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Evaluating prediction markets for internal control applications

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Zusammenfassung / Abstract

This study estimates the suitability of prediction markets (as instruments of internal control) by analyzing their event and progress sensitivity based on comprehensive experimental data. The underlying experiment was designed using expected average grades and closely observing students' (rank and file) and teachers' (leadership) behaviors. First, a kick-off study asked both parties about the factors that may influence the outcome of the teaching process. The resulting data served as the basis for a detailed tracking survey of four topic-specific indicators. Each week of the experiment, both students and teachers were asked to report on these indicators for 12 courses, thus producing two sets of 48 time-series data. Concurrently, 12 prediction markets were set up, in which the participants could buy and sell their forecasts 24 hours a day, seven days a week. The market utilized just one type of variable (i.e., the final average grade of each course) and the best traders could earn special commendations. The students were also encouraged to keep a trading journal that included the motives for their purchases and sales. For some courses, fake information was fed to the students in order to understand how it would influence the survey indicators, the prediction market prices, and their sensitivity to misinformation. Finally, this study reveals the results of these two extremely different control mechanisms (i.e., periodic detailed surveys vs. voluntary single-number prediction markets) and reports on how they performed and how fast their indications were adapted.

JEL-Klassifikation / JEL-Classification: B41, M29, M10

Schlagworte / Keywords: Prediction Markets, Forecast, Internal Control, Business Intelligence, Decision Support Systems, Strategic Control

Contents

1. Introduction

Since the beginning of prediction market research, various applications have been discussed. From the predictions of political elections results to supply chain information and project management, the spectrum is widely diversified. While the application spectrum does not lack variety, there has been little diversification in scientific research. Although an enormous number of articles regarding "open to the public" prediction markets are available, the academic presence of internal control prediction markets is surprisingly small (Christiansen 2007). Despite the potential of internal control prediction markets, as corporate governance tools, there are only a few relevant articles on comprehensive "real world" experiments such as the one Ortner has done before. (Henderson & Abramowicz 2007; Ortner 2000). In addition, most of the articles have focused on the accuracy and general applicability of prediction markets as internal control instruments. The subject of sensitivity, especially regarding the general development of the prediction target and event sensitivity concerning the identification of specific event influence has been neither discussed from an internal control perspective nor examined in a comprehensive field experiment.

The reason for more detailed research should not be underrated. While most of the "open to the public" prediction markets aim for the best possible forecasts, this outcome does not fit with their internal control application. Fast and precise predictions with low rates of volatility over time in an internal control setting can cause significant problems. For instance, the person using the instrument cannot reconstruct the development of the prediction in real time; thus, he/she is missing the opportunity to identify occurring risks. However, the identification of occurring risks is essential for the application as an internal control tool (Spira & Page 2012).

With different types of applications, it is also essential to distinguish between relevant features of the respective prediction market. Statements about sensitivity are, therefore, crucial for the application of internal control markets (O'Leary 2013) (Sharpe 1972). The relevant question in this context is as follows: Are prediction markets in general suitable as instruments for internal control?

This study fills the existing gap and provides both data and answers regarding the subject of sensitivity in internal control prediction markets. From its beginning, the plan has been to realize a reproducible, large-scale, and multiple-market field experiment in a controllable and transparent area. While the use of corporate prediction markets for research purposes tends to lack transparency and reproducibility, the experiment was realized in an academic setting. With a controllable number of influencing factors, the prediction markets were installed in several university courses to predict the respective average course grade. With the regular students of each course serving as participants and traders, all further requirements were best served. In addition, the internal course setting, with the course's average grades as prediction targets, has been suitable for corporate and other project settings.

The results of the field experiment depend on the grade of acceptance by the students themselves. With the high level of acceptance and the limited number of influencing factors in an academic setting, it is expected that the prediction market will perform comparably to real-world progress, with a high degree of sensitivity for real-world events. Furthermore, besides general comparability, it is expected that different phases of sensitivity (similar to a J-curve) will appear during the expectation formulation while approaching the prediction target (Bahmani-Oskooee & Ratha 2007).

2. Prediction markets for internal control

(A) The critical need for new internal control tools: The general acknowledgment for the failure of internal control systems is not a new aspect, especially since the 2007-2009 financial crisis. Instead, it has been more of a "mirror" for the corporate world that questions the existing system (Altamuro & Beatty 2010). Before this, Jensen (1993) stated that the existing internal control system was unable to deal with the rapid change of modern economies. Moreover, he argued that the final understanding of internal control for opening the black box firm, which was an extremely profitable venture and one of the major challenges of the 1990s. Regarding the solution of these challenges, he also mentioned that the development of new internal control tools is essential (Jensen 1993).

Through all those developments, the concept of risk became more relevant to the corporate world. With the ongoing and rising relevance of risk management in all divisions of modern firms, the concept of internal control included a new branch besides accounting and controlling (Power 2008). The detection of risk for corporate values therefore became essential for internal control and internal control tools were necessary to detect all types of risks (Spira & Page 2012). While quantified types of risks, such as credit or interest rate risks, could be detected, measured, and hedged in nearly real time through statistical and mathematical instruments, there was a special type of risk with a more challenging demand: operational risk (Cruz 2002). The psychological approach of operational risk, with human nature as incomputable weakness, limits the application spectrum of mathematical and statistical instruments. Even if operational risk could be measured and hedged, real-time detection was a different type of problem that could potentially be solved by applying new technologies and tools that consider human nature and interaction (Beroggi & Wallace 2012).

With a broader definition of the "internal control" application for a more transparency-focused approach of control, there is a long-lasting demand for reasonable real-time measuring tools (Wieland 2005). This demand is not just limited to corporations, but is also more or less transferable to governmental or hybrid projects. As an example, the open government approach clarifies that the black box firm is not the only black box to be opened (Lathrop & Ruma 2010). In addition, the idea of governmental prediction markets, even with slightly differing applications, is not a new one (Bell 2011). For the more efficient realization of megaprojects (e.g., characteristically hybrid projects), the world-renowned megaproject expert, Bent Flyvbjerg, argued the following:

Transparency is the main means of enforcing accountability in the public sector. Here we recommend a higher degree of publicness and of public participation, including stakeholder involvement, than is common for megaprojects. Megaproject development stands to benefit from more involvement by civil society. The conventional argument against public participation is that it slows down decision making and results in suboptimal outcomes. We read the evidence quite differently. Megaprojects that have tried to get by without publicness and participation have often run into such heavy opposition that the decision-making processes were destabilized and second-best solutions to both procedure and outcome forced upon actors and projects. There is little evidence that efficiency and democracy are trade-offs for megaproject decision-making. Quite the opposite. (Flyvbjerg 2003)

(B) Why prediction markets may potentially fit the gap: Since Ortner's (2000) first experiment on the application of prediction as instruments of regulatory compliance, the application spectrum has developed. The first time that prediction markets were specifically mentioned as instruments for internal control was by Henderson and Abramowitcz in 2007. In their article on prediction market applications for corporate governance, they argued that the rising costs of corporate auditing benefits the use of prediction markets as internal control tools. The rising costs, owing to the rising demand for transparency and disclosure of relevant information, also challenges traditional auditing and controlling mechanisms (Henderson & Abramowicz 2007). For the detection of fraud or general risks to significant corporate key numbers, prediction markets provide a much higher level of adaptation and, therefore, are a more efficient alternative (Prentice & Donelson 2010).

Prediction markets for internal control are defined as internal measurement instruments for the detection of ongoing risks to the prediction target over the entire prediction process. Based on this definition, internal control prediction markets are clearly distinguished from other prediction market applications. It is also apparent that the focus in internal control applications is on the process itself and not on the prediction target as the final key value. Moreover, this is what isolates the internal control application to internal prediction market applications, as, for example, Google has done in the past (Cowgill et al. 2009). Besides the corporate field of application, the use of internal control prediction markets can also be transferred to public (or similar) projects with a lack of internal (or even external) transparency.

For the example of corporative application internal positions, such as controllers or risk managers, and external stakeholders, such as public or cooperating firms, it is possible to observe the accruing chart to obtain a more frequent update on the prediction target progress. The prediction target itself is highly flexible and can be adjusted for any specific demand. As in the example of Henderson and Abramowitcz (2007), the application of internal control could be performed by a prediction market asking for strategic financial ratios, such as interest coverage. The occurring prediction chart on interest coverage provides a certain degree of information regarding the development of the financial ratio. This information, by implication, is highly dependent on the sensitivity of the prediction market.

However, the following question remains: Is it possible to predict occurrences, such as fraud, directly, and avoid questions on sensitivity? In real-world applications, it would be impossible to set the prediction target close to the beginning of an internal control process, since more concrete requests are necessary in certain areas. This would cause irregular high agency costs for the rolling setup of new prediction markets as potential fraud areas appear (Henderson & Abramowicz 2007).

In conclusion, the prediction target needs to be a more general result in the future. In addition, the in-between timeline would be the indicator for potential risks based on information traders have provided through their transactions. The efficiency of this type of application is limited to the sensitivity of the market during the runtime. However, the following questions remain: 1) How do sensitive traders react to certain events? 2) What types of events could have a high degree of sensitivity? And 3) How do traders in general form their expectations for internal control applications?

Although these questions may be answered in the following chapters, it can be stated that a precise prediction does not necessarily need a sensitive prediction market. However, for internal control applications, a sensitive market is necessary.

3. Methodology

3.1 Objective

The objective of this study is to determine the grade of efficiency in prediction markets for internal control applications. More precisely and consistent with the previously mentioned relevance of sensitivity, this study focuses on the general progress over time and specific event sensitivity, which is consistent with the respective literature regarding so-called play-money prediction markets. This may provide additional insights for the academic community (Blume et al. 2008).

Internal control, as defined in the widely recognized paper by Sawyer (1996), is a process for assuring the achievement of an organization's objectives in operational effectiveness and efficiency, reliable financial reporting, and compliance with laws, regulations, and policies (Sawyer et al. 1996). This definition clearly focuses on the process of assuring achievement. Regarding an internal control application for prediction markets, there is a shift in relevance from the prediction target itself to the process of prediction. This process is primarily influenced by the sensitivity of the prediction market itself. Therefore, the present exploratory study utilizes a multiple-perspective approach ranging from macro-analysis to micro-analysis.

The macro perspective is examined through a closer look at the progress sensitivity of the prediction market target over time. The objective is to understand the correlation between the real-world development of the prediction target over time and the actual prediction market chart progress. It is expected that an explorative analysis from the macro perspective can clarify the relevance regarding the progress sensitivity of prediction markets in internal control applications.

The micro perspective is examined by looking at the event sensitivity of the prediction market target over time. With this more trader-oriented approach, the objective is to understand what types of events influence traders to perform transactions in the prediction market. Moreover, the degree of influence for specific events is researched. It is expected that an explorative analysis from the micro perspective can clarify the relevance regarding the event sensitivity of prediction markets in internal control applications.

3.2 General settings

Field of application: As previously mentioned, in this field experiment, the internal control prediction market was examined in an academic setting. There are three main reasons for using this setting:

(1) **Relevance of feedback in the academic sector:** At the university, lecturers have significant difficulties obtaining real-time feedback information on the learning process of students in general. Thus, the relevance of feedback at universities has been a widely discussed topic (Leckey & Neill 2010). With an internal control prediction market, the lecturer theoretically has an advanced tool for examining the learning process and using the respective average grades as prediction targets and indicators. Lecturers can even examine the risks or even the real-world learning process in detail. Furthermore, the grade of sensitivity can make a difference between simply knowing that there could be something wrong and receiving detailed information regarding the timing and characteristics of possible changes toward prediction targets.

(2) **Controllable and reproducible field:** Transparency, a defining feature of the academic landscape, and the limited number of controllable factors that influence the academic teaching process over time, can enhance the overall significance and quality of the experimental results.

(3) **Transferability:** With respect to the highly flexible prediction target and the overall structure of the field experiment in the academic setting, results can be easily compared to all previously mentioned sectors, such as corporate applications in specific departments, teams

for hybrid projects or even expert groups in the government. If there is a group of people working to achieve a team-based target within a limited time horizon, then the results of this field experiment may be adoptable.

Prediction market: Regarding the high costs of a specifically programmed prediction market, an external service provider was selected. In this case, Prediki, an Austrian company specializing in prediction market services for the corporate world, provided the prediction market.

Prediction target: During the second week of the trimester, every student enrolled in one or more of the 12 selected courses received an invitation to participate in this prediction market study. The selected prediction targets were the average grades of the course, which were used to monitor the learning/grading process as a whole. Students were requested to trade in an internal control application and the focus of the study was to gain insights into the prediction process itself.

Traders: Courses were selected up to the third trimester to guarantee that there were no students without any knowledge about the learning/grading process at the university. Overall, six third trimester courses, four sixth trimester courses, and two ninth trimester courses were part of the field experiment.

Incentives: Three different types of incentives were provided to the students for actively trading in the market. The first incentive was purely financial; that is, the best trader in each market/course was promised 30 Euros. With 12 active courses and many students enrolled in more than one course, the maximum financial incentive was therefore 360 Euros. Additionally, to hedge the rising risk aversion, every student received a certificate of participation, which was signed by one of the university's professors (Luckner 2006). This certification was allowed to be mentioned in the Comments Section of the Bachelor's/Master's certification. Furthermore, the three best performers in each market/course received a special certification noting their performance and their comprehensive knowledge of trading mechanics.

Payoff structure: The Prediki prediction market used in the experiment is a second-generation prediction market with final payoff values. The average grades of each course, chosen as prediction targets, defines this fact (Slamka et al. 2012).

Setup structure: For the setup of the prediction market, a question and multiple-answer structure was provided. For every question regarding the average grades of each course, there were ten possible answers, and each as its own share could be traded (see Figure 1). The answers are related to the specific grading scheme of the university and they are well known to the students:

1.0 to 1.3	**2.0 to 2.3**	**3.0 to 3.3**	**4.0 to 5.0**
1.3 to 1.7	**2.3 to 2.7**	**3.3 to 3.7**	
1.7 to 2.0	**2.7 to 3.0**	**3.7 to 4.0**	

Figure 1. The variety of shares available to traders.

Through the students' transactions, the price algorithm calculates the value of each share/answer as a probability. Therefore, ten different charts for the respective probability of each answer were accumulated (Wolfers & Zitzewitz 2006). The general market chart was the median of all possible answers/shares and it represents the regular prediction market chart that is used for statements on sensitivity.

Price algorithm: For price calculations, an automated market maker was used. Regarding the comparably low numbers of traders (< 100 traders per market) and equally expected low rates of volatility, the automated market maker ensures the best performance (Othman 2012).

3.2 Macro perspective

The macro perspective is the methodological approach to analyze the more general "progress" sensitivity of prediction markets in internal control applications. For the macro perspective evaluation, a tracker study was used. This specific type of indirect study is a composition of regular questionnaires that are completed over the time of the prediction market experiment, with everyday questions on essential influencing factors for the prediction target. The answer structure of these questions thereby is the same as that of the prediction market to ensure the best possible comparability. The questionnaires were answered by the lecturers and the students of the respective courses.

Although the results from regular methods of using questionnaires to study real-world progress differ from the actual target progress, the diversification of input sources and questions on the essential influencing factors approximate the best possible progress data (Berg et al. 2008). The data provided by the tracker study is the comparable basis for the internal control application of prediction markets. Both methods will be evaluated by their respective ability to process information and predict final outcome.

For the composition of the tracker study, students were asked to write down their ideas about which factors influence intra-course grading. The intra-course grading process represents the prediction process of the prediction target. All of the students in the field experiment responded (N = 371).

According to the survey, four of 28 influencing factors were identified: 1) **Teaching** of the respective courses in general; 2) **Course content** and complexity; 3) **Student performance**; and 4) **Operative factors**, such as the trimester structure or group size. Factors with a relative accumulation below 5% were deemed not reliable enough to be chosen as essential influencing factors. Moreover, all primary influencing factors above 5% were treated equally, regardless of their individual quantified influence. The students were also asked to provide the percentage of influence (up to 100%) for all named influencing factors (see Figure 2).

Influencing factor	Abs. frequency	Rel. frequency	Impact
Teaching	564	47%	30%
Performance	276	23%	35%
Content	100	8%	29%
Operative	68	6%	19%
Others	62	5%	18%
Sleep	53	4%	19%
Life-balance	13	1%	17%
Weather	12	1%	14%
Luck	8	1%	17%
Social circumstances	8	1%	16%
Other students	7	1%	21%
Nutrition	6	1%	18%
Season	2	0%	23%
State of mind	2	0%	20%
Fraud	2	0%	28%
Social events	2	0%	15%
Living situation	2	0%	10%
Family	1	0%	20%
Hobby	1	0%	5%
Communication with older students	1	0%	30%
Illness	1	0%	1%
Critical live-changing events	1	0%	50%
Parties	1	0%	10%
Personal circumstances	1	0%	10%
Physical ability	1	0%	10%
Psychological circumstances	1	0%	20%
Course reputation	1	0%	5%
Time pressure	1	0%	50%
Total	1,198		

	26.60	Teaching
	30.71	Performance
114%	26.63	Content
84%	17.07	Operative

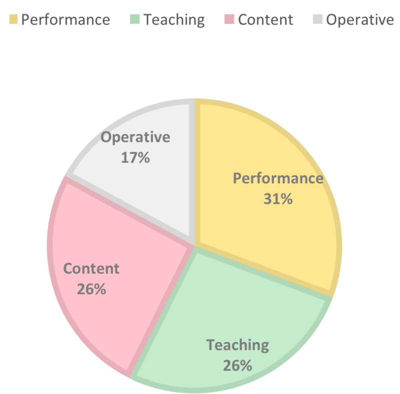

Figure 2. Quantified influence of the essential influencing factors

The results regarding the composition of the tracker study are expected. The items Teaching, Student Performance, and Course Content are near-equally relevant to the intra-course grading process. The Operative Factor item is surprising, since it is relevant with a quantified influence of 17%. Of the clustering process, [1] it is known that sub-factors (such as the general course structure during the trimester) and the timing of the lectures/exams are part of the Operational Factor. In sum, the Operational Factor represents all influences out of the expected reach of the students and lecturers. Thus, it could be seen as a factor that represents unexpected risks or chances with respect to the influencing factors presented in Figure 1 (Arrow & Lind 2014). This is approximate to the regular definition of operational risk (Power 2006).

The fact that the Operative Factor exerts a relevant influence on the intra-course grading process results in a major problem. Normally, each of the primary influencing factors needs to be evaluated by students and lecturers during the course. However, the Operative Factor cannot be evaluated like the other three items, owing to the unexpected feature. Therefore, the Operational Factor is not part of the regular evaluation. In the evaluation, the students and lecturers were asked simply to write down the number and influence of supporting (or disturbing) events during the runtime as an adjustment for the evaluation of the other three factors.

For the final analysis, all three questionnaire charts were compared to the prediction chart on the one hand. On the other hand, regarding the percentage composition of the essential influencing factors, the tracker study (as a whole) was compared to the prediction chart. For the following study, the three questionnaire charts are called “component charts” while the two evaluation schemes are referred to as “indicator charts.”

3.3 Micro perspective

Besides the macro perspective on progress sensitivity, a micro approach was selected to gain more detailed information regarding how traders behave when it comes to internal control applications. What types of events are relevant and to what degree do such events influence the prediction process

[1] Content-related similar answers were clustered for superordinate factors.

over time? To answer both questions, two distinct methods were used: the trading journal and event simulation.

(A) Trading journal: With the trading journal, the students were asked to write down specific information regarding every transaction executed in the prediction market. Such information contains the date of the transaction, the question that the transaction is related to, the answer and type (buy/sell) of transaction, the amount of credits invested, and an explanation justifying the transaction.

Students were asked to provide short, simple answers related to the justifying factor that influenced their decisions to trade on this particular answer. Regarding the additional amount of work, students were asked to maintain a trading journal. The certification incentive was bound to the submitted trading journal, whereas the financial incentive was not, in order to avoid serious conflicts with the work-related participation rate.

The objective of using the trading journals was to identify the justifying factors that influenced the trading decisions of the students in an internal control application of prediction markets. For analytic purposes, the trading journal was used to link the trading movements to specific events/factors that influenced the trader's decisions.

(B) Event simulation: To obtain a more precise view on the actual influence of several types of events, an initiative survey was administered in which the students were asked to provide specific examples regarding events that positively or negatively influenced the intra-course grading process at their university. Since the survey was part of the prior mentioned survey on the essential influencing factors, 371 students were involved.

Regarding the results of the survey, 206 single events were mentioned, of which the three most common negative events included: "long-term illness" of the lecturer/professor (56 times); "good weather" since it provokes one to do other things than study (38 times); and "change of lecturer" (20 times). Generally, negative events dominated the survey, especially since the first 11 events were negative ones. The most commonly-mentioned positive events included: "good tutorials" (20 times); "detailed exam limitation" (17 times); and "additional tutorials" (14 times).

Based on the survey, four events were identified and adjusted for intra-course simulation. The simulated events were chosen related to their impact on regular academic teaching. Non-realizable events were either those without the possibility to be simulated (e.g., weather) or those with strong ethical concerns regarding their influence on the students' real-world grades.

Events with a likely positive effect on the exam results were executed immediately, whereas events with a likelihood of negative effects were announced by the lecturer and reversed within two weeks.[2] Since all of the dates and times for the events were known, potential changes in the prediction market were analyzed. In support of this, all entries of the trade journal were examined.

4. Experimental data

4.1 Prediction accuracy

Although the prediction result was not the primary target of this study, the participating students were requested to focus more on the intra-course grading process than on the realized average grade of the respective course. If the prediction was unreliable and the insufficient transactions non-significant, as a direct consequence, there cannot be any significant insights into the prediction process.

For this study, it can be concluded that the prediction result is as accurate and reliable as regular applications for prediction markets. The participation was stable, with 32 to 69 active traders and 175 to 422 transactions per market over the three-month period. The mean standard error of the respective market ranged from 0.08 to 1.41 (Wolfers & Zitzewitz 2004), while the average mean standard error of all 12 prediction markets was 0.67. More detailed information on the performance of all 12 markets can be found in Table 1:

Lecturer	**Course**	**Final prediction**	**Realized outcome**	**Mean standard error**
Lecturer #6	Advanced Macroeconomics	2.93	2.87	0.08
Lecturer #7	Market and State	3.17	3.10	0.10
Lecturer #7	Game Theory	2.95	2.70	0.26
Lecturer #4	Advanced Macroeconomics	3.24	3.39	0.39

[2] The decision not to execute negative events is linked to the potential negative effect on students' actual grades.

Lecturer #4	Macroeconomics	3.33	3.62	0.51
Lecturer #1	Mathematics II/III	3.62	3.86	0.60
Lecturer #5	Advanced Economic Research	3.21	3.60	0.63
Lecturer #2	Introduction to Social Psychology	2.82	2.05	0.65
Lecturer #5	Macroeconomics	3.43	4.14	1.05
Lecturer #6	Market and State	3.14	4.16	1.18
Lecturer #3	Responsible Project Management	2.24	1.54	1.18
Lecturer #7	Economics of the Public Sector	3.09	4.40	1.41
			Average	**0.67**

Table 1. Prediction results and mean standard error for all 12 experimental prediction markets

The calculation of the mean standard error is based on the median prediction of the cumulative probabilities for all of the answer groups per market. The median was chosen since it was more robust against runaway transactions compared to the general average. This is especially important regarding the pure nature of the 372 participating students (Mises & Mayes 1990).

Finally, it was found that the prediction accuracy for this study was biased for a more positive prediction. Seven out of the 12 courses and three of the four courses with the highest mean standard error had a more optimistic, thus lower prediction compared to the realized outcome. This is in line with the results of academic research on students' self-assessments in higher education in which students tend to overestimate their performance (Boud & Falchikov 1989). In conclusion, the prediction results of all 12 prediction markets are even more precise.

4.2 Tracker study

With a reliable prediction result as a requirement for ongoing sensitivity analysis, the following chapter compares the prediction market chart with the results of the experiment supporting tracker study regarding the three essential influencing factors of the intra-course grading process. Therefore, it is necessary to decide between every component on the one hand and the lecturer or students on the other. The following figure displays a representative prediction market chart with weekly results of the tracker study regarding the three essential influencing factors and the students' and lecturers' evaluations over the experimental time period.

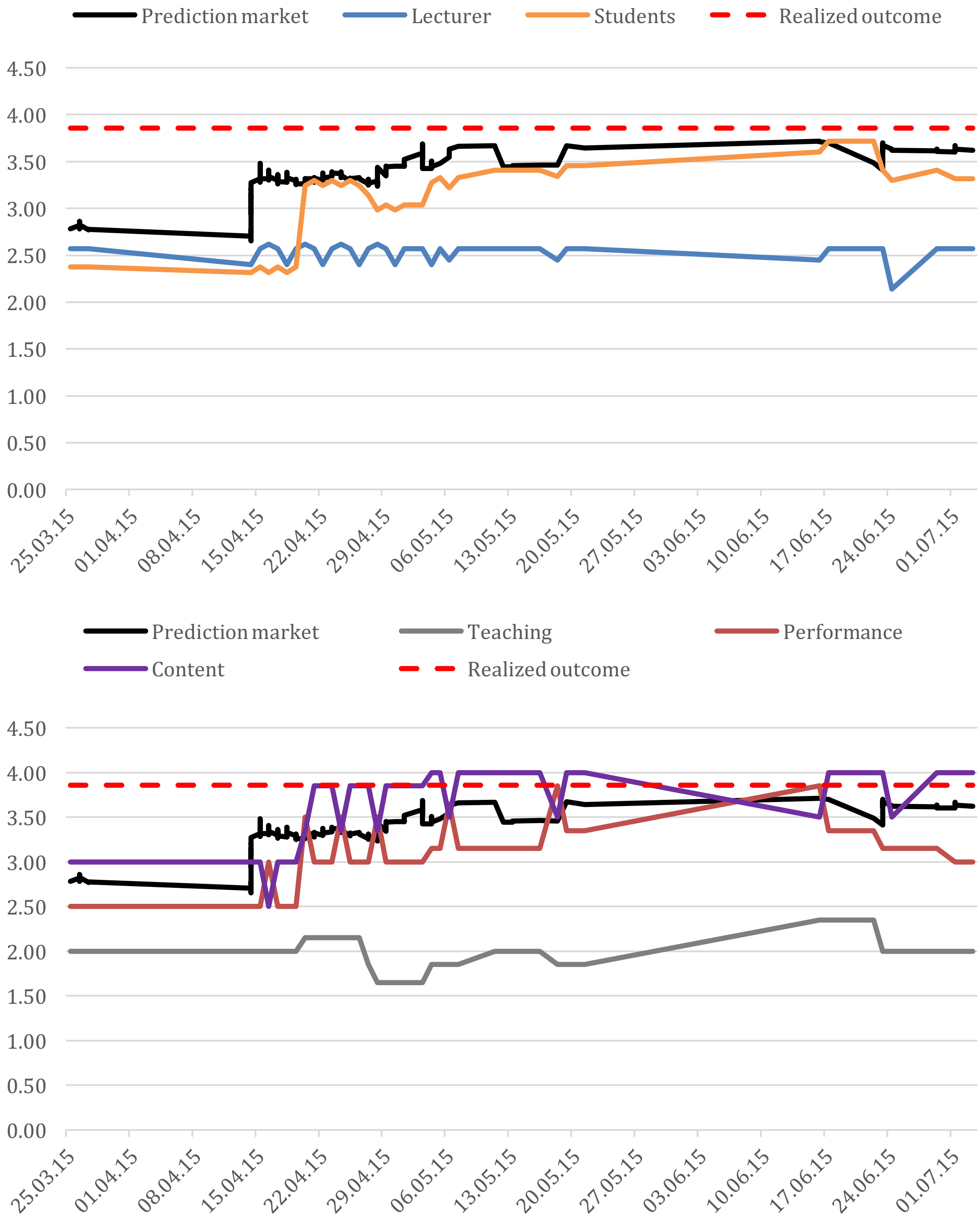

Figure 3. Mathematics II/III prediction chart, component charts, and total chart

As shown in Figure 3, the seven different charts of the prediction market and the tracker study differ significantly. The similarity between the prediction market chart and student evaluations of all three essential influencing factors over the experimental time period cannot be ignored. Equally obviously, lecturer evaluations of the same essential influencing factors differ considerably from the prediction market chart. For the stand-alone observation of the three essential influencing factors (i.e., Teaching, Student Performance, and Content), it is apparent that performance evaluation matches the prediction chart best. Content evaluation matches large parts of the prediction market chart. The worst match regarding the comparison is the evaluation of teaching, since it greatly differs between lecturer evaluations and the prediction market chart itself.

Mathematics II/III was chosen to be displayed in this sub-chapter, since it represents the median mean standard error for all of the prediction market results. Thus, Figure 2 can be seen as representative all of the other 11 prediction markets in this study. Although differences exist, there were two main reasons why the prediction market result was most likely the best possible scenario represented by the Mathematics II/III prediction market. As already explained in the prior sub-chapter, three markets were biased towards their respective simulated events.

L	Course	Teaching	Performance	Content	Lecturer	Students	Total indicator
#6	Market and State	0.01	0.75	0.77	0.75	0.77	0.84
#1	Mathematics II/III	0.12	0.79	0.73	-0.11	0.87	0.82
#5	Advanced Economic Research	0.53	0.56	0.80	0.18	0.86	0.72
#4	Macroeconomics	0.56	0.51	0.72	0.66	0.66	0.71
#7	Economics of the Public Sector	0.50	0.49	0.49	0.49	0.51	0.52
#4	Advanced Macroeconomics	0.11	0.69	0.46	0.61	0.36	0.52
#7	Market and State (se)	0.54	0.21	0.70	-0.59	0.65	0.45
#5	Macroeconomics	0.01	0.67	0.18	-0.36	0.71	0.40
#2	Introduction to Social Psychology	0.26	-0.49	0,00	0.18	-0.32	-0.05
#7	Game Theory (se)	0.15	-0.12	-0.16	-0.01	-0.15	-0.12
#6	Advanced Macroeconomics	0.20	-0.19	-0.13	-0.07	-0.16	-0.13
#3	Responsible Project Management (se)	0.20	-0.38	-0.75	-0.28	-0.75	-0.60
	Average	**0.14**	**0.29**	**0.32**	**0.12**	**0.33**	**0.34**
	w/o simulated events (se)	**0.25**	**0.42**	**0.44**	**0.26**	**0.47**	**0.48**

Table 2. Correlation table for prediction chart, component charts, and the total chart

Table 2 shows the correlation of the different component charts with the prediction market chart. The components are the three essential influencing factors, the lecturers' and students' evaluations, and the total evaluation, which was calculated as 50% of both evaluations. All of the components were evaluated over the experimental time period. At first glance, there seems to be a large spread in between the different markets. The correlation ranges from -0.60 to 0.84, which nearly represents the entire correlation scale. On second glance, regarding the simulated event markets, it is possible to identify the following patterns:

(A) Strong correlation pattern: As already concluded on an optical basis in Figure 2, the total evaluation and students' evaluations without simulated event markets seems to be highly correlative (0.47-0.48) with the respective prediction market chart. This may seem logical since students are traders and survey-takers equally and thus, they naturally have a better position within the information asymmetry. Nevertheless, concerning the type of information extraction, it is completely different. While the information is traded on the prediction market, it is calculated out of several answers regarding the three essential influencing factors within the survey. As a result, from the students' perspectives, there is a large gap between the survey and the prediction market. Moreover, it is assumed that the students never thought about answering the survey to reveal information on the same prediction target as with the prediction market. The even higher correlation for the total indicator may be explained through the correction of the students' overestimation by the lecturers' indicators.

The strong correlation between student evaluations and the prediction market chart is supported by the comparably strong correlation of the performance and content component chart. Both are content-related and close to the real-world student's expertise. Regarding the primary topic of real-world sensitivity, there is strong evidence that the student evaluations actually represent the best possible version of the real-world progress.

(B) Weak correlation pattern: By contrast, lecturer evaluations of all three essential influencing factors differ significantly from the prediction chart of the respective market, especially since there was only a low-level correlation of 0.26 without the three simulated event markets. Although it would be obvious to conclude that the teaching component chart is content-related and similar to lecturer evaluations, the data in Table 2 indicates otherwise. Only four of the 12 markets represent a correlation between the teachers' component chart and lecturer evaluations, within a 0.2 correlation spread. In conclusion, there is no real-world connection, as there is for student evaluations. Therefore, no strong support exists for this apparently obvious theory.

Arguably, regarding the macro perspective on progress sensitivity, it is necessary to ask whether the lecturers' or the students' prediction market charts are closer to the real-world process. In order to answer this highly important question, the following simple but enlightening approach was taken. As the realized outcome is a real-world value, it is possible to compare the final two weekly predictions of each progress indicator to obtain the best possible hint regarding which progress indicators are more realistic. Obviously, it is the indicator closer to the realized prediction target since it is defined as real-world value. For a better understanding, it is even possible to obtain the answer by observing the respective indicator charts, as shown in Figure 2. While the results in Figure 2 seem clear (since the students' indicators are much closer to the realized prediction targets), as for the lecturers' indicators, the mean standard error for all 12 markets is shown in Table 3.

Lecturer	**Course**	**Lecturer**	**Students**	**Spread**
Lecturer #6	Advanced Macroeconomics	1.42	0.44	0.98
Lecturer #7	Game Theory	0.56	0.17	0.39
Lecturer #7	Market and State	1.84	0.12	1.72
Lecturer #2	Introduction to Social Psychology	0.26	0.34	0.08
Lecturer #4	Advanced Macroeconomics	1.01	0.24	0.77
Lecturer #4	Macroeconomics	0.65	0.35	0.30
Lecturer #1	Mathematics II/III	1.29	0.54	0.75
Lecturer #5	Advanced Economic Research	1.60	0.36	1.24
Lecturer #3	Responsible Project Management	0.67	0.43	0.24
Lecturer #5	Macroeconomics	2.14	0.88	1.26
Lecturer #6	Market and State	2.59	1.29	1.31
Lecturer #7	Economics of the Public Sector	0.37	0.17	0.20
	Average:	**1.20**	**0.44**	**0.77**

Table 3. Mean standard error, realized outcome, and indicator charts for the final two weeks

The result is straightforward. The students' evaluations of the final two weeks prior to the realization of the prediction target were much closer to the final realized prediction target then it was for the lecturers' evaluations over the 12 markets. Therefore, at least in this study, it can be concluded that the lecturers' evaluations seem to be heavily biased toward some unknown reasons. In addition, the prediction market chart has a moderate correlation with the more detailed indicator represented through the tracker study. As for the methodological approach of the tracker study, which is bound to real-world information, the prediction market chart is likely to have a strong correlation with the real-world development of the prediction target.

4.3 Trading journal

For another perspective on the sensitivity of prediction markets in an internal control application, the following chapter goes beyond the macro approach and utilizes a behavioristic approach regarding the source of information of the traders' decision-making processes. As previously described, the students participating in this study were asked to maintain a trading journal in which they recorded the reasons for every transaction in the market.

Regarding the larger amount of voluntary work that is necessary to maintain a trade journal, the number of participating students dropped significantly. As a direct consequence, the clarified number of transactions was far below the total number of transactions for all 12 markets. In total, there were 3,043 transactions in all of the markets of which the transactions with clarifying records in the trade journals totaled 680. Thus, the following analysis is only representative for 22.35% of the total number of transactions in all 12 markets. Nevertheless, it can be argued that the clarified transactions are somewhat representative for all of the transactions since the submitted trading journals contained the clarified transactions for each respective student and not a share of the selected transactions. As long the students are comparable to 22.35%, the clarified transactions can also be seen as comparable.

	Lecturer #1 Mathematics II/III	**Lecturer #7** Market and State	**Lecturer #7** Economics of the Public Sector	**Lecturer #7** Game Theory
Transactions	419	289	177	176
Transactions (TJ)	60	61	39	49
Share (TJ)	**14%**	**21%**	**22%**	**28%**
Information:				
Insider	**12%**	**12%**	**5%**	**4%**
Fundamental	**24%**	**15%**	**15%**	**8%**
Technical	**76%**	**85%**	**85%**	**92%**

	Lecturer #5	**Lecturer #5**	**Lecturer #2**	**Lecturer #4**
	Advanced Economic	Macroeconomics	Introduction to	Advanced

	Research		Social Psychology	Macroeconomics
Transactions	219	189	399	227
Transactions (TJ)	79	40	69	74
Share (TJ)	**36%**	**21%**	**17%**	**33%**
Information:				
Insider	**0%**	**5%**	**12%**	**3%**
Fundamental	**11%**	**8%**	**15%**	**14%**
Technical	**89%**	**92%**	**85%**	**86%**

	Lecturer #4 Macroeconomics	**Lecturer #3** Responsible Project Management	**Lecturer #6** Advanced Macroeconomics	**Lecturer #6** Market and State
Transactions	282	290	175	201
Transactions (TJ)	75	29	68	37
Share (TJ)	**27%**	**10%**	**39%**	**18%**
Information:				
Insider	**7%**	**4%**	**4%**	**5%**
Fundamental	**16%**	**14%**	**16%**	**18%**
Technical	**84%**	**86%**	**84%**	**82%**

Total Transactions	Clarified (abs.)	Clarified (rel.)	**Technical**	**Fundamental**
3043	**680**	**22,35%**	**85,36%**	**14,64%**
			Insider	**6,16%**

Table 4. Trade journal, source of information, and transactions

The results of the submitted trading journals are displayed in Table 4. Hence, three different categories, as sources of information, are mentioned: technical information, fundamental information, and, as a sub-category of the latter, insider information. Derived from the meaning in investment practice, these three sources of information are defined as follows (Sharp et al. 1999):

Insider information is defined as course-specific information available to students actively participating in the course of the prediction target. Common journal entries include the following examples provided in Figure 4.

> "Very hard exam," "Result from an early exam,"
> "The new topic of the course is hard to understand,"
> "Simple course content," and "Changed type of exam."

Figure 4. Journal entries for insider information.

Fundamental information is defined as course-specific information available to students without actively participating in the course of the prediction target. Fundamental information is the superior category for insider information since both are considered course-specific. Common journal entries for fundamental information can be found in Figure 5.

"Lecturer is known for high drop-out rates," "Prior experience with the lecturer," "Experience with the general content," "Experience as a master's student," and "Grapevine."

Figure 5. Journal entries for fundamental information

Technical information is defined as purely based on chart information availability through the market tool. Regarding this experiment, the website of Prediki was the respective tool. Several examples for this type of information are displayed in Figure 6.

"Speculation," "Low-course," "Trend is your friend," "High volatility," and "Hedging."

Figure 6. Journal entries for technical information

The results of Table 4 are similar to regular market process information. Nearly 85.36% of transactions were based on technical information. As a direct consequence, nearly 85.36% of all transactions were not specifically bound to any real-world information. These transactions bound to such information were divided into intra-course (insider) information (with a share of 6.16%) and cumulative, general (fundamental) course-related information (with a share of 14.64%).

4.4 Simulated events

This chapter provides an even closer look at the micro-reaction of a prediction market in an internal control application. Thus, the following four artificial events were simulated [3] for the purpose of this study:

(A) Lecturer #3 Responsible Project Management – Changed type of exam
(B) Lecturer #7 Game Theory – Changed lecturer for the exam
(C) Lecturer #7 Market and State – Additional tutorials
(D) Lecturer #2 Introduction to Social Psychology *–Detailed exam limitation (not executed)*

The objective of these simulations was to obtain a more detailed view on how specific events affect traders' decision-making processes regarding the prediction market chart. This may be analyzed with

[3] Based on the criteria/survey of Sub-chapter 3.3b.

additional data from the prediction market chart, the trading journal entries, and specific data on the amount of transactions per respective date.

(A) 5/13/2015: 16.00 Announcement: A written exam as opposed to a regular term paper. All chart movements are displayed in Figure 7. On the day of the announcement, two transactions start to push the median course below its current level of 2.52. This is astonishing since the logical effect of the announcement was expected to negatively influence the prediction. The downward pressure stops two days later with a median course level of 2.28. Although there is short a time period in between, the median course level of 2.28 is close to the final prediction. Overall, the mean standard error improved.

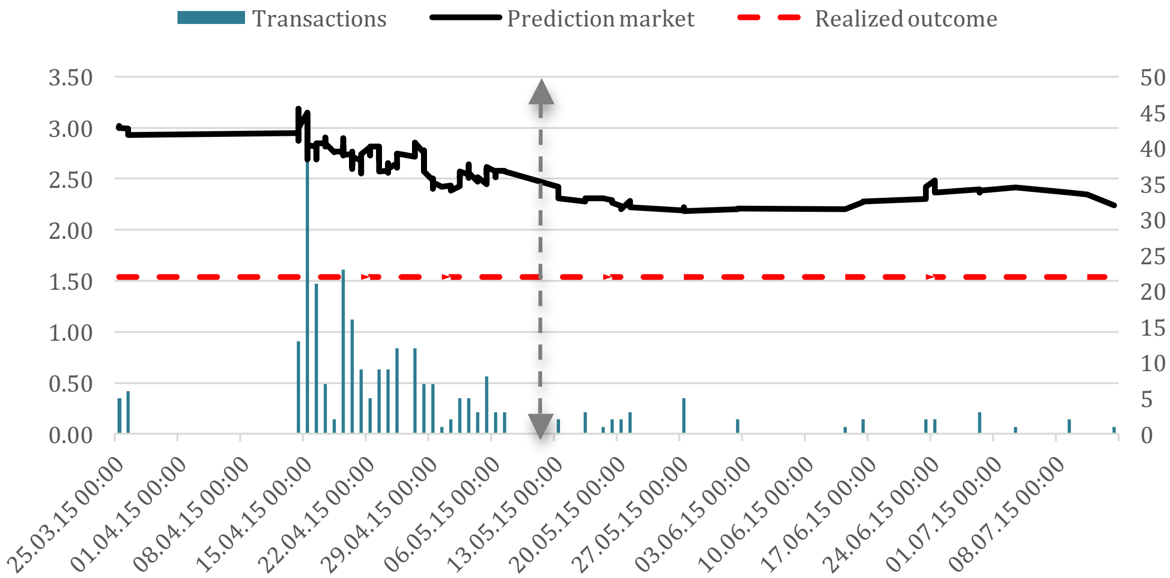

Figure 7. Prediction market chart – Responsible Project Management course

Among the students' trading journals in the "Responsible Project Management" course, two entries specifically mentioned the changed exam type (as insider information) with positive effects on the prediction target. The transaction data, as seen in Figure 7, is evidenced by the two transactions on 5/13/2015. Compared to the transaction data as a whole, the amount of two transactions per date are in line with the norm. Therefore, it is important to note that the significantly larger amounts of transactions in the beginning of the experiment follow the general understanding of the J-curve (Bahmani-Oskooee & Ratha 2007).

(B) 5/26/2015: 14.00 Announcement: A different lecturer (known for more difficult exams) develops the exam. As opposed to the first prediction market with a simulated event that was expected to negatively influence the prediction (but resulted in the opposite), the second analyzed prediction market had no chart movement within the three-week period after the announcement (see Figure 8). The final movement of the prediction market was two weeks before the announcement, with a median course level of 3.0. As for the non-existent course movement, the mean standard error was unaffected on the announcement date.

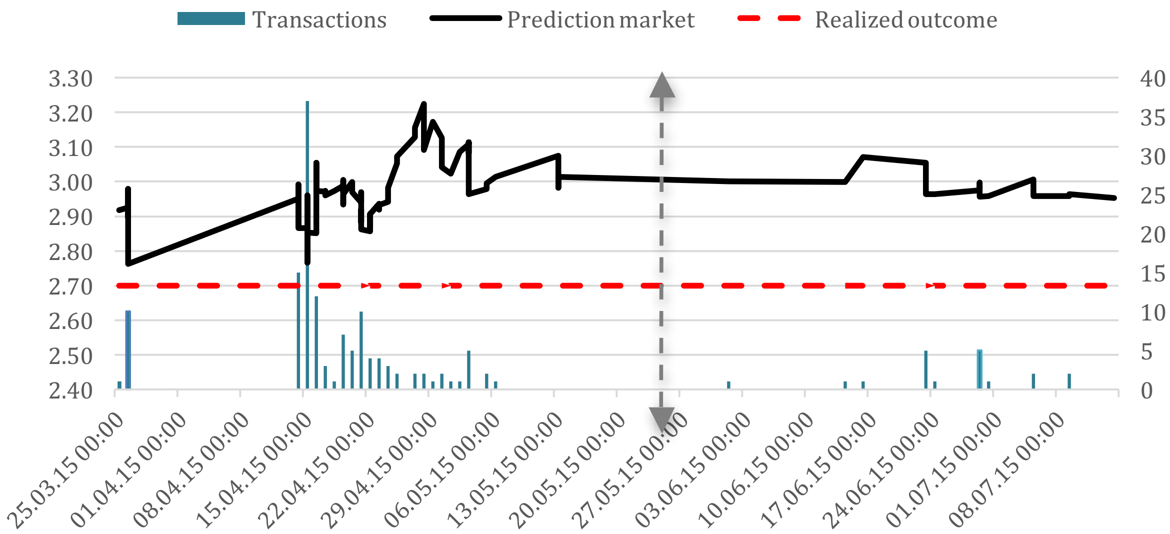

Figure 8. Prediction market chart – Game Theory

Trading journal entries that specifically mentioned the event were non-existent. This may have been caused by the relatively low rate of clarification, as previously stated in Sub-chapter 4.3. No transactions were recorded on the respective date. As for the data provided in Figure 8, the announcement of this specific event had no effect on the prediction.

(C) 02/07/2015: 14.00 Announcement: Additional tutorials prior to the exam. For the third prediction market with simulated events, data similar to that in the first event were observed. As displayed in Figure 9, after the announcement of the additional tutorials (a median course level of 3.30), the course experienced upward pressure until it reached a course level of 3.31. Thus, the course movement on the respective date expanded the mean standard error of the prediction market.

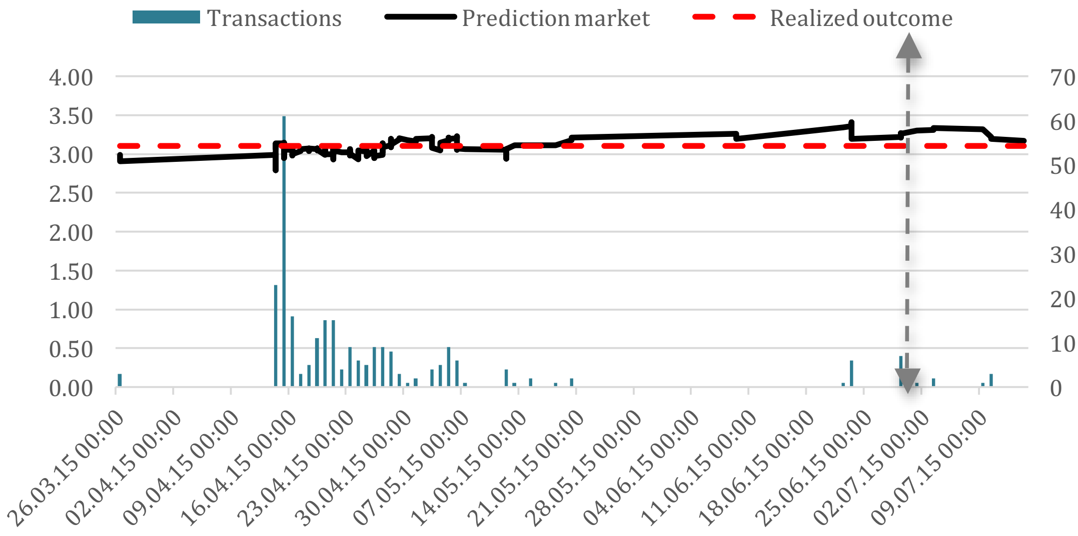

Figure 9. Prediction market chart – Market and State

Again, no trading journal entries were found that specifically mentioned the artifical event as insider information. In addition, the transaction data shows that one transaction was executed on the date of the announcement.

5. Analysis

5.1 Progress sensitivity

The more general, progress sensitivity, it depends on the indication of actual real-world development. Since the process of the prediction target development is particularly difficult to define, the best possible approach was necessary. The prediction market in an academic application facilitated the analysis since the number of influencing factors and surveys was limited. Therefore, the tracker study was not only possible, but it was applicable as a comparable prediction method for the internal control prediction market. For the matter of progress sensitivity, both methods need to be compared regarding their potential for processing information. As shown in Table 5, the squared deviations of the first and last predictions (per method) are compared.

		Prediction market			Total indicator		
L	**Course**	**Start**	**End**	**Percent spread**	**Start**	**End**	**Percent spread**
#1	Mathematics II/III	1.165	0.057	95.15%	1.927	0.840	56.41%
#6	Market and State Advanced	1.373	1.034	24.69%	7.076	4.037	42.95%
#5	Economic Research	0.374	0.152	59.39%	3.553	0.964	72.88%
#4	Macroeconomics	0.399	0.086	78.48%	2.250	0.206	90.83%

#7	Economics of the Public Sector	1.993	1.724	13.54%	7.673	2.154	71.93%
#4	Advanced Macroeconomics	0.291	0.022	92.52%	2.397	0.396	83.49%
#7	Market and State	0.013	0.005	57.88%	1.317	1.020	22.53%
#5	Macroeconomics	1.327	0.504	62.03%	4.182	2.285	45.36%
#2	Introduction to Social Psychology	0.875	0.591	32.44%	0.230	0.081	64.95%
#7	Game Theory	0.048	0.064	-34.80%	0.616	0.037	93.93%
#6	Advanced Macroeconomics	0.014	0.003	76.74%	1.877	0.947	49.52%
#3	Responsible Project Management	2.127	0.487	77.12%	0.011	0.204	-1692.99%
			Median:	**60.71%**			**60.68%**

Table 5. Percent spread – Start/End squared deviation per prediction method

The results are straightforward, since both prediction methods process information with comparable quality. The median of the percent spreads is nearly equal, with only a 0.3% difference in the prediction market method. The median was necessary as for one runaway market. In addition, the results may be interpreted independently from the actual prediction, especially since both methods adjusted their starting prediction to a more precise one (60.68% to 60.71%). Thus, it can be concluded that the general real-world sensitivity of both methods are reliable as for their respective quality of information processing.

With the given quality of information processing, the correlation data completes the analysis for a more comprehensive final statement. In addition, a moderate correlation of 0.49 for the tracker study's total indicator chart and the prediction market chart was identified. Therefore, it can be concluded that the chart of a prediction market in an internal control application is likely to indicate an approximate version of the real-world progress of the prediction target. As for the financial incentive provided within this study and the general voluntary nature of the students, it may be stated that the possibility of an even stronger correlation is probable.

Finally, it is important to mention that, even with a strong correlation with the progress indication, nothing was stated about the more detailed event sensitivity. However, analysis of all 12 prediction charts revealed a much smoother prediction market chart than that in the tracker study, except during the early expectation formulation phase. Therefore, low-level event sensitivity is expected from the macro perspective.

5.2 Event sensitivity

(A). Trading journals

The trading journals were particularly important for obtaining more insight into the type of information that causes traders in an internal control application for prediction markets to engage in new transactions. The results of the trading journals were consistent with general knowledge about market trading, since only 6.16% of the transactions were bound to actual real-world events. Additionally, as for insider information, another equally small share of 8.44% of non-course-bound information was identified. Both sources of information were identified as fundamental information, which is defined as information with a direct reference to the prediction target, but without the need to be course insider. Moreover, the total share of information that caused traders to engage in transactions was 14.60% and the majority of the transactions (85.40%) were based on pure technical information without any specific reference to the prediction target.

Regarding the matter of event sensitivity, only 6.16% of the transactions were based on insider information. This finding is relevant since it reflects intra-course events. This low level of event sensitivity could explain why the prediction market chart is much smoother than the students' indicator in Figure 2 or Figures 4, 5, and 6, as discussed in Sub-chapter 5.1. Again, this may be caused by the low financial incentive combined with the students' voluntary nature.

(B) Event simulation

Regarding the results of the event simulation in Sub-chapter 4.4, several conclusions can be made. The first and most obvious would be that the prediction market in this experiment was not influenced by specific events. It is (more or less) a trading chart that is primarily based on technical information without any connection to real-world events. While this conclusion seems obvious, it cannot explain the general prediction of the prediction target.

The second conclusion is that logically determining the influence of the simulated artificial events can be highly problematic. Therefore, it is possible to conclude that the prediction markets in this study were influenced by specific events, but the outcomes were not logically expected. Regarding an example from the logical perspective, it is very unlikely that additional tutorials caused the majority of students to perform worse in the exam. However, it may be argued that additional tutorials can improve students' understandings of the course content and materials on the upcoming exam.

With argumentation such as this, even logically confusing prediction market chart movements may be explained. In general, without comprehensive insider information, it is unlikely that one can understand single events through the prediction market chart. A potential solution to this problem may be to add market charts or reasoning journals to the prediction market, since these methods likely indicate insider information. Nevertheless, it may be concluded that all events that likely affect the prediction target can encourage traders to review their personal predictions and make more realistic ones.

5.3 Internal control application

Based on the experiment, the comprehensive analysis, and the existence of event sensitivity, the following are the likely outcomes of an internal control application of prediction markets, several of which are particularly relevant. First, regarding the moderate (or potentially strong) correlation of the prediction chart with the real-world progress of the prediction target, the prediction market in an internal control application reliably indicates the general progress of the prediction target. Moreover, the internal control mechanism may be used to monitor potential deviations from the designated prediction target and ensure early hedges against occurring risks.

Second, while general progress is transparent with the application of prediction markets, it is much less likely that an influence of specific events can be found in the prediction market chart. This is due particularly to the low level of event sensitivity. With only a small share of transactions related to the intra-course information, which is representative of the occurrence of specific events, the majority of chart-based information is from a technical perspective. Thus, the prediction market chart is much smoother than the real-world development of the prediction target. Furthermore, it has been stated that additional financial incentives, likely non-study applications, may enhance overall event sensitivity.

Third, based on the results of this study, it can be stated that an internal control application of prediction markets may be used to monitor the general development of the prediction target. However, specific events that influence the prediction will unlikely be observed by analyzing the prediction chart.

Finally, the prediction market for internal control application may be a useful and relatively inexpensive tool in the wide spectrum of internal control mechanisms. As shown in Sub-chapter 5.1, the prediction market method processes information with equal to slightly better quality than the comprehensive, complex, and more expensive tracker study method. Overall, with the prediction market application for internal control, users can obtain a fast, cheap, and reliable perspective on the prediction targets' progress development without losing information.

6. Conclusion

Based on the findings of this study, the internal control application of prediction markets appears to have great potential as measurement tool. The prediction market chart for internal control applications has a moderate correlation with the more detailed indicator represented through the tracker study. As for the methodological approach of the tracker study, which is bound to real-world information, the prediction market chart is likely to have a strong correlation with the real-world development of the prediction target. Moreover, prediction markets process information even more efficiently and with a significant one-week lead over the comparable tracker study.

Although individual events in this study were difficult to track, higher financial incentives in different application fields may solve the problem. For the source of information processed with the prediction market, only a small share of 14.60% was related to actual real-world development of the prediction target. The majority of transactions (85.40%) were based on technical information. Again, this may not be a problem, since regular share markets process information in the same manner. Although it can be stated that the application field is in an academic, corporate or project-based environment, the ability to monitor the progress development of target figures is valuable for users in every field. With an internal control application, prediction markets are able to enhance resource allocation, risk management, financial evaluation, and ultimately, the achievement of objectives in the corporate or project-based field, especially since the quality of financial analysis is ultimately dependent on efficient and reliable internal control mechanisms (Robinson et al. 2015).

There were two limitations in this study: the financial incentive for the prediction markets and the mutual supply of information. With the relatively low financial incentive, the primary motivation of traders was significantly limited. The consequence may be that data on event sensitivity was heavily biased. As for the mutual supply of information, the students were both the traders in the prediction market and the interviewees. Thus, the weekly survey may also be heavily biased towards the previously existing prediction market course. Evidence of this bias may be the estimated lag of one week in Figure 3.

Ongoing research in this field should focus on the realization of an experiment with an equally transparent research setup in the respective field, while addressing the aforementioned limitations. It would be interesting to compare the results of these field experiments with the results of this study. Such research would provide a closer look at the neutrality of the prediction markets in an internal control application, especially regarding their respective field of application.

Moreover, prediction markets may be used in an internal control application as guidance for lecturers to understand the students' understanding, learning or grading expectations. As shown in this study, the lecturers seemed heavily biased toward a realistic assessment of the students' understanding of the course material. It may be concluded that the lecturers did not know what the students had already discussed. Hence, the internal control application of prediction markets could enhance the teaching quality and increase the satisfaction of students in an academic environment.

Finally, ongoing research should evaluate the teaching quality of academic courses with and without a prediction market in an internal control application. Additional research could support the results of studies of better teaching quality on the application of prediction markets in an academic field. In this regard, the application should generally match the research setup utilized in this study.

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