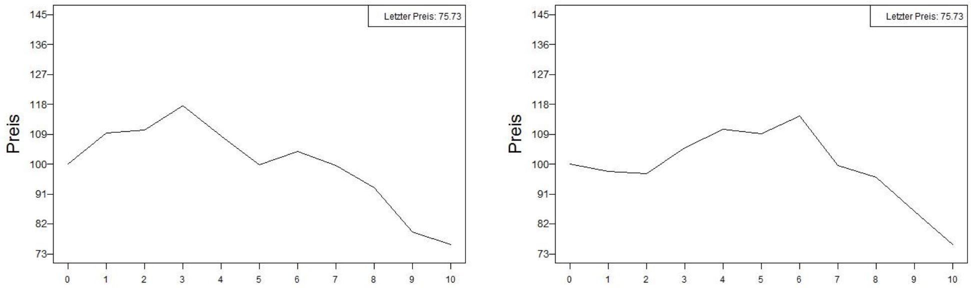
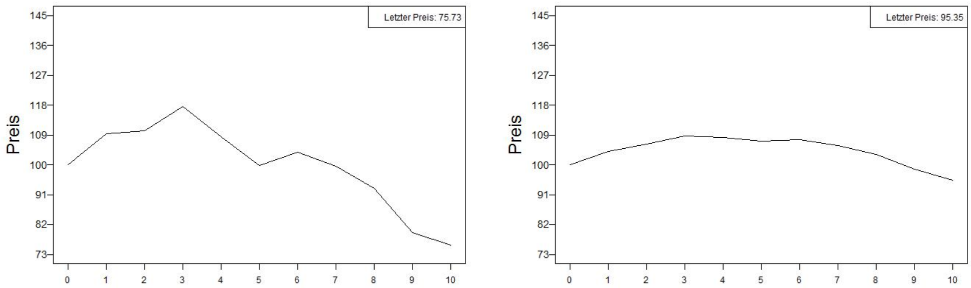


Figure D1: **Example of the treatment variation in volatility and scale in Task II.** This figure shows examples of the four conditions in Task II for the HIGH-volatility asset with trend DECREASING and presentation format RETURN.

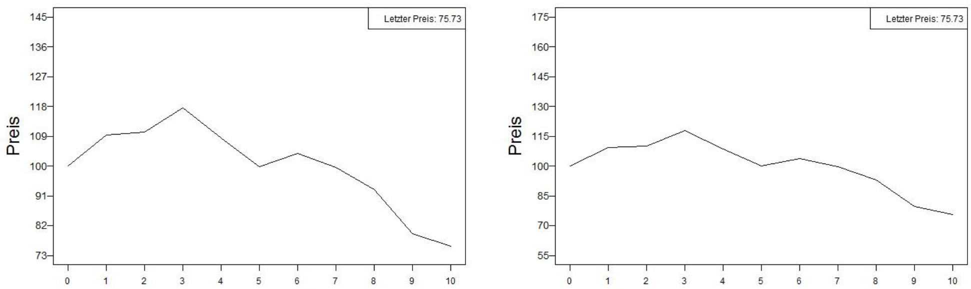
(1) SAME (same scale / same volatility)



(2) VOLATILITY (same scale / different volatility)



(3) SCALE (different scale / same volatility)



(4) BOTH (different scale / different volatility)

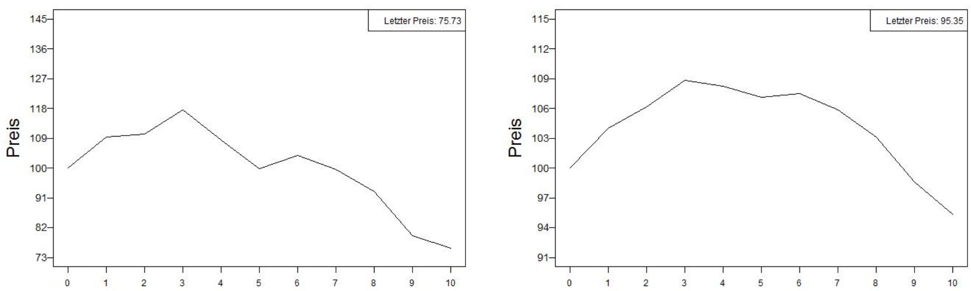


Figure D2: **Example of the treatment variation in volatility and scale in Task II.** This figure shows examples of the four conditions in Task II for the HIGH-volatility asset with trend DECREASING and presentation format PRICE.